

EARLY SILURIAN CHITINOZOANS IN THE APUCARANA SUB-BASIN (PARANÁ BASIN), SOUTH BRAZIL, AND THEIR BIOSTRATIGRAPHIC PROVENANCE

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ABSTRACT – Early Silurian chitinozoans recovered from cuttings samples of pre-Silurian units of the PETROBRAS 1-SE-1-SC well, near Seara in the State of Santa Catarina, southern Brazil, are compared with those from shales in the lower part of the Vargas Peña Formation at Minas Cué and the Asunción-1 well, eastern Paraguay. The obviously caved assemblages show a pronounced similarity with chitinozoan faunas belonging to the regional *Spinachitina wolfarti* – *Plectochitina* sp. A Subzone (*Conochitina elongata* Zone) of early Aeronian (early middle Llandovery) age. Because of down hole contamination, a stratigraphic provenance from the early Aeronian Vila Maria Formation is proposed.

Key words: Early Silurian, Paraná Basin, Chitinozoa.

RESUMO – Quitinozoários eo-silurianos presentes em amostras de calha contaminada por desabamento (caving), procedentes de dois distintos intervalos estratigráficos, sendo Paleozóico (pré-Siluriano) e outro pré-cambriano tardio do poço da PETROBRAS 1-SE-1-SC (Seara, Estado de Santa Catarina, sul do Brasil), são comparados com outros de mesma idade, ocorrentes em folhelhos da parte inferior da Formação Vargas Peña em Minas Cué e no poço Asunción-1, no Paraguai oriental. Constata-se uma estreita similaridade entre ambas as quitinofaunas, sugerindo para o material brasileiro uma atribuição à Subzona regional *Spinachitina wolfarti* - *Plectochitina* sp. A (Zona de *Conochitina elongata*), do eo-Aeroniano (parte mais antiga do Llandovery médio). Sua procedência estratigráfica é atribuída à Formação Vila Maria, situada acima do intervalo de profundidades onde os quitinozoários foram encontrados.

Palavras-chave: Eo-siluriano, bacia do Paraná, Quitinozoários.

INTRODUCTION

The presence of Silurian rocks in the Paraná Basin was first recognized by Harrington (1950) for basal shales in eastern Paraguay. These shales were later formally named the Vargas Peña Shale by Wolfart (1961) and, based on the presence of *Climacograptus*, they were assigned an Early Silurian age. The Vargas Peña clay pit was chosen as a type locality (Harrington, 1972; Wood & Miller, 1991). Shales in the same stratigraphic position in southern Brazil were defined as the Vila Maria Formation by Andrade and Camarço (1980). Faria (1982) described the Vila Maria lithologically and designated a type locality near Vila Maria, south of Arenópolis town in the State of Goiás, southern Brazil. Zalán *et al.* (1987) divided the formation into the Vila Maria Formation *s.s.* and the underlying Rio Ivaí Formation. They also defined three units of the Vila Maria Formation, a lower glaciogenic part, a middle unit with greenish-grey to brown calcareous shale that has yielded most of the reported fossils, and a upper part with

calcareous sandstones and siltstones. The lower part of the than Rio Ivaí Formation contain Vendian fossils, and is therefore referred to the Itajai Group (Paim *et al.*, 1997; Netto & Martini da Rosa, 2003; Teixeira *et al.*, 2004). A detailed lithological study of the Vila Maria Formation has been published by Pereira (1998).

In the Vila Maria Formation, a few metres below the contact with the overlying Furnas Formation, trace fossils occur that suggest an Ordovician or Silurian age (Burjack & Popp, 1981). Bivalves, gastropods and inarticulate brachiopods from the Vila Maria Formation have been described by Popp *et al.* (1981), and the gastropod *Plectronotus* (*Plectronotus*) *derbyi* Clarke, 1899 was identified by Boucot *et al.* (1986). The trace fossils and the invertebrate body fossils are in tentative, but not conclusive, agreement with a Silurian age for the Vila Maria Formation. Faria (1982), Milani & Daemon (1992), Milani *et al.* (1995) and Borghi *et al.* (1997) suggested a correlation with the Vargas Peña Formation of eastern Paraguay based on fossil content and lithology. The middle

shaly unit of the Vila Maria Formation has been the object of different attempts to age date this unit using palynomorphs. Gray *et al.* (1985) were the first to date the Vila Maria Shale as conclusively Silurian (Rhuddanian; early Llandovery) based on tetrahedral tetrads of land plants together with acritarchs and prasinophytes. Grahn (1991, 1992) dated the Vila Maria Formation as early-middle Llandovery (Rhuddanian – Aeronian) based on available chitinozoan information. Laranjeira *et al.* (1997) investigated cryptospores (pseudodyads and tetrads) and rare trilete spores recovered from the Vila Maria shale and suggested the same age interpretation as Grahn (1991, 1992). Radiometric dating with the Rb-Sr method on fresh rock samples of the Vila Maria shales from Três Barras Farm, State of Goiás by Mizusaki *et al.* (2002) indicated an age of 435.9 ± 7.8 MY, and the authors placed the Vila Maria Shale in the Rhuddanian – early Aeronian interval (see also Steemans & Pereira, 2002). The present study is the first attempt to correlate the Silurian chitinozoans from the 1-SE-1-SC well with those from the better known Vargas Peña Formation in eastern Paraguay (Milani & Daemon, 1992; Milani *et al.*, 1995; Grahn *et al.*, 2000; Mendlowicz Mauller *et al.*, 2004) and other contemporaneous strata in Brazil. Comprehensive reviews of the Vila Maria Formation can be found in Grahn (1992), Pereira (1998), and Grahn *et al.* (2000), and for the Vargas Peña Formation in Wood & Miller (1991) and Grahn *et al.* (2000).

MATERIAL AND METHODS

Seventeen samples, some of which yielded a rich chitinozoan assemblages, were investigated from PETROBRAS 1-SE-1-SC well (down hole mostly contaminated cuttings from the Paleozoic early Silurian Vila Maria Formation [3230 – 3288 m] levels 3234, 3253, and 3279 m, pre-Silurian Rio Ivaí Formation [3288 – 3625 m] levels 3399, 3453 and 3486 m, the Late Precambrian (Vendian) Itajai Group [3625 – TD 4000 m] levels 3636, 3645, 3696, 3732, 3750, 3786, and 3936 m), Minas Cué outcrop locality and the Asunción-1 well (cuttings from levels 2790, 2810, and 2820 m). The geographical positions of these localities are shown in Figure 1. The organic residues were studied for chitinozoans using a binocular stereoscopic microscope, and representative chitinozoan specimens were picked for scanning electron microscope (SEM) studies in co-operation with the Applied Biostratigraphy and Paleoecology Management (BPA) at PETROBRAS Research and Development Center (CENPES) in Rio de Janeiro, Brazil. Sample processing and SEM preparations were done according to the techniques described by Laufeld (1974). Most of the chitinozoan specimens recovered are compressed, and a correction factor of 0.8 (Paris, 1981; Jaglin, 1986) was used to calculate the uncompressed dimensions (values given in brackets) of the specimens. All photographed chitinozoans are stored at the Department of Stratigraphy and Paleontology at Universidade do Estado do Rio de Janeiro (UERJ/DEPA).

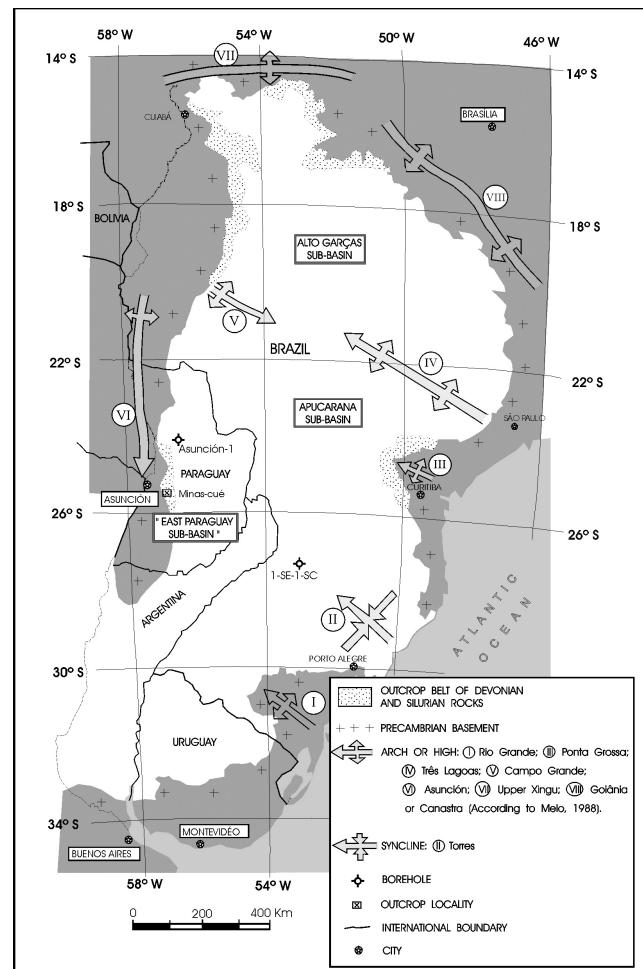


Figure 1. Map showing the geographical position of investigated localities in the Paraná Basin, Brazil and Paraguay (after Grahn *et al.*, 2000). Dark grey color symbolizes older precambrian terrain.

CHITINOZOAN BIOSTRATIGRAPHY

Altogether ten chitinozoan species were encountered in the investigated samples (Figure 3). Their regional stratigraphical ranges in the studied areas are given in Figure 2. Besides *Ancyrochitina primitiva?*, *Cyathochitina cf. campanulaeformis* and *Cyathochitina* sp. B, which are long-ranging Silurian species with a wide geographical distribution, the other species present have only been reported from the Early Silurian of western Gondwana (South America)(own observations). The lack of age-definitive megafossils in the Vila Maria Formation and the lower Vargas Peña Formation stress the importance of microfossils as biostratigraphic tools. Milani & Daemon (1992) and Milani *et al.* (1995) illustrated and determined chitinozoans from the Early Silurian of the Paraná Basin to generic level (one specimen was assigned to *Ancyrochitina laevisensis* [= *Ancyrochitina* sp.], see Milani & Daemon 1992, plate 1, fig. B, which is an early Rhuddanian species). These illustrated specimens were later determined to species level (Grahn *et al.* 2000). The presence of *Spinachitina* is characteristic for the Aeronian of western Gondwana, where this genus appears

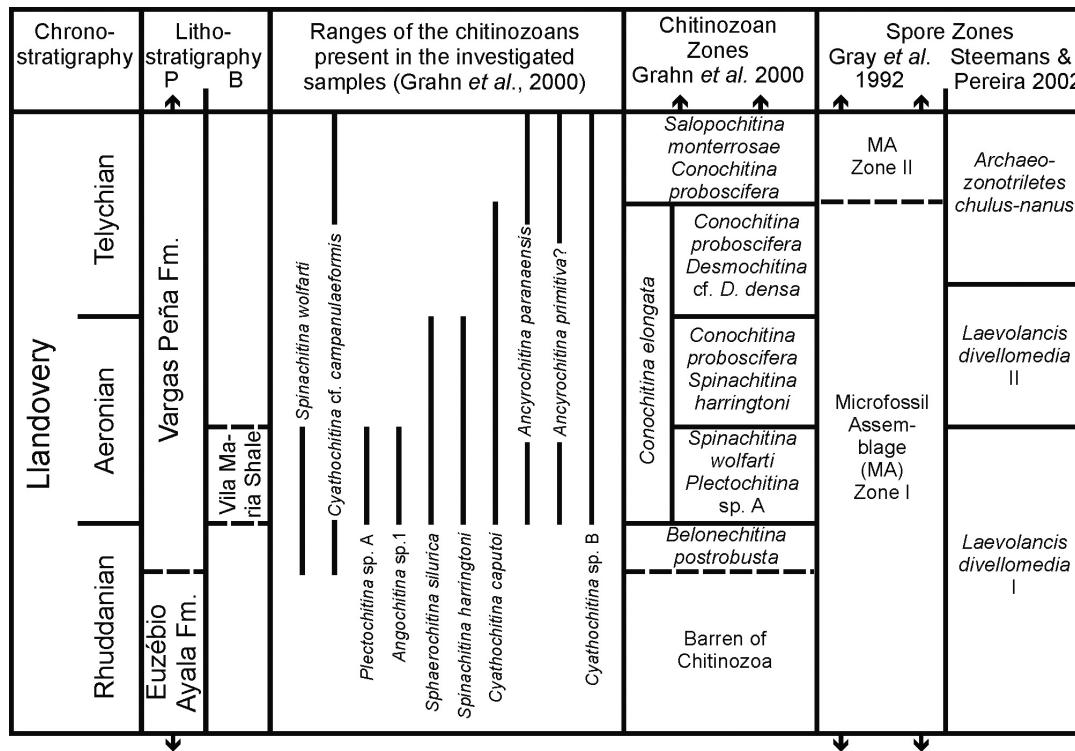


Figure 2. Integrated correlation of the chitinozoan species ranges in the investigated samples compared with Llandovery chitinozoan and spore successions of the Paraná Basin; P = Paraguay, B = Brazil.

in the latest Rhuddanian, reaches its maximum during the early Aeronian and disappears in the late Aeronian. It is a common genus in the lower part of the Vargas Peña Formation. The zonal index species *Spinachitina wolfarti* and/or *Plectochitina* sp. A sensu Grahn in Grahn et al. (2000) occur in all the three localities indicating the presence of the *Spinachitina wolfarti* – *Plectochitina* sp. A Subzone (Grahn et al., 2000). This subzone is tentatively assigned to the early Aeronian, and suggests that chitinozoans from the 1-SE-1-SC well, and the lower part of Vargas Peña Formation, are of this age, which agrees with the miospore age interpretation (Mizusaki et al. 2002; Steemans & Pereira, 2002). All chitinozoan species present are known from the literature, except for *Angochitina* sp. 1, which is described in the Systematic Paleontology section. The chitinozoan occurrences at the three localities are summarized as follows.

Minas Cué outcrop (25° 31' 28" S, 56° 50' 59" W). Vargas Peña Formation. *Cyathochitina caputoi* Costa, 1971, *Cyathochitina cf. campanulaeformis* (Eisenack, 1931), *Plectochitina* sp. A sensu Grahn in Grahn et al. (2000), *Sphaerochitina silurica* Grahn in Grahn et al. (2000), *Spinachitina harringtoni* Grahn in Grahn et al. (2000), and *Spinachitina wolfarti* Grahn in Grahn et al. (2000).

Asunción-1 well (24° 4' 12.55" S, 56° 27' 12.42" W). Vargas Peña Formation. 2730? – 2830 m. Samples: 2790 m. *Spinachitina wolfarti*. 2810 m. *Angochitina* sp. 1, *Cyathochitina* sp. B sensu Paris, 1981, and *Spinachitina wolfarti*. 2820 m. *Ancyrochitina primitiva?* Eisenack, 1964, *Angochitina* sp. 1, and *Spinachitina harringtoni*.

1-SE-1-SC well (27° 8' 36.4" S, 52° 17' 54.5" W). Vila Maria Formation. 3230 – 3288 m. Samples: 3234 m. Barren of

chitinozoans. 3253 m. Barren of chitinozoans. 3279 m. Barren of chitinozoans. Rio Ivaí Formation. 3288 – 3625 m. Samples: 3399 m. Barren of chitinozoans. 3453 m. *Angochitina* sp. 1. 3486 m. *Ancyrochitina primitiva?* Itajai Group. 3625 – TD 4000 m. Samples: 3636 m. *Angochitina* sp. 1. and *Cyathochitina* sp. B. 3645 m. *Ancyrochitina paranaensis* Grahn in Grahn et al. (2000) and *Cyathochitina* sp. B. 3696 m. *Angochitina* sp. 1. and *Spinachitina wolfarti*. 3732 m. *Angochitina* sp. 1. 3750 m. Barren of chitinozoans. 3786 m. *Angochitina* sp. 1 and *Cyathochitina* sp. B. 3936 m. *Plectochitina* sp. A.

SYSTEMATIC PALEONTOLOGY

The systematic inventory of the chitinozoans in alphabetical order by genus and species is presented below and illustrated in the Figure 3. Citations relating to the naming of these species are given in the references. The taxonomy used here follows that proposed by Paris et al. (1999). Only the previously undescribed species *Angochitina* sp. 1 will be described here.

Ancyrochitina paranaensis Grahn in Grahn et al. (2000).

Ancyrochitina primitiva? Eisenack 1964.

Angochitina sp. 1.

Cyathochitina cf. campanulaeformis (Eisenack 1931).

Cyathochitina caputoi Costa 1971.

Cyathochitina sp. B sensu Paris 1981.

Plectochitina sp. A sensu Grahn in Grahn et al. (2000).

Sphaerochitina silurica Grahn in Grahn et al. (2000).

Spinachitina harringtoni Grahn in Grahn et al. (2000).

Spinachitina wolfarti Grahn in Grahn et al. (2000).

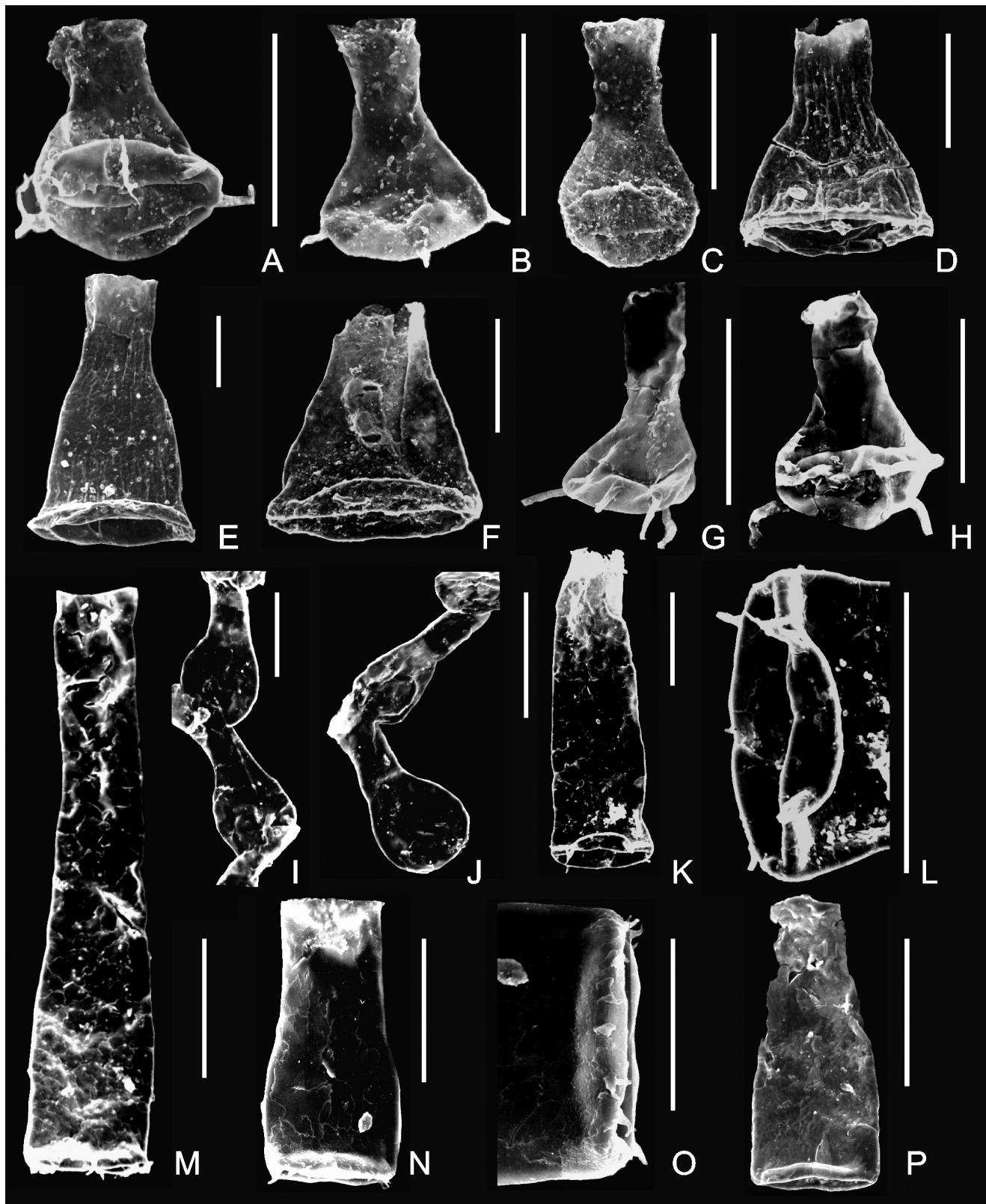


Figure 3. Chitinozoans from the Vargas Peña and Vila Maria formations. **A**, *Ancyrochitina paranaensis*, down hole contamination in Itajaí Group, well 1-SE-1-SC, 3645 m; **B**, *Ancyrochitina primitiva?*, Vargas Peña Formation, well Asunción-1, 2820 m; **C**, *Angochitina* sp. 1, Down hole contamination in Itajaí Group, well 1-SE-1-SC, 3732 m; **D**, *Cyathochitina caputoi*, Vargas Peña Formation, Minas Cué; **E**, *Cyathochitina cf. campanulaeformis*, Vargas Peña Formation, Minas Cué; **F**, *Cyathochitina* sp. B, Down hole contamination in Itajaí Group, Well 1-SE-1-SC, 3645 m; **G-H**, *Plectochitina* sp. A, Vargas Peña Formation, Minas Cué; **I-J**, *Sphaerochitina silurica*, Vargas Peña Formation, Minas Cué; **I**, chain with four specimens.; **J**, two specimens in a chain; **K-M**, *Spinachitina harringtoni*, Vargas Peña Formation, Minas Cué; **L**, detail of the specimen in figure K; **N-P**, *Spinachitina wolfarti*, Vargas Peña Formation, Minas Cué; **O**, detail of the specimen in figure N. The scale bars for figures A-N and P represent 100 µm, and 50 µm for figure O.

Group CHITINOZOA Eisenack, 1931
 Order PROSOMATIFERA Eisenack, 1972
 Family LAGENOCHEITINIDAE Eisenack, 1931 emend. Paris, 1981
 Subfamily ANGOCHITININAE Paris, 1981
 Genus ANGOCHITINA Eisenack, 1931

Angochitina sp.1
 (Figure 3C)

Description. This *Angochitina* species has a spherical body and a cylindrical neck widening towards the straight aperture. The vesicle is covered by minute simple spines. In well-preserved specimens, the flanks and neck display a gentle concave curve towards the aperture.

Dimensions. Eight specimens measured. Total length 125–154 µm; maximum width 68(54)–83(66) µm; width of aperture 39(31)–50(40) µm; length of neck ca. 1/3 of the total length; length of spines ≤ 4 µm.

Occurrence. Vila Maria and lower Vargas Peña formations, Paraná Basin, Brazil and Paraguay. Asunción-1 (levels 2810 and 2820 m) and 1-SE-1-SC (contaminated samples from levels 3453, 3636, 3696, 3732, and 3786 m). The *Spinachitina wolfarti* – *Plectochitina* sp. A Subzone (*Conochitina elongata* Zone). Tentatively dated as early Aeronian (early middle Llandovery).

CONCLUDING REMARKS

Biostratigraphic age control for the Vila Maria Formation is only possible using cryptospores. A suite of samples from Três Barras Farm, Goiás State, southern Brazil (Mizusaki *et al.*, 2002), contained palynomorphs belonging to the *Laevolancis divellomedia* Interval Biozone I for the Vila Maria Shale. Steemans & Pereira (2002) identified the same cryptospore zone and proposed an early Aeronian age for the lower Vargas Peña Formation. Gray *et al.* (1985) investigated spores in one sample from the same locality as Mizusaki *et al.* (2002). The phytoplankton assemblage present corresponds to the upper, but not the uppermost part, of Gray's (1985) Microfossil Assemblage Zone I, which ranges from the Llanvirn (beneath the *Didymograptus murchisoni* graptolite Zone) to the mid-Telychian (Gray, 1989; Gray *et al.*, 1992). No detailed biostratigraphic study of the acritarchs (Gray *et al.*, 1985; Wood & Miller, 1991) have been made, but the acritarchs from the Vila Maria Formation display Aeronian elements (cf. Le Hérissé *et al.*, 1995, 2001; Molyneux *et al.*, 1996).

Chitinozoans are rare in the Vila Maria Formation, and have only been found for certain as down hole contamination in older beds from 1-SE-1-SC well. Finds at Aldeia Creek, reported by Grahn *et al.* (2000), are as pointed out by the authors, questionable, since the actual locality has not been relocated. *Plectochitina* sp. A, one of the index species for the *Spinachitina wolfarti* – *Plectochitina* sp. A Subzone (*Conochitina elongata* Zone), occurs in the 1-SE-1-SC well. Further, *Angochitina* sp.1 is present in the 1-SE-1-SC, and it occurs together with *Spinachitina wolfarti* in Paraguay

(Grahn in Grahn *et al.*, 2000). *Ancyrochitina paranaensis*, another species from the 1-SE-1-SC, was first described from the Early Silurian of Paraguay by Grahn *et al.* (2000), and from the Vargas Peña clay pit as *Ancyrochitina* sp. by Miller (1996) and *Ancyrochitina* sp. 5 (Wood & Miller, 1997, pers. Commun.). It was first reported to range from upper Aeronian to Telychian (Grahn *et al.*, 2000), but this study shows that the species appeared already in the lower Aeronian. *Cyathochitina* sp. B is a common Llandovery species in the intracratonic basins of Brazil and Paraguay. Altogether this indicates an early Aeronian age for the caved Vila Maria Shale chitinozoans in 1-SE-1-SC, and the lower part of the Vargas Peña Formation.

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