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New graptolite, chitinozoan and acritarch records from the Pascha-Incamayo area, Cordillera Oriental, Argentina

Nouvel enregistrement de graptolites, de chitinozoaires et d'arcritarches dans la région de Pascha-Incamayo, Cordillera Oriental, Argentine

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ABSTRACT

A new fossil assemblage bearing graptolites, chitinozoans and acritarchs is analyzed based on material collected in the Pascha-Incamayo area, Salta Province, NW Argentina. The occurrence of *Hunnegraptus copiosus* (Lindholm, 1991), associated with specimens of the genus *Tetragraptus* (Salter, 1863), is highly relevant to improve the age assignment and correlate the fossil-bearing levels previously assigned to the Devendeus Formation. Different stages in the development of the index species of the Upper Tremadocian *H. copiosus* Biozone are described and illustrated. The precise stratigraphic ranges of the associated chitinozoans and acritarchs are discussed, according to the biostratigraphic analysis, and the stratigraphic relationships for the studied section are considered.

Mots clés :
Graptolites
Chitinozoaires
Acritarches
Trémadocien tardif
Cordillera Oriental
Nord-Ouest de l'Argentine

RÉSUMÉ

Une nouvelle association fossilifère constituée par des graptolithes, chitinozoaires et acritarches a été recueillie dans la région de Pascha-Incamayo, Province de Salta, Argentine. La présence de *Hunnegraptus copiosus* (Lindholm, 1991), accompagné des spécimens du genre *Tetragraptus* (Salter, 1863) est particulièrement importante pour préciser l'âge et la corrélation entre les niveaux contenant ces fossiles, qui avaient été d'abord attribués à la Formation Devendeus. Les différentes étapes dans le développement de l'espèce-index du Trémadocien supérieur (Biozone de *H. copiosus*) sont décrites et illustrées. À partir de l'analyse de la biostratigraphie des graptolites, l'extension stratigraphique des chitinozoaires et des acritarches associés est discutée, et la nécessité d'une révision des relations stratigraphiques à partir de la coupe étudiée est argumentée.

1. Introduction

Graptolites from the Lower Ordovician sequences of the Argentine Cordillera Oriental represent a useful tool to establish chronological precisions, palaeobiogeographical

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relationships and intercontinental correlations (Toro, 1996, 1999; Brussa et al., 2003; Toro and Brussa, 2003; Toro et al., 2003; Albanesi et al., 2008 and references therein), as well as to identify stratigraphic unconformities and diastrophic events (Toro, 1995; Albanesi et al., 2001). In the past, most of the information was related to the Floian interval (Toro, 1997; Toro and Maletz, 2007, 2008), but in recent years more emphasis was put on the development of a biostratigraphic graptolite scheme for the Tremadocian deposits (Ortega and Albanesi, 2002; Albanesi et al., 2008). In addition, multidisciplinary studies have been conducted recently to review and to accurately connect the stratigraphic ranges of trilobites, acritarchs and chitinozoans associated with graptolites in the Pascha-Incamayo area (Toro et al., 2003; Waisfeld et al., 2006; Rubinstein et al., 2007).

2. Geological setting

The Pascha-Incamayo area is located in Salta Province, in the southern part of the Cordillera Oriental, northwestern Argentina (Fig. 1). This area, belonging to the central Andean Basin, was situated on the western Gondwanan margin during the Ordovician. Keidel (1937, 1943) established the first local lithostratigraphic scheme for the Cambrian-Ordovician, in which the following units: Lampazar, Cardonal and Saladillo formations were defined from base to top and the overlying Parcha Formation was assigned to the Floian. After a sedimentological revision, Astini (2003) proposed an updated stratigraphic scheme for the Pascha-Incamayo area. This author introduced the Sococha Formation, consisting of a thick-bedded massive quartz-rich sandstone (Fig. 2). Overlaying shale-rich levels of the Lampazar Formation were interpreted as outer shelf deposits. Waisfeld and Vaccari (2008) (Fig. 1) assigned this unit to the Furongian based on trilobite fauna and conodonts. The Devendeus Formation was established by Astini between the Cardonal and Saladillo formations, for the deposits corresponding to the filling of a local paleovalley (Astini, 2003). The Saladillo Formation mainly comprises black shales bearing the oldest graptolite record in the studied area (Albanesi et al., 2001). They are interbedded with sandstones in its lower part, and overlaid by graded sandstones toward the contact with the Parcha Formation. This unit, reassigned to the Upper Tremadocian based on its conodont and graptolite contents (Albanesi et al., 2001), consists of greenish shales and abundant alternating sandstones packages, which indicate a regressive tendency with an upwards coarsening of the sequence. Further sedimentological analyses

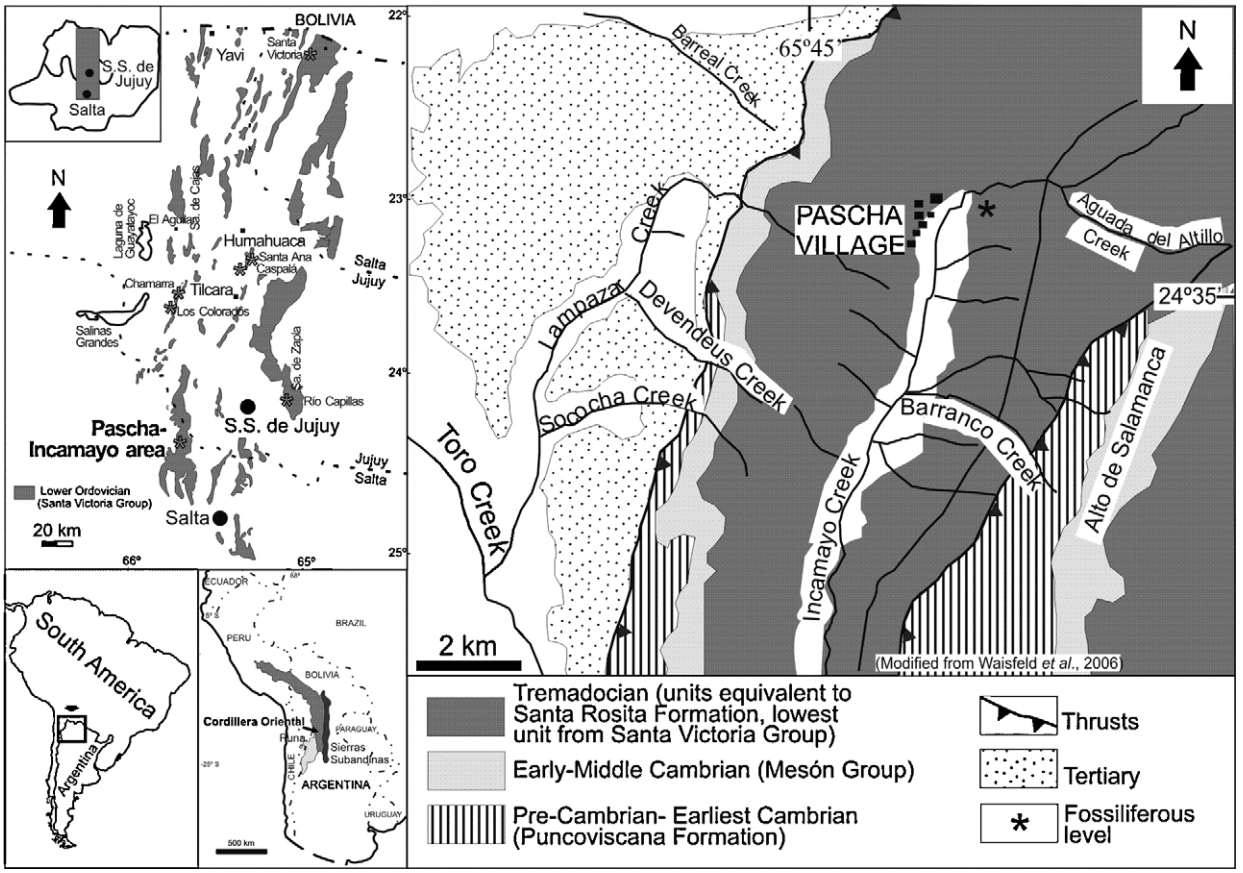

Fig. 1. Location map of the Pascha-Incamayo area in northwestern Argentina (modified from Waisfeld et al., 2006). Asterisk indicates the studied fossiliferous levels.

Fig. 1. Localisation de la région de Pascha-Incamayo dans le Nord-Ouest de l'Argentine (modifiée d'après Waisfeld et al., 2006). L'astérisque indique le niveau fossilifère étudié.

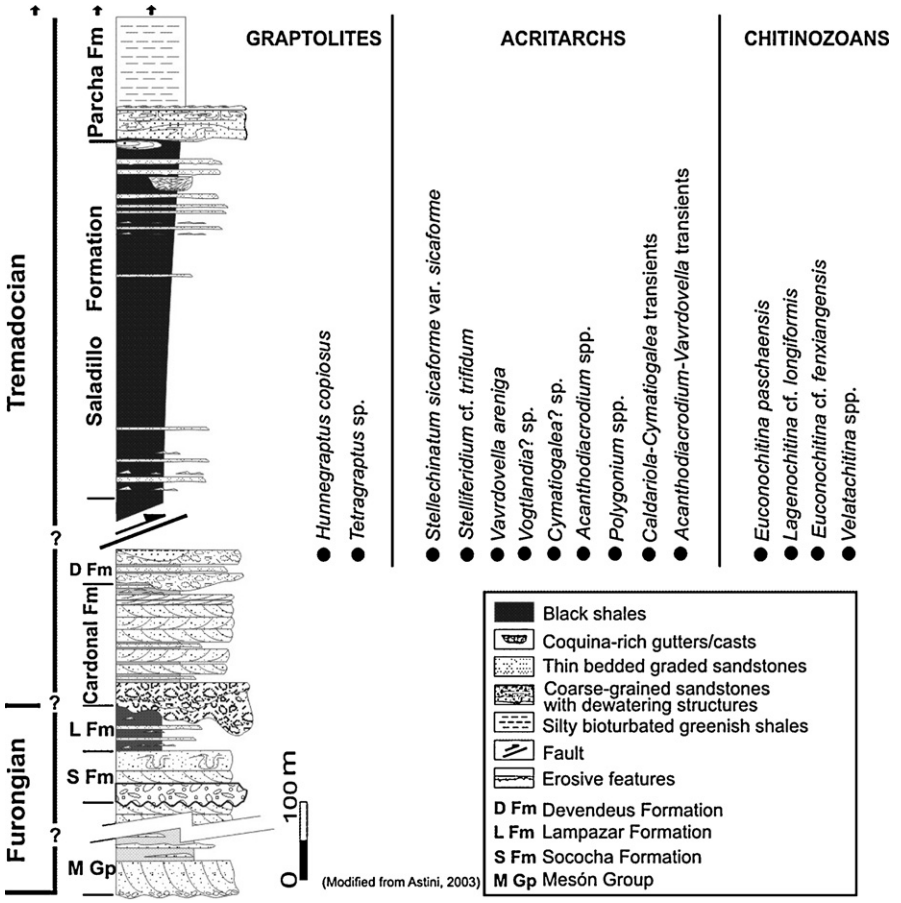

Fig. 2. Stratigraphic column of the studied section (modified from Astini, 2003).
Fig. 2. Coupe stratigraphique étudiée (d'après Astini, 2003, modifié).

suggest that the Tremadocian sequence was deposited in a tide-dominated platform alternating with successive transgressive systems tracts (Buatois et al., 2003). The Upper Cambrian-Lower Ordovician succession overlies the strata of the Meson Group, and its top is truncated by a fault. The studied section is exposed in the eastern margin of the Incamayo Creek. Additional graptolites, chitinozoans and acritarchs were found approximately 1 km to the east of the Pascha village (Figs. 1 and 2).

Graptolites and palynological slides are housed in the palaeoinvertebrate and palaeopalynological slide collections respectively, of the Department of Palaeontology, IANIGLA, CCT- CONICET Mendoza, Argentina.

3. Biostratigraphy

A large biostratigraphic record of different fossil groups makes the Pascha area a classic Lower Ordovician locality for the Cordillera Oriental of northwestern Argentina. Trilobite records and biozones were extensively analyzed (Kobayashi, 1935, 1937; Harrington, 1937, 1938; Harrington and Leanza, 1957, Waisfeld and Vaccari, 2008 and references therein). Waisfeld et al. (2006) and Waisfeld and Vaccari (2008) recently concluded that the trilobite *Ogygiocaris araiorhachis* Harrington and Leanza, 1957 ranges into the *Araneograptus murrayi* and *Hunnegraptus copiosus* biozones. Conodonts collected in the Pascha-Incamayo area were provisionally assigned to the *Cordylodus angulatus, Paltodus deltifer* and *Paraistodus originalis – Acodus deltatus* biozones (Ortega and Albanesi, 2003). This scheme was recently revised and the conodont biozones were correlated with the *Bryograptus, Kiaerograptus – Kiaerograptus supremus and Araenograptus murrayi – H. copiosus* graptolite biozones (Albanesi et al., 2008).

A detailed revision with updated data and multidisciplinary criteria is required to clarify the stratigraphic and structural complexity exhibited by the thick Ordovician successions of the area.

4. Graptolites

Several authors have provided information to establish a biostratigraphic graptolite scheme for the Pascha-Incamayo area (Rubinstein et al., 1999; Albanesi et al., 2001; Ortega and Albanesi, 2002). Ortega and Albanesi (2003) studied the graptolite and conodont faunas from

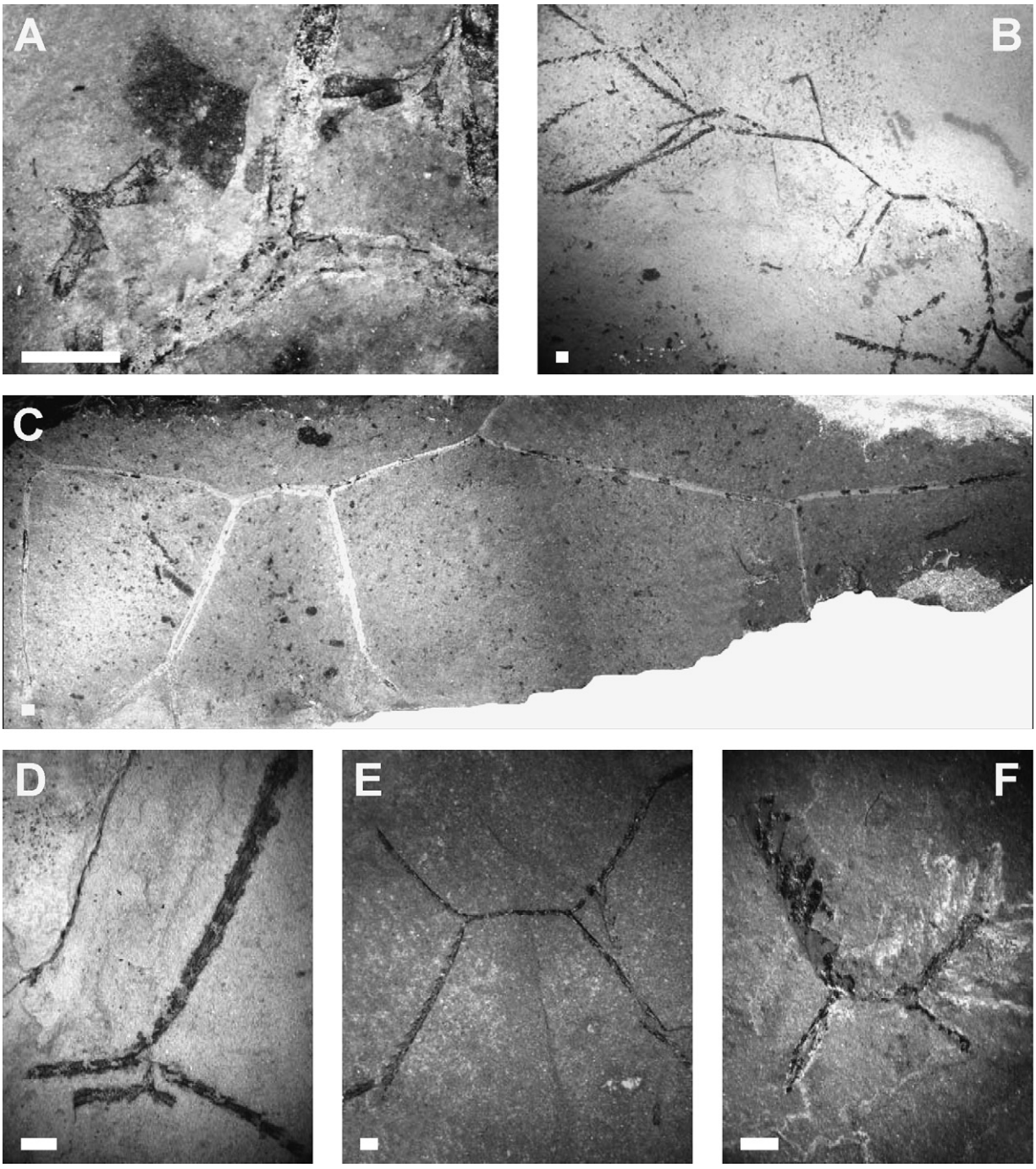

Fig. 3. Graptolites of the *Hunnegraptus copiosus* Biozone (Late Tremadocian) from the Pascha-Incamayo area, Cordillera Oriental, Argentina. A–E, *Hunnegraptus copiosus* A: proximal ends showing the sicular bitheca, IANIGLA-PI 1687. Barranco Creek. B: gerontic specimen with first, second, third and fourth order stipes, IANIGLA-PI 1674. Incamayo Creek. C: gerontic rhabdosome showing the first, second and third order stipes length variation, IANIGLA-PI 1675. Incamayo Creek. D: proximal end view associated with a fragment showing first and second order stipes IANIGLA-PI 1677. Incamayo Creek. E: complete madure rhabdosome IANIGLA-PI 1694. Aguada del Altillo Creek. F: *Tetragraptus* sp. Poorly preserved specimen, IANIGLA-PI 1673. Incamayo Creek. Scale: 1 mm.

Fig. 3. Graptolites de la Biozone de *Hunnegraptus copiosus* (Trémadocien tardif) de la région de Pascha-Incamayo, *Cordillera Oriental*, Argentine. A–E, *Hunnegraptus copiosus* A : extrémité proximale montrant la bithèque siculaire, IANIGLA-PI 1687. Vallée de Barranco. B : spécimen avec stypes de premier, deuxième, troisième et quatrième ordres, IANIGLA-PI 1674. Vallée d'Incamayo. C : rhabdosome adulte qui montre la variation de la longueur des stypes de premier, deuxième et troisième ordres, IANIGLA-PI 1675. Vallée d'Incamayo. D : vue de l'extrémité proximale associée à un fragment qui montre le premier et le deuxième ordres de stypes IANIGLA-PI 1677. Vallée d'Incamayo. E : rhabdosome complet adulte IANIGLA-PI 1694. Vallée de Aguada del Altillo. F : *Tetragraptus* sp. spécimen mal conservé, IANIGLA-PI 1673. Vallée d'Incamayo. Échelle : 1 mm.

the Saladillo and Parcha formations and proposed a biostratigraphic scheme with the *Bryograptus* and *Kiaerograptus* biozones, corresponding to the Upper Tremadocian, and the *K. supremus, A. murrayi* and *H. copiosus* biozones, indicating an Uppermost Tremadocian age. The authors recognized the index species of the *H. copiosus* Biozone, together with other specimens of the genera *Hunnegraptus* and *Paradelograptus* (Erdtmann et al., 1987), in the upper levels of the Parcha Formation, exposed in the eastern flank of the Incamayo Creek in the La Pedrera and Barranco sections. *H. copiosus* was also reported by Toro (Toro et al., 2003) in the upper part of the Parcha Formation along the Aguada del Altillo and Barranco creeks. Recently collected material from the Incamayo Creek (Figs. 1 et 3), represents different stages of the development of *H. copiosus*, which are associated with a few poorly preserved specimens of *Tetragraptus* sp. (Fig. 3F). Species of *Hunnegraptus* are restricted to Upper Tremadocian strata, with a wide palaeogeographic distribution including Scandinavia, where the species *H. copiosus* was erected (Lindholm, 1991), North America, where *H. copiosus* was mentioned in Canada (Jackson and Lenz, 2003) and the records of *H. novus* Berry, 1960 reviewed by Maltez (2006). In China (Zhang et al., 2005; Feng et al., 2007) and northwestern Argentina (Albanesi et al., 2001; Benedetto et al., 2002; Ortega and Albanesi, 2003, Fig. 2) both species were also mentioned. Despite of the wide distribution of the genus *Hunnegraptus*, only scarce records from South America showing the various ontogenetic stages of the rhabdosome development are available in the literature so far (Maletz and Egenhof, 2001). Morphological features of the proximal end of the studied rhabdosomes, along with the presence of a conspicuous sicular bitheca and the development of the primary stipes coincide with *H. copiosus*. First order stipes contain 5–11 theca. Second and third order stipes reach 12 and 15 mm. respectively (Fig. 3C). Some rhabdosomes possess dichotomies up to 4th order in gerontic specimens (Fig. 3B–C). As was discussed by Maltez (2006), the intraspecific variation of *Hunnegraptus* is not well understood. In addition, previously observed differences between *H. copiosus* and *H. novus* could be related to preservational conditions. Therefore, we prefer to maintain all the material as a single species of *Hunnegraptus*, representing juvenile to gerontic stages of *H. copiosus* (Fig. 3A–E). This analysis allows us to confirm that the bearing levels are equivalent to those previously assigned to the Upper Tremadocian (*H. copiosus* Biozone) from La Pedrera, Aguada del Altillo and Barranco sections (Ortega and Albanesi, 2003; Toro et al., 2003; Waisfeld et al., 2006).

5. Chitinozoans

Samples from two sampling points of the same stratigraphic level yielded different assemblages, with scarce and in general poorly preserved chitinozoans. One of the assemblages contains *Euconochitina paschaensis* de la Puente in (de la Puente and Rubinstein, 2009), *Euconochitina* sp. aff. *paschaensis* de la Puente in (de la Puente and Rubinstein, 2009) which probably correspond to *Euconochitina fenxiangensis* Chen et al., 2008 since it seems very similar to some specimens of this species (see Plate 1, fig. 5 of Chen et al., 2008) and possibly *Lagenochitina* cf. *longiformis* (Obut, 1995) (Fig. 4A–C). *E. paschaensis* and *Lagenochitina* cf. *longiformis* has been previously recorded from the upper part of the Saladillo Formation towards the upper part of the Parcha Formation, outcropping in the Pascha-Incamayo area, while *Euconochitina* sp. aff. *paschaensis* (probably synonym with *Euconochitina fenxiangensis*) has only been found in the lower part of the Parcha Formation (de la Puente and Rubinstein, 2009). The other assemblage, corresponding to a lateral facies change of the same stratigraphic level, contains a specimen doubtfully assigned to *Cutichitina* sp. (Fig. 4D) and some forms belonging to *Velatachitina* genus (Fig. 4E–H), which, in some cases, show a more lagenochinidae chamber shape (Fig. 4H). Specimens of the latter assemblage have not been observed in the previously studied Aguada del Altillo and Barranco creeks, in the Pascha-Incamayo area (de la Puente and Rubinstein, 2009).

The *E. paschaensis*, *Euconochitina* sp. aff. *paschaensis* and *Lagenochitina* cf. *longiformis* assemblage is present in levels assigned to the *Kiaerograptus*, *A. murrayi* and *H. copiosus* biozones of the Pascha-Incamayo area, ranging from the early Late Tremadocian to the Late Tremadocian (Waisfeld et al., 2006). *Euconochitina fenxiangensis* Chen et al. (2008) has been defined for the upper part of the Fenxiang Formation and the lower part of the Honghuayuan Formation, and assigned to the Late Tremadocian–early Floian according to the *Prioniodus proteus* and *P. elegans* zones (Chen et al., 2008). *Velatachitina* is a common genus in the chitinozoan assemblages of the Lower to Middle Ordovician from Gondwana.

6. Acritarchs

Acritarchs recorded in the studied levels, accompanying the graptolites *H. copiosus* and *Tetragraptus* sp., are low in abundance and diversity and relatively badly preserved (Fig. 4). The assemblage contains: *Stellechinatum sicaforme* Molyneux in (Molyneux and Rushton, 1988) var. *sicaforme* Autonym 1997, *Stelliferidium trifidum* (Rasul) Fensome et al., 1990, *Vavrdovella areniga* (Vavrdova) Loeblich and Tappan, 1976, *Vogtlandia*? sp. in (de la Puente and Rubinstein, 2009), *Cymatiogalea*? sp., *Acanthodiacrodium* spp., *Polygonium* spp. and transitional forms such as *Caldariola–Cymatiogalea* transients and *Acanthodiacrodium–Vavrdovella* transients. Most of these species are characteristics of the Late Tremadocian *messaoudensis-trifidum* acritarch assemblage and they have also been recorded from the upper section of the Parcha Formation (de la Puente and Rubinstein, 2009), in levels with graptolites that indicate the *H. copiosus* Biozone.

The *messaoudensis-trifidum* acritarch assemblage, which ranges across the Tremadocian–Floian boundary, was formerly documented in the Watch Hill Formation, Skiddaw Group, Lake District, northwestern England, by Molyneux and Rushton (1988) Afterward, it has been reported from different localities around the Gondwana margin, as in Ireland, Spain, Belgium and Germany, and also in Baltica, becoming a valuable tool for correlation of Late Tremadocian time slices of Gondwana and Baltica (Molyneux et al., 2007).

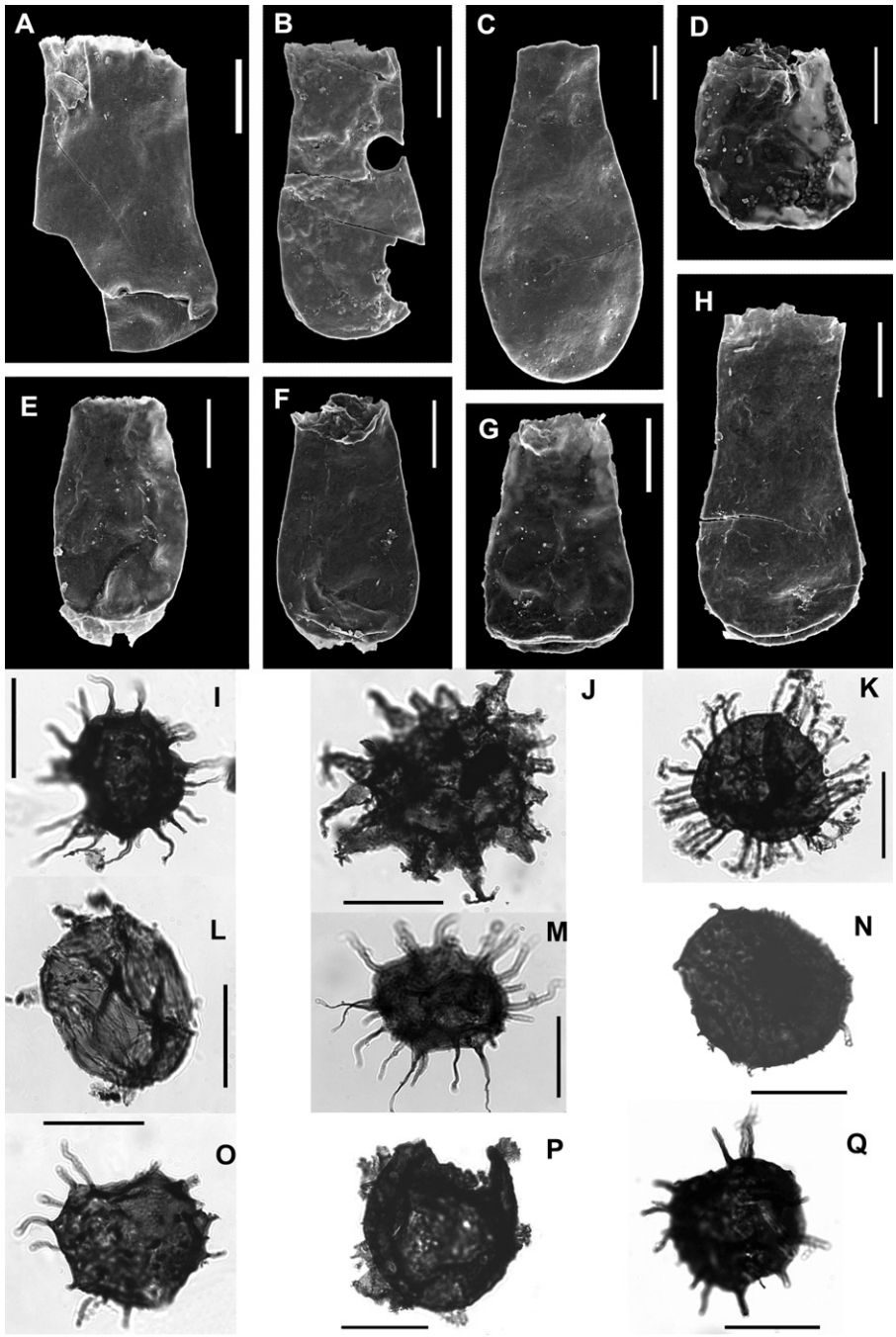

Fig. 4. Chitinozoans and acritarchs of the Late Tremadocian from the eastern margin of the Incamayo Creek, Cordillera Oriental, Argentina. A: *Euconochitina paschaensis*-8257'-Q32/4; B: *Euconochitina* cf. *fenxiangensis* -8257'-J31; C: *Lagenochitina* cf. *longiformis*-8257'-P29/4; D: ?*Cutichitina* sp.-8258'-N32; E: F, G, H, *Velatachitina* spp. -8258'- O29/1, K33/3, M32/4, M31/2; I: *Acanthodiacrodium* sp.-8257-J39/0A; J: *Vogtlandia*? sp.-7860-H32/0B; K: *Cymatiogalea*? sp.-8258-T25-2C; L: *Eisenackidium orientalis*-7859-M25/0A; M: *Stellechinatum sicaforme* var. *sicaforme*-7860-L29-2F-1; N: *Stelliferidium trifidum*-7859-H41-0G-1; O: Transient between *Acanthodiacrodium* and *Vavrdovella*-7859-B42-3G; P: Transient between *Caldariola* and *Cymatiogalea*-7860-V42-2G; Q: *Vavrdovella areniga*-7859-X38-0E. Scale for chitinozoans: 50 μm; scale for acritarchs: 20 μm. Specimen locations are based on the England Finder coordinates.

Fig. 4. Chitinozoaires et acritarches du Trémadocien tardif du côté est de la vallée d'Incamayo, *Cordillera Oriental*, Argentine. A : *Euconochitina paschaensis*-8257'-Q32/4 ; B : *Euconochitina* cf. *fenxiangensis*-8257'-J31 ; C : *Lagenochitina* cf. *longiformis*-8257'-P29/4 ; D : ? *Cutichitina* sp.-8258'-N32 ; E, F, G, H : *Velatachitina* spp. -8258'- O29/1, K33/3, M32/4, M31/2 ; I : *Acanthodiacrodium* sp.-8257-J39/0A ; J : *Vogtlandia* ? sp.-7860-H32/0B ; K : *Cymatiogalea* ? sp.-8258-T25-2C ; L : *Eisenackidium orientalis*-7859-M25/0A ; M : *Stellechinatum sicaforme* var. *sicaforme*-7860-L29-2F-1 ; N : *Stelliferidium trifidum*-7859-H41-0G-1 ; O : forme de transition entre *Acanthodiacrodium* et *Vavrdovella*-7859-B42-3G ; P : forme de transition entre *Caldariola* et *Cymatiogalea*-7860-V42-2G ; Q : *Vavrdovella areniga*-7859-X38-0E. Échelle pour les chitinozoaires : 50 μm ; échelle pour les acritarches : 20 μm. La localisation des spécimens se base sur les coordonnées du repéreur England Finder.

The only species not previously recorded in the *messaoudensis-trifidum* acritarch assemblage occurrences from northwestern Argentina is *Stellechinatum sicaforme* var. *sicaforme*.

It is worth noting the first appearance in the Late Tremadocian of *Eisenackidium orientalis* Rubinstein in (Rubinstein et al., 1999), widely distributed throughout the Floian of the Cordillera Oriental, Sierras Subandinas and Famatina, and therefore considered until now as a marker of the Floian of northwestern Argentina.

7. Conclusions

Specimens of the *Hunnegraptus* genus, previously collected from the Aguada del Altillo and Barranco creek headwaters, along with the extra material coming from the eastern margin of the Incamayo Creek, represent different stages in the development of *H. copiosus*.

New records of the index species associated with specimens of *Tetragraptus* sp., chitinozoans and acritarchs of the Incamayo Creek indicate a Late Tremadocian age, and permit the correlation between both exposures of the studied section.

The repetition of stratigraphic levels corresponding to the *H. copiosus* Biozone, is confirmed by means of graptolite, chitinozoan and acritarch studies. This duplication of strata could be explained by the presence of a fault in the studied section, not recognized to date. A multidisciplinary revision is being carried out to shed light on the stratigraphy and structure of the area.

Acritarchs accompanying this new record of the *H. copiosus* Biozone are similar to those previously recorded from the same biozone in the Aguada del Altillo and Barranco creeks, thus supporting a Late Tremadocian age. They correspond to the *messaoudensis-trifidum* acritarch assemblage displayed around the Gondwana margin. *Eisenackidium orientalis*, considered a potentially good biostratigraphical marker for the Floian of the central Andean and the Famatina basins, appears for the first time in the Latest Tremadocian.

Most of the chitinozoans coming from the eastern margin of the Incamayo Creek are also similar to those recorded from the Aguada del Altillo and Barranco creeks, indicating a Late Tremadocian age for this association. *Velatachitina* genus, restricted to Gondwana, is recorded for the first time in the Pascha-Incamayo area. Its presence in one of the samples could be related to lateral facies changes of the studied level.

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