Early Ordovician (Floian) ostracods from the Cordillera Oriental, Northwest Argentina

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The ostracod fauna from the Floian (Lower Ordovician) strata of the Cordillera Oriental, Argentina (Acoite Formation) are documented. One new genus *Acoitella* and four species are recognized, two of which are new (*Nanopsis victoria* sp. nov. and *Conchoprimitia frequens* sp. nov.). The diversity of the Early Ordovician ostracod faunas of the Central Andean Basin is evaluated. Compared with other regions, the ostracod diversity, at generic and specific level, of the Cordillera Oriental was comparatively high during the Tremadocian (nine species recorded) and comparatively low during the Floian (four species recorded). The taxonomic composition of the fauna is similar during the entire Early Ordovician of the Cordillera Oriental, where it displays a high percentage of soanellids. The Floian assemblages are characterized by the dominance of the eridostracan *C. frequens* sp. nov. with a high percentage of nondimorphic palaeocopids: *Nanopsis* and two genera of the Soanellidae family (*Saltite* and *Acoitella* gen nov.). An ostracod shell bed is described and interpreted to be a parautochthonous assemblage, as a result of transport within the same habitat. The composition of the fauna, with the presence of *Saltite* and *Nanopsis*, shows significant affinities with East Gondwana. Copyright © 2011 John Wiley & Sons, Ltd.

1. INTRODUCTION

Ostracods became very diverse during the Middle Ordovician, between the Floian and Darriwilian, and reached their maximum diversity during the Late Ordovician (Braddy *et al.*, 2004; Tinn and Meidla, 2004). Although the record of the Ordovician ostracods is vast, with hundreds of species described, it is very uneven, with temporal and spatial gaps mainly in the palaeocontinent of Gondwana. Thus, hundreds of species have been described from the palaeocontinents of Baltica (e.g. Jannusson, 1957; Sarv, 1959; Schallreuter, 1993a; Meidla, 1996), Laurentia (e.g. Swain, 1957, 1962; Kraft, 1962; Copeland, 1982; Warshauer and Berdan, 1982; Williams and Siveter, 1996), Avalonia (e.g. Siveter, 2009), Siberia (Kanygin, 1971; Melnikova, 1976, 2010, 2011) and adjacent terranes of Gondwana, like Ibero–Armorica (e.g. Vannier, 1986a, b; Vannier *et al.*, 1989), whereas only tens of species have been located in the Gondwana continent (e.g. South America, Australia). The Central Andean Basin, exposed along the western margin of Gondwana, contains a

6 km-thick Ordovician succession with abundant and diverse macro- and microfauna, the latter including ostracods. To date, only isolated occurrences of ostracods from Peru, Bolivia and Northwest Argentina have been documented (Hughes *et al.*, 1980; Přibyl, 1984; Rossi de García and Proserpio, 1976). Recently, however, detailed taxonomic studies have been undertaken on the Tremadocian ostracods of Northwest Argentina (Salas *et al.*, 2007; Salas and Vaccari, 2011; Schallreuter and Hinz-Schallreuter, 2007).

This study describes the first Floian ostracods from Northwest Argentina. The diversity and composition of the Central Andean Basin ostracod fauna is assessed on the basis of previous taxonomic analyses and from the fauna examined here. This significantly increases our understanding of the ostracod fauna from Gondwana and places this within the broader context of Ordovician ostracod studies.

2. GEOLOGICAL SETTING AND ORIGIN OF THE MATERIAL

The Central Andean Basin is the largest and most well-known autochthonous Palaeozoic basin from the western margin of Gondwana and from which most of the

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palaeontological information from the Lower Palaeozoic of South America is derived (Benedetto *et al.*, 2009). It has a sedimentary succession of up to 6 km thick and extends from Peru to Northwestern Argentina (Figure 1). The Argentinian Cordillera Oriental forms the southern edge of the basin; in this region, the Ordovician succession is remarkably thick and spans the Tremadocian to the Hirnantian. It is exposed over several thousand square kilometres and contains a variety of depositional environments from outer shelf to shoreface (Astini, 2003). Along the Cordillera Oriental, the lower

Ordovician strata are included in the Santa Victoria Group (Turner, 1960), which comprises the Santa Rosita Formation (upper Cambrian to upper Tremadocian) and Acoite Formation (Floian). The ostracod fauna documented here is from the Acoite Formation in the localities of La Ciénaga, Los Colorados-Chamarra and Santa Victoria (Figures 1 and 2).

2.1. La Ciénaga (locality A)

La Ciénaga locality is situated 5 km west of the town of Purmamarca in Jujuy Province. The area is structurally complex, and the Ordovician succession occurs as tectonically truncated packages within several thrust sheets that form the Tertiary structure of the region (Vaccari *et al.*, 2006 and references therein). Some different informal names were given for the Ordovician outcrops in the area (Harrington and Leanza, 1957), however, Vaccari *et al.* (2006) according to its lithostratigraphic similarities referred the succession to the Acoite Formation, a geographically widespread unit in the basin. Based on conodonts and graptolites, the succession is established as Floian age (Rao *et al.*, 1994). In addition, the presence of the trilobites *Thysanopyge* sp. and *Pliomeridius* sp., which occur elsewhere in the Acoite Formation (Santa Victoria area) within the *Baltograptus deflexus* Biozone indicate a middle to late Floian age (Fl2 – Fl3 according to Bergström *et al.*, 2009) (Vaccari *et al.*, 2006). The ostracod material studied here was collected from calcareous lenses of the upper part of the section that crop out at National Road Nº 52 (Figure 2**A**).

2.2. Los Colorados-Chamarra (locality B)

This area is situated 27.5 km northwest of Purmamarca on the western margin of the Cordillera Oriental. An important Palaeozoic succession crops out at this location, which is remarkable because of its thickness. The Palaeozoic outcrops are overlain by the Salta Group (Cretaceous). The Acoite Formation in the area displays a great lateral continuity and is more than 3 km thick. A synthesis of the stratigraphy of the area can be found in Astini *et al.* (2004). The lower levels of the Acoite Formation are characterized by grey to black mudstones, which gradually become more greenish with a progressive increase of sandstone beds toward the upper levels. The succession finishes with a thick interval of yellowish sandstones. The ostracod fauna is mainly located in the middle levels of the formation in the Chamarra section (Figure 2**B**), although some specimens are recorded in the Los Colorados section. The section was studied by Astini and Waisfeld (1993) who recognized several coarsening-upward and thickening-upward major cycles. From bottom to top, the cycles start with interbedded shales and siltstones deposited in an outer-shelf storm wave-base setting and finish with sandstones progressively interbedded with
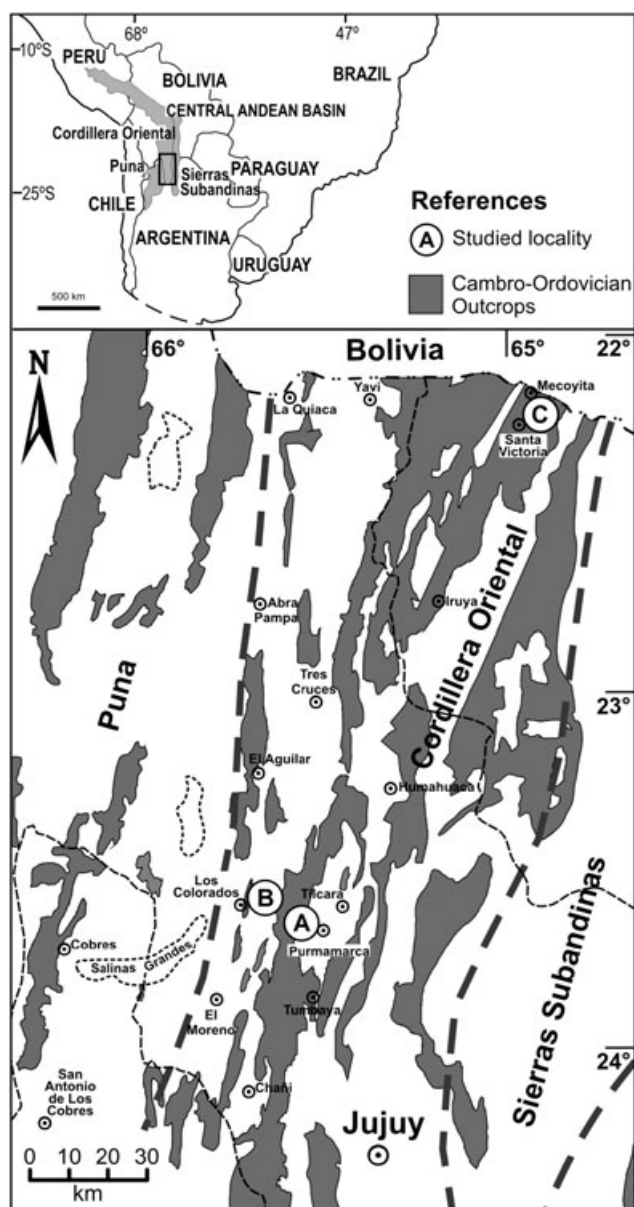

Figure 1. Location map showing Cambrian-Ordovician outcrops (modified from Balseiro *et al.*, 2011) **A**. La Ciénaga area; **B**. Los Colorados-Chamarra area; **C**. Santa Victoria area.
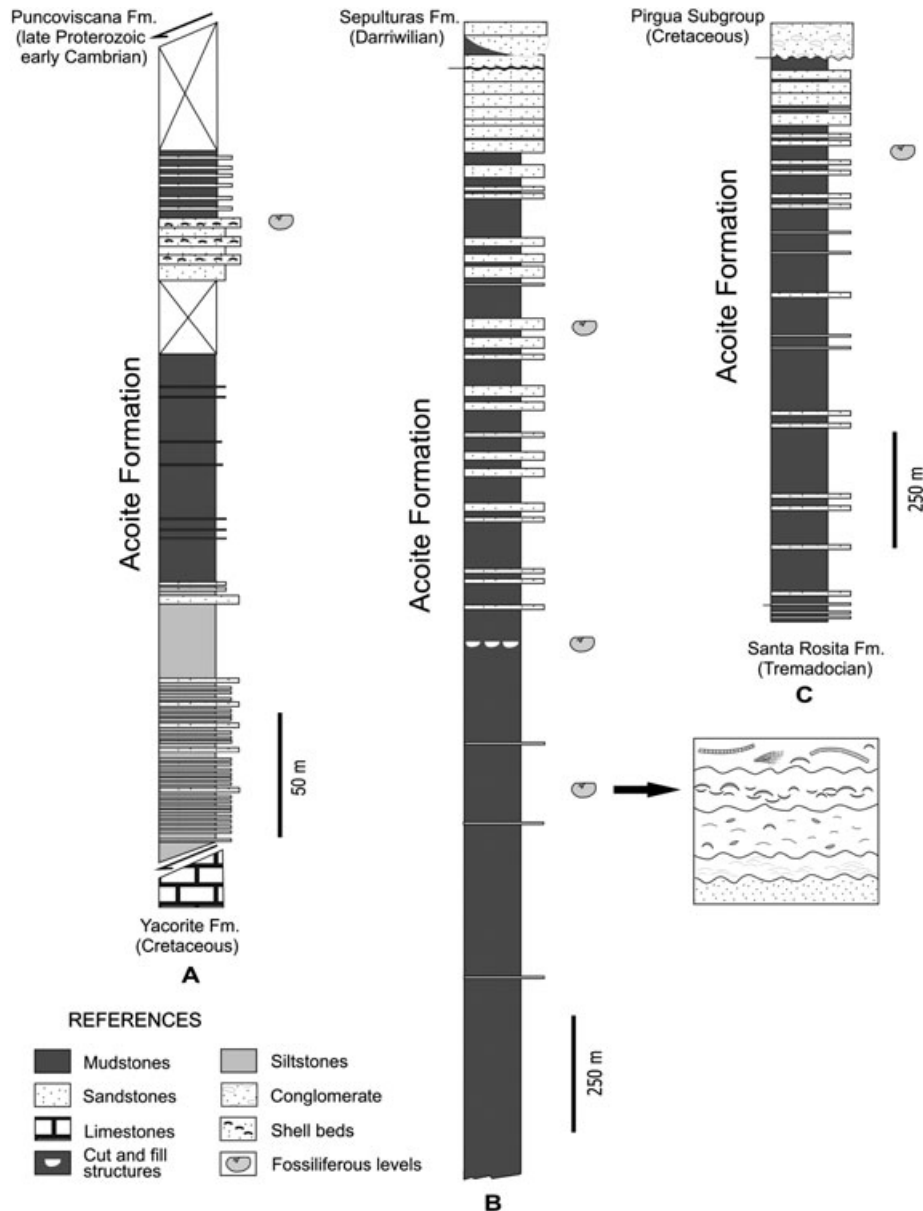
Figure 2. Stratigraphic sections of the Acoite Formation. **A**. La Ciénaga area (modified from Cichowolski, 2009); **B**. Los Colorados-Chamarra area; **C**. Santa Victoria area (modified from Waisfeld, 2001). In the second column (B) a schematic diagram of the bioclastic deposit with the ostracod shell bed is included.

storm-beds. The sandy packages at the top have been interpreted to be a storm-dominated and wave-dominated shoreface. In general, the environment has been interpreted as a storm-dominated and wave-dominated prograding deltaic system. The age of the Acoite Formation in the area has been attributed by Toro (1997 and references therein) to the Floian. Toro recognized four graptolites biozones in the formation, from bottom to top: *Tetragraptus phyllograptoides* Biozone, *Tetragraptus akzharensis* Biozone, *Baltograptus deflexus* Biozone and *Didymograptellus bifidus*

Biozone. The ostracod fauna was found within the *B. deflexus* Biozone, indicating a middle to late Floian age (Fl2-Fl3).

2.3. Santa Victoria (locality C)

Santa Victoria town is situated 50 km east of the city of La Quiaca in the northeastern end of the Argentinian Cordillera Oriental. The studied ostracod fauna was collected in the Acoite Formation in the outcrops of Santa Victoria – La Huerta River. In this area, the Acoite Formation overlies the Santa

Rosita Formation (upper Cambrian – upper Tremadocian), and reaches 1.2 km in thickness. It consists mainly of greenish to grey siltstones and sandstones interbedded with grey to black poorly bioturbated shales and siltstones. Coarsening-upward and thickening-upward cycles are progressively more frequent toward the upper levels, thick packages of bioturbated sandstones with hummocky cross-stratification are developed near the top. The lower to middle levels of the succession are interpreted as a middle to distal inner-shelf setting below the storm wave-base (Waisfeld *et al.*, 1999), whereas the coarsening observed at the top of the succession coincides with the coastal progradation recorded in other sectors of the basin (Waisfeld, 2001). A middle to late Floian age has been established for the Acoite Formation based on the graptolites (Toro, 1999) palynomorphs and trilobites (Rubinstein *et al.*, 1999). Ostracods were recorded in the middle levels of the section (Figure 2**C**).

3. TECHNIQUES OF STUDY

Rock samples of the studied material were collected during successive field expeditions, together with previously collected material from the fossil collection of the Centro de Investigaciones Paleobiológicas. Specimens from the La Ciénaga locality were recovered from acid residues obtained by processing calcarenite samples with 10% acetic acid. The material from the Los Colorados-Chamarra and Santa Victoria localities appears either with the original carapace preserved, or as internal moulds. These ostracods have been prepared mechanically using a 'Vibro-tool' and fine needles; the external moulds have been cast using latex rubber.

The specimens have been imaged with Scanning Electron Microscopy at the LABMEN of the University of San Luis, Argentina.

4. SYSTEMATIC PALAEONTOLOGY

Order Beyrichiocopida Pokorny, 1953,
Suborder Palaeocopina Henningsmoen 1953,
Superfamily Tetradelloidea Swartz 1936,
Family Soanellidae Kanygin 1971,
Genus *Acoitella* gen. nov.

Type species. *Sibiritella*? *angustilobata* Přibyl, 1984.
Other species. *Acoitella simplicata* (Přibyl, 1984).

Diagnosis. Small and equivalved Soanellidae. Amplete valves, circular to subelliptical outline. Quadrilobate, with ridge-like lobes. L1 and L4 curved to crescent-like situated over the anterior and posterior margin of the valves. L2 is the shortest lobe, is close to L1 and oblique to the dorsal margin. L3 is straight, longer than the other lobes, not

protruding to the dorsal margin and situated in the posterior half of the valve. Lobes are connected by a ventral connecting lobe. The area between the lobes is flat and broad. Marginal surface is broad and perpendicular to the lateral surface.

Etymology. Refers to the Acoite Formation, from which the species is recorded.

Occurrence. Recorded only in the Central Andean Basin of Argentina and Bolivia. Floian (Fl2-Fl3), Early Ordovician.

Discussion. This new genus has the typical circular to elliptical outline and lobate features of numerous soanellids from the Ordovician of other regions, mainly the Siberian taxa. Its quadrilobate valves with a connecting ventral lobe recall genera like *Soanella* Kanygin, 1967 (Middle Ordovician of the Siberian platform; see Schallreuter and Hinz-Schallreuter, 2004); *Fidelitella* (*Sibiritella*) Kanygin, 1967 (Middle Ordovician of the Siberian platform; see Schallreuter and Kanygin, 1992, figures 38.1–2, 40.1–2; Schallreuter and Hinz-Schallreuter, 2004) and *Quadrilobella* Ivanova, 1955 (Middle Ordovician of the Siberian platform; see Schallreuter and Hinz-Schallreuter, 2004). The most important resemblances between these taxa are their four elongate lobes, which could be connected with a ventral connecting lobe. However, *Acoitella* is small, with a maximum length recorded 1.16 mm, and its carapace is equivalved, without contact furrows or ridges and overlap platforms. The Siberian forms are larger in size, reaching up to 4 mm, and are inequivalved, with the left valve larger than the right. Additionally, in the new genus, L1 and L4 coincide with the anterior and posterior margins of the valve, without an extra lobular lateral surface, and the marginal surface is broad and perpendicular to the contact plane. Besides the previously mentioned features, in *Soanella*, L2 is not reduced and *Quadrilobella* is distinctly inequivalved, with a keel-like protuberance in the left valve that protrudes beyond the right valve.

The Ordovician North American genera, *Tetradellina* Harris, 1957 and *Zygobolboides* Spivey, 1939, are smaller than the Siberian forms, with a size comparable to the new genus. However, *Zygobolboides* is trilobate, with L2 reduced or fused with L1, whereas in *Tetradellina*, the distance between the lobes is the same, the lobes are not connected ventrally and the marginal surface is very narrow.

Saltite Rossi de García and Proserpio, 1976, a representative of the Soanellidae in the Tremadocian of Northwest Argentina, differs from *Acoitella* in its lack of a ventral connecting lobe and in the lack of a separation between the lateral and marginal surfaces.

The Bolivian soanellids, *Quadrilobella simplicata* Přibyl, 1984 from Sella and *Sibiritella*? *angustilobata* Přibyl, 1984 from Pantipampa, have been tentatively placed in a different genus by successive authors (Vannier *et al.*, 1995;

Schallreuter and Hinz-Schallreuter, 2004). However, according to the new material studied here, both species from Bolivia would belong to *Acoitella*.

Acoitella angustilobata (Přibyl, 1984)
Figure 3**A**–3**F**

1984. *Sibiritella*? *angustilobata*; Pribyl, p. 355.
2004. *Fidelitella* (*Sibiritella*) *angustilobata*; Schallreuter and Hinz-Schallreuter, p. 201.

Description. The valves have a subelliptic and amplete shape. The dorsal margin is straight and only slightly shorter than the maximum length of the valves. Average L:H (Length:Height ratio) is *ca*. 1.51. Cardinal angles are obtuse to nearly straight; both the anterior and posterior angles are between 100º and 110º. Anterior and posterior margins are evenly rounded; the ventral margin is convex in lateral view. Quadrilobate valves. The lobes are ridge-like and not protruded at the dorsal margin. L1 and L4 are crescent-like, located over the anterior and posterior margins between the lateral and marginal surfaces. L2 is the shortest lobe, it is straight, near L1 and is oblique to dorsal margin. L3 is the longest lobe, straight, perpendicular to the dorsal margin and is located in the posterior half of the valves nearer to L4 than to L2. Lobes are linked ventrally by a ridge-like connecting lobe. L2 and L3, in the union with the connecting lobe, are narrower. The surface between lobes is broad and flat. The marginal surface is almost perpendicular to the contact plane of separation of the valves, slightly concave and evenly wide around all the margin of the valves. The lateral surface and the lobes are smooth, whereas the marginal surface is weakly reticulate. The lobes lock inflated in the valves and sharper in the internal moulds. Valve hingement is straight and has small 'teeth' along its length. The 'teeth' are ridge-like and perpendicular to the hinge.

Material. There were around 40 specimens of valves and internal and external moulds including the figured material CEGH-UNC 24575–24580. Specimens are 0.48–0.92 mm in length.

Occurrence. *Acoitella angustilobata* (Přibyl, 1984) is known from the Acoite Formation of the La Ciénaga and
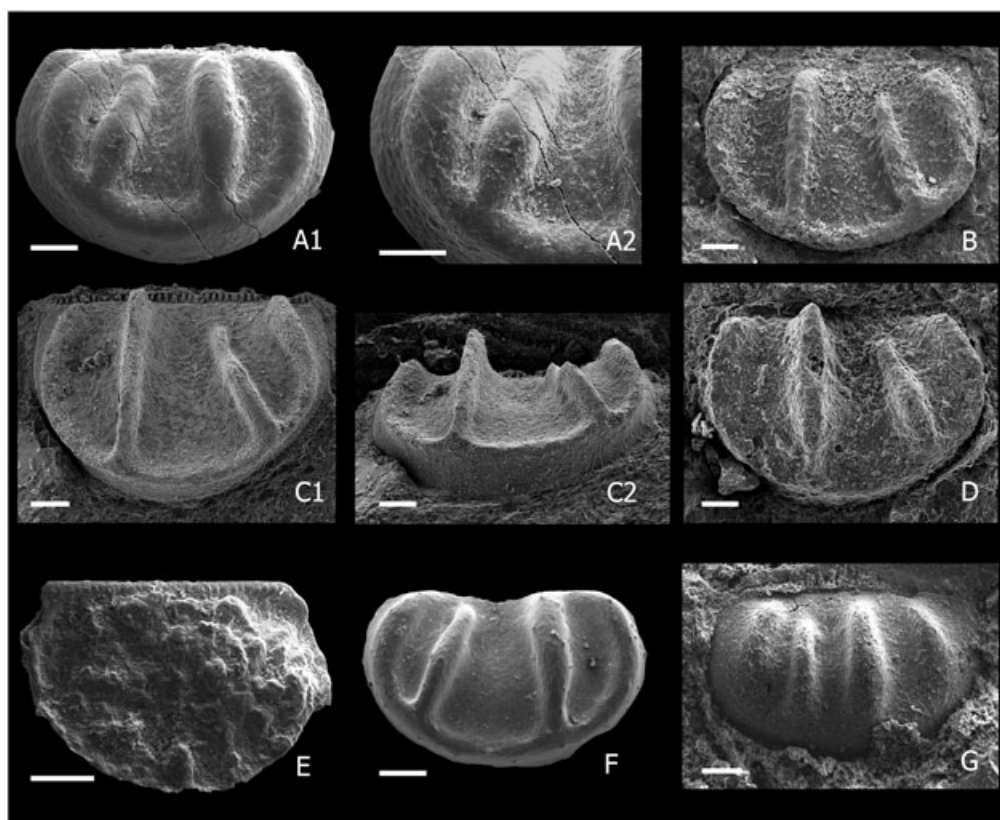

Figure 3. Middle to upper Floian ostracods from the Cordillera Oriental Argentina. **A-F**. *Acoitella angustilobata* (Přibyl, 1984), Acoite Formation from La Ciénaga section (A, E-F) and Chamarra section (B-D). **A**. CEGH-UNC 24575, left valve, **A1**. lateral view, **A2**. detail of the ornamentation. **B**. CEGH-UNC 24576, internal mould of right valve, lateral view. **C**. CEGH-UNC 24577, internal mould of right valve, **C1**. lateral view, **C2**. latero-ventral view. **D**. CEGH-UNC 24578, internal mould of right valve, lateral view. **E**. CEGH-UNC 24579, internal view of left valve, detail of the hingement. **F**. CEGH-UNC 24580, left valve, lateral view. **G**. *Saltite* sp., Chamarra section. CEGH-UNC 24581, internal mould of left valve, lateral view. Scale bars 100μm.

Los Colorados-Chamarra localities, Northwest Argentina (Figures 1 and 2), Floian, Fl2-Fl3, (*Baltograptus deflexus* Zone) and from the Pantipampa locality, Floian of Bolivia.

Discussion. The material from Argentina is considered conspecific with the Bolivian *Acoitella angustilobata* (Přibyl, 1984) on the basis of the valve outline and lobation. The Argentinian material also resembles *Quadrilobella simplicata* Přibyl, 1984 from the Floian of Bolivia. Confirmation of synonymy between these two species demands further analysis.

Genus *Saltite* Rossi de García and Proserpio, 1976
Saltite sp.
Figure 3**G**

Discussion. The main features observed in the recorded material (quadrilobate valves with long and well defined lobes) resemble *Saltite uchuy* Salas and Vaccari from the Tremadocian levels of the Parcha Formation in the Cordillera Oriental Argentina. However, the few specimens recorded, only two internal moulds, does not permit an accurate assignation, so it is left in open nomenclature.

Occurrence. Only known in the ostracod shell bed of the Acoite Formation in the Chamarra section, Los Colorados-Chamarra area (Figures 1, 2**B**), Middle to Late Floian (*Baltograptus deflexus* Zone), Jujuy Province, Argentina.

Superfamily Hollinoidea Swartz, 1936
Family Uncertain
Genus *Nanopsis* Henningsmoen, 1954
Nanopsis victoria sp. nov.
Figure 4**A**-4**D**

Holotype. CEGH-UNC 24583, left valve (Figure 4**B**).
Type locality. Santa Victoria area, Northwest Argentina.
Type horizon. Coquina levels of the middle part of the Acoite Formation, in the Santa Victoria-La Huerta River section, Middle to Late Floian (Fl2-Fl3), *Baltograptus deflexus* Zone, Salta Province, Argentina.
Derivation of the name. Refers to the Santa Victoria locality from which the species comes.
Diagnosis. *Nanopsis* species with trilobate, subelliptical valves. L1 and L2 are very close between each other. Adductorial sulcus (S2) deep, narrow, open dorsally and U-shaped. Posterior part of the valves almost entirely occupied by a broad lobate feature, with L3 poorly defined to indistinct. Lateral surface of the valves strongly punctuate.
Description. Valves have subelliptic and amplete lateral outlines. L:H ratio is *ca*. 1.52. The dorsal margin is straight and long, and is only slightly shorter than the maximum length of the valves. Lateral margins are evenly rounded and the ventral margin is convex. Cardinal angles are well defined and obtuse, both *ca*. 110º. The valves have a well-developed adductorial sulcus (S2) immediately in front

of the midheight of the valves. The sulcus is U-shape, narrow and deep, and does not overreach the ventral half of the valves. In its anterodorsal half the valves have two lobes (L1 and L2), which are short, rounded and very near between each other. L1 is poorly defined, whereas L2 is well defined, narrower and slightly shorter than L1. The sulcus S1 is short and slit-like. The posterior part of the valves is almost entirely occupied by a broad lobate feature, with L3 poorly defined to indistinct. When L3 is defined, the lobe is rounded, short and wider than the others. The lateral surface of the valve is punctuate, except at lobes L2 and L3. The marginal surface is nearly vertical and faintly reticulate. Marginal structures are lacking.

Material. Seven left valves and two right valves, including the figured material CEGH-UNC 24582, 24584–24585. Examined specimens range from 0.68 to 1.32 mm in length.

Occurrence. Known only from the type locality.

Discussion. The studied material is assigned to *Nanopsis* Henningsmoen, 1954 by its subelliptical and amplete valves and by its lobate features. The valves have three lobes which are restricted to their dorsal half, L1 and L2 are very close to each other; the adductorial sulcus is well defined and dorsally open, and the valves do not have marginal structures. The genus *Nanopsis* was originally described from the late Tremadocian of the Baltic region (Henningsmoen, 1954; Tinn and Meidla, 2004) where only one species, *Nanopsis nanella* (Moberg and Segerberg, 1906), was recorded. Recently, the distribution of the genus has increased. Salas *et al.* (2007) defined *Nanopsis coquena* Salas, Vannier and Williams from the Tremadocian of the Central Andean Basin in Argentina and more recently, Ghobadi Pour *et al.* (2011) defined a new species from the Tremadocian of Iran, *Nanopsis pairidaeza* and Salas and Vaccari (2011) included in the genus the species *Bumire pilloides* Schallreuter, 1998, from the Floian of Australia. The new species resembles the Tremadocian species *N. coquena* in valve outline and size, in the shape of its anterior lobes (L1-L2), in its relatively narrow adductorial sulcus (the sulcus is narrower in the new species) and in the posterior lobate features of the valves. However, in *N. coquena*, the posterior half of the valves is clearly divided into two lobes (L3 and L4), whereas in the new species the surface is more uniform, with L3 indistinct. Additionally, the lateral surface of the valves is punctuate in *N. victoria* sp. nov. and slightly reticulate in *N. coquena*.

In respect to *N. nanella* and *Nanopsis pilloides*, the new species is larger, S2 is narrower and the second lobe (L2) is bigger. However, the most conspicuous difference between the Argentinian species and the Baltic and Australian occurrences of *Nanopsis* species is in the development of L3, which is indistinct in the new species from Argentina. In respect to *N. pairidaeza*, the main difference is the ornamentation of
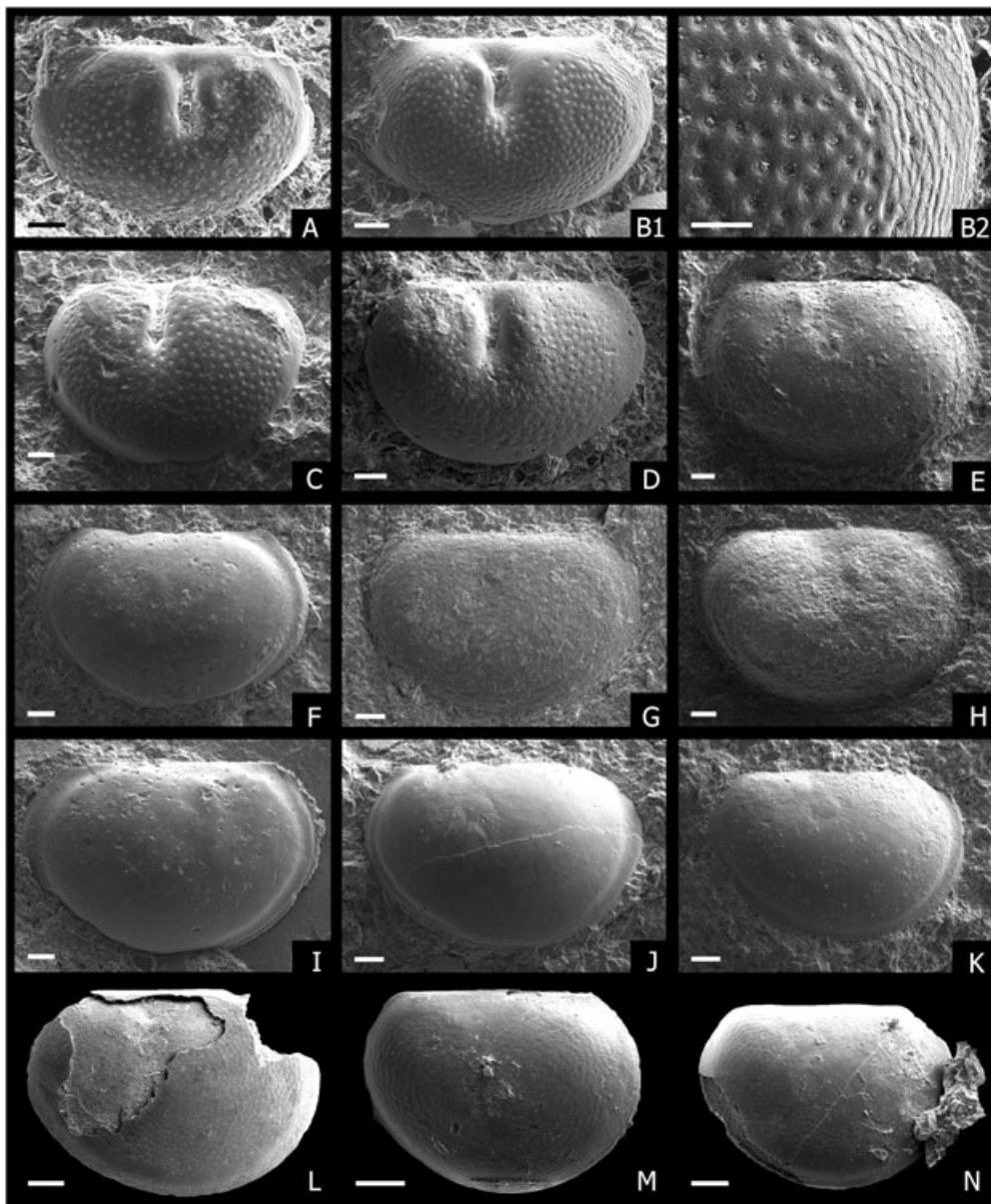
Figure 4. Middle to upper Floian ostracods from the Cordillera Oriental Argentina. **A-D**. *Nanopsis victoria* sp. nov., Acoite Formation from Santa Victoria area. **A**. CEGH-UNC 24582, right valve, lateral view, **B. Holotype** CEGH-UNC 24583, left valve, **B1**. lateral view. **B2**. detail of the ornamentation. **C**. CEGH-UNC 24584, left valve, lateral view. **D**. CEGH-UNC 24585, left valve, lateral view. **E-N**. *Conchoprimitia frequens* sp. nov., Acoite Formation from the Chamarra section (E, G-H), Santa Victoria area (F, I-K), and La Ciénaga section (L-N). **E**. CEGH-UNC 24586, internal mould of left valve, lateral view. **F**. CEGH-UNC 24587, internal mould of left valve, lateral view. **G**. CEGH-UNC 24588, internal mould of left valve, lateral view. **H**. CEGH-UNC 24589, internal mould of right valve, lateral view. **I. Holotype** CEGH-UNC 24590, internal mould of right valve, lateral view. **J**. CEGH-UNC 24591, internal mould of left valve, lateral view. **K**. CEGH-UNC 24592, internal mould of left valve, lateral view. **L**. CEGH-UNC 24593, left valve, lateral view. **M**. CEGH-UNC 24594, left valve, lateral view. **N**. CEGH-UNC 24595, left valve, lateral view. Scale bars 100μm, except B2 which is 50μm.

the valves, punctuate in the Argentinian form and strongly reticulate in the Iranian one.

Suborder Eridostracina Adamczak, 1961
Family Conchoprimitiidae Henningsmoen, 1953
Genus *Conchoprimitia* Öpik, 1935

Conchoprimitia frequens sp. nov.
Figure 4**E**-4**N**

Holotype. CEGH-UNC 24590, right valve (Figure 4**I**).
Type locality. Santa Victoria area, Northwest Argentina.
Type horizon. Coquina levels of the middle part of the

Acoite Formation, in the Santa Victoria-La Huerta River section, Middle to Late Floian (Fl2-Fl3), *Baltograptus deflexus* Zone, Salta Province, Argentina.

Derivation of the name. From the latin *frequens* is abundant, frequent.

Diagnosis. Conchoprimitia species with a subcircular outline. The valves have a rounded adductorial muscle spot and an indistinct, shallow, V-shaped short adductorial sulcus. The lateral surface is rugose and the muscle spot is smooth. Lateral and marginal surfaces are differentiated by a poorly defined bend.

Description. Valves have a subcircular postplete shape. Dorsal margin is straight and shorter than the maximum length of the valves. The maximum length of the valves is situated above the midheight in the dorsal half of the valves. Average L:H=1.42. Cardinal angles are obtuse, with the posterior one bigger than the anterior one. Ventral and lateral margins are rounded, with the posterior one broader than the anterior. The carapace is uniformly convex, and is widest in the posteroventral sector. The valves show a rounded adductorial muscle spot in the anterodorsal sector of the valves. Over the muscle field, some specimens present an indistinct, shallow, V-shaped, short (1/3 to 1/4 of the carapace height) adductorial sulcus. The lateral surface of the valve is rugose and the muscle spot is smooth. The lateral and marginal surfaces are slightly differentiated by a poorly defined bend. The overlap relationship of the valves is unknown. The internal moulds bear a well defined, narrow, short and U-shape sulcament (S2). In front of it there is a very poorly defined, rounded to slightly elongated node. The margin of the valves is flat.

Material. Over 150 specimens from valves to internal moulds, including the figured material CEGH-UNC 24586–24589, 24591–24595. Specimens we have examined range from 0.40 to 1.50 mm in length.

Occurrence. Conchoprimitia frequens sp. nov. is known from the Acoite Formation, *Baltograptus deflexus* Zone, middle to late Floian (Fl2-Fl3) in the sections of Chamarra, La Ciénaga and Santa Victoria, Jujuy and Salta provinces, Argentina.

Discussion. Conchoprimitia Öpik, 1935 is a very common and abundant genus in the Baltic region, from the Floian onwards, with several synonymous genera and a large number of defined species. Outside of the Baltic region, some species are known from Ibero–Armorica (Vannier *et al.*, 1989), Avalonia (Siveter, 2009), Perunica (Schallreuter and Kruta, 1988), Malopolska (Olempska, 1994) and the Precordillera Argentina (Salas, 2003). Before the Floian, one possible species of the genus, *Conchoprimitia*? *iglesiasi* Salas and Vaccari (2011), has been described from the Tremadocian of the Northwest Argentinian Basin. Recently, Tinn *et al.* (2010) revised all the Baltic species and included all of them in *Conchoprimitia socialis* (Brøgger, 1882),

attributing the differences to intraspecific variations. The main variations observed include the size of the carapace, the presence or absence of a sulcus or muscles spots and the microsculpture.

The material described here is attributed to *Conchoprimitia* because of its long hinge line, the postplete outline, the convex carapace, the lack of distinct lobes and sulci and the presence of a muscle field. The overlap of the valves is unknown. *Conchoprimitia frequens* sp. nov. resembles *C. socialis* in the subcircular outline of the valves, the rounded muscle field. However, the new species has a more circular outline, is smaller than the Baltic species (L reaches 4.45 mm in *C. socialis*), the muscle features are well developed, whereas the ornamentation is well defined near the margins of the valves and became vague toward the centre. The Polonian species, *Conchoprimitia*? *modlinski* Olempska, 1994, *Conchoprimitia*? *polonica* Olempska, 1994 and *Conchoprimitia*? *ventroincisurata* (Hessland, 1949), differs from *Conchoprimitia frequens* sp. nov. by the outline of the valves, by the smooth surfaces and by the indistinct and short sulcus that does not reach the dorsal margin. *Conchoprimitia* sp. from the Darriwilian of Portugal (see Vannier *et al.*, 1989) has a more elongated and amplete outline, and the surface is smooth.

With respect to *Conchoprimitia*? *iglesiasi* Salas and Vaccari from the Upper Tremadocian of the Central Andean Basin, the species differs in the lack of a muscle spot, in the tiny and rounded adductorial node and in the smooth lateral surface.

Conchoprimitia frequens sp. nov. is also recorded in the Floian levels of the Sella locality from Bolivia (unpublished data) and it could be synonymous with 'Haplorimitia? sp. n. Přibyl, 1984' from the same locality. However, this comparison has been made from very poor illustrations (Přibyl, 1984), thus the confirmation of this assignment requires further analysis.

5. BIODIVERSITY AND COMPOSITION OF THE CENTRAL ANDEAN BASIN FAUNAS

The first ostracods appeared during the late Tremadocian (Tr3) (Tinn and Meidla, 2004; Salas *et al.*, 2007; Williams *et al.*, 2008; Ghobadi Pour *et al.*, 2011) and thereafter diversified, reaching an early peak during the Darriwilian. The only detailed analysis of ostracod diversity through the Early and Middle Ordovician is for the Baltic region (Tinn *et al.*, 2006). This work characterized the Baltoscandian ostracod fauna as having low diversity, with only 14 species recorded for the Floian, and noted that the Early Ordovician was a period of rapid evolution for the group. This trend continued in the younger levels, and reached the maximum diversity in the latest Ordovician. This diversity is notably high in the

Baltic region (Meidla, 1996; Braddy *et al.*, 2004), although this could be due, at least in part, to the intensive studies conducted on the Baltic fauna during the last 100 years. In the Central Andean Basin, the number of ostracod species is significantly lower during the Early Ordovician, and they are well documented only throughout the Argentine Cordillera Oriental. However, our knowledge of the ostracods in this region is in its infancy and more sampling is necessary to fully explore the region. Several localities along the Cordillera Oriental Argentina were studied and a great amount of samples of trilobites were revised, and in all cases, the recorded species are the same. Therefore, the described fauna is considered as representative of the diversity of the basin. The earliest ostracod fauna in the region is from the late Tremadocian and is composed of five genera and nine species of palaeocopids, binodicopids and one possible eridostracan (Salas and Vaccari, 2011). During the Floian, the number of species is smaller, with only four species recorded in the Acoite Formation. Moreover, several species from the Floian of Bolivia have been described by Přibyl (1984), though these forms need a modern revision, some of them may be synonymous with the Acoite Formation species (personal data). If we considered the Argentinian and Bolivian forms together, the diversity of the Central Andean Basin would increase to about seven species (Table 1).

With respect to the composition of the ostracod fauna in the Early Ordovician succession of the Central Andean Basin, it is characterized by the abundance of representatives of the Soanellidae family and the lack of typical dimorphic palaeocopids. In addition, the genera *Nanopsis* and *Conchoprimitia* are common elements of the fauna. This composition is maintained from the Tremadocian to the Floian. The only difference between the two intervals of time is the presence of binodicopes, very abundant during the Tremadocian and absent in the Floian.

Despite the overall ostracod diversity, only one or two species have been identified from each horizon of Floian age. The Floian ostracod assemblages are dominated by *Conchoprimitia frequens* sp. nov., which is very abundant throughout the Ordovician succession in the three studied localities; in contrast, other species such as *Acoitella angustilobata* appear only in the Chamarra and La Ciénaga sections, whereas *Nanopsis victoria* sp. nov. occurs only at Santa Victoria (Table 1). The Floian assemblages from the Baltic region are also characterized by a low diversity, being monospecific or with only two or three species. From the Dapingian onward, the number of species increases and the assemblages become more varied. This low diversity is attributed to the early stages of evolution of the ostracod fauna (Tinn *et al.*, 2006). However, it is important to note that in the Central Andean Basin, the trilobite assemblages, coeval with the studied ostracods, are also poorly diverse. These assemblages are known as the *Thysanopyge* Fauna, and

are characterized by low diversity and low ecological complexity. These features are probably linked to the environmental conditions of a relatively deep, low energy and largely dysaerobic foreland shelf ramp (Waisfeld and Vaccari, 2008a, b). However, in order to achieve a better understanding of the ostracod assemblages and diversity and their relationship with the environment conditions, a continuation of the studies in the area is necessary.

6. TAPHONOMY

The dominant species, *Conchoprimitia frequens* sp. nov., besides having a wide geographic distribution in the basin, is abundant, forming in the Chamarra section an ostracod concentration, uncommon in the area. A large number of fossil concentrations are recorded in the middle and upper part of the Acoite Formation. These bioclastic deposits are mainly trilobite-dominated, and their detailed taphonomic analysis has been carried out by Waisfeld (1997). This author recognized a tabular bioclastic deposit with a complex microstratigraphy in the transition between the internal and external shelf of the Acoite Formation (Figure 2**B**). This interval of the formation is represented by greenish to dark grey or black mudstones, which are sporadically intercalated with thin beds of cross-laminated sandstones; in these levels, the shelly fauna is lacking and only graptolites and phyllocarids are recorded. The fossil concentration is 40 cm thick, and shows a complex internal structure. It is composed of successive bioclastic beds, 0.5–2 cm thick, with variable taxonomic compositions and biostratinomic features which are intercalated by thin sandstones beds (Figure 2**B**). Within this deposit, five different types of shell beds are distinguished, one of which is ostracod-dominated. The tabular bioclastic deposit was interpreted by Waisfeld (1997) as a shallowing-upward cycle. This author compared it with a top of parasequence concentrations described by Banerjee and Kidwell (1991), where the accumulations are the result of physical reworking in their own habitat. Dissimilar preservation of the fossil layers within each of these beds indicates that it was based on multiple events. The change in the dominance of the fauna between beds has been interpreted to be a community tracking in response to changes in the sea level. Among these layers, the 'ostracod shell bed' is conspicuous, whereas the rest of the succession lacks ostracods, and the same ostracod species only appears later in the succession (Figure 2). The 'ostracod shell bed' is nearly exclusively composed of *Conchoprimitia frequens* sp. nov. and of a much smaller proportion of *Acoitella angustilobata* and *Saltite* sp. The ostracods are associated with a scattered record of pygidia and cranidia of the trilobite *Ampyx* (Waisfeld, 1997). This shell bed is thin, approximately 0.5 cm thick, and has sharp contacts with the underlying

Table 1. Recorded species in the Early Ordovician of the Central Andean Basin; taxonomic group, age, locality of occurrence of the Floian species and occurrence of the genus in other palaeogeographical regions. P: Palaeocope, P-So: Palaeocope-Soanellidae, E: Eridostraca, B: Binodicope, Tr: Tremadocian, Fl: Floian. * species that need revision.

Genera and species	Group	Age	Central Andean Basin			Bolivia	Other records of the genus
			Argentina - Acoite Fm.- Floian				
			Sta. Victoria	La Ciénaga	Chamarra		
Nanopsis coquena Salas, Vannier, Williams, 2007	P	Tr					Baltic region, N. Iran, S. China?
Saltite erichseni (Harrington, 1938)	P-So	Tr					Australia, N. China?
Saltite uchuy Salas and Vaccari, 2011	P-So	Tr					
Saltite kuraq Salas and Vaccari, 2011	P-So	Tr					
Saltite? *waisfeldae* (Salas, Vannier, Williams, 2007)	P-So	Tr					
Conchoprimitia? *iglesiasi* Salas and Vaccari, 2011	E	Tr					Australia, China?
Orechina violetae Salas and Vaccari, 2011	B	Tr					
Orechina catalinae Salas and Vaccari, 2011	B	Tr					
Kimsella lucia Salas, Vannier, Williams, 2007	B	Tr					
Saltite sp.	P-So	Fl			x		Australia?
Nanopsis victoria sp. nov.	P	Fl	x				Australia
Acoitella angustilobata (Přibyl, 1984)	P	Fl		x	x	x	
Conchoprimitia frequens sp. nov.	E	Fl	x	x	x	x	Australia, Baltic region
* "*Zygobolboides*" tuctapariensis Přibyl, 1984	P-So	Fl				x	
* "*Zygobolboides*" changollaensis Přibyl, 1984	P-So	Fl				x	
* "*Parapyxion*" sp. n. Přibyl, 1984	?	Fl				x	

and overlying beds. The ostracod valves are disarticulated and preserved as internal and external moulds. The valves are of different sizes, showing a range of large to medium, although it is not possible to determine each of the ontogeny instars. The valves do not display any preferred alignment and show a random distribution, with convex-up or convex-down position of the valves (Figure 5). The associated trilobites are disarticulated, poorly fragmented and worn, features that have been interpreted by Waisfeld (1997) as the product of physical or biogenic reworked *in situ*, with a short period of exposure of the seafloor before becoming buried. This reworking would have removed only the smaller instars of the ostracods ontogeny, and left as a result a concentration poorly selected and without orientation of the valves. According to these features, the 'ostracod shell bed' is interpreted as a moderate energy parautochthonous thamnatocoenosis (see Boomer *et al*., 2003), and would be explained by the transport of the fauna within the same habitat and later affected by physical reworking.

A similar sedimentary succession was observed in the Ardwell Farm Formation from the Ordovician of Scotland, where a level with an ostracod accumulation appeared intercalated in an interval of dark shale with graptolites (Mohibullah *et al*., 2011). However, the Scottish case is considered an allochthonous concentration transported by turbidity current to a deeper-water environment, whereas the described ostracod shell-bed would be the product of transport within the same habitat, in a shallow-water environment in the internal shelf.

7. PALAEOBIOGEOGRAPHY

Analysis of Ordovician ostracod palaeobiogeography has shown that geography appears to be an important control on the distribution of the fauna. Thus, the composition of the fauna, at least at an upper taxonomic group level (suborder and family), displays an important palaeobiogeographic component, which can be observed at least since the Middle to Late Ordovician (e.g. Vannier *et al*., 1989; Williams *et al*., 2003). In this way, Gondwana and peri-Gondwana are mainly characterized by the dominance of binodicopid species and by the lack of dimorphic palaeocopids (Vannier *et al*., 1989; Braddy *et al*., 2004; Hinz-Schallreuter and
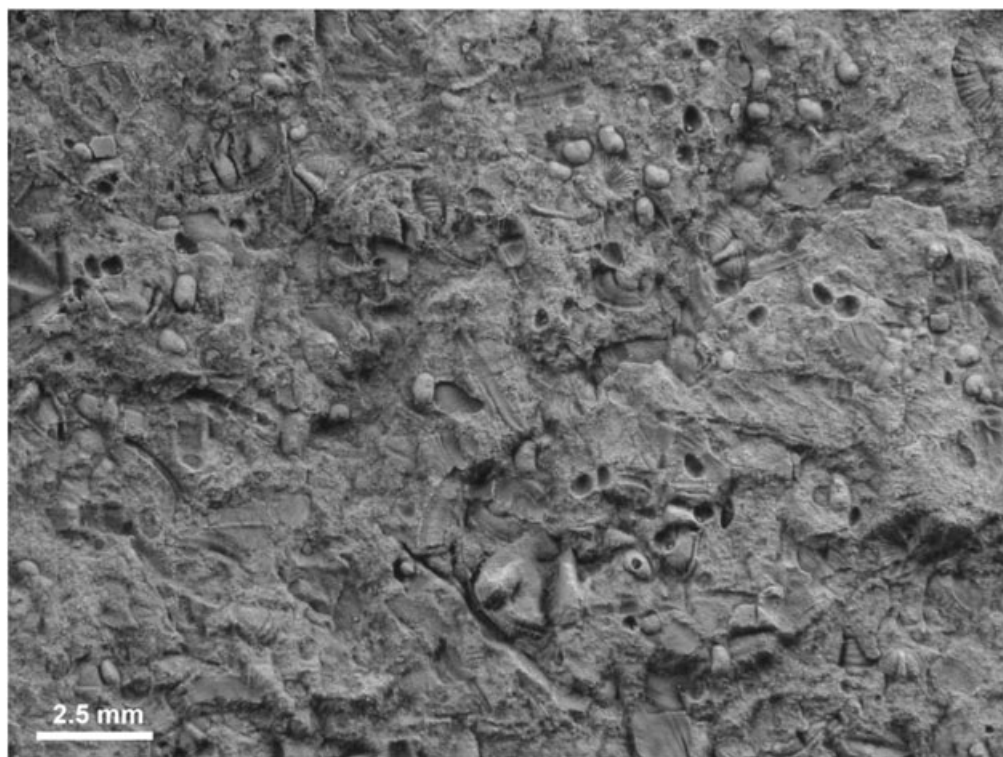
Figure 5. Ostracod shell bed concentration, Acoite Formation from the Chamarra section, middle to upper Floian age.

Schallreuter, 2007; Salas, 2007). The Floian fauna of the Central Andean Basin is dominated by the new species *Conchoprimitia frequens* sp. nov. *Conchoprimitia* is a geographically widespread genus, with a large number of known species since the Early Ordovician. However, genera like *Conchoprimitia*, featureless and with several species included in them, should be taken with caution because they could show a trend to homeomorphy and distort the real palaeobiogeographical relationships (Schallreuter, 1988; Williams *et al.*, 2003). The rest of the Floian fauna from Argentina is represented by the nondimorphic palaeocopid *Nanopsis* and by two genera of the Soanellidae family, *Acoitella* gen. nov. and *Saltite* Rossi de García and Proserpio, 1976. The Floian Baltic ostracod assemblages are also dominated by *Conchoprimitia* (Tinn *et al.*, 2006), but unlike the Cordillera Oriental, the other abundant ostracods are typical dimorphic palaeocopids. Thus, the general composition of the Central Andean Basin fauna resembles the common Gondwana assemblages.

Among the present genera, *Nanopsis* is a relatively widespread genus at least in the Tremadocian, it was recorded in the Central Andean Basin (Salas *et al.*, 2007), in the Baltic region (Henningsmoen, 1954; Tinn and Meidla, 2004), in the Alborz Mountain of northern Iran (Ghobadi Pour *et al.*, 2011) and probably in South China (Hou, 1953a) (the exact age of these Chinese ostracod-bearing horizons requires

confirmation). However, during the Floian, *Nanopsis* was recorded only in the Central Andean Basin (this contribution) and in Australia (Schallreuter, 1998; Salas and Vaccari, 2011). With respect to the soanellids, *Acoitella* is an endemic form, recorded only in the Cordillera Oriental Argentina and in Bolivia, and *Saltite* is recorded in the Tremadocian of Australia (Schallreuter, 1993b) and probably in North China (Hou, 1953b). Although the knowledge of the ostracod fauna in the Central Andean Basin, Australia and China during the Early Ordovician is still patchy and more sampling and studies are required, it is remarkable for the almost exclusively nondimorphic palaeocopids (soanellids and *Nanopsis*) and binodicopids in these regions (Figure 6).

Hinz-Schallreuter and Schallreuter (2007) and Schallreuter and Hinz-Schallreuter (2009) defined three faunal provinces, Australian, Armorican and Thuringian, for Gondwana and peri-Gondwana regions during the Late Ordovician. According to these authors, the Australian Province included Australia, the Argentine Cordillera Oriental, the Argentine Precordillera and the Spiti region of the Himalaya, and proposed a relationship between Australia and the Cordillera Oriental since Tremadocian times based on representatives of the Soanellidae. The new ostracod fauna from the Central Andean Basin supports this connection with East Gondwana during the Early Ordovician.
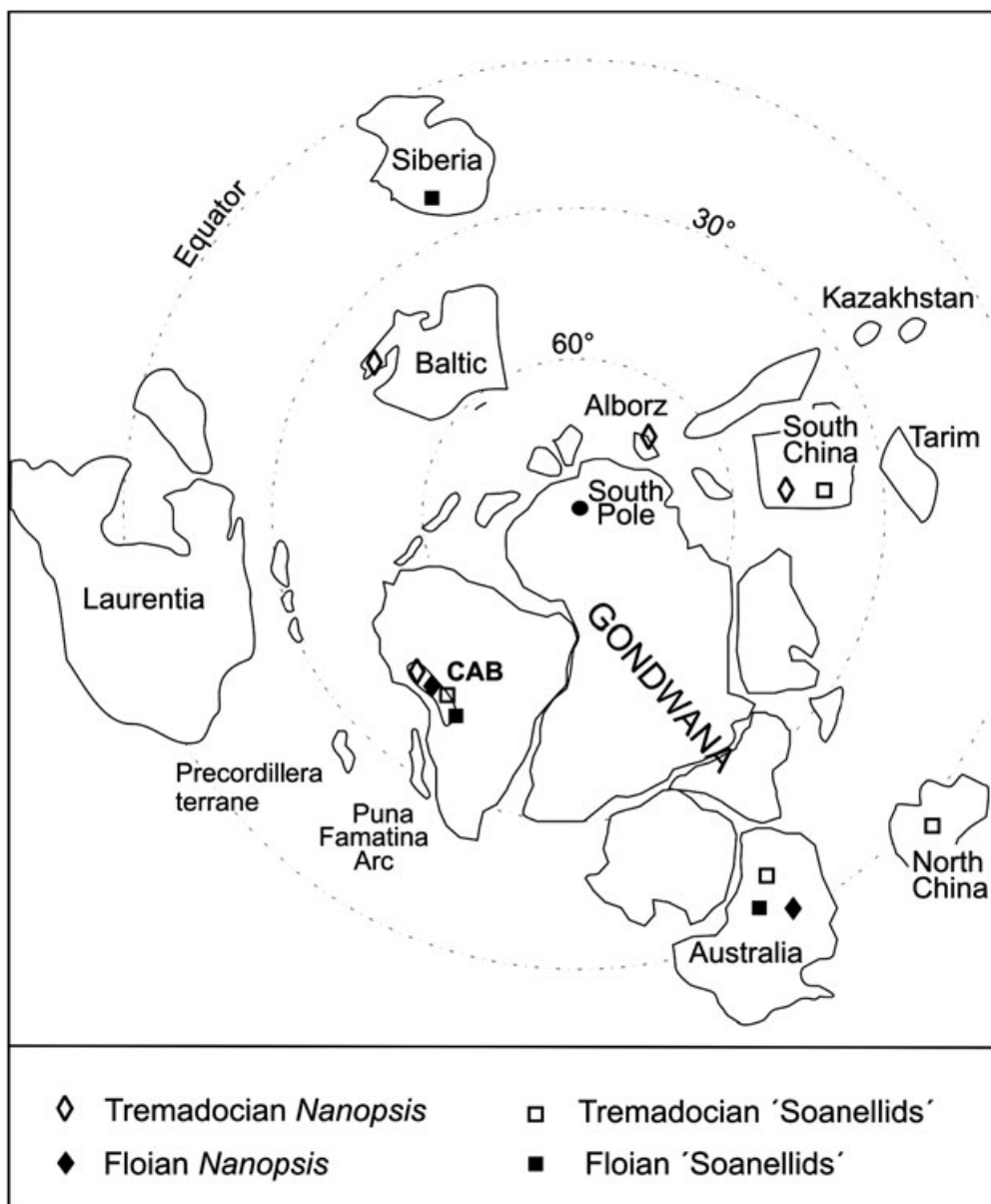
Figure 6. Palaeobiogeographical distribution of Tremadocian and Floian ostracods. CAB: Central Andean Basin (see text for explanation). Palaeogeographical map after Astini *et al.* (2007).

With respect to the inclusion of the Argentine Precordillera in the Australian Province, during the Early Ordovician, the fauna of Precordillera shows significant differences (families and genera), without any genus in common with the fauna of the Central Andean Basin. On the other hand, the faunal connection between the Precordillera and Australia begins during the Darriwilian with the record of the Pillinae (Salas, 2002). Yet, the remaining fauna exhibit a high percentage of endemic genera, and a mixture of genera with several affinities, Baltic, peri-Gondwanan and Australian, so it is difficult to include the Precordillera into a single biogeographic province (Salas, 2007).

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