Société Géologique du Nord

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SOCIÉTÉ GÉOLOGIQUE DU NORD
59655 VILLENEUVE D'ASCQ CEDEX

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SOCIÉTÉ GÉOLOGIQUE DU NORD

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NEW DATA ON LATE DEVONIAN AND EARLY CARBONIFEROUS BRACHIOPODS FROM NW SAHARA: MOROCCO, ALGERIA

Nouvelles données sur des brachiopodes du Dévonien supérieur et du Carbonifére inférieur du Sahara nord-occidental : Maroc, Algérie.

by Denise BRICE(*), Marie LEGRAND-BLAIN(**) & Jean-Pierre NICOLLIN(***)

(Planches I to V)

Abstract. — The new systematic data of this paper concern 60 taxa collected in the Late Famennian and Early Tournaisian deposits from the southern Anti-Atlas, Ma'der-Tafilalt regions (Morocco) and Timimoun area (Algeria). The deposits yield representatives from : the Strophomenids (*Leptagonia, Schuchertella*), the Productids (*Hamlingella,, Whidbornella, Kahlella, Acanthatia (?), Productina, Mesoplica, Semiproductus, Spinocarinifera, Ericiatia*), the Rhynchonellids (*Centrorhynchus, Macropotamorhynchus, Hemiplethorhynchus* (?), *Paurogastroderhynchus, Megalopterorhynchus, Shumardella, Gastrodetoechia*), and the Spiriferids (*Cyrtospirifer, Sphenospira, Dichospirifer, Prospira, Parallelora, Unispirifer, Eobrachythyris, Voiseyella, Hollardospirifer* n. gen., *Eochoristites, Eomartiniopsis Tylothyris, Syringothyris*). The occurrence of these brachiopods, their systematic analysis, stratigraphic position, and their relationships could be very useful for improving correlations between various neritic sedimentary series near the Devonian/Carboniferous boundary.

Résumé. — *Les nouvelles données systématiques de cette note concernent 60 taxons provenant du Famennien supérieur et du Tournaisien inférieur du sud de l'Anti-Atlas, du Ma'der-Tafilalt (Maroc) et de la région de Timimoun (Algerie). On y a récolté : des Strophomenides (genres Leptagonia, Schuchertella), Productides (genres Hamlingella,, Whidbornella, Kahlella, Acanthatia(?), Productina, Mesoplica, Semiproductus, Spinocarinifera, Ericiatia,), Rhynchonellides (genres Centrorhynchus, Macropotamorhynchus, Hemiplethorhynchus (?), Paurogastroderhynchus, Megalopterorhynchus, Shumardella, Gastrodetoechia), Spiriferides (genres Cyrtospirifer, Sphenospira, Dichospirifer, Prospira, Parallelora, Unispirifer, Eobrachythyris, Voiseyella, Hollardospirifer n. gen., Eochoristites, Eomartiniopsis Tylothyris, Syringothyris). La provenance de ces brachiopodes, leur analyse systématique, leurs affinités et leur position stratigraphique pourront être très utiles pour les corrélations entre des séries sédimentaires néritiques au voisinage de la limite Dévonien/Carbonifère.*

I. — INTRODUCTION

The aim of this paper is to bring useful data for correlating and dating brachiopod faunas from neritic series, where the index biostratigraphic fossils - ammonoids and conodonts - are absent or rare. This is the case in NW Sahara : between late Famennian (*Platyclymenia, Gonioclymenia)* and probably middle Early Tournaisian (*Gattendorfia)* cephalopod marker beds, the Devonian/Carboniferous boundary deposits are sandstones and limestones, locally yielding abundant brachiopods, but usually devoid of the diagnostic Siphonodellid conodonts and earliest *Gattendorfia* goniatites.

Systematic studies concern different collections of brachiopod faunas (Productids, Rhynchonellids, Spiriferids and several Strophomenids) now available collected in the Late Famennian and Tournaisian series. They belong to the Strophomenids (*Leptagonia, Schuchertella*), the Productids (*Hamlingella, Whidbornella, Kahlella, Acanthatia (?), Productina, Mesoplica, Semiproductus, Spinocarinifera, Ericiatia*), the Rhynchonellids (*Centrorhynchus, Macropotamorhynchus, Hemiplethorhynchus* (?), *Paurogastroderhynchus, Megalopterorhynchus, Shumardella, Gastrodetoechia*), and the Spiriferids (*Cyrtospirifer, Sphenospira, Dichospirifer, Prospira, Parallelora, Unispirifer, Eobrachythyris, Voiseyella, Hollardospirifer* n. gen., *Eochoristites, Eomartiniopsis, Tylothyris, Syringothyris*).

These faunas came from the southern (Assa, Akka, and Zemoul areas) and northeastern (Ma'der-Tafilalt) Anti-Atlas regions (Morocco) and the northwestern Algerian Sahara: Gourara, Timimoun area (fig. 1). The present authors have visited two main sections: - 1) Kheneg Lakahal (fig. 2), Dra Valley, 20 km south of Assa (material collected by S.

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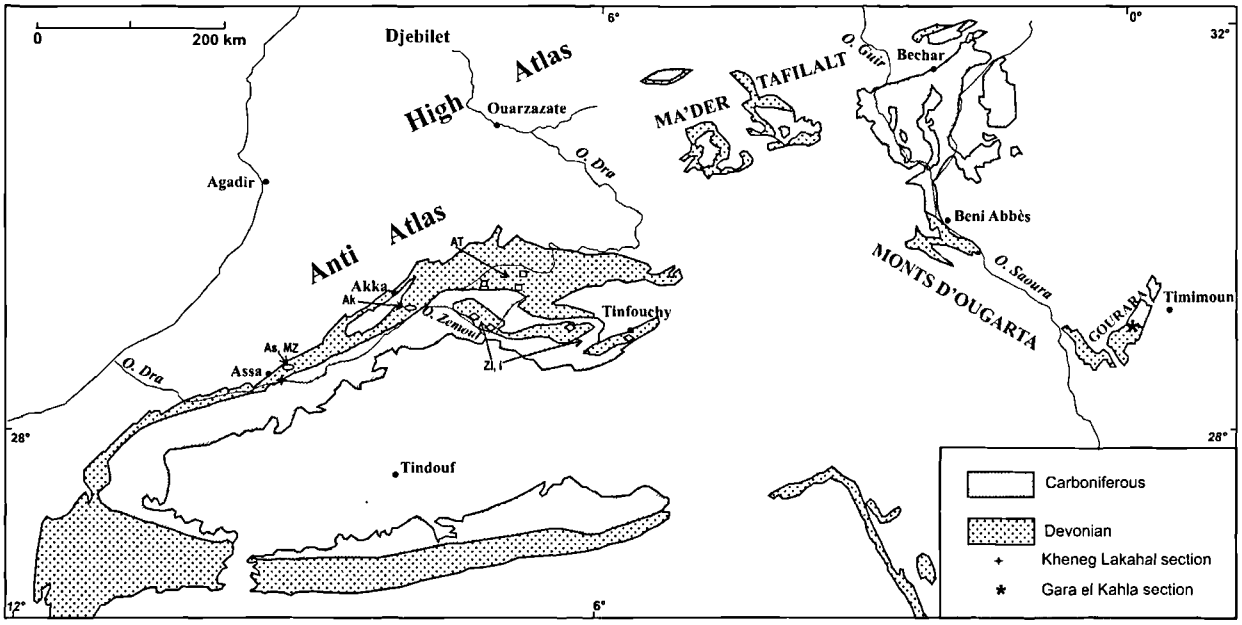

Fig. 1. — Cited localities in NW Sahara Devonian and Carboniferous outcrops (after "Carte géologique du Nord-Ouest de l'Afrique" (J. Fabre *et al.)* SNED Société Nationale Diffusion, Edition, Alger 1978).

Fig. 1. — Localités citées pour les gisements dévoniens et carbonifères du NW du Sahara (d'après « Carte géologique du Nord-Ouest de l'Afrique" (J. Fabre et al.) SNED Société Nationale Diffusion, Edition, Alger 1978).

Kaiser, R.T. Becker and Z.S Aboussalam, 2002-2003 ; D. Brice, J.-P. Nicollin and collaborators, SDS field-trip, March 2004) ; and - 2) Gara el Kahla, 20 km SW of Timimoun (fig. 3) (collected by M. Legrand-Blain and J Conrad, 1960'-70' years). Samples from the other sections have been collected : from Central Anti-Atlas, by H. Hollard (†), P. Jacquemont (†) and collaborators, 1950'-70 years ; from W Anti-Atlas (Hassi Rharouar), by P. Morzadec and D. Brice, 1975' years ; from Tafilalt - Ma'der, by Th. Becker and collaborators, 1990' years.

II. — CONCLUSIONS

According to the results of our systematic study of Productid, Rhynchonellid and Spiriferid brachiopods from NW Sahara (Morocco, Algeria), we find three successive faunas near the Devonian/Carboniferous boundary (Brice *et al*, 2004; Kaiser *et al.*, 2004; Brice *et al.*, 2005 submitted). First is a "Lower Fauna", Late Famennian [Zones IV(?)-V and lower part of VI (?)] according to Clymenid cephalopods. Second is an "Intermediate Fauna" within the latest Famennian [Strunian (?) where brachiopods are rare and consist of different taxa in southern Morocco : (Dfeif, Jfeirat, Mouilha], but this area is unfortunately inaccessible at this time. This "Intermediate Fauna" has not been found in northwestern Algerian Sahara. Finally: in all areas we found an "Upper Fauna", yielding Early Carboniferous (Tournaisian) marker brachiopods. In Timimoun area, (text-fig. 3) the Upper Fauna occurs in basal Upper Kahla Sandstones, and in the overlying *Gattendorfia* claystone horizon. A recent analysis of the Timimoun ammonoid fauna (Ebbighausen *et al.*, 2004) indicates, within the *Gattendorfia* evolutionary lineage a late level "*Paragattendorfia patens* Zone or even younger" probably middle Early Tournaisian.

III. — SYSTEMATIC PALAEONTOLOGY

COLLECTIONS — T. Becker & S. Kaiser = BK ; T. Becker = TB; D. Brice & J.-P.Nicollin = BN; D. Brice = DB; C. Brousmiche = CB ; J. Conrad = JC ; HH. Hollard = Ak, As, AT, Zl (cf. Appendix); P. Jacquemont = i; S. Kaiser = SK; M. Legrand = ML; P. Morzadec = MZ.

LOCALITIES, SECTIONS (figs 1-3) — MOROCCO: cf. Appendix of the present paper; "Cartes géologiques de l'Anti-Atlas 1/200 000", published 1969 - 1988; Brousmiche (1975), p.161-163; Hollard (†) (1981), Table 5. From West to East:

A. Map Foum el Hassane - Assa : (1) Kheneg Lakahal section (= KHL) (Fig. 2) BK, BN, SK Collections. [In this section, bed (- or +, in Kaiser et al., 2004) = unit (– or +) sometimes followed by the number of sample, "for instance - 2.9 = unit – 2 sample 9"]. (2) Hassi Rharouar section. MZ Collection; (3) Lemgaïrinat - Kheneg Aftes sections. CB, As Collections.

B. Map Akka -Tafagount - Tata. CB, As Collections.

C. Map Agadir Tissint - Oued Zemoul. AT, Zl, i Collections.

D. Map Todrha - Ma'der. TB Collection.

E. Map Tafilalt - Taouz. TB Collection.

ALGERIA, Timimoun - Gourara area : cf. Conrad (1984), p.127-134; Legrand-Blain (1995 b) Gara el Kahla Section (Fig. 3) ML, JC Collections.

REGISTRATION OF SPECIMENS. — Types, figured and cited specimens are housed : - in the Faculté Libre des Sciences, 41 rue du

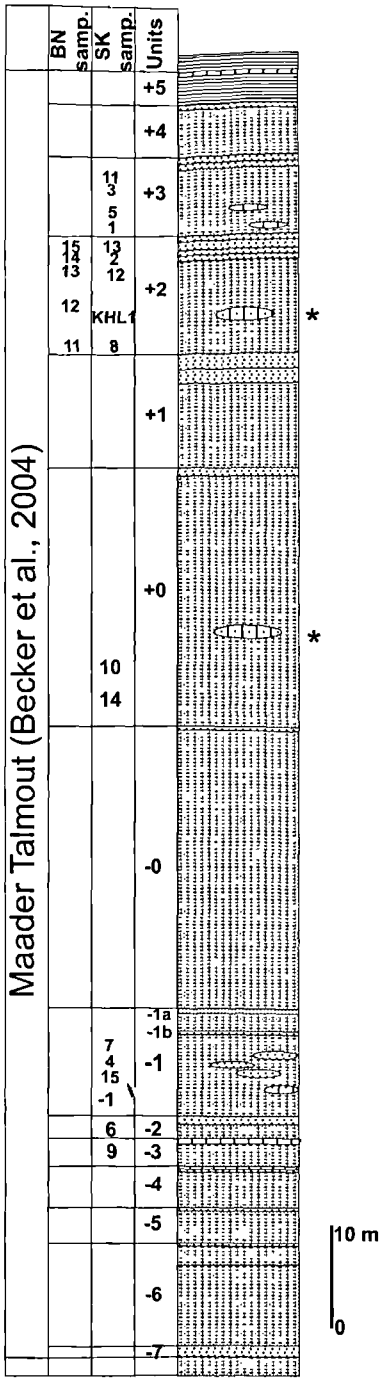

Fig. 2. — The Kheneg Lakahal section (after Kaiser *et al.*, 2004). Conodonts levels are indicated with (*) mark.

Fig. 2. — La coupe de Kheneg Lakahal (d'après Kaiser et al., 2004). Les niveaux à conodontes sont indiqués avec le signe (*).

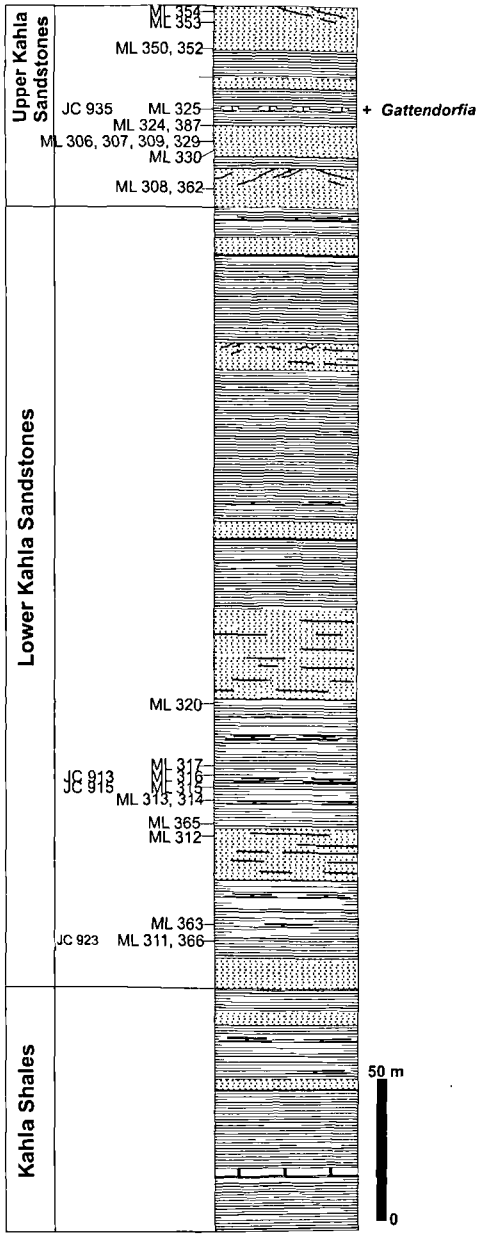

Fig. 3. — The Gara el Kahla section, western Algeria (after Conrad & Termier, 1970).

Fig. 3. — La coupe de Gara el Kahla, Algérie occidentale (d'après Conrad & Termier, 1970).

Port, 59046 LILLE CEDEX, France, "GFCL" (Spiriferids, Rhynchonellids and diverse brachiopods); - in the Muséum National d'Histoire Naturelle, Laboratoire de Paléontologie, 2 Rue Buffon 75005 PARIS, "R" = Typothèque and CB 1975 Collections (Productids, Morocco); - in the Lyon University, UFR Sciences de la Terre, 43 Bd du 11 novembre, 69622 VILLEURBANNE CEDEX : "FSL" (ML and JC Collections, Productids from Algeria described by Legrand-Blain,1995a) ; in the Museum für Naturkunde, Humboldt Universität, Invalidensstrasse 43, D-10099 BERLIN : "MB.B" (BK Collections from Ma'der and Tafilalt) ; in Alger University, UST Houari Boumediene, Faculté des Sciences de la Terre, ALGER : N° *1043001-1043008* (Rhynchonellids figured by Sartenaer ,1975).

ABBREVIATIONS — Specimen = sp; ventral valve = vv; dorsal valve = dv; internal mould of dorsal valve = imdv; external cast of dorsal valve = ecdv; internal mould of ventral valve = imvv; external cast of ventral valve = ecvv; length = L; valve width = W; sulcus width = Ws; thickness = T; delthyrial angle (°) = da; mc = median costae; lc = lateral costae.

BRACHIOPOD CLASSIFICATION. — We follow the classification available in the recently published volumes of "Treatise

on Invertebrate Paleontology Part H Brachiopoda Revised": Volumes 2, 3 (R.L. Kaesler, Editor, 2000); Volume 4 (R.L. Kaesler, Editor, 2002). The Spiriferid classification, not yet published in the "Treatise", was revised by Carter et al (1994).

IV — SYSTEMATIC

Order STROPHOMENIDA Öpik, 1934

Superfamily *STROPHOMENOIDEA* King, 1846
Family *RAFINESQUINIDAE* Schuchert, 1893
Subfamily *LEPTAENINAE* Hall & Clarke, 1894

Genus *LEPTAGONIA* M'Coy, 1844 – by D. BRICE

Diagnosis: (Cocks & Rong in Treatise Rev. 2000, v. 2, p. 246): Type species: *Producta analoga* PHILLIPS, 1836, Yorkshire, England, Carboniferous Limestone, Visean.

Leptagonia cf. *analoga* Phillips, 1836
(Pl. II, figs. 29-31)

2004 -*Leptagonia* cf. *analoga.* Brice, Legrand, Nicollin in Brice *et al.*, p. 16

2004 -*Leptagonia* cf. *analoga.* Brice, Legrand, Nicollin in Kaiser *et al.* p. 96

Material: : 7 specimens

Morocco : Assa area, Lemgaïrinat Formation ("Famennian V") As 31 (2 incomplete dv), As 259 (1 vv), MZ Collection Hassi Rharouar section MZ 2 (1 vv) "Lower fauna". Kheneg Lakahl section, BN Collection unit – 0 (1imdv) "Intermediate Fauna"; BK Collection unit + 3.3 (1 imvv, 1 emvv); Algeria, Gara el Kahla section, Upper Khala Sandstone ML 324 (1 imdv) "Upper Fauna"

Description

The specimens have a medium-sized, subquadrate shell, with hinge line corresponding to the maximum width of the shell. The ventral valves are slightly convexe at the umbo. There are 12-13 concentric rugae and fine radial costellae on the shell surface. The internal characteristics are typical of *Leptagonia.*

Discussion

These incomplete specimens have internal and external characteristics of *Leptagonia* and are most similar to *L. analoga.* However, their poor preservation prevents a more precise determination. They are closest to the lectotype of L. analoga (Brunton, 1968, fig. 27, pl. 3).

Range

Leptagonia is spread world-wide from Emsian to the Namurian (after Cocks *et al.* in Treatise Rev. 2000). Types of *L. analoga,* from Carboniferous limestone of Yorkshire (England), are Visean in age, but the species is mainly known in the Early Carboniferous in Eurasia, for instance in the Tournaisian and the Visean in the Kuznetsk Basin (Sarytcheva *et al.*, 1963). Rzhonsnitskaya & Mamedov (2000, p. 331) mention the presence of *L. analoga* with the rhynchonellid *Macropotamorhynchus* in the Kyarbi beds of the southern Transcaucasus region, corresponding to the transitional series between Arshakiakhbjur and the typical Carboniferous Gerankalasy suites that are likely basal Tournaisian in age. *L. analoga* is also recognized in the Upper Famennian series in Nanbiancun in South China (Xu in Yu, 1988), and associated with clymenids, below and above Hangenberg Horizon in NW of China in the Upper Hebukehe Formation of Xinjiang (Liang & Wang, 1991). In southern Morocco : (Assa area), *L.* cf. *analoga* has been collected - 1) from beds of Hassi Rharouar section dated by Hollard as Upper Famennian V = "Lower Fauna", - 2) from units – 0 and + 3 of the Kheneg Lakahal section = "Intermediate" and "Upper Faunas"; the species also exists in the "Upper Fauna" of the Timimoun area (Algeria).

Order ORTHOTETIDA Waagen, 1884
Suborder ORTHOTETIDINA Waagen, 1884

Superfamily *ORTHOTETOIDEA* Waagen, 1884
Family *SCHUCHERTELLIDAE* Williams, 1953
Subfamily *SCHUCHERTELLINAE* Williams, 1953

Genus *SCHUCHERTELLA* Girty, 1904 - by D. BRICE

Diagnosis: (Williams *et al. in* Treatise Rev. 2000, v. 2, p. 665): Type species: *Streptorhynchus lens* WHITE, 1862, Louisiana Limestone of Missouri (USA), latest Famennian (*praesulcata* Zone after Ziegler & Sandberg, 1984).

Schuchertella sp.
(Pl. II, figs 27-28)

2004 - *Schuchertella* sp. Brice, Legrand, Nicollin *in* Brice *et al.*, p. 16

2004 - *Schuchertella* sp. Brice, Legrand, Nicollin *in* Kaiser et al. p. 96

Material : 17 specimens

Morocco: Assa area, Kheneg Lakahal section, BN Collection unit – 6 (1 ecvv); unit – 3 (2 ecvv); unit – 0 (2 cvv), BD Collection Hassi Rharouar section late Famennian (V) fide Hollard (1 cvv) " Lower Fauna ". Kheneg Lakahal section BK Collection unit – 1 (1 vv); unit 0.10 (1vv, remains); BN unit + 1.11 (1 cvv) " Intermediate Fauna". Kheneg Lakahal section BN Collection, unit + 2.12 (3 cvv); + 2.13 (1 dv, remains); + 2.15 (2 dv, 1vv and remains); BK Collection, unit + 5.5 (1 vv); Algeria, Gara el Kahla section, Upper Kahla Sandstone ML 306 (1 emvv) " Upper Fauna".

Description

The shape of the valves, which are often incomplete, is variable. The greatest width is situated at the hinge line (pl. II, Fig. 27), but the lateral extremities are often broken making this uncertain. The ventral valves are usually slightly resupinate with a pair of unsupported teeth and a subcircular to elongate oval ventral muscle field. The dorsal valves are more convex than the ventral ones with (sometimes) a wide and feeble median depression. The ornamentation is costellate, with costellae added by intercalation.

Range

Schuchertella is a cosmopolitan genus of which the geographic and stratigraphic range (Upper Devonian – Upper Carboniferous) is in doubt according to Brunton *et al.* (Treatise Rev. 2000, v. 2, p. 665). In some levels of the

Strunian series of Etrœungt (Avesnois, France), the genus is very abundant. In North America, *Schuchertella* is found in the Late Devonian, the Mississippian, and the Pennsylvanian, as cited by Carter (1990, fig. 2). In Southern Morocco, the genus is present in the latest Famennian, Strunian and early Tournaisian.

Order PRODUCTIDA Sarytcheva & Sokolskaya, 1959 - by M. LEGRAND-BLAIN

Suborder PRODUCTIDINA Waagen, 1883

Family *PRODUCTELLIDAE* Schuchert, 1929

Subfamily *PRODUCTININAE* Muir-Wood & Cooper, 1960

Genus *PRODUCTINA* Sutton, 1938

Diagnosis: (Brunton *et al. in* Treatise Rev. 2000, v. 3, p. 426). Type species : *Productus sampsoni* WELLER, 1909, USA, Early Tournaisian.

Productina sp.

1995a - *Productina* sp. Legrand-Blain, p. 434, pl. 2, fig. 7.

1995b - *Productina* sp., Legrand-Blain, p. 92.

Material :

Timimoun area : ML 350b1-2 = FSL 413609 ; ML 352c1-2, vv. Upper Kahla Sandstone, Tournaisian. "Upper Fauna"

Family *PRODUCTIDAE* Gray, 1840

Subfamily *LEIOPRODUCTINAE* Muir-Wood & Cooper, 1960

Tribe *LEIOPRODUCTINI* Muir-Wood & Cooper, 1960

Genus *MESOPLICA* Reed, 1943

Diagnosis : (Brunton *et al.* in Treatise Rev. 2000, v. 3, p. 480): "Medium size; distinct ventral median fold bearing thicker spines in some; ribbing incipient anteriorly on corpus, trail; teeth absent; cardinal ridges short". Type species: *Leptaena praelonga* J. de C. SOWERBY, 1840. Devonshire, Pilton shales, A1-2, Late Famennian.

Shell texture and Range

The shell material on decorticated valves - as described on *P. praelongus* by Whidborne (1897) - consists of "coarse ramifying fibrous texture, which has the appearance of having originally been covered by an additional layer of shell". That structure is observable with naked eye on Strunian *M. praelonga* samples from England, W Germany, Urals, N Africa; also on *M. nigeraeformis* (Martynova) from Belgium Fa2d-Tn1a. It is identical to the " shagreen structure "described by Kotlyar (1990). On the contrary, it is absent on some earlier "*Mesoplica*" species, such as "*M.*" sp. 1 aff. *aktaica* from Moroccan Famennian IV-V ; the internal shell layer is smooth, sparsely pseudopunctate (Legrand-Blain, 1995a, p. 435 ; Brousmiche, 1975, pl. V, fig. 6a ; samples MZ 2 from Hassi Rharouar "Famennian V"). Consequently, "*Mesoplica* sp.1" could belong to a different (new Leioproductid ?) genus, listed below as "*Mesoplica* " gen. nov. ?

Mesoplica praelonga (Sowerby, 1840)

(Pl. I, figs. 14-20)

no 1929 - *Productus (Avonia) praelongus* : Dehée, p. 41, pl. VI, fig. 13-16.

pars 1975 - *Mesoplica praelonga* (Sowerby, 1840) : Brousmiche, p. 26, non pl. V fig. 1-8 (= " *Mesoplica"* gen. nov. ?).

1979 - *Mesoplica praelonga* (Sow.) : Nalivkin, p. 43, pl. XII fig. 23-26 (references).

1995a - *Mesoplica praelonga* (Sowerby, 1840): Legrand-Blain, p. 435, pl. II fig. 8-10.

1995b - *Mesoplica praelonga* (Sowerby, 1840): Legrand-Blain, p. 92.

2000 - *Mesoplica praelonga* (J. de C. Sowerby): Brunton *et al.* Treatise Rev., v. 3 p.480, fig. 322, 5a-d.

Material:

Dra Valley: Assa area, Kheneg Lakahal section, BN Collection, units - 6, - 4, - 3, - 2, many fragments ; unit - 1, "Productid bed", internal moulds of vv (BK - 1 a1-3, a5-7) and dv (BK - 1 a4). Kheneg Aftes, Tazout 1 Sandstone: As 108.30-34; As 108.32 = R 62656, vv. Hassi Rharouar: MZ 3, fragments. Zemoul area, Mouilha, Tazout 1 Sandstone: Zl 37.2,6,7,23. Timimoun area, Lower Kahla Sandstone: ML 311, 313 (ML 313 k1 = FSL 413610). All samples are collected in sandy sediments of the "Lower Fauna".

Description

A superficial primary shell layer, very thin, rarely preserved (BN - 3 w; Zl 37.7) is ornamented by dense concentric zones: 4 per mm length on external mould (BN - 6 d1 = GFCL 930, pl. 1, fig. 16). Usually, the inner shell appears with naked eyes as radially fibrous or "shagreen", with scattered pseudopunctae (BN - 4 = GFCL 929, pl. I, fig. 17; BK - 1bh = GFCL 911, pl.1, fig. 20).

Interior of ventral valve: a thin short median septum near the beak (Zl 37.7; BK -1.5). The muscle scars are undistinguishable within the "shagreen" shell substance.

Interior of dorsal valve: no hinge sockets. The cardinal process, massive at its base, passes laterally to a pair of cardinal ridges, and anteriorly to a thin septum, from which it may be separated by a shallow alveolus (BN - 6 d3 = GFCL 931, pl. 1 fig. 18 ; BK - 1 a4 = GFCL 910, pl. 1, fig. 14); muscle scars not well preserved.

Discussion

I have a replica of *Mesoplica praelonga* hypotype, N. Devon late Famennian: British Museum London B.M. B 22185 (fig. Muir-Wood & Cooper, 1960, pl. 44 fig. 1,3). In spite of the poor preservation of English and N African internal moulds, they may be considered as conspecific : same size, longitudinal profile, ornamentation, spines.

"*P. (Avonia) praelongus*" samples figured by Dehée (1929) from N France (= "*P. costatus* var. *muricatus*" in Carpentier, 1913 p.350), do not belong to *Mesoplica* as possessing numerous complete radial ribs; they are not Strunian, but Tournaisian "Petit Granite d'Avesnelles", Tn 2b. The resemblance between these specimens and *M. praelonga* is the median row of spines - a character occuring independently in unrelated genera (Muir-Wood & Cooper 1960, p. 17, 176).

Range of *Mesoplica praelonga*

The type locality of *M. praelonga* in SW England is Pilton A 1-2 beds (Goldring, 1970), assigned to LE palynozone (O'Liathain, 1993), i.e. Strunian, below the "Hangenberg event" occuring at the basal succeeding LN zone (Becker, 1996, table 2). The species is reported from many Strunian localities in Germany, Belgium, Russia. However some "*Mesoplica praelonga*" cited in the literature belong in fact to other species of the genus. For instance in Fa2d and Tn1a beds of Belgium, according to Legrand-Blain 1991, the "*P. praelongus*" cited by Demanet (1958) are *M. nigeraeformis* (Martynova, 1961).

Mesoplica (s.l.) nigeraeformis (Martynova, 1961)

1961 - *Plicatifera simplicior* (Whidborne) var. *nigeraeformis* var. nov. : Martynova, p. 86, pl. V, figs. 1-4.

1991 - *Mesoplica (s.l.) nigeraeformis* : Legrand-Blain, p. 42, pl. 2, fig. 19-20, 23-24, 27-28.

1995a - *Mesoplica (s.l.) nigeraeformis* : Legrand-Blain, p. 436, pl. 3, fig. 14.

Material :

Timimoun area : JC 915 b1-2, JC 923 a1. Lower Kahla Sandstone.

Discussion

The species, comparable to *Spinocarinifera* aff. *lotzi* by its general shape, is distinguished by the presence of a slight median sinus.

"Mesoplica" nov. gen. (?), nov. sp.

1975 - *Mesoplica praelonga,* Brousmiche, p. 26, pl. 5, fig. 1-8.

1995a - *Mesoplica*: sp. 1, aff. *aktaica* (Nalivkin, 1937), Legrand-Blain, p. 435-436, pl. 2, fig. 16-17.

1995b - *Mesoplica*: sp. 1, aff. *aktaica* (Nalivkin), Legrand-Blain, p. 92.

Material :

Dra Valley, Assa area, As 117 = R 62555, R 62656, As 118 = R 10321, As 260. Hassi Rharouar section: MZ 2. Zemoul area, Zl 21. All specimens from El Douiya and Lemgaïrinat Formations, in shaly-pelitic sediments, indicating rather soft bottoms. Age : Famennian (IV-V) according to Hollard (1981).

Description

External characters, cf. Legrand-Blain (1995a, p. 435). Shell structure: internal layer not "shagreen", but smooth, sparsely pseudopuntate (Brousmiche, 1975, pl. 5, fig. 6a, 7). Internal structure: absence of cardinal teeth and sockets.

Discussion

The presence or absence of inner fibrous "shagreen" shell, among the species attributed to *Mesoplica,* is probably an important diagnostic character, which needs to be examined in further studies. The "shagreen" structure, well exposed on the specimens of *M. praelonga s. str.,* is not described, and unknown, in many other species – especially *M. aktaica* (Nalivkin, 1937) to which the Moroccan species resemble externally and internally (absence of teeth and sockets). Kotlyar (1990) considers the "shagreen" structure as starting during Late Famennian. That hypothesis is confirmed by the Moroccan "*M.* aff. *aktaica*" devoid of fibrous test, Famennian (IV-V) in age. The materials now available are too incomplete for establishing any new species and genus.

Tribe *SEMIPRODUCTINI* Mc Kellar, 1970

Genus *SEMIPRODUCTUS* Bublichenko, 1956

Diagnosis: (Brunton *et al. in* Treatise Rev. 2000, v. 3, p.483): Type species: *Semiproductus minax* BUBLICHENKO, 1956, Kazakhstan, lower Tournaisian.

Semiproductus sp. 1

1975 - *Buxtonia scabricula* , Brousmiche, p. 37, pl. 5, fig. 15-19.

1995a - *Semiproductus* sp. 1, Legrand-Blain, p. 434, pl. 2, fig. 14-15.

1995b - *Semiproductus* sp. 1, Legrand-Blain, p. 92.

Material :

Morocco: Akka area. Ak 30.2-3 in CB 1975, fig = 18-19 = R 10331 ("Famennian V"). Zemoul area, Zl 15.2 = R 10329 in CB 1975 fig. 16 (El Douiya Formation); Zl 21 = R 62663 in Legrand-Blain 1995a, pl. 2, fig. 14 (El Douiya Formation); AT 139.1 = R 10330 in CB 1975 fig. 17 (Lemgaïrinat Formation). Zl 16 = R 62662, pl. 2, fig. 15 (base of Tazout 1). "Lower Fauna"

Semiproductus (?) sp. 2

1995a - *Semiproductus* (?) sp. 2. Legrand-Blain, p. 435, pl. 2, fig. 11-13.

Material :

Morocco: Zemoul area, Zl 65c1 = R 62661, M. LB 1995 pl. 2, fig. 11; Zl 64a2 = R 62652, pl. 2, fig. 12. Tazout 2-3 beds, near the *Gattendorfia* gr. *crassa* horizon. "Upper Fauna ", Tournaisian.

Genus *SPINOCARINIFERA* Roberts, 1971

Diagnosis : (Brunton *et al.* in Treatise Rev. 2000, v. 3, p. 485): "Small size; outline subquadrate with small but well-differentiated ears, profile strongly convex; dorsal valve weakly concave, geniculated with no spines; ribbing well formed anteriorly; cardinal process trifid with pit small, variable; cardinal ridges diverge from hinge close to ears". Type species: *Spinocarinifera adunata* ROBERTS, 1971; Australia, Hastarian.

Shell structure

Kotlyar (1990) emended the diagnosis of *Spinocarinifera,* after studying materials from Russia, adding the fibrous "shagreen" character of shell inner substance (analogous to *praelonga* texture), visible on worned shells. On the Australian type species, the shell structure is probably similar (Roberts 1971, pl. 19, fig. 15). The outer primary lamellar layer, finely striated, is sharply separated from the fibrous layer, as figured on *S. nigra* (Lazarev 1990, pl. X, fig. 5; Lazarev & Carter 2000, Fig. 3B, D). The "fibrous" inner shell texture is considered by Kotlyar as a diagnostic character of some Productid families, starting at uppermost Famennian. Lazarev & Carter (2000) report a shagreen texture within the ventral beak region of *Spinocarinifera* and some younger Retariinid genera. A question to be further examined, is the extent of the "shagreen" structure in the shell, perhaps different according to diverse genera: either covering the whole shell, or located only at the posterior part of ventral valve.

Spinocarinifera aff. *lotzi* (Paeckelmann, 1931)
(Pl. I, fig. 9a-b)

aff. 1931 - *Productus (Avonia) lotzi* Paeckelmann, p. 103, pl. 5, fig. 3 a-g.

1931 - *Productus (Avonia) niger* (Gosselet): Paeckelmann, (pars) p. 98, pl. 4, fig. 24, pl. 5 figs. 1, 2.

1975 - *Avonia niger* (Gosselet, 1888): Brousmiche, p. 35, pl. V, figs. 13-14.

1991 - *Spinocarinifera* aff. *lotzi* (Paeckelmann, 1931): Legrand-Blain, p. 39, pl. II, figs. 11-13, 15, 16.

1995a - *Spinocarinifera* aff. *lotzi* (Paeckelmann, 1931): Legrand-Blain, p. 436, pl. III, fig. 13.

1995b - *Spinocarinifera* aff. *lotzi* (Paeckelmann, 1931) : Legrand-Blain p. 93.

Material:

Dra Valley, Assa area, Kheneg Lakahal section, BN Collection unit - 7 (b1: 1 imvv, b2: 1 imdv), As 118.10 = R 62658: MLB 1995a, pl. 3, fig. 13 (El Douiya Formation). Zemoul area, Zl.29.3,9 = R 10327-R 10328, Zl 29.10,11,13 CB 1975, fig. 13-14 (Tazout 1 Sandstone). "Lower Fauna"

Description

A small shell, W = 16,5 mm, L > 13 mm; ventral trail flat medianly, with rounded costae, 4 per 5 mm width; rare spine bases on ventral costae, with corresponding depressions on dorsal valve. Interior of dorsal valve: no articulation, small massive cardinal process and short cardinal ridges, small triangular muscle scars. The shell texture (internal layer) is coarsely fibrous.

Discussion

The present species has been frequently described in the literature as "*P. niger* (Gosselet)" but the true *Spinocarinifera nigra* differs by its larger size, quadratic outline. The range of *Spinocarinifera lotzi* and *S.* aff. *lotzi* in Germany and Belgium (upper Strunian) is earlier than the true *Spinocarinifera nigra* (lower Hastarian). Out of W Europe, *Spinocarinifera* aff. *lotzi* is described from Morocco : (?) upper El Douiya Formation (*Clymenia* zone) and Tazout 1 sandstone.

Spinocarinifera aff. *inflata* (Sokolskaya, 1948)
(Pl. I, fig. 10)

aff. 1948 - *Plicatifera fallax* (Pander) var. *inflata* var. nov. : Sokolskaya, p. 92, pl. VI, figs. 7-9.

aff. 1963 - *Avonia inflata* (Sokolskaya) : Sarycheva *et al.*, p. 138, pl. XIV figs. 4-6.

aff. 1975 - *Avonia inflata* (Sokolskaya, 1948) : Litvinovitch *et al.*, p. 68, pl. XIX fig. 9-10.

1991 - *Spinocarinifera (Spinocarinifera) inflata* (Sokolskaya, 1948): Legrand-Blain, p. 38, pl. II, figs. 14, 17, 18 (references).

Material : 1 specimen.

Dra Valley, Assa area, Kheneg Lakahal section, GFCL 907, BK Collection unit - 2.6.5 (1 emvv). "Lower Fauna"

Description

A small elongated ventral valve; W = 14 mm, L > 15 mm. Ornamentation: spine ridges on umbo, grading into spine-bearing costae on the elongated trail: 5-6 per 5 mm width. Spines fine, numerous on trail. The dorsal valve and internal characters are not observable.

Discussion

The species has been included into the genus *Spinocarinifera* by Roberts (1971). The single Moroccan specimen has the same outline, dimensions and ornament as the type of *S. inflata* from Moscow basin, Malevka beds: lower Hastarian according to Rzhonsnitskaya (2000, p. 236). The species is reported also from latest Famennian Strunian in Russia; in Belgium, it is described from Royseux section, bed 104 (Legrand-Blain, 1991): just following bed 103, palynozone LE (Maziane *et al.*, 2002, fig. 8).

Spinocarinifera aff. *bulbosa* (Havlicek, 1984)
(Pl. I, fig. 11)

aff. 1984 - *Semiproductus bulbosus* sp. n.: Havlicek, p. 65, fig. 36, 37.

aff. 1987 - *Semiproductus bulbosus*: Havlicek & Röhlich, p. 145, pl. X, figs. 10-16.

aff. 1992 - *Semiproductus bulbosus*: Mergl & Massa, p. 60, pl. 7, figs. 16-22.

1995a - *Spinocarinifera* aff. *bulbosa* (Havlicek, 1984): Legrand-Blain, p. 437, pl. III, figs. 1-10.

1995b - "*Semiproductus*" (?) aff. *bulbosus* (Havlicek, 1984): Legrand-Blain, p.93.

2000 – *Spinocarinifera* (?) *bulbosus* (Havlicek): Mergl & Massa, pl. 4, fig. 2.

Material :

Dra Valley, Assa area, Kheneg Lakahal section, unit + 2 : BN Collection + 2.13, 1 vv with spines (GFCL 908, Pl. I, fig. 11) and several abraded vv fragments, BN + 2.13.II,t,x. Timimoun area, Gara el Kahla section, Upper Kahla Sandstone. ML324 c = R 413612 , 413613 MLB 1995a, pl. 3, fig. 7, pl. 2, fig. 8, ML 387 a1-2. All in " Upper Fauna ".

Description

Medium sized shell, W = 21-23 mm; outline subquadrate, ears well delimited, flanks steep. Dorsal valve strongly geniculated. Ornamentation: fine rugae on ears; costae probably discontinuous on umbo, more continuous and regularly spaced on trail: 9 per cm width. Spines numerous on ventral costae, attaining 7-8 mm in length.

Discussion

The type locality of *S. bulbosa* is in Murzuk basin, Libya: Ash Shati, Ashkidah Formation, Lower Tournaisian. The generic assignment of *Sp. bulbosa* has been discussed by Legrand-Blain (1995b). The specimens of Kh. Lakahal section, a little smaller in size than the types, are similar to *Spinocarinifera* aff. *bulbosa* from Algeria : Timimoun area, coquinas preceeding the *Gattendorfia* horizon.

Spinocarinifera sp. 1 aff. *arcuata* (Hall, 1858)

1995a - *Spinocarinifera* sp. 1 aff. *arcuata* (Hall, 1858), Legrand-Blain, p. 438-439, pl. III, figs. 11-12.

1995b - *Spinocarinifera* sp. 1 aff.*arcuata* (Hall, 1858), Legrand-Blain, p. 93.

Material :

Zemoul area, Zl 64 b1 = R 62665, Zl 64 b2 = R 62657, fig. MLB 1995a, pl. 3, fig. 11-12 (Tazout 2-3). Timimoun area, Gara el Kahla section, JC 935 d, ML 325 c: Upper Kahla Sandstone, *Gattendorfia* horizon. All in "Upper Fauna"

Superfamily *ECHICONCHOIDEA* Stehli, 1954
Family *SENTOSIIDAE* McKellar, 1970
Subfamily *SENTOSIINAE* McKellar, 1970
Tribe *BAGRASIINI* Nalivkin, 1979

Genus *ERICIATIA* Muir-Wood & Cooper, 1960

Diagnosis : (Brunton *et al.* in Treatise Rev. 2000, v. 3, p. 524): Type species : *Productus newberryi* HALL, 1857, Ohio, USA, Tournaisian (= *Bagrasia* Nalivkin in Sarytcheva *et al.*, 1960. Type species *Productus chonetiformis* Krestovnikov & Karpyshev, 1948).

Ericiatia cf. *chonetiformis* (Krestovnikov & Karpyshev, 1948)

1975 - *Ericiatia newberryi.* Brousmiche, p. 21, pl. 3, fig. 6-14.

1995a - *Bagrasia* cf. *chonetiformis* (Krestovnikov & Karpyshev, 1948), Legrand-Blain, p. 439, pl. 3, fig. 15-18.

1995b - *Bagrasia chonetiformis* (Krestovnikov & Karpyshev, 1948) = *Ericiatia newberryi in* Brousmiche 1975, Legrand-Blain, p. 92.

Material :

Dra Valley, Assa area, As 118.24 = R 10313, CB 1975 pl. 3 fig. 8 (El Douiya Formation, Famennian IV); - Akka area, Ak 30.13 = R 10314, Ak 86 = R 10318, Ak 72.1 = R 10319, CB 1975 pl. 3 fig. 9, 13, 14 (below Tazout 1; Famennian IV-V); - Zemoul area, AT 135.1 = R 62669, AT 135.4 = R 62670, AT 135.7 = R 62671, MLB 1995a, pl. 3, fig. 15, 16, 17. Zl 16.8-9 = R 10316, CB 1975, pl. 3 fig. 11, 12. Zl 28.1 = R 62651, MLB 1995a, pl. 3, fig. 18. (samples from Zemoul area are found in Tazout 1 sandstones). All specimens occur in "Lower Fauna" or below. The species is unknown in Timimoun area.

Suborder STROPHALOSIIDIINA Schuchert, 1913

Superfamily *STROPHALOSIOIDEA* Schuchert, 1913
Family *ARAKSALOSIIDAE* Lazarev, 1989
Subfamily *ARAKSALOSIINAE* Lazarev, 1989

The subfamily is characterised by : "... cicatrix reduced ... marginal structures absent" (Brunton *et al.* 2000, Treatise Revised v. 3, p. 576). Araksalosiid shells, abundant in Algero-Moroccan upper Famennian, are always devoid of cicatrix of attachment : "a flattening of the pedicle umbo... place of cementation of the pedicle valve to a foreign object" (Muir- Wood & Cooper, 1960, p. 5). They possess strong cardinal spines : - either a row on hinge-line, a chonetid-like morphology; - or a pair of "brushes" near cardinal extremities, without strong spines along the hinge-line. These cardinal spines probably served for attachment on the sea bottom.

The Araksalosiinae are common and diversified in upper Famennian (Lazarev, 1989), rare in lower Tournaisian : only the genera *Acanthatia* and *Ruthiphiala* (Brunton *et al.* in Treatise Rev., 2000).

Genus *ACANTHATIA* Muir-Wood & Cooper, 1960

Diagnosis : (Brunton *et al.* in Treatise Rev., 2000, v. 3, p. 576): Outline subcircular, cicatrix small ; interareas, but reduced in dorsal valve, narrow arched pseudodeltidium ; ventral spines strong at hinge, fine prostrate elsewhere, rare dorsally...Type species : *Heteralosia nupera* Stainbrook, 1947, uppermost Famennian, New Mexico, Percha Shale. The assignment to *Acanthatia* is tentative for N. African species, including *A. placita* Mergl, 1992 Libyan Tournaisian : they have apparently no cicatrix.

Acanthatia (?) *placita* Mergl & Massa, 1992

1992 – *Acanthatia placita* sp. n., Mergl & Massa, p. 57, pl. 6, figs 11-16.

1995a - *Acanthatia placita* Mergl, 1992, Legrand-Blain, p. 432, pl. 2, figs. 1-4.

1995b - "*Acanthatia*" *placita* Mergl, 1992, Legrand-Blain, p. 91.

2000 - *Acanthatia placita* Mergl - Massa, Mergl & Massa, pl. 4, fig. 11.

Material :

Dra Valley: Akka area, Ak 71 d = R 62659, MLB 1995a, pl. 1 fig. 2 (*Gattendorfia* horizon, Tournaisian). Timimoun area, Gara el Kahla section, ML 353 a 3 = FSL 413606, ML 353 a 6 = FSL 413607, ML 353 a 20 = FSL 413608, M.LB 1995 pl. 2, fig. 1, 3, 4 : Upper Kahla Formation, above the *Gattendorfia* horizon: Tournaisian. All these specimens in "Upper Faunas". The type locality of A. placita is: Aouinet Ouenine, Libya, Mrar Formation.

Acanthatia (?) sp. 1

1975 - *Agramatia* (?), Brousmiche, pl. 1, figs. 9-11.

1995a - *Acanthatia* (?) sp. 1, Legrand-Blain, p. 431-432, pl.1, figs. 10-12.

1995b - *Acanthatia* sp. 1, Legrand-Blain, p. 91.

Material :

Morocco : Assa area, As 260.3 = R 10300, CB 1975, pl. 1 fig. 10; As 260 11-15 (Lemgaïrinat Formation, Famennian IV-V); Zemoul area, AT 129.1 = R 10299, CB 1975, pl. 1, fig. 9; AT 129.14 = R 62653, AT 129.17 = R 62654, MLB 1995a, pl. 1, figs. 11, 12 (El Douiya Formation); Zl 48.1 = R 10301, CB 1975, pl. 1, fig. 11 (Lemgaïrinat Formation, Famennian IV-V).

Acanthatia (?) sp. 2

1995a - *Acanthatia* sp. 2, Legrand-Blain, p. 432, pl.1, fig. 9.

1995b - "*Acanthatia* " sp. 2, Legrand-Blain, p. 91.

Material:

Dra Valley, Assa area, Kheneg Lakahal section, unit + 3 : BK + 3.3 : dv fragment. Timimoun area : Gara el Kahla section, ML 307a1 = FSL 413605, MLB 1995a, pl. 1, fig. 9 (Upper Kahla Sandstone). "Upper Fauna".

Description

Medium-sized dorsal valve, W = 26 mm, L =18 mm. Interarea straight, umbonal area flat, passing anteriorly to a geniculated front. Dorsal ornament: conspicuous fine undulose rugae, faint radial ridges corresponding probably to ventral spines.

Discussion

The poorly preserved single specimen from Kh. Lakahal resembles the Algerian species "*Acanthatia* sp. 2", described from Kahla Sandstone, upper "coquinas" preceeding the *Gattendorfia* horizon.

Genus *HAMLINGELLA* Reed, 1943

Diagnosis : (Brunton *et al.* in Treatise Rev. 2000, v. 3, p. 576): "Resembling *Whidbornella*, but outline transversely subrounded, hinge line less than maximum width; ventral hinge spines curved with fine recumbent hairlike spines from delicate swollen bases covering valve, more erect spines dorsally; never ribbed; widely divergent ridges support cardinal process, border dorsal adductor scars posterolaterally". Type species: *Productella goergesi* PAECKELMANN, 1931, upper Famennian, Etroeungt, Rhine. Germany.

That diagnosis differs a little from the original description by Reed 1943: "hinge-line without any spine"- a distinguishing character cited also by Muir-Wood & Cooper (1960, p. 161), and observed on topotypical *H. goergesi* specimens from H. Paul's collection, Essen (cited Paul, 1939, p. 653-655, from Ratingen-Cromford section, beds 11, 13, 17: "Fa 2d - Tn 1a" equivalents according to Amler, 1995, fig. 4).

On the Moroccan materials (generally rolled in high energy sediments), the hairlike spines which covered the whole shell surface are not preserved, except for their bases and internal openings ; spine bases are absent from the hinge itself, but prominent brushes of slightly curved spines are inserted on the postero-lateral extremities of ventral valve.

Hamlingella talmouti Legrand-Blain nov. sp.
(Pl. I, figs 1-6. Table I)

DERIVATIO NOMINIS : from the geographic and lithostratigraphic name "Maader Talmout" - lower member of Tazout Formation.

HOLOTYPE : GFCL 918 = BK Collection - 2.6.2 (pl. 1, fig. 1 a-c) a decorticated ventral valve with a "brush" of spines preserved.

PARATYPES : GFCL 919 = BK - 2.6.4 (pl. 1, fig. 3) ; GFCL 920 = BK- 2.6.1.

LOCUS TYPICUS, STRATUM TYPICUM: Dra Valley Morocco: Assa area, Kheneg Lakahal section, unit - 2, 22 m above the base of Maader Talmout member (Kaiser *et al.*, 2004, fig. 1). Upper Famennian.

Material : : 16 internal / external moulds and decorticated shells

Dra Valley, Assa area, Kheneg Lakahal section : - unit - 7 (base of Maader Talmout member) : BN - 7 a1 = GFCL 923, BN - 7 a2 = GFCL 921, BN - 7 a6 = GFCL 922 (pl. 1, fig. 5, 4, 2) : dv (a1, 2, 3, 7, 8,11) and vv fragments. - Unit - 6, BN - 6 a1, 1 fragment of vv internal surface. – Unit - 2 : 3 imvv BK - 2.6.(1, 2, 3) and shell fragments. "Lower Fauna"

Diagnosis : Outline transversely subelliptical, 30-45 mm wide, hinge line inferior to maximum width; profile regularly and strongly concavo-convex; rugae and costae absent; some radial plicae faint and irregular near the front; minute spine bases covering both valves; a pair of brushes of strong spines extend from postero-lateral extremities; interareas straight, narrow, devoid of spine bases; interior of pedicle valve with strong diductor scars, minute dendritic adductors; interior of dorsal valve with bilobate cardinal process, and hinge sockets.

Description

The dimensions of the shells (table) show a hinge line always inferior to maximum width, which occurs about 1/4 posterior length. Irregular plicae are variable: either faint at front (holotype, pl. I, fig. 1a) or beginning at mid-length (paratype BK 2.6.4, pl. I, fig. 3). A narrow ventral area is devoid of spine bases (holotype, pl. I, fig. 1c; fig. 2). A brush of strong spines is sometimes preserved on ventral ears (pl. I, fig. 1c,5). The whole surface of both valves is covered by dense hair like spine bases; on dorsal internal moulds, the bases of spines appear as internal canalicules (pl. I, fig. 4b)

	Maximum W	Hinge -line W	L	Un-rolled L	hight v area	number spines / 5 mm W
Holotype	45	36	~ 34	~ 38	0,7	6
BN-7a1 dv	33	28	27	~ 31	?	6
BN-7a2 dv	36	~ 25	24	/	/	9
BN-7a6 vv	35	27	31	38	?	?
BK-2.6.4 vv	43	?	34	45	0,8?	?

Table I.

Interior of ventral valve : narrow dentritic adductor scars and large flabellate diductors (pl. I, fig. 2). Dorsal interior (pl. I, fig. 6): bilobate cardinal process passing to a long median septum, provided with a posterior alveolus, hinge sockets present.

Discussion

The new species is related to *H. goergesi* and *H. capillaris* (Reed, 1943) by its postero-lateral spine brushes, the hinge-line itself being devoid of strong spines; in this respect, it agrees with the original description of the genus *Hamlingella* by Reed (1943). (On the contrary, the Treatise Revised 2000, p. 578, fig. 410, 2 c-d includes in *Hamlingella* the species *piltonensis* (Reed 1943), provided with a row of long oblique cardinal spines).

H. talmouti differs from *H. goergesi* and *H. capillaris* by : - smaller size and less transverse outline, a more convex profile; - anterior faint plicae ; - larger size of hair-like spines covering the valves (*H. goergesi* : 3-5 spine bases per 1 mm width, as cited by Goldring (1957) and also observed on H. Paul topotypical collection, Essen).

Hamlingella sp.1, described from Timimoun area, Lower Kahla Sandstone (Legrand-Blain 1995b), similar to *H. talmouti* by the spine density, differs by a larger shell size, and a more transverse outline.

Hamlingella sp. 1
(Pl. I, fig. 7)

1995 a - *Hamlingella* sp. 1 : Legrand-Blain, p. 429, pl. 1, fig. 2.

1995 b - *Hamlingella* sp. 1 : Legrand-Blain, p. 91.

Material :

Dra Valley, Assa area, Kheneg Lakahal section, unit - 0, BN Collection - 0 a 1-3 = GFCL 925 : several abraded imvv, crushed against each others on a single sample (a1, a2) ; an isolated brush of spines (a3). "Intermediate Fauna". - Algeria, Gara el Kahla section: ML 312 a1 = FSL 413600, MLB 1995 pl. 1, fig. 2; ML 313 n1, ML 314 b1-2 (Lower Kahla Sandstone Formation: "Lower Fauna").

Description

Very large shells: W = 50 mm, L = 37 mm; outline transverse nearly semi-circular, hinge-line a little less than maximum width; longitudinal profile slightly convex ;

absence of radial costae and plicae. Ventral interarea straight, 1.3 mm maximum high at beak. Spines absent along hinge; isolated brushes observed (BN - 0 a3) not connected to shells : on the main samples (BN - 0 a1, a2), neither the spine brushes nor the hair-like spine bases are observed, probably because of poor preservation.

Ventral valve internal characters : long hinge teeth, oblique on hinge-line; dendritic adductor scars separated by a thin septum, large flabellate diductor scars. The shell material, preserved on internal moulds is coarsely pseudopunctate.

Discussion

By their large size and outline the Moroccan specimens are identical to *Hamlingella* sp.1. That species, in Algerian Sahara, Lower Kahla Sandstone, is associated with a typical Strunian Productid fauna.

Genus *KAHLELLA* Legrand-Blain, 1995

1995a - *Kahlella* nov. gen., Legrand-Blain, p. 430.

Diagnosis: (Brunton *et al.* in Treatise Rev. 2000, v. 3, p. 577): "Resembles *Whidbornella* with strong row of hinge spines, but with no anterior ribbing or sign of dorsal spines; fine impersistent rugae posterolaterally; cardinalia LEGRAND-BLAIN, 1995. Algerian Sahara, late Famennian.

Kahlella meyendorffi Legrand-Blain, 1995

1995a - *Kahlella meyendorffi*, nov. gen., nov. sp., Legrand-Blain, p. 430-431, pl. 1, figs. 1, 5-8.

1995b - "*Whidbornella*" gen. nov. sp. 1, Legrand-Blain, p. 92.

Material :

Algeria: Gara el Kahla section : holotype ML 314 a1 = FSL 413602 a (MLB 1995 pl. 1, fig.1); paratypes ML 314 a2 = FSL 413602 b, ML 314 a3 = FSL 413604, ML 314 a8 = FSL 413603 (MLB 1995 Pl. I fig. 7, 8, 5); ML 313 m1-3, ML 317, ML 320, ML 366 a1-3, JC 915 c1, pl. 1, fig.6. All specimens in Lower Kahla Sandstone Formation, late Famennian. "Lower Fauna"

Kahlella sp.
(Pl. I, figs. 12-13)

Material : : 11 specimens

Morocco : Assa area, Kheneg Lakahal section, unit -6, BN - 6 c1, fragmentary shell with cardinal spine bases ; unit -3, BN - 3b = GFCL 927, pl. 1, fig. 13; BN - 3p, q, incomplete shells ; unit - 2, BN - 2g = GFCL 928, pl. 1, fig. 12, fragment of a large-sized vv. Zemoul area, Zl 37 (Tazout 1 beds), poorly preserved fragments. All specimens in "Lower Fauna".

Description

Semi-circular regularly convex shells, the size of which increases in successive levels of Kh. Lakahal section: W = 37 mm in unit - 6 ; 38-45 mm in unit -3 ; 55 mm in unit – 2 (GFCL 928, pl. 1, fig. 12). Ventral valves covered by short spine ridges which do not form costellae: 6-7 per 5 mm width ; faint rugae on ears, some irregular radial plicae appearing near the front. Spines bases: very thin on ventral external surface (s); strong along the hinge-line (GFCL 927, pl. 1, fig. 13b).

Discussion

The poorly preserved samples from Kh. Lakahal resemble *K. meyendorffi* by their outline and ventral ornamentation, but the dorsal valves, complete hinge spines and internal characters are insufficiently observed. The size of specimen GFCL 928 is larger than typical *K. meyendorffi* (W = 34-45 mm).

Range

The genus *Kahlella* is originally described from Timimoun area, lower "coquinas" of lower Kahla sandstone Formation.

Genus *WHIDBORNELLA* Reed, 1943

Diagnosis: (Brunton *et al.* in Treatise Rev. 2000, v. 3, p. 578): "Outline subcircular to elongate, wide hinge-line; rugae irregular, mainly at ears; spines strong at ventral hinge, elongate spine bases tending to form incipient ribs anteromedianly; inner socket ridges at high angle to hinge supporting low cardinal process. Type species: *Leptaena caperata* SOWERBY, 1840, uppermost Famennian, Pilton beds, Devon, England.

Whidbornella cf. *pauli radiata* (Paeckelmann, 1931)
(Pl. I, fig. 8)

cf. 1931 - *Productella caperata* (Sowerby), var. nov. *radiata* : Paeckelmann, p. 67, pl. 3, figs 6-11.

p.p. 1957 - *Productella* (*Whidbornella*) *pauli*, nom. nov. var. *radiata* (Paeckelmann 1931) : Goldring, p. 218.

cf. 1975 - *Whidbornella pauli radiata* Paeckelmann, 1931: Brousmiche, p. 133, pl. 1, figs. 18-22.

cf. 1995a - *Whidbornella pauli* Goldring, 1957 : Legrand-Blain p. 430, pl. 1 figs. 3, 4.

1995b - *Whidbornella pauli* Goldring, 1957: Legrand-Blain, 91.

Material :

Dra Valley, Assa area, Kheneg Lakahal section, BN Collection unit – 6, - 6 b1 = GFCL 926, pl. 1, fig. 8, and decorticated vv fragments (BN - 6 b2, b3). - Zemoul area, Zl 29.1 = R 10305, CB. 1975 pl., fig. 18, Zl 29.5-8; Zl 37.1 = R 10308, CB 1975 pl. 1, fig. 22; Zl 37.13 = R 62668, MLB 1995 pl. 1, fig. 4. Zl 16, 17 (Zemoul area specimens in Tazout 1 beds) - Algeria, Gara el Kahla section, ML 311 b6 = FSL 413601, MLB 1995 pl. 1, fig.3; ML 317 c1 (Lower Kahla Sandstone Formation). All specimens in "Lower Fauna".

Description

Poorly preserved ventral valve fragments; W = 30 mm, L = 26 mm. Ornament : faint rugae on ears; umbo covered by minute spine ridges quincuncially arranged; anteriorly, these spine ridges increase in size, become radially aligned and form discontinuous costellae : 4-5 per 5 mm width. Along the hinge margin, there are some spine bases.

Discussion

There are gradations between species and subspecies of the genus *Whidbornella*, especially *W. caperata, W. pauli* and the "variety" *radiata*.

The range of the group is: Strunian in England, the type area (Pilton A1-A3 = palynozones LE- basal LN according to O'Liathain, 1993), NW Germany (upper part of Velberter Schichten at Langenhorst ="Strunium", cf. Michels 1986, Amler 1995) and Belgium ("Tn1a"); the group is reported from Central Asia (Altai), Japan. In N. Africa, *Whidbornella* spp. are found: in Morocco, Tazout 1; in Algeria: Lower Kahla Sandstone.

Subfamily *RHYTIALOSIINAE* Lazarev, 1989

Genus *STEINHAGELLA* Goldring, 1957

Diagnosis : (Brunton *et al.* in Treatise Rev. 2000, v. 3, p. 586): Type species : *Leptaena membranacea* PHILLIPS, 1841, SW England, late Famennian.

Steinhagella cf. *membranacea* (Phillips, 1841)

1975 - *Steinhagella membranacea* (Phillips, 1841), Brousmiche, p. 18, pl. 3, figs. 1-5.

1995a - *Steinhagella* cf. *membranacea* (Phillips, 1841), Legrand-Blain, p. 433, pl. 2, figs 5-6.

1995b - *Steinhagella* cf. *membranacea* (Phillips), Legrand-Blain, p. 91.

Material :

Morocco : Zemoul area, AT 129.3 = R 62664, AT 129.13 = R 62667, MLB 1995 pl. 2, fig. 5, 6; AT 130.1 = R 10309, CB 1975 pl. 3, fig. 2; AT 132.4 = R 10311, CB 1975, pl. 3, fig. 4; Zl 15.1 = R 10312, CB 1975 pl. 3, fig. 5; Zl 16.7 = R 10310, CB 1975 pl. 3, fig. 3. (El Douiya and Lemgaïrinat and basal Tazout 1 Formations) - Timimoun area, Gara el Kahla section, ML 312 e1, 314 c1-2, JC 915 a1 (Lower Kahla Sandstone Formation). "Lower Fauna".

Order RHYNCHONELLIDA Kuhn, 1949 - by D. BRICE

Superfamily *RHYNCHOTREMATOIDEA* Schuchert, 1913
Family *TRIGONIRHYNCHIIDAE* Schmidt, 1965
Subfamily *TRIGONIRHYNCHIINAE* Schmidt, 1965

Genus *CENTRORHYNCHUS* Sartenaer, 1970

Diagnosis : (Savage *et al.* in Treatise Rev. 2002, v. 4, p. 1067). Type species: *Camarotoechia baitalensis* REED, 1922. *C. charakensis* Brice, 1968, (fig. 721, 4d-l in the Treatise revised), from the upper Famennian in Afghanistan, has a covered septalium (Brice, 1968, fig. 2, 3). In my opinion, the genus belongs to Trigonirhynchiinae.

Centrorhynchus spp. cf. *lucida* (Veevers, 1959)
(Pl. II, figs 17, 20, 24-25 c-h)

Material : 47 specimens

Morocco: Assa area, Kheneg Lakahal section BN Collection unit - 7 (1 incomplete ecdv), unit – 6 (2 emvv, 1 emdv), unit – 5 (5 ecdv, 1 ecvv), unit – 2 (6 emdv), unit – 1 (4 emdv, 4 emvv, 1 vv, 1 imvv, 1 imdv). BK Collection unit - 1.1 (2 vv, 2 emdv, 1 dv, 1 emvv), – 1.7 (1 vv, 1 dv). Hassi Rharouar section, late Famennian (V), MZ Collection MZ 2 (2 incomplete sp, 7 dv, 2 vv), Algerian-Moroccan border, El Douiya Formation, i 792 (1 dv, 2 incomplete sp), "Lower Fauna"; i 848 (1 sp., 1 vv) late Famennian (Strunian ?) "Intermediate Fauna" (?).

Description

Shell transversely oval to subpentagonal, wider than long, slightly dorsi-biconvex, both valves are strongly plicated covered by radial simple costae originating at beaks, increasing in width from umbo, sulcus and fold well defined. Maximum width at mid-length or anteriorly. Ventral sulcus and dorsal fold starting at a short distance of the umbo, progressively deepening anteriorly with 3 (rarely 4) angular costae; flanks are flats or sometimes weakly concave then redressed near anterolateral margins as spurs, curved towards exterior. Dorsal valve more convex than ventral valve, with maximum deep at umbo. Fold starting at umbo, with 4 (rarely 5) costae, moderately high maximum, at the front or slightly posteriorly. Parietal costae absent.

Dental plates divergent. Dorsal septum present.

Discussion

These specimens belong to *Centrorhynchus* by external characters (shape, sulcus and fold, ornamentation) and by internal characters. They are close to *Centrorhynchus lucida* but they are always smaller and comparatively wider than australian species. These rhynchonellids probably belong to several species but, in many cases our material represented by casts or moulds, sometimes deformed, is inadequate for a formal specific determination. Some specimens from Hassi Rharouar section (collected by Morzadec and the author) remind *Centrorhynchus charakensis* (Brice, 1968, 1971) from the late Famennian of Robat-e Païˆ, and Ghouk, western Afghanistan; they have the same size and delicate connectivum covering the dorsal septalium.

Range

The genus *Centrorhynchus* has a world-wide distribution. It is known in late and latest Famennian (in the Strunian of Etrœungt in Avesnois, France) in western Europe, Pamir, Iran, Afghanistan, Transcaucasia, Australia, North America. But some attributions at this genus from Turkey, China, the former Soviet Union need confirmation. In southern Morocco, *C.* spp. cf. *lucida*, restricted to the "Lower Fauna". Its presence in Algerian-Moroccan border, in latest Famennian (Strunian ?) "Intermediate Fauna" (?) needs confirmation.

Centrorhynchus (?) sp.
(Pl. II, fig. 21)

Material : 3 specimens.

Morocco : Tafilalt, El Atrous, upper Hangenberg sandstones (2 cdv); Aoufilal section, upper beds level 29 MB.B.2395 = EAY.1 (1vv).

Discussion

The ventral valve (MB.B.2395, pl. 2, fig. 21) resembles to *Centrorhynchus* gr. *letiensis* (Gosselet, 1879) by its shape slightly convex, almost flat, a sulcus weakly developed and subangular costae that start at the beak (3 in the sulcus, 5 on the flanks). But it differs of *C. letiensis* by a smaller size. The dorsal valve, more convex than ventral valve, shows a moderately developed fold with 4 radial costae.

Range

The valves assigned tentatively to the genus *Centrorhynchus* have been collected by Sandra Kaiser in South Tafilalt, El Atrous section (20 km NW of Taouz). The first ones from the upper Hangenberg sandstones, the second one from the lower part of a thick brachiopod sandstone (55 m thick) belonging to the upper Ouaoufal Formation (Kaiser and Becker, written comm.), latest Famennian (?) in age.

Genus *MACROPOTAMORHYNCHUS* Sartenaer, 1970

Diagnosis : (Savage *et al.* in Treatise Rev. 2002, v. 4, p. 1056). Type species: *Camarotoechia mitcheldeanensis* VAUGHAN, 1905. Gloucestershire, England , early Tournaisian

Macropotamorhynchus Brice nov. sp. aff. *insolitus* Carter, 1987

(Pl. II, figs 11-12, 14-16)

Material : about 29 specimens

Morocco: Assa area, Kheneg Lakahal section, BN Collection unit + 0 (2 vv, 1 dv) " Intermediate Fauna ". Kheneg Lakahal section, BN Collection unit + 2.12 (remains), + 2.13 (1 ecdv, 1 imdv), + 2.15 (1 vv), BK Collection unit + 2.12 (1 dv), Algerian, Gara el Kahla section, Upper Kahla Sandstone ML 308 (1vv, 5 imdv), ML309 (2 emdv), ML 324 (1 incomplete vv), ML 330 (3 vv, 2 dv), ML 325 (5 sp.), ML 387 (2 emdv, 1 dv, 1 vv) " Upper Fauna ", Early Tournaisian.

Description

Small rhynchonellid medium for the genus, dorsibiconvex, usually sub-trigonal in outline, wider than long, the maximum width usually situated slightly anterior to mid-length. Width varies between 9 and 10 mm and length between 8 and 8.5 mm. Sulcus and fold only developed in the anterior part of the shell, well limited but moderately developped. Both valves covered by regular, simple, subangular costae originating at beaks, often 3 or 2 (rarely 1 or 4) in the sulcus, 4 or 3 (rarely 2 or 5) on the fold and 5-6 lateral costae. Parietal costae are absent. Dorsal valve more inflated than ventral valve, maximum posteriorly, umbonal region flattened with medial depression. Top of the shell is near the front generally a little more posteriorly.

Apical angle varies between 102 and 112°. Dental plates short and divergent. Dorsal septum short.

Discussion

These specimens belong to *Macropotamorhynchus* by their external and internal (unfortunately incompletely observed) characters. They are close to *M. insolitus* Carter, 1987, (but their size a little more large, and the number lateral costae 7-8 for *M. insolitus* 5-6 for african specimens).

Range

Macropotamorhynchus is a cosmopolitan genus known in the Early Carboniferous (Tournaisian) of Eurasia (Great Britain, Belgium, Ural, Kuznets Basin; in the Strunian and Tournaisian from Altaï, Tian Shan, Kazakhstan, Pamir; in the Early Mississipian (Tournaisian-Visean) from North America: Canada (Alberta), USA (Oklahoma, Pennsylvania, Maryland, New Mexico, Kentucky) and NW and W of Australia. *Macropotamorhynchus* nov. sp. aff. *insolitus* is present in southern Morocco : in the " Intermediate " and " Upper Fauna " in Kheneg Lakahal section and in the "Upper Fauna " in Algeria, Timimoun area.

Subfamily *HEMITOECHIINA* Savage, 1996

Genus *PAUROGASTRODERHYNCHUS* Sartenaer, 1970

Diagnosis : (Savage *et al.* in Treatise Rev. 2002, H4 p.1073). Type species : *Camarotoechia* (?) *nalivkini* ABRAMIAN, 1957, late Famennian, in the former Soviet Union (Armenia).

Paurogastroderhynchus presaharensis Brice nov. sp.

(Pl. II, figs. 1-7, 25 a-b. Table II)

1975 - *Paurogastroderhynchus* sp. Sartenaer, p. 6-7, pl. 2, figs. 1-3.

2004 - *Paurogastroderhynchus* sp. Brice, Legrand, Nicollin in Brice *et al.*, p. 15-16

2004 - *Paurogastroderhynchus* sp. Brice, Legrand, Nicollin in Kaiser *et al.*, p. 94, 95, 97.

DERIVATIO NOMINIS: name derived of Presahara region where species has been collected

LOCUS TYPICUS, STRATUM TYPICUM: Southern Morocco, Dra Valley, Assa area, Kheneg Lakahal section, described by Kaiser in Kaiser *et al.* (2004), from unit - 6 to - 1 (28 m thick), upper Famennian.

HOLOTYPE: GFCL 962 = BN - 4a, unit – 4, pl. 2, fig. 1a-d.

PARATYPES: GFCL 963 = BN - 4b, unit – 4 ; pl. 2, fig. 3, GFCL 964 = BN - 4c, unit – 4 ; pl. 2, fig. 4, GFCL 965 = BN - 3b, unit - 3 ; pl. 2, fig. 6, GFCL 966 = BN - 2j, unit - 2 ; pl. 2, fig. 7, GFCL 967 = BN - 5b, unit - 5 ; pl. 2, figs 2, 25b, GFCL 968 = - 5a, pl. 2, fig. 25a, unit - 5.

Material : 66 specimens.

Morocco: Assa area, Kheneg Lakahal section, BN Collection unit – 6 (1 dv), unit – 5 (1 imvv, 1 vv, 1 imdv, remains); unit – 4 (2 sp, 1 emvv, 1 emvd, 1 imvv); unit – 3 (1 imvv, 1 dv, 1 vv); BK Collection unit – 2.6 (2 ivv, 1 ivv, 2 ecdv, 6 idv) ; BN Collection unit – 2 (3 ecvv, 2 ecdv), BK Collection unit – 1.4 (1 ecvv joung specimen), - 1.7 (1 imdv) , - 1.1 (1 vv) ; BD Collection, Hassi Rharouar section Famennian (V) fide Hollard 1975 (2 dv) ; Algerian-Moroccan border, Lemgaïrinat Formation " Famennian V " ZI 57 (remains vv); Algeria, Gara el Kahla section, Lower Kahla Sandstone, ML 313 (2 emvv, 1 vv, 1 dv) , ML 365 (1 vv), 26 sp described by Sartenaer, 1975, types housed in the Alger University (pl. 2, fig. 3, ML 313j = 1043001, pl. 2, fig. 1, ML 313b = 1043003, pl. 2, fig. 2, ML 365a = 1043008). All specimens " Lower Fauna ".

Diagnosis. Large *Paurogastroderhynchus*, transversally elliptic, dorsi-biconvex, sulcus and fold moderately or weakly developed, start at a variable distance from the beaks, only separate of flanks in the anterior part of the valves. Front and sides of valves truncated by rectangular bending of valves. Costae strong, simple, (19 to 26), extending from beak, angular near the beaks, asymmetrical in the anterior part of the shell, median and parietal costae are usually indistinct. Dental plates and short dorsal septum.

Description

The ventral valve is shallow, weakly convex in the umbo region. The sulcus starts at a certain distance from the beak, it is weakly developed with flat bottom, only distinct in the anterior part of the valve. Flanks and sulcus truncated by rectangular bending of valves. Tongue is low and rectangular.

	Holotype	Paratype	Paratype	Paratype	Paratype	Paratype	ML 313
GFCL	962	963	965	966	967	968	969
W	30.5	-	42	34.5	26.5.	30?	42
L	29.9	-	-	30.8	26?	-	33
T	20	-	-	-	-	-	-
Apical angle (°)	117	127	130?	130	-	-	120

Table II — (Measurements in mm):

The dorsal valve is regularly convex, deeper than the ventral valve, recurved toward ventral valve near the commissures. ; it shows a weakly medialn on the posterior region. The fold starts about in front of the umbonal region, it is usually low, with a top almost flat, it is only developed in the anterior part of the shell

Ornamentation. Valves are covered by strong radial costae, narrow and angular near the beaks, wider and subangular or subrounded forward where they are asymmetric with central flank flattened and external flanks short and abrupt. Intercostae grooves narrover than costae. In specimens in which median and lateral costae could be counted the costal formula is as follows: 5-8/4-7 median costae; 7-9/8-10 lateral costae.

Dental plates are short and divergent. The dorsal septum is short.

Discussion

This species has external characters of the genus *Paurogastroderhynchus*: ornamentation, poorly developed anteriorly sulcus and fold, dental plates and short dorsal septum.

P. presaharensis differs from *P nalivkini* by larger size, a form not so globular and not higher than type species. Specimens from the Algerian Sahara are often larger than Morocco: specimens.

The species *serdelesencis* (Massa *et al.*, 1974) assigned to *Paurogastroderhynchus* by Mergl & Massa (1992) from the late Tournaisian of western Libya needs confirmation. According to these authors the Libyan specimens may represent a new genus.

Range

The genus is presently known by the type species, described by Abramian (1954) from SW Armenia where it characterizes an horizon of the late Famennian below the Etroeungt Zone. It is an index genus of a brachiopod zone of the Gortun Suite of of Transcaucasus (Armenia) which has conodonts indicating an age no older than the *styriacus* or *postera* Zone (Mamedov & Rzhonsnitskaya, 1985; Rzhonsnitskaya, & Mamedov, 2000). The genus is also present in the late Famennian of Iran (Azerbaidjan, Eastern Elburz), in Afghanistan (Sartenaer, 1970; Brice 1971) and latest Famennian (Strunian) in Mighan section Eastern Elburz (Wendt *et al.*, 2005). *P. presaharensis* nov. sp. is recognized in Algeria, Timimoun region (Sartenaer, 1975) and probably in the Ahnet area in Khenig Sandstones. It is represented in Morocco, Western Anti-Atlas, in the Kheneg Lakahal section where the species is abundant; and by some remains in Hassi Rharouar section in SE of Tinfouchy, and Zemoul area, in "Upper Famennian V" *fide* Hollard (SDS 1975, 1981).

Subfamily *RIPIDIORHYNCHINAE* Savage, 1996

Genus *HEMIPLETHORHYNCHUS* von Peetz, 1898

Diagnosis : (Savage *et al.* in Treatise Rev. 2002, v. 4, p. 1076). Type species: *Hemiplethorhynchus fallax* von PEETZ, 1898, Altai in the former Soviet Union, Tournaisian

Hemiplethorhynchus (?) sp. cf. *allani* (Carter, 1987)
(Pl. II, figs. 19, 22-23, 26)

Material : 7 specimens.

Morocco : Tafilalt: El Atrous, upper Hangenberg sandstones; Upper Ouaoufa section SK MB.B.2396 = EAZ 16 (2 vv, 1 imvv, 1 cvd) level 34; MB.B..2397 = EAX (1imdv) upper level 30; MB.B.2398 = EAY2 (1 imdv) level 28; MB.B.2399 = EAY (1vv, 1imdv) level 28.

Description

Shell small, subpentengonal rounded, slightly wider than long, maximum width at anterior part. Ventral valves are weakly convex, sulcus obscure, poorly delimited with flat bottom. Dorsal valves are more convex than ventral one, fold is low, sometimes not delimited from the flanks, it is recurved toward ventral valve near anterior commissure. Regular, simple, rounded or subangular costae originated from the apex; usually 5/4 median costae, 0 or 1-0 parietal costae, 6 lateral costae. Dental plates and dorsal septum are short.

Discussion

Owing to the lack of bivalve specimens, incomplete valves and the lack of information on the interior, these rhynchonellids are assigned with doubt to *Hemiplethorhynchus* on the basis of their shape, dorsal valve more convex than ventral one, ornamentation, dental plates and short dorsal septum. They resemble *Hemiplethorhynchus allani* (Warren) from the Banff Formation (Canada) figured by Carter (1987, pl. 13, fig. 13-37) by their outline but they are smaller and have less numerous costae.

Range

The genus *Hemiplethorhynchus* is known in the Tournaisian of the former Soviet Union (Altai, Kuznetsk), in North America Canada (Alberta), USA (Iowa), in Europa (*H.* (?) *pyrenaicus* Martinez-Chacon & Devolvé, 1986), and in China. The poor valves asssigned tentatively at *H* (?) sp. cf. *allani* collected by Sandra Kaiser in South Tafilalt, El Atrous section (20km NW of Taouz), in thick brachiopod sanstones (55 m thick) belong to the upper Ouaoufal Formation (Kaiser and Becker, written comm.), Tournaisian in age (?).

Family *LEIORHYNCHIDAE* Stainbrook, 1945
Subfamily *BASILICORHYNCHINAE* Savage, 1996

Genus *GASTRODETOECHIA* Sartenaer, 1965

Diagnosis: (Savage *et al.* in Treatise Rev. 2002, v. 4, p.1156). Type species: *Leiorhynchus utahensis* KINDLE, 1908, Montana, USA, lower Upper Famennian

Gastrodetoechia sp.
(Pl. II, figs 9-10)

1975 – *Gastrodetoechia* sp. Sartenaer, p. 7-9, pl. 1, fig. 2a-c.

Material: 2 specimens.

Morocco: Assa area, BD Collection, Hassi Rharouar section, Famennian (V) fide Hollard (1 dv), Lemgaïrinat Formation As 260 Famennian (V) fide Hollard (1 incomplete sp); Algeria, Gara el Kahla section, Lower Kahla Sandstone ML 314. All specimens "Lower Fauna"

Description and Discussion

The Moroccan dorsal valve from Assa area has a fold clearly delimited, low, beginning at the umbonal region, recurved anteriorly. Four median subangular costae start near the beak; one rounded lateral costa begins about at the umbo and another one at mid length.

The Algerian Sahara specimen is an incomplete internal mould of the shell. It is larger than the Moroccan one. The dorsal valve shows the trace of a long median septum and a low fold beginning at the umbo, its anterior part shows traces of two or three irregular low median costae; the anterior part of the ventral sinus shows the traces of two low median costae.

These poorly preserved specimens probably belong to different species but they have external and internal characters resembling those of the genus *Gastrodetoechia*.

Range

Gastrodetoechia is known in North America (USA and Canada), in Afghanistan, Iran, and in the North Africa. Sartenaer (1975) has described some specimens of western Sahara (Algeria), four from Oum el Guedour section (Mechem area) and one mould of dorsal valve from SW of Timimoun, Strunian (after Conrad & Termier, 1970). The genus exists also in southern Morocco : in the late Famennien (V) *fide* Hollard, 1981.

Family *PETASMARIIDAE* Savage, 1996

Genus *MEGALOPTERORHYNCHUS* Sartenaer, 1965

Diagnosis: (Savage *et al.* in Treatise Rev. 2002, v. 4, p. 1192). Type species: *Megalopterorhynchus haynesi* SARTENAER, 1965, Banff National Park, Alberta, Canada, Late Famennian.

Megalopterorhynchus sp.
(Pl. II, figs 13, 25i)

1975 - *Megalopterorhynchus* sp. Sartenaer, p. 4-6, pl.1, fig. 1a-e.

Material:

Morocco: Assa area, Kheneg Lakahal section, BN Collection unit - 5 (1ecdv); Algeria: Gara el Kahla section, Lower Kahla Sandstone ML 313 a1, figured in Sartenaer 1975, pl. 2, fig. 1 housed in the Alger University 1043002. All specimens "Lower Fauna"

Discussion

This cast of a dorsal valve has similar characters of the specimen from Timimoun region (westerna Sahara Algerian) figured by Sartenaer (1975) and attributed to *Megalopterorhynchus.*

Range

The genus is presently known in the late Famennian by the type species from Alberta (Canada), in southwestern Montana (U.S.A.), described by Sartenaer (1965), and Idaho (Sartenaer & Sandberg, 1974); in Afghanistan (Brice, 1971), central Iran (Djafarian & Brice, 1973), eastern Elburz, Armenia (Sartenaer, 1975), and northern Africa, western Sahara (Algeria) Timimoun region, and Morocco : (western Anti-Atlas).

Genus *SHUMARDELLA* Weller, 1910

Diagnosis: (Savage *et al.* in Treatise Rev. 2002, v. 4, p. 1194). Type species: *Rhynchonella missouriensis* SHUMARD, 1855, Missouri, USA, Tournaisian, Mississippian (Kinderhookian).

Shumardella Brice n. sp. aff. *fracta* Carter,1988
(Pl. II, figs 8 a-d)

Material: 3 specimens.

Algerian: Gara el Kahla section, Upper Kahla Sandstone ML 325 (3 sp) "Upper Fauna".

Description

Rhynchonellid of medium size, subtriangular to subpentagonal in outline, with greatest width anterior to mid-length, dorsi-biconvex, sulcus and fold beginning in posterior regions of valves but not strictly defined. Ornamentation absent or poorly developed, restricted at anterior margin: 3-2 median and 1-2 short low lateral costae or ondulations. Subangular commissures. Ventral valve very shallow almost flat except at umbonal region where is weakly convex; beak small, erected. Sulcus broad, moderately deep with dorsally deflected high ogival vertical tongue. Dorsal valve much more inflated than ventral valve particularly in umbonal region. Fold poorly defined, maximum height at mid-length.

Mensurations of two specimens in mm: L = 13.9; 16.1; W = 17.5; 16.4; T = 12.6; 12.2. Apical angle = 109°; 110°.

Dental plates short and divergent. Dorsal median septum.

Discussion

These specimens belong to *Shumardella* by their external characters in despite of some similarities with the genus *Ovlatchania* Abramov & Grigorjewa, 1986. They are close to *S. fracta* but their ornamentation is different.

Range

This genus is recorded in the Early Mississipian (Tournaisian-Visean) in North America after Carter (1990, fig. 2): in Canada (Alberta), USA (Missouri, Indiana, New Mexico, British Colombia), or Tournaisian in the former Soviet Union (Kuznetsk Basin and Kazakstan). *Shumardella* nov. sp. aff. *fracta* is only present in the "Upper Fauna" (Lower Tournaisian) in Algeria, Timimoun area.

Order SPIRIFERIDA Waagen, 1883
Suborder SPIRIFERIDINA Waagen, 1883

Superfamily *CYRTOSPIRIFEROIDEA* Termier & Termier, 1940 - by J-P. NICOLLIN
Family *CYRTOSPIRIFERIDAE* Termier & Termier, 1949
Subfamily *CYRTOSPIRIFERINAE* Termier & Termier, 1949

Genus *CYRTOSPIRIFER* Nalivkin in Frederiks, 1919 (1924)

Diagnosis: (Pitrat in Treatise 1965, v. 2, p. 697). Type species: *Spirifer verneuili* MURCHISON, 1840, Boulonnais, Frasnian.

Cyrtospirifer pseudorigauxia Nicollin nov. sp.
(Pl. IV, figs. 25-27; Fig. 4)

DERIVATIO NOMINIS: The name is derived from the external resemblance to the genus *Rigauxia* Brice, 1971.

LOCUS TYPICUS, STRATUM TYPICUM: Dra Valley, Morocco, Zemoul area, South of the Zemoul anticline, El Douiya Formation, Late Famennian (IV?) *fide* Hollard.

HOLOTYPE: GFCL 995 = i 792, pl.4, fig. 27.

PARATYPES: GFCL 996 = i 792, GFCL 997 = i 792, GFCL 998 = i 792, GFCL 999 = i 792, GFCL 2078 = i 792.

Material: 32 specimens

All ages are given *fide* Hollard

Morocco: Assa area, Lemgaïrinat Formation, Late Famennian (V), HH Collection, As 260 (2 sp, 1 vv); Akka area, Lemgaïrinat Formation, late Famennian (V or VI?), HH Collection, Ak 72 (2vv). Algerian-Moroccan border: Zemoul area, El Douiya Formation, LateFamennian (IV?), PJ Collection, i 792 (1 sp, 1 imsp, 1 vv, 2 imvv, 3 dv, 4 imdv), Lemgaïrinat Formation, Late Famennian (V), HH Collection, AT 141 (2 vv), Zl 27 (1 vv), PJ Collection, i 843 (1 imvv, 2 imdv); base of Tazout 1 Formation, Latest Famennian (VI), HH Collection, AT 135 (2 imsp, 7 vv, 2 dv), a little higher in Tazout 1 Formation, Zl 17 (1 sp, 1 vv, 1 imvv).

Diagnosis: Small *Cyrtospirifer* species that externally resembles *Rigauxia,* but differs internally by the presence of a delthyrial plate. It is ventribiconvex with a slightly curved ventral beak and a high ventral interarea. The sulcus is deep and well-limited. The ornamentation is made of 12-17 simple lateral costae and some marked growth lamellae. Micro-ornamentation made of capillae.

Description

The species is of small size for the genus (maximal width in adult specimens: 25 mm). It is equithyrid or slightly megathyrid and ventri-biconvexe.

The ventral valve is sub-pentagonal in outline and fairly strongly convex, especially in the posterior third portion. The flanks have stiff and regular slopes. The ventral beak is slightly curved, and generally doesn't overlap the interarea. The ventral interarea is relatively high, triangular, apsacline or sometimes nearly catacline, with numerous vertical striae and rarer horizontal ones. The delthyrium is open and narrow. The sulcus is moderately wide, deep, clearly limited by two bounding costae and has a v-shaped or rounded bottom.

The dorsal valve is much less convex than the ventral valve and is sub-trapezoidal in outline. The dorsal interarea is very low. The fold is narrow, well-limited by two distinct grooves and has a rounded top.

The ornamentation consists of 12-17 simple, relatively high, rounded or slightly angular costae. The interspaces are of the same width as the costae. The ornamentation of the sulcus and fold (*Cyrtospirifer*-type) reaches 12 ribs in adult specimens. Some marked growth lamellae are present in the posterior and medial part of the shell. Micro-ornamentation made of radial micro-striae prolonged in spines.

The observed internal characteristics are short and extra-sinal dental plates, a delthyrial plate (Fig. 4), short crural bases in the dorsal valve, and striated cardinal process.

Discussion

Externally, this species is very similar to representatives of the genus *Rigauxia* (Brice, 1988), in terms of its general size, shape, ornamentation of lateral slopes, fold and sulcus, and micro-ornamentation. It is mainly different from *Rigauxia* internally, due to the presence of a delthyrial plate. This feature with other external characters (general shape, sinus and fold ornamentation type) lead to assign this species to the genus *Cyrtospirifer*.

Among *Cyrtospirifer* species, *Cyrtospirifer archiaci* (Murchison, 1840) resembles to *C. pseudorigauxia.* However, this other small species from the Frasnian deposits of Boulonnais, differs from *C. pseudorigauxia* by the presence of mucrons on the lateral sides, a strongly curved ventral beak that overlaps the interarea, more numerous lateral costae, and long dental plates.

Range

Cyrtospirifer pseudorigauxia nov. sp. is largely present in the late Famennian (IV and V *fide* Hollard) series of many areas of southern Morocco: Assa, Akka and Zemoul areas. However, it hasn't been recognized in the two main sections of this study: Kheneg Lakahal in the Assa area and Gara el Kahla in the Timimoun area (northwestern Algeria). Near Sidi-el-Mouynir and Dfeif (Zemoul area) it also occurs higher in the Latest Famennian (Famennian VI, *fide* Hollard) series but seems to be rarer.

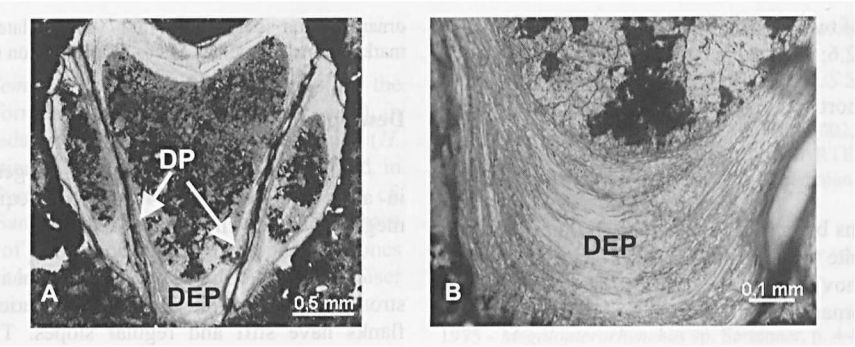

Fig. 4. — Internal structure of ventral valve of *Cyrtospirifer pseudorigauxia* n. sp., showing dental plates (dp) and delthyrial plate (dep), a (x 2,5), b (x 10).

Fig. 4. — Structure interne d'une valve ventrale de Cyrtospirifer pseudorigauxia n. sp., montrant les lames dentales (dp), la plaque delthyriale (dep), a (x2,5), b (x10).

As mentioned above, resemblances of this new species exist with taxa present in Boulonnais (North of France). But these taxa and especially *Rigauxia* are also abundant in the Upper Famennian deposits of Iran and Afghanistan.

Cyrtospirifer sp.1 aff. *leboeufensis,* Greiner, 1957
(Pl. III, figs. 6, 7)

aff. 1957 – *Cyrtospirifer leboeufensis* n. sp.: Greiner, p. 37, 38, pl. 13, figs. 1-9.

Material: 100 specimens

Morocco: Assa area, Kheneg Lakahal section, BN Collection, unit - 6 (12 vv, 1 imvv, 2 imdv, 1 ecdv), "Lower Fauna"; Hassi Rharouar section, Late Famennian (V?), MZ Collection, MZ 2, (8 vv). Akka area: Late Famennian (V, *fide* Hollard), HH Collection, Ak 30 (1vv). Algerian-Moroccan border: Zemoul area, El Douiya Formation, Late Famennian (IV or V, *fide* Hollard), PJ Collection, i 820 (2 vv); Lemgaïrinat Formation, Late Famennian (V, *fide* Hollard), PJ Collection, i 881 (8 vv, 3 dv, 2 imdv), i 828 (15 vv, 3 imvv, 8 imdv); Tazout 1 Formation, Latest Famennian (lower or middle part of Zone VI, *fide* Hollard), HH Collection, Zl 37 (20 vv, 2 dv, 1 imdv). Algeria, South Central Anti-Atlas, Tinfouchy area, upper Lemgaraïnat Formation, Late Famennian (IV or V, *fide* Hollard), HH Collection, Zl 57 (8 vv, 2 imvv).

Description

Specimens are fairly to strongly transverse, medium to large sized with an average width of 35-45 mm. The maximum width is at the hinge and the cardinal angles are acute.

The ventral valve is sub-trapezoidal in outline with the highest convexity in the posterior third of the valve. Lateral slopes are steeply convex near the sinus with convexity slightly decreasing towards the lateral extremities. The ventral beak is curved and pointed, and generally doesn't overlap the interarea. The ventral interarea is relatively high, triangular, horizontally striated, slightly concave, apsacline, and ventrally limited by sharp borders. The triangular delthyrium is open (delthyrial angle 60° or more) and wide at the base. The sulcus is moderately or fairly wide at the front. Specimens from the Kheneg Lakahal area have a very shallow, round-bottomed, and a poorly-limited sulcus. In other areas, the sulcus is a little deeper, sometimes with a v-shaped bottom and limited from the flanks by rounded borders.

The dorsal valve has a more sub-circular and less convex outline than the ventral valve, being most convex in the posterior third of the valve. The lateral slopes are slightly convex near the fold and then become concave towards the extremities. The fold is moderately wide at the front, fairly high with rounded top and well-limited from the flanks by two furrows that are wider than those of lateral slopes.

In terms of ornamentation, the lateral slopes are covered by 16-23 (average number) simple, wide and slightly rounded costae. The interspaces are strongly or slightly narrower than the costae. Seven to fifteen divided costae decorate the fold and sulcus. Micro-ornamentation made of fine radial capillae and concentric growth lines. Some marked growth lamellae are present in the anterior third of the shells of large specimens.

Internal structures observed are very long, divergent, extra-sinal (on the first groove of lateral flanks) dental plates. Additionally, a dorsal myophragm is present.

Discussion

Cyrtospirifer sp. 1. is similar to *C. leboeufensis* Greiner, 1957 (Conewango stage, Late Devonian of New York) by many characteristics (the general outline, the style of the costation, the poorly-defined sulcus, the high interarea, and the long dental plates) but differs by its umbo, which doesn't project far beyond the hinge-line and by the dental plates, which don't become convergent towards the anterior part of the shell.

Range

This species belongs to the "Lower Fauna" of the Kheneg Lakahal section (Late Fammenian series) of the Assa area. It is also present in the Late Famennian (Zones IV and V, *fide* Hollard) in other localities of Southern Morocco: the Hassi Rharouar section (Assa area), Akka and Zemoul areas. In the two last sectors, *C.* sp.1 aff. *leboeufensis* also occurs higher in the Latest Famennian series (Famennian V, *fide* Hollard) and would thus belong to the "Intermediate Fauna".

As mentioned above, it has resemblance with a North American species which occurs in levels of equivalent age.

Cyrtospirifer sp. 2 aff. *oleanensis* Greiner, 1957
(Pl. II, fig. 25j-k, Pl. III, figs. 3-5)

aff. 1957 – *Cyrtospirifer oleanensis* n. sp.: Greiner, p. 36-37, pl. 12, figs. 1-14.

Material: 88 specimens

Morocco: Assa area, Kheneg Lakahal section, BK Collection, unit – 3, sample - 3.9 (1ecvv); unit – 2, sample – 2.6 (1 ecvv); unit – 1, sample – 1.KHL - 1 (1 imdv), sample – 1.4 (1 imvv, 1 imdv), sample - 1.7 (1 imvv, 4 ecvv, 2 imdv, 1 ecdv), BN Collection, unit - 5 (2 imvv); unit – 4 (3 imvv); unit – 3 (10 ecsp, 3 imvv, 15 ecvv, 2 imdv, 11 ecdv); unit – 2 (1 imvv, 3 ecvv); unit – 1 (6 imvv, 3 imdv). Algeria: Gara el Kahla section, Lower Kahla Sandstone, coquina, Late Famennian (V-VI?), ML Collection, ML 313 (1imvv, 2ecdv); ML 315 (4 imvv, 1 dv, 2 imdv, 1ecdv); ML 316 (1imvv, 1ecvv, 1ecdv); ML 317 (1 imsp, 1 imvv). All specimens belong to the "Lower Fauna".

Description

Specimens are of medium to somewhat large size (width: 37-50 mm for adult specimens), megathyrid, and ventribiconvex. The cardinal extremities are moderately to strongly acute and sometimes weakly mucronate. The ventral valve is sub-trapezoidal in outline and generally strongly convex, with the greatest degree in the umbonal portion (posterior one third) of the valve. Towards the cardinal extremities, the convexity decreases so that the lateral profile becomes almost flat or sometimes weakly concave. The ventral umbo is more or less well detached from the posterior margin (average ventral apical angle in adult specimens = 110-120°). The ventral beak is pointed, moderately curved, and generally does not overlap the ventral interarea. The ventral interarea is triangular, often truncated, weakly to strongly concave, apsacline, and vertically and horizontally striated. The delthyrium is triangular, open, and moderately wide at the base (delthyrial angle = 48-54°). The ventral sulcus is moderately wide at the anterior margin (8-14 mm), deep, and has a round, v-shaped bottom that is generally well-limited by two wide costae.

The dorsal valve is semi-circular to sub-trapezoidal in outline and is less convex than the ventral valve with its highest convexity in the posterior third of the valve. The dorsal beak is small and the dorsal interarea is very low, almost catacline. The fold is narrow and relatively high, with a rounded top. It is well-limited by two wide furrows.

The ornamentation consists on up to 29 costae on lateral slopes in adult specimens (even 33 costae observed in one specimen). The costae are simple, weakly rounded or almost flat, wide near the sulcus, but become narrower towards the extremities. Interspaces are very narrow. 10-13 sulcal costae are present in adult specimens, although they are less wide than the lateral slope costae and bifurcate in a *Cyrtospirifer*-like pattern. Concentric growth lamellae are irregularly spaced, appearing mostly in the anterior part of the valve, but sometimes developed further posteriorly. Micro-ornamentation made of fine concentric lines and capillae visible in the interspaces.

Internal structures observed include: 1) short, divergent and extra-sinal (on the second or third groove of lateral slopes) dental plates, 2) an elliptic ventral muscular field that is longitudinally striated, and 3) a dorsal myophragm.

Discussion

This species has some similarities with *Cyrtospirifer oleanensis* Greiner, 1957, from the Conewango and Cussewago stages (Late Devonian deposits of New York, USA) such as a well-limited sulcus and similar ornamentation. However, this species differs by a less transverse outline.

C. convexus Cooper & Dutro, 1982 (Percha Formation, Box Member, Late Devonian series of New Mexico) has a higher interarea and a more acute delthyrial angle.

Cyrtospirifer sp. 2 is also different from *C.* sp. 1 by its shorter and more divergent dental plates and its more limited ventral sulcus.

Range

Like *Cyrtospirifer* sp.1, *C.* sp.2 belongs to the "Lower Fauna" of the Kheneg Lakahal section (the Late Famennian series of the Assa area). However, there are two differences with the previous species:

- it hasn't been found in Latest Devonian deposits in any other southern Moroccan locations.

- it is present in the "Lower Fauna" of the Gara el Kahla section (north-western Algerian Sahara).

Cyrtospirifer sp. 3 aff. *warrenensis* Greiner, 1957
(Pl. III, figs. 8-10)

aff. 1957 – *Cyrtospirifer warrenensis n.* sp.: Greiner, p. 35, pl. 11, figs. 1-10.

Material: . 17 specimens

Morocco: Assa area, Kheneg Lakahal section, BN Collection, unit - 5 (2 imdv); unit - 3 (1 imvv, 6 ecvv, 1 imdv, 3 ecdv). Algeria: Gara el Kahla section, Lower Kahla Sandstone, coquina, Late Famennian (V-VI ?) ML Collection, ML 312 (1 imvv, 1ecvv); ML 363 (1 imsp, 1imvv). All specimens belong to the "Lower Fauna".

Description

Specimens are medium to large-sized species (up to 50 mm for adult specimens), almost equithyrid or sometimes weekly brachythyrid. The cardinal angles are about 90° or more.

The ventral valve is sub-trapezoidal to sub-quadratic in outline and the lengh/width ratio of the valve is greater than 0.56. The overall curve is generally fairly strongly convex. The lateral slopes are steeply convex near the sinus and become concave towards the cardinal extremities. From back to front, the highest convexity is in the umbonal portion of the shell. The ventral beak is fairly curved. The ventral interarea is triangular, often truncated, strongly concave, apsacline, and striated vertically and horizontally. The delthyrium is triangular and open (delthyrial angle = approx. 50°). The ventral sinus is deep and wide at the anterior margin (anterior sinus valve width ratio = 0.31 to 0.42) with a rounded bottom. The transition between the sinus and the lateral slopes is marked by rounded ridges.

The dorsal valve is sub-quadratic in outline and is less convex than the ventral valve. There are gently convex lateral slopes, whose convexity decreases towards the cardinal extremities. From back to front, the highest convexity occurs in the middle or slightly in the posterior portion of the valve. The fold is wide, high, has rounded top, and is well-limited from the lateral slopes by two wide furrows.

The ornamentation includes 17-25 simple costae on lateral slopes. They are fairly wide and slightly rounded, becoming narrower and even obsolete towards the cardinal margins. The interspaces are very narrow. The sulcal costae are divided and somewhat numerous (11-17). Growth lamellae are prevalent beyond the posterior half of the valve. Micro-ornamentation made of thin concentric growth lines. No internal structures are observed.

Discussion

Cyrtospirifer sp. 3 is similar to *C. warrenensis* Greiner, 1957, from the Late Devonian deposits of New York in terms of the relatively limited sulcus and the short, divergent dental plates. However, its costae are less wide and its umbo does not project as broadly beyond the hinge-line.

From *C. tionesta* Greiner, 1957, this species differs by its more rounded costae (almost flat in *tionesta*) and shorter dental plates that don't become sub-parallel.

The species is different from *Cyrtospirifer* sp. 2 by a generally less transverse outline (L/W > 0.56) and by a poorly-defined sulcus border. The dental plates are shorter than those of Cyrtospirifer sp. 1.

Range

Cyrtospirifer sp. 3 has the same geographical distribution as *C.* sp. 2 in the Late Famennian series of the Kheneg Lakahal section (Assa area, southern Morocco) and the Gara el Kahala section (Timimoun area, northwestern Algerian Sahara). In both cases, it belongs to the "Lower Fauna". It's less abundant than *C.* sp. 2 and it is not present in some stratigraphical levels (units - 2 and - 1 in Kheneg Lakahal for example).

Again, and for the third time, we have found a resemblance to an Late Devonian North American species (*C. warrenensis*), which seems to be an important characteristic of most North African *Cyrtospirifer* species.

Cyrtospirifer sp. 4
(Pl. III, figs. 11, 12)

Material: 69 specimens

Morocco: Assa area, Kheneg Lakahal section, BK Collection, unit - 1, sample - 1.7 (1 imdv) - BN : unit - 1 (16 imvv, 8 emvv, 31 imdv, 13 emdv). All specimens belong to the "Lower Fauna".

Description

The specimens are small to medium sized (maximum width in adult specimens: 36 mm), generally fairly transverse, (length/width ratio: 0.33 to 0.47), ventri-biconvex and with acute cardinal extremities.

The ventral valve is sub-trapezoidal to sub-circular in outline and moderately convexe. Its highest convexity occurs in the posterior area near the umbo. The flanks are moderately steep, regularly sloped or with decreasing convexity in the most transverse specimens. The ventral beak is pointed and not or very slightly curved. The ventral interarea is moderately high and almost catacline. The sulcus is very narrow (anterior sinus valve width ratio: 0.13 to 0.23), moderately deep, with a round bottom and sharply delimited from flanks.

The dorsal valve is sub-circular in outline and poorly convex. Its highest convexity occurs in the posterior part. The flanks have weak slopes which regular or slightly decrease in some specimens. The fold is narrow, fairly high and has a rounded top.

The ornamentation consists of 13 to 20 simple costae which are high and rounded. The interspaces are slightly less wide than the costae. Scarce growth lamellae appear in the anterior part of the shell.

Micro-ornamentation made of thin concentric growth lines. Thin radial striae are also present but very difficult to be seen. Internal structures are not observed.

Discussion

Cyrtospirifer sp. 4 differs from *C.* sp. 2 by its much smaller average size and also by its narrower sulcus. Other external characters are similar to *C.* sp. 2. *C.* sp 4 is particularly well developed in the level - 1 of Kheneg Lakahal section. Larger specimens reported to *C.* sp. 2 occur rarely in the same level. So, we can wonder if *C.* sp. 2 cannot be small specimens of *C.* sp. 4. In this case, it would mean than, near the top of the Devonian in the Kheneg Lakahal area, environmental conditions are less favourable to costate Spiriferids, thus they got a smaller size. In the lower Carboniferous from the same area, the same observation can be made with the generally small specimens of *Voiseyella.*

Range

Cyrtospirifer sp. 4 has only been found in Late Famennian deposits of Southern Morocco: (Assa area, Kheneg Lakahal section) and belongs thus to the "Lower Fauna" (higher part). Its relative abundance compared to *C.* sp. 2 aff. *oleanensis* in the same levels and its significant smaller size could indicate the decline of the genus in this area before its total extinction at the end of the Devonian.

Genus *SPHENOSPIRA* Cooper, 1954 - by J.-P. NICOLLIN

Diagnosis: (Pitrat in Treatise 1965, v. 2, p. 700). Type species *Spirifera alta* HALL, 1866. Upper Devonian.

Sphenospira cf. *julii* (Dehée, 1929)
(Pl. III, figs. 15a-b)

cf. 1929 - *Spirifer julii* nov. nom.: Dehée, p. 19-21, pl. 2, figs. 1-8

Material : 11 specimens

Morocco: Assa area, Lemgaïrinat Formation, Late Famennian (V, *fide* Hollard), HH Collection, As 260 (2 vv). Algerian-Moroccan

border: Zemoul area, Lemgaïrinat Formation, Late Famennian (V, *fide* Hollard), PJ Collection, i 828 (2 vv, 1 dv, 1 imdv). Algeria, South Central Anti-Atlas: Tinfouchy area, upper Lemgaraïnat Formation, Late Famennian (IV or V, *fide* Hollard), HH Collection, ZI 57 (1 dv). Algeria, Gourara: Timimoun area, Gara el Kahla section, Lower Kahla Sandstone, coquina, Late Famennian (V-VI ?), ML Collection, ML 314 (1 imvv) ; ML 317 (1 imvv); ML 320 (2 imvv).

Description

The few material we have is only composed of isolated valves, more or less broken. However, many specimens show very well the high, slightly concave and vertically striated interarea, typical of the genus *Sphenospira*. In some of them, we have observed other characteristics of the genus : delthyrium partly closed by a delthyrial plate in its apical part, small remnants of frills visible on latero-posterior margins.

In all specimens, both ventral and dorsal valves are externally very similar to *Sphenospira julii*. Shells are generally large-sized, megathyrid, with sub-triangular to sub-trapezoidal outline. Sulcus of ventral valves are anteriorly wide, moderately deep, fairly poorly delimited. Folds of dorsal valves are wide, prominent, with rounded top. Ornamentation on lateral slopes consists of numerous, simple, wide and slightly rounded costae with much narrower interspaces. Some marked concentric growth lamellae are present mainly in the anterior part of the valves. Ornamentation of fold and sulcus has Cyrtospiriferid-like pattern.

It can be noticed that the two specimens of As 260 are smaller and have finer lateral costae.

Range

All specimens are Late Famennian (V) in age *fide* Hollard except in Timimoun area in northwestern Algeria where it could be present higher (Zone VI). In all this layers, *S.* cf. *julii* is not abundant and sometimes has some morphological features which can be slightly different from the type species (size, lateral costae).

This stratigraphic range in North Africa seems to be different from what is generally known from *Sphenospira julii*. In various countries of the world (Nicollin & Brice, 2004): western Europe (North of France, Belgium, Germany) and the former USSR countries, *S. julii* is considered as an important brachiopod marker for Strunian (= Famennian, Zone VI).

(?) Subfamily *CYRTIOPSINAE* Ivanova, 1972

Genus *DICHOSPIRIFER* Brice, 1971

Diagnosis: (Brice, 1971, p. 194). Type species: *Dichospirifer thylakistoides* BRICE, 1971, Late Famennian & Etrœungt Zone, Afghanistan.

Dichospirifer zemoulensis Nicollin & Brice, 2001

2001 - *Dichospirifer zemoulensis* Nicollin & Brice, p. 182-184, figs. 6.9-10, 7.

Material :

Morocco: Assa area, El Douiyat Formation, late Famennian (IV) As 111, Lemgaïrinat Formation, As 123, late Famennian (V) , " Lower Fauna "; Algerian-Moroccan border, Zemoul area, El Douiya Formation, Famennian (III ?) in Nicollin & Brice, AT 131.1 = GFCL 3106 fig. 6.9; AT 131.2 = GFCL 3107 fig. 6.10; AT 131.4 = GFCL 3108 fig. 7.1, AT 131.6 = GFCL 3109, AT 131.8 = GFCL 3110 fig. 7.2, AT 131.10 = GFCL 3111, AT 131.13 = GFCL 3112 fig. 7.3; ZI 15, ZI 55, i792 = GFCL 3113, i 844, Lemgaïrinat Formation, late Famennian (V?) i 813.

Range

Dichospirifer zemoulensis is present in Assa area, southern Morocco: in "Lower Fauna", and Algerian-Moroccan border in "Lower Fauna ?" late Famennian (V?) and below Famennian (III? - IV).

Superfamily *SPIRIFEROIDEA*, King, 1846

Family *SPIRIFERIDAE* King, 1846

Subfamily *PROSPIRINAE* Carter, 1974 – by D. BRICE

Three genera recognized in NW Sahara: *Prospira* Maxwell, 1954, *Parallelora* Carter, 1974, *Unispirifer* Campbell, 1957 are assigned to the subfamily Prosperinae by Carter (1974) and Carter *et al.*, 1994. They have many common characters: more or less transverse shape, median sulcal costa: lateral sulcal costae simple, not numerous, derived from sulcus-bounding costae; capillae; dental adminicula and denticulate hinge line. The discrimination between *Parallelora* and *Prospira* is mainly based on the aspect of interareas and ornamentation. *Parallelora* has parallel beak ridges and hinge line forming a rectangular interarea and has sometimes several lateral costae bifurcate. In *Prospira* the ventral interarea is triangular and lateral costae usually simple.

Genus *PROSPIRA* Maxwell, 1954

Diagnosis: (Pitrat in Treatise 1965, v. 2, p. 700). Type species: *Prospira typa* MAXWELL, 1954, Queensland, Early Carboniferous.

Prospira struniana (Gosselet, 1879)

2001 - *Prospira struniana* (Gosselet, 1879), Nicollin & Brice, p. 184, 186, figs. 8.1-5, 7, 9-12.

Material :

Morocco: Assa area, El Douiya Formation, late Famennian (IV), Nicollin & Brice, As 112, fig. 8.7 = GFCL 3151 ; As 117, fig. 8.1 = GFCL 3146 ; As 118, fig. 8.2-3 = GFCL 3147-3148 ; Lemgaïrinat Formation, late Famennian (V), "Lower Fauna", As 260, fig. 8.4-5 = GFCL 3149-3150; Algerian-Moroccan border, Zemoul area, El Douiyat Formation, late Famennian (IV), ZI 21, fig. 8.9 = GFCL 3152 ; Lemgaïrinat Formation, late or latest Famennian (V or VI), ZI 27 (1 dv) "Lower or Intermediate Fauna" ; base of Tazout Formation, latest Famennian (VI), "Intermediate Fauna", AT 135 (1vv) ; fig. 8.10-12 = MZ 3 sp.

Range

The type material originates from the latest Famennian (Strunian) of Avesnois (France). In Morocco: the species is present in the late Famennian (IV – V) in Assa area *fide* Hollard (1981) and latest Famennian (VI) in Zemoul area.

Prospira cf. *struniana* (Gosselet, 1879)

2001 - *Prospira* cf. *struniana* (Gosselet, 1879), Nicollin & Brice, p. 186, fig 8.6.

Material :

Morocco: Assa area, El Douiya Formation, late Famennian (IV), As 112, fig. 8.6 = GFCL 4642 in Nicollin & Brice, 2001, "Lower Fauna ?".

Range

Prospira cf. *struniana* is present in southern Morocco: in the Assa area of the north Jebel Tazout, in "Lower Fauna ?".

Prospira aff. *lapparenti* Brice, 1999
(Pl. IV, figs. 11-12)

1971 - *Eobrachthyris struninus alatus* (Gosselet, 1879), Brice, p. 190-192, pl. 13, fig. 7a-e, text-fig. 46.

1995b - *Eobrachthyris alatus* (Gosselet, 1879) *sensu* Brice, 1971 (p. 190) in Legrand-Blain, p. 93-94.

aff. 1999 - *Prospira lapparenti* Brice, p. 284-285, pl. 2, fig. 6.

Material:

Algeria: Gara el Kahla section, Kahla Mudstone, late Famennian (V ?), ML322 (5 vv, 3vd) "Lower Fauna ?".

Description

The valves are megathyrid, small-sized for the genus, with sharp mucronate lateral extremities, and a width/length ratio equal approximately to two (W = 22 -23 mm ; L = 8-13 mm). The ventral interarea is low, triangular (?), apsacline, concave. The sulcus is smooth, and the lateral costae are regular, rounded and covered by radial capillae. The fold shows a medial groove. Hinge-line is denticulate.

Discussion

These valves are tentatively assigned to *Prospira* in preference to *Parallelora* on account of the ornamentation (absence of bifurcated lateral costae and smooth sulcus). This species seems very close of *Prospira lapparenti,* but the determination is uncertain, owing to the lack of bivalve specimens.

Range

The type material of *Prospira lapparenti* (= *Eobrachythyris strunianus alatus* [Gosselet, 1879] in Brice, 1971, p. 190) has been collected from the late Famennian deposits in western part of the axial zone in Afghanistan. *Prospira* aff. *lapparenti* has been found only in the Gourara Basin of the Timimoun area in Algeria, dated upper Famennian (IV-V) according to Conrad & Termier (1970),"Lower Fauna ?".

Prospira sp. 1
(Pl. IV, figs.1-9)

1985 - *Eobrachythyris strunianus,* Legrand-Blain, pl. 2, fig. 1a-b

1995b - *Prospira* sp. 1, Legrand-Blain, p. 94.

Material : 48 specimens

Algeria: Gara el Kahla section, Upper Kahla Sandstone below the *Gattendorfia* horizon, ML 306 (12 incomplete vv, 4 dv), 309 (3 incomplete sp, 1 ecvv, 1 ecdv), 329 (1 incomplete vv), 362 (1 dv), 387 (8 imvv, 3 ecvv, 10 imdv, 3 ecdv); JC 935 (1vv) "Upper Fauna" within the *Gattendorfia* horizon, probably middle Early Tournaisian.

Description

The shells are megathyrid and mucronate (pl. 4, fig. 6), usually poorly preserved, with a variable size (width: 19-30 mm ; length : 10-16 mm). The ventral interarea is triangular, apsacline, slightly concave. One to three costae weakly developed are present in the wide and deep sulcus. One to three grooves are observed on the fold; the flanks show about twelve simple lateral costae. Radial capillae poorly preserved. Hinge-line denticulate. Dental plates are short and divergent. The muscle scar is partly enclosed by the bases of dental plates. There is a trace of a dorsal myophragm.

Discussion

This species has some similarities with *Prospira burnettensis* Maxwell, 1961: shape, ornamentation, internal characters, but its determination is uncertain, owing to the lack of bivalve specimens.

Range

This species has been recognized only in Algeria, Timimoun area, in "coquinas" below the *Gattendorfia* level, probably middle Early Tournaisian.

Prospira sp. 2
(Pl. IV, figs. 10, 13-14)

1995b - *Prospira* sp. 2, Legrand-Blain, p. 94-95.

Material: 3 specimens

Moroccan-Algerian border, Tazout 2-3 Formation, Zemoul area, Zl 65 (1 sp, 1vv). Algeria, Gara el Kahla, Upper Kahla Sandstone JC 935 (1 sp.) "Upper Fauna", early Tournaisian.

Description

The shells are poorly preserved, and slightly widest than length (W = 26-35 mm ; L = 22-25 mm). The ventral sulcus is wide and deep with 5 to 7 costae. The ventral interarea is low, masked by the recurved ventral beak. Flanks are covered by sixteen to twenty simple lateral costae and radial capillae. The hinge-line is denticulate, and the dental plates are extrasinal.

Discussion

This species is very different to the preceeding ones. It has some similarities with the type species: *P. typa,* but the material is inadequate to propose a specific determination.

Range

This species has been recognized in Algerian-Moroccan border and Algeria,Timimoun area, associated with the *Gattendorfia* cf. *crassa* horizon, in the "Upper Fauna", probably middle Early Tournaisian.

Genus *PARALLELORA* Carter, 1974

Diagnosis : (Carter, 1974, p. 680). Type species: *Spirifer marionensis* SHUMARD, 1855, Louisiana Limestone, Missouri, *praesulcata* Zone according to Ziegler & Sandberg (1984) (= *Mariona* Nalivkin, 1975 in Garanj et al.,Type species : *Spirifer marionensis* Shumard, 1855).

Parallelora sp. aff. *subsuavis* (Plodowski, 1968)
(Pl. IV, figs. 15-17)

1968 - *Spirifer subsuavis* n. sp., Plodowski, p. 253, pl. 1, fig. 5.

1970 - *Spirifer subsuavis* Plodowski, 1968, Plodowski, p. 52-57, pl. 1, figs. 5-10, pl. 11, fig. 2, text-figs. 23-28.

1995b - *Parallelora* sp. aff. *subsuavis* (Plodowski, 1968), Legrand-Blain, p. 94.

Material: 5 specimens

Algeria: Gara el Kahla section, Lower Kahla Sandstone, late Famennian (V-VI ?) ML 313 (? 1 vv, 1 emdv), ML 316 (1 vv), ML 365 (2 vv) "Lower Fauna".

Description and Discussion

These poorly preserved remains resemble to *Parallelora subsuavis* in the following characteristics: - a megathyrid mucronate form, - a narrow sulcus and fold, - a small ventral beak that curved above a low rectangular interarea, - their macro- and micro-ornamentation. The sulcus is flat with three costae one of which is the median costa. Lateral costae are flat and usually simple. A hinge-line denticulate has not been observed. The ventral valve of specimen ML 313 is included with a question mark because it seems rather close to *"Spirifer" (= Prospira)* cf. *struniana* from Strunian of Afghanistan described by Plodowski (1970).

Range

Parallelora is known - in North America at the top of late Devonian and early Mississippian (Tournaisian-Viséan) according to Carter (1990, fig. 2), - in the upper Famennian of the Urals (Nalivkin, 1979), - in *praesulcata* and *sulcata* Zones (conodonts) in Nanbiancun in South China (Xu in Yu & Yao, 1988), and in Tournaisian of Xinjiang, NW China (Chen & Archbold, 2000). Types of *P. subsuavis* from Dascht-e Nawar, in SW Afghanistan, are dated as Etrœungt Zone by conodonts (Plodowski, 1970, p. 14, 52). In Algeria, Timimoun area, it is associated with brachiopods of the "Lower Fauna", late Famennian (V) and (VI ?).

Parallelora (?) sp.
(Pl. IV, fig. 18 a-b)

Material: 1 specimen MB.B.2400

Morocco: central Ma'der, Bou Tlidat section, NE of Fezzou ,TB Collection 1 internal mould of a deformed specimen with cardinal extremities broken, in Stockum Limestone.

Description

This shell is large (length of the dorsal valve = 24 mm) with narrow and weakly-developed sulcus and fold. The sulcus shows three costa (one is median). The fold has three grooves, of which one is medial on the top of the fold. The incomplet flanks show fourteen to sixteen costae (four of them, on the dorsal valve are the result of divisions). The interareas are rectangular and narrow, well-delimited by ventral and dorsal parallel crests. The ventral valve shows traces of short divergent adminicula. A prominent muscular field is ornamented by six parallel ribs. The hinge-line is denticulate. In the dorsal valve, cardinal process with sixteen to twenty lamellae, and trace of a long myophragm (longer than mid-length). The gonoglyphe is well-developed in the posterior region of both valves.

Discussion

The tentative assignment of this incomplete and deformed specimen to *Parallelora* is justified by the rectangular interareas, several divisions in lateral costae, the hinge-line denticulate. However, important characteristics, such as outline, and ornamentation have not been observed. The genus *Prospira* is very close to *Paralellora,* differing by a triangular ventral interarea (not rectangular). *Paleospirifer* differs by its no denticulate hinge line.

This form also has similarities (size, length of the dorsal valve, dorsal fold) to *Parallelora nupera* Carter, 1988 from the Early Mississippian of the Glenn Park Formation of Illinois and Missouri.

Genus *UNISPIRIFER* Campbell, 1957

Diagnosis: (Pitrat in Treatise 1965, v. 2, p. 706). Type species: *Spirifer striatoconvolutus* BENSON & DUN, 1920, New South Wales, Tournaisian.

Unispirifer unicus Havlicek, 1984
(Pl. IV, figs. 19-21)

1984 - *Unispirifer unicus* sp. n., Havlicek, p. 66, figs. 27-29.

1985 – *Unispirifer* ex gr. *tersiensis* Rotay, 1938, Legrand-Blain, pl. 11, fig.5.

1987 – *Unispirifer unicus,* Havlicek & Röhlich, p. 156, pl. 11, figs. 10,11,13,15,17.

1995b - *Unispirifer unicus* Havlicek, 1984, Legrand-Blain, p. 94.

2000 - *Unispirifer unicus* Halite, 1984, Mergl & Massa, p. 46, fig. 3, pl. 4, figs. 3-4.

Material : 12 specimens

Morocco: Akka area, Tazout Formation *Gattendorfia* horizon, probably middle Early Tournaisian Ak 71 (2 imvv, 1 sp., 1 vv); Algeria: Gara el Kahla section, Upper Kahla Sandstone, early Tournaisian, ML 306 (3 incomplete vv) , ML 329 (1 emdv), ML 330 (1 imvv) ; ML 387 (1 emdv, 2 imvv). All specimens "Upper Fauna".

Description

The specimens are large with megathyrid, mucronate, and slightly ventri-biconvex profile. Anterior commissure uniplicate. Ventral valve regularly convex, with a triangular apsacline interarea, and a well-delimited sinus originating at the beak. The sinus is shallow near the anterior region and pass gradually into gently convex flanks. The hinge-line is denticulate, dental plates short and extrasinal. The diductor and adductor muscle fields are radially striated.

Discussion

These poorly preserved pecimens are attributed to *Unispirifer* rather than *Parallelora* of which they differ by

their outline much more transverse and triangular ventral interarea. They are assigned to *Unispirifer unicus* because the following characteristics: - the megathyrid and mucronate form, - the triangular ventral interarea, - the narrow sulcus and fold, and their ornamentation which consists of five costae on the sinus (one medial). The fold is obsolete with a median groove and two pair of lateral grooves here and there. The lateral costae are numerous (about 25) and simple (except one to three which are divided). The micro-ornamentation is poorly preserved, the hinge line is denticulate, and the short dental plates are divergent. *U senex* Carter, 1988, from the lowermost Kinderhookian of Illinois and *U. praeulbanensis* Bublichenko (Bublichenko & Nikitina, 1955) from Strunian of Altai in the former USSR are close to *U. unicus*.

Range

The genus *Unispirifer* is cosmopolitan in Lower Carboniferous (Tournaisian-Visean). In North America it is known in the lower part of the Mississippian (Kinderhookian-Osagean) according to Carter (1990, fig. 2), and in the Tournaisian of NW Australia (Roberts, 1971). *U. unicus* is present in the Lower Tournaisian of the Murzuk Basin (Western Libya) and in the "Upper Fauna" probably middle Early Tournaisian in southern Morocco : and Algeria, Timimoun area.

Subfamily *SERGOSPIRIFERINAE* Carter *in* Carter *et al.*, 1994

Genus *EOBRACHYTHYRIS* Brice, 1971

Diagnosis: (Brice, 1971, p.182). Type species: *Eobrachythyris proovalis* BRICE, 1971, late Famennian & Etroeungt Zone (?), Afghanistan.

Eobrachythyris hollardi Brice & Nicollin, 2000

2000 - *Eobrachythyris hollardi* Brice & Nicollin, p. 58-61, pl., figs 1-4, text-fig. 3.

Material:

Morocco: Assa area, El Douiya Formation, Famennian (IV *fide* Hollard 1981), pl. fig. 1 As 118 = GFCL 2680, in Lemgaïrinat Formation, Famennian (V *fide* Hollard 1981), As 31, As 260, Brice & Nicollin, 2000, fig. 2 As 260.1 = GFCL 2681, fig. 3, As 260.5 = GFCL 2682, fig. 4 As 260.3 = GFCL 2683, As 260.2 = GFCL 2684, As 260.4 = GFCL 2685. "Lower Fauna"

Range

The genus *Eobrachythyris* is known in the Upper Famennian, Etroeungt Zone (?) in late western part of the axial zone in Afghanistan, its presence in Poland is questionable; in southern Morocco, *E. hollardi* occurred in the Assa area, in late Famennian (IV-V) in the "Lower Fauna" and below.

Eobrachythyris jacquemonti Brice & Nicollin, 2000

2000 – *Eobrachythyris jacquemonti* Brice & Nicollin, p. 61-63, pl., figs. 5-9, text-figs. 4-6

Material:

Moroccan-Algerian border, Zemoul area, Tazout (2 ?) Formation, i 783, Tazout 2-3 Formation, i 821, early Tournaisian *fide* Hollard 1981, *in* Brice & Nicollin, 2000, pl. Holotype fig. 5 = GFCL 2686 ; fig. 6 = GFCL 2687 ; fig.7 = GFCL 2688, fig. 8 = GFCL 2689, fig. 9 = GFCL 2690, fig. 10 = GFCL 2691, fig. 11 = GFCL 2692, text-fig. 6 = GFCL 2693, text-fig. 5 = GFCL 2694, text-fig. 4 = GFCL 2695. "Upper Fauna" early Tournaisian.

? Family *IMBREXIIDAE* Carter 1992 - by J.P. NICOLLIN

Genus, species indet.
(Pl. III, fig. 16)

Material: : 9 specimens

Morocco: Akka area, Late Famennian (V, *fide* Hollard), HH Collection, Ak 30 (4 vv, 2 imvv, 1 sp). Algerian-Moroccan border: Zemoul area, Tazout 1 Formation, Latest Fammenian (VI, *fide* Hollard), HH Collection, Zl 29 (1 imsp, 1 imvv).

Description

Small to large size, almost equibiconvex, probably megathyrid (all specimens are broken).

Ventral valve with maximum convexity in the posterior part. Ventral beak weakly curved, not overlapping the interarea. Interarea triangular, slightly concave, apsacline, horizontally and vertically striated. Short pseudodeltidium (visible on serial sections). Delthyrium widely open at the basis. Sulcus beginning at beak, narrow and shallow, well limited by 2 bounding costae.

Dorsal valve with maximum convexity in the posterior part. Fold low and narrow, limited by 2 distinct furrows.

Lateral costae simple, low and rounded. Sulcus and fold ornamented: one medial sulcal costae and 2 or 3 lateral sulcal costae on each side, the more external deriving from the sulcus bounding costae.

Micro-ornamentation consisting in capillae and very distinct v-shape regularly imbricate growth lamellae.

Ventral interior with short dental plates and short delthyrial plate.

Discussion

According to the type of micro-ornamentation, this form should be placed in the Family Imbrexiidae. The features which differs from those given by Carter et al. (1994) are the presence of a short pseudodeltidium, fold and sulcus weakly developed, costae on lateral slopes not divided. Moreover, all the genera belonging to this family are Lower Carboniferous in age. Moroccan specimens are Late Famennian in age.

Range

This form has been found in southern Morocco: - in the Late Fammenian (V) of Akka area, - in the Latest Famennian (VI) of Zemoul area.

Superfamily *PAECKELMANELLOIDEA* Ivanova, 1972 – by J P. NICOLLIN

Family *STROPHOPLEURIDAE* Carter, 1974

Subfamily *STROPHOPLEURINAE* Carter, 1974

Genus *VOISEYELLA* Roberts, 1964

Diagnosis: (Roberts, 1964, p. 187). Type species: *Strophopleura anterosa* CAMPBELL, 1957 from Babbiboon, Werrie Basin, New South Wales, Upper Tournaisian.

The genus *Voiseyella* belongs to the Subfamily Strophopleurinae characterized internally mainly by denticulate hinge-line and absence of ventral septum; and externally mainly by small size and simple lateral ribs. Other important characteristics of the genus are the very transverse outline, and the smooth sulcus bordered by very wide costae.

Voiseyella sp. A aff. *anterosa* (Campbell, 1957)
(Pl. IV, fig. 29; Pl. 5, figs. 25, 26, table III)

aff. 1957 – *Strophopleura anterosa* n. sp., Campbell, p. 79, pl. 15, figs. 19-23.

Material: 59 specimens

Morocco: Assa area, Kheneg Lakahal section, BN Collection, unit + 0 (1 imdv, 1 emdv); unit + 1 (3 imvv, 1 ecvv, 4 imdv) ; unit + 2, sample + 2.11 (7 imvv, 3 ecvv, 5 imdv, 5 ecdv), sample + 2.12 (2 imvv, 1 imdv, 1 ecdv), sample + 2.13 (2 imvv, 2 ecvv, 2 imdv, 1 ecdv), sample + 2.14 (1 imdv, 1 ecdv, 1 ecvv), sample + 2.15 (2 imvv, 3 imdv). BK Collection, unit + 2, sample 12 (1 imvv, 1 ecvv) ; unit + 5 (3 imvv, 1 ecvv, 4 imdv). Specimens belong to the "Upper Fauna" except those of unit + 0 ("Intermediate Fauna").

Description

Small to medium sized (average width = 24-34 mm for adults specimens, less than 20 mm for juveniles). Equibiconvex, transverse shell with acute or sometimes mucronate cardinal extremities.

Ventral valve: Semicircular in outline, laterally weakly convex. Convexity decreasing near the lateral extremities and especially by mucronate specimens where they are almost flat. Beak small weakly overlapping the ventral area. Area low with sub-parallel borders, vertically striated. Hinge-line denticulate. Delthyrium open (delthyrial angle = 50°). Sulcus very narrow (2.5-4 mm, less for juveniles), shallow, smooth, flat-bottomed, well limited by 2 wide costae (much wider than lateral ones).

Dorsal valve: Outline and convexity similar to ventral valve. Beak very small, generally not overlapping the dorsal interarea. Median fold anteriorly narrow (2.5-5 mm, less for juveniles), low, with a median furrow more or less well developed beginning at the beak, well limited by two wide and deep border furrows.

Ornamentation: 7 to 12 costae on lateral slopes, simple, relatively wide and rounded, becoming obsolete laterally and absent near the cardinal extremities. Interspaces strongly or weakly narrower than costae. Concentric growth lamellae irregularly spaced developed near the anterior margin of the valve. Micro-ornamentation made of thin concentric growth lines and fine radial striae that can be seen only on well preserved specimens in the interspaces.

Internal structures observed : Lamellose cardinal process. Presence of a dorsal myophragm (Table III).

Discussion

We think that this species belongs to the genus *Voiseyella* because of its very tranverse outline, its narrow and smooth fold and sulcus, its micro-ornamentation made of capillae and fine growth lamellae, and its denticulate hingeline. *Acuminothyris* Roberts, 1963 which also belongs to Strophopleurinae, has more numerous lateral costae and a typical sub-imbricated micro-ornamentation which is not present here. *Celsifornix* Carter, 1974 (Strophopleuridae, Bashkiriinae) is different from *Voiseyella* because of its multicostate fold and sulcus but also by its higher interarea. *Prospira* Maxwell, 1954 (Spiriferidae, Prospirinae) is externally very close to *Voiseyella* but differs mainly by its costate sulcus and fold.

Voiseyella sp. A differs from the type species, *Voiseyella anterosa* (Campbell, 1957) by the presence of a median furrow on the dorsal fold and by having less costae on lateral slopes (5-6 for *V. anterosa*). *V. novamexicana* Roberts, 1964 is less transverse (L/W: 0.43), possesses sub-imbricated concentric growth lamellae regularly spaced and ventral beak more overlapping the delthyrium. It is about the same with *V. texana* Carter, 1967 which is less transverse (L/W: 0.62). From *V. tylothyriformis* (Krestovnikov and Karpychev, 1948), it differs by the lower convexity of the valve and a more transverse outline; from *V. sergunkovae* (Bublichenko, 1971) by a greater size and lower number of lateral costae, and from *V. pseudopostera* (Beznosova, 1963) by a greater size.

Range

Voiseyella sp. A aff. *anterosa* appears in the Latest Devonian of the Kheneg Lakahal section (Assa area, southern Morocco) and becomes much more developed in the Early Tournaisian of the same area. So, it is one of the rare taxa of the "Intermediate Fauna" as well as an important and abundant taxa of the "Upper Fauna".

Voiseyella has been defined with *V. anterosa* as type species in the Lower Carboniferous of Australia, New South Wales (Campbell, 1957); it has been found again in the same region by Roberts (1971). The genus is also largely present in levels of the same age in North America (Carter, 1967, 1999). In Algeria, Legrand-Blain (1995b) mentions three species, further described in this paper and different from *V. anterosa*, in the "Upper Fauna" of the Gara el Kahla section, northwestern Saharian Algeria.

We can already focus here a difference of affinity between *Voiseyella* species in North Africa: - in southern Morocco, the affinities seems to be with australian and north-american taxa (see comments on *V.* sp. B aff. *novamexicana*), - in north-western Algeria, the taxa are compared to species defined in the Russia (s.l.) territory (see comments on *V.* sp. 2 aff. *sergunkovae* and *V.*(?) sp. 3 aff. *tylothyriformis*).

	Ventral valves						Dorsal valves				
GFCL	4663	4664	4665	4666	4667	GFCL	4668	4669	4670	4671	4672
W	25.5	30	30	34	24	W	25	25	24	34	30
L	9	11	10.5	10	6	L	6	9	8.5	11	8.5
L/W	0.35	0.37	0.35	0.29	0.25	L/W	0.24	0.36	0.35	0.32	0.28
Ws	3	3.5	3	4	2.5	Wf	3	4.5	4		3
N costae	10	12	12	>10	8	N costae	7	7	10	8	12

Table III. — (Measurements in mm)

Voiseyella sp. B aff. *novamexicana* (Miller, 1881)
(Pl. V, figs. 27, 28, table IV)

aff. 1881 – *Spirifera novamexicana* : Miller, p. 314, figs. 10-10b.

Material : : 10 specimens

Morocco: Assa area, Kheneg Lakahal section, BK Collection, unit + 0.10 (1dv), BN Collection, unit + 0 (3 imdv); unit + 1 (1 imvv); unit + 2, sample + 2.12 (1 ecvv, 1 imdv), sample + 2.13 (1ecdv, 1 imvv, 1 ecvv).

Specimens belong to the "Upper Fauna" except those of unit + 0 ("Intermediate Fauna").

GFCL	4675	4676	4677	4678	4679
	Dors. Valve	Dors. valve	Dors. valve	Ventr. valve	Ventr. valve
W	20	35	24	26	27
L	8.5	15.5	10	10.5	11.5
L/W	0.43	0.44	0.42	0.40	0.43
Ws or Wb	4	6	4.5	3.5	3.5
N of Ic	14	13	13	12	12

Table IV. — (Measurements in mm)

Discussion

Voiseyella sp. B differs mainly from *V.* sp. A by a less transverse outline (length/width ratio of both valves > 0.40) and also by a higher number of lateral costae (12 to 14). Other characters are very similar to V. sp. A.

The outline of *V.* sp. B is comparable to those of *V. novamexicana* (same L/W ratio) but it has more numerous lateral costae and less curved ventral beak.

Range

Voiseyella sp. B is much less abundant but has the same stratigraphical range than *V.* sp. A in the Kheneg Lakahal section (Latest Devonian: "Intermediate Fauna" and Early Tournaisian : "Upper Fauna").

The species *V. novamexicana* is a very common Mississippian northamerican species.

Voiseyella sp. 2 aff. *sergunkovae* (Bublichenko, 1971)
(Pl. III, figs. 13, 14)

aff. 1971 - *Mucrospirifer sergunkovae* : Bublichenko, p. 108, pl. XIX, figs. 1-5.

1995b – *Voiseyella* sp. 2 aff. *sergunkovae*: Legrand-Blain, p. 95.

Material : : 10 specimens

Algeria: Gara el Kahla section, Upper Kahla Sandstone, "coquina" preceeding the *Gattendorfia* horizon, probably middle Early Tournaisian, ML Collection, ML 324 (2 imvv, 2 ecvv), ML 306 (2 imvv, 3 ecvv, 1 imdv). All specimens belong to the "Upper Fauna".

Description and Discussion

Very small shells (W: 10-18 mm) only found as internal moulds and external casts of ventral valves. Fairly transverse (length/width: 0.44 to 0.57) with acute cardinal extremities. Ventral valve moderate to strongly convex. Sulcus very narrow, somewhat deep and smooth, limited by 2 wide bounded costae. Ventral interarea low and concave. Hinge-line denticulate.

Lateral costae simple, rounded, wider than furrows, very blurred near the extremities because of bad preservation of material. Micro-ornamentation not observable for the same reasons.

Internal characters observed: very short and extra-sinal dental plates, presence of a ventral myophragm.

Like Legrand-Blain (1995b), we assign the few number of specimens to the genus *Voiseyella* because of their denticulate hinge-line, smooth sulcus and small size. Otherwise, Legrand (1995b) brought this form close to *"Mucrospirifer" sergunkovae* Bublichenko because of its similar ornamentation. It differs from *V.* sp. A and *V.* sp. B mainly by its smaller size and its less transverse outline.

Range

In Algeria (Timimoun section), *Voiseyella* sp. 2 is present in the lower part of Kahla sandstones, under the *Gattendorfia* horizon (probably middle Early Tournaisien, "Upper Fauna"). *"Mucrospirifer" sergunkovae* comes from Strunian of Altai (Siberia).

Voiseyella sp. 4
(Pl. IV, fig. 28)

1995b – *Voiseyella* sp. 4: Legrand-Blain, p. 95.

Material: 2 specimens

Algeria: Gara el Kahla section, Upper Kahla Sandstone, Early Tournaisian, ML Collection, ML 354 (1 imvv, 1 imdv). The 2 specimens belong to the "Upper Fauna".

Description and Discussion

Small species (width of the ventral valve: 16 mm, length: 8 mm), moderately transverse with very narrow (3 mm wide) and smooth sulcus. Sulcal bounding costae wide and raised. 6-7 simple costae on lateral slopes which are sub-angular and as wide as intercostal furrows. Micro-ornamentation made of radial capillae. Ventral interarea triangular and moderately high. Hinge-line denticulate. Dorsal fold relatively low with a very marked median furrow. Fold bounding furrows very wide. Short and extra-sinal dental plates. Presence of a ventral myophragm.

The main differences between this form and other forms described here are the followings: - from *Voiseyella* sp. A, a less transverse outline, - from *V.* sp. B a smaller number of lateral costae, - from *V.* sp. 2 lateral costae less wide and not rounded, - from *V.* sp. 3 a smaller general size. It is relatively close to *V. novamexicana* but doesn't show the sub-imbricate growth lamellae.

Range

In Algeria (Timimoun area), *Voiseyella* sp. 4 has been found in Upper Kahla sandstones above the *Gattendorfia* horizon (probably middle Early Tournaisian, upper part of the "Upper Fauna" in Gara el Kahla section).

Voiseyella (?) sp. 3 aff. *tylothyriformis* (Krestovnikov & Karpychev, 1948)
(Pl. V, fig. 24a-b)

aff. 1948 – *Spirifer (Lamellispirifer) tylothyriformis* : Krestovnikov & Karpychev, p. 19, pl. 1, figs. 3a-b, 4a-c.

1988 – *Voiseyella* aff. *tylothyriformis* : Legrand-Blain & Martinez-Chacon, pl. 1, fig. 21.

1995b – *Voiseyella* (?) sp. 3 = *Voiseyella* aff. *tylothyriformis* : Legrand-Blain, p. 95

Material: 9 specimens

Algeria: Gara el Kahla section, Upper Kahla Sandstone, coquina preceeding the *Gattendorfia* horizon, probably middle Early Tournaisian, ML Collection, ML 330 (2 imsp, 6 imvv, 1 imdv). All specimens belong to the "Upper Fauna".

Description and Discussion

Medium to rather large shells (W: 25-37 mm), almost equibiconvexe, moderately transverse (width/length ratio: 0.6-0.7) with rounded cardinal extremities. Ventral outline sub-losangic. Sulcus fairly narrow, with rounded to flat bottom, well limited by 2 wide bounded costae. Ventral beak relatively wide and curved. Ventral interarea fairly high, slightly concave, orthocline to slightly anacline. Denticulation of the hinge-line not observed.

Dorsal outline triangular. Fold rather low, with rounded top, well limited by 2 bounding furrows and presenting a median furrow.

10-12 costae on lateral slopes, simple, rounded, wider than intercostal furrows. Sulcus smooth or with a very blurred median costae. Some marked growth lamellae in the posterior part of the shell. Micro-ornamentation not observed.

Internal structures observed : short, divergent and extra-sinal dental plates.

Legrand-Blain (1995b) compared this form to "*Mucrospirifer tylothyriformis*" from the Late Famennian of the Ural after its dimensions and ornamentation. The attribution to the genus *Voiseyella* is not certain because the denticulate hinge-line has not been observed and also because in some specimens, the sulcus is not smooth.

Range

In Algeria (Timimoun section), this form is present in the lower part of Kahla sandstones, in "coquinas" under the *Gattendorfia* horizon (probably middle Early Tournaisian, "Upper Fauna" in Gara el Kahla section). In France, it has been found in Uppermost Famennian (late *praesulcata* zone) of La Serre (Central Massif).

The species *tylothyriformis* has been defined in Strunian of Ural (Zigane river). It is also mentioned in Famennian IV-V of the same region (Rzhonsnitskaya, 1988) and in the Lower Hastarian of Petchora (Fotieva, 1985).

Superfamily *THEODOSSIOIDEA* Ivanova, 1959
Family *ULBOSPIRIFERDAE* Johnson & Carter, 1994
Subfamily *ULBOSPIRIFERNAE* Johnson & Carter, 1994 in Carter *et al,* 1994

Hollardospirifer Nicollin nov. gen.

DERIVATIO NOMINIS: name dedicated to Henri Hollard.

TYPE SPECIES: *Hollardospirifer draensis* Nicollin nov. sp.

Diagnosis: Large, almost equibiconvex, equithyrid or weakly brachythyrid, semi-quadratic in ventral outline, sometimes slightly mucronated. Sulcus wide, moderately deep and poorly delimited in the anterior part. Fold wide and low. Sulcus and fold covered with divided costae. 25 (average) lateral costae, simple, wide, flat or slightly rounded. Short and extra-sinal dental plates with thickenings made of prismatic calcite crystals normal to the plates axes. No dorsal septum.

Discussion

The new genus *Hollardospirifer* is set in the family Ulbospiriferidae because of the presence of an inner prismatic shell layer. It is fairly close to *Tenisia* Martynova, 1970 from which it differs mainly by a more quadratic outline, sulcus and fold more developed, lacking of a dorsal septum.

After the external aspect, the specimen figured by Reed (1922, pl. XVI, fig.1) as *Spirifer pamiricus* from the Late Devonian of Chitral could be set in *Hollardospirifer* as well as the specimens figured by Abramian (1954, pl. 12, fig. 3, pl. 13, fig. 1; 1974, pl. 20, fig. 4, 5) from the Late Famennian of

Armenia, called *Cyrtospirifer pamiricus* (Reed, 1922) by this author. Unfortunately, no internal figuration or description is given and we don't know if all these specimens have inner prismatic shell layer.

Range

Hollardospirifer has been found in the Late Famennian (IV-V, *fide* Hollard) of Western Anti-Atlas, Morocco, Dra Valley, Zemoul area. It is one of the typical genera characterizing the "Lower Fauna" in sections where it can be defined as Dfeif for example.

In its biostratigraphic distribution table of Late Devonian brachiopods of Armenia, Abramian (1954) has created four brachiopod horizons in the Late Famennian below the Etroeungt Zone. Among these horizons, the third one is *Cyrtospirifer pamiricus* horizon.

Moreover, Chegodaev *et al.* (1984) in the guidebook of excursions in the Devonian of Caucasus indicate the presence of *C.* aff. *pamiricus* in the Shamamidzor Formation in the N. Yaidzhi village area (excursion 097). The Shamamidzor Formation corresponds to the *velifer* conodont Zone (lower part of Upper Famennian). So, the stratigraphic distribution of *C. pamiricus* in Armenia quite corresponds to that of *Hollardospirifer* in Morocco.

Hollardospirifer draensis Nicollin nov. sp.
(Pl. III, figs 1a-d, 2. Fig. 5)

DERIVATIO NOMINIS: name derived from Oued Dra valley

LOCUS TYPICUS, STRATUM TYPICUM: Morocco, Dra Valley, South of the Zemoul anticline, Lemgaïrinat Formation, Upper Famennian (V ?, fide Hollard)

HOLOTYPE: GFCL 4686 = i 813, pl. 3, fig. 2

PARATYPES: GFCL 4687 = i 792, GFCL 4688 = i 792, GFCL 4689 = i 813, GFCL 4690 = i 813, GFCL 4691 = i 813, GFCL 4707 = i 820.

Material: 70 specimens

All ages are given *fide* Hollard. Algerian-Moroccan border: Zemoul area, El Douiya Formation, Upper Famennian (IV), HH Collection, AT 132 (2 vv), Zl 61 (4 vv, 1 imdv), PJ Collection, i 792 (10 vv, 3 dv, 1 imdv); Upper Famennian (IV or V), HH Collection, AT 128 (1vv), PJ Collection, i 820 (10 vv, 5 dv); Lemgaraïnat Formation, Upper Famennian (IV), HH Collection, AT 140 (1 imsp), Lemgaïrinat Formation, Upper Famennian (V), PJ Collection, i 846 (14 vv), i 813 (3 sp, 10 vv, 4 dv). Algeria, South Central Anti-Atlas, Tinfouchy area, upper Lemgaraïnat Formation, Upper Famennian (IV or V), HH Collection, Zl 57 (1 vv).

Diagnosis. As for the genus.

Description

Large sized form, equithyrid or weakly brachythyrid, biconvex and almost equibiconvex, quadratic in dorsal view. Cardinal extremities sometimes slightly mucronated, or with angles very near to 90°. Lateral margins posteriorly almost straight, then becoming rounded towards the anterior commissure. Anterior commissure uniplicated.

Ventral valve sub-quadratic in outline. Longitudinal profile convex with maximum convexity in the posterior half, convexity decreasing in the anterior half. Lateral slopes steeply convex except near the cardinal extremities where the lateral profile becomes concave. Ventral beak strongly curved slightly overlapping the ventral interarea. Ventral interarea moderately high, trapezoidal, concave, apsacline, clearly ventrally limited by ridges beginning at the beak, with numerous thin vertical striae regularly spaced and some horizontal striae. Delthyrium open, wide, delthyrial angle (70-90°). Sinus beginning at the beak, wide, generally shallow, with rounded bottom, well limited near the beak, then poorly defined towards the front. The sinus borders appear like rounded ridges.

Dorsal valve with quadratic outline. Longitudinal and lateral profile somewhat similar to ventral valve. Dorsal beak small, slightly curved and weakly hiding the basis of delthyrium. Dorsal interarea low, anacline. Fold wide, fairly low, with rounded top, clearly separated from flanks by 2 furrows.

Lateral slopes costae simple, numerous (25 or more in adults, around 20 in juveniles), wide and flat or somewhat rounded anteriorly. Sulcus and fold costae divided (14-16).

Micro-ornamentation made of thin growth lines and capillae

Short (one-third of ventral valve), divergent and extra-sinal (on the first furrow after the border sinal costae) dental plates. Presence of thickenings around the dental plates made of calcite crystals normal to the plates axes.

Presence of a dorsal myophragm. No dorsal septum.

Range

As for the genus.

Family *PALAEOCHORISTITIDAE* Carter in Carter *et al.*, 1994 – by D. BRICE
Family *PALAEOCHORISTITIDAE* Carter, 1994

Genus *EOCHORISTITES* Chu, 1933

Diagnosis: (Pitrat in Treatise, 1965, v. 2, p. 709). Type species : *Eochoristites neipentaiensis* CHU, 1933, SE China, Early Carboniferous

Eochoristites platycosta (Havlicek, 1984)
(Pl. V, figs. 1-5)

1974 - *Fusella pesasicus* (Tolmatchev, 1924), Massa, Termier & Termier, p. 164, pl. 1, fig. 3-4.

1984 - *Prospira platycosta* sp. n., Havlicek, p. 66, figs. 27-29.

1985 – *Eochoristites* sp. 1, Legrand-Blain, pl. 11, figs. 6-7.

1985 – *Unispirifer* ex gr. *pesasicus* (Tolmatchev, 1924), Legrand-Blain, pl. 11, fig. 3.

1987 - *Prospira platycosta* Havlicek, 1984, Havlicek & Rölich, p. 157, pl. 11, figs. 10, 11, 13, 15, 17.

1992 - *Prospira platycosta* Havlicek, 1984, Mergl & Massa, p. 91, pl. 23, figs. 1-6.

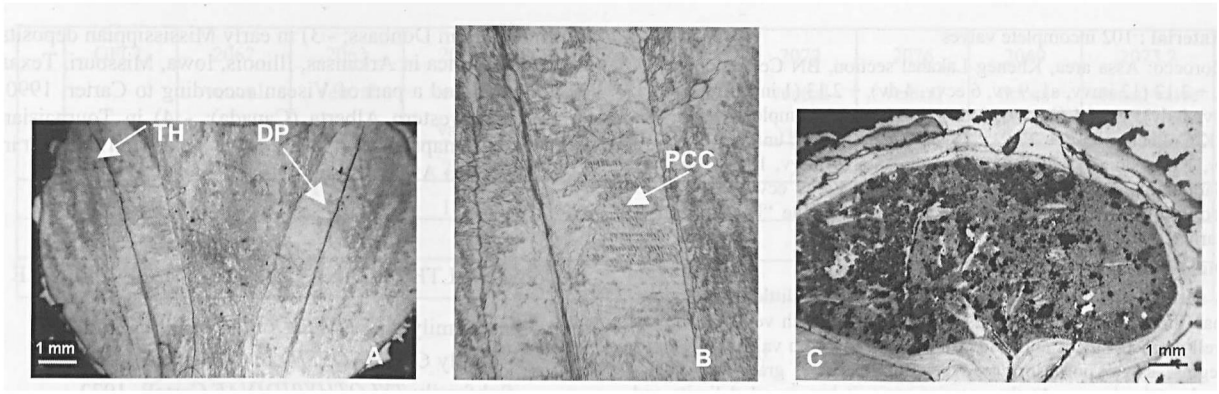

Fig. 5. — Internal structure of *Hollardospirifer draensis* n. sp., a: ventral valve showing dental plates (dp) with thickenings (th) made of calcite crystals normal to the plate axes – b : detail of prismatic calcite crystals (pcc) – c : dorsal valve with no dorsal septum.

Fig. 5. — Structure interne de Hollardospirifer draensis n; sp., a: valve ventrale montrant les lames dentales (dp) avec des épaississements (th), constitués de cristaux de calcite perpendiculaires aux axes des lames dentales – b: détail des cristaux de calcite prismatiques – c: valve dorsale sans septum dorsal.

1995b - *Eochoristites platycosta* (Havlicek, 1984), Legrand-Blain, p. 29.

2000 - *Prospira platycosta* Havlicek, 1984, Mergl & Massa, pl. 6, fig. 9.

Material: 20 specimens

Algeria: Gara el Kahla section, Upper Kahla Sandstone, ML 306 (2 emvv) ; ML 324 (8 emvv, 2 emdv), ML 329 (1 emvv, 3 emvv) ; ML 387 (3 emvv) and (?); Moroccan-Algerian border, Zemoul area, Tazout (2 ?) Formation, *Gattendorfia* horizon, i 783 (1 imvv + fragments). All specimens from the "Upper Fauna" Tournaisian.

Description

The ventral valves are subrectangular in outline with a brachythyrid or equithyrid form. They are moderately convex with maximum convexity at the umbo. The ventral beak is curved over the apsacline, gently concave interarea that is limited by a sharp edge. The sinus originates at the beak and is narrow as a rounded furrow in the posterior part, but shallow with a concave bottom towards the front. The ornamentation consists of one median flat cost, sometimes divided in the anterior part, and one pair of sulcal lateral costae. Lateral costae (20 to 23) are low and much broader than the grooves between them. They are simple except for 1 or 2 (rarely 3) which are divided. They gradually decrease in size, and are very fine towards the cardinal extremities. The dorsal valve is less high than the ventral valve, and has its maximum convexity at the umbo. The fold originates at the beak and is clearly delimited from the flanks. It is narrow, low and rather obsolete. Measurements (in mm) of one ventral valve (ML 324 a5) are as follows (L = 21.5, maximum W = 24, hinge-line 16?). Micro-ornamentation is poorly preserved. The dental plates are divergent and extrasinal, and the hinge line denticulate. There is a sub-rhomboidal deeply impressed posterior muscle field limited by ridges. Dorsal septum absent.

Discussion

Prospira was replaced by *Eochoristites* after discusion by Legrand-Blain (1985, 1995b). The type species of the genus, *E. neipentaiensis,* is larger than *E platycosta* and has only 17-18 lateral costae. The specimen from the Zemoul area, southern Marocco (pl. 4, fig. 5), is assigned with doubt to *E. platycosta* because it has much more lateral costae.

Range

The type material of *E. platycosta* came from the Ash Shati area of western Libya, in the western and northern flank of the Murzuk Basin, at the lower part of the Marar Formation, in pebble greywacke, 30 m above the base of the formation. The species is present in Algeria, Timimoun area, in the lower part of Upper Kahla Sandstone, at the top of the "coquina" beds, associated or below *Gattendorfia* horizon and in Algerian-Moroccan border, Zemoul area, in the "Upper Fauna".

Superfamily *MARTINOIDEA* Waagen, 1883 – by D. BRICE
Family *MARTINIIDAE* Waagen, 1883
Subfamily *EOMARTINIOPSINAE* Carter in Carter *et al.*, 1994

Genus *EOMARTINIOPSIS* Sokolskaya, 1941

Diagnosis: (Pitrat in Treatise, 1965, v. 2, p. 726). Type species: *Eomartiniopsis elongata* SOKOLSKAYA, 1941, Early Carboniferous in the former Soviet Union.

Eomartiniopsis lakahalensis Brice nov. sp.
(Pl. V, figs. 6-21, table V)

2004 – *Eomartiniopsis* sp. Brice, Legrand, Nicollin in Brice *et al.*, p. 16-17.

2004 – *Eomartiniopsis* sp. Brice, Legrand, Nicollin in Kaiser *et al,* p. 96, 98.

DERIVATIO NOMINIS: The name is derived from the type locality Kheneg Lakahal in Assa area, Morocco

LOCUS TYPICUS: Dra Valley, Kheneg Lakahal section, 20 km south Assa, Dra Valley, Anti-Atlas, southern Morocco.

STRATUM TYPICUM: unit + 2 (except 0 m 50 above the base) to unit + 5.

HOLOTYPE: GFCL 2062 = BK + 3.1 a 12, pl. 5, figs. 6 a-b.

PARATYPES: GFCL. 2063 to GFCL 2077, figs. 7 to 21.

Material : 102 incomplete valves

Morocco: Assa area, Kheneg Lakahal section, BN Collection unit + 2, + 2.12 (12 imvv, a1, 9 vv, 6 ecvv, 4 dv), + 2.13 (1 incomplete vv, 1 ivv, 1 dv), + 2.14 (10 vv , 2 dv), + 2.15 (12 incomplete vv, a1 dv). BK Collection unit + 2 + 2.2 (1 vv, 7 ecvv, 4 dv); unit + 3 + 3.1 14 vv, 1 dv), unit + 3.11 (3 imvv); unit + 5.5 (9 imvv, 1 vv). Algeria:, Gara el kahla, Upper Kahla Sandstone, ML 306 (1 ecvv), ML 324 (1 ecdv), ML 329 (1 ecdv). All specimens from the "Upper Fauna", Early (?) Tournaisian.

Diagnosis

A species of *Eomartiniopsis* with ventral valve a little more convex than the dorsal valve, a little larger than long, with ventral interarea well-defined, sulcus and fold developed along both valves. The sinus begins as a posterior groove and becomes gradually wider, moderately deeper. At the anterior regionit has rounded limits and forms a low tongue. Fold not well-defined. Internally, some specimens show valves covered with radiating pallial markings. Thin dental plates are observed but dorsal septum is absent and crural plates are not observed.

Description

The specimens are smooth, subequally biconvex, of medium size, with ventral valve slightly more inflated than the dorsal valve. They are transversely ovate in outline, brachythyrid, with rounded ears. The maximum width is attained near mid-length. The ventral valve is regularly convex, maximum in the posterior region. The curved beak is moderately high The ventral interarea is fairly defined by subangular rounded beak ridges, it is apscacline and weakly concave. The sulcus originates at the beak as a groove and becomes gradually wider and moderately deeper at the anterior region, with rounded limits and forming a low tongue. The convexity of the dorsal valve is maximum in the medial part of the valve. The fold is not clearly limited, but starts at the beak as a low rounded prominence and continues along the valve length. Ornamentation is lacking, except concentric well marked growth lamellae and occasional surperficial pits that are poorly preserved on restricted surfaces.

Internal characteristics include parallel thin dental adminicula in the posterior region that diverge slightly anteriorly. Muscle field is lanceolate and is limited laterally by dental plates; its surface is almost flat (slightly depressed) and ornamented by four grooves. In some specimens, the internal moulds of valves are covered with radial pallial markings. The dorsal septum is lacking, and the crural plates are not observed.

Discussion

This species belongs to *Eomartiniopsis* due its external and internal characteristics. It is close to *E. rostrata* (Girty, 1899), but *E. lakalalensis* differs by a smaller size, a less variable sulcus, a less defined fold and a lower tongue. *E. lakalalensis* also has similarities with *E. planosinuata* Poletaev, 1975, but it differs by a more defined sulcus and fold at the anterior region.

Range

The genus *Eomartiniopsis* is cosmoplitan. It is known - 1) in Tournaisian deposits of Russian (type material of *E. elongata* Sokolskaya, 1941 from the Moscow Basin), Donetz Basin, Pechtora, Ural; - 2) in Visean deposits in Kouzbass, and Baskirian in Donbass; - 3) in early Mississippian deposits in North America in Arkansas, Illinois, Iowa, Missouri, Texas (Tournaisian and a part of Visean according to Carter, 1990, fig. 2), - in western Alberta (Canada); - 4) in Tournaisian deposits in Bonaparte Gulf Basin (NW Australian), and 5) in upper Visean in Afghanistan.

Suborder DELTHYRIDINA Ivanova, 1972 – by D. BRICE

Superfamily *DELTHYRIDOIDEA* Phillips, 1841
Family *CYRTINOPSIDAE* Wedekind, 1926
Subfamily *TYLOTHYRIDINAE* CarteR, 1972

Genus *TYLOTHYRIS* North, 1920

Diagnosis: (Pitrat in Treatise 1965, v. 2, p. 687). Type species: *Cyrtia laminosa* M'COY, 1844, Tournaisian.

Tylothyris sp. aff. *laminosa* (M'Coy, 1844)
(Pl. IV, figs. 22, 24)

2004 – *Tylothyris* (?) sp; Brice, Legrand, Nicollin *in* Brice *et al.*, p. 16-17

2004 – *Tylothyris* (?) sp. Brice, Legrand, Nicollin in Kaiser *et al.* p. 96

Material: 6 specimens

Morocco: Assa area, Kheneg Lakahal section, BK Collection unit + 2 , + 2.12 (1 ivv), unit +3, 3.3 (3 incomplete ecvv); + 3.5 (remains). Algeria: Gara el Kahla, Upper Kahla Sandstone ML 324 (1 ecvv). "Upper Fauna" Early (?) Tournaisian.

Description and Discussion

The ventral valves show 5 or 6 lateral costae, wide sulcus with flat bottom, near extremities of hinge-line shell non costulated, bottom of sulcus flat. They recall juvenile specimens of *T. laminosa* from Fermanagh figured by Brunton (1984, fig. 119b). The internal mould of the specimen (Pl. 4, fig. 24) shows the track of a dorsal septum.

Range

According to Brunton (1984, p 83), *Tylothyris* species similar to *T. laminose* extend from western Europe through the Middle East to Australia. Stratigraphycally, the species is known from the late Tournaisian in the type locality and in Belgium, and from mid-Visean in NW Ireland, including the Fermanagh fauna.

Tylothyris (?) sp.
(Pl. IV, fig. 23)

Material: 1 specimen

Morocco: Tafilalt, M'karig section NE of Ouidane Chebbi, "Upper fauna ", BK Collection, *Stockumites* level with *St intermedius* MB.B.2394 (1 imdv).

Description

The outline is transversely semi-elliptical, 16 mm wide, with a maximum width at the hinge-line, 9.7 mm lenght, and is gently convex. The fold is low, and well-delimited, it is

	GFCL	2062 ventral valve	2063 ventral valve	2064 ventral valve	2067 ventral valve	2070 ventral valve	2072 ventral valve	2076 ventral valve	2069 dorsal valve	2073 ? dorsal valve
W		25.2	31	21 ?	20.2	21 ?	23	25.3		
L		24.9	24	17.2	18.8	15.2	17	24.1		
W									32.4	21
L									?	18

Table V. — (Measurements in mm)

narrow near the beak and increases moderately towards the anterior margin The top of the fold has a weak medial furrow. Each lateral slope is ornamented by six simple costae, that decrease rapidly in width towards the lateral extremities, where there is a small surface without costae. Traces of imbricate growth lamellae are present with several more important at mid-length.

Discussion

The tentative assignment of this dorsal valve mould to *Tylothyris* is due to some similarities with *Punctospirifer* gr. *solidirostris* (White) illustrated by Carter (1972, pl. 4, fig. 24-29), but we have not observed traces of puncta characteristic of the genus *Punctospirifer*.

Order SPIRIFERINIDA Ivanova, 1972 – by M. LEGRAND-BLAIN

Suborder SPIRIFERINIDINA Ivanova, 1972

Superfamily *SYRINGOTHYRDOIDEA* Frederiks, 1926

Family *SYRINGOTHYRIDIDAE* Frederiks, 1926

Subfamily *SYRINGOTHYRIDINAE* Frederiks, 1926

Diagnosis: (Pitrat in Treatise 1965, v. 2, p. 692). Type species: *Syringothyris typa* WINCHELL, 1863 = *Spirifer carteri* Hall,, 1857. Iowa, lower Mississippian. Carter *et al.*, 1994, p. 365: "Delthyrial plate and syrinx present". "Upper Famennian – Lower Permian"

Syringothyris cf. *uralensis* Nalivkin, 1975

(Pl. V, figs. 23 a-d)

cf. 1975 - *Syringothyris uralensis* Nalivkin, sp. n. : Nalivkin in Garanj *et al.*, p. 184, pl. 81, fig. 17a-d.

cf. 1979 - *Syringothyris uralensis* Nalivkin, 1975 : Nalivkin, p. 131, Pl. 61, figs. 1-6.

Material : : 1 specimen

Ma'der, Morocco. Bou Tlidat, "*Stockumites* bed", a few meters below the entry of *Gattendorfia* and *Siphonodella sulcata* (Becker, written comm.). MB.B.2401 housed in Berlin Museum für Naturkunde

Description

A big-sized internal mould with 2 valves connected, entirely and finely preserved, but distorted by antero-posterior compaction. Dimensions (mm) measured on internal moulds, slightly inferior to the external ones : vv width = 64; vv length ~ 33; ventral area heigth = 27; delthyrium width = 15; sinus width at front = 26; apical angle ~ 170°; delthyrial angle ~ 30°; angle between area plane and valve junction : ~ 70°.

Ventral valve: cardinal extremities slightly angular; median sinus well defined; lateral costae simple, 18 at least ; interarea procline, flat, except its anterior border, slightly incurved. Delthyrial opening bounded by strong adminicula; its lower 2/3 covered by stegidial plates embedded in rock coating. The syrinx internal mould is finely preserved: not a tube but a semicylindrical plate, inserted near the area plane and sinking slightly anteriorly, provided with fine oblique furrows (probably muscular insertions). Ventral muscle scar trapezoidal, short, bounded by the anterior extremities of adminicula in intra-sinal position. No median septum, but a low ridge between the muscle scar and departure of the syrinx. Coarse genital markings cover the posterior parts of the flanks and area. Dorsal valve semi-circular, cardinal extremities perpendicular; a rounded median fold divided by an internal median ridge. Dorsal muscle scars slightly impressed, ovale. Cardinal process broad, striated. Slight genital markings on the posterior parts of dorsal flanks. Articulation: strong ventral teeth inserted in oblique dorsal sockets; no denticles on the area.

Discussion

By the shape and position of the syrinx - semi-cylindric, inserted near the plane of ventral area - the described *Syringothyris* belongs to the group of *S. hannibalensis* (Swallow) - *S. ahnetensis* Legrand-Blain. These two species have a smaller size (50 - 55 mm width) and a less transverse outline. *Syringothyris uralensis* is shortly described in Russian literature as a large shell, similar to *S. hannibalensis*, from which it differs by a more transverse shape. The single Moroccan specimen cannot be determined without doubt; it bears about 18 lateral costae, instead of 25 on *S. uralensis*.

Range

In South Urals, *S. uralensis* was described originally (Nalivkin, 1975 in Garanj *et al.*, 1979) from Lytvin horizon, Strunian; later, Rzonsnitskaya (1988, p. 264, 268) reviewed the stratigraphic range of the species, as follows (translated from Russian) : "In South Urals, D.V. Nalivkin records [*Syringothyris*] in "Etroeungt coquina", which correspond approximately to Zigan beds, recently subdivided into several units. In the Sikaza section, units 6 and 6a correspond to uppermost Devonian. Units 6b, 6v, 6g separated as "Gumerovsky horizon" belong to *Acutimitoceras prorsum*

Zone. In that horizon, *Syringothyris uralensis* Nal. is found (unit 6g) associated with conodonts *Siphonodella sulcata*; its occurrence in units 6 and 6a needs confirmation".

Syringothyris sp. indet.

1974. *Syringothyris ahnetensis* (?). Legrand-Blain, p. 101.

1995. *Syringothyris ahnetensis* (?). Legrand-Blain, p. 94.

Material :

Algeria, Gara el Kahla section, upper Kahla sandstone Formation : (a) "coquinas" below the *Gattendorfia* horizon, ML 324, external moulds fragments; other fragmentary specimens housed in Alger University Paleontological Collections : ML330, ML387 = Coll. n° 1060012 (Mofredj A., 2002). (b) in the *Gattendorfia* horizon : 2 complete internal moulds of immature specimens, JC325 a1, a2. "Upper Fauna".

Description

Dimensions of JC 325 a2 (mm): W ~ 22, vv L ~ 18, dv L ~ 12. Lateral costae number ~ 12. Ventral area nearly flat, orthocline, 10.5 mm high. Delthyrium triangular, 5 mm basal width. Minute flat syrinx starting near the posterior part of the delthyrium.

Discussion

These specimens were previously cited as *Syringothyris ahnetensis* (?). They belong to the group of *S. ahnetensis* - *S. uralensis* by the shape of the syrinx, but their sate of preservation (fragmentary or immature shells) prevents any precise identification.

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APPENDIX

Locations and ranges according to Hollard (†) (1981), Brousmiche (1975), Brice & Nicollin (2000), Nicollin & Brice (2001).

OUED DRA VALLEY, WESTERN ANTI-ATLAS, MOROCCO.

Assa area (Geological map 1/200 000 FOUM EL HASSANE-ASSA, 1969, *Notes &Mém. Serv. Géol. Maroc,* N° 159).

As 31: left bank of Oued Amstil, 12 km E of Hassi Rharouar, x = 147.5, y = 185. Lemgaïrinat Formation, Famennian (V *fide* Hollard): *Leptaena* cf. *analoga, Eobrachythyris hollardi.*

As 108: Jebel Tazout, near Kheneg Aftes, x = 158.9, y = 188. Tazout 1 Sandstone, Strunian (?). *Mesoplica praelonga.* **As 111**: N of As 31, x = 156.3, y = 190.5, El Douyia Formation, Famennian (IV *fide* Hollard): *Dichospirifer zemoulensis.*

As 112: N of Jebel Tazout, x = 156, y = 190.5, El Douyia Formation, Famennian (IV *fide* Hollard): *Prospira struniana, P.* cf. *struniana.*

As 117: same locality, westwards, x = 151.3, y = 187.7, El Douyia Formation, Famennian (IV *fide* Hollard): (?) "*Mesoplica* gen. nov.", *Prospira struniana.*

As 118: same locality, a little more northwards, x = 153.3, y = 187.7, El Douiya Formation, Famennian (IV *fide* Hollard): *Spinocarinifera* aff. *lotzi,* "*Mesoplica* gen. nov.", *Ericiatia* cf. *chonetiformis, Prospira struniana, Eobrachythyris hollardi*

As 123: N of Jebel Tazout, left bank of Oued Amstil, x = 142.7, y = 185, Lemgaïrinat Formation, Famennian (V *fide* Hollard): *Dichospirifer zemoulensis.*

As 259: E of Hassi Rharouar, x = 135.5, y = 184.2, Lemgaïrinat Formation, Famennian (IV? *fide* Hollard): *Leptaena* cf. *analoga.* As 260: idem, Lemgaïrinat Formation, Famennian (V *fide* Hollard): (?) "*Mesoplica* gen. nov." *Acanthatia* (?) sp. 1, *Gastrodetoechia sp., Cyrtospirifer pseudorigauxia, Sphenospira* cf. *julii, Prospira struniana, Eobrachythyris hollardi.*

BD: SDS Field Trip 1975, Hassi Rharouar section, Famennian (V *fide* Hollard): *Centrorhynchus* spp. cf. *lucida, Paurogastroderhynchus presaharensis.*

MZ Jbel Tazout Upper Famennian V *fide* Hollard: *Prospira struniana.*

MZ 1: SDS Field Trip 1975, Hassi Rharouar section, Famennian (V *fide* Hollard): *Centrorhynchus* spp. cf. *lucida.*

MZ 2: SDS Field Trip 1975, Hassi Rharouar section, Upper Famennian (V *fide* Hollard): *Leptaena* cf. *analoga,* (?) "*Mesoplica* gen. nov." *Centrorhynchus* spp. cf. *lucida,, Cyrtospirifer* sp. 1 aff. *Leboeufensis.*

MZ 3: SDS Field Trip 1975, Hassi Rharouar section, (Strunian *fide* Hollard): *Mesoplica praelonga.*

Akka area (Geological map 1/200 000 AKKA - TAFAGOUNT – TATA, 1970. *Notes & Mém. Serv. Geol. Maroc,* N° 163).

Ak 30: E of the confluence of Oued Dra and Oued-Akka, x = 246.3 y = 239.3, Famennian (V *fide* Hollard): *Semiproductus* sp. 1, *Ericiatia* cf. *chonetiformis, Cyrtospirifer* sp. 1 aff. *leboeufensis,* Imbrexiidae indet.

Ak 71: left bank of Oued Dra near Rich el Bergat, x = 268, y = 254.3, Tazout Formation, *Gattendorfia* gr. *crassa* horizon *fide* H. Hollard, lower Tournaisian: *Acanthatia* (?) *placita, Unispirifer unicus.*

Ak 72: left bank of Oued Dra, near Mou Atifis., Lemgaïrinat Formation, Upper Famennian (V or VI ?): *Ericiatia* cf. *chonetiformis, Cyrtospirifer pseudorigauxia.*

Ak 86: right bank of lower Oued Akka, Upper Famennian (IV) ?: *Ericiatia* cf. *chonetiformis.*

OUED ZEMOUL AREA, CENTRAL ANTI-ATLAS, ALGERIAN-MOROCCAN BORDER (Geological map 1/200 000 AGADIR TISSINT – OUED ZEMOUL, 1971. Notes & Mém. Serv. Géol. Maroc, N°219. Topographic maps 1/200 000 of Algeria: IGMA, HASSI EL HAOUEIRRA, KHORB EL ETHEL.

AT 128: Dfeif, x = 369 y = 257, El Douiya Formation, Famennian (IV or V *fide* Hollard): *Hollardospirifer draensis.*

AT 129: Dfeif, idem, top of El Douiya Formation, Famennian (IV or V *fide* Hollard): *Acanthatia* (?) sp. 1, *Steinhagella* cf. *membranacea.*

AT 130: Dfeif, idem, base of Lemgaïrinat Formation, Famennian (IV or V *fide* Hollard): *Steinhagella* cf. *membranacea.*

AT 131: Dfeif, El Douiya Formation, Famennian (III ?): *Dichospirifer zemoulensis.*

AT 132: N of Dfeif, x = 363, y = 266.5, El Douiya Formation, Famennian (IV *fide* Hollard): *Steinhagella* cf. *membranacea, Hollardospirifer draensis.*

AT 135: N of Dfeif, base of Tazout Formation, Famennian (VI *fide* Hollard): *Ericiatia* cf. *chonetiformis, Cyrtospirifer pseudorigauxia, Prospira struniana.*

AT 139: hill E of Dfeif track, Lemgaïrinat Formation, Famennian (V *fide* Hollard): *Semiproductus* sp. 1.

AT 140: Oued Aouzergui, x = 314 y = 271.5, Lemgaïrinat Formation, Famennian (IV *fide* Hollard): *Hollardospirifer draensis.*

AT 141: Oued Aouzergui, x = 314, y = 270.6, Lemgaïrinat Formation, Famennian (V *fide* Hollard): *Cyrtospirifer pseudorigauxia.*

Zl 15: NE of Sidi-el-Mouynir, x = 326, y = 242.4, El Douiya Formation, Famennian (probably IV): *Semiproductus* sp. 1, *Steinhagella* cf. *membranacea, Dichospirifer zemoulensis.*

Zl 16: NE of Sidi-el-Mouynir, x = 330, y = 244.2, base of Tazout 1 Formation, Famennian (VI *fide* Hollard): *Semiproductus* sp. 1, *Whidbornella* cf. *pauli radiata, Ericiatia* cf. *chonetiformis, Steinhagella* cf. *membranacea.*

Zl 17: idem, a little higher in Tazout 1, Famennian (VI *fide* Hollard): *Whidbornella* cf. *pauli radiata, Cyrtospirifer pseudorigauxia.*

Zl 21: N flank of the Dra-el-Kelba anticline, x = 406, y = 218.5, El Douiyat Formation, Famennian (IV *fide* Hollard): "*Mesoplica* gen. nov.", *Semiproductus* sp. 1, *Prospira struniana.*

Zl 27: Jfeirat, NE of Bou Zrazer, x = 374, y = 237.8, Lemgaïrinat Formation, Famennian (V or VI *fide* Hollard): *Cyrtospirifer pseudorigauxia, Prospira struniana.*

Zl 28: idem, x = 374.8, y = 237.7, base of Tazout 1 Formation, Famennian (V or VI *fide* Hollard), *Ericiatia* cf. *chonetiformis.*

Zl 29: idem, x = 374.7, y = 237.6, Tazout 1 Formation, Famennian (VI *fide* Hollard): *Spinocarinifera* cf. *lotzi, Whidbornella* cf. *pauli radiata.* Imbrexiidae indet.

Zl 37: Mouilha, upper Oued Khorb-el-Ethel, near x = 411, y = 208, Tazout 1 Formation, Famennian (lower or middle part of Zone VI): *Mesoplica praelonga, Kahlella* sp., *Whidbornella* cf. *pauli radiata, Cyrtospirifer* sp. 1 aff. *leboeufensis.*

Zl 48: N of Oum el Ksi W pericline, x = 363, y = 217.8, Lemgaïrinat Formation, Famennian (V *fide* Hollard): *Acanthatia* (?) sp. 1.

Zl 55: E Igma pericline, x= 429.6, y = 224, El Douiya Formation, Famennian (IV *fide* Hollard): *Dichospirifer zemoulensis.*

Zl 61: Zemoul anticlinal, upper El Douiya Formation, Famennian (IV *fide* Hollard): *Hollardospirifer draensis.*

Zl 64: Jfeirat, NE of Bou Zrazer, x = 377.6, y = 236.5, Tazout 2 Formation, below the *Gattendorfia* gr. *crassa* horizon, Early Tournaisian: *Semiproductus* (?) sp. 2, *Spinocarinifera* sp. 1 aff. *arcuata.*

Zl 65: N flank of Oued Zemoul, Tazout 2-3 Formation, *Gattendorfia* gr. *crassa* horizon fide Hollard, Early Tournaisian: *Semiproductus* (?) sp. 2, *Prospira* sp. 2.

i 783 (= Zl 88): N of Zemoul anticline, x = 309, y = 254, Tazout (2 ?) Formation, *Gattendorfia* gr. *crassa* horizon, Early Tournaisian: *Eobrachythyris jacquemonti, Eochoristites platycosta.*

i 792: S of Zemoul anticline, x = 312.6, y = 227, El Douiya Formation, Famennian (IV ?): *Centrorhynchus* spp. cf. *lucida, Cyrtospirifer pseudorigauxia, Dichospirifer zemoulensis, Hollardospirifer draensis.*

i 813 (Zl 84): idem, Lemgaïrinat Formation, Famennian (V ?): *Dichospirifer zemoulensis, Hollardospirifer draensis*

i 820: idem, Famennian (IV or V): *Cyrtospirifer* sp. 1 aff. *leboeufensis, Hollardospirifer draensis*

i 821: Zemoul anticline, Tazout 2-3 Formation: *Eobrachythyris jacquemonti.*

i 828: Famennian (V ?) : *Cyrtospirifer* sp. 1 aff. *leboeufensis, Sphenospira* cf. *julii.*

i 843 = i 846 = Zl 94: Bou Zrazer (Jfeirat)anticline, Lemgaïrinat Formation, Famennian (V *fide* Hollard): *Cyrtospirifer pseudorigauxia, Hollardospirifer draensis.*

i 844 (= Zl 99) : idem, El Douiya Formation, Famennian (upper IV *fide* Hollard): *Dichospirifer zemoulensis.*

i 848 about 6°37'W, 29°10'N Strunian (?): *Centrorhynchus* spp. cf. *lucida.*

i 881: Igma anticline, Oued Leïredgui (?) about 6°26' W, 29°02' N: Famennian (V *fide* Hollard): *Cyrtospirifer* sp. 1 aff. *leboeufensis*

TINDOUCHY AREA, S CENTRAL ANTI-ATLAS, ALGERIA (topographic map 1/200 000 TINFOUCHY).

Zl 57: SE of Tinfouchy, near 5°50'W 28°50'N (IV or V), upper Lemgaïrinat Formation, Famennian (IV or V): *Paurogastroderhynchus presaharensis, Cyrtospirifer* sp. 1 aff. *C. leboeufensis, Sphenospira* cf. *julii, Hollardospirifer draensis.*

TIMIMOUN AREA, GOURARA, ALGERIA

(Geological maps of Algeria 1/500 000: TIMIMOUN, 1974; KERKAZ, 1952. Topographical maps of Algeria : TIMIMOUN, CHAROUINE, EL KSEIBAT. (J. Conrad, Fig. 6, p. 319, lithostratigraphy).

JC 915 (= ML 315): about N 28°59', W 00°03', Lower Kahla Sandstone, Famennian (V-VI ?): *Mesoplica (s.l.) nigeraeformis, Kahlella meyendorffi, Steinhagella* cf. *membranacea.*

JC 923 (= ML 322): about N 28°59, W 00°02', Kahla Mudstone, near the *Gonioclymenia* horizon, Famennian (V): *Mesoplica (s.l.) nigeraeformis, Prospira* cf. *lapparenti.*

JC 935 (= ML 325): about N 29°05', W 00°02', Upper Kahla Sandstone, the aammonoid locality described by Ebbighausen *et al.* (2004) *Gattendorfia jacquelinae, G.*cf. *crassa Acuminoteceras* spp., *Kahlacanites* (n. gen.),probably middle Early Tournaisian : *Spinocarinifera* sp. 1 aff. *arcuata, Macropotamorhynchus* nov. sp. aff. *insolitus, Shumardella* nov.sp. aff. *fracta, Prospira* sp. 1, *Prospira* sp. 2, *Syringothyris* sp. indet.

ML 306: about N 29°00', W 00°04', Upper Kahla Sandstone, "coquina" preceeding the *Gattendorfia* cf. *crassa,* Early Tournaisian : *Schuchertella* sp., *Macropotamorhynchus* nov. sp. aff. *insolitus, Prospira* sp. 1, *Unispirifer unicus, Voiseyella* sp. 2 aff. *sergungovae, Eochoristites platycosta, Eomartiniopsis lakahalensis.*

ML 307: idem, *Acanthatia* (?) sp. 2.

ML 308, 309: idem, base of "coquina", Early Tournaisian : *Macropotamorhynchus* nov. sp. aff. *insolitus, Prospira* sp. 1.

ML 311-320: about N 28°59', W 00°02, Lower Kahla Sandstone, "coquina", Famennian (V-VI ?).

ML 311: base of coquina: *Mesoplica praelonga, Whidbornella* cf. *pauli radiata.*

ML 312: *Hamlingella* sp 1, *Steinhagella* cf. *membranacea, Cyrtospirifer* sp. 3 aff. *warrenensis.*

ML 313: *Mesoplica praelonga, Hamlingella* sp. 1, *Kahlella meyendorffi, Paurogastroderhynchus praesaharensis, Megalopterorhynchus* sp., *Cyrtospirifer* sp. 2 aff. *oleanensis, Parallelora* aff. *subsuavis.*

ML 314: *Kahlella meyendorffi, Hamlingella* sp. 1, *Steinhagella* cf. *membranacea, Gastrodetoechia* sp., *Sphenospira* cf. *julii.*

ML 315: *Cyrtospirifer* sp. 2 aff. *Oleanensis*

ML 316: *Cyrtospirifer* sp. 2 aff. *oleanensis, Parallelora* aff. *subsuavis.*

ML 317: *Kahlella meyendorffi, Whidbornella* cf. *pauli radiata, Cyrtospirifer* sp. 2 aff. *oleanensis, Sphenospira* cf. *julii.*

ML 320: top of "coquina": *Kahlella meyendorffi , Sphenospira* cf. *julii.*

ML 322 (= JC 923): Kahla Mudstone, Upper Famennian (V ?): *Prospira* cf. *lapparenti.*

ML 324: about N 29°05', W 00°02, Upper Kahla Sandstone, coquina preceeding the *Gattendorfia* gr. *crassa* horizon, Early Tournaisian : *Leptagonia* cf.*analoga, Spinocarinofera* aff. *bulbosa, Macropotamorhynchus* nov. sp. aff. *insolitus, Voiseyella* sp. 2 aff. *sergunkovae, Eochoristites platycosta, Eomartiniopsis lakahalensis, Tylothyris* aff. *laminosa.*

ML 325: idem, *Gattendorfia* gr. *crassa* horizon, Lower Tournaisian: *Spinocarinifera* aff. *arcuata, Macropotamorhynchus* nov. sp. aff. *insolitus, Shumardella* nov. sp. aff. *fracta.*

ML 329, 330: about N 29°05', W 00°03', Upper Kahla Sandstone, "coquina" preceeding the *Gattendorfia* gr. *crassa* horizon, Lower Tournaisian.

ML 329: *Prospira* sp. 1, *Unispirifer unicus, Eochoristites platycosta, Eomartiniopsis lakalensis.*

ML 330: *Macropotamorhynchus* nov. sp. aff. *insolitus, Unispirifer unicus, Voiseyella* (?) sp. 3 aff. *tylothyriformis, Syringothyris* sp.

ML 350, 352: about N 29°11.5' E 00°04', Upper Kahla Sandstone, above the *Gattendorfia* horizon, Early Carboniferous: *Productina* sp.

ML 353, 354: about N 29°12', E 00°04', Upper Kahla Sandstone, Early Carboniferous ML 353: *Acanthatia* (?) *placita,* ML 354: *Voiseyella* sp. 4.

ML 362: *Prospira* sp. 1.

ML 363 (= ML 311): Lower Kahla Sandstone, late Famennian: *Cyrtospirifer* sp. 3 aff. *warrenensis.*

ML 365 (= ML 312): Lower Kahla Sandstone, late Famennian: *Paurogastroderhynchus praesaharensis.*

ML 366 (= ML 317): Lower Kahla Sandstone, Late Famennian: *Kahlella meyendorffi.*

ML 387 (= ML 324): Upper Kahla Sandstone, Early Tournaisian: *Spinocarinifera* aff. *bulbosa, Macropotamorhynchus* nov. sp. aff. *insolitus, Prospira* sp. 1, *Unispirifer unicus.*

PLATE I

(Scale bars = 5 mm, except Fig. 4b)

Fig. 1-6 — *Hamlingella talmouti* Legrand-Blain, nov. sp. Kheneg Lakahal section, "Lower Fauna", late Famennian.

1 a-c — Holotype GFCL 918 = BK - 2.6.2. Decorticated ventral valve, minute spine bases; (a) overall view, incipient radial plications near the front, (b) profile, (c) cardinal view showing the spine brush, the area devoid of spine bases. Unit – 2. *Valve ventrale décortiquée, couverte de bases de fines épines; (a) vue d'ensemble, amorces de plis radiaires près du front, (b) profil, (c) vue cardinale montrant une touffe de fortes épines postéro-latérales ("spine brush"), et l'area dépourvue de bases d'épines.*

2 — GFCL 922 = BN - 7 a6. Ventral valve internal mould; adductor and diductor muscle scars, area devoid of spine bases. Unit - 7. *Moule interne de valve ventrale, empreintes des muscles adducteurs et diducteurs, area dépourvue de bases d'épines.*

3 — Paratype GFCL 919 = BK - 2.6.4. Ventral valve internal mould, irregular radial plicae. Unit - 2. *Moule interne de valve ventrale, plis radiaires irréguliers.*
4 a-b — GFCL 921 = BN - 7 a2. (a) dorsal valve external mould, covered with fine spines, (b) detail of dorsal spines bases, minute internal canals preserved. Unit - 7. *a-b. — (a) moule externe de valve dorsale couvert de fines épines; (b) détail des bases d'épines dorsales avec leurs canalicules internes.*

5 — GFCL 923 = BN - 7 a1. Dorsal valve with two fragments of the ventral valve preserved on left side. — the posterior spine brush and a small fragment near the front. Unit - 7. *Valve dorsale avec deux fragments de valve ventrale conservés sur le côté gauche. — la touffe postérieure d'épines ("brush") et un petit fragment de coquille près du front.* 6 — GFCL 924 = BN - 7 a 8. Plaster print of a dorsal valve internal mould; bilobed cardinal process, hinge sockets, median septum, dendritic adductor scars. Unit - 7. *Réplique en plâtre d'un moule interne de valve dorsale; processus cardinal bilobé, fossettes dentaires, septum médian, empreintes des adducteurs dendritiques.*

Fig. 7 — *Hamlingella* sp. 1. GFCL 925 = BN - 0. Ventral valve internal mould, muscle scars, area devoid of spine bases. Kheneg Lakahal section, unit - 0. "Intermediate Fauna". *Moule interne de valve ventrale, empreintes musculaires, area dépourvue de bases d'épines.*

Fig. 8 — *Whidbornella* cf. *pauli radiata* (Paeckelmann, 1931). GFCL 926 = BN - 6 b1. Decorticated ventral valve, spine ridges passing anteriorly to costellae. Kheneg Lakahal section, unit - 6. "Lower Fauna", late Famennian. *Valve ventrale décortiquée, crêtes épineuses passant vers l'avant à des costules.*

Fig. 9 a-b — *Spinocarinifera* aff. *lotzi* (Paeckelmann, 1931). GFCL 906 = BN - 7 b1. Decorticated ventral valve, (a) ventral view, costae, fibrous "shagreen" shell material. (b) profile. Kheneg Lakahal section, unit - 7. "Lower Fauna", late Famennian. *Valve ventrale décortiquée, (a) vue ventrale, test fibreux d'aspect grenu ("shagreen" = cuir chagrin); (b) profil.*

Fig. 10 — *Spinocarinifera* aff. *inflata* (Sokolskaya, 1948). GFCL 907 = BK - 2.6.5. Plaster print of a ventral valve external mould. Kheneg Lakahal section, unit - 2. "Lower Fauna", late Famennian. *Réplique en plâtre d'un moule externe de valve ventrale.*

Fig. 11 — *Spinocarinifera* aff. *bulbosa* (Havlicek, 1984). GFCL 908 = BN + 2.13. A compacted ventral valve, long spines preserved. Kheneg Lakahal section, unit + 2. "Upper Fauna", Early Tournaisian. *Valve ventrale déformée par compaction, longues épines conservées.*

Figs. 12, 13 — *Kahlella* sp. Kheneg Lakahal section, "Lower Fauna" late Famennian.

12 — GFCL 928 = BN - 2 g. A large ventral valve, enclosing a *Paurogastroderhynchus* shell. Unit - 2. *Valve ventrale de grande taille, une coquille de* Paurogastroderhynchus *y est incluse.*

13 a-b — GFCL 927 = BN -3 b. (a) decorticated ventral valve, a row of cardinal spine bases (upper right), (b) detail of cardinal spine bases. Unit - 3. *(a) Valve ventrale décortiquée, bases d'épines cardinales conservées (en haut, à droite); (b) détail des bases d'épines.*

Fig. 14-20 — *Mesoplica praelonga* (Sowerby, 1840). Kheneg Lakahal and Mouilha sections, "Lower Fauna", late Famennian.

14 a-b — GFCL 910 = BK - 1 a4. Dorsal valve internal surface; (a) cardinal process and cardinal ridges, (b) profile, strong geniculation. Kheneg Lakahal, Unit - 1. *Valve dorsale, surface interne. (a) processus cardinal et crêtes cardinales ; (b) profil, forte géniculation.*

15 — GFCL 932 = BN - 1 a1. Trail of ventral valve, median fold bearing a row of strong spines, smaller spine bases and faint radial costae on flanks . Kheneg Lakahal, Unit - 1. *Chape de la valve ventrale, pli médian pourvu d'une rangée de fortes épines; sur les flancs, fines épines et vagues côtes radiaires.*

16 — GFCL 930 = BN - 6 d1. Ventral valve external mould, fine superficial concentric zones. Kheneg Lakahal, Unit - 6. *Valve ventrale, moule externe orné de fines zones concentriques.*

17 — GFCL 929 = BN - 4. Decorticated ventral valve, median row of thick spine bases, fibrous "shagreen" shell material. Kheneg Lakahal. Unit - 4. *Valve ventrale décortiquée, rangée médiane de fortes bases d'épines, test fibreux d'aspect grenu ("shagreen").*

18 — GFCL 931 = BN - 6 d3. Dorsal valve internal surface, cardinal ridges, median fold. Unit - 6. *Valve dorsale, surface interne; crêtes cardinales, pli médian.*

19 a-b — GFCL 912 = Zl 37.7. Decorticated ventral valve; (a) ventral view, "shagreen" shell material ; (b) profile. Mouilha, top of Tazout 1 (Hollard, 1971, fig. 2. — fossiliferous bed, 25 m below the "Poudingue de Bou-Mgheirfa"). *Valve ventrale décortiquée; (a) vue ventrale, test d'aspect grenu ("shagreen") ; (b) profil.*

20 — GFCL 911 = BK - 1 bh. Decorticated ventral valve, median row of strong spines ; "shagreen" shell material. Kheneg Lakahal, unit - 1. *Valve ventrale décortiquée, rangée médiane de fortes bases d'épines; test d'aspect grenu ("shagreen").*

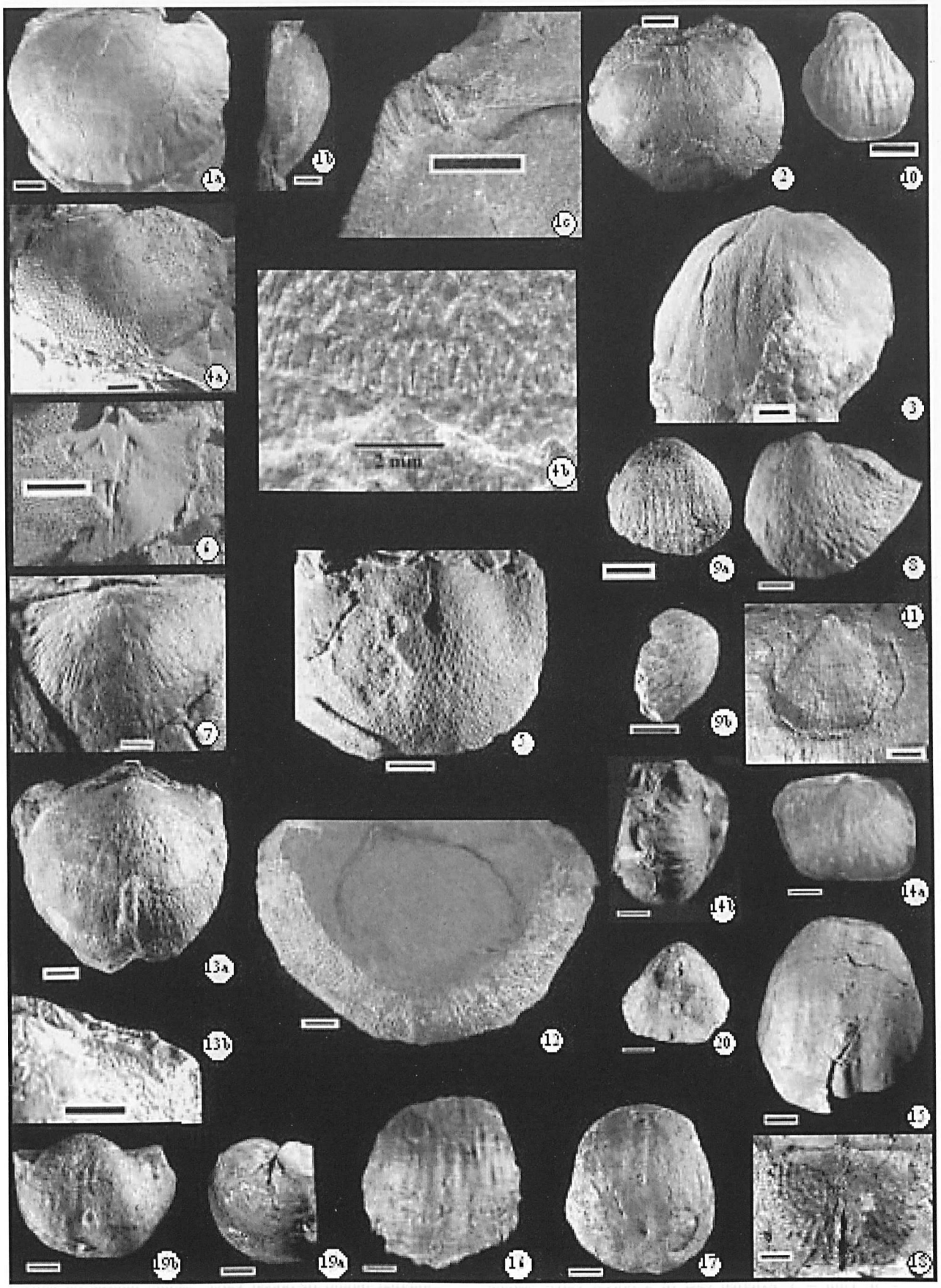


PLATE II

Scale bars = 5 mm

Figs 1-7, 25 a-b — *Paurogastroderhynchus presaharensis* Brice nov. sp. Kheneg Lakahal section, "Lower Fauna", late Famennian, southern Morocco, except fig. 5, Gara el Kahla section, Timimoun area, Algerian Sahara "Lower Fauna", late Famennian.

1a-d — Holotype GFCL 962 = BN - 4a, dorsal, ventral, posterior, lateral views of a decorticated specimen. Unit - 4. *Vues dorsale, ventrale, postérieure, latérale d'un spécimen décortiqué.*

2 & 25b — Paratype GFCL 967 = BN - 5b, 25a — Paratype GFCL 968 = BN - 5a, ventral views of 2 decorticated specimens. Unit – 5. *Vue ventrale de 2 spécimens décortiqués.*

3 & 4 — Paratypes GFCL 963 = BN - 4b & Paratype GFCL 964 = BN - 4c, posterior view of 2 decorticated specimens showing the short traces of dental plates and dorsal septum. Unit - 4. *Vue postérieure de 2 spécimens décortiqués montrant les traces des courtes lames dentales et celui du court septum dorsal.*

5 — GFCL 969 = ML 313 a4, dorsal view of a large specimen. *Vue dorsale d'un grand specimen.*

6, 7 — Paratypes GFCL 965 = BN - 3b, Unit – 3, fig. 6; GFCL 966 = BN – 2j, Unit – 2, fig. 7. — dorsal view of 2 decorticated large specimens. *Vue dorsale de 2 grands spécimens décortiqués.*

Fig. 8 a-d — *Shumardella* Brice nov. sp. aff. *fracta* Carter, 1988, Gara el Kahla section, "Upper Fauna", Early Tournaisian.

8 a,b,d — GFCL 970 = ML 325 3, ventral, posterior, anterior views of a decorticated specimen. *Vues ventrale, postérieure, antérieure d'un spécimen décortiqué.* 8c — GFCL 971 = ML 325 2, dorsal view of an another specimen. *Vue dorsale d'un autre spécimen*

Figs 9-10 — *Gastrodetoechia* sp.

9 — GFCL 972 = MZ 2, Rharouar section, "Lower Fauna", late Famennian, Souhern Morocco; dorsal view of an incomplete specimen. *Vue dorsale d'un spécimen incomplet.*

10 — GFCL 979 = HH As 260, Assa area, "Lower Fauna", late Famennian, southern Morocco; dorsal view of a decorticated large specimen. *Vue dorsale d'un grand spécimen décortiqué.*

Figs 11-12, 14-16 — *Macropotamorhynchus* Brice nov. sp. aff. *insolitus* Carter, 1987, Gara el Kahla section, "Upper Fauna", Early Tournaisian.

11 a-b — GFCL 973 = ML 325.1,

12 a-b. — GFCL 974 = ML 325.2: ventral, dorsal views of 2 decorticated specimens. *Vues ventrale, dorsale, de 2 spécimens décortiquésé.*

14, 15 — GFCL 975 = ML 325.3, GFCL 976 = ML 308.13, ventral view of 2 decorticated specimens showing the trace of short dental plate. *Vue ventrale de 2 spécimens décortiqués montrant la trace de courtes lames dentales.*

16 — GFCL 977 = ML 308.16, dorsal view of a decorticated specimen showing the trace of the short dorsal septum. *Vue dorsale d'un spécimen décortiqué montrant la trace du court septum.*

Figs 13, 25i —,*Megalopterorhynchus* sp., Kheneg Lakahal section, "Lower Fauna", late Famennian GFCL 978 = BN - 5i, Unit – 5, external cast of a dorsal valve. *Moule externe d'une valve dorsale.*

Figs. 17-18, 20, 24-25c-h — *Centrorhynchus* spp. cf. *lucida* (Veevers, 1959), Kheneg Lakahal section, except 17-18, Rharouar section "Lower Fauna", late Famennian, southern Morocco.

17 — GFCL 980 = MZ 1, ventral view of a large decorticated specimen close to *C. charakhensis. Vue ventrale d'un grand spécimen décortiqué proche de* C. charakhensis.

18 — GFCL 913 = MZ 2, dorsal view of another large incomplete specimen. V*ue dorsale d'un autre grand spécimen incomplet.*

20, 24 — GFCL 981= BN – 1 b3 = fig. 20 = dorsal valve, GFCL 994 = BN – 1 b6 = fig. 24 = ventral valve, Unit – 1, two external mould of small valves. *Deux moules externes de petites valves : dorsale (20) ; ventrale (24).*

25 c-h — GFCL 982 = BN - 5c, ventral valve, *valve ventrale,* GFCL 983 = BN - 5d cast of an incomplete dorsal valve, *moule d'une valve dorsale incomplète.* GFCL 984, 985, 988 = BN - 5e, - 5f, - 5h, casts of three incomplete ventral valves, *moules de 3 valves ventrales incomplètes.* GFCL 986 = BN -5g, an internal mould of dorsal valve. *Un moule interne de valve dorsale.* Unit - 5

Figs 19, 22-23, 26 — *Hemiplethorhynchus* (?) sp. South Tafilalt, Morocco, El Atrous section, upper part Aoufilal Formation, Early Tournaisian (?).

19 — MB.B.2396 = EAZ 16, level 34, a ventral valve, une valve ventrale.

22 — MB.B.2397 = EAX, upper part level 30.

23 — MB.B.2398 = EAY2 , level 28.

26 — MB.B.2399 = AY, level 28, three internal moulds of dorsal valves. *Trois moules internes de valves dorsales.*

Figs. 21 — *Centrorhynchus* (?) sp., South Tafilalt, Morocco, El Atrous section, upper part Aoufilal Formation, MB.B.2395 = EAY.1 level 28, latest Famennian (?). — a mould of ventral valve almost flat with an obsolete sulcus. *Un moule externe de valve ventrale presque plane avec un sinus très peu marqué.*

Fig. 25 j-k — *Cyrtospirifer* sp. 2 aff. *oleanensis* Greiner, 1957, Kheneg Lakahal section, "Lower Fauna", late Famennian, southern Morocco. 25j. — GFCL 4657 = BN – 5 j, internal mould of a ventral valve showing the short extra-sinal traces of the dental plates. *Moulage interne d'une valve ventrale montrant les traces de lames dentales extrasinales.* 25k. — GFCL 4658 = BN – 5 k, cast of an incomplete ventral valve. *Moule d'une valve ventrale incomplète.*

Figs 27-28. — *Schuchertella* sp., Kheneg Lakahal section, southern Morocco, " Upper Fauna ", Tournaisian; Unit + 2. 27 — GFCL 989 = BK + 2.13a, dorsal valve. *Valve dorsale.* 28. — GFCL 990 = BK + 2.13b, internal mould of ventral valve. *Moule interne de valve ventrale.*

Figs 29-31 — *Leptagonia* cf. *analoga* Phillips, 1836. 29 — GFCL 991 = As 31, Assa area, "Lower Fauna", late Famennian, southern Morocco, ventral valve. *Valve ventrale.* 30 — GFCL 992 = As 259, east Hassi Rharouar section, Assa area, "Lower Fauna", late Famennian, southern Morocco, ventral valve. *Valve ventrale.* 31 — GFCL 993 = ML 324, Gara el Kahla section, Timimoun area, "Upper Fauna", Early Tournaisian, Algerian Sahara, internal mould of dorsal valve. *Moule interne de valve dorsale.*

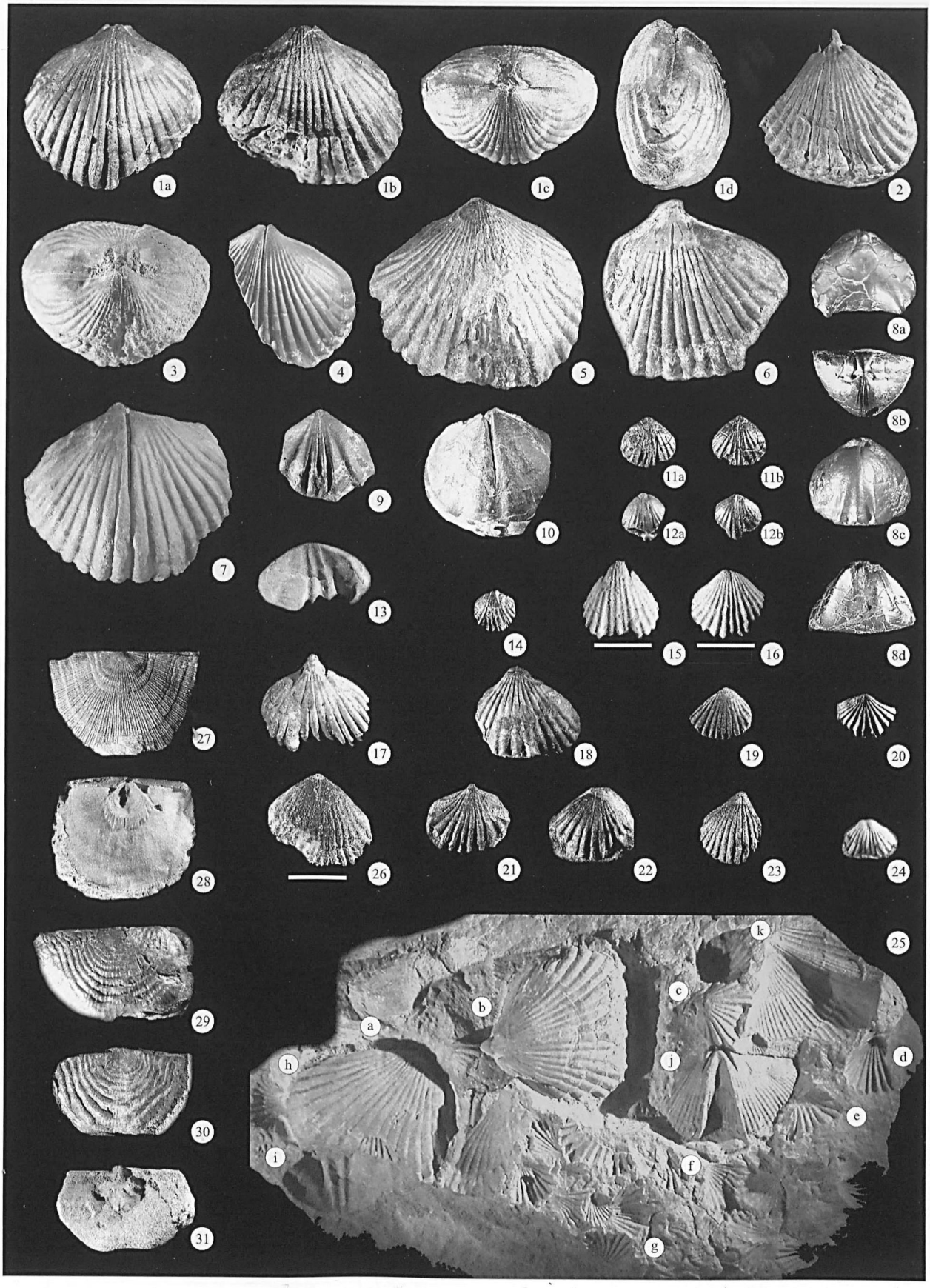


PLATE III

Scale bars = 1 cm

Figs 1, 2. — *Hollardospirifer draensis* Nicollin nov. sp. Aouzergui wadi section, Zemoul area, late Famennian, southern Morocco.

1a-d. — GFCL 4707 = AT 140, dorsal, ventral, posterior and lateral view of a decorticated specimen. *Vues dorsale, ventrale, postérieure et latérale d'un spécimen décortiqué.* 2. — Holotype, GFCL 4686 = i 813, dorsal view. *Vue dorsale.*

Figs 3-5 — *Cyrtospirifer* sp.2 aff. *oleanensis* Greiner, 1957, Kheneg Lakahal section, "Lower Fauna", late Famennian, southern Morocco.

3 — GFCL 4654 = BK - 1.7, unit – 1, internal mould of ventral valve showing muscular scar and short extra-sinal dental plates. *Moule interne d'une valve ventrale montrant l'empreinte musculaire et les lames dentales courtes et extra-sinales.*

4a-b — GFCL 4655 = BN - 3k, unit – 3, ventral and posterior view of a plasticine mould specimen. *Vues ventrale et postérieure du moulage en plasticine d'un spécimen.*

5 — GFCL 4656 = BN – 3m, unit – 3, incomplete internal mould of dorsal valve, *moule interne incomplet d'une valve dorsale.*

Figs 6, 7 — *Cyrtospirifer* sp.1 aff. *leboeufensis* Greiner, 1957, Zemoul area, late Famennian, southern Morocco.

6 — GFCL 4652 = i 881, dorsal view of an incomplete decorticated specimen. *Vue dorsale d'un spécimen décortiqué incomplet.*

7 — GFCL 4653 = Zl 57, ventral view of a decorticated specimen. *Vue ventrale d'un spécimen décortiqué.*

Figs 8-10. — *Cyrtospirifer* sp.3 aff. *warrenensis* Greiner, 1957, Kheneg Lakahal section, "Lower Fauna", late Famennian, southern Morocco.

8 — GFCL 4659 = BN – 3k, unit – 3, ventral view of a plasticine mould specimen. *Vue ventrale du moulage en plasticine d'un spécimen.*

9 — GFCL 4660 = BN – 3k, unit – 3, ventral view of an other plasticine mould specimen. *Vue ventrale du moulage en plasticine d'un autre spécimen.*

10 — GFCL 4661 = BN – 3k, unit – 3, internal mould of a dorsal valve. *Moule interne d'une valve dorsale.*

Figs 11, 12 — *Cyrtospirifer* sp.4, Kheneg Lakahal section, "Lower Fauna", late Famennian, southern Morocco.

11 — GFCL 4709 = BN – 1.12, unit –1, incomplete ventral valve of a decorticated specimen. *Valve ventrale incomplète d'un spécimen décortiqué.*

12 — GFCL 4710 = BN – 1.12, unit –1, incomplete dorsal valve of a decorticated specimen. *Valve dorsale incomplète d'un spécimen décortiqué.*

Figs 13, 14 — *Voiseyella* sp. 2 aff. *sergunkovae* (Bublichenko, 1971), Gara el Kahla section, Timimoun area, "Upper Fauna", Lower Tournaisian, Algerian Sahara. 13. — GFCL 4681 = ML 324, incomplete internal mould of ventral valve. *Moule interne incomplet d'une valve ventrale.* 14. — GFCL 4682 = ML 324, an other internal mould of ventral valve. *Un autre moule interne de valve ventrale.*

Fig. 15 — *Sphenospira* cf. *julii* (Dehée, 1929), Djebel Tazout, Assa area, late Famennian, southern Morocco.

15a-b. — GFCL 4662 = As 260, ventral and posterior view (with high interarea) of a decorticated specimen. *Vues ventrale et postérieure (avec interarea haute) d'un spécimen décortiqué.*

Fig. 16 — ? Imbrexiidae, genus and species indet., East of the confluence of Dra wadi-Akka wadi, Akka area, late Famennian, southern Morocco. GFCL 4685 = Ak 30, ventral view of a decorticated specimen. *Vue ventrale d'un spécimen décortiqué.*

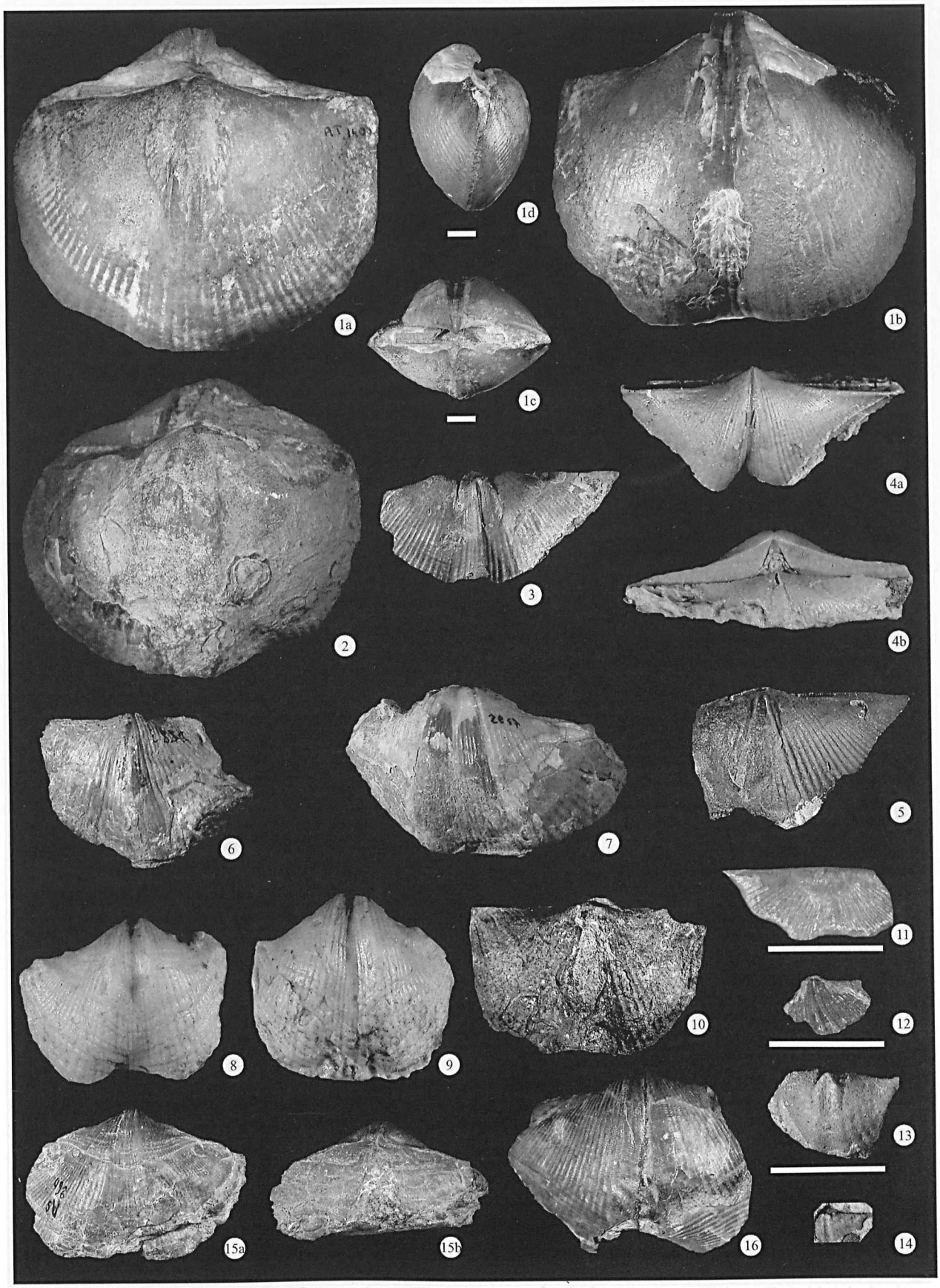


PLATE IV

Scale bars = 5 mm

Figs 1-9 — *Prospira* sp. 1, Gara el Kahla section, Timimoun area, Algerian Sahara, "Upper Fauna", Tournaisian.

1 & 5 — GFCL 2030 = ML 362 c and 5. — GFCL 2034 = ML 309 a1, two dorsal valves. *Deux valves dorsales.*

2 & 9 — GFCL 2031 = ML 309 a2 and a9. — GFCL 2038 = JC 935 a1, two internal moulds of a ventral valves. *Deux moules internes de valves ventrales.*

3, 4, 8 — 3) GFCL 2032 = ML 309 a4; 4) GFCL 2033 = ML 306 a8; 8) GFCL 2037 = ML 309 a3, three incomplete ventral valves. *Trois valves ventrales incomplètes.*

6 — GFCL 2035 = ML 306 a5, a mucronate ventral valve. *Une valve ventrale avec mucrons.*

7 — GFCL 2036 = ML 329, an incomplete internal mould of ventral valve. *Un moule interne de valve ventrale incomplète.*

Figs 10, 13-14 — *Prospira* sp. 2, "Upper Fauna", Tournaisian.

10 a-b — GFCL 2044 = JC 935, Gara el Kahla section, Timimoun area, Algerian Sahara, "Upper Fauna", Tournaisian., ventral and dorsal views of an incomplete specimen. *Vues dorsale et ventrale d'un spécimen incomplet.*

13 a-b, 14 — Zemoul area southern Morocco, "Upper Fauna", Tournaisian, GFCL 2045 = HH Zl 65 W 206 a7, posterior and ventral views of a specimen; 14 — GFCL 2046 = HH Zl 65 W 206 a8, dorsal view of an another specimen. *13 a-b vues postérieure et ventrale d'un spécimen ; 14 vue dorsale d'un autre spécimen.*

Figs 11-12 — *Prospira* aff. *lapparenti* Brice, 1999, Gara el Kahla section, Timimoun area, Algerian Sahara, "Lower Fauna", late Famennian.

11 a-d — GFCL 2039-2042 = ML 322 a-d, a) ventral valve. *Une valve ventrale ;* b-d) dorsal valves. *Des valves dorsales.*

12 — GFCL 2043 = ML 322 a9, dorsal valve. *Valve dorsale.*

Figs 15-17 — *Parallelora* sp. aff. *subsuavis* (Plodowski, 1968), Gara el Kahla section, Timimoun area, Algerian Sahara, "Lower Fauna", late Famennian.

15 — GFCL 2047 = ML 313 q,

16 — GFCL 2048 = ML 313.2 a latex mould of a dorsal valve. *Réplique en latex d'une valve dorsale.*

17 — GFCL 2049 = ML 365 d1, 2 incomplete.ventral valves. *Deux valves ventrales incomplètes.*

Figs 18 a-b — *Parallelopora* (?) sp. Tafilalt BK M'karig section, *Stockumites* bed, "Upper Fauna", Tournaisian, MB.B. , a) ventral view, b) dorsal view of a internal mould showing gonoglyphes, cardinal process, denticulate hinge line and the track of the myophragm. *a) vue ventrale, b) vue dorsale d'un moule interne montrant les empreintes génitales, la ligne cardianle denticulée et la trace du myophragme.*

Figs 19-21 — *Unispirifer unicus* Havlicek, 1984, Gara el Kahla section, Timimoun area, Algerian Sahara, "Upper Fauna", Tournaisian.

19 — GFCL 2050 = ML 329 b3 external mould of a dorsal valve. *Moulage externe d'une valve dorsale.*

20 a-b — GFCL 2051 = ML 306 b2 a ventral valve and its micro-ornamentation. *Une valve ventrale et sa micro-ornementation.*

21 — GFCL 2052 = ML 306 b3 an another ventral valve. *Une autre valve ventrale.*

Figs 22, 24 — *Tylothyris* sp. aff. *T. laminosa* (M'Coy, 1844), Assa area, Kheneg Lakahal section, southern Morocco. "Upper Fauna" Tournaisian.

22 — GFCL 2053 = BN + 2.12 an external mould of a ventral valve. *Moulage externe d'une valve ventrale.*

24 — GFCL 2054 = BK + 2.12 an internal mould of ventral valve showing the track of the ventral septum. *Moule interne d'une valve ventrale montrant la trace du septum ventral.*

Fig. 23 — *Tylothyris* (?) sp. Morocco. — Tafilalt, M'karig section NE of Ouidane Chebbi, " Upper fauna ", MB.B.2394 BK, *Stockumites* bed with *St. intermedius*, an internal mould of a dorsal valve. *Un moulage interne d'une valve dorsale.*

Figs 25-27 — *Cyrtospirifer pseudorigauxia* nov. sp., Assa area (fig.25) and Zemoul area (fig.26, 27), late Famennian, southern Morocco.

25a-b — GFCL 2079 = As 260, ventral and dorsal view of a decorticated specimen. *Vues ventrale et dorsale d'un spécimen décortiqué.*

26a-c. — GFCL 4651 = AT 135, ventral, dorsal and posterior view of an internal mould. *Vues ventrale, dorsale et postérieure d'un moule interne.*

27. — Holotype, GFCL 995. — ventral view. *Vue ventrale.*

Fig. 28 — *Voiseyella* sp. 4, Gara el Kahla section, Timimoun area, "Upper Fauna", Algerian Sahara. GFCL 4683 = ML 354, incomplete internal mould of ventral valve. *Moule interne incomplet d'une valve ventrale.*

Fig.29 — *Voiseyella* sp. A cf. *anterosa* (Campbell, 1957), Kheneg Lakahal section, « Upper Fauna », Lower Tournaisian, southern Morocco. GFCL 914 = BK + 2.12, unit + 2, internal mould of ventral valve. *Moule interne d'une valve ventrale.*

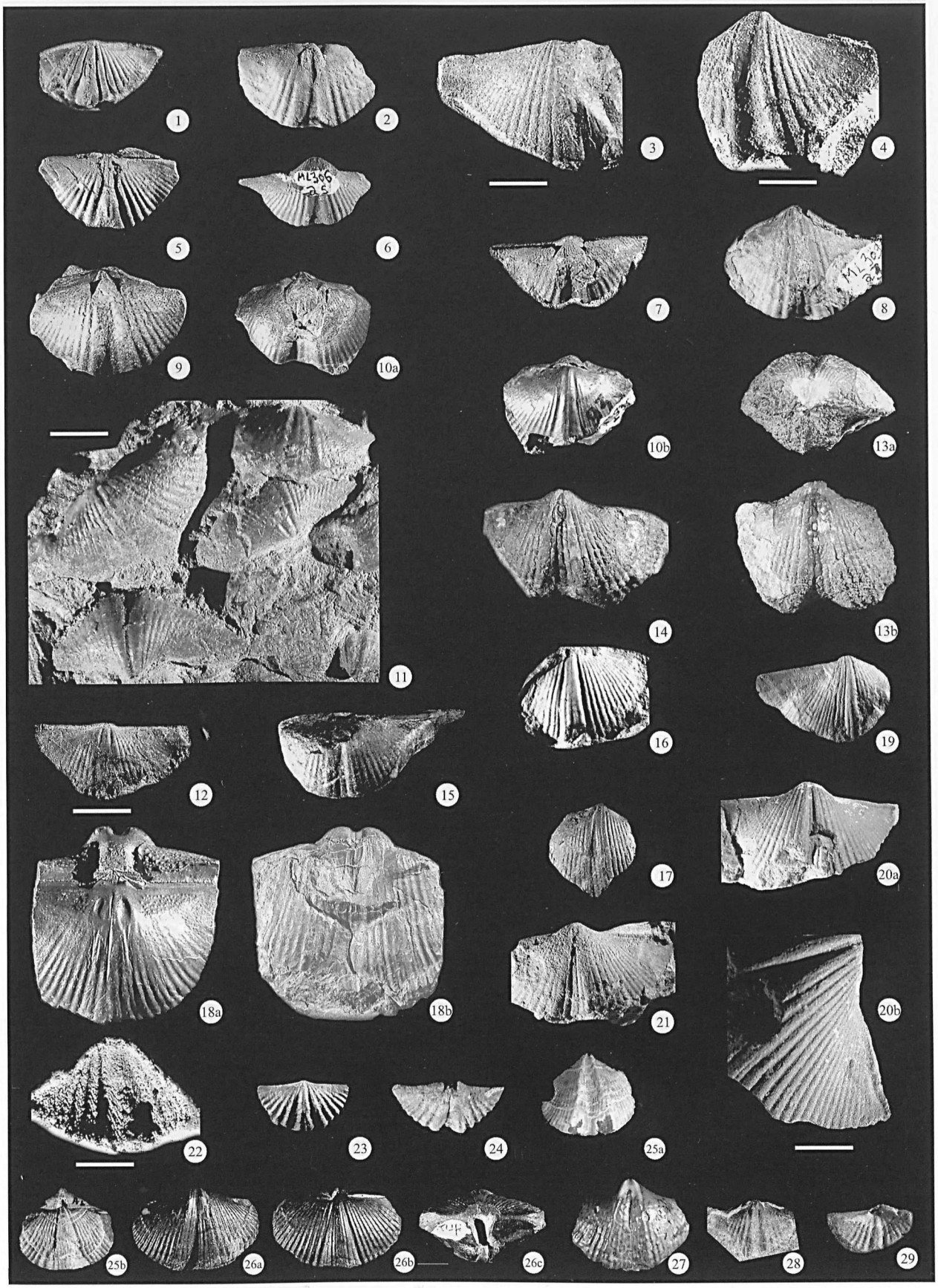


PLATE V

Scale bars = 5 mm

Figs 1-4 — *Eochoristites platycosta* (Havlicek, 1984), Gara el Kahla section, Timimoun area, Algerian Sahara, "Upper Fauna", Tournaisian.

1 — GFCL 2057 = ML 324 a5, an external mould of a ventral valve. *Un moulage externe de valve ventrale.*

2 — GFCL 2058 = ML 324 a6, an incomplete dorsal valve. *Une valve dorsale incomplète.*

3, 4 — 3) GFCL 2059 = ML 387 a2; 4) GFCL 2060 = ML 387 a1, two ventral valves. *Deux valves ventrales.*

Fig 5 — (?) *Eochoristites platycosta* (Havlicek, 1984), Zemoul area, " Upper Fauna ", southern Morocco, GFCL 2061 = HH i 783, an external mould of a ventral valve. *Un moulage externe de valve ventrale.*

Figs 6-21. — *Eomartiniopsis lakahalensis* Brice nov. sp. Gara el Kahla section, Assa area, southern Morocco, " Upper Fauna", Tournaisian.

6 a-b — Holotype GFCL 2062 = BK + 3.1 a12, ventral and posterior views of one ventral valve. *Vues ventrale et postérieure d'une valve ventrale.*

7, 8, 10, 15, 16 — Paratypes, 7) GFCL 2063 = BK + 2.2 a2; 8) GFCL 2064 = BK + 5 a10; 10) GFCL 2066 = BN + 2.15; 15) GFCL 2071 = BK + 3.1 a15; 16) GFCL 2072 = BK +3.1 a2, five other ventral valves. *Cinq autres valves ventrales.* 9 — Paratype GFCL 2065 = BK + 3.1 a13, transversal section of one ventral valve showing the dental plates. *Section transversale d'une valve ventrale montrant les lames dentales.*

11, 19, 21 — Paratypes, 11) GFCL 2067 = BK + 3.1; 19) GFCL 2075 = BK + 2.2 a7; 21) GFCL 2077 = + 5.a1, three decorticated ventral valves showing the muscular field. *Trois valves ventrales décortiquées montrant le champ musculaire.*

12 — Paratype GFCL 2068 = BN + 2.15 a6, internal palleal markings on a ventral valve. *Traces palléales internes sur une valve ventrale.*

13, 18, 20 — Paratypes, 13) GFCL 2069 = BN + 2.12 a17; 18) GFCL 2074 = BK + 2.2 b1; 20) GFCL 2076 = BK + 2.2 a14, three dorsal valves. *Trois valves dorsales.*

14 — Paratype GFCL 2070 = BN + 2.12 a23 a ventral valve wider than other specimens. *Une valve ventrale d'un spécimen plus large que les autres spécimens.*

17 a-b — Paratype GFCL 2073 = BK + 2.2 a4, ventral and lateral views of a joung specimen. *Vues ventrale et latérale d'un spécimen juvénile.*

Fig 23 a-d — *Syringothyris* cf. *uralensis* Nalivkin, 1975, Bou Tlidat, Ma'der, Morocco, " *Stockumites* bed ", Tournaisian. MB.B2401. Internal mould of a complete specimen, posterior view, b) anterior view, d) delthyrial area, details of the posterior part of syrinx, cardinal process. *Moule interne d'un spécimen complet, a) vue postérieure, b) vue antérieure, c) vue dorsale, d) région delthyriale, détail de la partie postérieure du syrinx, processus cardinal.*

Fig. 24 — *Voiseyella* (?) sp.3 aff. *tylothyriformis* (Krestovnikov & Karpychev, 1948), Gara el Kahla section, Timimoun area, "Upper Fauna", Algerian Sahara.

24 a-b — GFCL 4684 = ML 330, ventral and dorsal view of a decorticated specimen. *Vues ventrale et dorsale d'un spécimen décortiqué.*

Figs 25, 26 — *Voiseyella* sp. A aff. *anterosa* (Campbell, 1957), Kheneg Lakahal section, "Upper Fauna", Lower Tournaisian, southern Morocco.

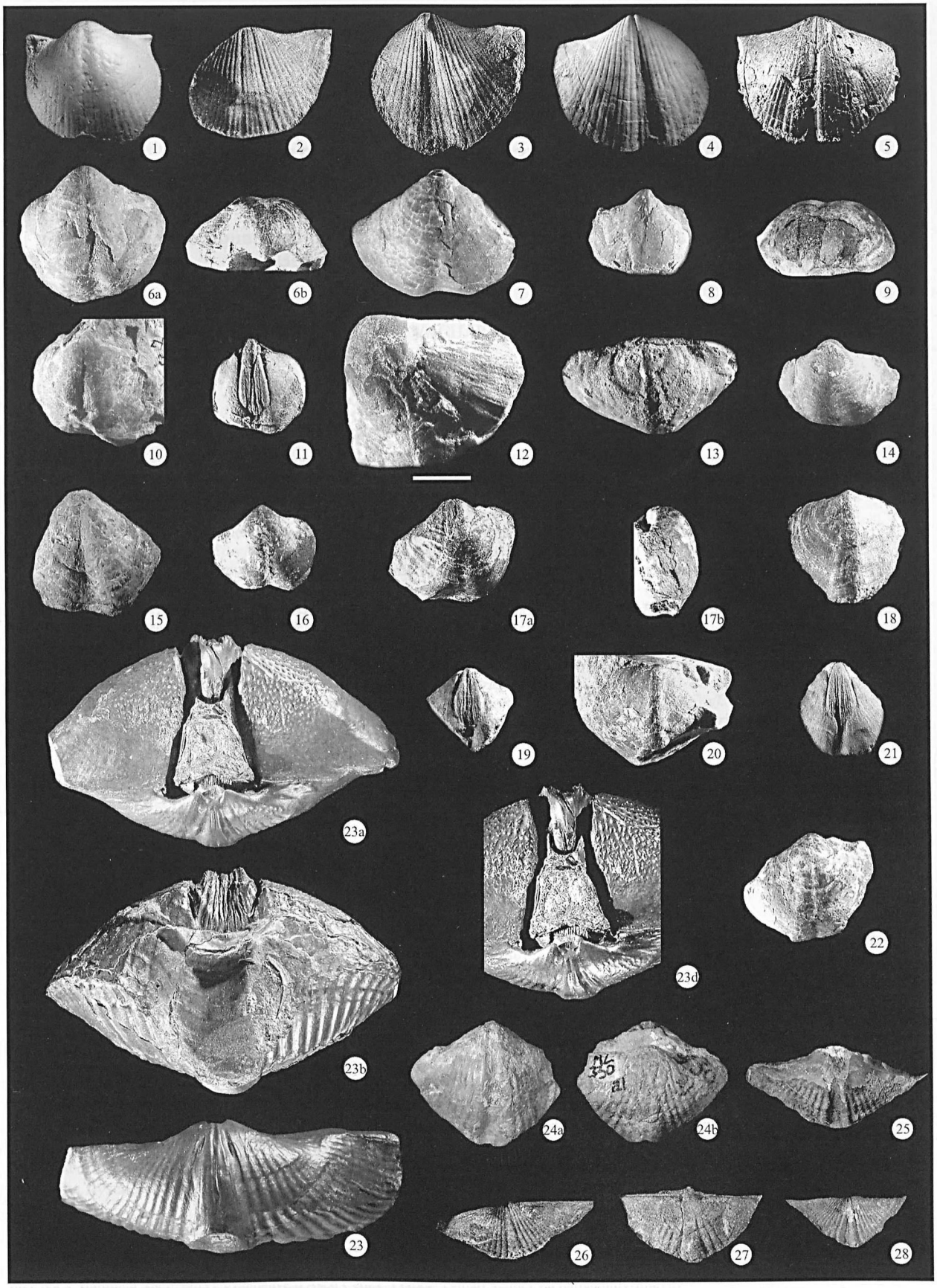
25 — GFCL 4673 = BN + 2.11, unit + 2, internal mould of a ventral valve. *Moule interne d'une valve ventrale.*

26 — GFCL 4674 = BN + 2.11, unit + 2, internal mould of a dorsal valve. *Moule interne d'une valve dorsale.*

Figs 27, 28 — *Voiseyella* sp. B aff. *novqmexicana* (Miller, 1881), Kheneg Lakahal section, "Intermediate Fauna", latest Famennian, southern Morocco.

27 — GFCL 4675 = BN + 0.9, unit + 0, internal mould of a dorsal valve. *Moule interne d'une valve dorsale.*

28 — GFCL 4680 = BN + 0.9, unit + 0, internal mould of a ventral valve. *Moule interne d'une valve ventrale.*



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FORAMINIFERS AND ALGAE FROM THE REWORKED LATE VISÉAN LIMESTONES OF THE BELLVER FORMATION, EASTERN PYRENEES, SPAIN

Foraminifères et algues des calcaires du Viséen supérieur, remaniés dans la Formation de Bellver, Pyrénées orientales espagnoles

by Javier SANZ-LOPEZ (*), Daniel VACHARD (**), and Marie-France PERRET (***)

(Plates VI to VIII)

Abstract. — The Bellver Formation (Carboniferous Culm facies of the Cadí nappe, eastern Pyrenees, Catalonia, Spain) contains conglomerate palaeochannels and turbidite beds with carbonate clasts. Some of the carbonate blocks are exotic, derived principally from late Viséan rocks in the immediate substrate; they especially relate to late Asbian/early Brigantian deposits. Older Viséan and Middle Devonian microfossils have also been reworked. The probable provenance of the shallow-marine carbonates is discussed. The associations of algae studied are diverse, especially the metaspondyl and vestibuled dasyclad *Eovelebitella* aff. *occitanica*. The associations are characteristic of a palaeogeographic area that includes the French Montagne Noire, eastern Spanish Pyrenees, eastern French Pyrenees and Spanish Betic Cordillera.

Résumé. — *La Formation de Bellver (faciès Culm du Carbonifère de la Nappe de Cadí dans les Pyrénées orientales de Catalogne en Espagne) referme des paléochenaux conglomératiques et des niveaux turbiditiques à éléments carbonatés. Certains de ces éléments calcaires sont exotiques et proviennent du substrat immédiat d'âge viséen (Asbien supérieur-Brigantien inférieur). Des remaniements de microfossiles datés d'un Viséen plus ancien et du Dévonien moyen sont également observés. La provenance probable de ces calcaires d'eaux peu profondes est discutée. Les algues sont diversifiées, avec notamment la dasycladale métaspondyle et vestibulaire Eovelebitella aff. occitanica. L'unité paléogéographique catalane est comparée avec le Sud de la France (Montagne Noire, Pyrénées orientales) et le Sud de l'Espagne (Cordillères Bétiques).*

I. — INTRODUCTION

The Early Carboniferous (Mississippian) series of the Pyrenees and Montagne Noire are characterised by Tournaisian and Viséan hemipelagic carbonates and cherts, overlain by Viséan to Moscovian siliciclastic rocks, often called the Culm facies deposits. The Culm facies of the Pyrenees has been interpreted as constituting synorogenic flysch sediments (Delvolvé *et al.*, 1993) and its age varies along the mountain range. The variation in the age of the sediments has been explained as consistent with the model of migration of the Variscan deformation, indicating a migration of the flysch facies landwards, towards the south-west.

The age of the flysch has been variously estimated from the scarce fossil content, or frequently inferred from the age of the limestone lying beneath it. Alternatively, the benthic fauna from reworked platform limestone clasts and olistolites found inside the flysch deposits have given an indication of its age. These clasts are derived from the erosion of carbonate platforms built on the opposite margin of the tectonically active basin (Delvolvé and Souquet, 1994), or from the upper parts of allochthonous units at the active margins (Delvolvé *et al.*, 1998).

Perret and Delvolvé (1988) and Delvolvé *et al.* (1993, 1998) reported the different ages of the reworked limestone as ranging from Viséan V3b to early V3c in the Montagne Noire (Vachard, 1974a, 1978); late Viséan to the Viséan/Serpukhovian boundary in the Mouthoumet; latest Viséan to late Serpukhovian in the Haut Pays de Sault and the Arize Massif of the Pyrenees (fig. 1A); Serpukhovian in the Aure Valley; Bashkirian in the Ossau and Aspe valleys; and Moscovian in the Cinco Villas Massif. However, studies of these carbonates are still necessary because there are some discrepancies in the data, including the Serpukhovian age of limestone olistolites from the Montagne Noire and Mouthoumet Massif, as determined by Poty *et al.* (2002).

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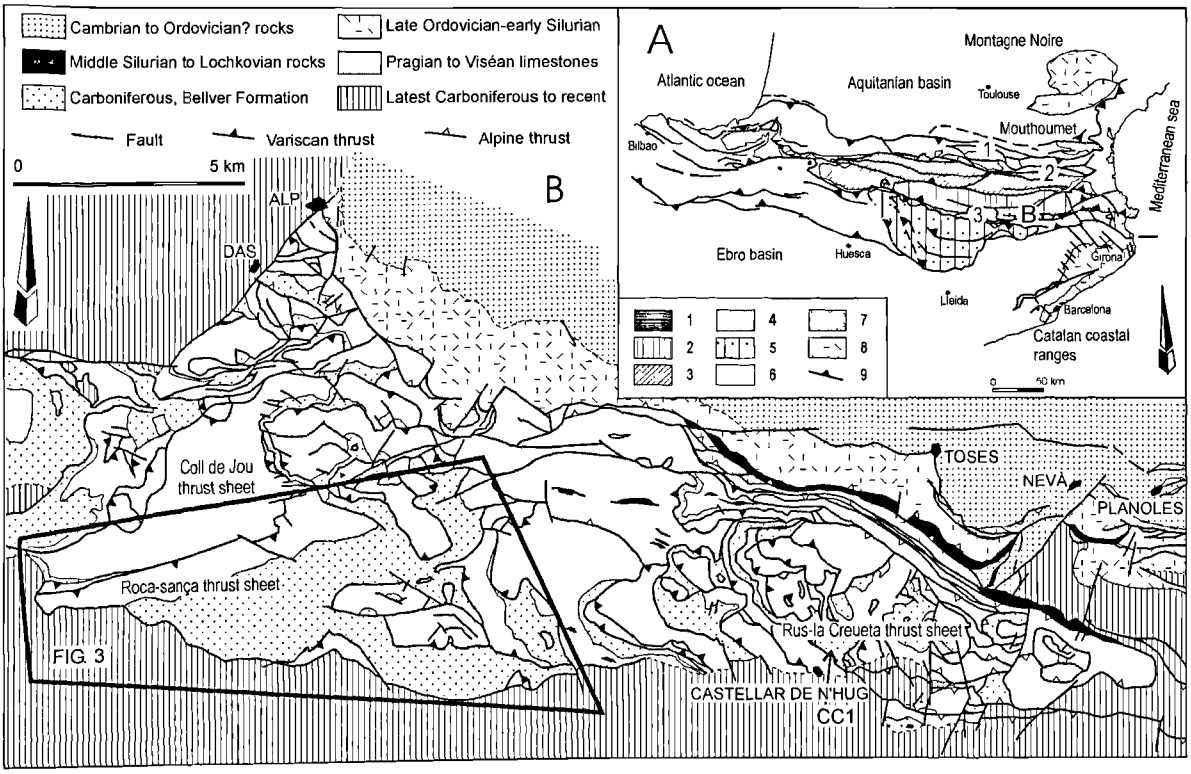

Fig. 1A. — Sketch map of the Pyrenees with the locations of the study area (B) and other sites referred to in the text. Legend: 1-4, Palaeozoic rocks of the Axial Zone included in the thrust sheets of Rialp: 1, Benasque-Orri: 2, Gavarnie and probable eastward continuation: 3, Les Nogueres and Cadí: 4; 5, post-Variscan rocks in the Cover upper thrust sheets; 6 post-Variscan rocks in the Lower thrust sheets and North Pyrenean Zone; 7, Palaeozoic rocks of the North Pyrenean and Basque massifs; 8, Palaeozoic rocks from adjacent Montagne Noire and Catalan coastal ranges; 9, Alpine thrust faults. Numbered Pyrenean areas are the Arize Massif (1), the Haut Pays de Sault (2) and the Les Nogueres thrust sheets (3). 1B. – Detailed map of the central part of the Cadí nappe, modified from Vergés *et al.* (1994). Variscan thrust sheets, the location of sample CC1 in the Rus-la Creueta thrust sheet, and the area shown in Fig. 3 are indicated.

Fig. 1A. — Carte géologique schématique des Pyrénées. Localisation des régions étudiées et de celles citées dans le texte. Légende: 1-4, terrains paléozoïques de la Zone Axiale, inclus dans les nappes de charriage de Rialp: 1, Benasque-Orri: 2, Gavarnie et son extension orientale probable: 3, les Noguères et Cadí: 4; 5, terrains postvarisques des nappes supérieures de couverture; 6, terrains postvarisques des nappes inférieures et de la Zone Nord-pyrénéenne; 7, terrains paléozoïques des massifs Basques et Nord-pyrénéens; 8, terrains paléozoïques de la Montagne Noire et de la zone côtière Catalane; 9, chevauchements alpins. Les zones pyrénéennes numérotées sont: le Massif de l'Arize (1), le Haut Pays de Sault (2) et l'unité des Noguères (3). 1B. – Carte géologique détaillée de la partie centrale de la nappe de Cadí (modifiée de Vergés et al. 1994) où sont indiqués le nom de quelques nappes varisques, la localisation de l'échantillon CC1 dans la nappe de Rus-la Creueta ainsi que la zone détaillée sur la figure 3.

An information gap exists regarding the Culm facies and reworked platform limestones in the eastern Spanish Pyrenees. Delvolvé *et al.* (1998) studied two diachronous turbiditic wedges, and dated them from reworked platform limestone in the French Haut Pays de Sault (fig. 1A). They were interpreted as late Viséan and late Serpukhovian in age, respectively. Perret (1993) identified late Viséan algae and foraminifers from the Castellàs breccia on the Freixe thrust sheet of the Spanish Les Nogueres area. Reworked platform limestone from the Alp-Castellar de n'Hug area (Cadí nappe) contributes to the characterisation of the Culm facies of the eastern Spanish Pyrenees.

II. — GEOLOGICAL FRAMEWORK

The Cadí nappe corresponds to the uppermost Alpine thrust sheet of the Freser antiformal stack of Muñoz (1985), and is located between the Rocabruna and Prats d'Aguiló sites in the south-eastern Pyrenees (fig. 1). Silurian–Mississippian rocks lie beneath the Stephanian–Permian to Garumnian unconformity along the nappe. The pre-Stephanian rocks show the development of Variscan folding and thrusting and resulting in the differentiation of Variscan thrust sheets (fig. 1B). The reworked Carboniferous carbonate blocks from within the Roca-sança (Domingo, 1985) and Rus-la Creueta thrust sheets (Llac, 1979) have been studied. The latter sheet is located on the upper part of the Variscan stack of units on the Alp Massif described by Domingo (1985) and Domingo *et al.* (1988), whereas the Roca-sança thrust sheet is situated on the lower part.

The Carboniferous Culm facies of the Cadí nappe of Muñoz (1985), the Segre tectonic unit and the Upper Nogueres thrust sheets (south-eastern Pyrenees) were designated the Bellver Formation by Brower (in Hartelvelt, 1970, and Boersma, 1973). This siliciclastic unit overlies late

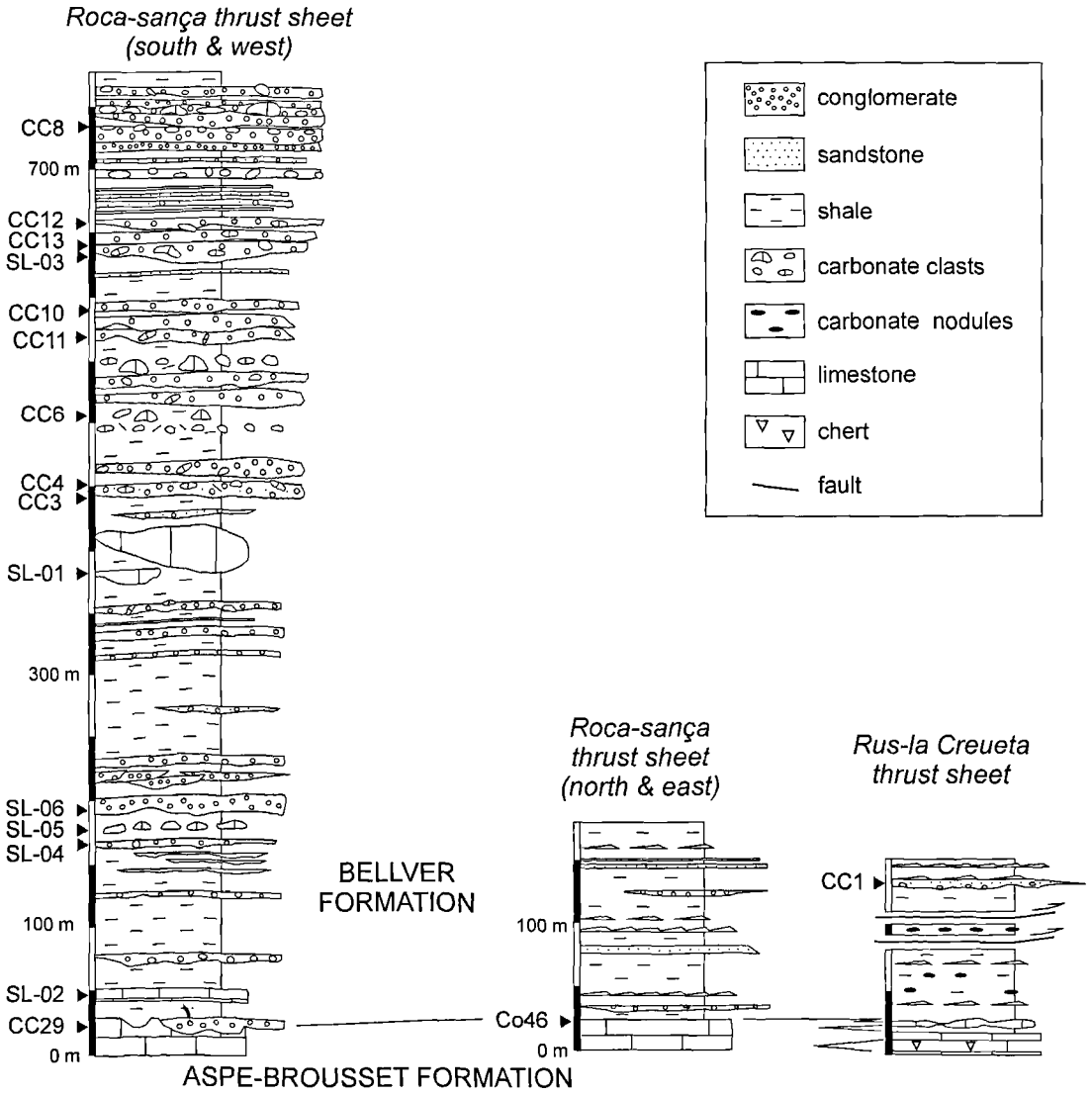

Fig. 2. — Composite stratigraphic sections of the south and west, north and east parts of the Roca-sança thrust sheet, and the Rus-la Creueta thrust sheet from the Bellver Formation and the locations of samples studied in this work.

Fig. 2. — Coupes stratigraphiques schématiques de la Formation de Bellver dans les secteurs sud et ouest, puis nord et est, de la nappe de Roca-sança et dans la nappe de Rus-la Creueta. Les échantillons étudiés y sont localisés.

Viséan limestone of the Aspe-Brousset Fm. (Boersma, 1973; Perret, 1993; Sanz-López, 1995, 2002). Llac (1989) assigned the Bellver Fm. in the Cadí nappe to the Viséan. He obtained several samples of plant remains (*Archaeocalamites* sp. and *Sphenopteridium speciosum*) from along the Fou de Bor track (Coll de Jou thrust sheet).

III. — LITHOSTRATIGRAPHIC SUCCESSIONS

The boundary between the Bellver and Aspe-Brousset formations is gradational in the Rus-la Creueta thrust sheet. Cherty shale lies both above and lateral to the chert and limestone of the Aspe-Brousset Fm. in many outcrops on the Rus-la Creueta unit (Tossal de Rus, Creueta de Castellar; fig. 2). The cherty shale is green or red, containing the remains of crinoids and bivalves, with limestone nodules. This is overlain by 10–12 m of shale that begins with inter-layered millimetre-thick beds of siltstone and fine-grained sandstone with ripple trains and convoluted laminations. This shale and sandstone sequence represents a deep-water turbiditic facies that shows pervasive bioturbation in the form of abundant *Dyctiodora* trails.

On the Erola de Castellar, the Bellver Fm. is thrust over the Aspe-Brousset Fm., and some tectonic slices may be recognized where shale with beds of carbonate nodules is repeated (fig. 2). The shale in one of the upper slices contains a one-metre-thick bed with an erosive base and grains fining upwards. The first centimetres contain a minor quantity of carbonate cement with prevailing millimetre clasts of limestone and less abundant shale, quartz and chert. The coarser grains in the lower part of the bed are succeeded by sandstone and pebbly sandstone with horizontal laminations, fine-grained sandstone to siltstone with convoluted

laminations of climbing ripples, and finally shale. The limestone clasts (sample CC1, figs. 1B and 2) contain ooids, intraclasts, coated grains, crinoids, bryozoans, brachiopods, foraminifers and algae.

In the lower thrust sheets of the Alp stack, the Bellver Fm. lies upon an erosive unconformity over Devonian to Carboniferous limestone (Sanz-López, 1995). Domingo *et al.* (1988) interpreted the base of the Bellver Fm. as an unconformity, which is particularly clear in the Roca-sança thrust sheet (fig. 3). The irregular surface has 5 m of relief features. A palaeokarst development is recognizable and this is associated with carbonate breccias. The erosion plane truncates older rocks to the south of the thrust sheet.

The distribution and facies characteristics of the Bellver Fm. change along the length of the Roca-sança thrust sheet (fig. 3). In the north and east (fig. 2), it comprises about 150 m of shale with thin, fining upward beds of fine-grained sandstone with climbing ripples of regular ridges. The sand grains are quartz, feldspar and chert. There are some infrequent beds 20–100 cm thick. They are structureless, fining-upward sandstone with clay clasts, plant remains and rare bivalves. Pillar and dish structures reflect de-watering. Some local conglomerate beds have a short lateral dimension. They contain clasts measuring a few centimetres in diameter and a sandy matrix. Rarely, the conglomerate is matrix-supported and corresponds to debris-flows, whereas others beds are mud-flows. Shale can include sandstone or siltstone nodules less than 1 cm in diameter, plant remains, and burrows of *Dyctiodora*.

A section one kilometre thick in the Bellver Fm. is preserved west and south of the Roca-sança thrust sheet (figs. 2 and 3) in the inverse limb of the Gréixer anticline. The succession can be discerned, although the thickness can only be approximately estimated because the outcrop is discontinuous and the beds are folded and faulted. The base of the unit is erosive with buried, small faults and carbonate breccias or rare pebbly sandstone palaeochannels filling the cavities. Lying above is burrowed shale and fine-grained sandstone that includes some micro-conglomerates, debris-flows deposits and coarse-grained sandstones. Carbonate breccias contain clasts of nodular limestone similar to that located below the Bellver Fm. A stratified block of nodular limestone with foraminifers and corals (sample SL-02) was also observed. It is 12 m thick and lies near the base of the formation. The thickness of the lower part of the Bellver Fm. is estimated to be between 140 and 200 m. Conglomerate palaeochannels, together with debris-flow deposits, are frequently seen in the upper 60 m in the Gréixer ravine. The multi-storey filling of palaeochannels are 5–8 m thick. They fine upwards and have rare cross-laminations of migrating sand bars with southward foresets. The clasts consist of quartz, chert, granitoid, gneiss and metamorphic rock fragments, Cambro–Ordovician volcanic rocks, shale, sandstone and limestone. Some carbonate clasts in the Gréixer ravine have originated from a near-shore facies and they contain corals and oolites (samples SL-04, SL-05 and SL-06). The stratigraphic intervals of shale and sandstone within the channel fills show thinning-upward cycles.

The succession (fig. 2) continues as an 80 m thick shaley unit. This is followed by 250–500 m containing palaeochannels 10–15 m thick between other fine-grained facies occurring below the overlying thrust sheets. The basal part contains abundant mass flows and some hectometric to decametric carbonate olistolites. Blocks correspond to packstone with brachiopods, corals and crinoids, and to carbonate breccias with quartz grains (sample SL-01). The channel bodies represent recurrent infill composed of sets several metres thick with units of differing grain size, shale beds, and occasional cross stratification. The deposits vary from clast- to matrix-supported. The conglomerate beds may have been reworked in the uppermost few centimetres, and are succeeded by coarse-grained sandstones. In one of these upper sections, small channels are filled by fine sandstone with ripple structures directed southward. Horizons of limestone, sandstone or shale blocks are frequently found towards the tops of the channels.

Sections where shale with centimetric to millimetric beds of fine- to medium-grained sandstone are interspersed between the intervals containing abundant palaeochannels. These interchannel units contain beds 20–40 cm thick, with more variable grain sorting, as well as minor channels of microconglomerates and conglomerates.

Flute-type sole marks, linguoid ripples and bioturbation (most visible in the shale beds) can be seen. The few measured palaeocurrents indicate directions to the south or south-west. The beds are arranged in metric to decametric sequences, thinning upwards. Those that thicken upwards are very rare. Debris or mud-flow beds up to 3 m thick are either rare or, conversely, predominant as sequences 50–100 m thick. Reworked blocks of limestone, in these beds, may have diameters of 20–40 cm, whereas intraformational blocks are as large as one metre.

The limestone clasts are of variable sizes and lithologies. These can be nodular cephalopod limestones, similar to those described in the Famennian to Viséan formations (Sanz-López, 1995), or nearshore facies limestone clasts. The latter group is composed of mudstone to grainstone with intraclasts, ooids, coated grains, pellets, oncolites and bioclasts (bryozoa, crinoids, algae, foraminifers, productid brachiopods, gastropods and bivalves). Some clasts are carbonate breccias with centimetre clasts of quartz and sandstone. Limestone clasts can include pyrite. Other carbonate blocks show dissolution of the outer surface and retain only incipient cementation, or they may exhibit dolomitization and contain ferruginous oxides.

IV. — LOCATIONS OF SAMPLES

IVa. — **In the Rus-La Creueta thrust sheet** (figs.1B and 2):

CC1 locality. - Several slides with carbonate clasts from the megaturbidite at the Erola de Castellar de n'Hug.

IVb. — **In the Roca-sança thrust sheet** (figs. 2 and 3):

CC3 and CC4. - Clasts collected from several conglomerate palaeochannels on the road to the Coll del Pal, Devesa del Paller.

CC6. - A limestone clast collected from a debris-flow deposit at the Font Canaleta.

CC8, CC10, and CC11. - Limestone clasts included in palaeochannels on the road to the Coll del Pal, to the south of the La Collada de la Bofia.

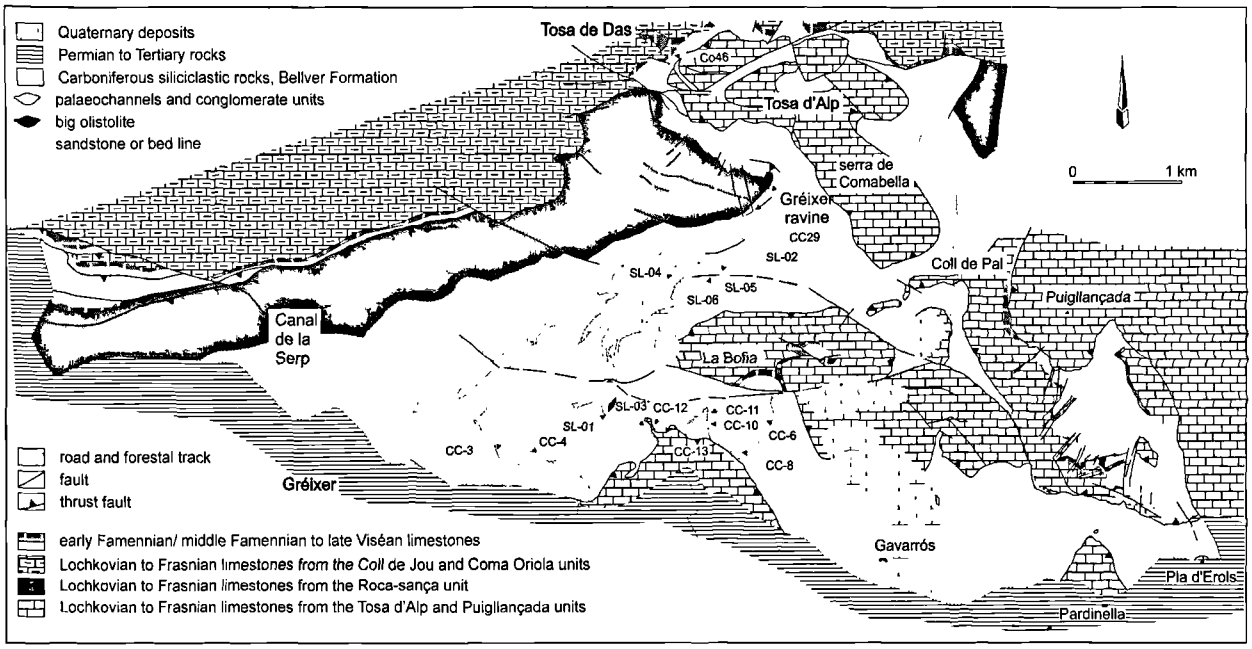

Fig. 3. — Geological sketch of the Roca-sança thrust sheet with sedimentary details from the Bellver Formation and the locations of the samples studied in this work. Devonian outcrops from Vergés *et al.* (1994).

Fig. 3. — Carte géologique de la nappe de charriage de Roca-sança avec les détails sédimentologiques de la Formation de Bellver et la localisation des échantillons étudiés dans ce travail. Le dessin des affleurements dévoniens est de Vergés et al. (1994).

CC12, CC13, and SL-03. - Limestone clasts collected in paleochannels on the road to the Coll del Pal, Trufa de Gel-Collet Roig area.

SL-01. - Blocks of limestone, packstone with bioclasts and quartz grains collected in the extension of a hectometric carbonate olistostrome, at the Mirador del President locality.

SL-02. - Bedded limestone up 12 m thick, consisting of wackestone to packstone containing crinoids and corals. This occurs near the base of the Bellver Fm. in the Gréixer anticline, immediately above the first 1.5-6 m of shale of the formation; the limestone is interpreted as an olistolite.

SL-04 and SL-06. - Breccia blocks composed of millimetric limestone clasts (packstone to grainstone), quartz grains and sandstone. These samples were collected from palaeochannels exposed in the Gréixer ravine.

SL-05. - A limestone clast from a boundstone containing corals that was collected in a debris-flow matrix-supported conglomerate exposed on the track between the Coll del Pal road and the Gréixer ravine.

V. — ASSEMBLAGES OF MICROFACIES AND MICROFOSSILS

The investigated material is represented by four groups of microfacies.

1. Coarse gravity flow (sand flow, sample CC1). Calcareous sandstones or very sandy rudstones, with numerous oolites, coated grains, intraclasts and bioclasts (crinoids, palechinid radioles, tests and spines of brachiopods, foraminifers and algae).

2. Olistolite consisting of algal grainstone, bioclastic packstone, and intraclastic and bioclastic grainstone of shallow subtidal environments, often with evidence of diagenetic dolomite seen as isolated rhombohedrons (samples CC3, CC4, CC11, CC12, CC13, SL-06, and SL-01). The organic content consists of crinoids, brachiopods (mainly Productoidea), gastropods, palechinid radioles, rare corals (*Hexaphyllia*), rare bivalves, algae and foraminifers.

3. Microbialites of Spongiostromata and *Praethocoprolithus* (samples CC6, CC8, CC12, SL-02, and SL-03). The texture is generally clotted to micritic. Metazoa (bryozoans, crinoids, sponges) and foraminifers are rare. Only *Eotuberitina reitlingerae* Miklukho-Maklay and *Diplosphaerina inaequalis* (Derville) are found frequently.

4. Other microfacies. Sample CC10 is a completely neosparitized bioclastic micropackstone, and may correspond to a gravity deposit.

The assemblages of microfossils are summarized in Table 1 (foraminifers) and Table 2 (algae, pseudo-algae and metazoa often mistaken for algae in the literature: *Praethocoprolithus*, *Spirorbis* occasionally confused with *Asphaltina*, and the basal part portions of sponges confused with *Mitcheldeania*).

The tables reveal the biodiversity of algae and the presence of three types of foraminifers: (a) a Devonian *Uralinella*, (b) a form similar to *Rectodiscus*, and (c) a large number of organisms that are late Viséan in age.

SAMPLES OF THE CERDANYA	CC1	CC3	CC4	CC5	CC6	CC8	CC10	CC11a	CC11b	CC12	CC13	SL-01	SL-02	SL-03	SL-04	SL-05	SL-06
Archaediscus karreri	x				x						x						
A. ex gr. *chernoussovensis*	x																
A. ex gr. *stilus*	x														x		
Asteroarchaediscus ex gr. *parvus*			x				x										
Climacammina sp.							x										
Diplosphaerina inaequalis	x		x		x		x	x	x	x	x		x	x	x	x	x
Earlandia elegans	x										x			x	x		
E. vulgaris	x										x						
Endostaffella delicata	x																
Endothyra apposita	x										x						
E. ex gr. *bowmani*	x																
E. ex gr. *donbassica*								x									
E. ex gr. *prisca*	x								x	x							
E. ex gr. *similis*	x		x														
E. sp.	x											x			x		
Eostaffella proikensis	x									x	x						
Eostaffellina sp.								x									
Eotuberitina reitlingerae	x		x	x	x	x			x								
Globivalvulina sp. ?											x				x		
Globoendothyra aff. *parva*											x						
Haplophragmina sp.			x														
Howchinia gibba	x										x						
Koskinobigenerina sp.	x		x														
Koskinotextularia sp.											x						
Lituotubella magna	x																
Mediocris mediocris	x																
Nodosarchaediscus sp.											x						
Omphalotis minima	x																
Palaeotextularia ex gr. *longiseptata*	x																
Parathurammina sp.													x				
Parathurammina suleimanovi	x																
Polysphaerinella bulla	x							x		x		x				x	
Pseudoammodiscus sp.	x																
Pseudoendothyra spp.	x	x	x								x						
Pseudotaxis brazhnikovae							x										
Radiosphaera basilica												x					
Rectodiscus ? sp.	x																
Tetrataxis compacta											x						
T. ex. gr. *angusta*	x																
T. ex gr. *paraminima*	x		x							x	x		x				
Uralinella cf. *augusta*	x																
Vissarionovella ? sp.	x																

Table I. — List of the foraminifers contained in the reworked limestone clasts of the Bellver Formation.

Tabl. I. — Liste des foraminifères contenus dans les clastes carbonatés remaniés dans la Formation de Bellver.

VI — BIOSTRATIGRAPHY

The upper limestones of the Aspe-Brousset Fm. in the Gréixer ravine yielded (sample CC29, figs. 2 and 3) *Gnathodus bilineatus* (Roundy), *Lochriea commutata* (Branson and Mehl), *Lochriea nodosa* (Bischoff), *Pseudognathodus homopunctatus* (Ziegler) and *Vogelgnathus campbelli* (Rexroad). These conodont species are assigned to the *Lochriea nodosa* Zone of the English Brigantian Stage (late Viséan). A neighbouring section yielded a sample (Sanz-López, 2002; sample Co46, fig. 2) with *Lochriea multinodosa* (Wirth), and faunas of the *L. nodosa* Zone are found at the top of the limestone in other thrust sheets where the erosive character of the Bellver Fm. is not demonstrable. *Lochriea multinodosa* is a taxon referred to the late Brigantian (latest Viséan) from the Cantabrian Mountains and Pyrenees, close to the Serpukhovian basal boundary.

The resedimented foraminifers and algae are attributed to the late Viséan. According to the stratigraphical distribution of the genera *Asteroarchaediscus*, *Endostaffella*, *Globoendothyra*, *Howchinia*, *Koninckopora*, *Koskinobigenerina*, and *Lituotubella*, and because of the absence of *Calcifolium*, *Coelosporella* and *Loeblichia*, the age of the reworked limestones is late Asbian to early Brigantian (i.e., upper "V3bγ" to lower "V3c") (Gallagher, 1996, 1998; Gallagher and Somerville, 1997; Cózar, 1996, 2003; Cózar and Somerville, 2004).

The correlation between the Viséan in Britain and in Belgium poses problems. The *L. nodosa* Zone is usually correlated with the Belgium "V3c" division, but Groessens (1976) and Conil *et al.* (1991) noted the appearance of the index fossil *L. nodosa* in the Anhée Limestone (in Belgium this is the *bilineatus* conodont Zone) from the base of the "V3bγ" unit. Consequently, this unit could be equivalent to

SAMPLES OF THE CERDANYA	CC1	CC3	CC4	CC5	CC6	CC8	CC10	CC11a	CC11b	CC12	CC13	SL-01	SL-02	SL-03	SL-04	SL-05	SL-06
Anatolipora sp.			?								?						
Aphralysia sp.	?														X		X
Cabrieropora ? n. sp.			X								X						
Claracrusta sp.				X													
Dasyclad indet.												X					
Eovelebitella aff. *occitanica*			X								X						
Epistacheoides sp.	X		X						X		X						
Fasciella sp.	X		X						X	X		X			X		
Fourstonella sp.	X										X						
Girvanella ducii	X	X	X		X			X	X	X	X	X	X		X	X	X
Koninckopora tenuiramosa	X																
Koninckopora inflata	X																
K. mortelmansi	X																
Mitcheldeania nicholsoni	X				X	X				?						X	
Moravammina cf. *segmentata*	X																
Nostocites sp.											X						
Ortonella sp.	X										X			X			
Oncolite												X	X	X			
Paleoberesella sp.	X																
Praedonezella ? sp.				X					X								
Praethocoprolithus sp.				X	X	X		X		X			X	X	X		
Pseudosolenopora owodenkoi			X														
Root of sponge						X											
Solenopora sp.			X								?					X	
Spirorbis sp.						X		X									
Spongiostromata					X	X				X		X					
Stacheia sp.											X						
Ungdarella sp.	X								X		X						
Wetheredella sp.			X								X						
Windsoporella ? sp.											X						

Table II. — List of algae and other microfossils often confused with algae in the reworked microfacies of the Bellver Formation.

Tabl. II. — Liste des algues et autres microfossiles parfois confondus avec elles. Microfaciès remaniés dans la Formation de Bellver.

the English middle-late Brigantian. Another possibility is that the appearances of *L. nodosa* in the different basins are diachronous.

None studied single microfossil is really characteristic of the Serpukhovian. For instance, the encountered specimens of *Globivalvulina* (= *Biseriella* auct.) and *Richella* are questionable (Tables I-II). Rare *Uralinella* and some *Moravammina* suggest a Devonian (probably Givetian) age for some bioclasts (sample CC1), whereas *Rectodiscus*? sp. might indicate an Arundian (= late Moliniacian; formerly "V2a") reworking in the Bellver Fm.

VII — DISCÚSSION AND PALAEOGEOGRAPHY

The Bellver Formation is preserved as a fine-grained turbidite facies in the eastern slices of the Cadí nappe as the Rus-la Creueta thrust sheet. In contrast, the south-west part of the Roca-sança thrust sheet contains submarine braided channel systems in which the channels are both vertically and laterally stacked within channel–levee complexes. Chaotic facies can be locally abundant. This stacking of channels is interpreted as representing the inner parts of deep-sea suprafan lobes.

The clasts can be divided into a siliciclastic group, which is in part inherited with an extra-basin origin, and a separate carbonate group. The lithified carbonate clasts come from the Silurian to Mississippian carbonate formations of the Cadí nappe, except for some nearshore limestone facies (intertidal to subtidal) clasts. These carbonate fragments have been resedimented in debris-flows, palaeochannel fills and as olistolites in the Roca-sança unit, and as grains from a megaturbidite bed in the Rus-la Creueta unit.

Study of the bio-components of the clasts suggests some rare specimens with Devonian and early Viséan ages, but many of the bioclasts are probably from the late Asbian/early Brigantian stages. The youngest of the clasts are thus, in part,

equivalent in age to the nodular limestone of the Aspe-Brousset Fm., which occurs beneath the Bellver Fm. The studied carbonate clasts were therefore derived through the erosion of the Viséan carbonate platform, equivalent in age to the hemipelagic sedimentation of the Aspe-Brousset Limestones.

The geographical location of the nearshore platform deposits is uncertain but it must be situated close to the Roca-sança sheet. This assumption is made based upon the presence of two olistolites of hectometric size that are incorporated in the Bellver Fm.

A feature favouring a southern provenance is the absence of the Aspe-Brousset Fm., removed by erosion, within the southern outcrops of the Roca-sança thrust sheet. This formation is also absent in other units, that were located southwards in a restored pre-Variscan position (as the Coll de Jou thrust sheet). Furthermore, where the Aspe-Brousset Fm. is preserved in the inverse limb of the Gréixer anticline, it contains small corals and the large articulated stems of crinoids, which are not found in the more nodular facies observed towards the northern normal limb. Consequently, the proximal facies of the Aspe-Brousset Fm. seems to lie adjacent to the southern outcrops. In the same way, a provenance from the upper thrust sheets in the Cadí nappe (which must be located to the north-east of the Roca-sança unit) is unlikely, because a gradational boundary between the nodular facies of the Aspe-Brousset Fm. and the Bellver Fm. occurs. In those areas (Serra Cavallera and Castellar de n'Hug), the Bellver Fm. is characterized by fine-grained turbidite beds and only a carbonate megaturbidite episode containing limestone clasts has so far been detected.

A northern provenance for the nearshore carbonate clasts has not been ruled out, because many of these are incorporated in the palaeochannel deposits of the Roca-sança unit, and the few measured palaeocurrent features indicate flow directions from north to south or east to west.

Platform-derived clasts have been described from the eastern French Pyrenees (Arize and Haut Pays de Sault; 1 and 2 in fig. 1A, respectively), Mouthoumet Massif and the Montagne Noire (fig. 1A). Serpukhovian clasts have been described from the French side, where carbonate platforms were probably located to the north-west of their present locations, according to the interpreted origin of the "écailles de Cabrières" (Engel *et al.*, 1981) and the Roc de Nitable nappe (Bessière and Schulze, 1984). Alternatively, a Serpukhovian carbonate platform is interpreted as having been erected on the edge of an allochthonous unit in the Haut Pays de Sault, and later destroyed (Delvolvé *et al.*, 1998).

The beginnings of siliciclastic sedimentation seem to have taken place in the latest Viséan at different localities within the eastern Pyrenees, Mouthoumet and Montagne Noire, if we consider the evidence from ammonoid occurrences (Délépine, 1935 in the Arize Massif, La Mandette fauna; Bessière *et al.*, 1980 in the Mouthoumet Massif; Engel *et al.*, 1981 in the Montagne Noire) just beneath and in the lower beds of the Culm sequences. Consequently, some Serpukhovian carbonate platforms could be coeval with the siliciclastic sedimentation in the north-eastern Pyrenees. So far Serpukhovian platform-derived clasts are unknown in the study area, the Spanish eastern Pyrenees.

Using the evidence provided by *Eovelebitella,* a late Viséan palaeoprovince can be reconstructed. *Eovelebitella* is understood here to be as described by Vachard and Aretz (2004), i.e., a synonym of *Japhetella.* Late Viséan *Eovelebitella* are known in the Montagne Noire (southern France) (Vachard, 1974b, 1978; Vachard and Aretz, 2004), the French Pyrenees (Arize Massif) (Delvolvé *et al.*, 1994), the eastern Spanish Pyrenees (this work) and the Betic Cordillera (south-eastern Spain) (Buchroithner *et al.*, 1980; Mamet and Herbig, 1990). The species is apparently absent in Central Morocco. We have never found *Eovelebitella* in England. The taxon *Eovelebitella* sp. mentioned by Cózar and Somerville (2004, fig. 14.32) corresponds directly to the definition of *Windsoporella* (see Vachard, 1980, fig. 58, p. 281). In the context of the dilemma regarding the block relationships in the western Palaeotethys, the presence of *Eovelebitella* confirms the mutual assemblage of the Montagne Noire, the Pyrenees and the Betic Cordillera during the late Viséan.

VIII. — CONCLUSIONS

1. Deep-sea fan sedimentation of the Bellver Fm. in the Cadí nappe began in late Viséan times and included the erosion of older carbonate successions. Study of the reworked carbonate clasts supports the differentiation of those containing known Devonian to Mississippian local facies, and others with exotic origins that correspond to several exogenous Mississippian facies.

2. The exotic clasts contain rare Devonian and Arundian bioclasts, and many reworked clast samples and microfacies are probably late Asbian/early Brigantian ("V3bγ"-"lower V3c") stages, as indicated by the presence of *Ungdarella, Howchinia, Eovelebitella, Asteroarchaediscus* ex gr. *parvus,* and *Koskinobigenerina.*

3. The location of the Viséan shallow carbonate platform equivalent to the hemipelagic carbonates of the Aspe-Brousset Fm. is currently unknown. It may be located to the south, according to the disposition of the unconformity below the Bellver Fm. and the presence of large olistolites. However, a northern or eastern location is not ruled out because many clasts fill channels that indicate that provenance.

4. The algae are diverse, especially the metaspondyl and vestibuled dasyclad *Eovelebitella* aff. *occitanica.* The presence of *Eovelebitella* indicates a provincial link between the Montagne Noire, the Pyrenees, and the Betic Cordillera during the late Viséan.

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PLATE VI

Fig. 1. — *Mitcheldeania nicholsoni* Wethered, 1886. Transverse section. Thin section CC1/4'. x 54.

Fig. 2. — *Epistacheoides* sp. Transverse section. Thin section CC1/3. x 54.

Fig. 3. — *Eostaffella proikensis* Rauser-Chernoussova, 1948. Axial section. Thin section CC1/2. x 80.

Fig. 4. — *Aphralysia* ? sp. Longitudinal section. Thin section CC1/4'. x 54.

Fig. 5. — *Lituotubella magna* Rauser-Chernoussova, 1948, Subaxial section. Thin section CC1/2, x 80.

Fig. 6. — *Endostaffella delicata* Rozovskaya, 1963. Axial section. Thin section CC1/2. x 80.

Fig. 7. — *Moravammina* cf. *segmentata* Pokorny, 1951. Longitudinal section. Thin section CC1/1. x 32.

Fig. 8. — *Mediocris mediocris* (Vissarionova, 1948). Axial section. Thin section CC1/1. x 108.

Fig. 9. — *Uralinella* cf. *augusta* Sabirov, 1974. Axial section. Thin section CC1/4'. x 108.

Fig. 10. — *Archaediscus* ex gr. *stilus* Grozdilova & Lebedeva in Grozdilova, 1953. Subaxial section. Thin section CC1/2. x 160.

Fig. 11. — *Fourstonella* sp. Longitudinal section. Thin section CC1/3. x 32.

Fig. 12-13, 15. — *Archaediscus* ex gr. *chernoussovensis* Mamet, Choubert & Hottinger, 1966. Three axial sections. Thin section CC1/3. x 80.

Fig. 14. — *Koskinobigenerina* sp. Broken subaxial section. Thin section CC1/3. x 32.

Fig. 16. — *Pseudoammodiscus* sp. Subaxial section. Thin section CC1/3. x 54.

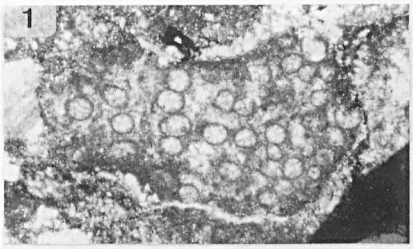
Fig. 17, 20. — *Tetrataxis* ex gr. *paraminima* Vissarionova, 1948. Two subaxial sections.

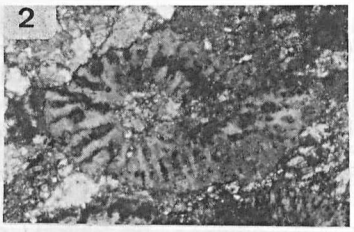
17. Thin section CC1/3. x 32.

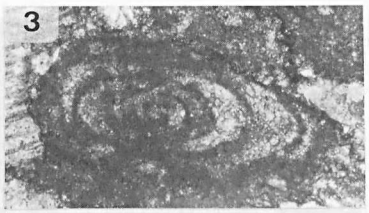
20. Thin section CC1/2. x 80.

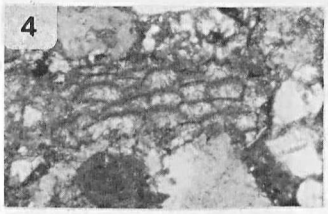
Fig. 18. — *Howchinia gibba* (von Moeller, 1880). Oblique section. Thin section CC1/2. x 80.

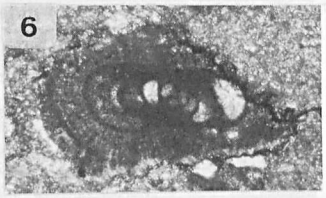
Fig. 19. — *Fasciella* sp. Transverse section. Thin section CC1/3. x 54.

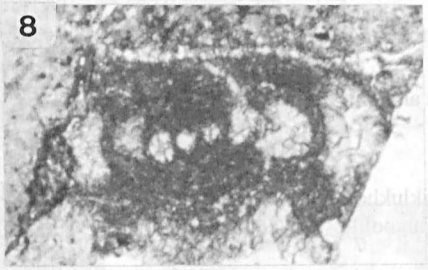


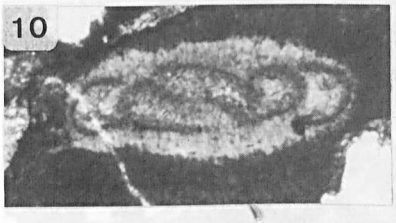


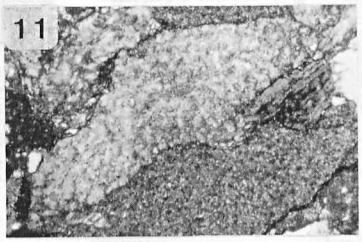


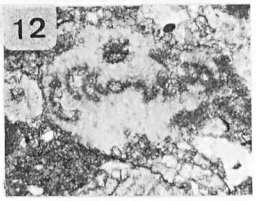


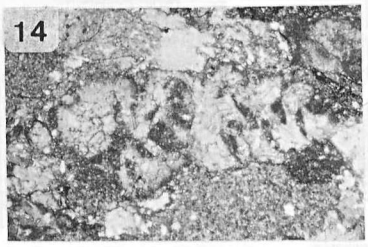


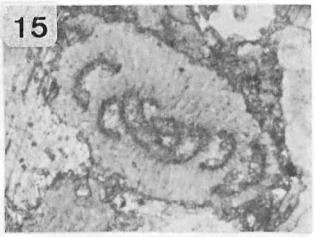


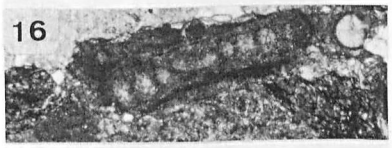


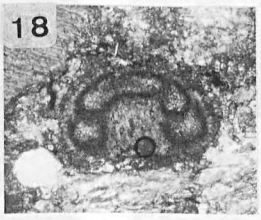


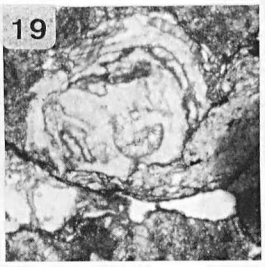












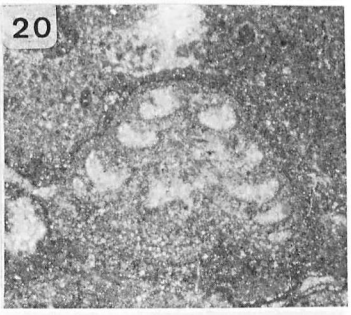


PLATE VII

Fig. 1, 3. — *Pseudosolenopora owodenkoi* (Chanton-Guvenç, 1971).

1. Subtransverse section. Thin section CC4/3. x 32.

3. Subaxial section. Thin section CC4/3. x 32.

Fig. 2?, 14. — *Koskinobigenerina* sp.

2? Probable juvenile specimen (may be also *Consobrinella* or juvenile *Koskinotextularia*). Thin section CC4/2. x32

14. Adult specimen. Thin section CC4/2. x 32.

Fig. 4. — *Fourstonella* sp. Recrystallized longitudinal section. Thin section CC13. x 32.

Fig. 5, 10. — *Asteroarchaediscus* ex gr. *parvus* (Rauzer-Chernousova, 1948).

5. Subaxial section showing the rugosities. Thin section CC4/2. x 160.

10. Axial section included in an oolite. Thin section CC4/3. x 160.

Fig. 6. — *Eotuberitina reitlingerae* Miklukho-Maklay, 1958. Two longitudinal sections in an oolite. Thin section CC4/1. x 80.

Fig. 7. — *Praethocoprolithus* sp. Longitudinal section. Thin section CC5/1. x 32.

Fig. 8, 11. – *Windsoporella* (?) sp.

8. Tangential section through two whorls Thin section CC13. x 80.

11. Oblique section through a whorl. Thin section CC13. x 54.

Fig. 9. — *Girvanella ducii* Wethered, 1890. Longitudinal and transverse sections. Thin section CC4/1. x 54.

Fig. 12, 15, 17. — *Eovelebitella* aff. *occitanica* Vachard, 1974b.

12. Tangential section through a whorl. Thin section CC13.x 54.

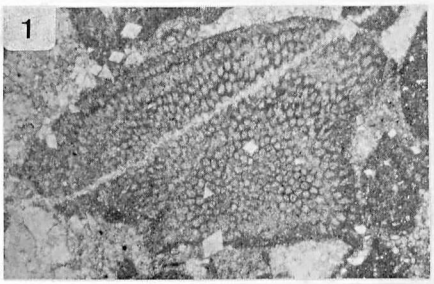
15. Subaxial section through a whorl. Thin section CC 4/3. x 80.

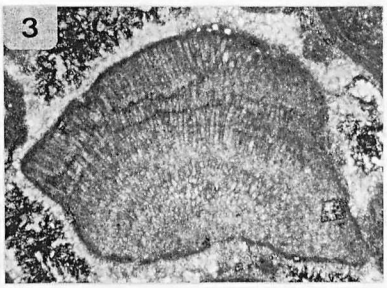
17. Subaxial section through four articles Thin section CC 4/3. x 32.

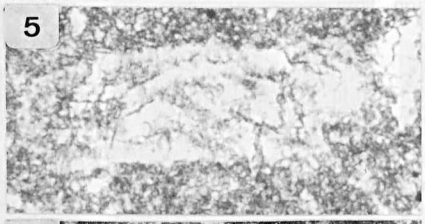
Fig. 13, 16. — *Cabrieropora* (?) n. sp.

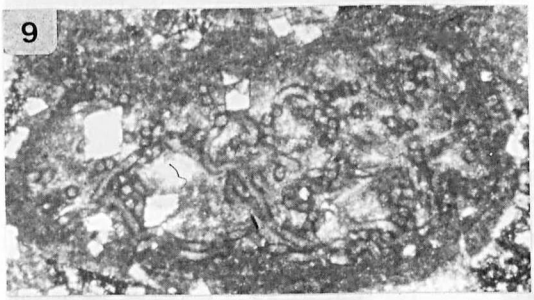
13. Oblique section through a whorl. Thin section CC 4/3. x 54.

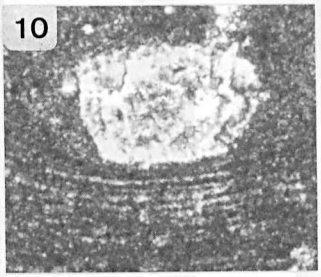
16. Oblique section through a whorl. (compare with Fig. 13). Thin section CC13. x 80.

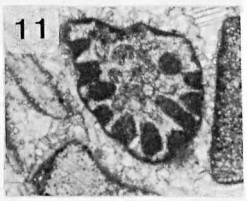


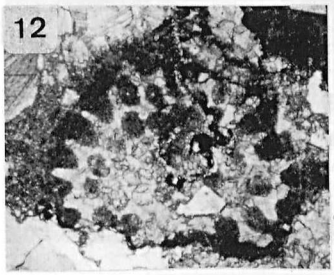


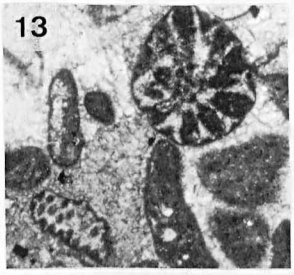


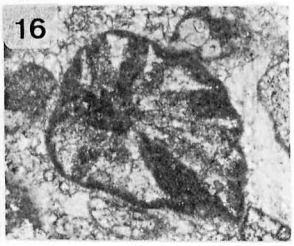












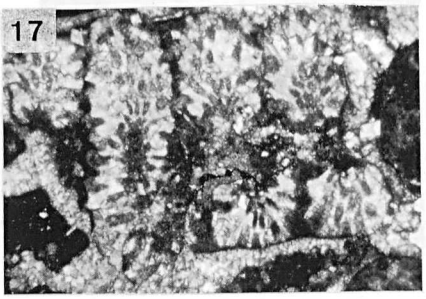


PLATE VIII

Fig. 1. — Crinoid (*Pentacrinus*?). Oblique section. Thin section CC4/1. x 54.

Fig. 2. — *Eostaffella proikensis* Rauzer-Chernoussova, 1948. Subaxial section. Thin section CC1/2. x 80.

Fig. 3. — *Claracrusta* sp. Longitudinal section. Thin section CC5/1. x 32.

Fig. 4. — Root of a sponge. Longitudinal section. Thin section CC8. x 32.

Fig. 5. — *Radiosphaera basilica* Reitlinger, 1957. Thin section SL-01. x 80.

Fig. 6. — *Fasciella* sp. Transverse section. Thin section CC12. x 32.

Fig. 7. — *Rectodiscus*? sp. Axial section. Thin section CC1/2. x 130.

Fig. 8. — *Polysphaerinella bulla* (Conil & Lys, 1968). Transverse section. Thin section CC1/2. x 32.

Fig. 9. — *Praedonezella*? sp. Transverse section of the basal part? Thin section CC5/1. x 54.

Fig. 10, 15. — *Archaediscus karreri* Brady, 1873. Thin section CC 13. x 80.

10. Subaxial section.

15. Axial section.

Fig. 11. — *Tetrataxis* ex gr. *paraminima* Vissarionova, 1948. Subaxial section. Thin section CC13. x 54.

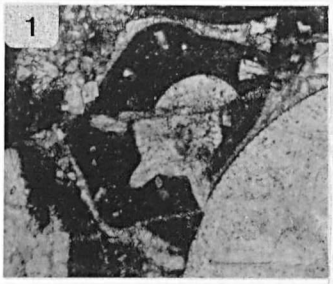
Fig. 12. — *Spirorbis* sp. Longitudinal section. Thin section CC11. x 32.

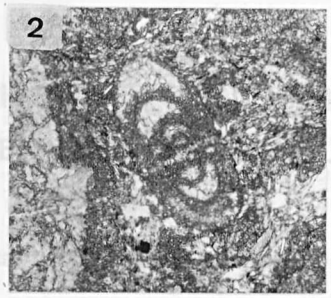
Fig. 13. — *Globoendothyra* aff. *parva* (Chernysheva, 1948). Axial section. Thin section CC13. x 160.

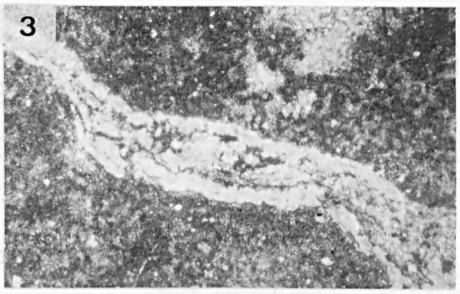
Fig. 14. — *Tetrataxis compacta* Conil & Lys, 1964. Subaxial section. Thin section CC13. x 32.

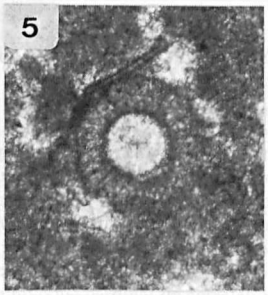
Fig. 16. — *Howchinia gibba* (von Moeller, 1880). Oblique section. Thin section CC13. x 80.

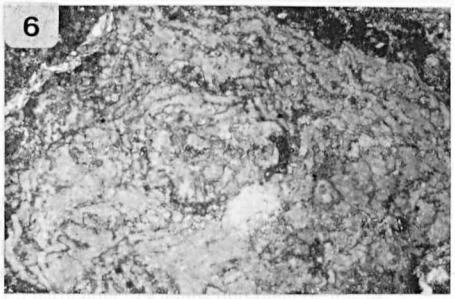
Fig. 17. — *Endothyra apposita* Ganelina, 1956. Subtransverse section. Thin section CC13. x 54.

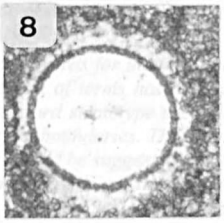


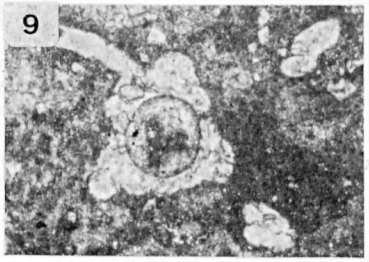


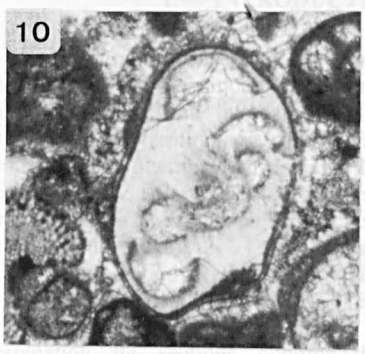


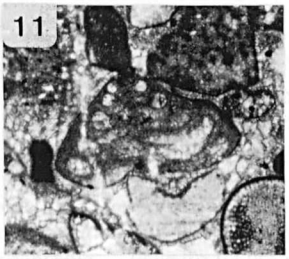


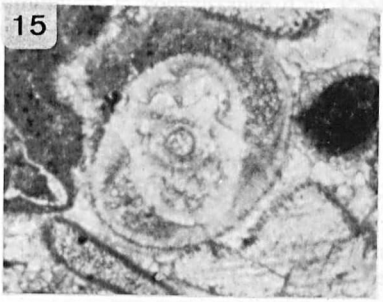


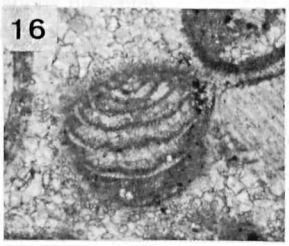












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LES UNITES DE L'HISTOIRE GEOLOGIQUE ; DISCUSSION SUR LES CONVENTIONS ET L'ECHELLE DES TEMPS

Units of the geological history ; discussion on conventions and the time scale.

par Gilles Serge ODIN (*), Silvia GARDIN (*), Francis ROBASZYNSKI (**) et Jacques THIERRY (***)

Résumé. — La double terminologie en langue anglaise désigne différemment la notion de temps et la notion de dépôt recouvertes par les termes d'unités stratigraphiques. Cet usage ne paraît pas indispensable ; en français, on a longtemps utilisé sans ambiguité une seule série de termes. On encourage cette terminologie simple qui est favorisée par l'adoption du concept de point stratotypique mondial (PSM) qui garantit la continuité de la succession des unités. Ces PSM définissent ainsi des limites. Le principe de leur unicité ne devrait pas interdire la proposition de sections auxiliaires, sans désigner de point type auxiliaire. Enfin, il ne nous paraît pas nécessaire d'appliquer rigidement ce concept de PSM en dehors de l'intervalle où les fossiles constituent l'outil univoque cardinal de corrélation. En particulier, les temps plio-quaternaires ne paraissent pas devoir bénéficier de la lourde procédure de désignation de ces points types.

Abstract. —*The dual terminology in English uses different words for the time and the time-rock stratigraphical units. This use does not appear necessary ; in French, a single series of terms has been used for long. This simple terminology is preferred and consistent with the use of the global standard stratotype section and point (GSSP) concept. These GSSP make sure the continuity of the sucessive units. They define boundaries. The unique character of GSSP do not preclude the proposal of auxiliary sections where no auxiliary point should be suggested however. Finally, it does not appear necessary to rigidly apply the GSSP concept out of the interval where fossils are the key unequivocal tool for correlation. Especially, Plio-Quaternary times do not appear to need or benefit the heavy procedure of designation of GSSP.*

I. — INTRODUCTION

Le stratigraphe utilise pour désigner les unités de l'histoire de la Terre, une terminologie qui fut normalisée dans les années 80 au niveau international. Des propositions pour simplifier cette terminologie ont été faites. Elles concernent principalement quatre aspects de notre langage et des concepts qu'il recouvre : 1- le système de double terminologie avec des termes propres pour chacun des aspects temporel et concret des corps de roche ; 2- l'assertion selon laquelle le Point Stratotypique Mondial (PSM) définit la base d'un étage qui coïncide avec le sommet de l'étage précédent au lieu de, tout simplement, la limite d'étage ; 3- la répugnance devant la désignation de sections additionnelles (auxiliaires) qui accroîtraient la connaissance d'un PSM et pourraient ainsi élargir le domaine de corrélation directe ; 4- des principes de subdivision qui doivent s'adapter aux informations présentes dans les roches qui diffèrent selon leur âge et conditionnent les outils de datation.

II. — LA DOUBLE TERMINOLOGIE DES UNITES

Le stratigraphe est amené à manier deux concepts différents lorsqu'il désigne ses unités : celui de temps et celui d'ensemble de couches déposées durant ce temps (Rey *et al.*, 1997). Ainsi pour désigner les temps pendant lesquels vivaient les dinosaures on écrit les dinosaures vivaient durant le Secondaire (ou Mésozoïque). Lorsqu'on désigne les roches contenant les fossiles de dinosaures on écrit : les fossiles de dinosaures se trouvent dans le Mésozoïque (sous entendu, dans les roches qui constituent l'ensemble de couches désigné sous le nom de Mésozoïque). On comprend là les deux concepts recouverts par le mot Mésozoïque : temps et couches.

Afin de formaliser cette nécessaire distinction, la terminologie à la mode (en pays anglophones surtout) recommandait une double hiérarchie des unités stratigraphiques. La figure 1 donne les termes anglais, la figure 2 donne les termes proposés en français (cf. Odin et Odin, 1990). On note que, dans la terminologie francophone, il n'y a pas l'équivalent de l'anglais "Early/Late" ; les traductions correspondantes "précoce" ou "ancien" et "tardif" ou "récent", ne sont pas usitées pour qualifier des unités formelles.

En 2004, l'expérience a montré que l'instauration de cette dualité parfois imposée par certaines publications, ne facilitait pas la communication, ni avec les géologues non-stratigraphes, ni dans le cadre de l'enseignement et qu'elle

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Unités	Roche	Temps	Exemple
Hiérarchie principale	Erathem	Era	Cénozoïque
	System	Period	Néogène
	Series	Epoch	Miocène
	Stage	Age	Burdigalien
subdivisions	Lower - Middle - Upper	Early - Middle - Late	

Fig. 1. — Langage conventionnel des auteurs anglophones pour les unités stratigraphiques.

Fig. 1. — Conventional language for stratigraphical units in English.

Unités	Roche	Temps	Exemple
Hiérarchie principale	Érathème	Ère	Cénozoïque
	Système	Période	Néogène
	Série	Époque	Miocène
	Étage	Âge	Burdigalien
subdivisions	Inférieur - Moyen - Supérieur		

Fig. 2. — Langage conventionnel correspondant en français pour les unités stratigraphiques.

Fig. 2. — Corresponding language in French for styratigraphical units.

Unités		Roche & Temps	Exemple
Mondiales	Hiérarchie principale	Ère	Cénozoïque
		Système	Néogène
		sous-Système	Miocène
		Étage	Burdigalien
	subdivisions	Inférieur - Moyen - Supérieur	
Régionales		sous-Étage super-Étage	Gargasien Sénonien

Fig. 3. — Langage conventionnel simplifié proposé pour les unités stratigraphiques.

Fig. 3. — Simplified conventional language suggested for stratigraphical units.

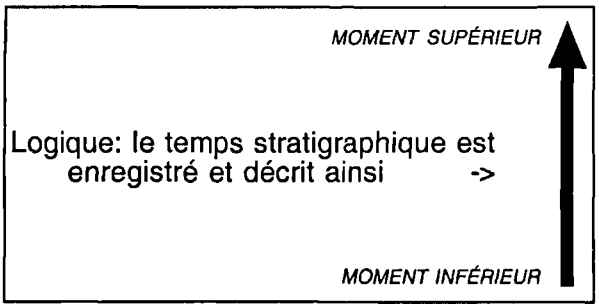

Fig. 4. — Le temps géologique s'exprime dans les dépôts sédimentaires régis par le principe de superposition.

Fig. 4. — The geolgical time is expressed in the sedimentary deposits submitted to the superposition principle.

n'était pas utilisée avec succès par la majorité des stratigraphes.

Une récente proposition de la Commission de Stratigraphie de la Société Géologique de Londres (Zalasiewicz *et al.*, 2004) est favorable à une simplification de cette terminologie. La définition des unités stratigraphiques à l'aide de conventions portant sur des limites favorise cette simplification. En effet, le concept de Point Stratotypique Mondial (GSSP en anglais, pour Global standard Stratotype Section and Point) permet une exacte coïncidence entre la base d'un étage et le sommet du précédent dès lors que le PSM est choisi dans une succession continue. Tout le temps étant représenté par des dépôts, il n'y a donc pas de distinction entre le temps représenté par les couches et le temps désigné dans les unités de temps ce qui n'était pas garanti avec les stratotypes historiques souvent bornés par des arrêts de dépôt. On peut alors utiliser un même mot recouvrant la même histoire pour désigner unités de temps et unités déposées.

Nos collègues britanniques plaident pour une hiérarchie Ère, Période, Époque, Âge (ou Étage) et pour les subdivisions "précoce/tardif" (colonne "Temps", fig. 1). L'usage francophone favorise les termes Ère, Système, Étage (fig. 3) avec les subdivisions inférieur/moyen/supérieur, voire avec des sous-unités là où le besoin s'en fait sentir (sous-systèmes dans le Cénozoïque). Les équivalents de ces termes qui désignent d'abord les *ensembles de roches* sont l'usage dans de nombreuses langues incluant l'allemand, l'espagnol, le grec, l'italien, etc ..., dès les débuts du développement de la stratigraphie. Régionalement, d'autres subdivisions telles des sous-étages ou des groupes d'étages sont communément utiles (fig. 3).

Au niveau des conventions mondiales, la raison majeure pour favoriser cette hiérarchie n'est pas seulement due à un usage traditionnel dans telle ou telle langue. Un tel usage est historique et 1- n'a jamais généré de problème de compréhension ; 2- recommande l'emploi de termes dont le sens ne peut pas être confondu avec d'autres termes du langage courant (tels que période ou époque) ; 3- respecte l'expression concrète du temps géologique, à savoir les roches déposées de bas en haut qui caractérisent l'histoire de la terre décrite de bas en haut dans la succession des corps de roches. Ainsi, un temps plus ancien est immédiatement conçu comme inférieur par tout stratigraphe (fig. 4).

III. — LES LIMITES D'ETAGES CONVENTIONELLES

Nous admettons que la continuité requise dans les successions de corps de roches pour définir un PSM (fig. 5), permet au dit PSM de définir une limite (par exemple la limite Campanien-Maastrichtien) ; ce terme simple de limite doit remplacer avantageusement l'expression consacrée par un ancien usage à savoir, "la base d'une unité qui devient automatiquement le sommet de l'unité inférieure" (Remane *et*

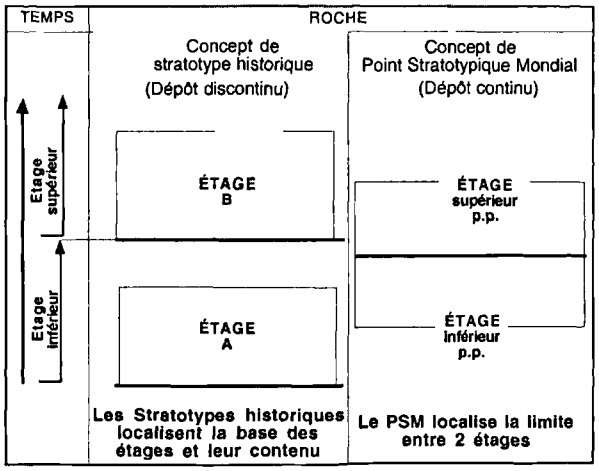

Fig. 5. — Stratotypes historiques et stratotypes de limite modernes pour les unités stratigraphiques.

Fig. 5. — Historical stratotypes and modern boundary stratotypes for stratigraphical units.

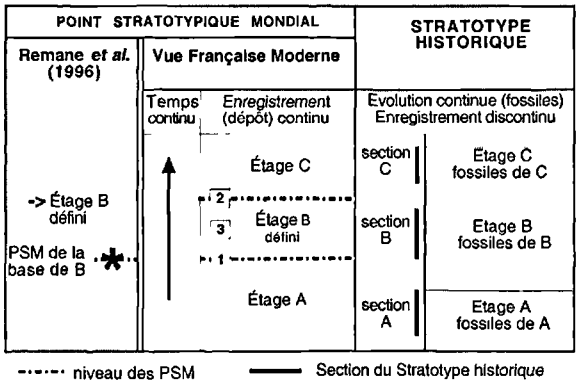

Fig. 6. — Définition conventionnelle complète d'un étage en stratigraphie.

Fig. 6. — Full conventional definition of a geological stage.

al., 1996) généralement simplifié en base de l'unité (par exemple la base du Maastrichtien).

Les stratigraphes francophones rappellent que ***la définition complète d'un étage nécessite 3 éléments*** : la définition de ses deux limites et le choix d'un nom pour le désigner (fig. 6). Ce nom est généralement dérivé d'un stratotype historique illustré par son ***contenu***. Cette position nous paraît plus raisonnable que celle rappelée par Remane *et al.* (1996) qui soutenaient qu'un étage était défini dès lors que le PSM de sa base était adopté. Cette vue a conduit, alors que les unités stratigraphiques mondiales restent encore en cours d'élaboration après 30 années de travaux, à admettre des étages dont on définit la base sans que le sommet n'en soit situé ou défini ou que le nom de l'étage qui le précède soit proposé ou admis (c'est le cas de plusieurs "étages" du Primaire ou Paléozoïque par exemple du Darriwilien, au Dévonien moyen). Ces étages au contenu non désigné formellement ne sont pas complètement définis.

IV. — DES SECTIONS AUXILIAIRES UTILES

Les règles admises par la Commission Internationale de Stratigraphie sont très strictes : le PSM définit l'unité, est et doit rester unique. Cette règle a conduit à rejeter, parfois, la proposition faite pour une *section auxiliaire* c'est-à dire pour une section autre que celle où est concrétisé le point stratotypique et étudiée parallèlement. Pourtant, une seule section n'illustre que rarement une palette large d'outils stratigraphiques (divers groupes biostratigraphiques complétés par les aspects chimio- et physico-stratigraphiques). Aussi, l'opinion de beaucoup de stratigraphes francophones est qu'il n'est pas inutile que la définition d'un PSM soit accompagnée de l'étude de sections auxiliaires prises dans des environnements de dépôt différents permettant d'illustrer d'autres événements que ceux visibles dans la section type. C'est ce qui nous avait conduit à proposer une section complémentaire continentale pour la limite limite Crétacé / Paléogène ou Mésozoïque-Secondaire / Cénozoïque-Tertiaire (Odin, 1990). Cette proposition permettait, fait très exceptionnel, d'impliquer, grâce au marqueur de temps précis donné par l'anomalie d'iridium, un domaine souvent délaissé par le stratigraphe. Quoiqu'il en soit, ce ne fut pas accepté. Par contre, d'autres groupes de travail ont eu l'imprudence, en proposant une section auxiliaire, de *désigner* par la même occasion, un niveau supposé équivalent à celui du PSM. Lorsque l'on a compris, quelques mois plus tard, que la contemporanéité était peu assurée voire incorrecte entre PSM et point de la section auxiliaire, la décision était déjà votée et l'on s'est retrouvé avec deux niveaux de référence désignés distincts.

Une ou des sections auxiliaires sont donc bienvenues mais il ne faut pas y désigner formellement un niveau de référence et se contenter de le suggérer ou de le situer dans un intervalle dont la corrélation est solidement assurée. C'est ce qui a été fait pour la limite Campanien-Maastrichtien à Tercis à laquelle une section des Apennins a été adjointe sans désigner de niveau limite dans cette dernière. On s'est limité à souligner la localisation d' événements-clés observés pour les foraminifères planctoniques, les nannofossiles et l'enregistrement magnétostratigraphique (Odin, 2001, p. 779 ; 815). Une démarche similaire a été suivie, autre exemple, pour la limite entre les étages Aalénien et Bajocien (Jurassique moyen) avec des sections auxiliaires en Écosse et au Portugal (Morton, 1990 ; Rocha *et al.*, 1990 ; Pavia *et al.*, 1997).

V. — DES PRINCIPES DE SUBDIVISION ADAPTES AUX MARQUEURS PRESENTS

Les principes de subdivision discutés ci-dessus sont adaptés aux temps phanérozoïques caractérisés par un enregistrement précis de l'évolution biologique illustré par la présence abondante de fossiles. La biostratigraphie est l'outil cardinal de corrélation entre 530 et 5 Ma. En règle générale, la définition des limites (par les PSM) ne saurait se faire efficacement sans contrôle biostratigraphique. *Historiquement et pratiquement, les étages, comme les subdivisions de rang supérieur, sont d'abord une expression de l'évolution biologique telle qu'elle fut perçue par les*

pionniers de la stratigraphie. Pour eux, c'est le changement de faune qui impliquait la création d'une unité stratigraphique. Notre opinion est que cette pratique n'est pas adaptée à l'ensemble des couches géologiques et, par conséquent, qu'il convient de proposer d'autres principes en dehors de l'intervalle de temps précisé ci-dessus.

Pour saisir la nécessité d'envisager des conventions différentes pour les différentes étapes de l'histoire de la terre, rappelons d'abord les caractéristiques des cinq groupes principaux d'outils stratigraphiques utilisés pour reconstituer cette histoire.

La géochronologie (caractérisation d'un niveau par un âge numérique mesuré) et la biostratigraphie (caractérisation d'un niveau par un âge relatif repéré par les fossiles) sont des outils stratigraphiques univoques (Odin & Odin, 1990) car à chaque caractère correspond un *moment unique* de l'histoire de la terre. La lithostratigraphie (caractérisation d'un niveau par la nature de la roche), la chimiostratigraphie (caractérisation d'un niveau par une propriété chimique, voire isotopique) et la magnétostratigraphie (caractérisation d'un niveau par une propriété magnétique) sont des outils plurivoques car à une même caractéristique pourra correspondre *plusieurs moments* de l'histoire de la terre. Géochronologie et biostratigraphie révèlent des âges univoques plus ou moins précis (situés dans un intervalle de temps plus ou moins court). L'outil le plus plurivoque est la magnétostratigraphie ; le signal donné par l'analyse est binaire : polarité inverse ou polarité normale.

La figure 7 rappelle quelques caractères des outils stratigraphiques ; on remarque immédiatement les différences fondamentales entre les 3 domaines pré-phanérozoïque, phanérozoïque et plio-quaternaire.

1) Les temps pré-phanérozoïques

Pour tout ce qui précède l'apparition des animaux à squelette (le Précambrien), la géochronologie est l'*outil univoque cardinal*. Au Précambrien, la rareté des informations biostratigraphiques mais aussi, à notre connaissance, l'imprécision de leur localisation dans le temps ne paraissent pas compatibles avec une définition de limite efficace (c'est à dire reconnaissable dans un vaste domaine géographique) au moyen d'un concept de PSM similaire à celui du Phanérozoïque. Cette reconnaissance des caractéristiques biostratigraphiques à la limite implique, pour le Phanérozoïque, un rôle déterminant de cet outil. Reconnaissant cette difficulté, la Commission Internationale de Stratigraphie a recommandé de substituer aux PSM des *âges numériques conventionnels*. Les unités sont alors définies entre deux âges numériques choisis en fonction de notre connaissance des coupures de l'histoire.

Quant à l'adoption récente d'une unité édiacarienne pour les dépôts précédant immédiatement le Phanérozoïque, l'avenir jugera si cette nouvelle convention est utile dans la pratique. En effet, dérogeant à ce principe de limite numérique, cet Édiacarien est borné, à sa base, par un PSM qui tient compte de caractères litho- et chimiostratigraphiques dénotant la fin d'une glaciation. La biostratigraphie n'est illustrée que très localement dans le monde et l'âge numérique est imprécis par rapport à la convention admise pour l'ancien Protérozoïque III, qu'il remplace.

APPROCHE	UNICITE	QUATERNAIRE	PHANÉROZOÏQUE	PRÉCAMBRIEN
Lithologie (lithostratigraphie)	plurivoque	très utilisé (cycles astronomiques, séquences)	parfois utilisé	utilisé (régional)
Géochimie (chimiostratigraphie)	plurivoque	très utilisé (âge)	utilisé	utilisé mais signal déformé
Paléomagnétisme (magnétostratigraphie)	plurivoque	très utilisé (âge)	utilisé / rare (jusqu'à 150 Ma)	peu utilisé signal déformé
Paléontologie (biostratigraphie)	univoque (relatif)	très utilisé (climat)	outil cardinal (âge: omniprésent)	peu utilisé (outil svt absent)
Datation isotopique (géochronologie)	univoque (numérique)	très utilisé	peu utilisé (rare)	outil cardinal (quoique rare)

Fig. 7. — Outils de la stratigraphie et leur application dans divers domaines de l'histoire géologique.

Fig. 7. — Stratigraphical tools and their use in the different domains of the geological history.

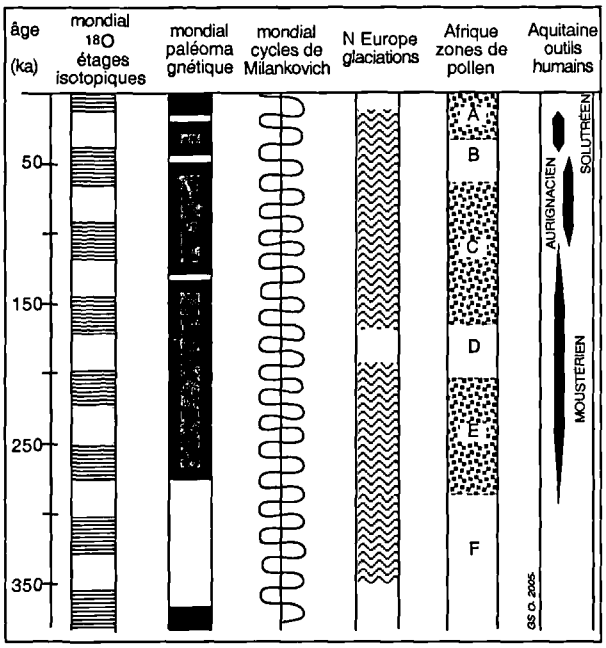

Fig. 8. — Les unités stratigraphiques pratiques dans les dépôts du Quaternaire.

Fig. 8. — Stratigraphical units used in the Quaternary deposits.

2) Les temps quaternaires (ou plio-quaternaires)

Pour les 3 à 5 derniers Ma, des étages conventionnels ne paraissent pas nécessaires. Ils auraient, d'ailleurs, une autre signification que les étages du Phanérozoïque quant à leur durée. Selon nous, de nombreux outils stratigraphiques permettent de subdiviser efficacement l'histoire récente de la terre en unités claires pour tous. Chaque caractéristique, chaque succession stratigraphique sera mieux décrite au moyen de l'échelle qui lui est propre. Evidemment, les coupures observées avec les différents outils ne sont pas précisément contemporaines (fig. 8).

La notion de précision est importante dans cette optique car si, pour le Précambrien, définir une limite à quelques millions d'années près n'est pas inadmissible, pour le

Phanérozoïque, ces limites nécessitent une précision de l'ordre de 0,1 Ma tandis que, pour le Plio-Quaternaire, la précision de l'enregistrement (et de la connaissance) atteint dix mille ans. C'est une autre caractéristique des différents domaines de l'histoire géologique qui justifie d'adapter les principes de leur description historique. Pour ces temps récents, un langage commun sera mis en place par le fait que toutes ces catégories d'unité (géochimiques, biostratigraphiques, lithologiques, climatiques, magnéto-stratigraphiques, industrie humaine etc ...) peuvent être *in fine* corrélées entre elles par des âges numériques mesurés ou estimés. Nous admettons, parmi ces unités utiles et acceptables mais non exclusivement, les subdivisions traditionnelles de Pliocène ou de Quaternaire.

Dans cet intervalle de temps, chaque spécialiste doit donc pouvoir utiliser les unités propres à l'outil dont il dispose dans les couches étudiées. La question de la définition de ces termes traditionnels reste posée. Les quaternaristes sont très clairs : une coupure majeure se situe vers 2,6 Ma. C'est une dégradation climatique reconnue dans le domaine marin comme dans le domaine continental par divers outils (biostratigraphique, géochimique). Ces mêmes experts ne voient pas de coupure autour de 1,8 Ma, âge qui correspond à la limite Miocène-Pléistocène admise par les spécialistes du Néogène ce qui anime un vif débat qui pourrait être résolu par l'acceptation du principe de subdivisions parallèles suggéré ici.

VI. — DES CONVENTIONS DISTINGUEES DES CONNAISSANCES

Les notions conventionnelles discutées ici sont adoptées dans le cadre de structures de décision internationales. Elles sont recommandables pour une utilisation généralisée lorsqu'un accord existe. Ces conventions ne doivent pas être mêlées avec des informations relevant de la connaissance. Par exemple, les caractéristiques de ces limites : insertion dans une biozonation, position dans une succession magnétostratigraphique, âge numérique etc... sont strictement dépendantes de connaissances, voire d'opinions qui ne peuvent qu'être propres à chaque spécialiste et, éventuellement, fluctuer en fonction de la connaissance. Ces connaissances, ces opinions ne sauraient être "recommandées" de manière administrative et singulièrement par une structure internationale, sans tendre à l'établissement d'une pensée unique contraire aux usages scientifiques jusqu'à ce jour.

C'est ainsi que, lorsqu'une échelle est proposée par des auteurs, tout ce qui concerne autre chose que la localisation des limites sort du domaine des conventions et devrait être distingué. Jusqu'ici, les responsables des commissions et sous-commissions internationales de stratigraphie séparaient ces aspects de l'échelle des temps (voir par exemple l'échelle proposée à Rio par Remane, 2000). Pourtant, la tendance de récents responsables semble être de confondre leur rôle d'animateur de groupes de travail et leurs opinions sur telle ou telle connaissance stratigraphique. Prenons deux exemples d'opinions : la place du Quaternaire dans l'échelle et les âges numériques.

L' échelle des temps géologiques distribuée à Florence (Congrès géologique international, Août, 2004) ne cite pas le Quaternaire dans sa subdivision principale. A ce jour, ceci ne relève en rien d'une décision de la Commission de Stratigraphie mais uniquement de l'opinion personnelle des animateurs actuels de cette commission. De même, l'âge de la base de cette unité relève d'une question en cours de discussion et il n'y a pas de nouvelle recommandation devant se substituer aux usages antérieurs.

Quant aux âges donnés en face des limites entre unités, ils n'ont aucun caractère de recommandation et nécessiteraient une critique détaillée. Ils ne sont, au mieux, qu'une opinion et l'on doit même écrire qu'ils n'améliorent pas la connaissance délivrée dans d'autres travaux plus spécialisés même si les incertitudes proposées sont affichées comme plus précises. Pour nous, ces âges "nouveaux" posent problème vis à vis de la connaissance établie. Pour le Miocène en particulier, la précision des nombres suggérés ne nous paraît pas réaliste. L'Union Internationale des Sciences Géologiques qui est la structure couronnant les commissions internationales, a renoncé à apporter son aval à cette production florentine devant la situation conflictuelle créée par certains choix ; ainsi, comme il est d'usage, les informations non conventionnelles de ce document n'engagent que leurs auteurs.

Note : l'expression Point Stratotypique Mondial est notre proposition pour traduire le *Global standard Stratotype Section and Point* (GSSP) des anglophones. La traduction littérale serait : *Point et section stratotypiques conventionnels mondiaux*. L'emploi de "global" en français est impropre puisqu'il s'agit, en anglais, du globe terrestre. Conventionnel correspond mieux au "standard" anglais que standard en français. L'ensemble abrégé (PSSCM) est complexe et, l'élément essentiel de ce concept étant le point, nous suggérons de l'abréger PSM.

Remerciements. — Cette discussion a bénéficié des commentaires de nombreux collègues au cours de son élaboration ainsi que lors de sa présentation lors du Congrès de Florence (VIII-2004) de même que lors de sa présentation à la réunion mixte Comité National français INQUA / AFEQ (Paris I-2005). Elle a été présentée en langue anglaise (Odin *et al.*, 2004). Nous remercions les rédacteurs des Carnets de Géologie pour leur permission de publier cette adaptation résumée et complétée.

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APPLICATION DE L'ANALYSE FACTORIELLE AU TRIAS D'EL KHEMIS DES MESKALA : BASSIN D'ESSAOUIRA (MAROC)

Application of the factorial analysis to Trias of El Khemis des Meskala : Essaouira basin (Morocco)

par M. MENZHI (*), L. BAHI (**) et A. EL OUARGHIOUI (***)

Résumé. — Dans le bassin d'Essaouira, le Trias constitue un objectif majeur dans la recherche pétrolière. Cette série triasique, déposée en discordance sur les terrains paléozoïque est composée de siltstones, d'argiles et d'évaporites, avec une intercalation de dolérites.
Le bassin d'Essaouira est composé de plusieurs secteurs dont celui d'El Khemis des Meskala renferme le plus important gisement gazifère du Maroc.
L'application de l'analyse en composantes principales a permis de retrouver les différents faciès et de mieux limiter les niveaux formant cette série sédimentaire.

Abstract. — *In the Essaouira basin, the Trias constitutes a major objective in oil prospecting. This triassic series, deposited in discordance on paleozoic terrains composed of siltstones, clays and evaporites, with a dolerite intercalation.*
The Essaouira basin is composed of several sectors of which that of El Khemis of Meskala that contains the most significantgas layer of Morocco.
The application of the analysis in principal components made it possible to find the various facies and to better limit the levels forming this sedimentary series.

I. — INTRODUCTION

Le bassin d'Essaouira compte parmi les régions du Maroc qui a suscité les travaux d'explorations et d'exploitations de nombreux pétroliers. Ce bassin est actuellement la partie la plus étudiée sur la côte marocaine à cause de sa richesse potentielle en hydrocarbures (Broughton et Trépanier 1993; Medina, 1995).

Il s'est agi pour nous d'explorer le champ des méthodes statistiques et d'analyses de données appliquées au bassin d'Essaouira en général et aux réservoirs en particulier. Pour cela, nous avions besoin de nombreuses données de base à traiter pour obtenir des résultats significatifs. Nos recherches dans ce but ont été récompensées grâce à l'aide que nous ont réservé les gens de l'ONAREP.

II. — LE BASSIN D'ESSAOUIRA : VUE D'ENSEMBLE :

1) Présentation géographique

Le bassin d'Essaouira se présente comme une importante structure légèrement ovale (110 x 80 km) de direction EW. Vers l'Ouest, il plonge sous l'océan atlantique où il est interrompu par le talus continental. Sa délimitation au Nord, est difficile et moins nette puisque le bassin vient en contact avec celui de Doukkala par l'intermédiaire d'un important soulèvement transversal enfoui sous les terrains les plus récents. Vers l'Est, le bassin d'Essaouira est bordé par les Jbilet et l'Atlas paléozoïque. Enfin, au Sud, il est limité par le bassin d'Agadir.

L'épaisseur totale de la couverture sédimentaire varie de 2 à 6,5 km et augmente progressivement de l'Est à l'Ouest.

2) Cadre géologique

Le bassin d'Essaouira compte parmi les divers bassins côtiers formant le bassin sud-ouest marocain (fig. 1). D'un point de vue structural, une succession d'événements tectoniques a permis une subsidence importante (en relation avec les bassins de Doukala et d'Agadir) entraînant une accumulation de sédiments variés. Ce bassin a connu une première structuration polyphasée du Carnien à l'Hettangien pendant le rifting de l'Atlantique central (Le Roy, 1997 ; Le Roy *et al.*, 1997).

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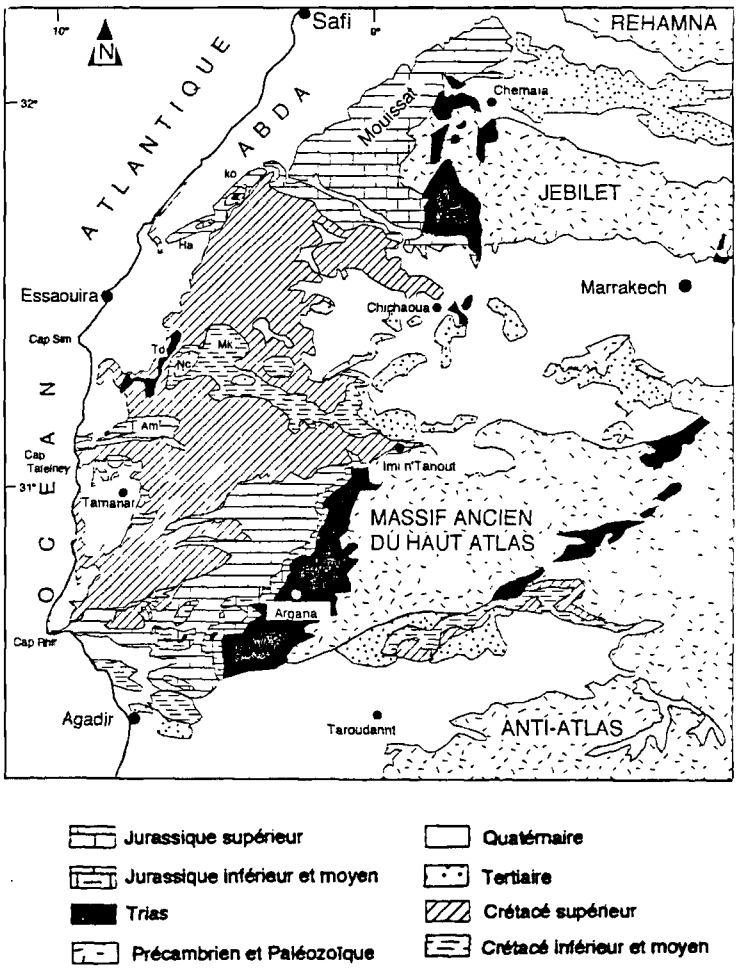

Fig 1. — Carte géologique du Haut Atlas occidental et ses régions limitrophes.
Am : Amsittène ; Ha : Jbel Hadid ; Ko : Jbel Kourati ; Mk : Meskala; Nc : Necnafa; Td: Tidsi;
(Extrait de la carte géologique du Maroc au 1/1 000 000)

Fig. 1. — Geological map of the High Western Atlas and its bordering areas.

3) Le Trias dans le bassin d'Essaouira

Le Trias du bassin d'Essaouira se présente en discordance angulaire sur le paléozoïque (Le Roy, 1997).

A l'affleurement, il est limité à certaines structures diapiriques (Tidsi, Amsitten et Hadid) (Medina, 1995 ; Hafid, 1999). Ces terrains triasiques se différencient par le caractère complexe de la répartition des épaisseurs. Ils sont composés essentiellement d'unités silteuses, de niveaux évaporitiques, de dolérites et d'argiles (fig. 2).

Ces terrains triasiques renferment le plus important gisement gazifère du Maroc découvert en 1980 dans la région de Meskala (Hafid, 1999).

En général le Trias marocain compte d'importants gisements salifères qui n'affleurent que rarement en raison de leur dissolution en surface. Dans notre secteur, ces séries salifères varient d'épaisseur suivant les endroits.

III. — METHODES ET SECTEUR D'ETUDE

L'exploitation empirique des données diagraphiques consiste à représenter chaque paramètre par une courbe ou divers paramètres qui en dérivent, puis à comparer les figures ou paramètres obtenus entre eux. De même, il est possible de synthétiser la corrélation entre les différentes variables dans un nuage de points. Une droite de régression peut être ajustée pour représenter la meilleure synthèse de la relation linéaire entre les variables (prises deux à deux). Ces méthodes sont parlantes, mais fastidieuses et non exemptes d'arbitraire. Pour remédier à cela, nous avons opté pour l'utilisation des analyses multivariées.

1) Utilisation des analyses multivariées

Il est à rappeler que les principaux objectifs des techniques d'analyses multivariées sont : (1) de réduire le nombre de variables et (2) de détecter la structure des

relations entre variables, ce qui revient à classifier les variables. Par conséquent, les analyses multivariées sont appliquées comme des méthodes de synthèse des données (réduction), ou de détection de structure.

Ces analyses consistent essentiellement à établir quelles sont les relations existant entre les observations, entre les variables, et entre les observations et les variables. A cette fin, l'analyse en composantes principales est un outil permettant une meilleure présentation de nos données. Elle a comme objectif (1) de résumer les informations contenues dans un fichier de données quantitatives, (2) de créer de nouvelles variables synthétisant les principales variables d'origine (appelées axes factoriels), (3) de fournir une représentation graphique permettant une interprétation facile des résultats (Dassonville, 1990, 1993).

2) Le choix des diagraphies

Les diagraphics sont un enregistrement en continu d'une propriété physique le long des parois d'un forage. Elles constituent un outil très précieux permettant la caractérisation des matériaux en place. Ainsi, les diagraphies permettent une assistance remarquable dans la situation et dans l'évaluation des formations géologiques (réservoirs d'hydrocarbures, séquences sédimentaires,...). Elles donnent une image continue de la succession des couches traversées par un sondage et, grâce aux corrélations entre puits qu'elles permettent d'établir, elles donnent une idée de la répartition géographique des faciès.

Les différents paramètres utilisés dans notre étude sont :
le Gamma Ray, le sonique, la densité, le neutron et la résistivité auxquels nous ajoutons la profondeur de chaque échantillon .

3) Le secteur d'étude et le forage choisi

Dans notre étude, nous nous intéressons aux différents forages du bassin d'Essaouira. Au sein de ces forages nous avons ciblé notre étude sur le Trias de la région de Meskala et plus précisément le forage Mkl-102, dont les coordonnés sont les suivants : X : 116 067 et Y : 102 722

Le forage MKL-102, effectué entre 1981 et 1982, a été choisi afin de reconnaître l'existence du réservoir gréseux du Trias, ainsi que les réservoirs calcaires du Dévonien et des siltstones du Silurien-Ordovicien.

IV. — ANALYSES

L'ensemble des mesures des paramètres des diagraphies est la seule information dont nous disposons. Ces diagraphies présentent des avantages résidant essentiellement dans :

- la continuité de l'observation
- la quantification des paramètres permettant leur traitement par des moyens informatiques.

Les variables (paramètres diagraphiques) n'étant pas toutes exprimées dans la même unité, elles n'ont pas toutes le même poids ou importance. Signalons d'abord que les caractéristiques (moyennes et écarts-types) des distributions sont très différentes ; cette hétérogénéité ne facilitera pas l'analyse de faciès entre les échantillons car une même différence pour deux paramètres (variables) distincts n'aura pas la même signification. Afin d'éviter ce problème, nous travaillons sur les données **centrées réduites**. De ce fait, toutes les variables ont la même moyenne (données centrées : M=0) et le même écart-type (données réduites : σ=1). Ainsi, la précision des résultats sera d'autant plus grande que les données seront homogènes et exhaustives.

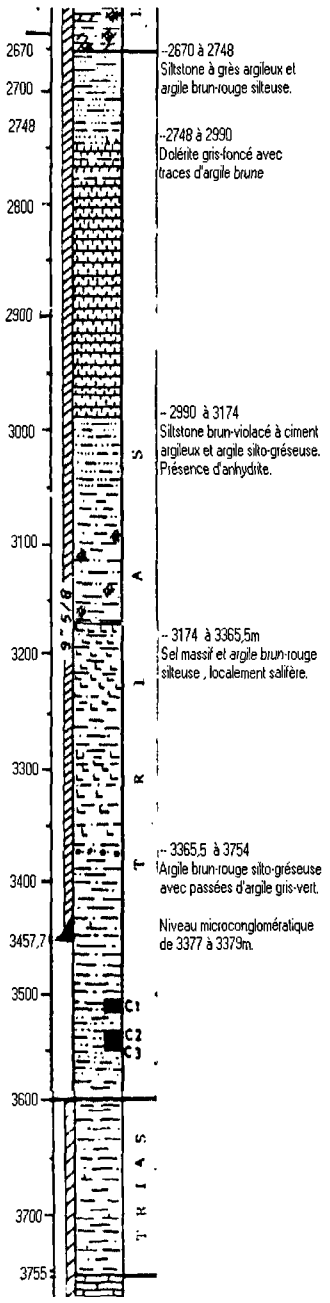

Fig. 2. — Log stratigraphique du puits Mkl 102.

Fig. 2. — Stratigraphic log of the well Mkl 102.

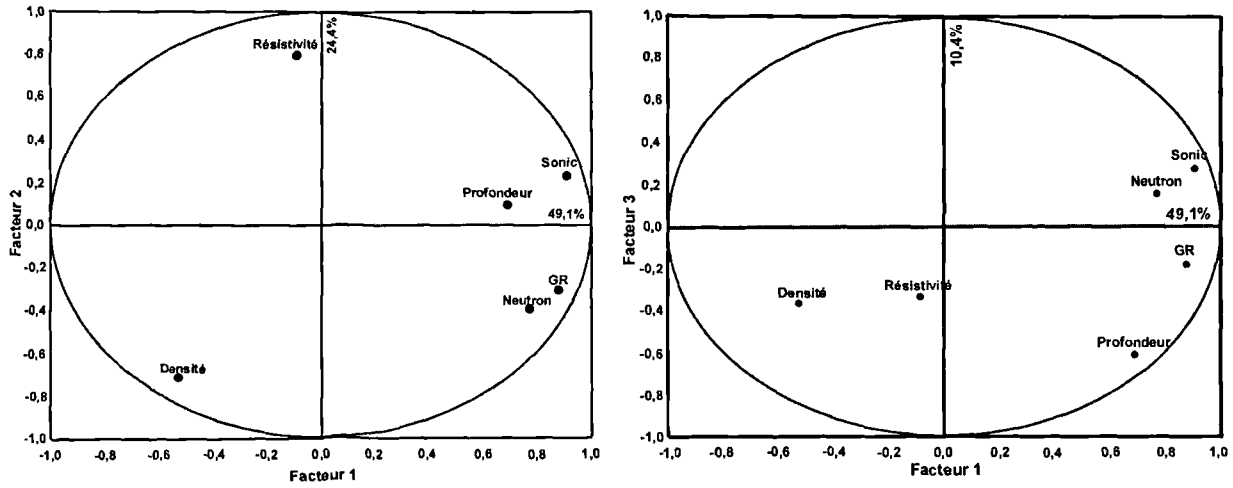

Fig.3. — Cercles de corrélations du premier facteur avec les facteurs 2 et 3.

Fig. 3. — Circles of correlations of the first factor with factors 2 and 3.

Afin de limiter l'incertitude quant à la représentativité de l'échantillonnage, nous avons opté pour un pas d'échantillonnage de 25 cm sur une profondeur de 1095m.

La représentation graphique des 4381 individus dans les plans factoriels est bien matérialisée. En effet chaque individu nous intéresse non pas en tant qu'individu mais en tant que "représentant d'un type de faciès présent dans le secteur.

Etude des variables :

Dans notre étude, les pourcentages de variance expliquée par les quatre premiers axes sont respectivement de :

49.1% - 24.4% - 12.4% - 10.0%.

Ainsi nous recueillons 49.1 % de l'inertie globale du nuage sur le premier axe factoriel et 24.4% sur le deuxième axe (fig. 3). Ces résultats doivent par ailleurs s'apprécier en tenant compte de la dimension de l'espace dans lequel le nuage est construit (Dimension 6). Si la dispersion du nuage était homogène dans les 6 directions orthogonales du repère principal d'inertie, chaque axe correspondrait à un pourcentage de variance égal à 100 / 6 =16.666 %.

Le pourcentage de variance expliquée par le premier plan est de 73.5%, ce qui représente une bonne qualité de représentation du nuage dans ce premier plan. Autrement dit, 73.5% des différences de comportement entre les six paramètres sont globalement expliquées par les deux premiers facteurs.

Le premier axe (dit premier axe factoriel) est associé au premier facteur qui intègre pour l'essentiel les variables ' le gamma ray ', ' le neutron ', ' le sonic' et ' la profondeur '. Cet axe présente un effet de taille puisque toutes les variables ont tendance à être positivement corrélées les unes aux autres. Ce premier axe est, par définition, celui qui permet la meilleure différenciation lithofaciologique au sens diagraphique du terme. La disposition des observations le long de cet axe confirme cette interprétation puisqu'on retrouve les roches denses et résistantes à gauche sur le graphe et les roches (argiles et silts) à droite et les intermédiaires au centre (a et b, fig. 4).

Le deuxième axe (deuxième axe factoriel) est lui même associé à une variable composite (le deuxième facteur ou deuxième composante factoriel) non corrélée linéairement à la variable composite précédente et il intègre pour l'essentiel les variables 'densité' et 'résistivité'. La position des variables le long de cet axe est essentiellement liée à la conductivité électrique, à la densité permet d'interpréter ce deuxième facteur comme le facteur de la dynamique du sel dans les couches formant la série.

Ainsi, nous remarquons que le premier axe factoriel individualise très bien les différentes formations argileuse, silteuse et même les dolérites. Quant au second axe factoriel, il caractérise la formation salifère et il la subdivise en trois sous-unités :

1) la première unité allant de 3169.50m à 3230.00m

2) la deuxième unité va de 3230.00m à 3303.75m

3) la dernière unité va de 3303.75m à 3364.25m

La première et la dernière unité présentent des valeurs de résistivités plus importantes que la seconde, ce qui donne une idée sur la relation entre les dépôts de sel, la compaction et la subsidence qu'a connus le bassin.

Cette série salifère est caractérisée par sa faible porosité qui explique ses moyennes à fortes résistivités et une faible radioactivité. La faible porosité confirme la compaction de la série.

Le plan factoriel (1x3) de la figure 4b, nous montre une distinction spatiale des différents groupes lithofaciologiques. Celle-ci est marquée par une stratification de ces groupes lithofaciologiques suivant le troisième axe factoriel qui est corrélé avec la profondeur.

La figure 5 présente une synthèse de la participation des différents axes factoriels. Ainsi, elle fournit une coupe montrant la disposition d'axe factoriel dominant, en fonction de la profondeur, ce qui traduit la signification des trois premiers facteurs et dessine la répartition des différents faciès.

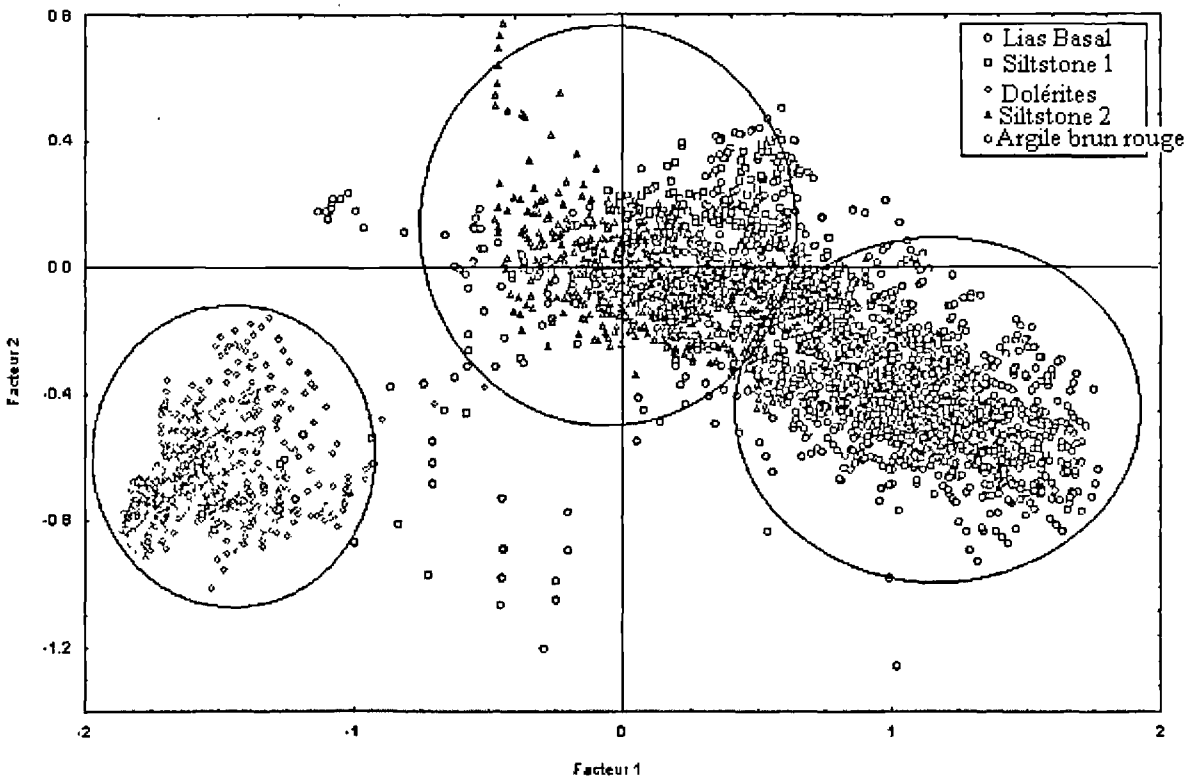

Fig.4a. — Plan factoriel représentatif du puits Mkl 102 : plan 1x2.

Fig. 4a. — Factorial plane representative of the well Mkl 102: 1x2 plane.

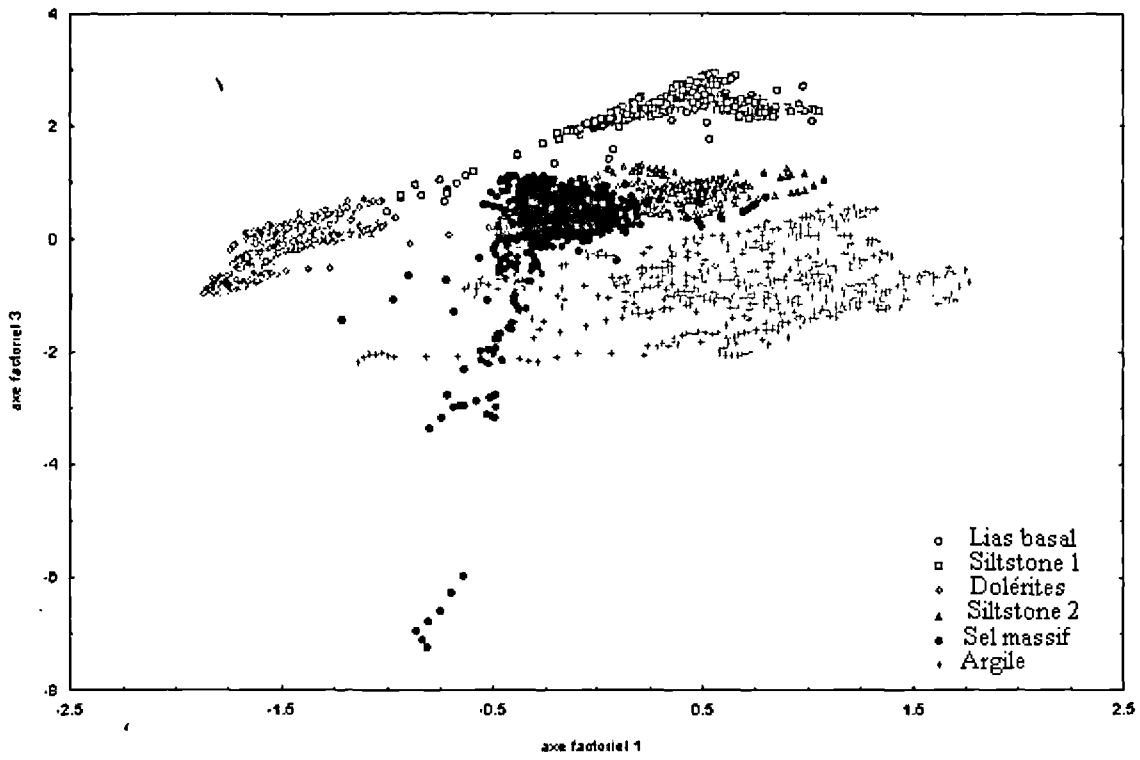

Fig.4b. — Plan factoriel (1x3) représentatif du puits Mkl-102

Fig. 4b. — Factorial plane (1x3) representative of the well Mkl-102 well.

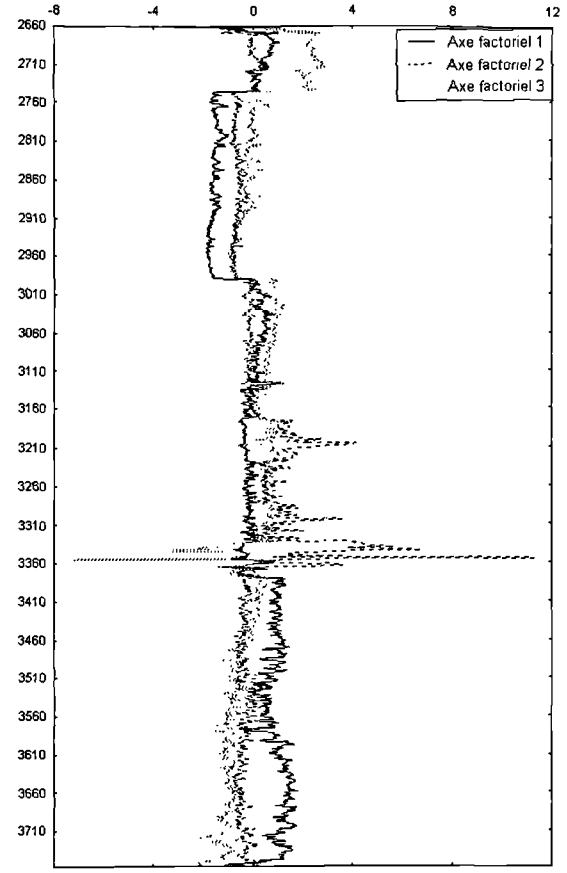

Fig 5. — Représentation des trois premiers axes factoriels du forage MKL102.

Fig. 5. — Representation of the first three factorial axes of the drilling MKL102.

V. — CONCLUSION

Cette étude nous a permis de mettre en évidence les relations existant entre les différents paramètres diagraphiques. Elle indique aussi une répartition temporelle en présentant les différentes affinités existant entre les échantillons le long du forage.

En effet, les paramètres mesurés en continu sur environ 1095 m de profondeur ont permis par les techniques d'analyses statistiques multivariées de visualiser les différents groupes qui composent la séquence lithostratigraphique : la transition sédiment-dolérites vers 2745.50m est notamment très bien marquée, au lieu de 2748m indiquée dans le log habillé. De même, les traitements individualisent bien les sédiments évaporitiques.

La position des argiles et des siltstones révèle un milieu de sédimentation de très basse énergie, de type fluviatile, deltaïque ou lagunaire, en concordance avec l'hypothèse de comme le propose Rompetrol (1983).

Compte tenu de ces résultats, nous pouvons répertorier le nombre d'individus concernés dans l'individualisation de chaque axe factoriel et de calculer le pourcentage d'intervention dans cette individualisation. Cette tentative sera faite par la suite dans le cadre global du bassin et en étudiant les différents secteurs.

La prise en considération d'autres descripteurs (par exemple la nature des formations, l'existence ou l'absence d'hydrocarbure, nature de ce dernier, ...) pourrait permettre d'approfondir nos connaissances sur l'énergie de l'environnement sédimentaire, sur la diagenèse ainsi que sur la paléogéographie de tout le bassin d'Essaouira.

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