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Review of Palaeobotany and Palynology

journal homepage: www.elsevier.com/locate/revpalbo

Late Tremadocian chitinozoans and acritarchs from northwestern Argentina (Western Gondwana)

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ARTICLE INFO

Article history: Received 13 June 2008 Received in revised form 17 November 2008 Accepted 13 December 2008 Available online 24 December 2008

Keywords: chitinozoans acritarchs late Tremadocian northwestern Argentina western Gondwana

1. Introduction

Chitinozoan and acritarch assemblages have been recorded from the Pascha-Incamayo area of the Cordillera Oriental (Eastern Cordillera) (Fig. 1). The productive samples come from the Saladillo and Parcha formations, the acritarchs of which have received preliminary mention (Rubinstein and Toro 2002; Rubinstein et al., 1999, 2007; Waisfeld et al., 2006) (Fig. 2), and independent stratigraphical control is provided by late Tremadocian graptolites. In the present work, palynomorphs are described, figured and extensively analyzed for the first time. Ordovician chitinozoan records are still scarce in South America. Data are available from Argentina (Volkheimer, 1978; Volkheimer et al., 1980; Ottone et al., 1992; Achab et al., 2006), Brazil (Grahn, 1992; Grahn and Paris, 1992; Ottone et al., 2001), and Bolivia (Heuse et al., 1999). Some of these data were included in the global synthesis of Ordovician chitinozoan by Paris et al. (2004) and were taken into account in the Ordovician stratigraphic chart of Webby et al. (2004). Concerning the acritarchs, additional references on the messaoudensis-trifidum assemblages are available from different sections of the Cordillera Oriental, Central Andean Basin, northwestern Argentina (Rubinstein et al., 1999; Rubinstein and Toro, 1999, 2001, 2002; Rubinstein, 2003; Toro et al., 2003; Waisfeld et al., 2006).

2. Geological setting

The Pascha-Incamayo region (Salta Province, northwestern Argentina) is located at the southern end of the Cordillera Oriental

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ABSTRACT

Chitinozoans and acritarchs are recorded from the Saladillo and Parcha formations of the Pascha-Incamayo area (Salta Province), Cordillera Oriental, northwestern Argentina. These organic microfossils coexist with graptolites of the *Kiaerograptus, Araneograptus murrayi* and *Hunnegraptus copiosus* biozones of early late Tremadocian and late Tremadocian age respectively. This is the oldest chitinozoan record from western Gondwana, and one of the few Tremadocian chitinozoan assemblages documented in the world. The stratigraphical range and the palaeobiogeographic affinities of the recovered acritarchs (*messaoudensistrifidum* association) and the chitinozoans assemblages are discussed at regional and at global scale. A new chitinozoan species, *Euconochitina paschaensis*, is described.

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belonging to the Central Andean Basin (Fig. 1). During the Ordovician the area was located on the western Gondwanan margin. Keidel (1937, 1943) established the local lithostratigraphy of the Ordovician sequences and defined from base to top the following Tremadocian units: Lampazar, Cardonal, Saladillo and Parcha formations, equivalent to the Tremadocian Santa Rosita Formation from other areas of the Cordillera Oriental. These formations overlie the Cambrian Chalhualmayoc Formation (upper unit of the Mesón Group). Astini (2003), after a revision of the lithostratigraphy of the Pascha-Incamayo area, introduced the Sococha Formation. This unit comprises the lowest Ordovician deposits and consists of a thick-bedded massive quartzrich sandstone. He interpreted the overlying shale-rich Lampazar Formation as outer shelf deposits. Astini (2003) also introduced the Devendeus Formation, between the Cardonal Formation and the succeeding Saladillo Formation, corresponding to the local filling of a paleovalley. The Saladillo Formation overlies the Devendeus Formation and extends over the Cardonal Formation onto the interfluves. The Saladillo Formation mainly comprises black shales with interbedded sandstones in its lower part, with several intercalated graded sandstones higher in the succession. The unit starts with a transgressive cycle as well as the Lampazar Formation shales. The investigated sequence ends with the Parcha Formation, comprising greenish shales and more abundant alternating sandstone packages. The Parcha Formation indicates a regressive tendency with the coarsening of the sequence towards the top. The contact between the Saladillo and the Parcha formations is marked by a thick and tabular sandstone body resulting from a seismicity induced deposition (Astini, 2002; Waisfeld et al., 2006). This Tremadocian sequence is interpreted as a deposition in tide-dominated platform environments alternating with successive transgressive systems tracts (Buatois et al.,

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Fig. 1. Location map (extracted from Waisfeld et al., 2006).

2003). In this work, studies are focused on the Saladillo and Parcha formations outcropping in Aguada del Altillo and Barranco's Creeks where the composite section (Fig. 2) exposes 480 m of the Saladillo Formation and 1040 m of the Parcha Formation.

3. Biostratigraphy of the Saladillo and Parcha formations

The stratigraphically and structurally complex Pascha-Incamayo region contains a diverse macrofauna. Paleontological information is available for trilobites (Kobayashi, 1935, 1937; Harrington and Leanza, 1957; Waisfeld and Vaccari, 2003; Waisfeld et al., 2006), graptolites (Ortega and Albanesi, 2002, 2003, 2005; Toro et al., 2003) and conodonts (Albanesi et al., 1997; 2001). Ortega and Albanesi (2002, 2003, 2005) identified graptolites of the Bryograptus and Kiaerograptus biozones in the Saladillo Formation, and of the Kiaerograptus supremus, Araneograptus murrayi, and Hunnegraptus copiosus biozones in the Parcha Formation, suggesting an early late Tremadocian age for the Saladillo Formation and a late Tremadocian age for the Parcha Formation. Recently, Waisfeld et al. (2006) revised the trilobites and graptolites from the same generalized section as that of the present work (see Fig. 2). They concluded that the *Kiaerograptus* Biozone ranges within most of the Saladillo Formation and is equivalent to the Aorograptus victoriae Biozone from other sections of the Cordillera Oriental and Bolivia (Waisfeld et al., 2006 and references therein). The A. murrayi Biozone is already represented in the upper part of this unit and extends up to the middle part of the Parcha Formation. The H. copiosus Biozone is restricted to the upper part of the Parcha Formation. The two latter biozones indicate a late Tremadocian age. The trilobite *Ogygiocaris araiorhachis* ranges into the *A. murrayi* and *H. copiosus* biozones (Waisfeld et al., 2006).

4. Palynological data of the Saladillo and Parcha formations

Nine samples from the Saladillo (S) and Parcha (P) formations were investigated (Fig. 2). They were collected from outcrops along the Aguada del Altillo and Barranco's Creeks, two tributaries of the Incamayo River (Fig. 1), during field investigations for graptolites and trilobites. Eight of them were found to be productive. Sample S 3 yielded exclusively acritarchs, sample S 2 yielded only chitinozoans, whereas the six other samples contain both acritarchs and chitinozoans (S 1, P 2, P 3, P 4, P 5, and P 6) (Fig. 2).

Palynological productivity of the samples studied varied from a very low number of palynomorphs, 16 acritarchs and 4 chitinozoans in P 5, to a moderate number of individuals, 90 acritarchs and 120 chitinozoans in the richest sample (P 6). Relative abundance of both groups is variable through the section, with levels where chitinozoans are predominant (71 chitinozoans and 51 acritarchs) as in sample P 3, and levels with 140 acritarchs but barren in chitinozoans, as in sample S 3. Acritarch specimens were encountered in two slides per sample whereas chitinozoans were hand-picked from the remaining organic residue. It should be taken into account that the specimens of the fossiliferous samples are moderately to poorly preserved due to compaction, burial and tectonics, therefore they are all flattened, carbonized and fragmented. As a consequence, identification of many of them is difficult.



Fig. 2. Generalized stratigraphic column of the Saladillo and Parcha formations from Pascha-Incamayo region with the graptolite zones, and palynomorphical data (modified from Waisfeld et al., 2006).

4.1. Chitinozoans

Some samples (S 1, P 2, and P 5) yielded very poorly preserved chitinozoans. These assemblages contain only a few damaged individuals whose specific determinations remain tentative (see Fig. 2). Other samples (S2, P3, P4, and P6) yield relatively better preserved specimens and the chitinozoan analyses are based on these samples.

The upper part of the Saladillo Formation (sample S 2) yielded numerous specimens of *Euconochitina paschaensis* sp. nov. and a few *Lagenochitina* cf. *longiformis* (Obut, 1995) (Plates I and III). Hints and Nõlvak (2006) reported fairly similar individuals which they also identified as *L*. cf. *longiformis* in the upper Tremadocian-lowest Floian of Baltoscandia (*Paroistodus proteus* Conodont Zone).

The next chitinozoan-bearing samples (P 3 and P 4) are from the lower part of the Parcha formation. Sample P 3 still contains *E. paschaensis* sp. nov. and *L. cf. longiformis* (Obut, 1995), together with abundant *Euconochitina* sp. aff. *paschaensis* sp. nov. (Plate II) and some specimens of *Clavachitina* sp. (Plate III,3,9). In sample P 4, *E. paschaensis* sp. nov. coexists with rare *Desmochitina* sp. cf. *L. brevicollis* Taugourdeau and de Jekhowsky, 1960 (Plate III,5).

The uppermost sample (P 6) also contains *E. paschaensis* sp. nov. and *L. cf. longiformis* (Obut, 1995) associated with rare *Lagenochitina*

Plate I. Late Tremadocian chitinozoans from Saladillo and Parcha, Pascha-Incamayo area, northwestern Argentina. Scale bars represent 50 µm.

cf. *conifundus* (Poumot, 1968). *L. conifundus* (Poumot, 1968) is usually regarded as a late Tremadocian taxon in the Northern Gondwana chitinozoan zonation (Webby et al., 2004). It is associated with *Euconochitina symmetrica* in Bohemia (Fatka, 1993).

4.2. Acritarchs

Even though acritarchs of the Pascha-Incamayo section have been already reported in previous contributions (Waisfeld et al., 2006; Rubinstein et al., 2007), a revision of levels bearing acritarchs, carried out in the present study, enables identification of a greater number of diagnostic species of the late Tremadocian *messaoudensis-trifidum* acritarch assemblage (Plate IV). This assemblage, first described from the Watch Hill Formation, Skiddaw Group, Lake District, northwestern England, by Molyneux and Rushton (1988) is recognized as a useful tool for correlation of late Tremadocian time slices of Gondwana and Baltica and the base of the Floian in Gondwana (Molyneux et al., 2007). New data come especially from levels with graptolites of the *Araneograptus murrayi* graptolite biozone, corresponding to the upper part of the Saladillo Formation and the lower part of the Parcha Formation (Fig. 2).

A few taxa characteristics of the *messaoudensis-trifidum* acritarch assemblage occur in the upper section of the Saladillo Formation, in levels with graptolites considered by Toro (in Waisfeld et al., 2006) to be equivalents of the *Kiaerograptus* Biozone sensu Ortega and Albanesi, (2003). Identified taxa are *Stellechinatum* cf. *uncinatum* (Downie) Molyneux, 1987, *Stelliferidium* cf. *trifidum* (Rasul) Fensome et al., 1990 and *Acanthodiacrodium* spp. In the uppermost Saladillo Formation, *Vavrdovella areniga* (Vavrdova) Loeblich and Tappan, 1976 first appears, together with graptolites indicating the beginning of the *Araneograptus murrayi* graptolite Biozone. The lower section of the overlying Parcha

1–10. 1.	<i>Euconochitina paschaensis</i> sp. nov. Lower part of the Parcha Fm.
	P 4. 9313, O39
2.	Lower part of the Parcha Fm.
	P 4. 9313, O38/3
3.	Upper part of the Parcha Fm.
	P 6, 7291, R43/4
4.	Upper part of the Saladillo Fm.
	S 2, 7290b, N34
5.	Lower part of the Parcha Fm.
	P 3. 6131b. O40/3
6.	Upper part of the Saladillo Fm.
	S 2, 7290b, K37
7.	Lower part of the Parcha Fm.
	P 3. 6131b. P41
8.	Lower part of the Parcha Fm.
	P 3. 6131b. K41
9.	Lower part of the Parcha Fm.
	P 4 9313 M37/2
10a-10b.	Lower part of the Parcha Fm.: 10b. Detail of the base.
	P 4. 9313, K37/2
Plate II. Late Tr	emadocian chitinozoans from sample P 3, lower part of the Parcha Fm., Pascha-Incamayo area, northwestern Argentina. Scale bars represent 50 µm. (see on page 70)
1-8.	Euconochitina sp. aff. paschaensis sp. nov.
1.	6131a, J37
2a-2b.	6131b, N40/4; 2b. Detail of the base.
3.	6131b, N37
4.	6131b, N38
5. G. Ch	6131a, H37/3
6a-6D.	6131b, M38/2; 6b. Detail of the base.
7. 82_8b	01310, N39 6131 J 4011: 9h. Datail of the base
04 00.	
Plate III. Late T	remadocian chitinozoans from Saladillo and Parcha, Pascha-Incamayo area, northwestern Argentina. Scale bars represent 50 μm. (see on page 71)
1a-1b-1c.	Lagenochitina cf. longiformis (Obut, 1995); 1b. Detail of the neck surface; 1c. Detail of the base surface.
	P 3. 6131b, P39/1
2.	Lagenochitina cf. longiformis (Obut, 1995)
	S 2. 7290b, N38
3.	Clavachitina sp.
	P 3. 6131b, M39/4
4a-4b.	Probable broken Lagenochitina cf. longiformis (Obut, 1995) specimen; 4b. Detail indicating well-differentiated internal and external membranes.
	S 2, 7291b, P45/1
5.	Desmochiting sp. cf. L. brevicollis (Taugourdeau and de Jekhowsky, 1960)
	P 4, 9313, N36
6.	Lagenochitina cf. conifundus (Poumot, 1968)
	P 6 7291b 043/3
7	Lagenochiting of configurates (Pourot 1968)
	P. 6. 7291a M11/2
8	I demochting of confindus (Pounot 1968)
0.	S 2 7200b H20/A
0	
э.	
	1.5,010,010



Plate I.



Plate II (caption on page 68).



Plate III (caption on page 68).

Formation, also corresponding to the *A. murrayi* Biozone, has yielded a more diverse assemblage that comprises 11 taxa, including the first occurrences of *Caldariola glabra* var. *glabra* (Martin) Molyneux and Rushton, 1988, *Cymatiogalea deunffi* Jardiné et al., 1974, *Rhopaliophora palmata* (Combaz and Peniguel) Playford and Martin, 1984, *Coryphidium*? sp., *Peteinosphaeridium* sp., *Vogtlandia*? sp. and *Polygonium* spp.

The upper section of the Parcha Formation, in levels with graptolites that indicate the *Hunnegraptus copiosus* Biozone, contains an acritarch assemblage which is dominated by galeate acritarchs such as *Stelliferidium* cf. *trifidum*, *Cymatiogalea deunffi* and *?Caldariola glabra* var. *glabra* (probably *Caldariola-Cymatiogalea* transients). It is worth noting the presence of transitional forms such as *Acanthodia-crodium*-coryphomorph acritarchs (*Coryphidium-Vavrdovella*) transients and *Cymatiogalea messaoudensis* Jardiné et al., 1974Cymatiogalea deunffi Jardiné et al., 1974 transients. The first confirmed appearance of *Coryphidium* sp. is in levels assigned to the *H. copiosus* Biozone; this genus was recorded with doubt in the *A. murrayi* Biozone.

According to the subdivisions established for the *messaoudensistrifidum* acritarch assemblage in the Skiddaw Group of England (Cooper et al., 1995), sample S 1, from the *Kiaerograptus* Biozone, would be correlated with the uppermost part of sub-assemblage 1 due to the occurrence of *Stelliferidium* cf. *trifidum*. The FADs of *Peteinosphaeridium* and *Rhopaliophora palmata* in P 4, corresponding to the *A. murrayi* Biozone, enable correlation with the base of the sub-assemblage 2. The genus *Coryphidium*, firmly identified in samples P 5 and P 6, corresponding to the *H. copiosus* Biozone, suggests correlation with the uppermost sub-assemblage 3.

5. Paleogeographic affinities

The Central Andean Basin is usually regarded as part of the western Gondwana margin.This margin has been considered as being located at middle to high paleolatitudes during the Ordovician (Astini, 1998; Webby et al., 2004). In Bolivia, late Tremadocian chitinozoans identified as *Desmochitina* sp. group *minor* by Heuse et al. (1999), are regarded here as conspecific with the paratype of *L. brevicollis* (Taugourdeau and de Jekhowsky, 1960), a typical component of late Tremadocian chitinozoan assemblages in Northern Gondwana regions. In the Saladillo and Parcha formations, Lagenochitinidae specimens with an ogival chamber are very similar to *L. conifundus*, another typical Gondwanan

Plate IV.	Late Tremadocian acritarchs from Saladillo and Parcha, Pascha-Incamayo area, northwestern Argentina. Scale bars represent 10 µm.
1.	Caldariola glabra var. glabra (Martin) Molyneux & Rushton, 1988
	P 2. 6129a, R24/0
2.	Caldariola glabra var. glabra (Martin) Molyneux & Rushton, 1988
	P 4.6130c, J21/3
3.	Caldariola glabra var. glabra (Martin) Molyneux & Rushton, 1988
	P 6. 7291d, Y36/0
4.	Vavrdovella areniga (Vavrdova) Loeblich & Tappan, 1976
	S 3. 7285a, G19/2
5.	Coryphidium sp.
	Р 6. 7291b, Н39/0
6.	Coryphidium? Sp.
	P 4. 6130a, F37/4
7.	Transient between Acanthodiacrodium and Coryphidium
	P 6. 7291a, M37/2
8.	Transient between Acanthodiacrodium and Coryphidium
	P 4. 6130e, D18/0
9.	Vavrdovella areniga (Vavrdova) Loeblich & Tappan, 1976
	P 3. 6131a, T41/0
10.	Stelliferidium cf. trifidum (Rasul) Fensome et al., 1990
	P 6. 7291a. 032/1
11.	Stelliferidium cf. trifidum (Rasul) Fensome et al., 1990
	P 6. 7291a. C33/0
12.	Stelliferidium cf. trifidum (Rasul) Fensome et al., 1990
	P 3. 6131a, F35/4
13.	Vogtlandia ? sp.
	P 6, 7291c, C32/0
14.	Vogtlandia'? sp.
	P 6. 7291c, 137/0
15.	Vogtlandia? sp.
	P 6, 7291a, G42/3
16.	Voetlandia? sp.
	P 6, 7291a, 133/2
17.	Transient? between Caldariola and Cymatiogalea
	P 6 7291c W38/4
18.	Transient between Cymatiogalea messaoudensis and Cymatiogalea deunffii
	P.6. 7291b M34/3
19.	Transient between Cymatiogalea messaoudensis and Cymatiogalea deunffii
	P. 6. 7291b F41/4
20.	Cymatiogaleg deunffii Iardiné et al. 1974
	P 4 6130e R28/0
21.	Cymatiosalea deunffii Iardiné et al., 1974
	P 2. 6129a C3/4/4
22.	Rhonalianhora nalmata (Combaz & Peniguel) Playford & Martín
	P 4 6130b V30/1
23.	Peteinoshaeridium sp.
	P 4 6130c M35/0
24	Stellechinatum of uncinatum (Downie) Molyneux 1987

P 4. 6130b, L34/0



species reported from the Algerian Sahara (Poumot, 1968) and from Bohemia (Fatka, 1993). Northern Gondwana affinities have already been documented for Early Ordovician chitinozoans from Argentina. Eremochitina brevis Benoît and Taugourdeau, 1961, a northern Gondwana index species for the Floian, has been reported in the Central Andean Basin and in the Famatina Basin (Achab et al., 2006). Conochitina decipiens Taugourdeau and de Jekhowsky, 1960, is also a classical component of Early Ordovician chitinozoan assemblages from northern Gondwana. It has been reported in the Famatina Basin where it is associated with E. brevis, and is present in the Acoite Formation (Los Colorados area, middle part of the Cordillera Oriental, northwestern Argentina) (de la Puente, unpublished data). In South America, C. decipiens has been reported from Bolivia (Heuse et al., 1999) and from Brazil (Grahn, 1992). Some affinities are noted also with South China, where northern Gondwana taxa are also known in the Early Ordovician (e.g. E. brevis; see Wang and Chen, 1994). In Laurentia and Baltica very few data are available on late Tremadocian chitinozoans. Therefore, affinities of the Argentinian faunas with faunas from these areas cannot be ascertained with the exception of Lagenochitina cf. longiformis in Estonia (Hints and Nõlvak, 2006).

The *messaoudensis-trifidum* assemblage has been reported from the margin of Gondwana in the southern hemisphere during the Lower Ordovician. Considered as a typical cold-water assemblage of high latitudes, it has been documented in several peri-Gondwanan localities such as England and Wales, Ireland, Spain, Belgium, Germany, the Czech Republic and Turkey. Additionally, some of the characteristic taxa have been found in Baltica, located at intermediate latitudes (Molyneux et al., 2007). Even though northwestern Argentina was located at the Gondwana margin, it was at an intermediate paleolatitudinal position, between 30° and 40° S. Therefore, the *messaoudensis-trifidum* acritarch assemblage of Pascha-Incamayo represents the lowest latitudinal occurrences from all the peri-Gondwanan localities and is also at lower latitude than occurrences from Baltica.

6. Material and methods

Samples were processed using standard palynological HCI-HF-HCl acid maceration techniques. The organic residue was sieved using a 10 µm sieve, and oxidized for 1 to 5 min using concentrated nitric acid. The acritarchs are mounted as permanent palynological slides and examined using light microscopy with interference contrast, whereas the chitinozoans are hand-picked and mounted on stubs for scanning electron microscope (SEM) examinations.

The palynological slides are housed in the collection of the Palaeopalynology Unit, IANIGLA, CCT, Mendoza, labeled MPLP (Mendoza-Paleopalinoteca-Laboratorio de Paleopalinología). Illustrated specimens are located with England Finder coordinates.

7. Systematics

The taxonomic and morphological terminology proposed by Paris et al. (1999a) for chitinozoa is adopted here. The measurements used are: L = length; Lp = chamber length; Ln = oral tube length; Dp = chamber diameter; da = oral tube diameter; dn = neck diameter; dcoll = collarette diameter; lcoll = collarette length. Measurements are given in microns (μ m).

Table 1

Values calculated on 41 individuals of *E. paschaensis* sp. nov. from samples S 2, P 3, P 4, and P 6. Coeff. of 0.7 is used for restoring the values of Dp, dn and dcoll after flattening

Values (µm)	L	Dp	dn	dcoll.	dcoll./dn	Ln/L
Maximum	209	109	80	87	1,29	0.64
Mean	167	88	58	59	1,03	0.47
Minimum	134	71	39	45	0,85	0.30
Holotype	147	81	52	57	1,1	0,4

Table 2

Values calculated on 40 individuals of *E.* sp. aff. *paschaensis* sp. nov. from sample P 3. Coeff. of is 0.7 used for restoring the values of Dp, dn and dcoll after flattening

Values (µm)	L	Ln	Dp	dn	dcoll.	dcoll./dc	Ln/L
Maximum	303	116	107	80	83	1,3	0.49
Mean	181	66	87	67	69	1,04	0.35
Minimum	116	41	42	49	59	1	0.22

Incertae sedis group Chitinozoa Eisenack, 1931 Order Prosomatifera Eisenack, 1972 Family Conochitinidae Eisenack, 1931 emend. Paris, 1981 Subfamily Conochitininae Paris, 1981 Genus Euconochitina Taugourdeau, 1966 emend. Paris et al., 1999a Type species: Conochitina conulus Eisenack, 1955

Euconochitina paschaensis sp. nov. (Plate I,1-10)

Name derivation: from Pascha, the name of a village close to the studied section.

Holotype: Plate I,1 (slide repository number 9313, coordinates O39). **Type stratum:** Lower part of the Parcha Formation, sample P 4, located at 160 m above the base of the formation.

Type locality: section along the Aguada del Altillo (tributary of the Incamayo River), Pascha-Incamayo region, Salta Province, north-western Argentina (Fig. 1).

Paratypes: Plate I,2 (slide repository number 9313, coordinates O38/3). **Material**: the available specimens are generally flattened and in some cases poorly preserved (collarette frequently damaged). 15 individuals are from sample S 2 (upper part of the Saladillo Formation), 11 from sample P 3, 30 from sample P 4 (lower part of the Parcha Formation), 4 from sample P 5, and 114 are from sample P 6 (upper part of the Parcha Formation).

Diagnosis: *Euconochitina* species with a short conical chamber (Lp/L less than 0.5), a flat base, and a cylindrical neck ended by a short sub-cylindrical collarette; vesicle entirely smooth.

Description: The recovered individuals have a small conical chamber tapering up to the middle part of the vesicle. The neck is cylindrical and represents usually about half of the total vesicle length. In the observed population, however, some specimens have a significantly shorter chamber, with Lp representing about one third of the vesicle length (Plate I,7). The neck ends with a short membranous collarette (up to 30 µm). This collarette is subcylindrical (Plate I,2,9,10a) or may flare very slightly around the aperture (Plate I,1,4,8). In the measured population the mean values of the collarette and of the neck diameters are very close (see Table 1). The actual diameter of the collarette, however, may be slightly underestimated due to its weak folding resulting from the flattening processes (Plate I,5,7,10). The chamber wall is smooth, and the base is flat. However, flattening may modify the silhouette of the vesicle, so that the base may appear slightly convex (Plate I,4,7, and 10) and the rounded margin may appear sharp when the base is folded inside the chamber (Plate I,8). The prosome has not been directly observed in the available specimens but its elongate cast is visible on some individuals (e.g., Plate I,1 and 6). Rare chain-like structures ("twins") are observed (Plate I,3).

Dimensions: see Table 1.

Discussion: the specimens recovered from the Saladillo and Parcha formations recall *Euconochitina symmetrica* (Taugourdeau and de Jekhowsky, 1960) to some extent. However, *E. paschaensis* sp. nov. does not display the wide flaring collarette, which is the diagnostic feature of typical *E. symmetrica* populations from the early Floian of Algeria (Taugourdeau and de Jekhowsky, 1960; Benoît and Taugourdeau, 1961) or from Eastern Canada (Achab, 1980). Although the overall size and the chamber shape of the populations from Algeria and Argentina are quite similar, the specimens from Argentina clearly separate from the

Saharan type material owing to the very poor widening of their collarette (mean value of dcoll/dn close to 1 instead of 1.16 for *E. symmetrica* populations from the Sahara). For that reason, the Argentine individuals are considered here as belonging to a new species, *Euconochitina paschaensis* representing probably the oldest in terms of an evolutionary lineage ending with the typical *E. symmetrica*. An extensive biometric revision of the Saharan material has been completed recently, allowing better documented comparisons (de la Puente and Paris, in preparation). The Tremadocian specimens of *E. symmetrica* from the Eastern Yangtze Gorges illustrated by Wang and Chen (1992; Plate I, Fig. 1–2, 4–5, 9) seem also to have a narrow aperture in the range of the dcoll, values measured on *E. paschaensis* sp. nov.

Geographical and stratigraphical distribution: In Argentina, *Euconochitina paschaensis* sp. nov. occurs in the upper part of the Saladillo Formation, and ranges through the Parcha Formation. These two formations are well dated by late Tremadocian graptolites (see Waisfeld et al., 2006, and references therein). The productive sample from the Saladillo Formation is referred to the *Kiaerograptus* Biozone of early late Tremadocian age, whereas the samples from the Parcha Formation are attributed to the *A. murrayi* and to the *H. copiosus* biozones of late Tremadocian age. *E. paschaensis* sp. nov. is also present in Lower Ordovician sequences near the town of Santa Ana, eastern Cordillera Oriental, northwest Argentina (de la Puente, unpublished data).

Euconochitina sp. aff. paschaensis sp. nov. (Plate II,1–8)

Material: 47 individuals from sample P 3; 1 broken specimen from sample P 2.

Description: These specimens show a small ovoid chamber and a cylindrical neck that ends with a short and straight membranous collarette (lcoll mean value = $18 \mu m$). The length of the neck is highly variable (Ln = $41-116 \mu m$). The margin is rounded and the convexity of the base is frequently accentuated due to flattening. The chamber surface is smooth.

Dimensions: see Table 2.

Discussion: This form is fairly close to *Euconochitina paschaensis* sp. nov. as both have more or less similar vesicle length (mean of L= 167 μ m for *E. paschaensis* and 181 μ m for *E. sp. aff. paschaensis*). However, the present form is excluded from *E. paschaensis* sp. nov. because it has a more cylindrical silhouette of its vesicle (mean da/Dp=0.77 instead of 0.66 for *E. paschaensis* sp. nov.) and because it has a convex to rounded base. The ovoid chamber of *E. sp. aff. paschaensis* is possibly accentuated due to flattening that favoured the protrusion of its originally convex base. The neck of *E. sp. aff. paschaensis* sp. nov. is significantly shorter than those of *E. paschaensis* sp. nov. (mean Ln/L=0.35 for *E. sp. aff. paschaensis* sp. nov., but 0.47 for *E. paschaensis* sp. nov.). The plot diagram on Fig. 3 illustrates these morphological differences. Moreover, because *E. sp. aff. paschaensis* sp. nov. is recorded in one sample only, when *E. paschaensis*

L/Ln *E. paschaensis* sp. nov.- *E.* sp. aff. *paschaensis* sp. nov.



Fig. 3. Diagram showing the dispersion of values for L/Ln *E. paschaensis* sp. nov. (rhombus) and for L/Ln *E.* sp. aff. *paschaensis* sp. nov. (squares).

Table 3

Values calculated on 6 individuals of *Clavachitina* sp. from sample P 3. Coeff. of 0.8 is used for restoring the values of Dp, dn and dcoll after flattening

Values (µm)	L	Ln	Dp	dn	Ln/L
Maximum	348	174	95	59	0.50
Mean	287	117	73	45	0.40
Minimum	255	94	64	37	0.34

sp. nov. occurs in all the chitinozoan bearing samples, it seems unlikely to be simply a variant of our new species.

Geographical and stratigraphical distribution: *E.* sp. aff. *paschaensis* sp. nov. has been recovered from the lower part of the Parcha Formation (sample P 3) where it is associated with *E. paschaensis* sp. nov., *Lagenochitina* cf. *longiformis*, and *Clavachitina* sp. and with late Tremadocian graptolites of the *Araneograptus murrayi* Biozone. A broken specimen has been observed in sample P 2.

Genus *Clavachitina* Taugourdeau, 1966 emend. Paris et al., 1999a Type species *Rhabdochitina claviformis* Taugourdeau, 1961

Clavachitina sp. (Plate III,3,9)

Material: 6 individuals from sample P 3 (lower part of the Parcha Formation).

Description: The specimens have a claviform shape, with an elongate ovoid chamber and a fairly short cylindrical neck. The vesicle wall is perfectly smooth (Plate III,3,9). In the available individuals, the apertural part is frequently broken and therefore the shape of the collarette can rarely be documented. The shoulder is weakly marked. No antiapertural structure or mark has been observed.

Dimensions: see Table 3.

Discussion: In their general outline the observed specimens recall *Lagenochitina destombesi* Elaouad-Debbaj, 1988. However, the present individuals are much smaller than the Moroccan species (Dp=117.5 μ m; dn=63.8 μ m; L=519 μ m). The specimen represented on Plate III,9 recalls *Fustichitina ventriosa*, Achab 1980, which is, however, much larger (Dp=150-200 μ m; dn=80-120 μ m; L=400-700 μ m).

Geographical and stratigraphical distribution: In the Pascha-Incamayo area, *Clavachitina* sp. is only recorded in the lower part of the Pascha Formation (P 3), i.e. in the late Tremadocian (*Araneograptus murrayi* Biozone).

Family Lagenochitinidae Eisenack, 1931 emend. Paris, 1981 Subfamily Lagenochitininae Paris, 1981 Genus Lagenochitina Eisenack, 1931 emend. Paris et al., 1999a Type species Lagenochitina baltica Eisenack, 1931

Lagenochitina cf. longiformis (Obut, 1995) (Plate III,1a-2, 4a-4b)

Synonymy:

2006 – Lagenochitina cf. longiformis (Obut, 1995); Hints and Nõlvak, Plate IV, 15–25

Material: 2 specimens recovered in sample S 2 (upper part of the Saladillo Formation); 7 specimens from sample P 3 (lower part of the Parcha Fomation), and 3 specimens recovered in sample P 6 (upper part of the Parcha Fomation).

Table 4

Values calculated on 6 individuals of *Lagenochitina* cf. *longiformis* from samples S 2 and P 3. Coeff. Of is 0.8 used for restoring the values of Dp, dn and dcoll after flattening

Values (µm)	L	Ln	Dp	dn	dcoll	Ln/L
Maximum	474	210	135	72	100	0.50
Mean	362	158	114	64	88	0.40
Minimum	276	97	93	50	72	0.34

Dimensions: see Table 4.

Description: the observed specimens show an elongate ovoid chamber. The well-developed cylindrical neck (Ln close to half of the vesicle length) ends in a gently flaring collarette (l coll about 50 µm). The aperture is finely denticulate. The flexure and the shoulder are well developed. The fairly thick wall of the vesicle is glabrous. However, small corrugations or wrinkles occur on the flanks. This rugose aspect fades away on the neck (Plate III,1b) and on the base (Plate III,1c), which is rounded and seems devoid of any apical mark.

Discussion: these specimens are close to *Eremochitina longiformis* as defined by Obut (1995). The main difference is the lack of a conspicuous mucron. In the Russian material, however, the latter seems different from the true membranous tubular copula characteristic of the genus *Eremochitina* Taugourdeau and de Jekhowsky, 1960. Consequently, we suggest an assignment of the species *longiformis* to *Lagenochitina* rather than to *Eremochitina*. The Argentine individuals are generally smaller (see Table 4) than the Russian species (L=533–693 µm; Dp=160–162 µm; da=75–83 µm). Among the polymorphic Estonian population identified as *Lagenochitina* cf. *longiformis* by Hints and Nõlvak (2006), some specimens (e.g., Plate IV,17,23) are identical to the Argentine ones. In spite of the presence of an apical mark in most of the Estonian individuals, we include them in our synonymy list.

Geographical and stratigraphical distribution: *L. longiformis* (Obut, 1995) was defined in the early Arenigian, Sementsovo Horizon (regional stage) of the Moscow Syncline where it occurs in the Danilov 10 (depth 1990.5–1997.9 m) and Dyakonovo 4 (depth 2063–2075 m) boreholes (O. Obut, personal communication, 2007). Hints and Nõlvak (2006) reported *L. cf. longiformis* Obut 1995 from a clay lens within the glauconite sandstone of the Leetse Formation at Kadriorg, Tallinn, north Estonia. The Estonian assemblage is provisionally assigned to the late Tremadocian (part of the *proteus* conodont Zone) (Hints and Nõlvak, 2006).

Lagenochitina cf. conifundus (Poumot, 1968) (Plate III,6,7,8)

Material: 3 specimens from the youngest productive sample (P 6) of the Parcha Formation and 1 from the Saladillo Formation (S 2). **Dimensions**: L=271–484 μ m; Dp=80–109 μ m; dn=60–67 μ m; dcoll=64 μ m.

Description: the observed specimens present a smooth claviform chamber with a very distinctive truncate or ogival base. The neck ends in a collarette that apparently flares around the aperture (partly damaged). The dimensions of the two specimens from the Parcha Formation (Plate III,6–7) are significantly smaller than the holotype of *Lagenochitina conifundus* described by Poumot (1968). The latter has a total length of 470 µm and a chamber diameter of 215 µm, whereas in the largest Argentine specimen L is only 320 µm (the neck length is 120 µm) and Dp 92 µm (coeff. of 0.8, for pre-flattening restoration). The individual recorded in the Saladillo Formation (Plate III,8) is more in the size range of *L. conifundus*, but its base is conspicuously truncated.

Discussion: *Amphorachitina* is a rejected genus in the classification of Paris et al. (1999a) and mentioned as junior synonym of *Lagenochitina* Eisenack, 1931. *L. conifundus* is a common element of the North Gondwana Domain. When compared with the type material of Poumot (1968, Plate 1, fig. 6) and with the specimen illustrated by Fatka (1993, text-Fig. 3), the individuals observed in the upper part of the Parcha Formation and in the Saladillo Formation display fairly similar silhouettes. However their smaller size, and/or truncated base does not permit a firm assignment to the species *conifundus*.

Geographical and stratigraphical distribution: *L. conifundus* was defined by Poumot (1968) in samples from Saharan wells belonging to the Tremadocian. According to Paris (1990), it also occurs in the basal part of the Klabava Formation, Bohemia, without other chitinozoans. It coexists with *Lagenochitina* e.g. *esthonica* and *Conochitina* spp.

in Algeria (Paris 1990). In Bohemia, according to Fatka (1993), *L. conifundus* is associated with *E. symmetrica*, and the *messaouden-sis-trifidum* acritarch palynoflora in samples KL-7 and KL-16 in the lowermost part of the Klabava Formation. *L. conifundus* is the index species of the eponymous chitinozoan biozone of North Gondwana (Paris 1990; Webby et al., 2004), which indicates a late Tremadocian age (TS.1c-1d) in Webby et al. (2004).

Order Operculatifera Eisenack, 1931 Family Desmochitinidae Eisenack, 1931 emend. Paris, 1981 Subfamily Desmochitininae Paris, 1981 Genus Desmochitina Eisenack, 1931 Type species Desmochitina nodosa Eisenack, 1931

Desmochitina sp. cf. L. brevicollis (Taugourdeau and Jekhowsky, 1960) (Plate III,5)

Material: A single specimen has been observed the Parcha Formation (sample P 4).

Description: This specimen of fairly small size (L=147 μ m; Dp=117 μ m) has an ovoid smooth chamber ended by a very short and slightly flaring collarette (lcoll=13 μ m). The damaged base was probably flat.

Discussion: Because the base is obviously broken this form cannot be firmly identified at species level. It is, however, tentatively referred to Desmochitina sp. cf. L. brevicollis (Taugourdeau and de Jekhowsky, 1960). This species, which was originally assigned to the genus Lagenochitina, is under revision as the paratype illustrated by Taugourdeau and de Jekhowsky (1960, Plate VIII, fig. 110) displays Desmochitina characters whereas the holotype (Taugourdeau and de Jekhowsky, 1960; Plate VIII, fig. 109) is more likely to be a Lagenochitina with a broken neck. On Plate III,4a-4b, a broken individual, most likely a broken specimen of L. cf. longiformis, looks very similar to brevicollis (the arrow indicates well-differentiated internal and external membranes; the external one looks like a collarette). Desmochitina sp. cf. L. brevicollis from the Parcha Formation (P 4) is close to the paratype designated by Taugourdeau and de Jekhowsky (1960), which has a flat base and sub-parallel flanks. It recalls also the individuals Heuse et al. (1999) identified as Desmochitina sp. group minor in equivalent Tremadocian levels from the northern part of the same Central Andean basin in southern Bolivia.

Geographical and stratigraphical distribution: The species *brevicollis* was described in stratigraphically poorly constrained Early Ordovician strata from the subsurface of Sahara (Taugourdeau and de Jekhowsky, 1960), but below the FAD of *E. symmetrica* regarded as the first Floian chitinozoan biozone in northern Gondwana (Paris, 1990; Webby et al. 2004). *Desmochitina* sp. group *minor* illustrated by Heuse et al. (1999) from the East Cordillera in southern Bolivia are from the upper part of the Cieneguillas Formation and from the lowermost part of the overlying Obispo Formation. The latter strata are assigned to the late Tremadocian *A. murrayi* and *H. copiosus* graptolite zones and are therefore contemporaneous with the Parcha Formation.

8. Conclusions

The chitinozoan and acritarch associations recovered from the chronostratigraphically well constrained Saladillo and Parcha formations in northwestern Argentina provide useful correlation tools for dating other Tremadocian formations devoid of graptolite data, at least at the scale of the peri-Gondwana regions.

The late Tremadocian *messaoudensis-trifidum* acritarch assemblage in the Cordillera Oriental, northwestern Argentina, ranges throughout the *Kiaerograptus, A. murrayi* and *H. copiosus* graptolites biozones, thus from TS.1b to TS.1d (time-slices of Webby et al., 2004).

Comparing the records of the *messaoudensis-trifidum* acritarch assemblage of Pascha- Incamayo with those from other peri-

Gondwanan localities that lack independent age control (i.e. Wales) or have only graptolites (i.e. England and Spain) or chitinozoans (i.e. Bohemia and Germany), the age of the Pascha-Incamayo assemblage is independently controlled by two fossil groups, graptolites and chitinozoans, with most specimens coming from the same levels.

Because of its abundance, *Euconochitina paschaensis* sp. nov. could be a late Tremadocian index chitinozoan in the Central Andean Basin and most likely in other Gondwanan regions. The range of *E. paschaensis* can be regarded as a time equivalent of the *conifundus*/"*brevicollis*" biozone documented in numerous core drills in the Algerian Sahara (e.g., in the El Gassi and Foum Tinselem formations). In northern Gondwana, the *conifundus*/"*brevicollis*" biozone is assigned to the late Tremadocian as it precedes the early Floian *symmetrica* biozone (Paris et al., 1999b; Webby et al. 2004). This is consistent with the range of the acritarchs of the *messaoudensis-trifidum* association recovered from the Saladillo and Parcha formations.

For the moment, *E. paschaensis*, which is regarded as a new species, is of little help in documenting the palaeobiogeographical affinities of the Pascha-Incamayo area. Subordinate taxa, such as *D.* sp. cf. *L. brevicollis* and *L. cf. conifundus*, in spite of their open nomenclature owing to their scarcity in the available samples, suggest affinities with northern Gondwana chitinozoan assemblages, and strengthen similar affinities already documented in neighbouring areas of Argentina (Famatina region) or countries (Bolivia) for the Tremadocian and the Floian.

Acknowledgements

The authors are grateful to Blanca Toro (IANIGLA, Mendoza) and Ricardo Astini (CICTERRA-Universidad Nacional de Córdoba) for graptolite and stratigraphic discussions respectively, and Beatriz Waisfeld and Emilio Vaccari (CIPAL, Córdoba) for the collection of the samples. Special thanks to Aicha Achab (INRS, Quebec), and Olga Obut (Institute of Petroleum Geology and Geophysics, Novosibirsk) for their valuable discussions on the study of chitinozoans. We also wish to thank Dr. Florentin Paris (Rennes, France) and the anonymous reviewer for their useful comments and linguistic improvement of this manuscript and to Michael Stephenson (Nottingham, UK) for the editorial work. This work has been supported by CONICET (PIP N° 5948), FONCyT (PICT 2006 N° 01272), and SECyT-ECOS Project A05U01 (Scientific Cooperation Programme between Argentina and France). It is a contribution to the International Geoscience Programme IGCP 503 'Ordovician Palaeogeography and Palaeoclimate'.

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