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The ammonoids from the Grès du Kahla supérieur of Timimoun (Middle-early Late Tournaisian; Gourara, Algeria)

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Abstract

The ammonoids from two very prolific horizons in the upper Kahla Sandstone (Tournaisian, Early Carboniferous) of Timimoun (Gourara, Algeria) are described monographically. Nine new ammonoid species are introduced: *Imitoceras altilobatum* n. sp., *Triimitoceras amplisellatum* n. sp., *Kazakhstania inequalis* n. sp., *Acrocanites imperfectus* n. sp., *Xinjiangites scalaris* n. sp., and *Becanites canalifer* n. sp. from the North African *Kazakhstania-Acrocanites* Assemblage as well as *Acrocanites recurvus* n. sp., *Becanites singularis* n. sp., and *Becanites inflateralis* n. sp. from the *Pericyclus-Progoniatites* Assemblage. The first of these is one of the most diverse ammonoid faunas known from this time interval.

Introduction

Middle and early Late Tournaisian ammonoids belong to the poorest known representatives in the Palaeozoic history of the clade. In some regions with otherwise rich Early Carboniferous ammonoid records, this time interval is represented by black shales and cherts, which are extremely poor in macrofossils. Therefore, ammonoid faunas from this interval are reported from only a few regions.

Missouri – The Chouteau Limestone and Northview Shale yielded ammonoid faunas (Smith 1903; Miller & Collinson 1951), which probably belong in the Middle Tournaisian or earliest Late Tournaisian. From these two formations, the genera *Imitoceras*, *Masonoceras*, *Gattendorfia* (?), *Prodromites*, *Xinjiangites*, *Goniocyclus* (restricted to the Chouteau Limestone), and *Protocanites* are known.

Indiana – The Rockford Limestone was very productive for ammonoid faunas (Hall 1860; Miller 1891; Gutschick & Treckman 1957); they most likely come from the earliest Late Tournaisian. The fauna is composed of the genera *Imitoceras*, *Gattendorfia*, *Prodromites*, *Muensteroceras*, and *Protocanites*. Its similarity to the fauna of the Chouteau Limestone led Miller & Collinson (1951) to assume that the two are time equivalents.

Kentucky – Early, middle, and late Osagean ammonoid assemblages (Work & Mason 2003, 2004, 2005) show a succession similar to the occurrences in Algeria. The Cave Run Lake fauna (Nancy Member of the Borden Formation; early Osagean) with *Kazakhstania*, *Furnishoceras*, and *Muensteroceras* (Work & Mason 2005) probably represents a time equivalent of the lower assemblage from the Grès de Kahla supérieur.

Belgium – The assemblages first described by de Koninck (1844, 1880) and later revised by Delépine (1940) from the Calcaire de Vaulx and the Calcaire de Calonne contain the genera *Acrocanites*, *Xinjiangites*, and *Becanites* (Calcaire de Vaulx) as well as *Imitoceras*, *Pericyclus*, *Xinjiangites*, *Temertassetia*, *Jerania*, *Bouhamedites*, and *Progoniatites* (Calcaire de Calonne); they have probably an earliest Late Tournaisian age.

Thuringia – Phosphatic nodules in the Rußschiefer near Zadelsdorf yielded ammonoids of the genera *Gatten-*

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dorfia, *Pericyclus*, *Acrocanites*, *Xinjiangites*, *Stenocyclus*, *Progoniatites*, and *Becanites* (?) (Schindewolf 1922, 1926, 1939). This appears to be a mixed fauna, of which at least some elements have a Late Tournaisian age.

Montagne Noire – The Horizon à Lydiennes (Lydiennes Formation) yielded a small ammonoid fauna with *Globimitoceras*, *Gattendorfia*, *Goniocyclus*, *Nigrocyclus*, and *Eocanites* (Böhm 1935; Korn & Feist 2007); this fauna suggest that a Middle Tournaisian age is represented.

Kazakhstan – Librovitch (1940) described species of the genera *Acutimitoceras*, *Paragattendorfia* (?), *Gattendorfia*, *Karagandoceras*, *Kazakhstania*, *Xinjiangites*, *Asiacyclus*, and *Eocanites* from the Kassini Beds and the genera *Asiacyclus*, *Xinjiangites*, and *Terektytes* from the Terekty Beds. The Kassini Beds in particular yielded an assemblage similar to the Grès de Kahla supérieur.

North Xinjiang – The lower Heishantou (Donggulobasitao) Formation contains a rich ammonoid fauna with the genera *Gattendorfia*, *Kazakhstania*, *Xinjiangites*, *Pericyclus*, *Zhifangoceras*, *Protocanites*, and *Becanites* (Sheng 1984; Liang & Wang 1988, 1991; Ruan 1995). Parts of this fauna are, in its genus composition, very similar to the assemblage from the Grès de Kahla supérieur.

New South Wales – *Xinjiangites* and *Protocanites* occur in the Namoi Formation together with a prionoceratid (Delépine 1941; Campbell et al. 1983). The fauna may be a time equivalent of the Grès de Kahla supérieur.

North African ammonoid faunas from the Middle and early Late Tournaisian have been described from various places:

- Area of Taouz in the Tafilalt (Anti-Atlas) – Faunas from the lower part of the Oued Znaïgui Formation yielded the genera *Acutimitoceras* (?), *Gattendorfia*, *Jdaidites*, *Goniocyclus*, and *Protocanites* (Korn et al. 2002, 2007); they can be attributed to the Middle Tournaisian.
- Aguelmous, Ma'der region (Anti-Atlas) – time equivalent faunas contain *Globimitoceras*, *Goniocyclus*, and *Protocanites* (Ebbighausen & Bockwinkel, 2007).

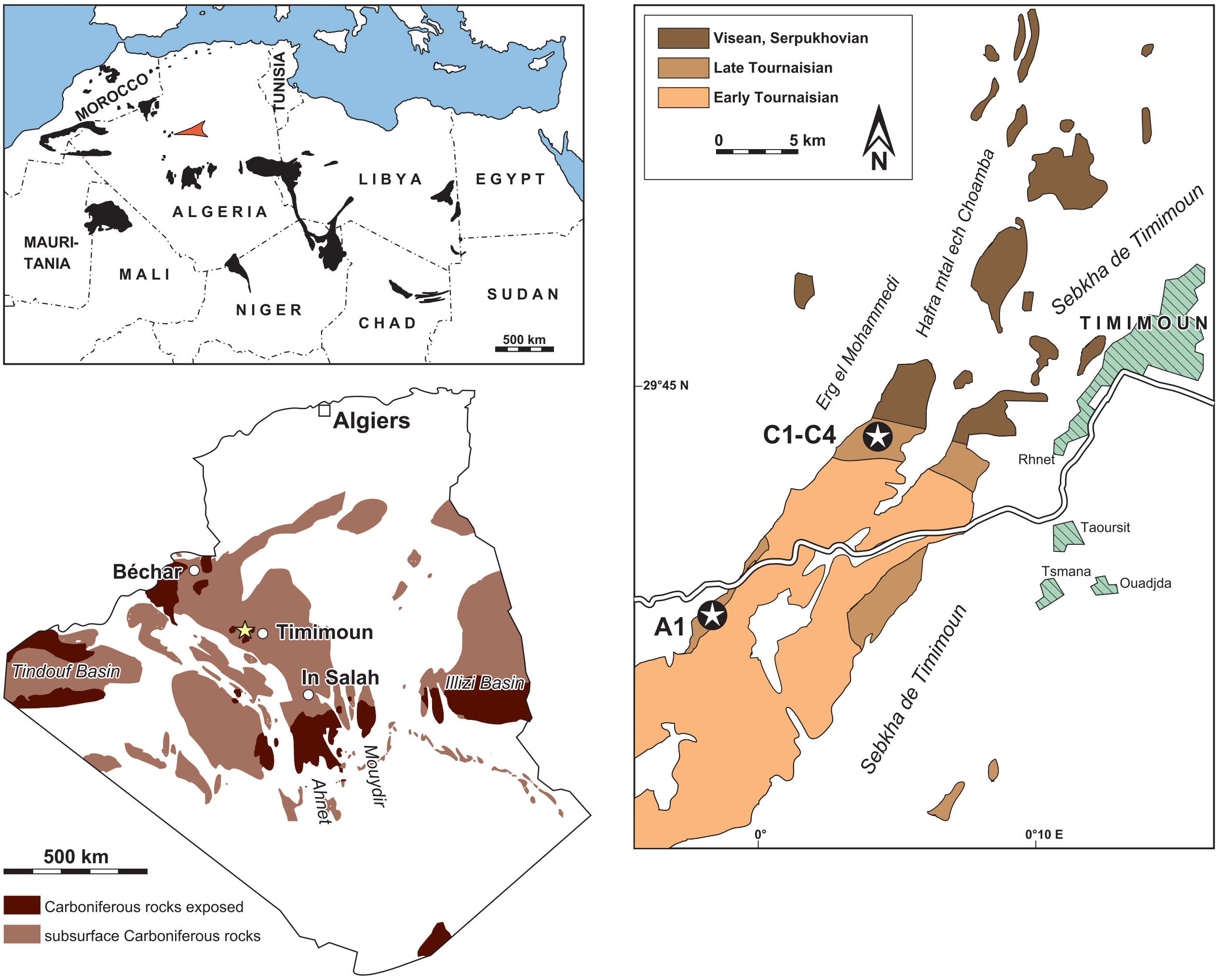

Figure 1. The outcrop of Palaeozoic rocks in northern Africa and Iberia and the geographic position (marked by an asterisk) of the fossil localities in the Grès de Kahla supérieur near Timimoun.

- Oued Smide north of the Ma'der – another small fauna with only *Gattendorfia* and *Acrocanites* was described by Korn et al. (2007).
- Area of Taouz in the Tafilalt (Anti-Atlas) – The fauna from the middle part of the Oued Znaïgui Formation is composed of *Irinoceras*, *Triimitoceras*, *Muensteroceras*, *Mouydiria*, *Ouaoufilalites*, *Bouhamedites*, *Progoniatites*, *Pericyclus*, *Helicocyclus*, *Jerania*, and *Becanites* (Korn et al. 2003a). This fauna has an early Late Tournaisian age and can be interpreted as time equivalent with the younger of the here described faunas (i.e. samples TIM-A1 and TIM-C1).
- Area of Timimoun (Gourara, Algeria) – The fossiliferous section was discovered by Meyendorff (1939), who mentioned Early Tournaisian ammonoids (Ebbighausen et al. 2004). Some ammonoids from the Grès de Kahla supérieur were figured by Conrad (1984). These represent the genera *Acrocanites* and *Becanites*. New findings from this locality will be described in this article. The problematicum *Duodecimedusina stella* has already been described by Korn et al. (2008).
- Oued Temertasset and Hassi Habadra in the Mouydir (Algeria) – the Argiles de Teguentour are already well known for their ammonoid faunas (Termier & Termier 1950; Follot 1953; Conrad & Pareyn 1968; Conrad 1984). In these articles, only species of the genera *Imitoceras*, *Pericyclus*, *Muensteroceras*, *Rotopericyclus*, and *Progoniatites* were figured. A detailed monographic description of the fauna will be published in a parallel article (Korn et al. 2010).

Geological setting

The ammonoid faunas described here come from two localities 28 and 15 km west-southwest of Timimoun (Gourara, western Algeria), at the south-western margin of the Grand Erg Occidental (Figs 1, 2). Carboniferous sedimentary rocks are exposed between the sand dunes of the Grand Erg, extending over a distance of approximately 40 km in a SW–NE erosion window that ranges in width between a few hundreds of metres and 10 km. The rocks are gently inclined towards the north-east. Their succession (Conrad 1984) consists mainly of shales with several intercalated sandstone formations; carbonates are very rare and restricted to distinct horizons.

The Carboniferous succession of Timimoun begins with the Grès de Kahla, a more than 300 m thick succession of shales with prominent sandstone intercalations, of which the lower portion at least partly has a Late Devonian age (Conrad 1984). The Grès de Kahla supérieur has a thickness of about 80 m and contains two major shaly portions, of which the lower one yielded a fauna of the *Gattendorfia*-*Kahlacanites* Assemblage (Ebbighausen et al. 2004; Korn et al.

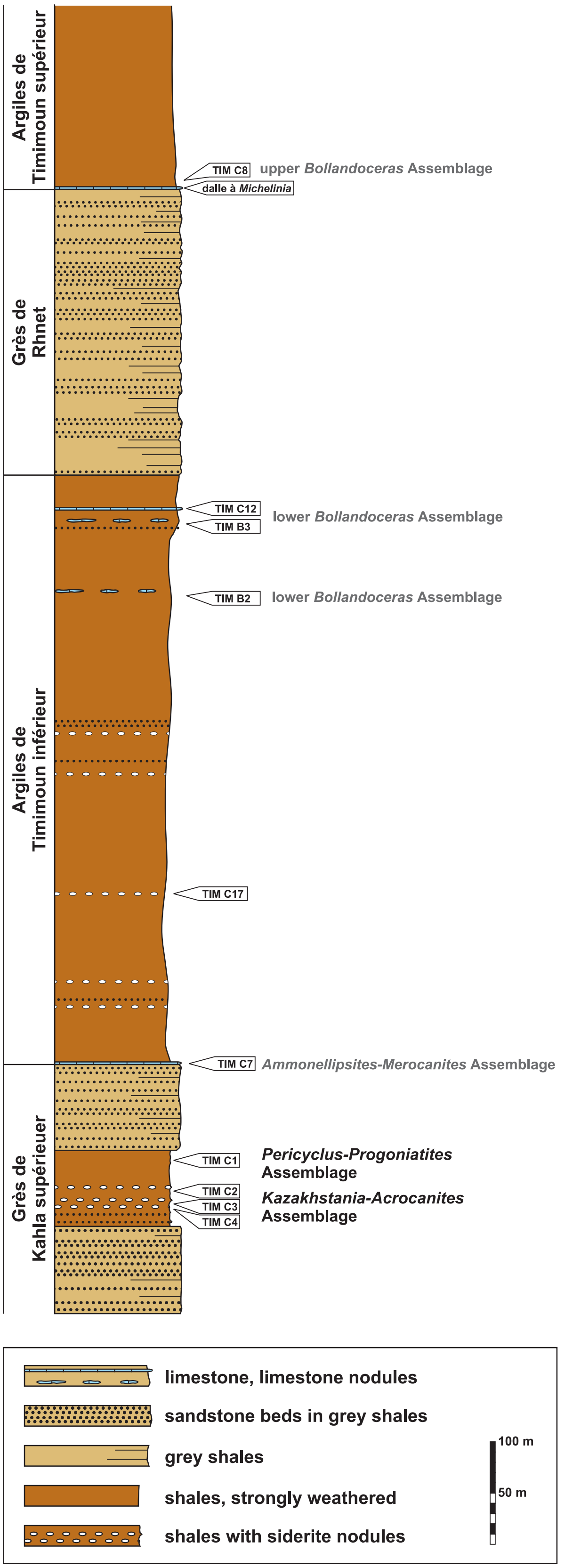

Figure 2. Stratigraphic section of the Early Carboniferous (Mississippian) rock succession near Timimoun with the position of the assemblages from the Grès de Kahla supérieur (After Ruzhencev & Bogoslovskaya 1971; Riley 1990; Korn et al. 2004, 2007). For a description of the faunas from the *Ammonellipsites-Merocanites* Assemblage and *Bollandoceras* assemblages, see Ebbighausen et al. (2010) and Bockwinkel et al. (2010).

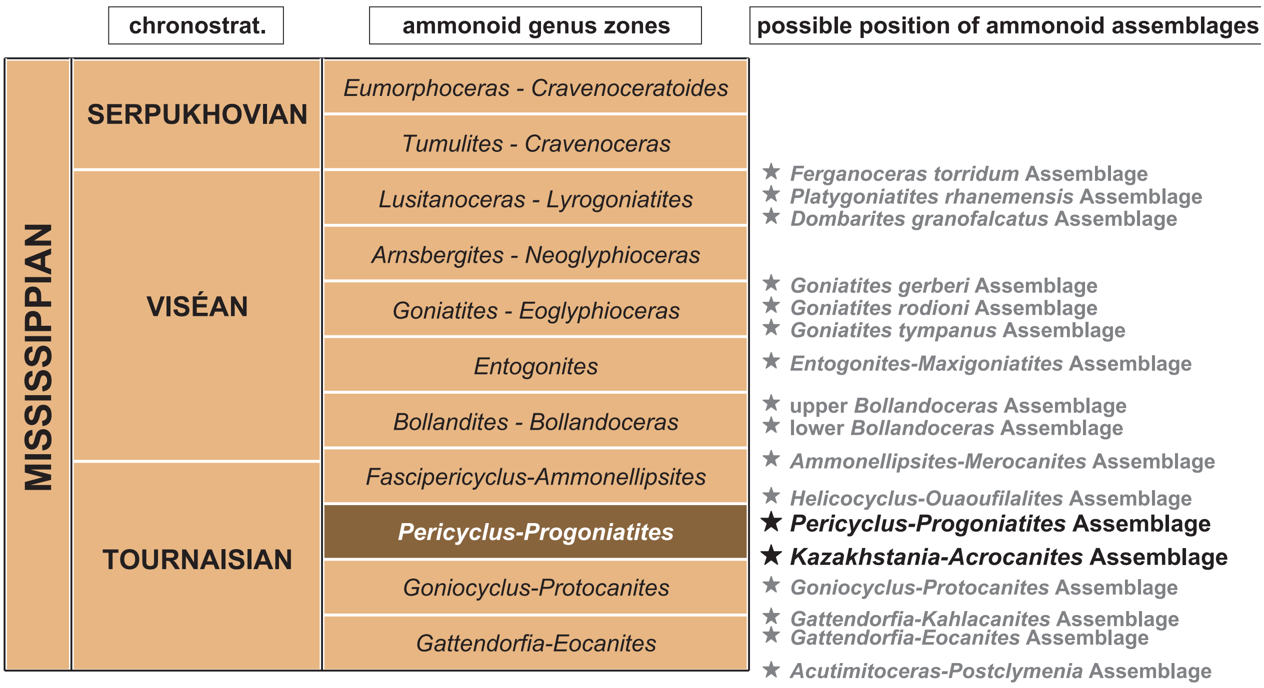

Figure 3. Stratigraphic scheme of the Early Carboniferous (Mississippian) chronostratigraphy and ammonoid zonation, with correlation of the North African ammonoid assemblages (after Korn et al. 2004, 2007). Highlighted the position of the assemblages from the Grès de Kahla supérieur.

2007). In the upper of the two shaly intervals, four horizons with ammonoids were discovered, of which the lower three contain a fauna of the *Kazakhstania-Acrocanites* Assemblage and the upper one belongs to the *Pericyclus-Progoniatites* Assemblage (Fig. 3). The faunas of the higher fossiliferous horizons (Dalle à *Merocanites* and Argiles de Teguentour) are described in parallel (Ebbighausen et al. 2010; Bockwinkel et al. 2010).

Biostratigraphy and palaeogeography

The lower of the newly described faunas has, with its generic composition including *Kazakhstania*, an unquestionably position between the horizons bearing *Goniocyclus* and *Pericyclus*, and therefore, a position near the Middle-Late Tournaisian boundary is most likely. However, it cannot be stated here with certainty if this fauna has a Middle or Late Tournaisian age.

A comparable fauna with *Kazakhstania*, but with the endemic *Furnishoceras* and true *Muensteroceras* is known from the Borden Formation of Kentucky (Work & Mason 2005); this was dated by conodonts as *multistriatus* Zone, i.e. with a position within the early Ivorian (= basal Late Tournaisian) of the Belgian chronostratigraphic scheme.

In Europe, the faunas of the Calcaire de Vaulx and Calcaire de Calonne are most similar to the assemblages described here, with the first being a time equivalent of the lower assemblage (*Kazakhstania-Acrocanites* Assemblage) and the latter being an equivalent of the upper assemblage (*Pericyclus-Progoniatites* Assemblage).

Material

At total of more than 2,900 specimens were studied from the Grès de Kahla supérieur. They come from two main localities (TIM-A and TIM-C, the latter section containing TIM-C4, TIM-C3, TIM-C2, and TIM-C1 in ascending order; Fig. 2). The material is deposited in the cephalopod collection of the Museum für Naturkunde, Berlin (MB.C. prefix).

28 km west-southwest of Timimoun, locality and sample TIM-A1 (29.1308° N; 0.0212° W):

Imitoceras dimidium Korn, Bockwinkel & Ebbighausen, 2010	9 specimens (MB.C.18638.1–9)
Triimitoceras tantulum Korn, Bockwinkel & Ebbighausen, 2010	1 specimen (MB.C.18639)
Acrocanites recurvus n. sp.	8 specimens (MB.C.18640.1–8)
Pericyclus circulus Korn, Bockwinkel & Ebbighausen, 2010	5 specimens (MB.C.18641.1–5)
Pericyclus trochus Korn, Bockwinkel & Ebbighausen, 2010	37 specimens (MB.C.18642.1–37)
Pericyclus intercisus Korn, Bockwinkel & Ebbighausen, 2010	6 specimens (MB.C.18643.1–6)
Ouaoufilalites creber Korn, Bockwinkel & Ebbighausen, 2010	2 specimens (MB.C.18644.1–2)
Temertassetia coarta Korn, Bockwinkel & Ebbighausen, 2010	52 specimens (MB.C.18645.1–52)
Muensteroceras subparallelum Korn, Bockwinkel & Ebbighausen, 2010	322 specimens (MB.C.18646.1–322)
Mouydiria scutula Korn, Bockwinkel & Ebbighausen, 2010	10 specimens (MB.C.18647.1–10)
Dzhaprakoceras vergum Korn, Bockwinkel & Ebbighausen, 2010	10 specimens (MB.C.18648.1–10)

Progoniatites globulus Korn, Bockwinkel & Ebbighausen, 2010	12 specimens (MB.C.18649.1–12)
Becanites singularis n. sp.	1 specimen (MB.C.18650)
Becanites inflateralis n. sp.	6 specimens (MB.C.18651.1–6)
15 km west-southwest of Timimoun, locality and sample TIM-C4 (29.2264° N; 0.0811° E):	
Xinjiangites scalaris n. sp.	40 specimens (MB.C.18652.1–40)
15 km west-southwest of Timimoun, locality and sample TIM-C3 (29.2264° N; 0.0811° E):	
Imitoceras altilobatum n. sp.	8 specimens (MB.C.18653.1–8)
Triimitoceras amplisellatum n. sp.	16 specimens (MB.C.18654.1–16)
Kazakhstania inequalis n. sp.	656 specimens (MB.C.18655.1–656)
Acrocanites imperfectus n. sp.	25 specimens (MB.C.18656.1–25)
Xinjiangites scalaris n. sp.	650 specimens (MB.C.18657.1–650)
Becanites canalifer n. sp.	3 specimens (MB.C.18658.1–3)
15 km west-southwest of Timimoun, locality and sample TIM-C2 (29.2264° N; 0.0811° E):	
Imitoceras altilobatum n. sp.	4 specimens (MB.C.18659.1–4)
Triimitoceras amplisellatum n. sp.	26 specimens (MB.C.18660.1–26)
Kazakhstania inequalis n. sp.	39 specimens (MB.C.18661.1–39)
Acrocanites imperfectus n. sp.	274 specimens (MB.C.18662.1–274)
Xinjiangites scalaris n. sp.	223 specimens (MB.C.18663.1–223)
Becanites canalifer n. sp.	54 specimens (MB.C.18664.1–54)
Sample TIM-C2 + C3	
Kazakhstania inequalis n. sp.	9 specimens (MB.C.18665.1–9)
Acrocanites imperfectus n. sp.	3 specimens (MB.C.18666.1–3)
Xinjiangites scalaris n. sp.	19 specimens (MB.C.18667.1–19)
15 km west-southwest of Timimoun, locality and sample TIM-C1 (29.2264° N; 0.0821° E) (Fig. 4):	
Imitoceras dimidium Korn, Bockwinkel & Ebbighausen, 2010	26 specimens (MB.C.18668.3–26)
Imitoceras strictum Korn, Bockwinkel & Ebbighausen, 2010	2 specimens (MB.C.18669.1–2)
Acrocanites recurvus n. sp.	1 specimen (MB.C.18670)
Pericyclus tortuosus Korn, Bockwinkel & Ebbighausen, 2010	1 specimen (MB.C.18671)
Pericyclus circulus Korn, Bockwinkel & Ebbighausen, 2010	4 specimens (MB.C.18672.1–4)
Pericyclus trochus Korn, Bockwinkel & Ebbighausen, 2010	15 specimens (MB.C.18673.1–15)
Pericyclus intercisus Korn, Bockwinkel & Ebbighausen, 2010	14 specimens (MB.C.18674.1–14)
Ouaoufilalites creber Korn, Bockwinkel & Ebbighausen, 2010	1 specimen (MB.C.18675)
Temertassetia coarta Korn, Bockwinkel & Ebbighausen, 2010	49 specimens (MB.C.18676.1–49)
Muensteroceras subparallelum Korn, Bockwinkel & Ebbighausen, 2010	252 specimens (MB.C.18677.1–252)
Dzhaprakoceras vergum Korn, Bockwinkel & Ebbighausen, 2010	14 specimens (MB.C.18678.1–14)
Becanites inflateralis n. sp.	4 specimens (MB.C.18679.1–4)

Systematic Palaeontology

The descriptive part of this monograph will mainly focus on the illustration and morphometric analysis of the species with particular attention to their ontogenetic development. Korn (2010) published the key for the description of the species, including explanation of methods. Sutural terminology follows Korn et al. (2003b).

Order **Goniatitida** Hyatt, 1884
Suborder **Tornoceratina** Wedekind, 1914
Superfamily **Prionocerataceae** Hyatt, 1884
Family **Prionoceratidae** Hyatt, 1884
Subfamily **Imitoceratinae** Ruzhencev, 1950

Imitoceras **Schindewolf, 1923**

Type species. Ammonites rotatorius de Koninck, 1844 (original designation).

Genus definition. Imitoceratinae with large discoidal conch, reaching a conch diameter of 150 mm. Conch subinvolute or subevolute in early juveniles; umbilicus closes completely early in ontogeny. Suture line with slightly pouched, often very narrow external lobe; ventrolateral saddle strongly asymmetric and ventrally inclined; adventive lobe strongly asymmetric and V-shaped with convex ventral flank and concave dorsal flank; adventive lobe much deeper than the external lobe.

Included species.
abundans: *Imitoceras abundans* Miller & Collinson, 1951, p. 460; Missouri.
altilobatum: *Imitoceras altilobatum* n. sp.; Gourara (Algeria).
brevilobatum: *Imitoceras brevilobatum* Miller & Collinson, 1951, p. 462; Missouri.
dimidium: *Imitoceras dimidium* Korn, Bockwinkel & Ebbighausen, 2010; Mouydir (Algeria).
discoidale: *Aganides discoidalis* Smith, 1903, p. 13; Iowa.
indianense: *Goniatites indianensis* Miller, 1891, p. 90; Indiana.

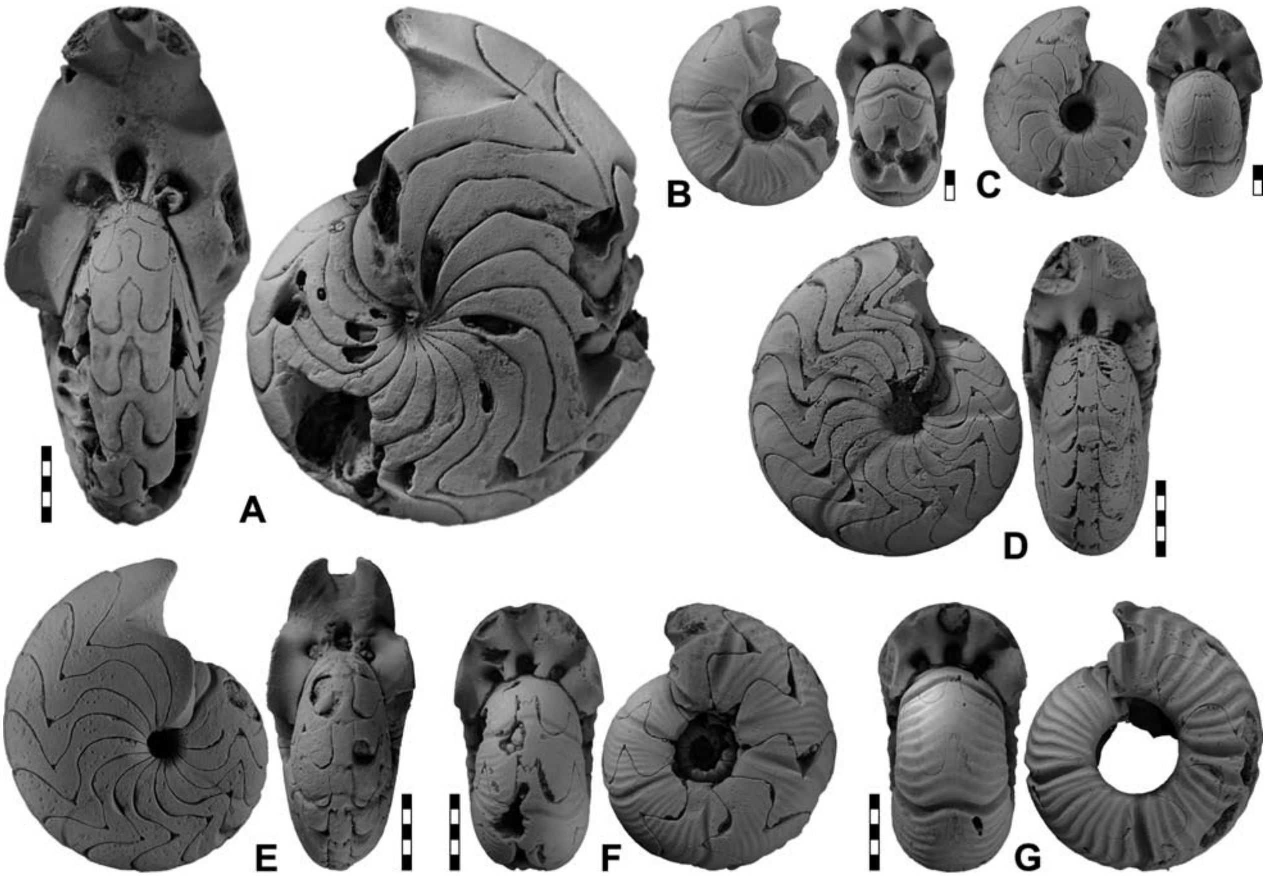

Figure 4. Selected ammonoids from locality TIM-C1; all ×2.0. **A.** *Imitoceras dimidium* Korn, Bockwinkel & Ebbighausen, 2010, specimen MB.C.18668.1. **B.** *Temertassetia coarta* Korn, Bockwinkel & Ebbighausen, 2010, specimen MB.C.18676.2. **C.** *Muensteroceras subparallelum* Korn, Bockwinkel & Ebbighausen, 2010, specimen MB.C.18677.2. **D.** *Muensteroceras subparallelum* Korn, Bockwinkel & Ebbighausen, 2010, specimen MB.C.18677.1. **E.** *Dzhaprakoceras vergum* Korn, Bockwinkel & Ebbighausen, 2010, specimen MB.C.18678.1. **F.** *Temertassetia coarta* Korn, Bockwinkel & Ebbighausen, 2010, specimen MB.C.18676.1. **G.** *Pericyclus intercisus* Korn, Bockwinkel & Ebbighausen, 2010, specimen MB.C.18674.1.

ixion: *Goniatites Ixion* Hall, 1860, p. 125; Indiana.
jessiae: *Goniatites Jessiae* Miller & Gurley, 1896, p. 46; Iowa.
lentiforme: *Imitoceras lentiforme* Miller & Collinson, 1951, p. 466; Missouri.
orientale: *Imitoceras orientale* Liang, 1976, p. 216; Tibet.
oxydentale: *Imitoceras oxydentale* Bockwinkel & Ebbighausen, 2006, p. 108; Anti-Atlas.
propinquus: *Goniatites propinquus* Winchell, 1862, p. 365; Michigan.
rotatorium: *Ammonites rotatorius* de Koninck, 1844, p. 565; Belgium.
sinuatum: *Aganides sinuatum* Gordon, 1965, p. 166; Arkansas.
strictum: *Imitoceras strictum* Korn, Bockwinkel & Ebbighausen, 2010; Mouydir (Algeria).
tardum: *Imitoceras tardum* Work & Nassichuk in Work, Nassichuk & Richards, 2000, p. 31; British Columbia.
wurmi: *Imitoceras Wurmi* Schindewolf, 1926, p. 71; Thuringia.
xizangense: *Imitoceras xizangense* Liang, 1976, p. 217; Tibet.

Discussion. Many of the species of *Imitoceras* require revision, and it is not clear if all the species listed above really belong to the genus. *Imitoceras* possesses a set of sutural characters that clearly separates it from other genera, (1) the slightly pouched external lobe, (2) the strongly asymmetric, ventrally inclined ventrolateral saddle, and (3) the asymmetric adventive lobe. *Irinoceras* Ruzhencev, 1947 has a much stronger pouched external lobe, and the possibly ancestral genus *Nicimitoceras* Korn, 1993 has a lanceolate external lobe. *Triimitoceras* Korn, Bockwinkel, Ebbighausen & Klug, 2003 has a rather symmetric adventive lobe and is also distinguished from *Imitoceras* by its conch ontogeny with a low whorl expansion rate.

Imitoceras altilobatum n. sp.

Figures 5, 6

Derivation of name. From the Latin altus (= deep) and lobus (= lobe), because of the rather deep external lobe.

Holotype. Specimen MB.C.18659.1, illustrated in Figure 5A.

Type locality and horizon. 15 km west-southwest of Timimoun, locality and sample TIM-C2 (Gourara, West Algeria); *Kazakhstania-Acrocanites* Assemblage.

Material. 10 specimens, conch diameter up to 18 mm.

Diagnosis. *Imitoceras* with thinly globular conch in the early juvenile stage, conch width index continuously reduced during ontogeny, conch thickly discoidal at 18 mm dm; early growth stage subinvolute, closure of the umbilicus at 5 mm dm; aperture low in juveniles and high in adults; margin broadly rounded, flanks converging towards the broadly rounded venter. Internal mould without constrictions. Suture line with slightly pouched, moderately deep external lobe; ventrolateral saddle strongly asymmetric, ventrally inclined; adventive lobe V-shaped and asymmetric with steeper ventral side.

Table 1. Conch ontogeny (Figs 6A, C–E) of *Imitoceras altilobatum* n. sp.

dm	conch shape	whorl cross section shape	aperture
2 mm	thinly globular; subinvolute (ww/dm ~ 0.90; uw/dm ~ 0.18)	moderately depressed; very strongly embracing (ww/wh ~ 1.90; IZR ~ 0.52)	low (WER ~ 1.65)
8 mm	thinly pachyconic; involute (ww/dm ~ 0.70; uw/dm ~ 0.02)	weakly depressed; very strongly embracing (ww/wh ~ 1.15; IZR ~ 0.50)	high (WER ~ 2.05)
18 mm	thickly discoidal; involute (ww/dm ~ 0.57; uw/dm ~ 0.02)	weakly compressed; very strongly embracing (ww/wh ~ 0.95; IZR ~ 0.46)	high (WER ~ 2.20)

Table 2. Conch dimensions (in mm) and proportions for reference specimens of *Imitoceras altilobatum* n. sp.

	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
holotype MB.C.18659.1	18.0	10.2	10.8	0.2	5.8	0.57	0.95	0.01	2.18	0.46
paratype MB.C.18653.1	12.9	8.6	7.9	0.3	4.3	0.66	1.08	0.02	2.23	0.46
paratype MB.C.18659.2	8.8	6.1	5.4	0.2	2.7	0.69	1.13	0.02	2.10	0.49

Table 3. Suture line proportions (Fig. 6B) for *Imitoceras altilobatum* n. sp.

specimen	at dm	EL w/d	EL/VLS	EL/AL	MS h	VLS w/h	remarks
holotype MB.C.18659.1	16.5 mm	0.32	0.53	0.56	0.00	0.60	A lobe slightly deeper than E lobe

Discussion. *Imitoceras altilobatum* differs from *I. dimidium* from the Mouydir in the deeper external lobe, the less asymmetric adventive lobe, and in the umbilicus, which is not funnel-shaped as in *A. dimidium*. *I. strictum* possesses steinkern constrictions and is thus clearly separated from *I. altilobatum*. *I. altilobatum* is, in comparable growth stages, stouter than the other two species (ww/dm ~ 0.60 in *I. altilobatum* and only 0.50 in *I. dimidium* and *I. strictum* at 15 mm dm).

I. ixion and *I. rotatorium* possess a stronger asymmetric adventive lobe with an incurved dorsal flank, in contrast to the almost straight dorsal flank in *I. altilobatum*.

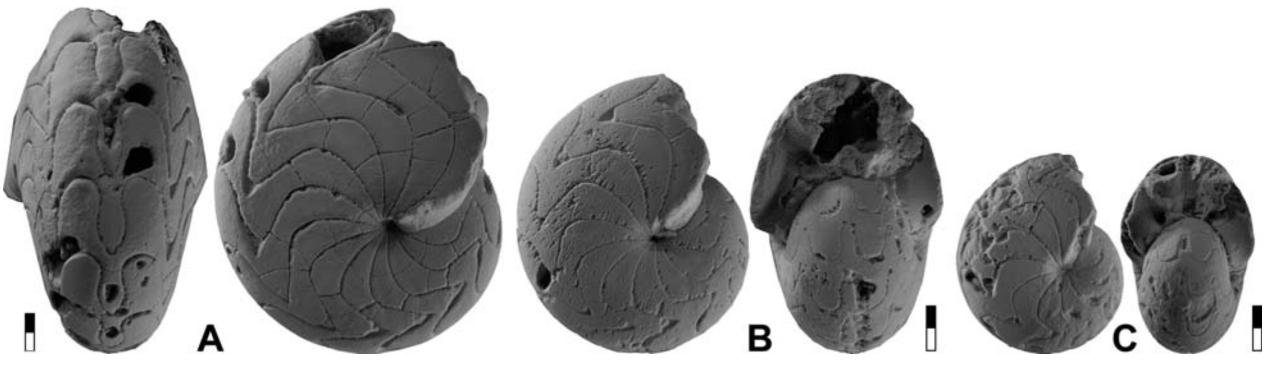

Figure 5. *Imitoceras altilobatum* n. sp. **A.** Holotype MB.C.18659.1 from locality TIM-C2; ×2.5. **B.** Paratype MB.C.18653.1 from locality TIM-C3; ×3.0. **C.** Paratype MB.C.18659.2 from locality TIM-C2; ×3.0.

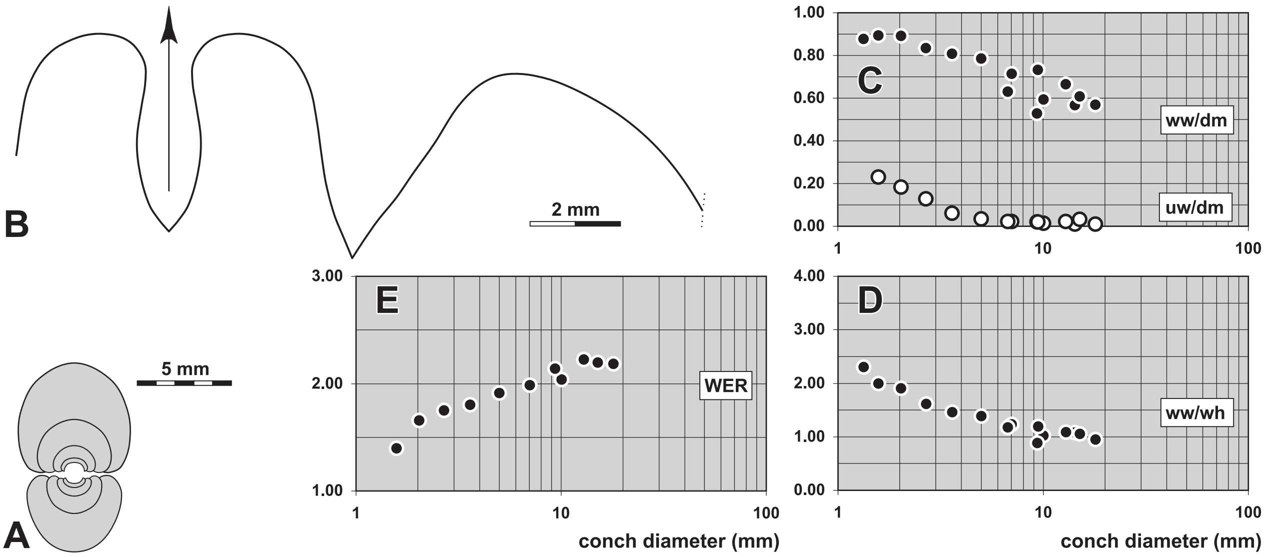

Figure 6. *Imitoceras altilobatum* n. sp. from locality TIM-C2. **A.** Cross section of paratype MB.C.18659.3; ×2.5. **B.** Suture line of holotype MB.C.18659.1, at 16.5 mm dm, 10.1 mm ww, 10.3 mm wh; ×6.0. **C–E.** Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh), and whorl expansion rate (WER) of all available specimens.

Triimitoceras Korn, Bockwinkel, Ebbighausen & Klug 2003

Type species. *Triimitoceras epiwocklumeriforme* Korn, Bockwinkel, Ebbighausen & Klug 2003 (original designation).

Genus definition. Imitoceratidae with discoidal conch that is triangularly coiled in juveniles. Aperture and whorl expansion rate usually low (WER 1.50 to 1.70) and rarely higher in adult conchs. Suture line with slightly pouched or lanceolate external lobe and large, V-shaped adventive lobe.

Included species.
amplisellatum: *Triimitoceras amplisellatum* n. sp.; Gourara (Algeria).
epiwocklumeriforme: *Triimitoceras epiwocklumeriforme* Korn, Bockwinkel, Ebbighausen & Klug, 2003, p. 79; Anti-Atlas (Morocco).
tantulum: *Triimitoceras tantulum* Korn, Bockwinkel & Ebbighausen, 2010; Mouydir (Algeria).

Discussion. *Triimitoceras* has a suture line typical for the family Imitoceratinae. As in *Imitoceras* Schindewolf, 1923, the external lobe of the type species is slightly pouched, the ventrolateral saddle is strikingly asymmetrical, and the adventive lobe is much deeper than the external lobe. However, the conch of *Triimitoceras* has a much lower aperture (WER less than 1.80 in contrast to *Imitoceras* with more than 2.25), and the conspicuous steinkern constrictions of the type species (see below) are not known in that strength from *Imitoceras*. The cardinal difference, of course, is the triangular coiling of the inner whorls of *Triimitoceras*, not known from any other Carboniferous prionoceratid.

Triimitoceras amplisellatum n. sp.

Figures 7, 8

Derivation of name. From the Latin amplus (= wide) and sella (= saddle), because of the wide dorsolateral saddle.

Holotype. Specimen MB.C.18660.1, illustrated in Figure 7B.

Type locality and horizon. 15 km west-southwest of Timimoun, locality and sample TIM-C2 (Gourara, West Algeria); *Kazakhstania-Acrocanites* Assemblage.

Material. 43 specimens, conch diameter of up to 24 mm.

Diagnosis. Triimitoceras with a thinly globular conch in the early juvenile stage, conch width index continuously reduced during ontogeny, conch thickly discoidal at 12 mm dm; early growth stage subinvolute, closure of the umbilicus at 5 mm dm; aperture low in juveniles and moderate in adults. Internal mould with concavo-convex constrictions with narrow and shallow ventral sinus; juvenile stage strongly tripartite caused by deep constrictions. Suture line with lanceolate, deep external lobe with slightly diverging flanks; ventrolateral saddle almost symmetric and broadly rounded; adventive lobe V-shaped, almost symmetric.

Discussion. Triimitoceras amplisellatum differs from *T. tantulum* mainly in the strongly tripartite inner whorls and in the higher aperture in comparable growth stages (WER = 1.60 in *T. tantulum* but 1.95 in *T. amplisellatum* at 15 mm dm). *T. epiwocklumeriforme* has a pouched external lobe in the adult suture line, which is lanceolate in *T. amplisellatum*.

Table 4. Conch ontogeny (Figs 8A–C, E–G) of *Triimitoceras amplisellatum* n. sp.

dm	conch shape	whorl cross section shape	aperture
2 mm	thinly globular; subinvolute (ww/dm ~ 0.90; uw/dm ~ 0.15)	moderately depressed; very strongly embracing (ww/wh ~ 1.90; IZR ~ 0.60)	low (WER ~ 1.60)
8 mm	thinly pachyconic; involute (ww/dm = 0.65–0.70; uw/dm ~ 0.02)	weakly depressed; very strongly embracing (ww/wh ~ 1.20; IZR ~ 0.58)	low to moderate (WER ~ 1.70–1.80)
16 mm	thickly discoidal; involute (ww/dm ~ 0.50; uw/dm ~ 0.02)	weakly compressed; very strongly embracing (ww/wh ~ 0.90; IZR ~ 0.50)	moderate (WER ~ 1.95)

Table 5. Conch dimensions (in mm) and proportions for reference specimens of *Triimitoceras amplisellatum* n. sp.

	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
paratype MB.C.18660.2	14.4	7.3	7.4	0.6	–	0.51	0.99	0.04	–	–
paratype MB.C.18660.6	11.1	6.8	6.2	0.2	3.1	0.62	1.10	0.02	1.93	0.50
holotype MB.C.18660.1	9.0	5.6	4.7	0.3	2.5	0.62	1.19	0.03	1.89	0.47

Table 6. Suture line proportions (Fig. 8D) for *Triimitoceras amplisellatum* n. sp.

specimen	at dm	EL w/d	EL/VLS	EL/AL	MS h	VLS w/h	remarks
holotype MB.C.18660.1	7.6 mm	0.36	0.41	0.68	0.00	0.88	dorsolateral saddle very wide

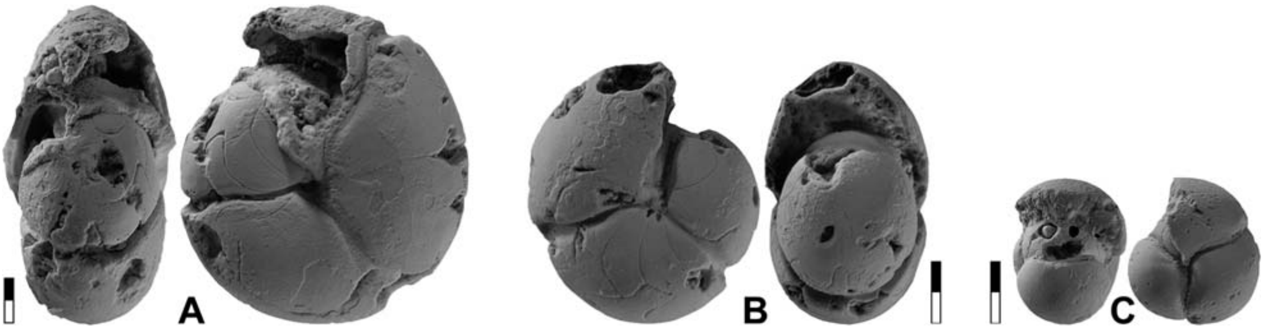

Figure 7. *Triimitoceras amplisellatum* n. sp. **A.** Paratype MB.C.18660.2 from locality TIM-C2; ×3.0. **B.** Holotype MB.C.18660.1 from locality TIM-C2; ×4.0. **C.** Paratype MB.C.18654.1 from locality TIM-C3; ×4.0.

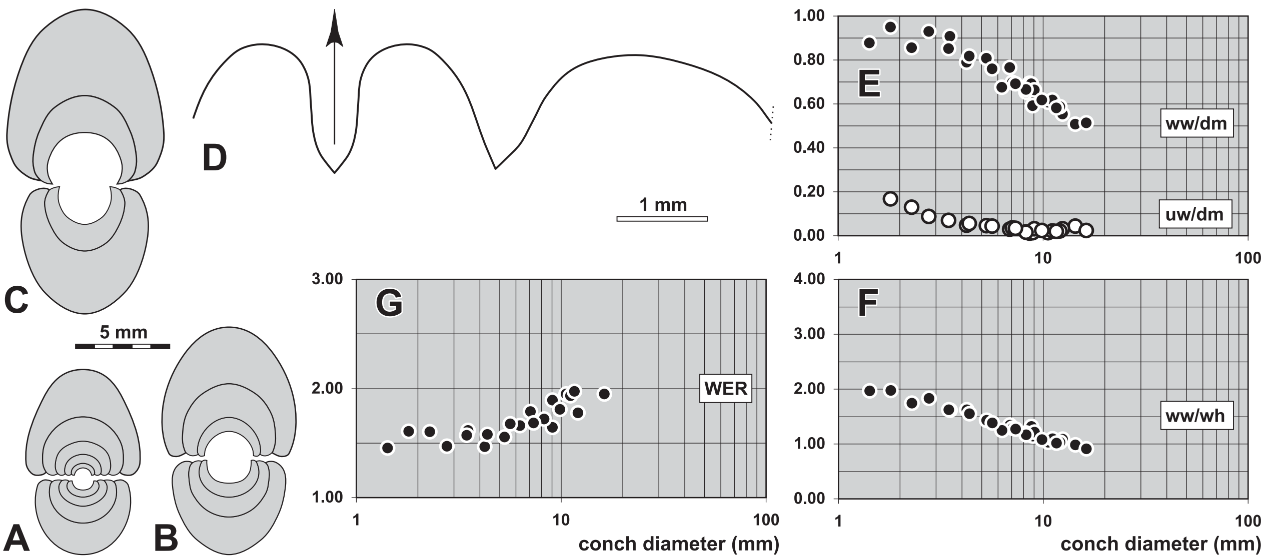

Figure 8. *Triimitoceras amplisellatum* n. sp. from locality TIM-C2. **A.** Cross section of paratype MB.C.18660.3; ×2.5. **B.** Cross section of paratype MB.C.18660.4; ×2.5. **C.** Cross section of paratype MB.C.18660.5; ×2.5. **D.** Suture line of holotype MB.C.18660.1, at 7.6 mm dm, 5.2 mm ww, 4.2 mm wh; ×12.0. **E–G.** Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh), and whorl expansion rate (WER) of all available specimens.

Family **Gattendorfiidae** Bartzsch & Weyer, 1987
Subfamily **Gattendorfiinae** Bartzsch & Weyer, 1987

Kazakhstania Librovitch, 1940

Type species. Gattendorfia (*Kazakhstania*) *karagandaensis* Librovitch, 1940 (original designation).

Genus definition. Gattendorfiidae with extremely discoidal, evolute conch, venter applanate or rounded. Suture line with deep, lanceolate and slightly pouched external lobe; adventive lobe much smaller than the external lobe, rounded or acute.

Included species.
americana: *Kazakhstania americana* Miller & Garner, 1955, p. 129; Michigan.
colubrella: *Ammonites colubrellus* Morton, 1836, p. 154; Ohio.
compressa: *Gattendorfia* (*Kazakhstania*) *compressa* Ruan, 1995, p. 413; Xinjiang.
cuneata: *Gattendorfia* (*Kazakhstania*) *cuneata* Ruan, 1995, p. 414; Xinjiang.
depressa: *Gattendorfia* (*Kazakhstania*) *depressa* Librovitch, 1940, p. 72; Karaganda (Kazakhstan).
evoluta: *Gattendorfia evoluta* Vöhringer, 1960, p. 159; Rhenish Mountains.
inequalis: *Kazakhstania inequalis* n. sp.; Gourara (Algeria).
karagandaensis: *Gattendorfia* (*Kazakhstania*) *karagandaensis* Librovitch, 1940, p. 68; Karaganda (Kazakhstan).
mangeri: *Kazakhstania mangeri* Work & Mason, 2005, p. 720; Kentucky.
mongolica: *Kazakhstania mongolica* Kusina in Kusina & Lazarev, 1994, p. 165; Mongolia.
nitida: *Kazakhstania nitida* Bockwinkel & Ebbighausen, 2006, p. 113; Anti-Atlas (Morocco).
umbilicata: *Gattendorfia* (*Kazakhstania*) *umbilicata* Ruan, 1995, p. 412; Xinjiang.

Kazakhstania inequalis n. sp.
Figures 9, 10

Derivation of name. Latin inequalis, with reference to the various shapes of sutural lobes.

Holotype. Specimen MB.C.18655.1, illustrated in Figure 9A.

Type locality and horizon. 15 km west-southwest of Timimoun, locality and sample TIM-C3 (Gourara, West Algeria); *Kazakhstania-Acrocanites* Assemblage.

Material. 704 specimens with a conch diameter up to 18 mm.

Diagnosis. Kazakhstania with thinly pachyconic conch in the earliest juvenile stage, becoming continuously slender during ontogeny and being extremely discoidal at 12 mm dm; conch evolute above 2 mm diameter with a slight reduction of the umbilical width in the adult stage; venter broadly rounded; aperture low in juveniles and becoming moderately high during ontogeny. Steinkern smooth except for prominent, almost linear, slightly rursiradiate constrictions. Suture line in the adult stage with very deep lanceolate external lobe (more than twice as deep as the adventive lobe), symmetrically rounded ventrolateral saddle, small and V-shaped adventive lobe and lateral lobe of the same size and shape like adventive lobe.

Table 7. Conch ontogeny (Figs 10A–D, F–H) of *Kazakhstania inequalis* n. sp.

dm	conch shape	whorl cross section shape	aperture
2 mm	thickly discoidal; evolute (ww/dm = 0.48–0.55; uw/dm = 0.45–0.50)	moderately depressed; moderately embracing (ww/wh = 1.65–1.85; IZR = 0.25–0.30)	low (WER = 1.60)
8 mm	extremely or thinly discoidal; evolute (ww/dm = 0.32–0.40; uw/dm = 0.48–0.55)	weakly depressed; moderately embracing (ww/wh = 1.25–1.40; IZR = 0.15–0.20)	low or moderate (WER = 1.70–1.80)
20 mm	extremely discoidal; evolute (ww/dm = 0.30–0.35; uw/dm ~ 0.45)	weakly depressed; moderately embracing (ww/wh = 1.00–1.15; IZR = 0.15–0.20)	moderate (WER = 1.80–2.00)

Table 8. Conch dimensions (in mm) and proportions for reference specimens of *Kazakhstania inequalis* n. sp.

	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
holotype MB.C.18655.1	10.9	3.5	3.0	5.6	2.5	0.33	1.20	0.51	1.69	0.15
paratype MB.C.18655.7	9.1	3.2	2.5	4.7	2.2	0.35	1.26	0.52	1.72	0.15
paratype MB.C.18655.2	8.7	3.2	2.5	4.4	2.1	0.36	1.26	0.50	1.73	0.16
paratype MB.C.18655.8	7.2	2.8	1.9	3.9	1.6	0.38	1.45	0.54	1.67	0.15

Table 9. Suture line proportions (Fig. 10E) for *Kazakhstania inequalis* n. sp.

specimen	at dm	EL w/d	EL/VLS	EL/AL	MS h	VLS w/h	remarks
paratype MB.C.18655.7	8.7 mm	0.36	0.50	1.05	0.00	0.72	A lobe V-shaped
paratype MB.C.18655.2	7.0 mm	0.30	0.66	0.85	0.00	0.46	A lobe rounded

Discussion. *Kazakhstania inequalis* differs from the two Kazakhian species *K. karagandaensis* and *K. depressa* in the much wider external lobe and in the much stronger constrictions. The American species *K. colubrella*, *K. americana*, and *K. mangeri* differ in their asymmetric adventive lobe, furthermore, *K. colubrella* has a narrower umbilicus. The Chinese species have a much narrower umbilicus. Similarities in conch shape exist with the Moroccan *K. nitida*, but this species has a depressed whorl cross section.

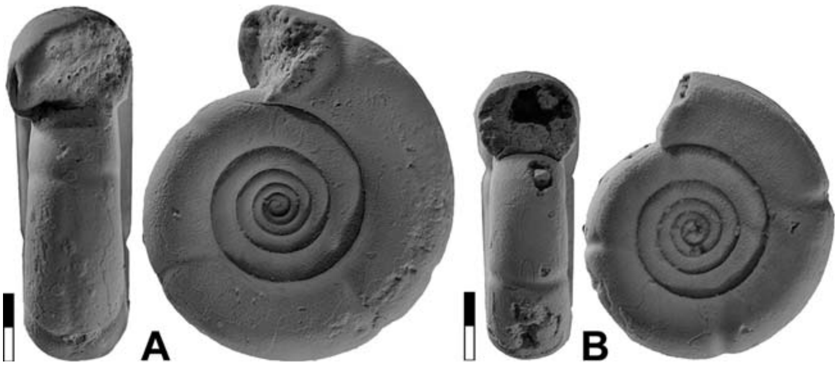

Figure 9. *Kazakhstania inequalis* n. sp. from locality TIM-C3; all ×4.0. **A.** Holotype MB.C.18655.1. **B.** Paratype MB.C.18655.2.

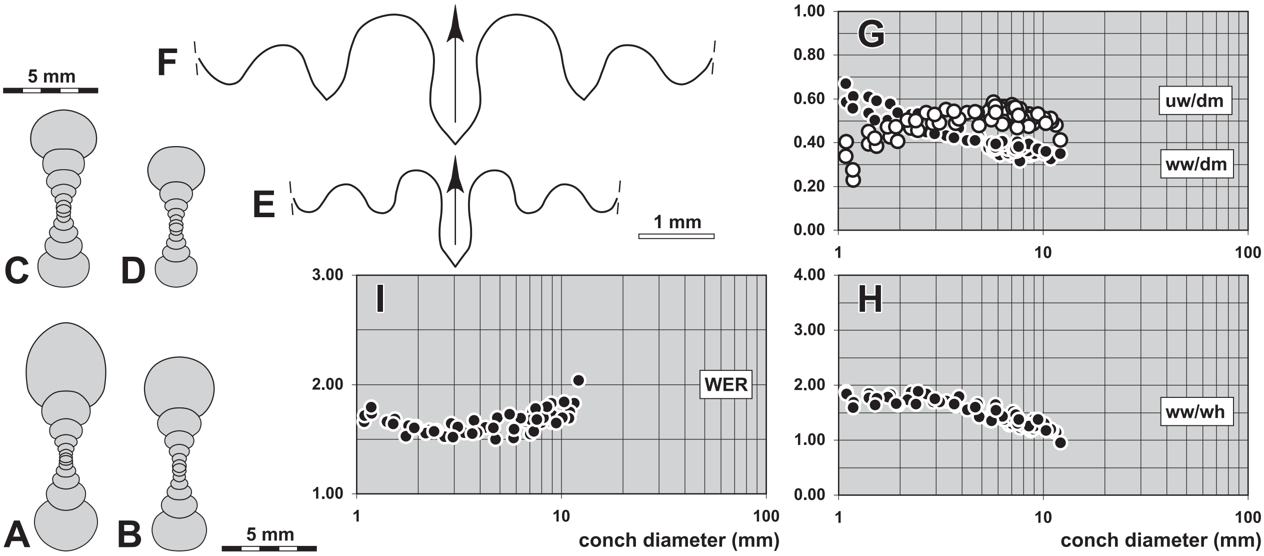

Figure 10. *Kazakhstania inequalis* n. sp. from locality TIM-C3. **A.** Cross section of paratype MB.C.18655.3; ×2.5. **B.** Cross section of paratype MB.C.18655.4; ×2.5. **C.** Cross section of paratype MB.C.18655.5; ×2.5. **D.** Cross section of paratype MB.C.18655.6; ×2.5. **E.** Suture line of paratype MB.C.18655.2, at 7.0 mm dm, 2.7 mm ww, 2.2 mm wh; ×10.0. **F.** Suture line of paratype MB.C.18655.7, at 8.7 mm dm, 3.2 mm ww, 2.6 mm wh; ×10.0. **G–I.** Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh), and whorl expansion rate (WER) of all available specimens.

Family **Acrocanitidae** Korn, Bockwinkel & Ebbighausen, 2007

Family definition. Prionocerataceae with lenticular, evolute to almost involute conch form. Suture line multilobate with increasing number of lateral lobes.

Included genera.
Acrocanites Schindewolf, 1922
Jdaidites Korn, Bockwinkel & Ebbighausen, 2007

Acrocanites **Schindewolf, 1922**

Type species. *Acrocanites multilobatus* Schindewolf, 1922 (original designation).

Genus definition. Acrocanitidae with extremely discoidal, subevolute or evolute conch, venter narrowly rounded in the juvenile and intermediate stage and subacute or acute in the adult stage of some species. Four to seven lobes on the flank and the umbilical wall.

Included species.
disparilis: *Acrocanites disparilis* Korn, Bockwinkel & Ebbighausen, 2010; Mouydir (Algeria).
imperfectus: *Acrocanites imperfectus* n. sp.; Gourara (Algeria).
multilobatus: *Acrocanites multilobatus* Schindewolf, 1922, p. 15; Thuringia.

recurvus: *Acrocanites recurvus* n. sp.; Gourara (Algeria).
smidensis: *Acrocanites smidensis* Korn, Bockwinkel & Ebbighausen, 2007, p. 138; Anti-Atlas (Morocco).
tornacensis: *Acrocanites tornacensis* Delépine, 1940, p. 30; Belgium.

Remarks. *Acrocanites* has usually been placed in the order Prolecanitida. This assignment was based on the high number of lobes, as seen in advanced prolecanitids, and the pouched shape of the lobes, which are separated by inflated saddles. However, the ontogeny of the suture line displays significant differences between *Acrocanites* and the prolecanitids, particularly in the timing of the introduction of new lobes and their shapes. Prolecanitid ammonoids show a rapid ontogenetic unfolding of suture characters, and the full number of lobes is reached in a rather early growth stage, as Korn et al. (2003b) showed for *Becanites africanus*. In contrast, *Acrocanites* has a very slow ontogeny of sutural elements, with the full lobe number reached only in the sixth or seventh whorl. Early stages of *Acrocanites* have a very low adventive lobe but a lanceolate external lobe, which is twice as deep; they resemble *Kazakhstania* Librovitch, 1940 in this respect. Therefore, a connection of *Acrocanites* with the gattendorfiin ammonoids of the superfamily Prionoceratoidea is more likely than a prolecanitid origin (Korn et al. 2007).

Acrocanites imperfectus n. sp.

Figures 11, 12

Derivation of name. Lat. imperfectus, because of the relatively low number of sutural elements.

Holotype. Specimen MB.C.18662.1, illustrated in Figure 11B.

Type locality and horizon. 15 km west-southwest of Timimoun, locality and sample TIM-C2 (Gourara, West Algeria); *Kazakhstania-Acrocanites* Assemblage.

Material. 302 specimens, conch diameter up to 21 mm.

Diagnosis. Acrocanites with thinly pachyconic conch in the earliest juvenile stage, becoming rapidly slender during early ontogeny and being extremely discoidal at 20 mm dm; conch evolute or very evolute in all stages with a slight reduction of the umbilical width in the adult stage; venter broadly rounded in juveniles and narrowly rounded in adults; aperture low or very low. Steinkern smooth. Suture line in the adult stage with slightly pouched external lobe; three pouched and acute or rounded lobes on the flank, saddles between these lobes weakly inflated; two small V-shaped and acute lobes on the umbilical wall.

Table 10. Conch ontogeny (Figs 12A–D, G–I) of *Acrocanites imperfectus* n. sp.

dm	conch shape	whorl cross section shape	aperture
2 mm	thinly discoidal; evolute (ww/dm ~ 0.40; uw/dm ~ 0.50)	weakly depressed; weakly or moderately embracing (ww/wh = 1.30–1.50; IZR = 0.12–0.18)	low (WER = 1.60–1.75)
8 mm	extremely discoidal; evolute or very evolute (ww/dm = 0.28–0.32; uw/dm = 0.55–0.65)	weakly depressed; moderately embracing (ww/wh = 1.20–1.40; IZR = 0.20–0.25)	very low (WER = 1.40–1.50)
20 mm	extremely discoidal; evolute (ww/dm ~ 0.25; uw/dm = 0.50–0.55)	weakly compressed; moderately embracing (ww/wh ~ 0.90; IZR = 0.20–0.25)	low (WER ~ 1.55)

Table 11. Conch dimensions (in mm) and proportions for reference specimens of *Acrocanites imperfectus* n. sp.

	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
paratype MB.C.18662.2	15.9	4.4	4.0	8.8	3.4	0.27	1.08	0.56	1.61	0.17
holotype MB.C.18662.1	13.1	3.8	3.4	7.3	2.6	0.29	1.12	0.55	1.54	0.24
paratype MB.C.18662.3	12.6	3.4	2.7	7.5	2.4	0.27	1.25	0.59	1.52	0.13

Table 12. Suture line characteristics (Figs 12E, F) for *Acrocanites imperfectus* n. sp.

specimen	at dm	EL w/d	external lobe	adventive lobe	lateral lobes
holotype MB.C.18662.1	12.9 mm	0.47	pouched	slightly asymmetric, rounded	4, rounded or acute, rather wide
paratype MB.C.18662.3	12.2 mm	0.35	lanceolate	asymmetric, pointed	3, acute and very narrow

Discussion. *Acrocanites imperfectus* differs from *A. recurvus* of the higher horizon of Timimoun and from *A. disparilis* from the Mouydir in the lower number of sutural elements. *A. disparilis* possesses five large lobes on the flank and two or three small lobes on the umbilical wall, whereas *A. imperfectus* shows only three large lobes on the flank and one or two small lobes on the umbilical wall. The external lobe is subparallel in *A. disparilis* but pouched in *A. imperfectus*. *A. smidensis* possesses only three lobes on the flank and umbilical wall and is thus clearly separated from *A. imperfectus*, which has four or five lobes.

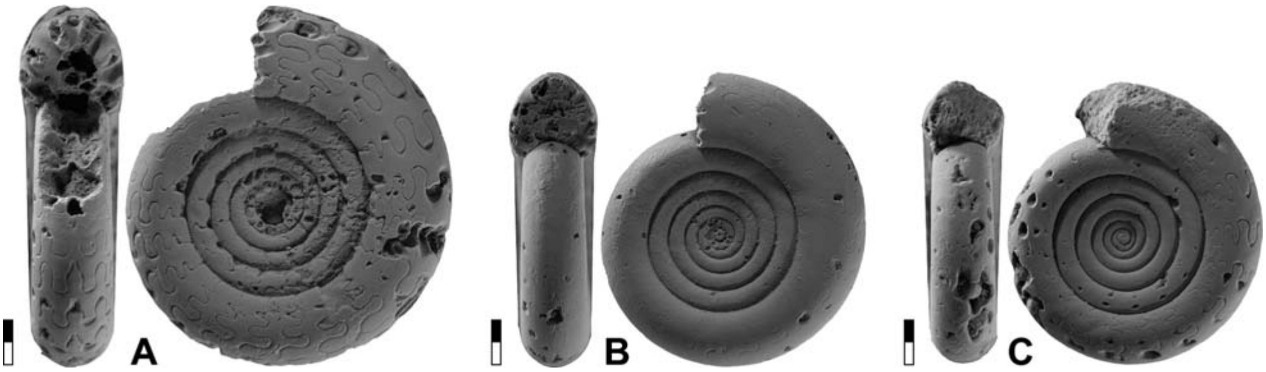

Figure 11. *Acrocanites imperfectus* n. sp. from locality TIM-C2; all ×3.0. **A.** Paratype MB.C.18662.2. **B.** Holotype MB.C.18662.1. **C.** Paratype MB.C.18662.3.

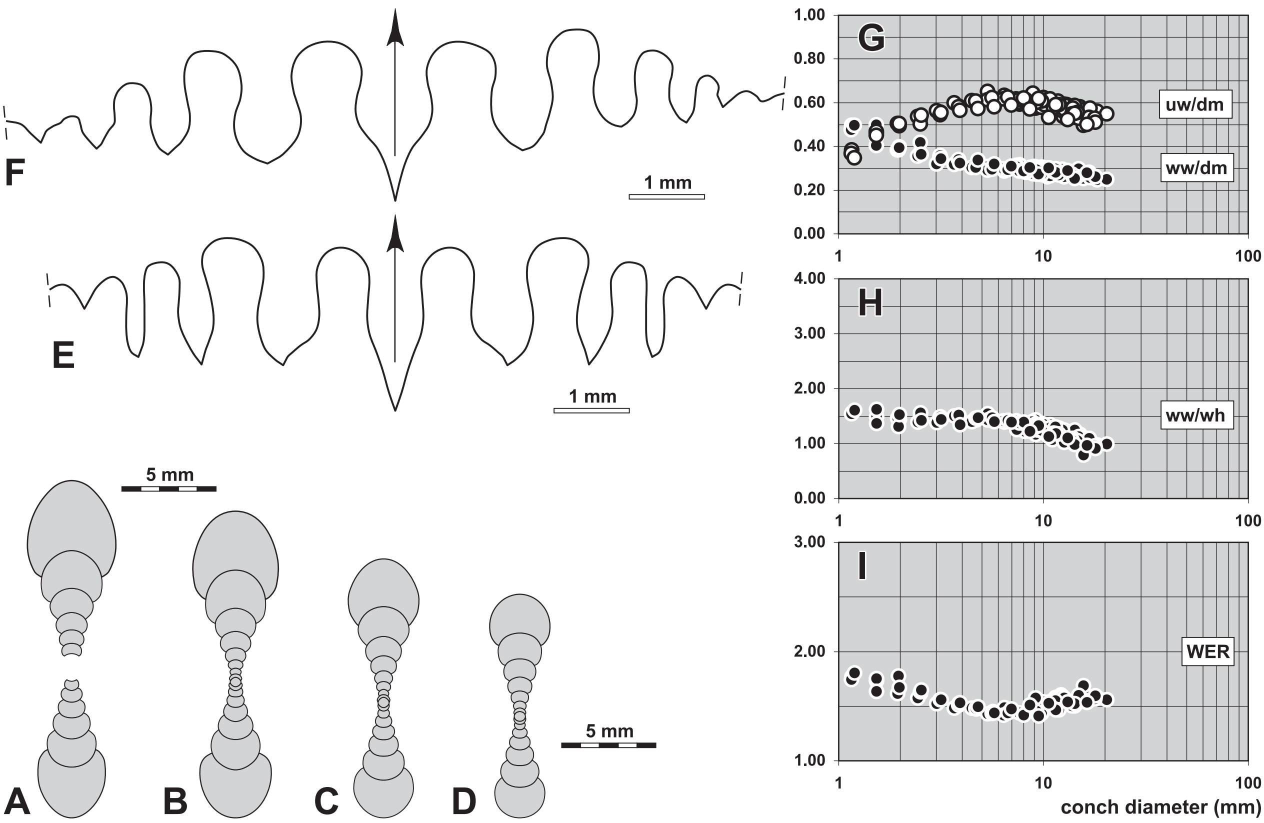

Figure 12. *Acrocanites imperfectus* n. sp. from locality TIM-C2. **A.** Cross section of paratype MB.C.18662.4; ×2.5. **B.** Cross section of paratype MB.C.18662.5; ×2.5. **C.** Cross section of paratype MB.C.18662.6; ×2.5. **D.** Cross section of paratype MB.C.18662.7; ×2.5. **E.** Suture line of paratype MB.C.18662.3, at 12.2 mm dm, 3.4 mm ww, 2.8 mm wh; ×10.0. **F.** Suture line of holotype MB.C.18662.1, at 12.9 mm dm, 3.7 mm ww, 3.4 mm wh; ×10.0. **G–I.** Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh), and whorl expansion rate (WER) of all available specimens.

Acrocanites recurvus n. sp.

Figures 13, 14

1984 *Acrocanites tornacensis*. – Conrad, pl. 5, figs 3–5.

Derivation of name. From the Latin recurvus (= backwardly bent), because of the suture line.

Holotype. Specimen MB.C.18670, illustrated in Figure 13.

Type locality and horizon. 15 km west-southwest of Timimoun, locality and sample TIM-C1 (Gourara, West Algeria); *Pericyclus-Progoniatites* Assemblage.

Material. 9 specimens (the holotype and eight poorly preserved paratypes), conch diameter up to 24 mm.

Diagnosis. *Acrocanites* with extremely discoidal, subevolute conch at 20 mm dm; venter narrowly; aperture low. Steinkern smooth. Suture line in the adult stage with lanceolate external lobe; eight pouched and acute or rounded lobes on the flank, outer four saddles between these lobes weakly inflated; continuous size decrease of the lobes on the flank towards the umbilicus.

Discussion. *Acrocanites recurvus* resembles *A. disparilis* from the Mouydir, but differs in the slightly thicker conch (above 20 mm conch diameter: ww/dm = 0.25 in *A. recurvus* but only 0.20 in *A. disparilis*) with a broader venter. The suture line of *A. recurvus* shows an almost continuous size decrease of the lobes on the flanks, whereas in A. *disparilis* the lobes near the umbilicus are very small.

The poorly known *A. multilobatus* and *A. tornacensis* may possess a similarly high number of lobes. The fragmentary material suggests that the umbilicus is narrower than in *A. recurvus*.

Table 13. Conch proportions of *Acrocanites recurvus* n. sp.

dm	conch shape	whorl cross section shape	aperture
23 mm	extremely discoidal; subevolute (ww/dm ~ 0.25; uw/dm ~ 0.43)	weakly compressed; strongly embracing (ww/wh ~ 0.75; IZR ~ 0.33)	low (WER ~ 1.66)

Table 14. Conch dimensions (in mm) and proportions for the holotype of *Acrocanites recurvus* n. sp.

	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
holotype MB.C.18670	23.3	5.8	7.7	9.9	5.2	0.25	0.75	0.43	1.66	0.33

Table 15. Suture line characteristics (Fig. 14) for *Acrocanites recurvus* n. sp.

specimen	at dm	EL w/d	external lobe	adventive lobe	lateral lobes
holotype MB.C.18670	21.9 mm	0.41	lanceolate	slightly asymmetric, acute	7, all acute, outer three pouched
holotype MB.C.18670	c. 18.0 mm	0.41	lanceolate	slightly asymmetric, acute	6, all acute, outer two pouched

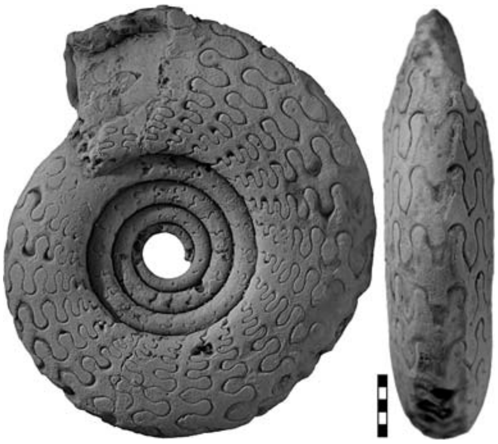

Figure 13. *Acrocanites recurvus* n. sp., holotype MB.C.18670 from locality TIM-C1; ×2.5.

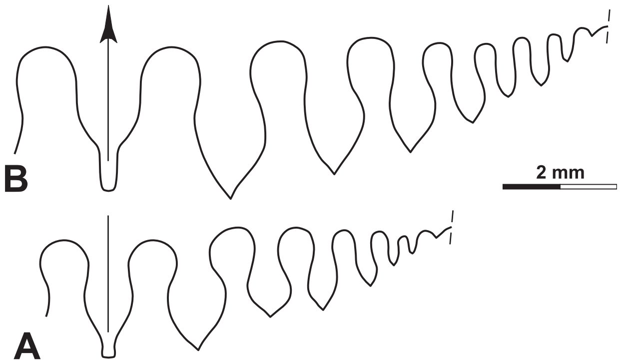

Figure 14. *Acrocanites recurvus* n. sp. from locality TIM-C1. **A.** Suture line of holotype MB.C.18670, at 4.7 mm ww, 4.9 mm wh; ×7.5. **B.** Suture line of the same specimen, at 21.9 mm dm, 5.7 mm ww, 7.7 mm wh; ×7.5.

Suborder **Goniatitina** Hyatt, 1884
Superfamily **Pericyclaceae** Hyatt, 1900

Family **Muensteroceratidae** Librovitch, 1957

Family definition. Muensteroceratid ammonoids with usually discoidal and involute or subinvolute conch, rarely pachyconic. Suture line with subparallel-sided or parallel-sided external lobe with straight flanks (external lobe V-shaped in ancestral forms); prongs of the external lobe lanceolate; median saddle very low to moderately low.

Xinjiangites **Ruan, 1995**

Type species. *Xinjiangites applanatus* Ruan, 1995, p. 419 (original designation)

Genus definition. Muensteroceratidae with insignificant ontogenetic changes of the conch; shape pachyconic in juveniles and discoidal in the adult stage, subinvolute or involute throughout ontogeny; flanks and venter broadly rounded with compressed whorl cross section; umbilical wall often flattened, umbilical margin narrowly rounded or subangular. Ornament with fine, usually convex rectiradiate growth lines with rather deep ventral sinus; sometimes with shell constrictions parallel to the growth lines. Suture line with very narrow or narrow external lobe with slightly diverging flanks and very low median saddle; ventrolateral saddle broadly rounded; adventive lobe V-shaped, symmetric or slightly asymmetric.

Included species.
applanatus: *Xinjiangites applanatus* Ruan, 1995, p. 419; Xinjiang.
brevis: *Xinjiangites brevis* Ruan, 1995, p. 420; Xinjiang.
delepinei: *Muensteroceras delepinei* Campbell, Brown & Coleman, 1983, p. 87; New South Wales.
medium: *Munsteroceras medium* Miller & Collinson, 1951, p. 472; Missouri.
perspectivum: *Goniatites perspectivus* de Koninck, 1880, p. 113; Belgium.
rotella: Goniatites rotella de Koninck, 1880, p. 106; Belgium.
scalaris: *Xinjiangites scalaris* n. sp.; Gourara (Algeria).

Discussion. *Xinjiangites* differs from the other genera of the family Muensteroceratidae in its slightly diverging external lobe. It must be stated, however, that this character is rather unstable and that even specimens of the type species of *Muensteroceras*, *M. parallelum* (Hall, 1860) may show slightly diverging flanks of the external lobe. This led Ruan (1995) to the incorrect conclusion that *M. koninckianum* Schindewolf, 1951 (= *Goniatites inconstans* de Koninck, 1880) belongs to his new genus.

***Xinjiangites scalaris* n. sp.**
Figures 15, 16

Derivation of name. After the Latin scalaris = stairway, because of the shape of the umbilicus.

Holotype. Specimen MB.C.18663.1, illustrated in Figure 15C.

Type locality and horizon. 15 km west-southwest of Timimoun, locality and sample TIM-C2 (Gourara, West Algeria); *Kazakhstania-Acrocanites* Assemblage.

Material. 932 specimens, conch diameter up to 54 mm.

Diagnosis. Xinjiangites with thickly pachyconic conch up to 8 mm dm, thereafter continuous transformation into a thinly discoidal conch at 50 mm dm; conch subinvolute throughout ontogeny; umbilical margin subangular, umbilical wall flattened and oblique; aperture low in juveniles and moderately high above 10 mm dm. Steinkern in the adult stage smooth except for rhythmic folds, course convex with extremely deep ventral sinus. Suture line with narrow, V-shaped external lobe with gently sinuous flanks and very low median saddle; ventrolateral saddle broadly rounded and slightly asymmetric; adventive lobe V-shaped, almost symmetric with slightly curved flanks.

Table 16. Conch ontogeny (Figs 16A–C, E–G) of *Xinjiangites scalaris* n. sp.

dm	conch shape	whorl cross section shape	aperture
2 mm	thickly pachyconic; subinvolute (ww/dm ~ 0.80; uw/dm ~ 0.20)	moderately depressed; very strongly embracing (ww/wh ~ 1.85; IZR ~ 0.50)	low (WER ~ 1.65)
8 mm	thickly pachyconic; subinvolute (ww/dm = 0.73–0.78; uw/dm = 0.20–0.30)	moderately depressed; very strongly embracing (ww/wh = 1.70–1.80; IZR ~ 0.48)	low (WER ~ 1.65)
20 mm	thickly discoidal; subinvolute (ww/dm = 0.53–0.56; uw/dm = 0.24–0.28)	weakly depressed; strongly embracing (ww/wh = 1.20–1.30; IZR = 0.40–0.45)	moderate (WER = 1.75–1.90)
50 mm	thinly discoidal; subinvolute (ww/dm ~ 0.40; uw/dm ~ 0.20)	weakly compressed; strongly embracing (ww/wh ~ 0.85; IZR ~ 0.44)	moderate (WER ~ 1.75)

Table 17. Conch dimensions (in mm) and proportions for reference specimens of *Xinjiangites scalaris* n. sp.

	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
paratype MB.C.18657.1	42.1	18.8	16.8	9.8	–	0.45	1.12	0.23	–	–
paratype MB.C.18657.2	37.2	17.2	16.6	8.7	9.9	0.46	1.04	0.23	1.86	0.40
paratype MB.C.18657.6	25.5	13.1	11.3	5.9	6.4	0.51	1.16	0.23	1.78	0.43
holotype MB.C.18663.1	19.2	11.3	8.5	4.1	4.8	0.59	1.33	0.21	1.78	0.44
paratype MB.C.18663.2	13.0	8.6	5.1	3.1	3.2	0.66	1.69	0.24	1.76	0.37

Table 18. Suture line proportions (Fig. 16D) for *Xinjiangites scalaris* n. sp.

specimen	at dm	EL w/d	EL/VLS	EL/AL	MS h	VLS w/h	remarks
holotype MB.C.18663.1	18.1 mm	0.51	0.64	0.72	0.18	0.80	flanks of E lobe slightly sinuous

Discussion. *Xinjiangites scalaris* has a wider umbilicus (uw/dm > 0.20) than *X. applanatum* and *X. brevis* from Xinjiang (uw/dm = 0.10–0.15), a wider external lobe, and a higher median saddle. *X. medium* has a similar conch like *X. scalaris*, but differs in the very narrow external lobe.

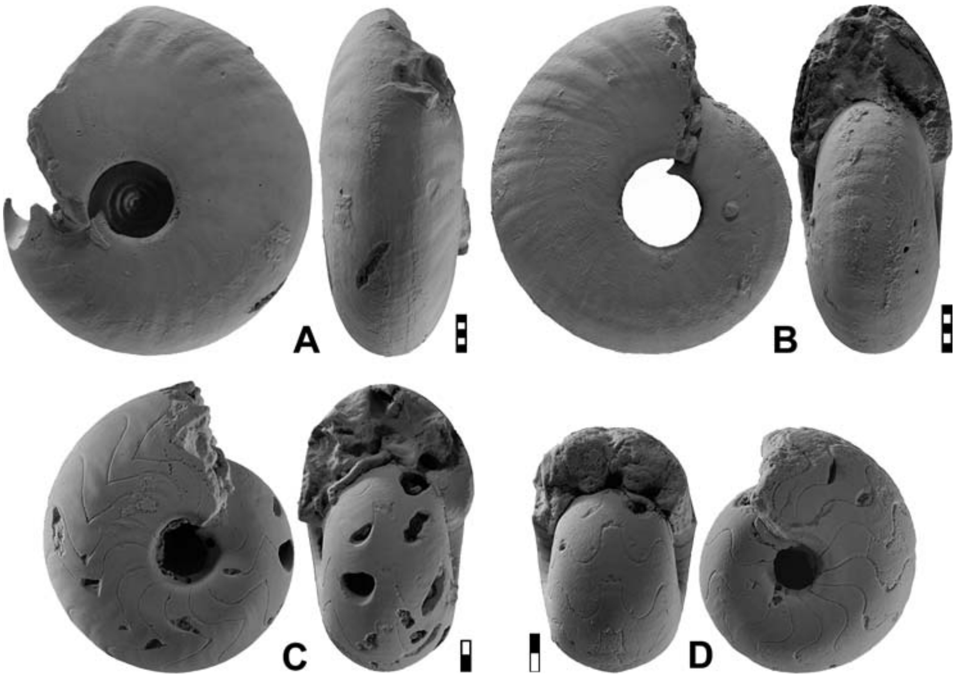

Figure 15. *Xinjiangites scalaris* n. sp. **A.** Paratype MB.C.18657.1 from locality TIM-C3; ×1.0. **B.** Paratype MB.C.18657.2 from locality TIM-C3; ×1.25. **C.** Holotype MB.C.18663.1 from locality TIM-C2; ×2.0. **D.** Paratype MB.C.18663.2 from locality TIM-C2; ×2.5.

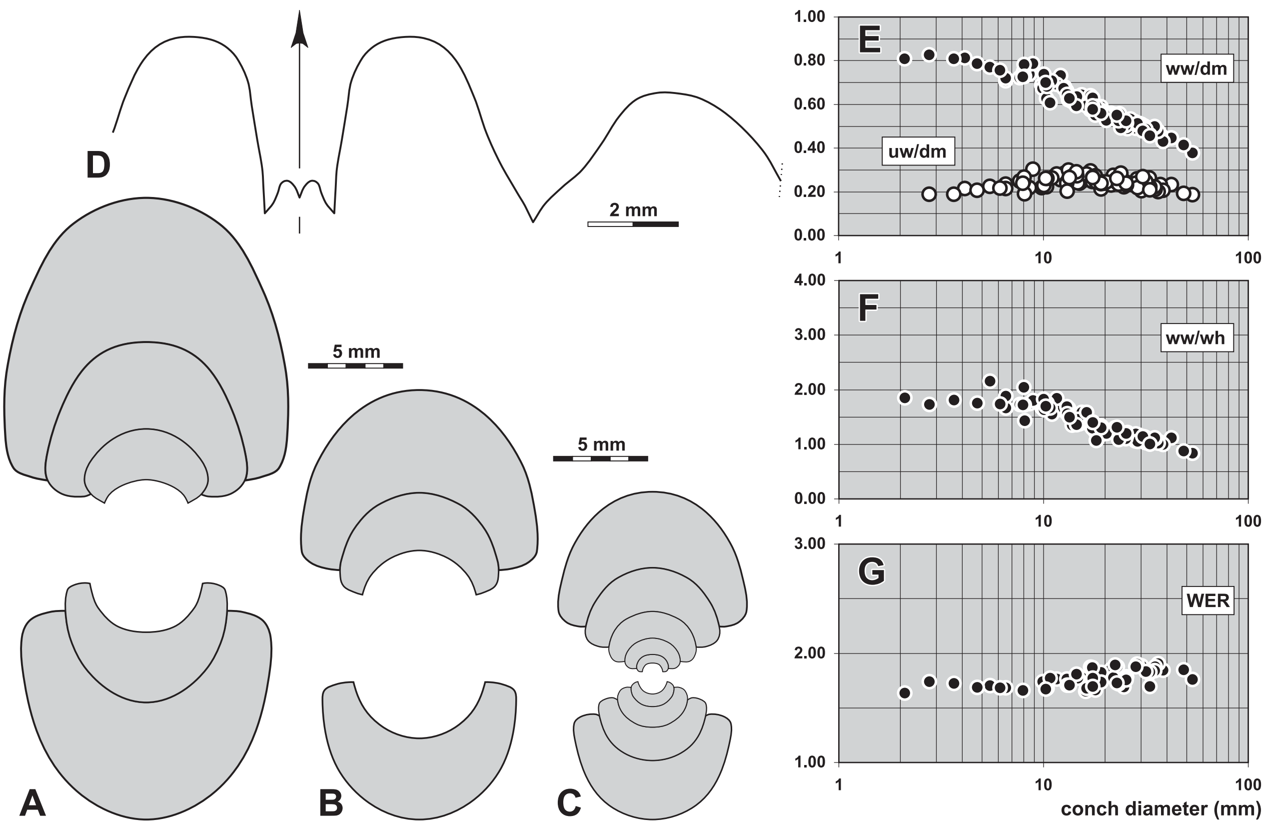

Figure 16. *Xinjiangites scalaris* n. sp. **A.** Cross section of paratype MB.C.18657.3 from locality TIM-C3; ×2.5. **B.** Cross section of paratype MB.C.18657.4 from locality TIM-C3; ×2.5. **C.** Cross section of paratype MB.C.18657.5 from locality TIM-C3; ×2.5. **D.** Suture line of holotype MB.C.18663.1 from locality TIM-C2, at 18.1 mm dm, 11.0 mm ww, 7.2 mm wh; ×6.0. **E–G.** Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh), and whorl expansion rate (WER) of all available specimens.

Order **Prolecanitida** Miller & Furnish, 1954
Suborder **Prolecanitina** Miller & Furnish, 1954
Superfamily **Prolecanitaceae** Hyatt, 1884
Family **Prolecanitidae** Hyatt, 1884
Subfamily **Prolecanitinae** Hyatt, 1884

Becanites Korn, 1997

Type species. *Protocanites algarbiensis* Pruvost, 1914 (original designation).

Genus definition. Prolecanitinae with a suture line consisting of external lobe, adventive lobe, lateral lobe, umbilical lobe, and internal lobe. External lobe parallel-sided or pouched, adventive lobe pouched, lateral lobe lanceolate or pouched.

Included species.
abnobensis: *Protocanites supradevonicus abnobensis* Vöhringer, 1960, p. 506; Black Forrest.
africanus: *Becanites africanus* Korn, Bockwinkel, Ebbighausen & Klug, 2003, p. 77; Anti-Atlas.
algarbiensis: *Prolecanites algarbiensis* Pruvost, 1914, p. 17; South Portugal.
canalifer: *Becanites canalifer* n. sp.; Gourara (Algeria).
clymeniaeformis: *Goniatites clymeniaeformis* de Koninck, 1880, p. 95; Belgium. [Homonym of *Goniatites clymeniaeformis* Münster, 1839; synonym of *Protocanites tornacensis* Schindewolf, 1951]
geigenensis: *Protocanites geigenensis* Schmidt, 1924, p. 153; Franconia.
gurleyi: *Prolecanites Gurleyi* Smith, 1903, p. 53; Missouri.
inflateralis: *Becanites inflateralis* n. sp.; Mouydir (Algeria).
nuraensis: *Protocanites lyoni* var. *nuraensis* Librovitch, 1940, p. 78; Karaganda.
singularis: *Becanites singularis* n. sp.; Gourara (Algeria).
tornacensis: *Protocanites tornacensis* Schindewolf, 1951, p. 50; Belgium.

Discussion. *Becanites* differs from the genus *Eocanites* Librovitch, 1962 (in Bogoslovsky et al. 1962) in the shape of the lateral lobe, which is very small and V-shaped in *Eocanites* but lanceolate in *Becanites*. *Michiganites* Ruzhencev, 1962 (in Bogoslovsky et al. 1962) differs from *Becanites* in an additional lateral lobe.

Becanites canalifer n. sp.

Figures 17, 18

Derivation of name. From the Greek canal bearing, with reference to the ventral groove.

Holotype. Specimen MB.C.18664.1, illustrated in Figure 17B.

Type locality and horizon. 15 km west-southwest of Timimoun, locality and sample TIM-C2 (Gourara, West Algeria); *Kazakhstania-Acrocanites* Assemblage.

Material. 57 specimens, conch diameter up to 14 mm.

Diagnosis. Becanites with thinly pachyconic conch in the earliest juvenile stage, becoming rapidly slender during early ontogeny and being extremely discoidal at 12 mm dm; conch evolute in all stages above 2 mm diameter with a slight increase of the umbilical width in the adult stage; whorl cross section subquadrate; venter flattened with a spiral groove; aperture moderately high. Steinkern smooth. Suture line with lanceolate, slightly pouched external lobe, broad and slightly pouched adventive lobe with subparallel flanks, and a lanceolate lateral lobe.

Table 19. Conch ontogeny (Figs 18A–D, F–H) of *Becanites canalifer* n. sp.

dm	conch shape	whorl cross section shape	aperture
2 mm	thinly discoidal; evolute (ww/dm ~ 0.40; uw/dm ~ 0.45)	weakly depressed; weakly embracing (ww/wh ~ 1.30; IZR ~ 0.15)	moderate (WER ~ 1.80)
8 mm	extremely discoidal; evolute (ww/dm = 0.30–0.35; uw/dm = 0.50–0.55)	weakly depressed; weakly embracing (ww/wh = 1.10–1.20; IZR = 0.05–0.10)	moderate (WER = 1.75–1.90)
14 mm	extremely discoidal; evolute (ww/dm ~ 0.32; uw/dm = 0.50–0.53)	weakly depressed; weakly embracing (ww/wh ~ 1.20; IZR ~ 0.05)	moderate (WER = 1.80–1.90)

Table 20. Conch dimensions (in mm) and proportions for reference specimens of *Becanites canalifer* n. sp.

	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
paratype MB.C.18664.2	13.9	4.3	3.9	7.4	3.7	0.31	1.12	0.53	1.84	0.06
holotype MB.C.18664.1	11.8	3.7	3.1	6.3	2.9	0.31	1.18	0.53	1.76	0.06
paratype MB.C.18664.3	8.6	2.9	2.5	4.3	2.3	0.34	1.17	0.50	1.85	0.08

Table 21. Suture line proportions (Fig. 18E) for *Becanites canalifer* n. sp.

specimen	at dm	EL w/d	EL/VLS	EL/AL	MS h	VLS w/h	remarks
holotype MB.C.18664.1	11.4 mm	0.42	0.91	0.96	0.00	0.46	E lobe much deeper than A lobe

Discussion. *Becanites canalifer* is the only species of the genus with a distinctive ventral groove. The subquadrate whorl cross section is a further criterion for separation of the new species; this character is only known from the insufficiently described *B. geigenensis*.

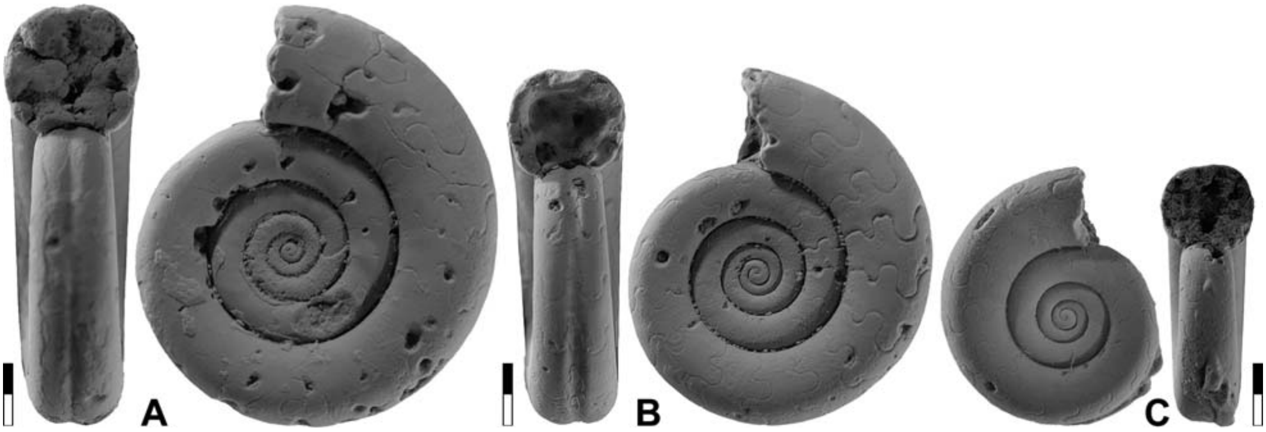

Figure 17. *Becanites canalifer* n. sp. from locality TIM-C2; all ×4.0. **A.** Paratype MB.C.18664.2. **B.** Holotype MB.C.18664.1. **C.** Paratype MB.C.18664.3.

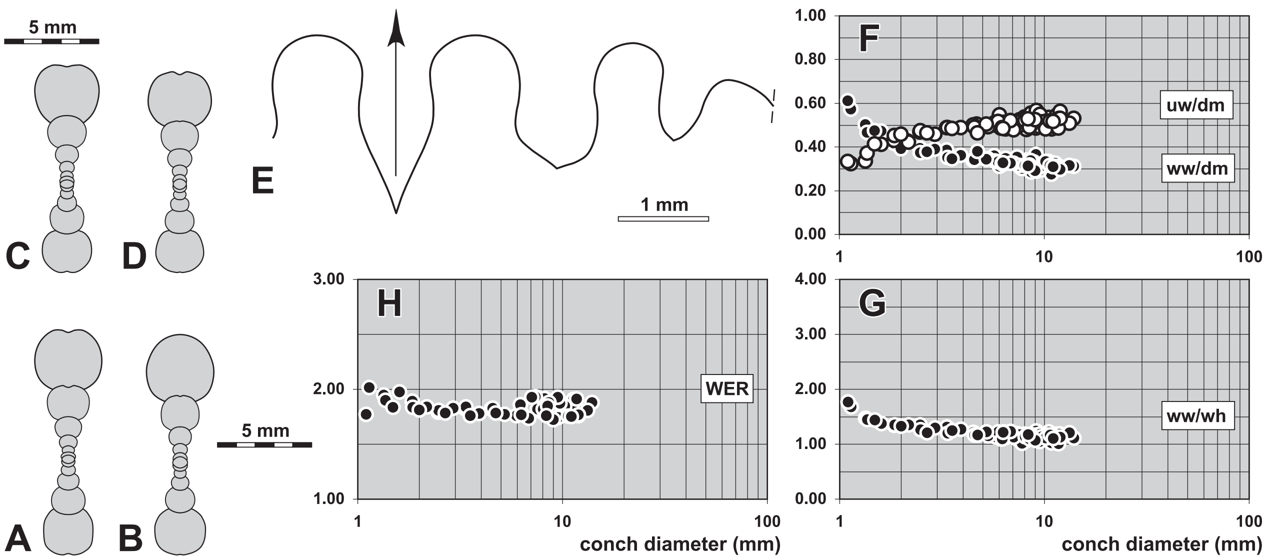

Figure 18. *Becanites canalifer* n. sp. from locality TIM-C2. **A.** Cross section of paratype MB.C.18664.4; ×2.5. **B.** Cross section of paratype MB.C.18664.5; ×2.5. **C.** Cross section of paratype MB.C.18664.6; ×2.5. **D.** Cross section of paratype MB.C.18664.7; ×2.5. **E.** Suture line of holotype MB.C.18664.1, at 11.4 mm dm, 3.5 mm ww, 3.3 mm wh; ×12.0. **F–H.** Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh), and whorl expansion rate (WER) of all available specimens.

Becanites singularis n. sp.

Figures 19, 20

Derivation of name. After the Latin singularis, because only one specimen is known.

Holotype. Specimen MB.C.18650, illustrated in Figure 19.

Type locality and horizon. 28 km west-southwest of Timimoun, locality and sample TIM-A1 (Gourara, West Algeria); *Pericyclus-Progoniatites* Assemblage.

Material. Only the holotype with 15.5 mm.

Diagnosis. Becanites with extremely discoidal, evolute conch at 15 mm dm; whorl cross section subquadrate; venter slightly flattened; aperture moderately high. Steinkern smooth. Suture line with pouched external lobe, broad and tongue-shaped adventive lobe with subparallel flanks, and a pouched lateral lobe.

Table 22. Conch proportions of *Becanites singularis* n. sp.

dm	conch shape	whorl cross section shape	aperture
15 mm	extremely discoidal; evolute (ww/dm ~ 0.28; uw/dm ~ 0.57)	weakly depressed; weakly embracing (ww/wh ~ 1.08; IZR ~ 0.02)	moderate (WER ~ 1.80)

Table 23. Conch dimensions (in mm) and proportions for the holotype of *Becanites singularis* n. sp.

	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
holotype MB.C.18650	15.5	4.4	4.1	8.8	4.0	0.28	1.08	0.57	1.80	0.02

Table 24. Suture line proportions (Fig. 20B) for *Becanites singularis* n. sp.

specimen	at dm	EL w/d	EL/VLS	EL/AL	MS h	VLS w/h	remarks
holotype MB.C.18650	15.2 mm	0.40	0.84	1.29	0.00	0.48	A lobe as wide as the E lobe

Discussion. *Becanites singularis* differs from *B. canalifer* in the absence of the median groove and from *B. inflateralis* in the much wider umbilicus (at 15 mm dm: uw/dm ~ 0.57 in contrast to 0.45 in *B. inflateralis*) and the much lower aperture. The very wide umbilicus is a criterion to separate *B. singularis* from nearly all of the other species of the genus.

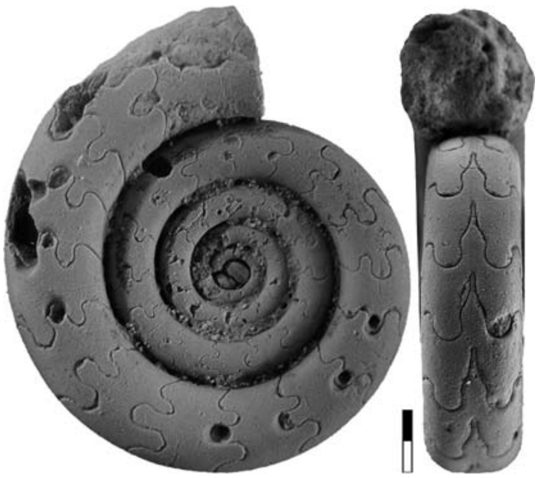

Figure 19. *Becanites singularis* n. sp., holotype MB.C.18650 from locality TIM-A1; ×4.0.

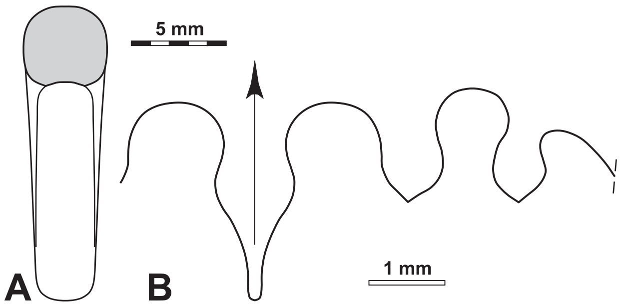

Figure 20. *Becanites singularis* n. sp. from locality TIM-A1. **A.** Dorsal view of holotype MB.C.18650; ×2.5. **B.** Suture line of holotype MB.C.18650, at 15.2 mm dm, 4.3 mm ww, 4.0 mm wh; ×10.0.

Becanites inflateralis n. sp.

Figures 21, 22

1984 *Protocanites lyoni*. – Conrad, pl. 5, fig. 6.

Derivation of name. Combination of the Latin inflatus and lateralis, because of the inflated lateral lobe.
Holotype. Specimen MB.C.18679.1, illustrated in Figure 21.

Type locality and horizon. 15 km west-southwest of Timimoun, locality and sample TIM-C1 (Gourara, West Algeria); *Pericyclus-Progoniatites* Assemblage.

Material. 10 specimens, conch diameter up to 21 mm.

Diagnosis. Becanites with extremely discoidal, subevolute conch at 20 mm dm; whorl cross section subquadrate; flanks flattened an parallel; venter slightly flattened; aperture high. Steinkern smooth. Suture line with pouched external lobe, broad and asymmetric adventive lobe with subparallel flanks, and pouched lateral lobe.

Table 25. Conch proportions of *Becanites inflateralis* n. sp.

dm	conch shape	whorl cross section shape	aperture
20 mm	extremely discoidal; subevolute (ww/dm ~ 0.34; uw/dm ~ 0.43)	weakly depressed; weakly embracing (ww/wh ~ 1.01; IZR ~ 0.02)	high (WER ~ 2.23)

Table 26. Conch dimensions (in mm) and proportions for the holotype of *Becanites inflateralis* n. sp.

	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
holotype MB.C.18679.1	20.2	6.9	6.8	8.7	6.7	0.34	1.01	0.43	2.23	0.02

Table 27. Suture line proportions (Fig. 22B) for *Becanites inflateralis* n. sp.

specimen	at dm	EL w/d	EL/VLS	EL/AL	MS h	VLS w/h	remarks
holotype MB.C.18679.1	20.0 mm	0.39	0.88	1.14	0.00	0.44	A lobe and L lobe pouched

Discussion. *Becanites inflateralis* differs from *B. canalifer* in the absence of the median groove and from *B. singularis* in the much narrower umbilicus (at 15 mm dm: uw/dm ~ 0.43 in contrast to 0.57 in *B. singularis*) and the much higher aperture. A criterion to separate *B. inflateralis* from other species is the pouched lateral lobe, which is lanceolate in most the other species of the genus. *B. africanus*, for instance has a much less pouched lateral lobe; additionally it has a narrower umbilicate conch.

Figure 21. *Becanites inflateralis* n. sp., holotype MB.C.18679.1 from locality TIM-C1; ×3.0.

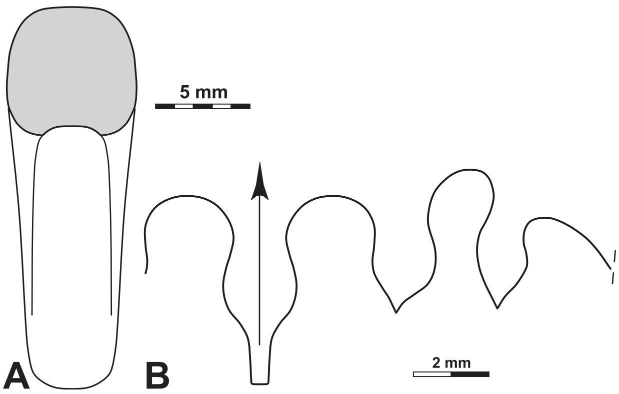

Figure 22. *Becanites inflateralis* n. sp. from locality TIM-C1. **A.** Dorsal view of holotype MB.C.18679.1; ×2.5. **B.** Suture line of holotype MB.C.18679.1, at 20.0 mm dm, 6.8 mm ww, 6.7 mm wh; ×5.0.

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