

Devonian chitinozoan biozones of Western Gondwana

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ABSTRACT:

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A formal Devonian chitinozoan biozonation for western Gondwana is proposed. This palaeogeographic province corresponds to South America, and was located in medium to high latitudes during the Devonian. Devonian chitinozoans are known from northern Argentina, Bolivia, Brazil and eastern Paraguay. Altogether 230 localities (including wells and outcrops) are included in this study, and 171 species have been encountered. One new species, *Angochitina praedensibaculata*, is described. A biozonation based on the first occurrence of critical chitinozoan species is introduced. Thirteen biozones are defined: the *Angochitina praedensibaculata*, *Angochitina strigosa*, *Urochitina lobo*, *Ramochitina magnifica*, *Ancyrochitina pachycerata*, *Ancyrochitina parisi*, *Alpenachitina eisenacki*, *Ramochitina stiphrospinata*, *Fungochitina microspinosa* – *Ancyrochitina taouratinensis*, *Hoegisphaera glabra*, *Urochitina bastosi* – *Sommerochitina langei*, *Fungochitina fenestrata* and *Fungochitina ultima* zones. These biozones are compared with known spore zones from the same area, and chitinozoan biozones on a global basis.

Key words: Devonian, Western Gondwana, Chitinozoa, Biostratigraphy.

INTRODUCTION

Devonian miospores have been extensively used for the Devonian biostratigraphy of Brazil (MELO & LOBOZIAK 2003 and references therein), Bolivia (e.g. MCGREGOR 1984, MELO 2000, and references therein), eastern Paraguay and northern Argentina (OTTONE 1996 and references therein). WOOD & ISAACSON (1992), RACHEBOEUF & al. (1993), OLIVEIRA (1991), LE HÉRISSE & al. (1996) and LE HÉRISSE (2001) outlined an acritarch stratigraphy for western Gondwana (South America). From several studies in Argentina, Bolivia, Paraguay, Uruguay and Brazil it is obvious that a certain degree of acritarch endemism existed in western Gondwana basins. Devonian conodonts (*Cryptotaxis* sp.) are so far known only from the Frasnian – middle Famennian? in the Solimões Basin, northwestern Brazil (HÜNICKEN & al. 1988). For a review of the literature and further information on the Devonian shelly faunas, see MELO (1988) and GRAHN (1992). Chitinozoans have been used for

regional Devonian biozonation in the basins of western Gondwana (for references, see below). The purpose of this paper is to correlate all these regional schemes into a Devonian chitinozoan biozonation valid for western Gondwana, to compare it to an available and relevant miospore biozonation (Text-fig. 7), and to the chitinozoan biozonation on a global basis (Text-figs 3, 7).

PREVIOUS CHITINOZOAN STUDIES IN THE DEVONIAN OF WESTERN GONDWANA

Since the papers by LANGE (1949, 1952, 1967a-b), SOMMER & BOEKEL VAN (1964), PÖTHE DE BALDIS (1979), QUADROS (1982, 1988), BURJACK & PARIS (1989), GRAHN (1992) and GRAHN & PARIS (1992), new geological information has been published about Devonian Chitinozoa from Brazil and Paraguay (MELO & al. 1996; GRAHN & MELO 2002, 2003, 2004, in press; GRAHN in press; GRAHN & al. 2000, 2001, 2002, 2003, 2005;

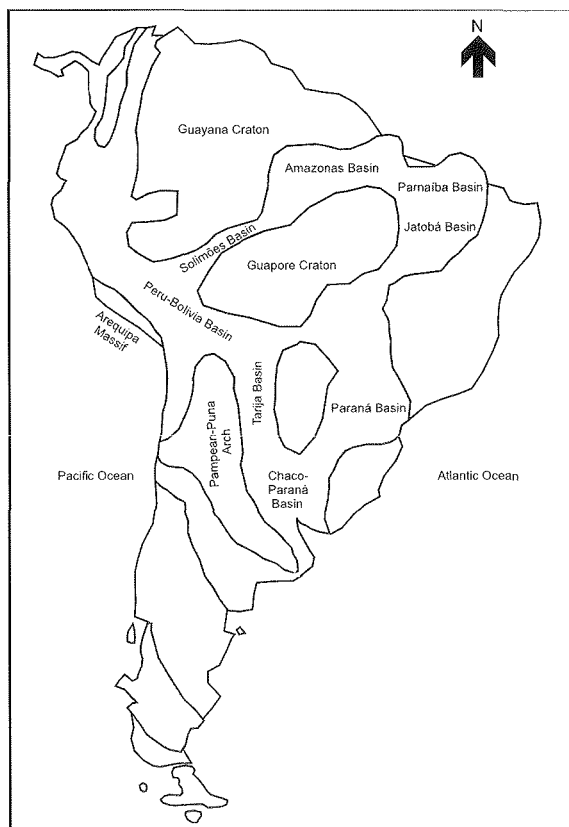


Fig. 1. Devonian sedimentary basins in South America. Based on WOOD & ISAACSON 1992

AZEVEDO-SOARES & GRAHN 2005; GAUGRIS & GRAHN in press), and they were also the subject of a doctoral thesis by QUADROS (1985). Chitinozoans of Devonian age have been described or discussed from Bolivia (COUSMINER 1964; SUÁREZ-RIGLOS 1975; GAGNIER & al. 1989; WOOD & ISAACSON 1992; RACHEBOEUF & al. 1993; WOOD 1994; LIMACHI & al. 1996; OTTONE & ROSSELLO 1996; VAVRDOVÁ & al. 1996; MELO 2000; GRAHN 2002), and northern Argentina (VOLKHEIMER & al. 1983; 1986; OTTONE 1996; GRAHN & GUTIÉRREZ 2001; GRAHN 2003).

NOTES ON THE DEVONIAN PALAEOGEOGRAPHY AND PALAEOENVIRONMENT OF WESTERN GONDWANA

South America was a part of Gondwana and located in medium to high latitudes during the Devonian (SCOTESE 2005). Cold water with a Malvinocaffric fauna prevailed during the Early Devonian (MELO 1988), but from the late Eifelian – early Givetian the conditions changed towards warm water conditions, and the Malvinocaffric fauna slowly became extinct. At the end

of the Famennian a glaciation took place, but the chitinozoans disappeared from western Gondwana (in the *Vallatisporites hystricosus* [VH] Interval spore Zone) before this event (*Retispora lepidophyta* – *Vallatisporites vallatus* [LVa] Interval spore Zone). Chitinozoan provincialism was evident in the Paraná, Tarija and Peru-Bolivia basins during the Early Devonian, and in the Middle Devonian a great influx of Laurentian faunas can be noticed all over western Gondwana. A certain degree of endemism of acritarchs is noted in the Late Devonian (LE HÉRISSE 2001).

CHITINOZOAN BIOSTRATIGRAPHY

Bolivia

Twenty localities have been investigated for chitinozoans from the Peru-Bolivia Basin in southern Bolivia. The Devonian chitinozoans discussed by GAGNIER & al. (1989), RACHEBOEUF & al. (1993) and WOOD (1994) were commented upon by GRAHN (2002). LIMACHI & al. (1996) defined a biozone with *Urochitina lobo* and *Sphaerochitina densibaculata* for the top of the Tarabuco and Santa Rosa formations, with the additional chitinozoan species *Cingulochitina* sp. and *Hoegisphaera* sp. This is a late Lochkovian assemblage, and confirms the dating by GRAHN (2002). VAVRDOVÁ & al. (1996) discussed a chitinozoan fauna from northern Bolivia (Madre de Dios Basin) with *Angochitina filosa*, *Urochitina* cf. *lobo*, *Lagenochitina navicula* and *Cingulochitina serrata* in Late Lochkovian strata in the Tequeje Formation, and *Ramochitina magnifica* and *Hoegisphaera* cf. *glabra* for latest Lochkovian – Pragian strata in the same formation.

Argentina

Seven localities have been studied from northern Argentina. OTTONE (1996) discussed chitinozoans from the Los Monos Formation in the Quebrada Galarza well, Tarija Basin. The chitinozoan fauna have a low diversity, which is common in a late Givetian – early Frasnian fauna, i.e. *Fungochitina pilosa*, *Angochitina* spp., *Lagenochitina* sp. and *Ancyrochitina* sp. From the Puesto el Tigre well in the same basin, VOLKHEIMER & al. (1986) described chitinozoans from three Early Devonian assemblages in the Puesto El Tigre Formation, i.e. *Cingulochitina serrata*, *Sphaerochitina densibaculata* and *Urochitina lobo* (late Lochkovian), *Hoegisphaera* sp. and *Ramochitina magnifica* (Pragian), and *Ancyrochitina parisi* (late Emsian). From the Tonono and Ramos wells in the Tarija Basin, they also mentioned *Fungochitina*

Chrono-stratigraphy	Argentina		Bolivia		Paraguay	Brazil				Chitinozoa biozonation	
	Tarija Basin Volkheimer et al. 1986 Oltone 1996	Precordillera Le Hérisse et al. 1996	Peru-Bolivia Basin Grahn 2002	Madre de Dios Basin Dufka in Vavrdova et al. 1996	Parana Basin Grahn et al. 2000, 2002	Solimões Basin Grahn et al. 2003	Amazonas Basin Grahn & Melo 2002, 2003, 2004 Azevedo-Soares & Grahn 2005	Parnaíba & Jatobá basins Grahn et al. 2001, 2005 Grahn & Melo in press	Paraná Basin Grahn et al. 2000, 2002 Gaugris & Grahn in press	Western Gondwana This paper	Global Paris et al. 2000
Famennian						F. ultima	R. cf. R. ritae			F. ultima	Fungochitina ultima
							R. ritae			Fungochitina fenestrata	Fungochitina fenestrata
Frasnian			L. avelinoi			Angochitina mourai	Urochitina bastosi Sommerochitina langei			U. bastosi S. langei	A. avelinoi A. hispida
			Fungochitina pilosa					L. avelinoi	H. glabra R. derbyi	Hoegispheera glabra	Hoegispheera glabra
Givetian	Fungochitina pilosa		Ancyrochitina langei Fungochitina pilosa						A. langei F. pilosa	Fungochitina microspinosa Ancyrochitina taouratinensis	P. perforata L. jardinei
			A. taouratinensis						F. microspinosa A. taouratinensis	Ancyrochitina taouratinensis	A. cornigera
Eifelian			Alpenachitina eisenacki		Alpenachitina eisenacki	Ancyrochitina arirambaense Alpenachitina eisenacki	Alpenachitina eisenacki	A. latipes A. langei	A. eisenacki S. biconstricta	Alpenachitina eisenacki	Eisenackitina aranea
			R. ramosi		?	?		A. n.sp. A	?	Not yet defined	A. eisenacki
Emsian	A. parisi	Armeriochitina aff. panzuda	A. parisi						A. parisi	A. parisi	Not yet defined
			?								A. panzuda
Pragian		Bulbochitina bulbosa	Ancyrochitina sp. A							Ancyrochitina pachycerata	Ancyrochitina pachycerata
	Ramochitina magnifica		Ramochitina magnifica	Ramochitina magnifica	Ramochitina magnifica			Ramochitina sp. A&B		Ramochitina magnifica	Ramochitina magnifica
Lochkovian	Urochitina loboii	Urochitina loboii	Urochitina loboii	Urochitina loboii		U. loboii R. jutaiense				Urochitina loboii	Urochitina simplex
			Eisenackitina cf. E. bohemica			Angochitina filiosa	Eisenackitina cf. bohemica A. cf. S. densibaculata			Angochitina strigosa A. praedensibaculata	Angochitina strigosa Eisenackitina bohemica

Fig. 2. Chronostratigraphy and chitinozoan zones in the Devonian of western Gondwana. In the Amazonas Basin 1 = Total Range Subzone of *Ramochitina derbyi* and 2 = Total Range Subzone of *Lagenochitina avelinoi*

pilosa in the Givetian Tonono Formation. LE HÉRISSE & *al.* (1996) discussed *Cingulochitina serrata*, *Urochitina* cf. *loboii*, and *Ramochitina jutaiense* (late Lochkovian) from the Talacasto Formation in the Cerro del Fuerte section, Argentine Precordillera. Finally, GRAHN & GUTIÉRREZ (2001) and GRAHN (2003) mentioned Middle Devonian species from the Rincón Formation in the Los Horcones-2 and El Caburé-1 wells, Chaco-Paraná Basin.

Brazil and eastern Paraguay

In GRAHN & *al.* (2000) a regional chitinozoan biozonation was suggested for the Early Devonian of the Paraná Basin including eastern Paraguay, and in GRAHN

& *al.* (2002) a Middle-Late Devonian chitinozoan biozonation was erected for the same area. LANGE (1967b) achieved the first Devonian biozonation of the Paraná Basin, and PÖTHE DE BALDIS (1979) discussed Late Devonian chitinozoans from Paraguay. Devonian chitinozoans from the Amazonas Basin have been described by GRAHN & MELO (2002, 2003, 2004), MELO & *al.* (1996), LANGE (1967a) and BOEKEL VAN (1966, 1967, 1968), and chitinozoans from the Solimões Basin by QUADROS (1988) and GRAHN & MELO (2003), and from the Parnaíba and Jatobá basins by REGALI (1964), SOMMER & BOEKEL VAN (1964), QUADROS (1982), GRAHN & MELO (in press), GRAHN & *al.* (2001), and GRAHN & *al.* (2005).

Characterization of zone: this zone is defined from the FO of *Angochitina strigosa* to the FO of *Urochitina lobo*i in the late Lochkovian. Characteristic species in this zone are *Ancyrochitina cantabrica*, *Ancyrochitina ollivierae*, *Angochitina filosa*, *Eisenackitina* cf. *bohemica* and *Plectochitina* sp.nov. A. (Text-fig. 4).

Lower boundary reference section: well 1-AM-1-AM at level 1522 m, which is 22 m below the top of the Manacapuru Formation.

Representative occurrences of zone: well 1-AM-1-AM, 1500-1522 m, and several outcrop localities in the Trombetas and Xingu areas, Amazonas Basin, Brazil (GRAHN in press).

Lithostratigraphic distribution: upper Manacapuru Formation, Amazonas Basin and lower Jutai Formation, Solimões Basin, northern Brazil.

Age range: early – “middle” Lochkovian.

Remarks: *Angochitina strigosa* ranges through the early – “middle” Lochkovian.

***Urochitina lobo*i Interval Range Zone**

Definition of base of zone: FO of *Urochitina lobo*i

Characterization of zone: this zone is defined from the FO of *Urochitina lobo*i to the FO of *Ramochitina magnifica* in the latest? Lochkovian. Other species are *Ancyrochitina brevis*, *Margachitina saretensis*, *Margachitina tenuipes*, *Ramochitina jutaiense* and *Sphaerochitina densibaculata*.

Lower boundary reference section: well 1-JD-1-AM (Jandiatuba n° 1), Solimões Basin (Jandiatuba Sub-basin), level 2440 m, which is 100 m above the base of the Jutai Formation.

Representative occurrences of zone: well 1-JD-1-AM, 2420-2440 m, upper Jutai Formation, Solimões Basin, Brazil. Lower Puesto el Tigre Formation, Tarija Basin, Argentina.

Lithostratigraphic distribution: upper Jutai Formation, Solimões Basin, Brazil. Lower Talacasto Formation, Tarija Basin, Argentine Precordillera. Lower Tequeje Formation, Madre de Díos Basin, northern Bolivia. Upper Tarabuco and lower Santa Rosa formations, Peru-Bolivia Basin, southern Bolivia.

Age: late Lochkovian.

Remarks: In the Jutai Formation the presence of *Urochitina lobo*i was independently dated as late Lochkovian (zone Z of BZ miospore zone) by RUBINSTEIN & al. (2005). *Sphaerochitina* cf. *patula* by GRAHN & MELO (2003) is conspecific with *Angochitina* sp. B (Text-fig. 4) in the present study.

***Ramochitina magnifica* Interval Range Zone**

Definition of base of zone: FO of *Ramochitina magnifica*.

Characterization of zone: this zone is defined from the FO of *Ramochitina magnifica* to the FO of *Ancyrochitina pachycerata* in the Pragian s.l. *Ramochitina* cf. *magnifica* and *Hoegisphaera* cf. *glabra* are other common taxa.

Lower boundary reference section: Jaguariaiva Section, Paraná Basin (Apucarana Sub-basin), southern Brazil, about 15 m above the contact with the underlying Furnas Formation.

Representative occurrences of zone: Jaguariaiva, Tibaji – Telêmaco Borba, and Baliza sections, Paraná Basin, southern Brazil. Well Asuncion-1, Santa Elena Formation, 2270-2360 m, Paraná Basin, eastern Paraguay. Tarabuco, La Yesera, Sobo-Sobo and Sella sections, Peru-Bolivia Basin, southern Bolivia, and upper Tequeje Formation in the Pando well (1817-1883.5 m), Madre de Díos Basin, northern Bolivia. Puesto el Tigre well (ca. 400 m below the contact with the overlying Tonono Fm.), Tarija Basin, northern Argentina.

Lithostratigraphic distribution: lower Ponta Grossa Formation, Paraná Basin, southern Brazil. Upper Santa Elena Formation; Paraná Basin, eastern Paraguay. Middle Tequeje, upper Santa Rosa and Lower Icla formations, Madre de Díos and Peru-Bolivia basins, Bolivia, and Middle Puesto el Tigre Formation, Tarija Basin, northern Argentina.

Age: latest? Lochkovian – Pragian s.l. The FO of *R. magnifica* is somewhat uncertain. In the Paraná Basin this species appears in younger beds than those in the uppermost Furnas Formation dated as late Lochkovian (zone Si of MN miospore zone) by RUBINSTEIN & al. (2005). The same beds were dated as early Pragian by DINO & RODRIGUES (1990) and LOBOZIAK & al. (1995). In eastern Paraguay the species occur together with Lochkovian – early Pragian miospores (Si – B miospore zones, PEREIRA 2000) in cuttings from the upper Santa

Elena Formation. In northern Argentina *R. magnifica* occurs above *U. lobo* and together with a similar fauna as in the lower Ponta Grossa Formation. In Bolivia it occurs together with Pragian miospores (VAVRDOVÁ & *al.* 1996; MELO 2000) and chitinozoans (RACHEBOEUF & *al.* 1993). *R. magnifica* has not been found together with chitinozoan species characteristic of the Lochkovian.

***Ancyrochitina pachycerata* Interval Range Zone**

Definition of base of zone: FO of *Ancyrochitina pachycerata*.

Characterization of zone: this zone is defined from the FO of *Ancyrochitina pachycerata* to the FO of *Ancyrochitina parisi* in the late Emsian. Another species present is *Ancyrochitina* sp.nov. C (GAUGRIS & GRAHN in press) in the lower part of the zone.

Lower boundary reference section: well 9-PPG-7-PR (Projeto Ponta Grossa n° 7) at level 118.60 m, which is 16.40 m above the TD of the well. Paraná Basin (Apucarana Sub-basin), southern Brazil.

Representative occurrences of zone: well RVR-1, 174.50-215.50 m, well 9-PPG-7-PR, 28.80-118.60 m, and well 9-PPG-6-PR (Projeto Ponta Grossa n° 6), 20.50-30.40 m, Paraná Basin, Brazil.

Lithostratigraphic distribution: lower Ponta Grossa Formation, Paraná Basin, southern Brazil.

Age: late Pragian – early Emsian.

Remarks: *Ancyrochitina pachycerata* ranges from the late Pragian to the early Emsian. Its FO in the Paraná Basin is within a sequence dated by miospores (GAUGRIS & GRAHN in press) as late Pragian – pre-late Emsian. Within this zone occur in the uppermost Jaicós Formation (well 1-TM-1-MA [Tem medo n° 1], core 67, 1313.38-1313.70 m), Parnaíba Basin, northern Brazil, an interval with *Ramochitina* sp. A and *R.* sp. B, dated by miospores as latest Pragian – earliest Emsian? (Su Interval Zone) (STEEMANS in GRAHN & *al.* 2005).

***Ancyrochitina parisi* Interval Range Zone**

Definition of base of zone: FO of *Ancyrochitina parisi*.

Characterization of zone: this zone is defined from the FO of *Ancyrochitina parisi* to the last occurrence of

Ancyrochitina pachycerata. In this zone occurs also *Ramochitina ramosi* (first occurrence).

Lower boundary reference section: well Puesto el Tigre 1, at a level ca. 250 m below the contact with the overlying Tonono Formation, Tarija Basin, northern Argentina.

Representative occurrences of zone: well Puesto el Tigre 1, 50-250 m (below the contact with Tonono Formation), Tarija Basin, northern Argentina. La Yesera section, upper Icla Formation, Peru-Bolivia Basin, southern Bolivia. Tibaji – Telémaco Borba (ca. 63-70 m) and Baliza (ca. 13-25 m) sections, upper Ponta Grossa and lowermost São Domingos formations, Paraná Basin, southern Brazil.

Lithostratigraphic distribution: upper Puesto el Tigre Formation, Tarija Basin, northern Argentina. Upper Icla Formation, Peru-Bolivia Basin, southern Bolivia. Upper Ponta Grossa and lowermost São Domingos formations, Paraná Basin, southern Brazil.

Age: late Emsian (possibly including late early Emsian and earliest Eifelian). A late Emsian age for the upper Ponta Grossa / lowermost São Domingos formations is supported by miospores (LOBOZIAK & MELO 2000) and megafossils (MELO 1988).

Undefined interval

Between the upper Emsian / lowermost Eifelian and the upper lower Eifelian (Itaim and lowermost Pimenteira formations in the Parnaíba Basin and Lontra Member of the Maecuru Formation in the Amazonas Basin) occurs an interval with a few non-diagnostic chitinozoan species. This is probably due to unsuitable lithologies for chitinozoan preservation (i.e. sandstones). The taxa present in this undefined interval are *Ancyrochitina latipes* with an early Eifelian FO (lower AD pre-LEM miospore Zone, GRAHN & *al.* 2001) in the Parnaíba Basin (known from early-middle Givetian, Illinois, U.S.A.), *Angochitina* sp.nov. A (restricted to the GS miospore Zone, which ranges from possible latest Emsian to early Eifelian, GRAHN & MELO 2004) and *Hoegisphaera cf. glabra*.

***Alpenachitina eisenacki* Interval Range Zone**

Definition of base of zone: FO of *Alpenachitina eisenacki*

Characterization of zone: this zone is defined from the first occurrence in this interval of *Alpenachitina eisenacki* in the late early Eifelian to the first occurrence of

Ramochitina stiphrospinata in the early Givetian. Also present in this biozone are *Ancyrochitina* cf. *ancyrea*, *A. aff. langei*, *A. arirambaense*, *A. langei*, *A. aff. morzadeci*, *Eisenackitina aranea*, *Lagenochitina praeavelinoi*, *Linochitina* aff. *santullaensis* and *Ramochitina* sp. A.

Lower boundary reference section: well 1-AM-1-AM at level 1405.4 m, which is 6.4 m below the base of the Ererê Formation, Amazonas Basin, northern Brazil.

Representative occurrences of zone: well 1-MS-5-AM (Rio Maués n° 5), 1515.0-1546.0 m, Ererê Formation, Amazonas Basin, northern Brazil. Well 1-RSP-1-MT (Projeto Rondonópolis, Serra de Petrovina n° 1), 279.0-348.0 m, São Domingos Formation, Paraná Basin (Alto Garças Sub-basin). Sobo-Sobo and Tarabuco sections, Huamampampa Formation, southern Bolivia (Peru-Bolivia Basin).

Lithostratigraphic distribution: Lower Uerê Formation, Solimões Basin, Upper Lontra Member of the Maecuru Formation and Lower Ererê Formation, Amazonas Basin, Lower Pimenteira Formation, Parnaíba Basin, northern Brazil. Lower São Domingos Formation, Paraná Basin, southern Brazil. Huamampampa Formation, Peru-Bolivia Basin, southern Bolivia. Upper Rincón Formation, Tarija and Chaco-Paraná basins, northern Argentina.

Age: late early Eifelian – earliest Givetian.

Remarks: *Alpenachitina eisenacki* ranges from late early Eifelian to early Givetian (upper LLI miospore zone in the Paraná Basin, LOBOZIAK & al. 1988; GRAHN & al. 2002). *Ancyrochitina* cf. *latipes* and *Ancyrochitina* cf. *cornigera* in GRAHN & al. (2002) are determined as *sensu stricto* in the present study.

***Ramochitina stiphrospinata* Total Range Zone**

Definition of base of zone: FO of *Ramochitina stiphrospinata*.

Characterization of zone: this zone is defined from the FO of *Ramochitina stiphrospinata* to the FO of *Fungochitina microspinosa* in the middle Givetian. In the *R. stiphrospinata* Zone many species have their first occurrence, of which some are restricted to the early Givetian (see Text-fig. 5).

Lower boundary reference section: well 2-PM-1-MA (Pindare Mirim n° 1), core 47, level 1537.8 m, Parnaíba Basin, northern Brazil.

Representative occurrences of zone: well 1-RX-1-AM (Rio Abacaxis n° 1), 2647-2695 m, Ererê Formation, Amazonas Basin and well 1-RB-1-MA (Ribeirãozinho n° 1), 1175-1182 m, lower Pimenteira Formation, Parnaíba Basin, northern Brazil. Angosto de Huacareta section, Huamampampa Formation, Peru-Bolivia Basin, southern Bolivia.

Lithostratigraphic distribution: Ererê Formation, Amazonas Basin, Lower Pimenteira Formation, Parnaíba Basin, northern Brazil. Lower São Domingos and upper “Lima” formations in the Paraná Basin, southern Brazil and eastern Paraguay, respectively. Huamampampa Formation, Peru-Bolivia Basin, southern Bolivia.

Age: early Givetian.

Remarks: *Ramochitina stiphrospinata* is restricted to the early Givetian (LLI miospore Zone) as dated by miospores (MELO & LOBOZIAK 2003, GRAHN & MELO 2004).

***Fungochitina microspinosa* – *Ancyrochitina taouratinensis* Concurrent Range Zone**

Definition of base of zone: FO of *Fungochitina microspinosa*.

Characterization of zone: this zone is defined from the first occurrence of *Fungochitina microspinosa* and the co-occurrence with *Ancyrochitina taouratinensis* in the middle-late Givetian to the first occurrence of *Hoegisphaera glabra*. Other characteristic species in this interval are *Ancyrochitina brevicornuta*, *Lagenochitina* sp. B, *Plectochitina* sp. A *sensu* GRAHN 2002, *Ramochitina pimenteiraense* and *Ramochitina* sp. nov. C *sensu* GAUGRIS & GRAHN in press. Species with their last occurrences in this zone are *Ancyrochitina langei*, *A. morzadeci*, and *Ramochitina boliviensis*.

Lower boundary reference section: well 1-RSP-1-MT, level 264.00 m, São Domingos Formation, Paraná Basin (Alto Garças Sub-basin).

Representative occurrences of zone: well 1-RB-1-MA, 1171.5 – 1175.0 m, lower Pimenteira Formation, Parnaíba Basin, northern Brazil. Well 1-RSP-1-MT, 220.00-264.00 m, São Domingos Formation, Paraná Basin, southern Brazil. Angosto de Huacareta section, lower Los Monos Formation, Peru-Bolivia Basin, southern Bolivia.

Lithostratigraphic distribution: lower Pimenteira Formation, Parnaíba Basin, northern Brazil. São

Age: early-late Frasnian.

Remarks: *Hoegisphaera glabra* ranges from the Frasnian to the middle Famennian. *Lagenochitina avelinoi* has been widely used as an index species in the regional correlations, but it has different ranges in the different basins. In the Amazonas Basin the species is restricted to the BJ miospore Zone of early Frasnian age (GRAHN & al. 2002). In the Parnaíba Basin the FO of *L. avelinoi* is in the earliest Frasnian (BJ miospore Zone, GRAHN & al. 2001), and it ranges to the early Famennian (V – GF miospore zones). The ranges in the Paraná Basin is within the late Frasnian (IV miospore Zone, GRAHN & al. 2002), and in the uppermost part *L. avelinoi* can be mixed with *Angochitina pseudoavelinoi*, which is a similar species (GAUGRIS & GRAHN in press).

***Urochitina bastosi* – *Sommerochitina langei* Concurrent Range Zone**

Definition of base of zone: FO of *Urochitina bastosi* and *Sommerochitina langei*.

Characterization of zone: this zone is defined from the FO of *Urochitina bastosi* and *Sommerochitina langei* to the FO of *Fungochitina fenestrata*. This interval is characterized by a rich and abundant chitinozoan fauna (see Text-fig. 6).

Lower boundary reference section: well 2-SL-1-MA (Santa Luzia nº 1), core 47, 1616.0 m, upper Pimenteira Formation, Parnaíba Basin.

Representative occurrences of zone: well Caima PH-2, 103.42-119.30 m, Amazonas Basin and well 2-SL-1-MA, 1561?-1616.0 m, Parnaíba Basin, Brazil.

Lithostratigraphic distribution: lower Barreirinha Formation, Amazonas Basin, upper Pimenteira – lower Cabeças formations, Parnaíba Basin, and Inaja Formation, Jatobá Basin.

Age: late Frasnian – late Famennian.

Remarks: *Urochitina bastosi* range from the late Frasnian (upper IV miospore Zone, GRAHN & MELO 2002) into the late Famennian (VCo miospore zone). The upper limit of *Sommerochitina langei* is uncertain, but the species occurs in the late Famennian.

***Fungochitina fenestrata* Total Range Zone**

Definition of base of zone: FO of *Fungochitina fenestrata*.

Characterization of zone: this zone is defined from the FO of *Fungochitina fenestrata* to the FO of *Fungochitina ultima*. Other diagnostic species are *Ramochitina famennense*, *R. oliveirai* and *Ramochitina ritae*.

Lower boundary reference section: well 2-MN-1-AM, level 979.76 m, upper Barreirinha Formation, Amazonas Basin.

Representative occurrences of zone: well 2-MN-1-AM, 974.66-979.76 m, and well Caima PH-2, 37.20-103.42 m, Amazonas Basin, northern Brazil.

Lithostratigraphic distribution: upper Jandiatuba and Uerê formations., Solimões Basin (Jandiatuba Sub-basin), and upper Barreirinha Formation, Amazonas Basin, northern Brazil.

Age: late Famennian.

Remarks: In western Gondwana *Fungochitina fenestrata* ranges within the late Famennian (MELO & al. 1996). From the base of the VCo miospore Zone to the base of the VH miospore Zone (GRAHN & MELO 2002; MELO & LOBOZIAK 2003).

***Fungochitina ultima* Total Range Zone**

Definition of base of zone: FO of *Fungochitina ultima*.

Characterization of zone: this zone corresponds to the total range of the index species in the Solimões and Amazonas basins. Other species present in this interval are *Fungochitina* aff. *ultima* and *Ramochitina* cf. *ritae*.

Lower boundary reference section: well Caima PH-2, level 36.04 m, lower Curiri Formation, Amazonas Basin.

Representative occurrences of zone: well 1-JD-1-AM, 2241-2247 m, Solimões Basin, and well Caima PH-2, 7.80-36.04 m, Amazonas Basin, northern Brazil.

Lithostratigraphic distribution: upper Jandiatuba and Uerê formations, Solimões Basin (Jandiatuba Sub-basin), and Lower Curiri Formation, Amazonas Basin, northern Brazil.

Age: latest Famennian.

Remarks: In western Gondwana *Fungochitina ultima* ranges within the lower VH miospore zone (GRAHN & MELO 2003).

Chrono-stratigraphy	Miospores		Chitinozoans		
	(a)	(b)	Western Gondwana This paper	Global Paris et al. 2000	
Famennian	LN	LVa		Fungochitina ultima	
	LE	Rle			
	LL				
	VH	Hys	Fungochitina ultima		
	VCo	Rad	Fungochitina fenestrata	Fungochitina fenestrata	
	GF	TP	Urochitina bastosi Sommerochitina langei	Angochitina avelinoi	
	GH				
	"V"				
	Frasnian	"IV"	BMu	Hoegisphaera glabra	Hoegisphaera glabra
		BM	BPI		
BJ					
Givetian	TCo	Trg	Fungochitina microspinosa Ancyrochitina taouralinensis	R. viridarum	
				P. perforata	
	Linochitina jardinei				
	A. cornigera				
Eifelian	Lem	LLi	R. stiphrospinata	Eisenackitina aranea	
	pre-Lem	Per	Alpenachitina eisenacki	Alpenachitina eisenacki	
Emsian	AD	GS	Not yet defined		
	AP		Ancyrochitina parisi	Not yet defined	
	FD				
	AB		Not yet defined	A. panzuda	
Pragian	Su	Ems	Ancyrochitina pachycerata	Bursachitina bursa	
	pre-Su		?	Bursachitina bulbosa	
	PoW		Ramochitina magnifica	A. caeciliae	
Lochkovian	BZ	NsZ	Urochitina loboi	A. comosa	
	F		Angochitina strigosa	U. simplex	
	Z		Angochitina strigosa	F. lata	
	S		Angochitina praedensibaculata	Eisenackitina bohemica	
	MN				

Fig. 7. Correlation between Devonian miospore and chitinozoan zones in western Gondwana. The double-headed arrow next to the encircled letter E (within the Ems miospore Zone) indicates the maximum stratigraphic span proposed by RUBINSTEIN & al. (2005) for their *D. emsiensis* morphon Assemblage Zone, described from the Solimões and Paraná basins (Jutai and uppermost Furnas formations respectively). Other conventions: (a) = Western European miospore zonation after STREEL & al. (1987) and STEEMANS (1989). (b) = Western Gondwanan (North Brazil) miospore zonation after MELO and LOBOZIAK (2001, 2003)

SYSTEMATIC PALEONTOLOGY

Group Chitinozoa EISENACK, 1931
 Order Prosomatifera EISENACK, 1972
 Family Lagenochitiniidae EISENACK, 1931
 Subfamily Angochitiniinae PARIS, 1981
 Genus *Angochitina* EISENACK, 1931

Angochitina praedensibaculata sp.nov.
 (Text-fig. 8 A-E)

2005. *Sphaerochitina* aff. *S. densibaculata* AZEVEDO-SOARES & GRAHN, fig. 6:6, 8.
 (in press). *Sphaerochitina* cf. *S. densibaculata*; GRAHN, pl. 2, fig. 14

DERIVATION OF NAME: Latin, praedensibaculata, referring to the morphological similarity to *Sphaerochitina densibaculata* (VOLKHEIMER & al. 1986), which it precedes in the stratigraphic record.

DIAGNOSIS: An *Angochitina* species with a cylindrical neck. The vesicle is densely covered by simple and thick spines.

HOLOTYPE: Fig. 8 E. UERJ/DPA no. 200885.

TYPE LOCALITY: Well 1-AM-1-AM, cuttings at 1536 m, lower Manacapuru Formation.

DESCRIPTION: This species has a cylindrical neck and an ovoid body. The vesicle is densely covered by simple and thick spines up to 10 μ m long.

DISCUSSION: The ornamentation of *A. praedensibaculata* is similar to that present in *Sphaerochitina densibaculata* (VOLKHEIMER & al. 1986) although the spines are longer in *A. praedensibaculata*.

DIMENSIONS: (nine specimens measured): Total length 147-233 μ m. Holotype 233 μ m; maximum width 100(80)-116(93) μ m. Holotype 116(93) μ m; width of aperture 54(43)-67(54) μ m. Holotype 67(54) μ m; length of neck 1/3-2/3 of the total length (Holotype 1/2 of the total length; length of spines 5-10 μ m. Holotype ca. 10 μ m.

OCCURRENCE: Amazonas Basin, well 1-AM-1-AM and outcrop localities along Rio Mapuera (GRAHN in press). Lower part of the Manacapuru Formation (AZEVEDO-SOARES & GRAHN 2005).

CONCLUSIONS

This chitinozoan biozonation for the Devonian of western Gondwana (South America) is hampered by the lack of information from Peru, Ecuador, Colombia and Venezuela. Complementary information from the investigated areas will alter and refine this biozonation. The Early and Late Devonian chitinozoan assemblages show endemism, especially during the Early Devonian. A great influence from Laurentia is notable in the chitinozoan assemblages from the Middle Devonian. South America was in a polar to circumpolar position during the Early Devonian (SCOTSE 2005), and the chitinozoan assemblages therefore should reflect a cold water fauna. In Pragian to upper Eifelian strata, the Malvinokaffric chitinozoan assemblages display a low diversity and abun-

dance (GAUGRIS & GRAHN in press). Thereafter the conditions changed to warmer water conditions (MELO 1988). A transgression initiated in the latest Eifelian is connected to the highest chitinozoan abundance and diversity (in early Givetian) during the Devonian in western Gondwana. Abundance and diversity were lower in the late Givetian – early Frasnian, again increasing during a transgression at the end of the Frasnian. The chitinozoans became extinct or produced no fossilizable parts just before the latest Famennian glaciation. The nature of the material available for sampling (mostly oil company borings and isolated outcrops) has prevented a more closely spaced sampling, which undoubtedly could reveal a more detailed chitinozoan biozonation for western Gondwana. One species, *Angochitina praedensibaculata*, is described as new.

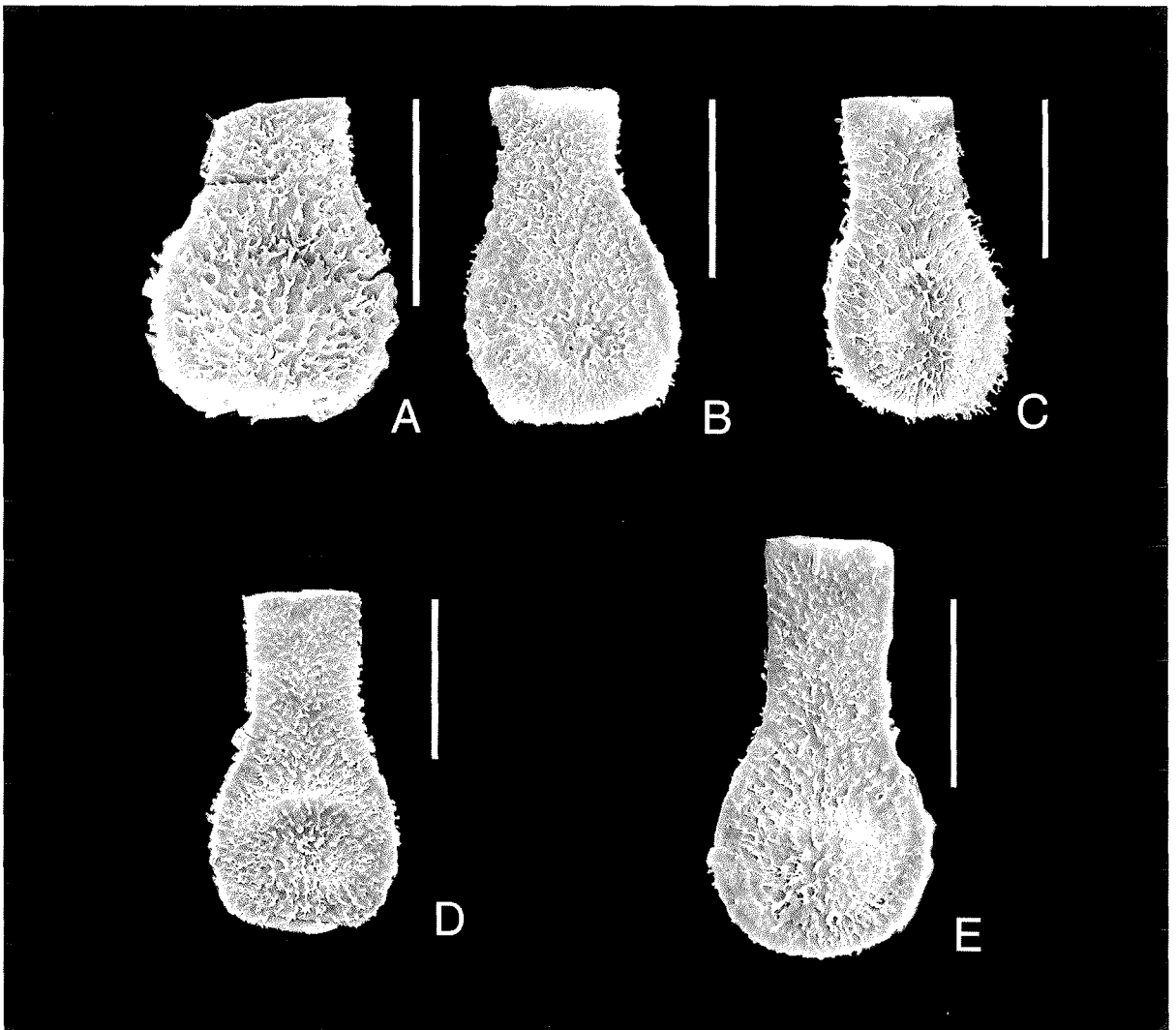


Fig. 8. *Angochitina praedensibaculata* from the lower Manacapuru Formation in well 1-AM-1-AM. The scale bars represents 100 μm .

A. Cuttings at 1527 m. B-C. Cuttings at 1536 m. D. Cuttings at 1587 m. E. Holotype. Cuttings at 1536 m.

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