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Silurian-Devonian chitinozoan biostratigraphy along the Urubu, Uatumã and Abacate rivers in the western part of the Amazonas Basin, Northern Brazil

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Abstract. Outcrops along the Urubu, Uatumã and Abacate rivers in the western part of the Amazonas Basin, northern Brazil, have been investigated for chitinozoans. Diverse and abundant chitinozoan assemblages of Late Silurian (late Ludlow and early Pridoli) age occur together with early Lochkovian, early Givetian and Frasnian assemblages. The lower part of the Manacapuru Formation crops out extensively in the area, and can be as old as late Ludlow, which indicates that the base of this formation is diachronous. Other rock units less commonly exposed in this region include the upper Manacapuru (early Lochkovian), upper Ererê (early Givetian) and lower Barreirinha formations (Frasnian). Of the 54 species encountered (some for the first time in Brazil), 29 are left in open nomenclature, and three are newly described: *Armigutta urubuense*, *Ramochitina bjornsundquisti* and *Saharochitina gomphos*.

Key words: Silurian, Devonian, Amazonas Basin, Chitinozoa, Biostratigraphy.

Introduction

In the 1950's, pioneer geological mapping was carried out by the newly created Brazilian national oil company Petrobras along the Urubu, Uatumã and Abacate rivers in the western part of the Amazonas Basin, northern Brazil (Fig. 1). The main purpose of these efforts was to sample outcrops along these rivers, and to describe the geology of the area. The geological results were presented in a series of internal reports by Kremer (1956), Swan (1957) and Freydanck (1958). Partly based on these samples, Lange (1957, 1963a, b, 1967) proposed a preliminary chitinozoan-acritarch biostratigraphy for the area. The Urubu River area was revisited in the early 1990's by Petrobras geologists, who conducted more limited sampling restricted to roadcuts along the BR-174 highway. In the light of more recent results from chitinozoan (e.g. Grahn and Paris 1992, Grahn and Melo 2002, in print, Azevedo-Soares and Grahn in print) and miospore (Melo and Loboziak 2003) studies, Lange's biostratigraphic scheme badly needs revision. Guimarães Coelho (1994) made a preliminary attempt at updating the chitinozoan stratigraphy of the region under the supervision of one of us (J.H.G.M.). The present paper is an outcome of further investigations on the chitinozoan taxonomy and biostratigraphy which is now compared with other, more intensively investigated areas of Brazil. A historical review of the different Silurian and Devonian formations in the Amazonas Basin is given in Grahn (1992). The Silurian rock units were also discussed by Grahn and Paris (1992).

Material and methods

The sites of the outcrops investigated in this paper are shown in Fig. 1, except for AGS 610, the geographic location of which is unknown (omitted in Swan's map 1957). Altogether 27 samples have been investigated from the Manacapuru, Ererê and Barreirinha formations of the Amazonas Basin. The residues were studied for chitinozoans using a binocular stereoscopic microscope, and representative chitinozoan specimens picked for scanning electron microscope (SEM) studies at the former DIGER/SEGEX (CENPES, Petrobras) lab in Rio de Janeiro. Light-microscope photographs of selected specimens were also made at CENPES. Sample processing and SEM-preparations were done according to the techniques described by Laufeld (1974).

Geologic setting and chitinozoan biostratigraphy

The localities along the Urubu, Uatumã and Abacate rivers are situated in the northern margin and downstream into the central area of the Amazonas Basin. According to Lange (1967) they were believed to represent a stratigraphic sequence from the Pitinga Formation (now dated early Llandovery-Ludlow) to the Barreirinha Formation (Frasnian-late Famennian), see Fig. 5. Because major tectonic movements were unproven in the area, an undisturbed stratigraphy was also implied by Lange (1967). New biostratigraphic evidence in this paper challenges Lange's interpretation by detecting downdip disturbances in the stratal succession along the Urubu River, which may result from either faulting (tectonic recurrencies) or unconformities at the boundaries of some rock units (see Fig. 2). The studied samples collectively ranges in age from late Ludlow to Frasnian. Reworking occurs at two localities (Pt. 10 and AGS 541, see Figs 1–2). Five chitinozoan assemblages can be distinguished (Fig. 4), i.e. A (late Ludlow), B (early Pridoli), C (early Lochkovian), D (early Givetian), and E (Frasnian). These are described below.

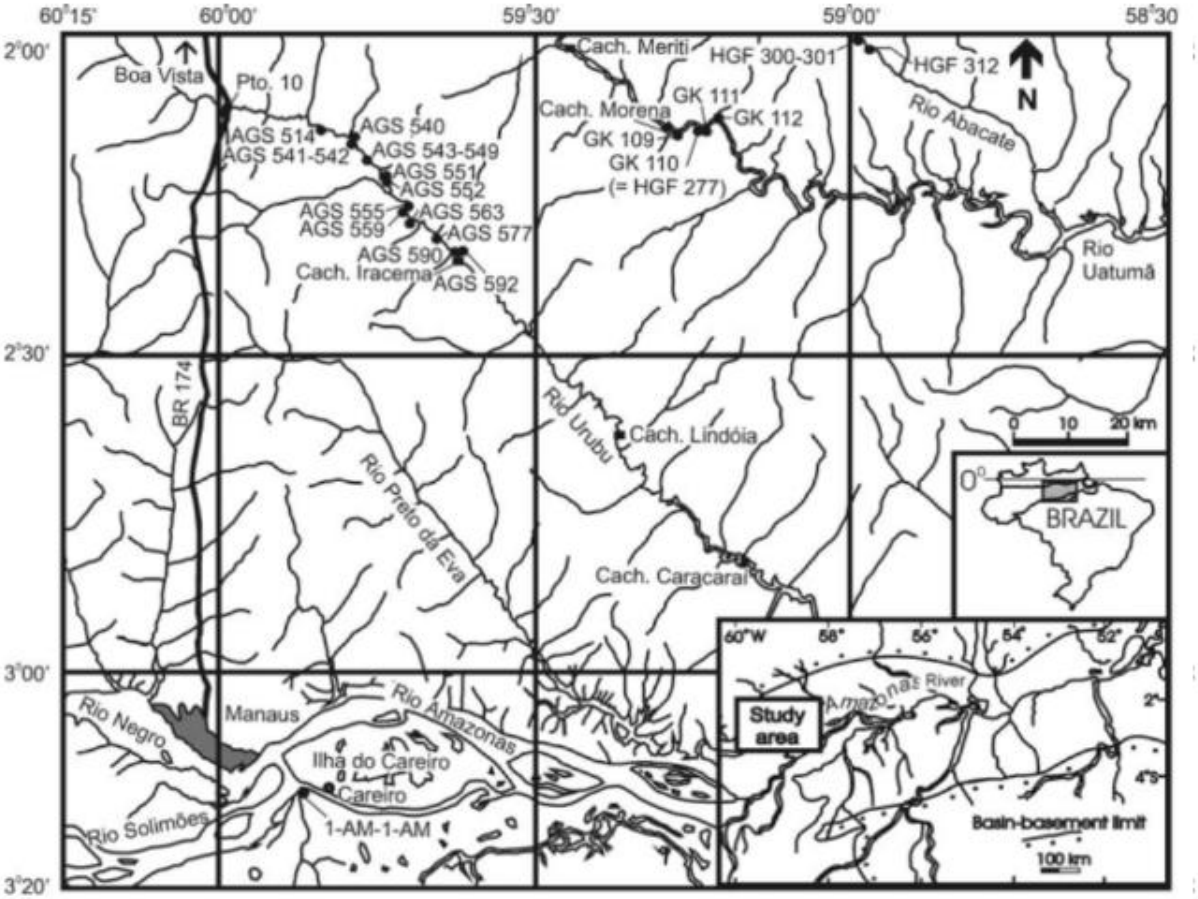

Fig. 1. Location map of outcrops along the Urubu, Uatumã and Abacate rivers and well 1-AM-1-AM in the western Amazonas Basin, northern Brazil (modified from Guimarães Coelho 1994). Sample collecting codes: AGS by Swan (1957), GK by Kremer (1956), HGF by Freydanck (1958), Pt. 10 by a Petrobras field party in the early 1990's.

Results

Assemblage A (late Ludlow)

This assemblage supposedly is from the oldest part of the Manacapuru Formation, although the possibility of an uppermost Pitinga position cannot be ruled out for the moment. In well 1-AM-1-AM, the reference section for the Silurian-Devonian boundary in the subsurface of the Amazonas Basin (Azevedo-Soares and Grahn in print), the base of the Manacapuru Formation is situated within the lower Pridoli. The stratigraphic position of Assemblage A requires a re-investigation of the Manacapuru Formation along the Urubu River. The joint occurrence of *Ancyrochitina polentinensis* Schweineberg 1987 (Plate II, figs 8–9), *Cingulochitina* sp. A sensu Paris 1981 (Plate IV, figs 6–7) and *Tanuchitina* aff. *T. cylindrica* (Taugourdeau and Jekhowsky 1960) sensu Boumendjel 1987 (Fig. 6.5) excludes a Pridoli age for these rocks, and the occurrence of *Eisenackitina granulata* (Cramer 1964) (Plate IV, figs 19–20), *Euconochitina gordonensis* (Cramer 1964) (Plate IV, figs 11–12) and *Pterochitina perivelata* (Eisenack 1937) (Plate V, figs 12–14) indicates no older age than late Ludlow. Most of the other species recorded (Plates I–VI, figs 2–4, 6) have a Ludlow – early Pridoli range. Besides, another good indicator of Ludlow age for the assemblage is the acritarch *Tyrannus giganteus* (Jardiné et al. 1974) Wood and Tekbali 1987, which has not been reported from beds younger than Ludlow (Wood and Melo 1998).

Localities: AGS 540, 541 (reworked into Ererê Formation), 542, 543, 544, 545, 547, and 549 (Figs 1–2).

Assemblage B (early Pridoli)

This assemblage is typical for the lower Manacapuru Formation as defined in well 1-AM-1-AM (Azevedo-Soares and Grahn in print). Chitinozoan species such as *Angochitina?* sp. sensu Grahn and Paris 1992 (Plate III, figs 16–17), *Armigutta urubuense* n. sp. (Plate VI, figs 1–4), *Ramochitina bjornsundquisti* n. sp. (Plate V, figs 15–17), and *Saharochitina gomphos* n. sp. (Plate VI, figs 9–11) indicate an early Pridoli age. *Angochitina?* sp. and *R. bjornsundquisti* are also known from early Pridoli in well 1-AM-1-AM (Grahn and Paris 1992, Azevedo-Soares and Grahn in print), and *R. bjornsundquisti* also occurs in Kirusillas Formation equivalents, Subandean Bolivia (authors observations).

Localities: Pt. 10 (reworked into upper Manacapuru Formation); AGS 514, 548, 551, 552, 555, 559, 610; HGF 300, 301, 312.

Assemblage C (early Lochkovian)

This assemblage is representative for the upper Manacapuru Formation as defined in well 1-AM-1-AM (Azevedo-Soares and Grahn in print). Characteristic chitinozoans include *Eisenackitina* cf. *E. bohemica* (Eisenack 1934) (Plate V, figs 1–2), *Lagenochitina navicula* Taugourdeau and Jekhowsky 1960 (Plate V, fig. 5) and *Pterochitina megavelata* Boumendjel 2002 (Plate I, fig. 6). Other species present are *Angochitina* sp. B (Plate I, figs 5, 8), *Angochitina filosa* Eisenack 1955 (Plate III, figs 7–8) and *Ancyrochitina* sp. D (Plate III, fig. 4). The two former species have also been reported from the Pridoli.

Localities: Pt. 10; AGS 563, 577.

Assemblage D (early Givetian)

This assemblage characterizes the Ererê Formation. Diagnostic species are *Alpenachitina eisenacki* Dunn and Miller 1964 (Plate I, fig. 1) and *Ancyrochitina morzadeci* Paris 1981 (Plate II, fig. 7), that jointly indicate an early Givetian age. Concerning other associated palynomorphs, large sized, spinose zonate/camerate trilete spores, of the genera *Grandispora* and *Samarisporites* are common. The acritarch *Navifusa bacilla* (Deunff 1955) Playford 1977 (= *N. brasiliensis*) is also present in the Ererê Formation, but elsewhere it is also known beginning in the Emsian.

Localities: AGS 541, 590.

Assemblage E (Frasnian)

This assemblage is from the lower Barreirinha Formation The only chitinozoan taxon recorded comprises a badly characterized *Angochitina* (*Angochitina* sp. A, Plate III, fig. 11) species closely related to *F. pilosa*. Other associated palynomorphs include numerous miospores bearing hooked processes (Hystricosporites), as well as the acritarch *Maranites brasiliensis* (Brito 1965) emend. Burjack and Oliveira 1989 (common in the Frasnian, but elsewhere poorly represented since the Givetian).

Localities: AGS 592; GK 109?, 110, 111, 112?

Systematic paleontology

Fifty-four chitinozoan species have been identified, some of them for the first time in Brazil. Their regional stratigraphic ranges in the study area are given in Fig. 4. Only those left in open nomenclature and the new species will be discussed below. Most of the specimens recovered are compressed, and a correction factor of 0.8 (Paris 1981, Jaglin 1986) was used to calculate the uncompressed dimensions (values given within brackets) of the specimens. The taxonomy follows the scheme proposed by Paris et al. (1999).

Group Chitinozoa Eisenack 1931
Order Operculatifera Eisenack 1931
Family Desmochitinidae Eisenack 1931 emend. Paris 1981
Subfamily Desmochitininae Paris 1981

Genus *Bursachitina* Taugourdeau 1966

Bursachitina sp. A
Plate III, figs 14–15

?1967 Tipo 110 – Lange, Pl. 8, fig. 110

Description: A *Bursachitina* species with a wide conical body. Margin rounded and flexure inconspicuous. Base slightly convex. The general outline resembles that of *Eisenackitina granulata*. *Bursachitina* sp. A differs from the latter in having a smooth vesicle.

Dimension (2 specimens measured): Total length 171–188 µm, maximum width 175(140)–195(156) µm, width of aperture 50(40)–88(70) µm.

Occurrence: Amazonas Basin, lower Manacapuru Formation, Assemblage B (early Pridoli); locality AGS 514.

Subfamily Pterochitininae Paris 1981

Genus *Cingulochitina* Paris 1981

Cingulochitina sp. A sensu Paris 1981
Plate IV, figs 6–7

1981 *Cingulochitina* sp. A – Paris, p. 174-175, text-fig. 78, Pl. 19, fig. 18, Pl. 20, fig.18, Pl. 21, figs 9, 21, Pl. 29, fig. 4
1991 *Cingulochitina* sp. A – Herbosch et al., p. 312, fig. 35
2002 *Cingulochitina* sp. A – Verniers et al., p. 309–310

Description: For a description of *Cingulochitina* sp. A, see Paris 1981 and Verniers et al. 2002.

Dimension (6 specimens measured): Total length 93–123 µm, maximum width 37(30)–48(38) µm, width of aperture 30(24)–35(28) µm.

Occurrence: Amazonas Basin, possibly lower Manacapuru Formation, Assemblage A (late Ludlow); localities AGS 541, 542, and 543; HGF 312. This species was originally described from Ludlow strata in the basal part of the Sazes Formation, Buçaco Synclinal, Portugal (Paris 1981). Herbosch et al. (1991) and Verniers et al. (2002) reported it from the coeval Ronquières Formation, Brabant Massif, Belgium.

Cingulochitina aff. *C. ervensis* Paris 1979 (in Babin et al. 1979)
Plate IV, figs 8–9

1967 Tipo 67 – Lange, Pl. V, fig. 67
2003 *Cingulochitina* aff. *C. ervensis* – Azevedo-Soares and Grahn (in print), Pl. 1, fig. 14

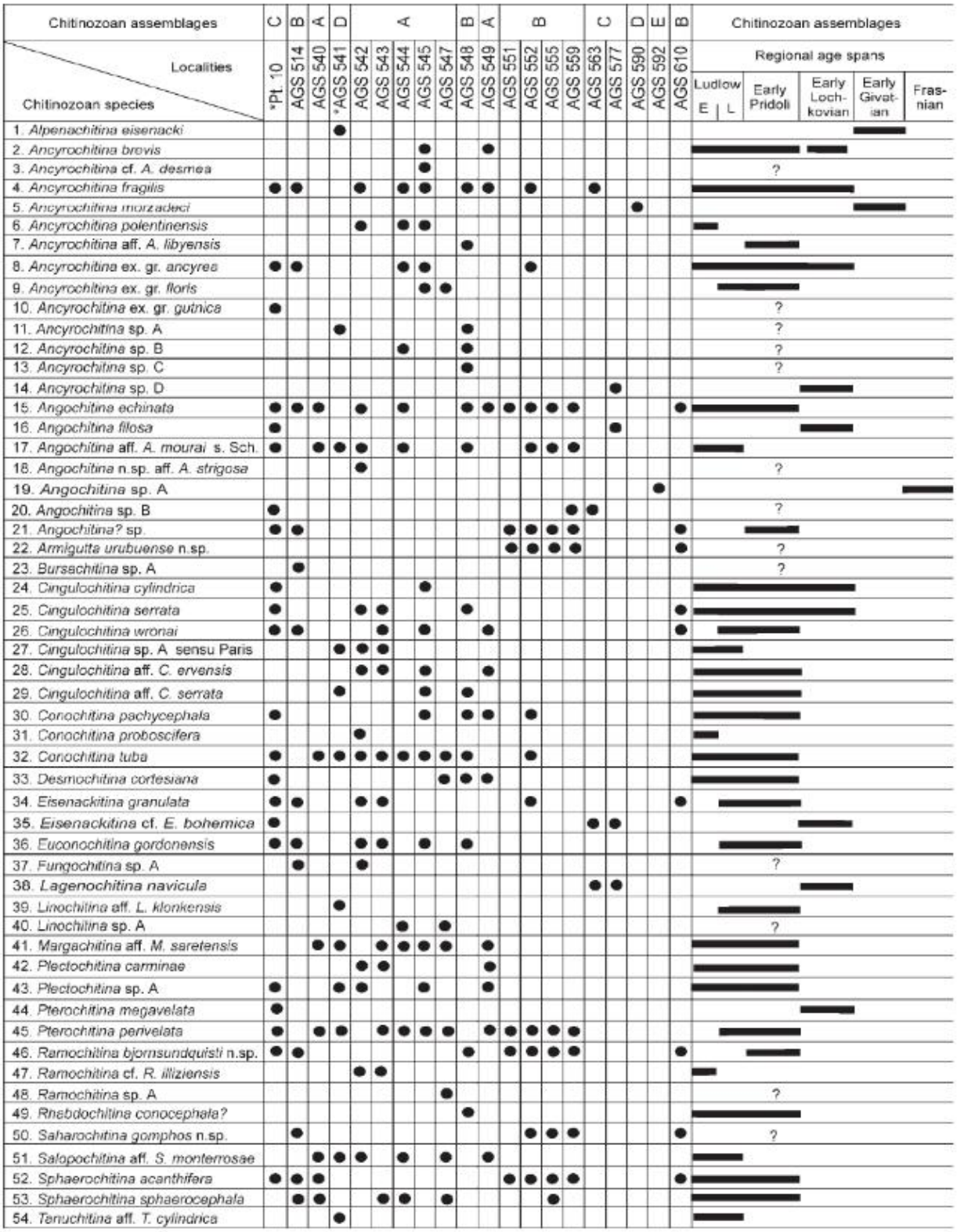

Fig. 2. Chitinozoan distribution chart in outcrops along the Urubu River and their respective age spans in the area. Asterisks mark localities with reworked chitinozoan faunas (see text).

Description: For a description of *Cingulochitina ervensis*, see Paris in Babin et al. 1979. *Cingulochitina* aff. *C. ervensis* differs from *C. ervensis* sensu stricto in having more convex flanks.

Dimension (31 specimens measured): Total length 98–157 µm, length of neck 1/5–1/3 of the total length, maximum width 45(36)–76(61) µm, width of aperture 30(24)–60(48) µm.

Occurrence: Amazonas Basin, lower Manacapuru Formation, Assemblage A and B (late Ludlow-early Pridoli); localities AGS 542, 543, 545 and 549; HGF 312. Azevedo-Soares and Grahn (in print) reported it from early Pridoli in the upper Pitinga Formation of well 1-AM-1-AM (Amazonas Basin).

Cingulochitina aff. *C. serrata* (Taugourdeau and Jekhowsky 1960)
Plate IV, fig. 10

Description: For a description of *Cingulochitina serrata*, see Paris 1981. *Cingulochitina* aff. *C. serrata* differs from *C. serrata* sensu stricto in having convex flanks and a shorter neck.

Dimension (7 specimens measured): Total length 95–132 µm, length of neck 1/5 of the total length, maximum width 72(58)–75(60) µm, width of aperture 55(44)–60(48) µm.

Occurrence: Amazonas Basin, lower Manacapuru Formation, Assemblages A and B (late Ludlow-early Pridoli); localities AGS 541, 545 and 548; HGF 312.

Subfamily Margachitininae Paris 1981

Genus *Margachitina* Eisenack 1968

Margachitina aff. *M. saretensis* Boumendjel 2002
Plate V, figs 7–8

2002 *Margachitina* sp. aff. *saretensis* – Jaglin and Paris, p. 346–348, Pl. 1, fig. 4 (further references)

Description: For a description of *Margachitina* aff. *M. saretensis* (*M.* sp. aff. *saretensis*), see Jaglin and Paris 2002.

Dimension (31 specimens measured): Total length (excl. peduncle) 68–127 µm, length of peduncle 25–68 µm, maximum width 90(72)–127(102) µm, width of aperture 55(44)–93(74) µm.

Occurrence: Amazonas Basin, possibly lower Manacapuru Formation, Assemblage A (late Ludlow); localities AGS 540, 541, 543, 544, 545, 547 and 549. Jaglin and Paris (2002) indicated a Pridoli to Lochkovian age for occurrences of this species in the Algerian and Libyan Sahara.

Genus *Linochitina* Eisenack 1968

Linochitina aff. *L. klonkensis* Paris and Laufeld 1981 (in Paris et al. 1981)
Plate V, fig. 6

Chitinozoan assemblages	E?	E		E?	B		
Localities / Chitinozoan species	GK 109	GK 110	GK 111	GK 112	HGF 300	HGF 301	HGF 312
1. *Angochitina echinata*					●		●
2. *Angochitina* aff. *A. strigosa*						●	●
3. *Angochitina* sp. A		●	●				
4. *Angochitina* sp. B					●	●	
5. *Angochitina?* sp.							●
6. *Cingulochitina wronai*							●
7. *Cingulochitina* aff. *C. serrata*							●
8. *Cingulochitina* aff. *C. ervensis*							●
9. *Cingulochitina* sp. A sensu Paris							●
10. *Eisenackitina granulata*							●
11. *Pterochitina perivalata*							●
12. *Sphaerochitina sphaerocephala*							●

Fig. 3. Chitinozoan species in outcrops along the Uatumã and Abacate rivers.

Description: For a description of *Linochitina klonkensis*, see Paris and Laufeld in Paris et al. (1981). Due to its small size, absence of tubular copula, and the very few individuals available for study this species is referred to *L.* aff. *L. klonkensis*.

Dimension (2 specimens measured): Total length 143–149 µm, length of neck 1/3 of the total length, maximum width 57(46)–60(48) µm, width of aperture 43(34)–46(37) µm.

Occurrence: Amazonas Basin, possibly lower Manacapuru Formation, Assemblage A (late Ludlow); locality AGS 541.

Linochitina sp. A
Plate I, figs 3–4

Description: A *Linochitina* species with an elongated ovoid body and a short neck. Flexure inconspicuous. Vesicle covered from aperture to base by tightly arranged transversal ribs.

Dimension (4 specimens measured): Total length 95–135 µm, length of neck 1/4 of the total length, maximum width 51(41)–72(58) µm, width of aperture 29(23)–56(45) µm.

Occurrence: Amazonas Basin, possibly lower Manacapuru Formation, Assemblage A (late Ludlow); localities AGS 544, 547.

Subfamily Eisenackitininae Paris 1981

Genus *Eisenackitina* Jansonius 1964

Eisenackitina cf. *E. bohemica* (Eisenack 1934)
Plate V, figs 1–2

1967 Tipos 76–77 – Lange, Pl. 6, figs 76–77
1992 *Eisenackitina* cf. *bohemica* – Grahn and Paris, Pl. 3, fig. 10

Fig. 4. Diagram showing regional chitinozoan ranges in the investigated outcrop sections.

2003 *Eisenackitina* cf. *E. bohemica* – Azevedo-Soares and Grahn, Pl. 1, fig. 18

Description: For a description of *Eisenackitina bohemica*, see Paris 1981. *E.* cf. *E. bohemica* has a shorter body and comparatively wider aperture.

Dimension (18 specimens measured): Total length 181–300 µm, maximum width 176(141)–275(220) µm, width of aperture 76(61)–127(102) µm.

Occurrence: Amazonas Basin, upper Manacapuru Formation, Assemblage C (early Lochkovian); localities Pt. 10; AGS 563, 577.

Subfamily Orbichitininae Achab, Asselin, Soufiane 1993

Genus *Armigutta* Schallreuter 1981

Armigutta urubuense n. sp.
Plate VI, figs 1–4

Derivation of name: Latin, *urubuense*, referring to the Rio Urubu, from which the holotype is described (locality AGS 555).

Diagnosis: An *Armigutta* species with a sphaerical body and a short cylindrical neck. The margin is provided with six long appendices branching at their tips. The vesicle wall is covered by tubercles. *A. urubuense* commonly occurs in chains.

Holotype: Plate VI, fig. 3. UERJ/DEPA collection 2222/0111.

Type locality: AGS 555.

Description: See diagnosis.

Dimensions (25 specimens measured): Total length 88–150 µm. Holotype 150 µm. Length of appendices 32–67 µm. Holotype 67 µm. Maximum width 64(51)–110 (88) µm. Holotype 105 (84) µm. Width of aperture 30(24)–57(46) µm. Holotype 47(38) µm. Length of neck 1/5 of the total length.

Occurrence: Amazonas Basin, lower Manacapuru Formation, Assemblage B (early Pridoli); localities AGS 551, 552, 555, 559, and 610.

Genus *Salopochitina* Swire 1990

Salopochitina aff. *S. monterrosae* (Cramer 1969)
Plate VI, figs 12, 14–15

1967 Tipos 89 a–b, 90 – Lange, Pl. 7, figs 89 a–b, 90
1968 *Conochitina filifera* – Jardiné and Yapaudjian, Pl. 6, figs 1–2

Description: For a description of *Salopochitina monterrosae*, see Cramer (1969) and Swire (1990, as *S. bella*). *Salopochitina* aff. *S. monterrosae* differs from *S. monterrosae* sensu stricto in having a granulate vesicle.

Dimension (45 specimens measured): Total length 135–370 µm, length of neck 1/5–1/3 of the total length, length of appendices max. 123 µm, maximum width 94(75)–263 (210) µm, width of aperture 47(38)–141(113) µm.

Occurrence: Amazonas Basin, possibly lower Manacapuru Formation, Assemblage A (late Ludlow); localities AGS 540, 541, 542, 544, 547, and 549. This species also occurs in Guinea-Bissau together with *Margachitina elegans* and *Tanuchitina* cf. *T. cylindrica* (Florentin Paris, personal communication 2003). The same association is also verified in the Amazonas Basin. Similar chitinozoans were reported as *Conochitina filifera* from Ludlow strata in the Polignac Basin (Algerian Sahara) by Jardiné and Yapaudjian (1968).

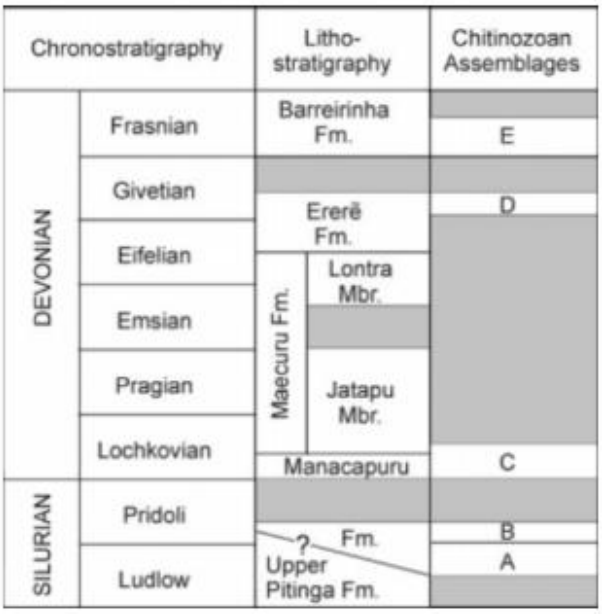

Fig. 5. Correlation diagram for the investigated sequences. After Jekhowsky (1960).

Order Prosomatifera Eisenack 1972
Family Conochitinidae Eisenack 1931 emend. Paris 1981
Subfamily Conochitininae Paris 1981

Genus *Rhabdochitina* Eisenack 1931

Rhabdochitina conocephala? Eisenack 1934 sensu Boumendjel 1987
Plate VI, fig. 13

1967 Tipos 51, 99–100 – Lange, Pl. 4, fig. 51, Pl. 8, figs 99–100
1987 *Rhabdochitina conocephala?* – Boumendjel, p. 73–74, Pl. 2, figs 4, 8
1992 *Rhabdochitina conocephala?* – Grahn and Paris, Pl. 2, fig. 7
2003 *Rhabdochitina conocephala?* – Azevedo-Soares and Grahn, Pl. 2, fig. 6

Description: For a description of *Rhabdochitina conocephala?* in the sense used herein, see Boumendjel (1987).

Dimension (1 specimen measured): Total length 800 µm, width 118(94) µm, width of aperture 127(102) µm.

Occurrence: Amazonas Basin, lower Manacapuru Formation, Assemblage B (early Pridoli); locality AGS 548. Boumendjel (1987) described *R. conocephala?* from Ludlow strata of the lower Mehaiguène Formation in the Algerian Sahara. It has also been reported from early Pridoli strata in the upper Pitinga Formation (Grahn and Paris 1992) and lower Manacapuru Formation (Azevedo-Soares and Grahn in print), Amazonas Basin.

Subfamily Tanuchitininae Paris 1981

Genus *Tanuchitina* Jansonius 1964

Tanuchitina aff. *T. cylindrica* (Taugourdeau and Jekhowsky 1960) sensu Boumendjel 1987
Fig. VI, fig. 5

?1967 Tipo 97 – Lange, Pl. 4, fig. 97
1987 *Tanuchitina* sp. aff. *cylindrica* – Boumendjel, p. 74, Pl. 1, figs 4, 8–9
1992 *Tanuchitina* sp. aff. *cylindrica* – Grahn and Paris, Pl. 2, fig. 12

Description: For a description of *Tanuchitina* aff. T. *cylindrica* in the sense used herein, see Boumendjel (1987).

Dimension (1 specimen measured): Total length 675 µm, width 113(90) µm, width of aperture 84(67) µm.

Occurrence: Amazonas Basin, possibly lower Manacapuru Formation, Assemblage A (late Ludlow); locality AGS 541. Boumendjel (1987) described *T.* sp. aff. *cylindrica* from Ludlow strata of the upper Mederba Formation in the Algerian Sahara, and Grahn and Paris (1992) mention it from the upper Pitinga Formation (late Ludlow?) in the Amazonas Basin.

Fig. 6. Chitinozoans from outcrops along Urubu River. The scale bars represent 100 µm.
1 – *Sphaerochitina acanthifera* Eisenack 1955. Manacapuru Fm. AGS 555. 2 – *Sphaerochitina acanthifera* Eisenack 1955. Manacapuru Fm. AGS 555. 3 – *Sphaerochitina sphaerocephala* (Eisenack 1932). Manacapuru Fm. AGS 514. 4 – *Sphaerochitina sphaerocephala* (Eisenack 1932). ?Manacapuru Fm. AGS 540. 5 – *Tanuchitina* aff. *T. cylindrica* (Taugourdeau and Jekhowsky 1960). Manacapuru Fm. AGS 541.

Family Lagenochitinidae Eisenack 1931 emend. Paris 1981
Subfamily Lagenochitininae Paris 1981

Genus *Saharochitina* Paris and Grahn 1999 (in Paris et al. 1999)

Saharochitina gomphos n. sp.
Plate VI, figs 9–11

1967 Tipo 102 – Lange, Pl. 8, fig. 102
2003 *Saharochitina* n. sp. A – Azevedo-Soares and Grahn (in print), Pl. 2, fig. 7

Derivation of name: Greek, *gomphos*, bolt, peg, nail, referring to the general shape of the species.

Diagnosis. A *Saharochitina* species with a short conical body and a long cylindrical neck.

Holotype. Plate VI, fig. 11. UERJ/DEPA collection 2219/0014.

Type locality: AGS 552.

Description: *Saharochitina gomphos* is characterized by its short conical body. The long subcylindrical neck widens at the aperture. The vesicle is glabrous and the flexure distinct. A mucron is present on the base (see Plate VI, fig. 9).

Dimensions (35 specimens measured): Total length 333–582 µm. Holotype 474 µm. Maximum width 105(84)–289(231) µm. Holotype 182 (146) µm, width of aperture 63(50)–200(160) µm. Holotype 109(87) µm, length of neck 66–85% of the total length. Holotype 3/4 of the total length.

Occurrence: Amazonas Basin, lower Manacapuru Formation, Assemblage B (early Pridoli); localities AGS 514, 552, 555, 559, and 610. Azevedo-Soares and Grahn (in print) mention *S. gomphos* as *Saharochitina* n. sp. A from well 1-AM-1-AM, Amazonas Basin.

Subfamily Angochitininae Paris 1981

Genus *Fungochitina* Taugourdeau 1966

Fungochitina sp. A
Plate V, figs 3–4

Description: A *Fungochitina* species with a conical body and a cylindrical neck. Flexure distinct. Vesicle wall provided with simple spines. Aperture straight.

Dimension (3 specimens measured): Total length 146–162 µm, maximum length of spines 12 µm, maximum width 86(69)–94(75) µm, width of aperture 43(34)–52 (42) µm, length of neck ca. 1/2 of the total length.

Occurrence: Amazonas Basin, lower Manacapuru Formation, Assemblages A and B (late Ludlow–early Pridoli); localities AGS 514, 542.

Genus *Angochitina* Eisenack 1931

Angochitina aff. *A. mourai* sensu Schweineberg 1987
Plate II, figs 9–10

1987 *Angochitina* sp. aff. *A. mourai* – Schweineberg, p. 62–63, Pl. 4, figs 5–11

Description: For a description of *Angochitina* aff. *A. mourai* in the sense used herein, see Schweineberg (1987). Schweineberg mentions multirooted spines in his description, but this is not obvious from his illustrations. The specimens from the Amazonas Basin have simple spines.

Dimension (36 specimens measured): Total length 115–222 µm, maximum length of spines 7 µm, maximum width 63(50)–118(94) µm, width of aperture 30(24)–73 (58) µm, length of neck 1/3 – 1/2 of the total length.

Occurrence: Amazonas Basin, lower Manacapuru Formation, Assemblages A and B (late Ludlow–early Pridoli); localities Pt. 10; AGS 540, 541, 542, 544, 548, 552, 555, and 559. Schweineberg (1987) described the species from Ludlow strata in the Province of Palencia, northern Spain.

Angochitina n. sp. aff. *A. strigosa* Boumendjel 2002
Plate III, figs 12–13

Description: For a description of *Angochitina strigosa*, see Boumendjel 2002. *Angochitina* n. sp. aff. *A. strigosa* is smaller than *A. strigosa* sensu stricto, and its neck tapers towards the collarette.

Dimension (5 specimens measured): Total length 245–336 µm, maximum width 80(64)–100(80) µm, width of aperture 50(40)–77(62) µm, length of neck 43–55% of the total length.

Occurrence: Amazonas Basin, lower Manacapuru Formation, Assemblages A and B (late Ludlow – early Pridoli); localities AGS 542; HGF 301, 312.

Angochitina sp. A
Plate III, fig. 11

Description: A poorly characterized *Angochitina* species with an ovoid body, and a subcylindrical neck that slightly tapers aperturewards. Aperture straight. Vesicle wall covered with small simple spines.

Dimension (15 specimens measured): Total length 160–215 µm, maximum length of spines 10 µm, maximum width 110(88)–135(108) µm, width of aperture 44(35)–69 (48) µm, length of neck 29–49% of the total length.

Occurrence: Amazonas Basin, lower Barreirinha Formation, Assemblage E (Frasnian); localities AGS 592; GK 110, 111.

Angochitina sp. B
Plate I, figs 5, 8
1967 Tipo 88 – Lange, Pl. 6, fig. 88

Description: An *Angochitina* species with an ovoid body and a wide neck that widens aperturewards. Flexure distinct. Vesicle covered by small simple spines that become larger near the aperture. The general outline is similar to that of *Sphaerochitina patula* Jaglin 1986, from which *Angochitina* sp. B differs in having spines.

Dimension (9 specimens measured): Total length 124–216 µm, maximum width 71(57)–105(84) µm, width of aperture 55(44)–74(59) µm, length of neck 4/5–1/2 of the total length.

Occurrence: Amazonas Basin, Manacapuru Formation, Assemblages B and C (early Pridoli–early Lochkovian); localities Pt. 10; AGS 559, 563; HGF 300, 301.

Genus *Ramochitina* Sommer and van Boekel 1964 emend. Paris, Grahn, Nestor, Lakova 1999

Ramochitina bjornsundquisti n. sp.
Plate V, figs 15–17

1967 Tipo 5 – Lange, Pl. 1, fig. 5
?1967 Tipo 34 – Lange, Pl. 3, fig. 34
1992 *Gotlandochitina* sp. A – Grahn and Paris, Plate 3, figs 1, 5
2003 *Ramochitina* n. sp. A – Azevedo-Soares and Grahn, Plate 2, figs 4–5

Derivation of name. Latin, *bjornsundquisti*, in honour of Dr. Björn Sundquist for his eminent contribution to geology during his 16.5 years as editor of GFF (former Geologiska Föreningens i Stockholm Förhandlingar) and Geologiskt Forum.

Diagnosis. A characteristic *Ramochitina* species with a sphaerical to slightly ovoid body, and a short cylindrical neck provided with long branching spines at the aperture. Similar spines occur on the body.

Holotype. Plate V, fig. 15. UERJ/DEPA collection 2219/0018.

Type locality: AGS 552.

Description: A *Ramochitina* species with a spherical or slightly ovoid body. The neck is subcylindrical and widened aperturewards. Flexure distinct. Well-preserved specimens bear six long spines around the aperture. These branch once, and each of these branches might be further subdivided up to four times. Similar spines occur on the body.

Dimensions (73 specimens measured): Total length 96–200 µm. Holotype 125 µm. Length of spines at the aperture maximum 54 µm. Holotype 42 µm. Length of spines on the body maximum 67 µm. Holotype 58 µm. Maximum width 60(48)–110(88) µm. Holotype 83(66) µm. Width of aperture 32(26)–67(54) µm. Holotype 42(34) µm. Length of neck 1/4–2/5 of the total length. Holotype 1/3 of the total length.

Occurrence: Amazonas Basin, lower Manacapuru Formation, Assemblage B (early Pridoli); localities Pt. 10; AGS 514, 548, 551, 552, 555, 559, and 610.

Ramochitina cf. *R. illiziensis* Boumendjel 1985
Plate I, fig. 2; Plate VI, figs 5–6

Description: For a description of *Ramochitina illiziensis*, see Boumendjel 1985 (as *Gotlandochitina illiziensis*). In the type material of *R. illiziensis* spines on

the lower anteaperturward part of the body generally are branching. This is not the case for *R.* cf. *R. illiziensis*.

Dimension (7 specimens measured): Total length 138–158 µm, maximum length of spines (on the body) 28 µm, maximum length of spines (on the neck) 7 µm, maximum width 76(54)–94(59) µm, width of aperture 34(30)–42(47) µm, length of neck 4/5–1/2 the total length.

Occurrence: Amazonas Basin, possibly lower Manacapuru Formation, Assemblage A (late Ludlow); localities AGS 542, 543.

Ramochitina sp. A
Plate VI, figs 7–8

Description: A *Ramochitina* species with an ovoid body and a short cylindrical neck. The vesicle is covered with ca. 30 longitudinal ridges which may interconnect over minor distances (see Plate VI, fig. 8).

Dimension (2 specimens measured): Total length 180–182 µm, maximum width 100(80)–107(86) µm, width of aperture 47(38)–51(41) µm, length of neck 1/3 of the total length.

Occurrence: Amazonas Basin, possibly lower Manacapuru Formation, Assemblage A (late Ludlow); locality AGS 547.

Subfamily Ancyrochitininae Paris 1981

Genus *Ancyrochitina* Eisenack 1955

Ancyrochitina cf. *A. desmea* Eisenack 1964
Plate II, figs 3–4

1967 Tipo 11 - Lange, Plate 1, fig. 11

Description: An *Ancyrochitina* species with an ovoid to spherical body and a cylindrical neck that slightly widens near the aperture. Flexure distinct. At about its middle part, the neck bears six long spines that subdivide along their length into 6 or more small branches. The margin bears six appendices that branch three times at their tips. Each of these branches may be further subdivided into six or more small branches.

Dimension (28 specimens measured): Total length 125–193 µm, maximum length of spines 63 µm, maximum length of appendices 46 µm, maximum width 75(60)–111 (89) µm, width of aperture 40(32)–60(48) µm.

Occurrence: Amazonas Basin, possibly lower Manacapuru Formation, Assemblage A (late Ludlow); locality AGS 545.

Ancyrochitina aff. *A. libyensis* Jaglin 1986
Plate II, fig. 10

Description: For a description of *Ancyrochitina libyensis*, see Jaglin (1986). *Ancyrochitina* aff. *A. libyensis* differs from *A. libyensis* sensu stricto in having a longer neck and a spherical body.

Dimension (1 specimen measured): Total length 169 µm, maximum length of appendices 44 µm, maximum length of spines 11 µm, maximum width 93(59) µm, width of aperture 62(47) µm, length of neck 1/3 of the total length.

Occurrence: Amazonas Basin, lower Manacapuru Formation, Assemblage B (early Pridoli); locality AGS 548.

Ancyrochitina ex. gr. *ancyrea* (Eisenack 1931)
Plate II, figs 11–12

1967 Tipo 13 – Lange, Pl. 2, fig. 13

Description: A group of *Ancyrochitina* species characterized by appendices with an antler-like branching. The body is conical and provided with a subcylindrical neck that widens at the straight aperture. On the neck occur a crown of long simple spines.

Dimension (23 specimens measured): Total length 137–213 µm, maximum length of spines on the neck 27 µm, maximum length of appendices 42 µm, maximum width 73(58)–123(98) µm, width of aperture 31(25)–75 (60) µm, length of neck 2/5–2/3 of the total length.

Occurrence: Amazonas Basin, lower Manacapuru Formation, Assemblages A and B (late Ludlow–early Pridoli); localities Pt. 10; AGS 514, 544, 545, and 552.

Ancyrochitina ex. gr. *floris* Jaglin 1986
Plate II, figs 13–14

Description: A group of *Ancyrochitina* species with short conical appendices with an antler-like branching at their tips. The body is conical and the neck cylindrical. Simple spines occur on the neck. It differs from *A. floris* s.s. in having a glabrous body.

Dimension (2 specimens measured): Total length 180–184 µm, maximum length of appendices 40 µm, maximum width 80(64)–128(102) µm, width of aperture 56 (45) µm, length of neck 1/2 of the total length.

Occurrence: Amazonas Basin, possibly lower Manacapuru Formation, Assemblage A (late Ludlow); localities AGS 545, 547.

Ancyrochitina ex. gr. *gutnica* Laufeld 1974
Plate II, figs 15–16

Description: For a description of *Ancyrochitina gutnica*, see Laufeld (1974). *Ancyrochitina* ex. gr. *gutnica* is a group of specimens that differs in having an ovoid body and a comparatively shorter neck.

Dimension (2 specimens measured): Total length 160–183 µm, maximum length of spines 36 µm, maximum length of appendices 36 µm, maximum width 84(67)–87 (70) µm, width of aperture 54(43)–55(44) µm, length of neck 2/5 of the total length.

Occurrence: Amazonas Basin, lower Manacapuru Formation, Assemblage B (early Pridoli); locality Pt. 10.

Ancyrochitina sp. A
Plate III, fig. 1

Description: This species has a conical body and a cylindrical neck. The margin is provided with six long appendices that branch at their tips. Flexure distinct. The middle of the neck displays long simple spines which become smaller aperture wards.

Dimension (4 specimens measured): Total length 138–200 µm, maximum length of spines 40 µm, maximum length of appendices 50 µm, maximum width 86(69)–104 (83) µm, width of aperture 50(40)–60(48) µm, length of neck 1/3–1/2 of the total length.

Occurrence: Amazonas Basin, lower Manacapuru Formation, Assemblages A and B (late Ludlow–early Pridoli); localities AGS 541, 548.

Ancyrochitina sp. B
Plate III, fig. 2

Description: A slender *Ancyrochitina* species with a conical body and a long cylindrical neck. The margin has six short and thick appendices that branch at their tips. Body and neck are provided with multi-rooted and simple spines. Aperture straight.

Dimension (5 specimens measured): Total length 213–222 µm, maximum length of spines 11 µm, maximum length of appendices 29 µm, maximum width 84(67)–136 (109) µm, width of aperture 41(33)–61(49) µm, length of neck 1/2–3/5 of the total length.

Occurrence: Amazonas Basin, lower Manacapuru Formation, Assemblages A and B (late Ludlow–early Pridoli); localities AGS 544, 548.

Ancyrochitina sp. C
Plate III, fig. 3

Description: A species with a conical body and a cylindrical neck. The margin display six short and thick appendices that branch at their tips. Somewhat aperturewards of the flexure there are six long and simple spines. The spines become smaller aperturewards.

Dimension (2 specimens measured): Total length 164–189 µm, maximum length of spines 33 µm, maximum length of appendices 16 µm, maximum width 100(80)–109 (87) µm, width of aperture 53(42)–56(38) µm, length of neck 1/2 the total length.

Occurrence: Amazonas Basin, lower Manacapuru Formation, Assemblage B (early Pridoli); locality AGS 548.

Ancyrochitina sp. D
Plate II, fig. 4

1967 Tipo 17 – Lange, Pl. 2, fig. 17

Description: The species has an ovoid body and a long cylindrical neck. Flexure distinct. Margin provided with 4–6 long simple appendices, and the aperture displays a crown of up to 10 simple spines.

Dimension (2 specimens measured): Total length 237–438 µm, maximum length of spines 37 µm, maximum length of appendices 175 µm, maximum width 86(69)–163 (130) µm, width of aperture 39(31)–63(50) µm, length of neck 55% of the total length.

Occurrence: Amazonas Basin, upper Manacapuru Formation, Assemblage C (early Lochkovian); locality AGS 577.

Genus *Plectochitina* Cramer 1964

Plectochitina sp. A
Plate V, figs 9–10

1967 Tipo 12 a, b – Lange, Pl. 2, figs 12 a, b

Description: A *Plectochitina* species with 8–10 simple, thick spongious appendices with a wide base. Body conical and provided with a cylindrical neck that widens at the aperture.

Dimension (29 specimens measured): Total length 120–205 µm, maximum length of appendices 62 µm, maximum width 61(49)–127(102) µm, width of aperture 18 (14)–67(54) µm, length of neck 1/3–3/5 of the total length.

Occurrence: Amazonas Basin, lower Manacapuru Formation, Assemblages A and B (late Ludlow–early Pridoli); localities Pt. 10; AGS 541, 542, 545, and 549.

Concluding remarks

Chitinozoans have been recovered from the Manacapuru (perhaps also uppermost Pitinga), Ererê and Barreirinha formations along the Urubu, Uatumã and Abacate rivers in the Amazonas Basin (Fig. 5). The chitinozoans make up five distinct assemblages (A–E). Assemblage A is characterized by the Ludlow species *Ancyrochitina polentinensis, Cingulochitina* sp. A and *Tanuchitina* aff. *T. cylindrica*. The presence of *Eisenackitina granulata, Euconochitina gordensis* and *Pterochitina perivelata* restricts the age to late Ludlow, and the occurrence of the acritarch *Tyrannus giganteus* confirms an age no younger than Ludlow. This assemblage seems to be present in the lower Manacapuru Formation; if confirmed, this implies that the base of this formation is diachronous (late Ludlow to early Pridoli). Assemblage B has a diagnostic fauna for the early Pridoli with *Angochitina?* sp. and the newly described species *Armigutta urubuense, Ramochitina bjornsundquisti*, and *Saharochitina gomphos*. This fauna occurs in the lower Manacapuru Formation (Azevedo-Soares and Grahn in print). Higher up, *Eisenackitina* cf. *E. bohemica, Lagenochitina navicula* and *Pterochitina megavelata* are diagnostic species for an early Lochkovian age of Assemblage C, that occurs in the upper Manacapuru Formation (and elsewhere, also in the lower Jatapu Member of the Maecuru Formation).

Assemblage D consists of *Alpenachitina eisenacki* and *Ancyrochitina morzadeci*, which jointly suggest an early Givetian age in the Amazonas Basin (Grahn and Melo in print), although the regional inception of *A. eisenacki* is somewhat older (late early to late Eifelian, the uppermost Lontra Member of Maecuru Formation in well 1-AM-1-AM, see Fig. 1). The youngest assemblage, Assemblage E, is considered Frasnian based mainly on acritarch and spore data. The chitinozoan species present are non-diagnostic. Whether the chitinozoan assemblages A–C can be formalized into biozones or not requires further investigations. Assemblage D is characteristic for the *Ramochitina stiphrospinata* Zone (Grahn and Melo in print). By contrast, Assemblage E cannot be safely attributed to any known Late Devonian chitinozoan biozone (see Grahn and Melo 2002).

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