Lower and Middle Devonian Malvinokaffric ostracods from the Precordillera Basin of San Juan, Argentina

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ABSTRACT

Ostracod from the upper Lower to Middle Devonian rocks of the Argentine Precordillera Basin (Talacasto and Punta Negra formations) are studied. One new genus *Pircawayra* nov. gen., and five species (including three new: *Pircawayra gigantea* nov. gen. and sp., *Lapazites trinodis* nov. sp. and *Keslingiella*? *teresae* nov. sp.) are defined. The recorded ostracod fauna closely resembles that coeval from Bolivia and South Africa, exhibiting a remarkable endemism, not only at the genus level, but also at the species level. In addition to its low-diversity, the Malvinokaffric ostracod association is also characterized by having large, thick, coarsely ornamented and swollen valves. The similar ostracod composition from the Andean and South African basins suggests faunal exchange between these two areas. Based on the ostracod faunas, the Malvinokaffric Realm is clearly recognizable at least up to the Middle Devonian.

1. Introduction

The Malvinokaffric Realm was originally identified as a major southern paleobiogeographical region during the Devonian (Richter and Richter, 1942), based on a conspicuous endemic distribution of trilobites from southern South America, Antarctica and South Africa. Since then it has also been recognized as a major paleogeographic division because of the coincident endemic distribution of other well-known Devonian groups, such as brachiopods (Boucot et al., 1967; Boucot, 1971). The disappearance of the Malvinokaffric Realm was usually postulated to have taken place by the Late Devonian, and has been related to extrinsic control factors (eustatic, climatic and oceanographic) favoring the entrance of cosmopolitan elements (Isaacson, 2007). However, recent studies have postulated that the "collapse" of this Realm had already occurred by Middle Devonian times (Pinto Bossetti et al., 2012 and references therein), suggesting that the Malvinokaffric Realm should be restricted to the Early Devonian. Moreover, some authors have proposed a 'mixed area' for the Lower Devonian records of the Argentine Precordillera Basin based on brachiopod data (Herrera et al., 1998; Isaacson, 2007). This evidence suggests that the signature of strong Malvinokaffric faunal endemism in this basin would not exist in some groups since Early Devonian times. However, greater precision in defining this paleobiogeographical Realm for the Middle Devonian faunas of the Argentine Precordillera is restricted by scarce paleontological records.

The ostracods are regarded as good paleogeographical indicators, taking account its limited dispersal capabilities since most of Paleozoic ostracods are considered benthic neritic (see Schallreuter and Siveter, 1985; Vannier et al., 1989). Only after the Silurian there is evidence for a pelagic mode of life in ostracods, however this feature is restricted to a few groups like Myodocopes in the Silurian and Myodocopes and Entomozoaceans during the Devonian (Siveter et al., 1991; Olempska, 2002 and cites there in).

In Argentina, Paleozoic ostracod fauna has been scarcely documented, and the studies have been almost entirely focused on the Ordovician (Schallreuter, 1996; Salas, 2002a,b, 2003, 2007, 2011; Salas et al., 2007; Salas and Vaccari, 2012). In turn, Devonian ostracod records include only materials intimated by Baldis and Rossi de García (1975) and Rossi de García and Proserpio (1975), and systematic analyzes of upper Silurian-lower Devonian fauna from the Argentine Precordillera (Cerro del Fuerte section, Los Espejos and Talacasto formations) and the Bolivian Altiplano (Tarabuco and Santa Rosa formations) by Vannier et al. (1995).

Here we report new discoveries of a stratigraphically well-constrained fauna from Lower-Middle Devonian (Lochkovian to Givetian?) units of the Precordillera Basin, the Talacasto and Punta Negra formations.

Paleontologic findings of the Punta Negra Formation represent a significative progress of its faunal record, otherwise integrated only by an isolated report by Herrera and Bustos (2001).

This paper includes a taxonomic study of the recorded ostracod taxa. We discuss the stratigraphic and biostratigraphic scheme of the involved units, and include the ostracods into this scheme. Finally, we compare coeval ostracods from Bolivia and South Africa, providing new insights into the recognition of the Malvinokaffric Realm during Early-Middle Devonian times, based on these new evidences from Argentina.

2. Stratigraphic setting and provenance of the material

The studied Devonian succession is widespread and well-exposed between the San Juan and Jáchal rivers in the Central Precordillera of San Juan Province in central-western Argentina (Fig. 1). The stratigraphic units are the siliciclastic Talacasto and Punta Negra formations, which integrate the Lower-Middle Devonian Gualilán Group (Baldis, 1975).

The Talacasto Formation (Padula et al., 1967) records a lower Lochkovian-upper Emsian marine succession of intensely bioturbated greenish-gray mudstones, with intercalated beds of sandstone. It is ca. 1145 m thick in the Loma de los Piojos section to the north (where is it thickest) and shows typical dark muddy levels at the base, passing upwards to sandy levels. According to Astini (1991), this unit corresponds to a muddy shelf depositional system developed during a highstand. The Talacasto Formation overlies the mainly Silurian shelf system of the Los Espejos Formation and is succeeded by the Punta Negra Formation. The age of the Talacasto Formation is based on its rich brachiopod fauna. Herrera (1991, 1993, 1995a), Racheboeuf and Herrera (1994) and Herrera and Bustos (2001) assigned the basal part of this unit to the early (but not earliest) Lochkovian in the entire basin. Its upper part is considered diachronous and progressively younger to the north (Herrera, 1991; Rustán, 2011) (Fig. 2). The uppermost levels of the Talacasto Formation at its type locality of Talacasto Creek (Fig. 1), and toward the southern area of the basin, were referred to the latest Pragian by Herrera and Bustos (2001). However an earliest Emsian age has been suggested for the same stratigraphic position, based on palynological data (Le Hérissé et al., 1996: 502) and brachiopods (Herrera, 1993: 292). These uppermost levels at Talacasto Creek correspond to a distinctive nodule-bearing ochre horizon, which has been interpreted as stratigraphic marker by Keidel (1921) and Astini (1991). This bed, nearly 10 m thick, is laterally continuous for more than 100 km up to the Loma de los Piojos section, to the north (Fig. 1), allowing reliable correlation between sections (Rustán, 2011) (Fig. 3). The strata overlying this guide horizon are considered to be early Emsian in age or younger.

In its type locality at the San Juan River, the Punta Negra Formation overlies the guide horizon of Keidel (1921) by and unconformable boundary and is typically composed of a lower Emsian to lower Frasnian? coarsening and thickening-upward succession of intercalated green to blackish green sandstones and siltstones. The rocks in the type locality are arranged in tabular heterolithic layers between 0.2 m and 1.5 m thick, displaying conspicuous rhythmicity (González Bonorino, 1975; Bustos and Astini, 1997). In all the southern sections and up to the Talacasto Creek section to the north, the base of the Punta Negra Formation is composed of a thick interval (nearly 35–40 m) of alternating green and purple pelites, which overlie the Talacasto Formation through an unconformity (paraconcordance) recognizable by a sharp lithological contrast with the sandy guide horizon of Keidel (1921) (Fig. 3).

A significant lateral variation of lithofacies, changing to more greenish colors and less obvious rhythmical arrangement can be identified in the Punta Negra Formation in the northeastern and western sections (see Baldis, 1973). For example, between Niquivil and Jáchal to the north (Fig. 1), the pelitic basal interval (more than 120 m in thickness in some cases) is green and lacks purple color. For this reason, outcrops of the Punta Negra Formation in this region were described erroneously as "post-devonian strata" by Keidel (1921). At sections near Jáchal (typically at the Loma de Los Piojos section), the boundary between the Talacasto and Punta Negra formations is hundreds of meters above the marker stratigraphic horizon of Keidel (op cit.; Fig. 3), so that the Talacasto Formation exhibits a thick Emsian upper interval, indicating a probable late Emsian age (or younger) for the base of the Punta Negra Formation in this area.

The Punta Negra Formation is covered in almost all sections by Carboniferous glacigenic deposits of the Guandacol Formation, with an erosive and unconformable base. Despite this, an overall thickness of approximately 1000 m has been calculated for the Punta Negra Formation along the basin (Bustos, 1996).

The sedimentary environment of the Punta Negra Formation was initially interpreted as submarine fans (González Bonorino, 1975; González Bonorino and Middleton, 1976; Peralta and Ruzycki de Behrenstein, 1990; Peralta, 2005; between others), but later was interpreted as a deltaic system (Astini, 1990; Bustos, 1996; Poiré and Morel, 1996; Bustos and Astini, 1997). More recently it has been interpreted as a shallow marine environment formed on the inner shelf, with areas of shallow into continental facies, according to plant debris and taphonomic data (Edwards et al., 2009).

The paleontological content of the Punta Negra Formation is poorly known, only Herrera and Bustos (2001) described a brachiopods assemblage recorded approximately at the middle part of the unit in Las Chacritas River section (few kilometers to the West from the Las Casitas River section). The other paleontological finding in the formation is represented by the trilobite *Acanthopyge* (*Lobopyge*) *balliviani* (Kozlowski, 1923) recorded in Loma de Los Piojos setion by Rustán (2011). These paleontological data support a late Pragian-early Emsian (between San Juan River and the Talacasto area) or late Emsian (to the north, near Jáchal) to the early Frasnian age for the Punta Negra Formation.

The Devonian ostracod fauna described here is derived from both the Talacasto and Punta Negra formations at three different locations in the Central Precordillera of San Juan Province, Central-West Argentina (Figs. 1 and 3).

2.1. Talacasto Creek section

The section runs in an E-SW trend over the Provincial Route 436, 60 km northwest of the city of San Juan. In this section the Devonian succession is well exposed, although of reduced thick. The Punta Negra Formation in this section overlies the Talacasto Formation directly above the guide horizon of Keidel, having 840 m of thickness according Bustos (1996). The ostracods come from the pelitic green and purple basal interval of the Punta Negra Formation (30°59′51″ S/68°47′5″ W). The most productive fossiliferous level is located ca. 12.5 m above the top of the guide horizon of Keidel, and approximately 3 m below a conspicuous tabular brownish sandstone layer of great lateral continuity (Fig. 3). Accompanying fauna includes brachiopods, a single trilobite remain and a fish spine.

In this locality, the brachiopods recorded at the top of the Talacasto Formation suggest a late Pragian or early Emsian age (Herrera, 1995b; Herrera and Bustos, 2001). According poor
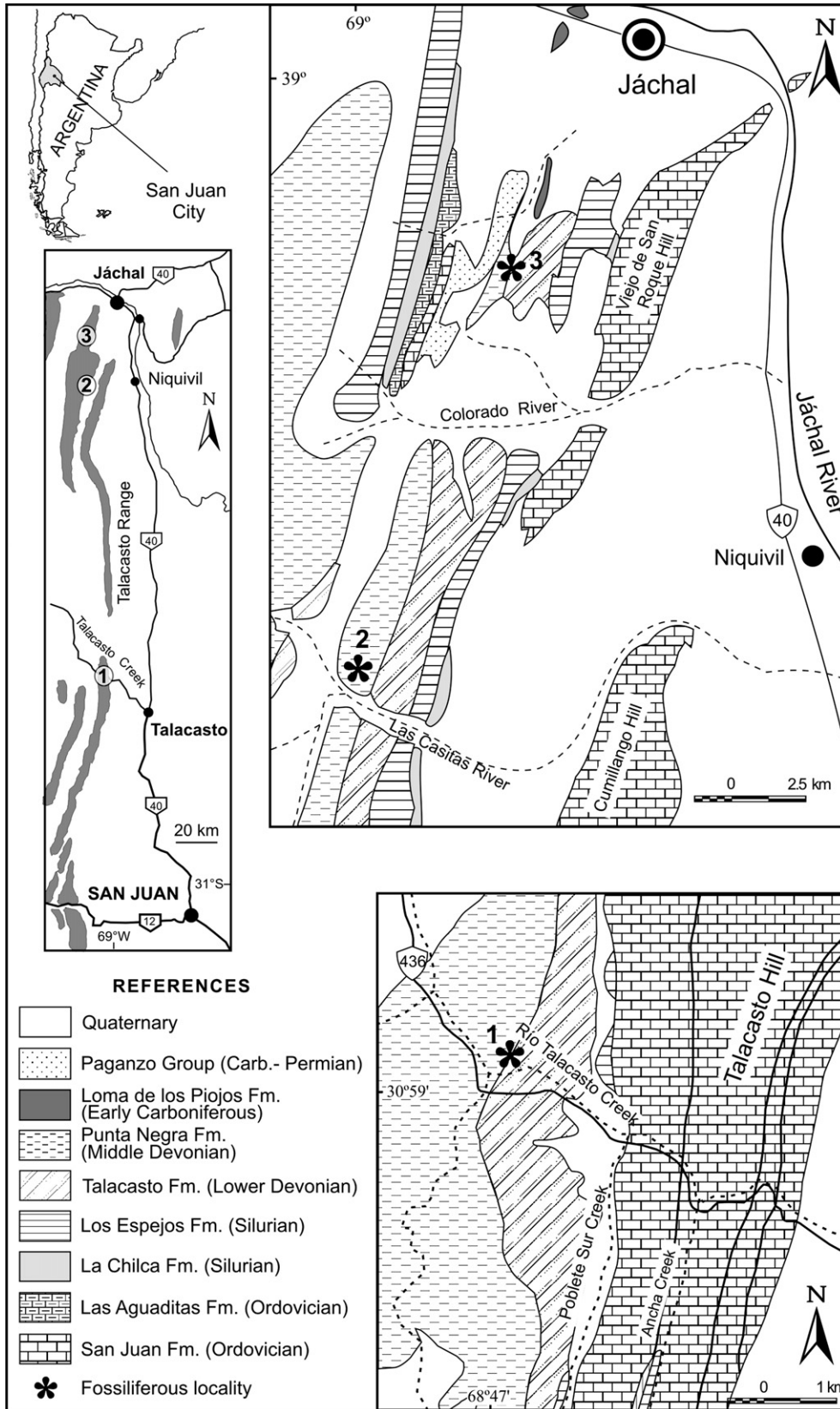
Fig. 1. Geological setting of the studied area and location of the Talacasto Creek (1), Las Casitas River (2) and Loma de los Piojos (3) sections.
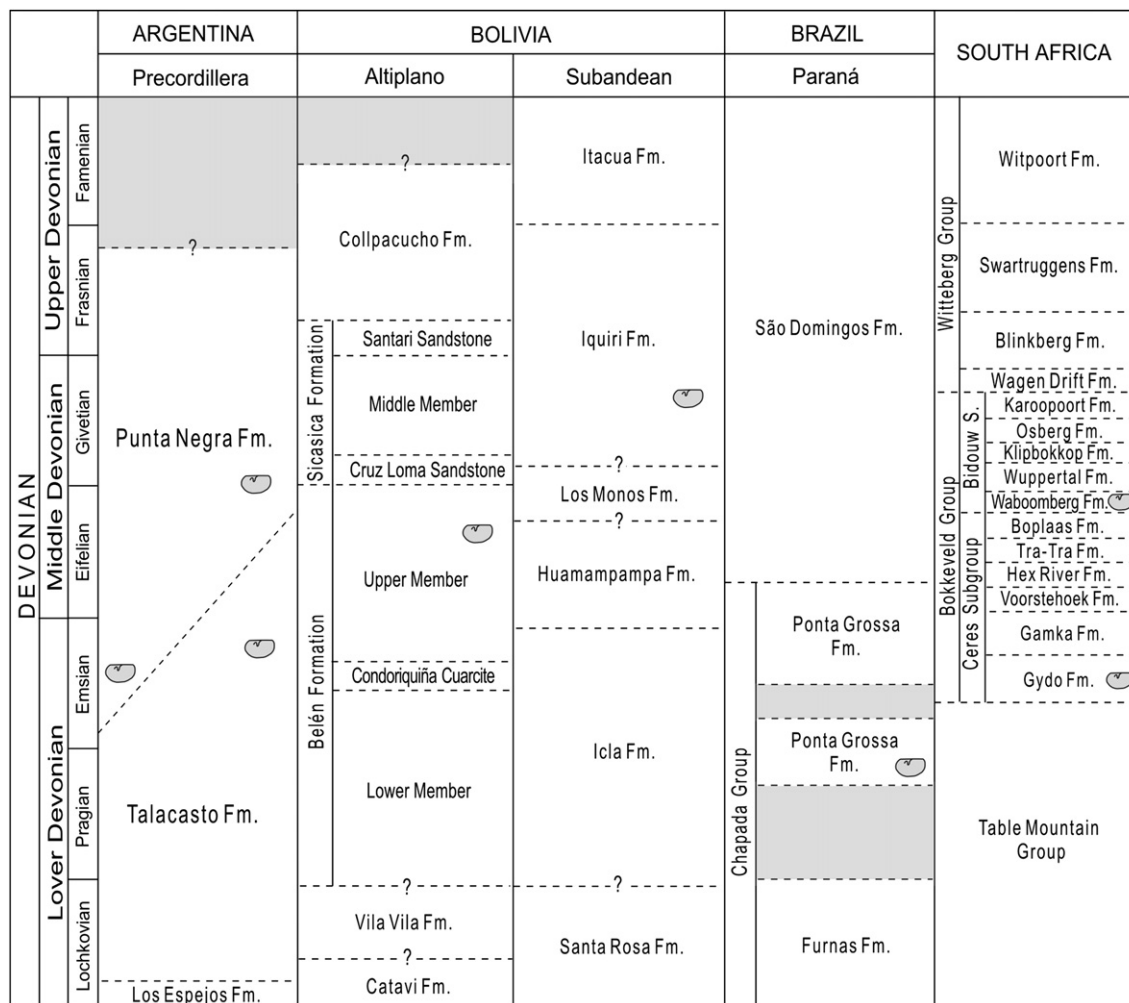
Fig. 2. Chronostratigraphic chart of the Devonian Malvinokaffric basins. The ostracod records are indicated.

palynologic evidences, the base of the Punta Negra Formation is considered early Emsian (cited by Herrera and Bustos, 2001).

2.2. De Las Casitas River section

The section runs in an E-W trend over a little creek approximately 20 km to the southwest of the small town of Niquivil. The recorded ostracods come from the upper levels of the Punta Negra Formation, which has a thickness of 189 m. The unit unconformably overlies the Talacasto Formation, while the guide horizon of Keidel is 250 m below the boundary between the formations. In this section the Punta Negra Formation exhibits a typical lateral change of lithofacies, as previously commented: it starts with a thick green pelitic interval, while a sandy coarsening and thickening-upward interval completes the upper part of the formation. Ostracods occur in this upper interval that is composed of brownish and greenish-brown micaceous sandy layers of tabular and lenticular geometry, often exhibiting syn-sedimentary deformation and vegetation debris. The single ostracod bearing-level is a thin (10–20 cm) light brownish tabular layer of micaceous coarse sandstone located 171.5 m above the base of the Punta Negra Formation (30°31′12″S/68°48′30″W) (Fig. 3). The associated fauna includes brachiopods, bivalves, crinoids, gastropods, corals and hyolithids

The Middle Devonian age given for this fossiliferous level is based on stratigraphic grounds, and is commented in the biostratigraphic section.

2.3. Loma de Los Piojos section

This section is located to the north of the Central Precordillera, ca. 8 km southwest of the city of Jáchal. The ostracods were collected from both the Talacasto and Punta Negra formations in an east-west transect situated at 30° 18.504′ S/68° 47.399′ W.

In the Talacasto Formation ostracods are recorded in a bed of brownish-green mudstones and fine sandstones (LP1), located nearly 182.5 m above the guide horizon of Keidel (30°18′ 41.98″S/ 68°47′12.62″W) (Fig. 3). The accompanying fauna is composed of brachiopods, trilobites, bivalves, crinoids, gastropods, hyolithids, conularids, corals and orthoconic nautiloids. An Emsian age has been interpreted according its brachiopod content (Herrera, 1995b).

At the Loma de Los Piojos section, the Punta Negra Formation totalizes 310 m in thickness, exhibiting a stratigraphic succession very similar to that of the Las Casitas River section. The ostracods are recorded 245 m above the base (LP2) in a 50 cm thick bed, which includes a 1.5 m thick interval intercalated between greenish brown sandy beds (30°18′30.2″S/68°47′ 12.62″W) (Fig. 3). This fossiliferous bed consists of greenish dark-gray and slightly micaceous massive mudstones, with frequent 1–3 mm diameter quartz pebbles, and oblate nodules. This horizon includes abundant and diverse fauna of trilobites, bivalves, brachiopods, gastropods, hyolithids, cephalopods, crinoids, bryozoans and corals, accompanied by profuse carbonaceous plant debris and trace fossils.

Fig. 3. Stratigraphical distribution of the ostracod fauna in the Talacasto and Punta Negra formations in Talacasto Creek, Las Casitas River and Loma de los Piojos sections.

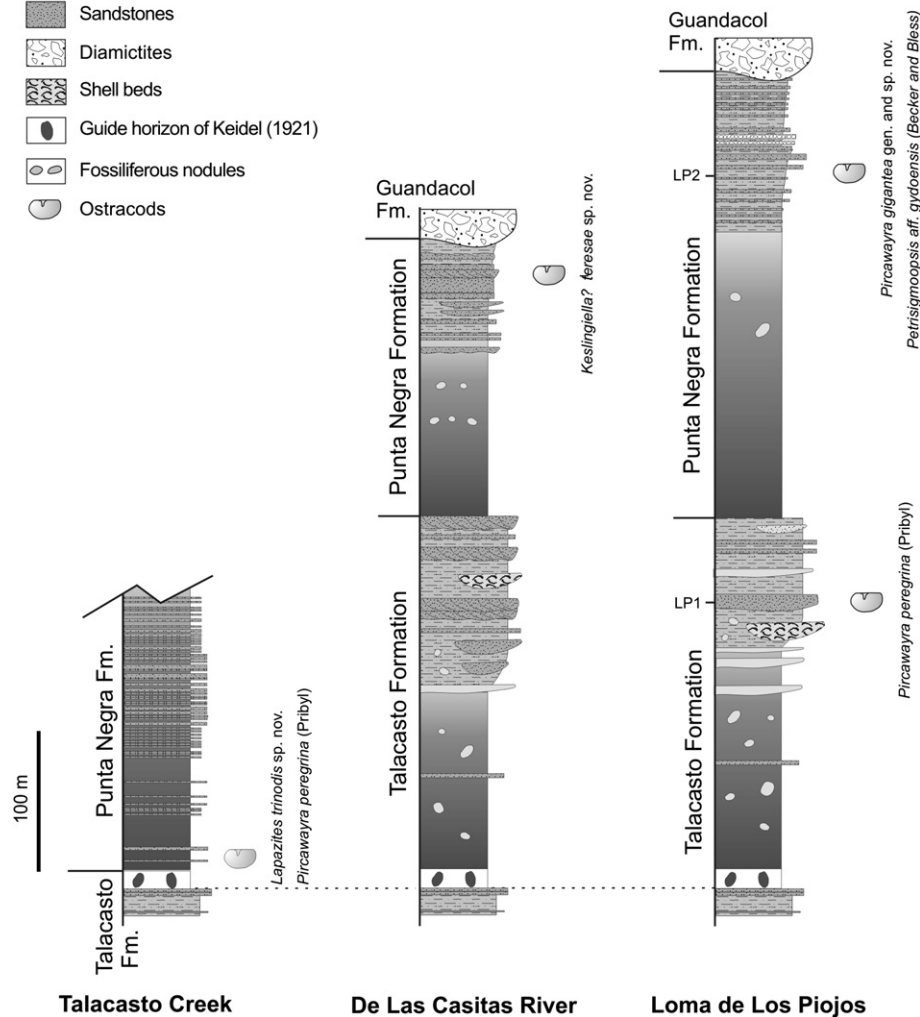According Rustán and Vaccari (2010), the record of the trilobite *Acanthopyge* (*Lobopyge*) *balliviani* in the LP2 level suggests a Middle Devonian age. This trilobite is considered a Middle Devonian biostratigraphic marker in Bolivia, where was first recognized in the Upper Member of the Belén Formation (Ahlfeld and Braniša, 1960; Braniša, 1965; Kozlowski, 1923). In the Argentine Precordillera it is recorded in the Chigua Formation (Baldis, 1967; Baldis and Longobucco, 1977) in strata reliably considered of Middle Devonian age (Leanza, 1968; Amenábar et al., 2006, 2007; Amenábar, 2009).

3. Techniques of study

Rock samples of the studied material were collected during successive field expeditions by one of us (JJR), was also studied material from the fossil collection of the CIPAL (Centro de Investigaciones Paleobiológicas). The material from Talacasto and Punta Negra formations appears mainly as internal and external moulds and in some exceptionally cases with the original carapace preserved (only in Loma de Los Piojos section, Fig. 3). These ostracods have been prepared mechanically using a 'Vibro-tool' and fine needles; the external moulds have been cast using latex rubber.

The specimens were photographed with a Leica EC3 digital camera and a Leica lupe.

The material is deposited in the paleontological collections of the CIPAL, Centro de Investigaciones Paleobiológicas, Universidad Nacional de Córdoba, Argentina, under the prefix CEGH-UNC.

4. Systematic paleontology

Order Palaeocopida Henningsmoen, 1953
Suborder Binodicopina Schallreuter, 1972
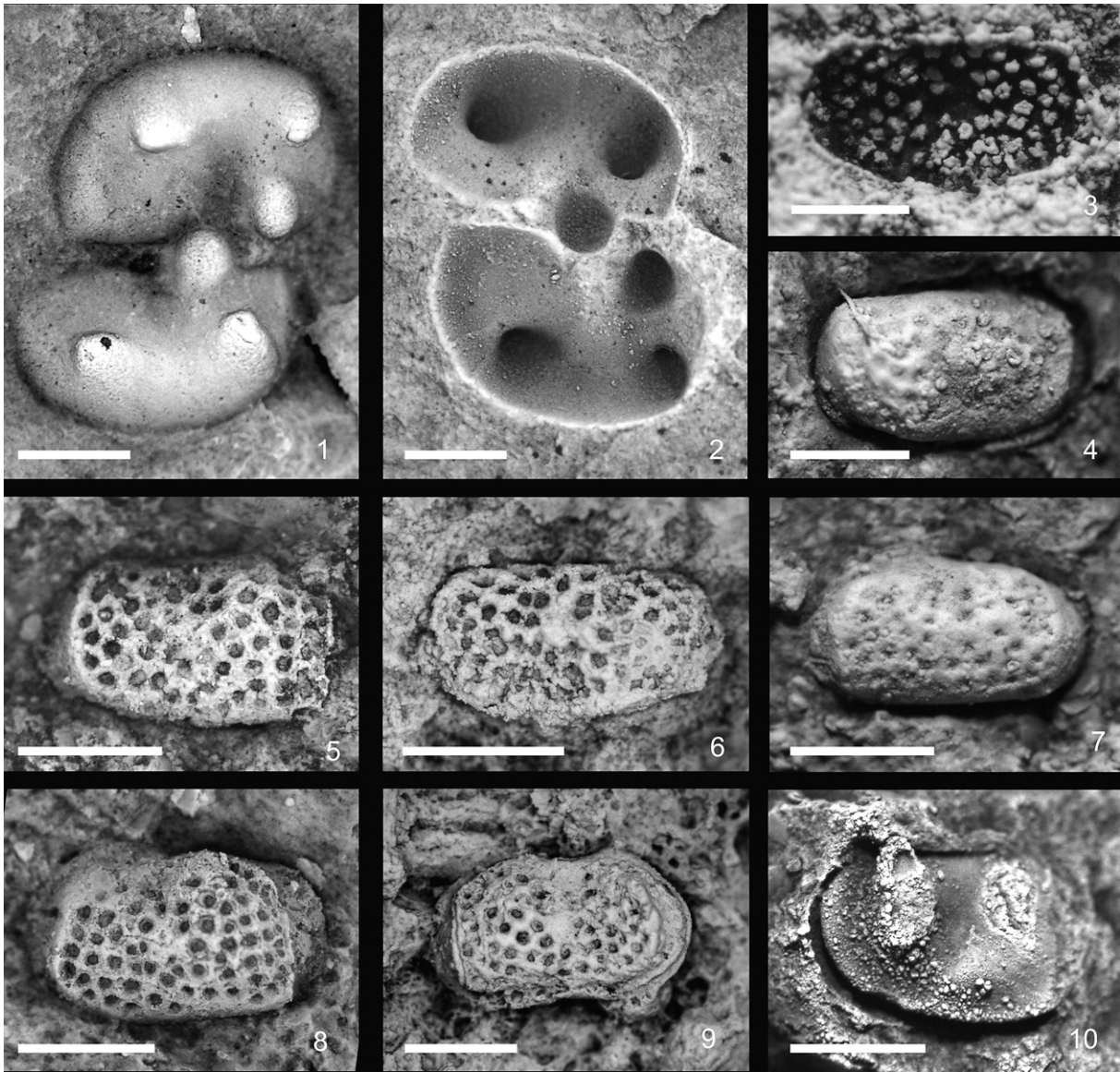Superfamily Drepanelloidea Ulrich and Bassler, 1923
Family Bollidae Bouček, 1936
Genus *Petrisigmoopsis* Pinto and Purper, 1981
Type species: *Petrisigmoopsis wolffi* Pinto and Purper, 1981
Petrisigmoopsis aff. *Petrisigmoopsis gydoensis* (Becker and Bless in Becker et al., 1994)
Fig. 4(10).

Fig. 4. (1)–(2). *Lapazites trinodis* nov. sp. Holotype CEGH-UNC 25401. Carapace preserved in butterfly orientation. (1). External mold, latex cast, (2). external mold. (3)–(9). *Keslingiella*? *teresae* nov. sp. (3), (6). Left valve, lateral view, CEGH-UNC 25402, (3). external mold, (6). latex cast. (4). Internal mold, right valve, lateral view, CEGH-UNC 25403. (5). External mold, latex cast, left valve, lateral view, CEGH-UNC 25404. (7). Holotype CEGH-UNC 25406, internal mold, right valve, lateral view. (8). Paratype CEGH-UNC 25407, external mold, latex cast, left valve. (9). Paratype CEGH-UNC 25408, external mold, latex cast, right valve, lateral view. (10). *Petrisigmopsis* aff. *gydoensis* (Becker and Bless in Becker et al., 1994), internal mold, lateral view, CEGH-UNC 25409. Scale bars 1500 μm.

Description. Subcircular, amplete to slightly postplete outline. Dorsal margin straight and long. Anterior margin rounded, the posterior margin is broken, however looks wider than the anterior. Convex ventral margin. Anterior cardinal angle obtuse (130°). Valves with two thick, prominent and well-defined lobes (L2 and L3), not united by their ventral end. L2 located in anterior half of valves, reaches its ventral half and overreaching dorsal margin, rounded in dorsal and ventral ends. L3 longer, curved toward the anterior part of valve, dorsal end rounded, not overreach dorsal margin. L1 very faint, located between lateral and marginal surface. Marginal surface convex.

Discussion. The described material is very similar to *P. gydoensis* (Becker and Bless) (in Becker et al., 1994), from Gydo Formation (Emsian) of South Africa. However, here only one internal mold of a left valve is recorded, and it is therefore not possible to determine, with certainty, the material to species level. The taxa are similar in their size, in the outline of the valves, in the position, shape and size of their lobes (L2 and L3), and in the lack of a connected ventral lobe. The Argentinian specimen differs by its very faint to absent anterior lobe (L1), and in the presence of a bend between the lateral and marginal surfaces. In the studied material, L4 is unknown because the recorded mold is broken.

Baldis and Rossi de García (1975) defined several new genera from the Talacasto Formation (Lower Devonian) in the Argentine Precordillera. Among these, are *Bilobeyrichia*, *Argentibolbina*, *Platibolba* and *Argentinobolbina* for which, however, a proper comparison with the specimen described here is not possible until the revision of these taxa is complete.

Material. Only the figured specimen CEGH-UNC 25409 (Fig. 4(10)).

Occurrence. The species is only recorded in the LP2 level (Eifelian–Givetian) of the Punta Negra Formation in Loma de los Piojos section, Argentine Precordillera (Figs. 1 and 3).

Suborder Platycopina Sars, 1866.
Superfamily Kloedenelloidea Ulrich and Bassler, 1908.
Uncertain family.
Pircawayra nov. gen.

Type species: *Pinnatulites*? *peregrina* Přibyl, 1984.
Other species: *Pircawayra gigantea* nov. gen. and sp., and possibly Gen. 1 sp. A from South Africa (Becker et al., 1994).
Derivation of name: In Quechua language "pirca" means wall and "wuayra" means air, and they refer to the internal structure of the carapace of the new genus.
Diagnosis. Large valves that reach 5 mm. Amplete to slightly postplete outline. Valves unisulcate. Sulcus straight, well defined and open dorsally. Rounded preadductorial node immediately in front of sulcus. Node more developed in the inner side of valve than in the exterior. Thick valves, with an internal structure consisting of vertical walls that form a reticulum. Valves smooth. Valve overlap unknown.
Discussion. A very particular internal structure of the carapace is recognized in the new genus. Specimens have large and thick carapaces, whose thickness is not uniform along the entire valve. The thickest part is in the center of the anterior and posterior half of the valves, and the narrowest part is toward the margins. Internally the valves are constituted by vertical walls that form a circular or hexagonal reticulum. Thus the air columns (formed by the reticulum) of ca. 0.17 mm in diameter perpendicularly crossing nearly the whole thickness of the shell, being covered by the more external layer of the valves (Fig. 5(6)). Usually, with the exfoliation of the shell, after the animal's death, the carapaces show hexagonal or circular scars over the lateral surface of the valves (Fig. 5(1)), the number of scars varies with the species between 30 and 60; in some cases, the scars are also visible in the internal molds (Fig. 5(4)). In the external molds the structure is preserved as closely spaced columns (Fig. 5(12)).
Similar structures have been described by several authors in genera from the Ordovician to Devonian (Adamczak, 1968; Kesling and Chilman, 1987; Olempska, 1994). For example, in the Devonian genus *Ctenoloculina* Kesling, Adamczak (1968) and Kesling and Chilman (1987) recorded a hollow structure of the carapace that shows a thick internal layer and a very thin external layer, separated by pillars. Due to the external layer usually being absent, the remains of the pillars look like coarse papillae. Olempska (1994) described the shell structure of *Lembitsarvella polonica* Olempska and *Pinnatulites procera* (Kummerow), from the Ordovician of Poland. Though the internal structure is different in the two genera, both show hollow spaces in their carapaces. Although it is not yet known with certainty what the function of this structure is, these authors relate the structures to buoyancy, with the possibility of reducing the weight of the shell to permit more active swimming or to functions related to light sensitivity.
The greatest similarity of *Pircawayra* nov. gen. is with *Pinnatulites* Hessland, 1949, from the Early Ordovician of the Baltic region, mainly in the presence of a comparable internal structure of the carapaces, however in *Pinnatulites* the air columns traverse the entire thickness of the shell, and open on outer and interior surface of the valve (Olempska, 1994). Other important difference is the presence in the new genus of a preadductorial node and an adductorial sulcus S2. The large size of the valves is also noteworthy, reaching 5 mm.
Gen. 1 sp. A from the Emsian of the Gydo Formation in South Africa (Becker et al., 1994; Pl. 1, (1) may be congeneric based on its sub-rectangular and amplete outline, its large size of the valves, its circular adductorial node, presence of an adductorial sulcus, and possession of a bend between the lateral and marginal surface. In addition, Becker et al. (1994) mentioned a remnant of a frill, features not observed in the Argentine material.

Occurrence. Lower−Middle Devonian of Argentine Precordillera and Altiplano Boliviano, and possibly Emsian levels of South Africa.

Pircawayra peregrina (Přibyl, 1984)
Fig. 5(11)−(15).
1984. *Pinnatulites*? *peregrina* Přibyl, Pl. 2, Fig. 3.

Diagnosis. Pircawayra species with an elliptical outline, a shallow and poorly defined adductorial sulcus and a flat lateral surface.
Description. Elliptical and amplete outline. Valves large, *L* reaches 5 mm, situated at valve mid-height. Average *L:H* ratio *ca.* 1.78. Cardinal angles poorly defined and obtuse. Anterior is bigger than the posterior. Dorsal margin straight and long. Lateral margins rounded, the anterior sharper than the posterior. Ventral margin slightly convex. Adductorial sulcus straight, shallow and perpendicular to dorsal margin. Lateral surface of valves nearly flat, only slightly wider in posterior half. Marginal surface narrow and almost perpendicular to the lateral surface. Valves smooth. Hexagonal scars in anterior and posterior sector when the valves are exfoliated. Internal moulds exhibit a rounded and well defined preadductorial node immediately in front sulcus.
Discussion. Přibyl (1984) defined *Pinnatulites*? *peregrina* on the basis of one mold from the upper Member of the Belén Formation in Bolivia. The new material recorded in the Argentine Precordillera is assigned to this species on the basis of the size and the outline of the carapace, by the weakly defined adductorial sulcus and by the hexagonal scars presents in the middle part of the anterior and posterior sector of the valves (Fig. 5(11), (13), (14)).
Material. Nearly twenty valves, including internal and external molds, and one external mold preserved in butterfly aspect. Figured specimens are CEGH-UNC 25395 (Fig. 5(9)), CEGH-UNC 25397 (Fig. 5(11) and (12)), CEGH-UNC 25398 (Fig. 5(13)), CEGH-UNC 25399 (Fig. 5(14)) and CEGH-UNC 25400 (Fig. 5(15)). Additional not figured specimens are CEGH-UNC 25417−25427, 25439−25442.
Occurrence. Pircawayra peregrina is recorded in the lower levels of the Punta Negra Formation in the Talacasto Creek section (Emsian), and at the level LP1 of the Talacasto Formation at the Loma de los Piojos section (Emsian), Argentine Precordillera (Fig. 3). Upper Member of the Belén Formation (Emsian-Eifelian), Bolivia (Fig. 2).

Pircawayra gigantea nov. gen. and sp.
Fig. 5(1)−(10).

Holotype: CEGH-UNC 25388, right valve (Fig. 5(1)).
Paratypes: CEGH-UNC 25389, internal mold of right valve (Fig. 5(2) and (3)), CEGH-UNC 25392, internal mold of left valve (Fig. 5(6)).
Type locality and age: upper levels of the Punta Negra Formation, Givetian, (level LP2), in the Loma de los Piojos section (Fig. 3), Argentine Precordillera.
Derivation of name: it refers to the large carapace.
Diagnosis. Pircawayra species with sub-rectangular outline, well defined, narrow, long and deep sulcus and a very high lateral surface.
Description. Valves sub-rectangular and amplete in outline. Large, *L* = 5.19 mm, located in the mid-height of valves. *L:H* relation *ca.* 1.70. Dorsal margin straight and long. Lateral margins rounded with anterior narrower than posterior one. Ventral margin slightly convex. Adductorial sulcus well developed, deep and long reaching the ventral half of valves. Rounded preadductorial node immediately in front of sulcus. Node better defined on the inner side of the valves than on the exterior. L3 well developed and almost completely occupies the posterior half of valve. Lateral surface
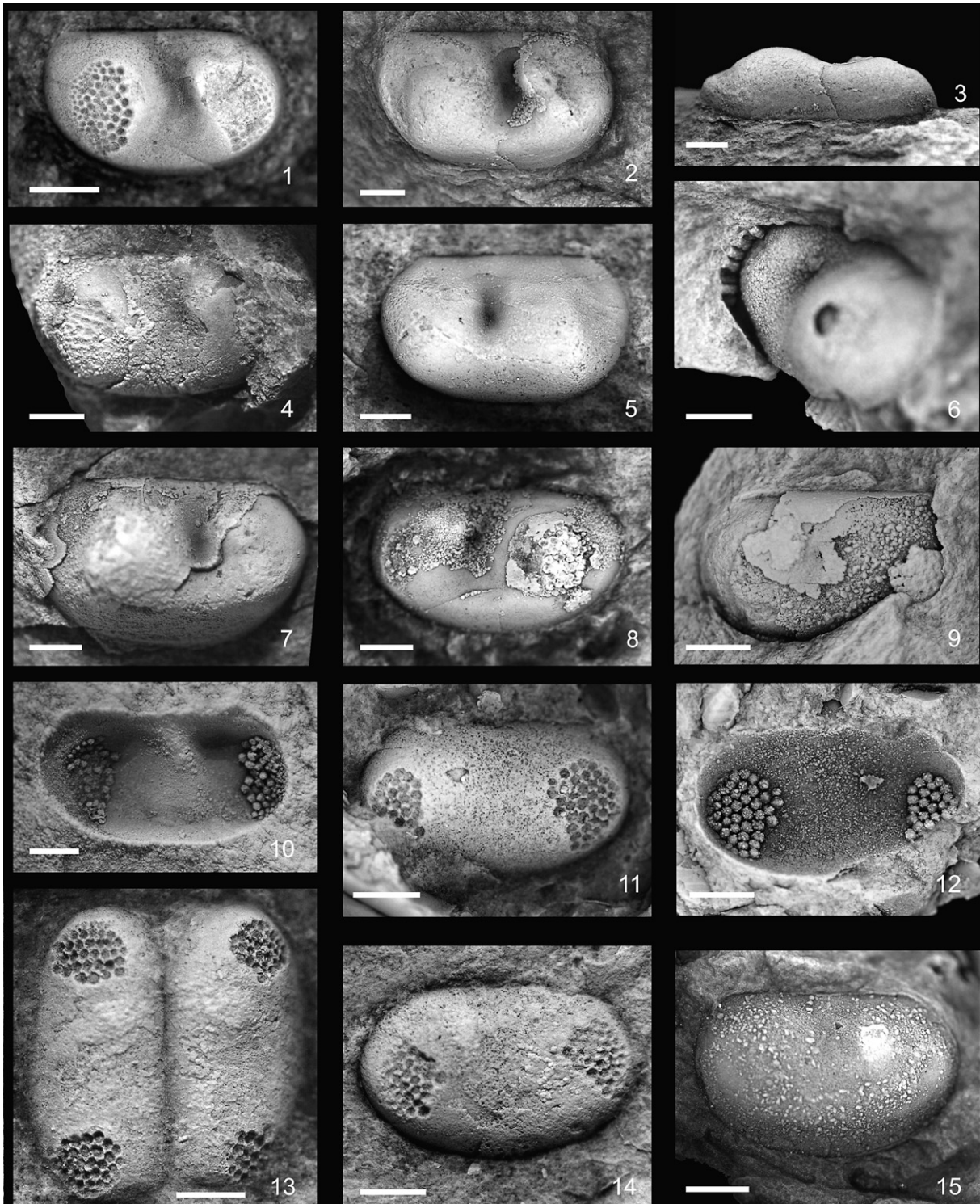
Fig. 5. (1–8, 10). *Pircawayra gigantea* nov. gen. and sp. (1). Holotype. Right valve, lateral view, CEGH-UNC 25388. (2)–(3). Paratype CEGH-UNC 25389, internal mold of right valve, lateral and ventral views respectively. (4). Internal mold of right valve, lateral view, CEGH-UNC 25390. (5). External mold, latex cast, left valve, lateral view, CEGH-UNC 25391. (6). Paratype CEGH-UNC 25392, internal mold of left valve, posterior view where is possible to observed the filling of the columns of the valve. (7). Internal mold of right valve that preserves part of the shell, lateral view, CEGH-UNC 25393. (8). Internal mold of left valve where is possible to observed preserved, in the center of the posterior half of the valve, the columns of the carapace, lateral view, CEGH-UNC 25394. (10). External mold of left valve, lateral view, CEGH-UNC 25396. (9), (11)–(15). *Pircawayra peregrina* (Přibyl, 1984). (9). Internal mold of left valve where is possible to observed preserved, in the center of the posterior half of the valve, the columns of the carapace, lateral view, CEGH-UNC 25395. (11)–(12). Left valve, lateral view, CEGH-UNC 25397. (11). External mold, latex cast, (12). External mold. (13). External mold preserved in butterfly orientation, latex cast, CEGH-UNC 25398. (14). External mold, latex cast, left valve, lateral view, CEGH-UNC 25399. (15). Internal mold of right valve, lateral view, CEGH-UNC 25400. Scale bars 1000 μm.

convex, the highest part in posterior half of valves. Lateral surface smooth, the exfoliated valves show in their mid-anterior and mid-posterior part rounded to hexagonal scars (ca, 0.15 mm of diameter) (Fig. 5(1)). External molds with columns which are equivalent to the scars (Fig. 5(10)). Marginal surface narrow and perpendicular to plane of separation of valves, probably punctate, however this feature is visible only in one example.

Discussion. The material is assigned to *Pircawayra* based on its carapace features, the large size, the thick valves, the outline and mainly by the internal structure of the valves. Structure especially reflected in the external molds. The new species differs from *Pircawayra peregrina* (Přibyl, 1984) in its very high valves, in its sulcus S2, long and deep, and in its rounded and well developed pre-adductorial node.

Material. Fifteen internal and external molds between left and right valves, some molds show different depth of exfoliation. Figured specimens, in addition to the types, are CEGH-UNC 25390 (Fig. 5(4)), CEGH-UNC 25391 (Fig. 5(5)), CEGH-UNC 25393 (Fig. 5(7)), CEGH-UNC 25394 (Fig. 5(8)) and CEGH-UNC 25396 (Fig. 5(10)). Additional specimens not figured are CEGH-UNC 25429−25438.

Occurrence. Only recorded in its type locality.

Uncertain Family.
Genus *Lapazites* Přibyl, 1984.
Type species. *Lapazites grandis* Přibyl, 1984.
Lapazites trinodis nov. sp.
Fig. 4(1) and (2).

Holotype: CEGH-UNC 25401, external mold of a carapace preserved in butterfly orientation (Fig. 4(1) and (2)).

Type locality and age: lower levels of the Punta Negra Formation, Emsian, Talacasto Creek section, Argentine Precordillera (Fig. 3).

Derivation of name: the name refers to the three well developed nodes of the carapace.

Diagnosis. *Lapazites* species with posteroventral node well-defined and spine-like.

Description. Sub-rectangular and amplete lateral shape. $L = 3$ mm, located in dorsal half of valves. Dorsal margin straight and long. Lateral margins nearly straight to slightly rounded, ventral margin convex. Cardinal angles well defined with anterior obtuse (ca. 120°) and posterior one nearly straight. Valves with three rounded, well defined and prominent nodes. Adductorial node situated in anterodorsal part of valves, immediately in front of the adductorial sulcus. Other two nodes in ventral half of valves: one in anterior part and the other in the posterior. Posterior node immediately behind adductorial sulcus and spine-like, with spine toward posterior part. Adductorial sulcus poorly defined, reaches ventral half of valves. Lateral surface smooth with the nodes corrugated.

Discussion. The material is assigned to *Lapazites* Přibyl, 1984 from the upper Member of the Belén Formation (Emsian-Eifelian), Bolivia, mainly because of the presence of two rounded nodes (L1 and L2) in the anterior half of the valves. L2 is set in the antero-dorsal half of the valve, immediately below the dorsal margin and anterior of the adductorial sulcus, L1 is located in the antero-ventral half of the valve. The new species is similar to *Lapazites grandis* Přibyl, 1984, the only known species of the genus, in their large size and in the presence of a third node in the posterior half of the carapace. However, they show significant differences in their posterior morphology. L3 in *L. grandis* is poorly defined and apparently occupies most of the posterior half of the valves, whereas in the new species the node is positioned in the postero-ventral part of the valves and is well defined, rounded to spine-like and very

prominent. In addition, *L. trinodis* sp. nov. has a more quadrate carapace while *L. grandis* is elongate in outline.

Material. Only the holotype, external mold of a carapace preserved in butterfly orientation (CEGH-UNC 25401), one internal mold of a left valve and two internal molds of right valves. Figured specimens in addition to the type is CEGH-UNC 25401 (Fig 4(1) and (2)). Additional material not figured is CEGH-UNC 25428.

Occurrence. The species is recorded from the lower levels of the Punta Negra Formation (Emsian) in the Talacasto Creek section, Argentine Precordillera.

Order Podocopida Sars, 1866.
Suborder Metacopina Sylvester-Bradley (in Benson et al., 1961).
Superfamily Quasillitoidea Coryell and Malkin, 1936.
Family? Quasillitidae Coryell and Malkin, 1936.
Genus *Keslingiella* Pinto and Purper, 1981.

Type species: *Keslingiella pillai* Pinto and Purper, 1981.

Keslingiella? *teresae* sp. nov.
Fig. 4(3)–(9).

Holotype: CEGH-UNC 25406, internal mould of right valve (Fig. 4(7)).

Paratypes: CEGH-UNC 25407, external mold, left valve (Fig. 4(8)), CEGH-UNC 25408, external mold, right valve (Fig. 4(9)).

Type locality and age: upper levels of the Punta Negra Formation, Givetian, in the Las Casitas River section, Argentine Precordillera (Fig. 3).

Derivation of name: this species is named for Teresa Sánchez, Argentine paleontologist.

Diagnosis. Subrectangular and amplete outline. Faint V-shaped adductorial sulcus. Rounded, smooth adductor muscle spot. Lateral surface coarse reticulate, with circular mesh. Smooth and broad marginal surface. There is a ridge between lateral and marginal surfaces.

Description. Sub-rectangular to elliptical and amplete lateral shape. Dorsal margin straight to slightly convex and shorter than maximum length. Maximum length reaches 2.5 mm. Average $L:H$ ca. 1.77. Ventral margin straight, sub-parallel to dorsal margin. Lateral margins regularly rounded, posterior broader than anterior one. Cardinal angles poorly defined and obtuse. V-shape and very faint adductorial sulcus. Below sulcus, in mid-height of valves, there is a small, rounded and smooth adductor muscle spot. Maximum width of carapace in posterior half. Steeply sloping, broad and smooth marginal surface at anterior and posterior margins of valves, with a ridge-like bend between lateral and marginal surfaces. Lateral surface coarse pitted or reticulate with circular mesh. Marginal ridge at free margin.

Discussion. The Argentine material is very similar to *Keslingiella* Pinto and Purper, 1981, an endemic genus from the Malvinokaffric Realm, which has only been recorded in the Middle Devonian of Bolivia and South Africa (Lethiers et al., 2001). They are similar in carapace shape, in the faint adductorial sulcus, in the broad, smooth and sloping marginal surface, and in the reticulated lateral surface with a circular mesh. However, a diagnostic feature of *Keslingiella* is the lack of a smooth central area corresponding to the adductorial muscle scar, which is present in the described species. Because of this feature the generic assignment remains in doubt. With respect to *Keslingiella pillai* Pinto and Purper, the only species of the genus, the new species differs in the presence of the muscle spot, in its larger size, in the absence of spines and in the better defined ridge between the lateral and marginal surface.

The new species differs from "*Jenningsina*" n. sp. A, from the Middle Devonian of Bolivia and South Africa (Lethiers et al., 2001),

mainly because of its possession of a rounded adductorial spot and by the absence of a central pit, which in "*Jenningsina*" n. sp. A is formed by the vertical fusion of the two central meshes of the ornamentation reticulum. In addition, the new species is more elongate, and has lateral margins which are more evenly rounded with a well-defined ridge between the lateral and marginal surfaces, mainly developed in the anterior and posterior margins. The overlap conditions of the valves are unknown.

Keslingiella? *teresae* is also similar to Gen. 4 sp. A from the Emsian-late Eifelian of South Africa (Becker et al., 1994) mainly because of the presence of a muscle spot, the presence of a ridge between the lateral and marginal surface in the anterior and posterior half of the valves, and in the punctate lateral surface and smooth marginal surface. On other hand, the internal mold of the studied species also resembles Gen. 5 sp. A from the Early-Middle Devonian of South Africa (Becker et al., 1994). These two forms could be assigned to the new species; however the poor descriptions and illustrations of the South African ostracod faunas are of very limited help for comparison. The same is the case of *Scrobicula* sp. from the Talacasto Formation of the Early Devonian of the Argentine Precordillera (Baldis and Rossi de Garcia, 1975).

Material. Several internal and external molds. Figured specimens, in addition to the types, are CEGH-UNC 25402 (Fig. 4(3)), CEGH-UNC 25403 (Fig. 4(4)), CEGH-UNC 25404 (Fig. 4(5)) and CEGH-UNC 25405 (Fig. 4(6)). Additional specimens not figured are CEGH-UNC 25443–25444.

Occurrence. This species comes from the upper levels of the Punta Negra Formation (Eifelian-Givetian) in the Las Casitas River section, Argentine Precordillera (Fig. 3), and probably from the Early-Middle Devonian of South Africa.

5. General discussions

5.1. Biostratigraphy and stratigraphic correlation

The Devonian Malvinokaffric Realm is characterized by scarcity or absence of main biostratigraphic markers such as ammonoids, graptolites and conodonts (Racheboeuf et al., 1993: 72). In addition, local to regional biostratigraphic schemes for Malvinokaffric basins based on trilobites (e.g. Braniša, 1965; Wolfart, 1968) and brachiopods (e.g. Herrera, 1993, 1995a,b) have proven to be of limited use (Holloway and Rustán, 2011).

During the last twenty years, these circumstances have led to the development of more comprehensive biostratigraphic schemes, based on palynological indicators of global extent, with emphasis on South America (e.g. Racheboeuf et al., 1993; Grahn, 2002; Troth et al., 2011; among others). In the context of this progress, however, the Lower-Middle Devonian Gualilán Group is still poorly understood from a biostratigraphic point of view, and the age of its units are habitually adjusted using brachiopod data (works by Herrera and collaborators).

In turn, the stratigraphic relationships and age of the Talacasto and Punta Negra formations have received different interpretations. Recently, the use of the guide horizon of Keidel (1921) allowed a new correlation scheme of the different stratigraphic sections, making more evident the diachronism between the units of the Gualilán Group (Rustán, 2011; see the stratigraphic setting herein). According to this interpretation, the upper part (above the guide horizon of Keidel) of the Talacasto Formation in the northern sections of the basin (mainly Loma de los Piojos and other sections near the Jáchal area) is stratigraphically equivalent to the base of the Punta Negra Formation at the Talacasto Creek to the south (Figs. 1 and 3). As a consequence of this new stratigraphic scheme, the brachiopod biozones defined by Herrera (1993, 1995a) above the guide horizon, supposed as stratigraphically successive

and commonly used for post-Pragian sedimentary successions, may be coeval and thus meaningless. Consequently, strata of the Gualilán Group overlying the horizon of Keidel, have presently not biozones reliably defined on the basis of marine invertebrates.

In this context additional elements, such as the reported ostracods of the Gualilán Group might be relevant as biostratigraphic indicators.

For example, the new genus *Pircawayra* is exclusively recorded in Emsian to early Middle Devonian strata. In particular, *Pircawayra peregrina* (Přibyl) seems to be interesting due it is restricted to a mainly Emsian age. In the Argentine Precordillera, this species is recorded both in the green and purple pelitic basal interval of the Punta Negra Formation at the Talacasto Creek section, as well as in the (laterally equivalent) upper levels of the Talacasto Formation at the Loma de los Piojos section (in the LP1 level), both located above the guide horizon of Keidel (Figs. 2 and 3). The Emsian age interpreted for the bearing levels are based on palynological and brachiopod data (Herrera, 1995b; Herrera and Bustos, 2001: 369). However, as *P. peregrina* also occurs in the lower levels of the upper member of the Belén Formation in the Bolivian Altiplano (Přibyl, 1984), a younger age (i.e. early Eifelian) should not be discarded for *P. peregrina* (according Blieck et al., 1996). The stratigraphic distribution of *P. peregrina* in Precordillera is thus in accordance with the proposed diachronism of the boundary between the Talacasto and Punta Negra formations, and would encompass the Emsian-early Middle Devonian interval. The congeneric species, *P. gigantea* nov. sp. has only been recorded in the LP2 level of the Punta Negra Formation at Loma de los Piojos section (Fig. 3), which is considered Middle Devonian based on the presence of the trilobite *Acanthopyge* (*Lobopyge*) *balliviani* (see comments in the stratigraphic setting).

Meanwhile, *Petrisigmoopsis* has an approximately coincident Emsian-Middle Devonian stratigraphic range. *Petrisigmoopsis aff. P. gydoensis* (Becker and Bless) is recorded only in the Middle Devonian level LP2 in Precordillera (Fig. 3), although its closest species *P. gydoensis* has older (Emsian) records in the Gydo Formation of South Africa (Becker et al., 1994).

Lapazites constitutes a similar case. *Lapazites trinodis* nov. sp. is reliably recorded in Emsian layers of the lower part of the Punta Negra Formation at the Talacasto Creek section, but the stratigraphic range of the genus would encompass the early Middle Devonian, according records of *L. grandis* from the upper member of the Belén Formation from Bolivia (Přibyl, 1984).

According all these revised stratigraphic records, the genera *Pircawayra*, *Lapazites* and *Petrisigmoopsis*, should be considered altogether most probably indicating late Early-Middle Devonian ages in Malvinokaffric basins.

Although *Keslingiella* has been considered coeval to these genera up to the present, it would be also present in older (Lochkovian-Pragian) levels of the Talacasto Formation as it may be the same form described by Baldis and Rossi de García (1975) as *Scrobicula* sp. (Lethiers et al., 2001). This interpretation complicates the correlation of the Las Casitas River section in the Argentine Precordillera, where the only ostracod recognized is *Keslingiella*? *teresae* nov. sp.. However, this ostracod level is considered laterally equivalent to the level LP2 at Loma de Los Piojos locality, taking into account its stratigraphic position (about 200 m above of the base) in the context of the very similar stratigraphic arrangement between both sections. Consequently a Middle Devonian age is interpreted for the fossiliferous level of the Las Casitas River section.

This would also permit the correlation between the Las Casitas River section with the only previous faunal record of the Punta Negra Formation: the level of the Las Chacritas River section reported by Herrera and Bustos (2001) a few kilometers toward the west. Since the LP2 level at Loma de los Piojos section, based on its

lithology (greenish mudstones with abundant vegetal debris) and its brachiopod content (including *Salopina*, *Metaplasia* and *Mutationella*, according L. Benedetto, personal communication), is correlated with that of Las Chacritas River. Therefore, we consider the fauna recorded by Herrera and Bustos to be of Middle Devonian age, in contrast with the late Emsian age tentatively proposed by these authors.

Hence, according the stratigraphic and bioestratigraphic scheme discussed, the fossiliferous intervals of the Punta Negra Formation at Las Casitas River, Las Chacritas River and Loma de Los Piojos sections, are interpreted as approximately equivalent and Middle Devonian in age.

5.2. Affinities of the ostracod fauna

Totaling only five species within four genera (*Pircawayra peregrina* (Přibyl), *Pircawayra gigantea* gen. and sp. nov., *Lapazites trinodis* sp. nov., *Keslingiella? teresae* sp. nov. and *Petrisigmoopsis* aff. *P. gydoensis* (Becker and Bless), the upper Lower and Middle Devonian ostracod faunas from the Gualilán Group show low-diversity. The most abundant species are *Pircawayra peregrina* and *Pircawayra gigantea*. At present, *Pircawayra* has only been recorded in Argentina, Bolivia and South Africa. *P. gigantea* is exclusive to the Argentine Precordillera, while *P. peregrina* has previously been described from the Emsian − Eifelian levels of the Belén Formation in Bolivia (Přibyl, 1984). *Petrisigmoopsis* Pinto and Purper is another typical genus of these three regions during the Early to Middle Devonian, and is also present in the Silurian of Brazil (in Becker et al., 1994) and Argentina (Vannier et al., 1995). The genus *Lapazites* Přibyl can be found at approximately coeval levels of the Belén Formation in Bolivia (Přibyl, 1984), as well as in the Argentine Precordillera (Talacasto and Punta Negra formations). Finally, the genus *Keslingiella* Pinto and Purper, only recorded with

certainty in Bolivia and recognized here with doubt, is another common genus in the Devonian of the Argentine Precordillera. Several similar forms have also been reported from the Emsian and Eifelian levels of the Gydo and Waboomberg formations in South Africa (Becker et al., 1994).

Although the ostracod fauna from the Argentine Precordillera is represented by palaeocopids, platycopids and metacopids, which define a common worldwide Devonian association, the taxa are of restricted geographical distribution. The upper Lower and Middle Devonian ostracod faunas closely resemble coeval ones from Bolivia and South Africa, exhibiting endemism at the species and genus level. This endemism, together with low diversity, signals a typical Malvinokaffric faunal association, as has already been noted for fauna from Bolivia (Lethiers et al., 2001; Racheboeuf et al., 2012) and South Africa (Becker et al., 1994). This uniform ostracod composition from the Andean and South African basins suggests faunal exchange between these areas, supporting a similar high paleolatitudinal position (Fig. 6). Shared features of these faunas could be attributed to cool water in a cool-temperate climate conditions with marked seasonality at high paleolatitudes as 60°S to 70°S (Becker et al., 1994; Lethiers et al., 2001).

In addition to the similar taxonomic composition and endemism, the Malvinokaffric ostracod fauna show other noteworthy features: thick, coarsely ornamented or swollen valves, usually very large in size, which frequently include giant carapaces that reach 5 mm in length. Based on these features, Lethiers et al. (2001) proposed a new assemblage named "Neritic Malvinokaffric Ecotype" in order to separate it from the "Eifelian Ecotype" sensu Becker in Bandel and Becker (1975), in which the ostracod association comes from "carbonate environment deposited under tropical waters". This new paleoecologically driven association is characterized by low diversity assemblages, mainly composed of Palaeocopina, Platycopina, and Metacopina with large, thickened
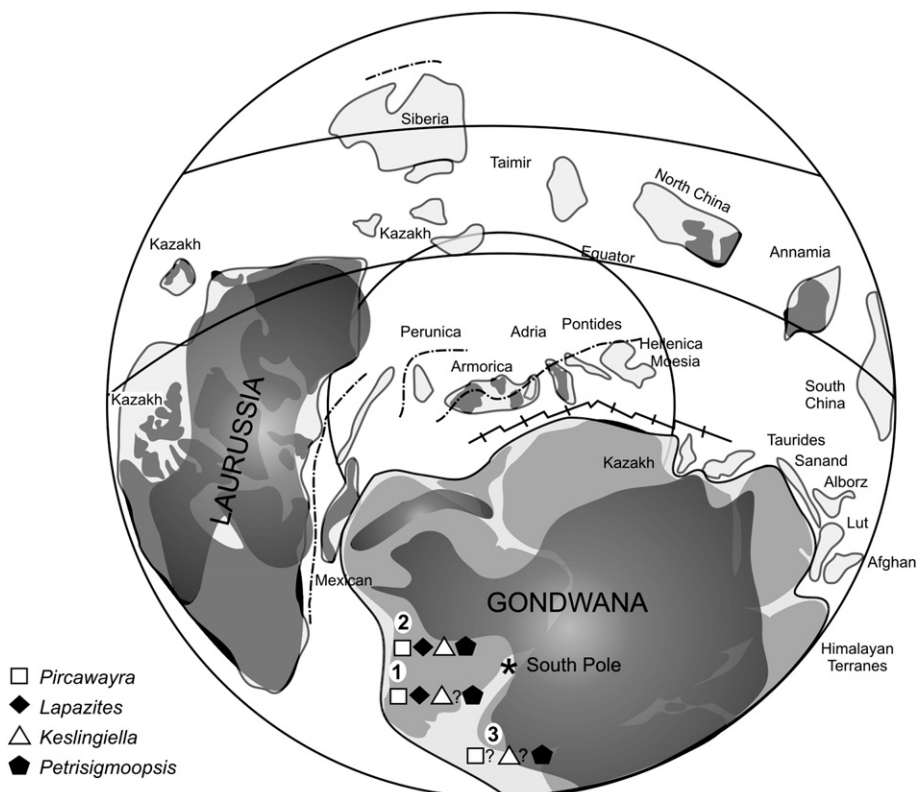

Fig. 6. Devonian schematic paleogeographical reconstruction with ostracod distribution. 1 − Argentine Precordillera; 2 − Bolivia; 3 − South Africa. Modified from Rustán (2011).

and ornamented carapaces developed in a shallow marine, non-carbonate environment of low to moderate water energy. Casier (in Racheboeuf et al., 2012), however, dismissed the validity of this new assemblage and related the fauna from the Pisacaviña section (Belén Formation) in Bolivia with his Assemblage III of the Eifelian Mega Assemblages (Casier, 1987).

The clear paleobiogeographical signature of the ostracod faunas has significant implications for the recognition of the Malvinokaffric Realm as a major paleobiogeographical unit during late Early to Middle Devonian times. Working on the São Domingos Formation, Paraná Basin, Brazil, Pinto Bossetti et al. (2010) proposed that a transgression at the Eifelian–Givetian transition "led to a drastic ecological change that was responsible for the disappearance of the Malvinokaffric Realm." The authors based their hypothesis on records of a faunal crisis involving extreme reduction in size, an alleged lack of diagnostic Malvinokaffric indicators, and the appearance of supposed immigrants and alien elements (orthoconic nautiloids were cited). Recently Pinto Bosetti et al. (2012), proposed the disappearance or at least a decline of the Malvinokaffric Realm in the Paraná Basin had already taken place by the early Emsian, in relation to regressive-transgressive events. These authors worked on a restricted part of the basin using presence/absence data from faunal lists, including taxa interpreted as Malvinokaffric endemics (strikingly orthoconic nautiloids), and linking their paleobiogeographic conclusions to indirect evidence from stratigraphic and taphonomic observations. Our evidence based on ostracod, stratigraphic and geographic distributions do not support conclusions made by Pinto Bosetti and collaborators.

According to the Devonian ostracod faunas, the Malvinokaffric Realm is clearly recognizable at least 'til the late Eifelian in South Africa (Becker et al., 1994), to the Givetian in Bolivia (Lethiers et al., 2001) and to the Givetian in the Argentine Precordillera.

6. Conclusion

Middle Devonian ostracods from Argentina are described by first time. The fauna is recorded in the upper levels of the Talacasto Formation and in Punta Negra Formation in the Argentine Precordillera. The diversity of the described assemblages is low, with five species described, of which one genus and three species are new, *Pircawayra gigantea* nov. gen. and sp., *Lapazites trinodis* nov. sp. and *Keslingiella*? *teresae* nov. sp. The age of the fossiliferous levels could be established in function of the associated fauna, and the recorded ostracods helped to the correlation between the studied sections in order to recognize a more exact scheme for stratigraphic units of the Gualilán Group. However, the ostracod data are not enough to propose a biostratigraphic scheme, and no one ostracod species could be consider as indicative of a determined age.

This fauna shows a marked endemism with common genera and species with Bolivia and South Africa. Both its faunistic composition and its morphological features are undoubtedly of Malvinokaffric affinities. In this way, according the ostracod data from the Precordillera Argentina, the Malvinokaffric Realm is recognizable at least until the Givetian.

Acknowledgments

References

Adamczak, F., 1968. Palaeocopa and Platycopa (Ostracoda) from Middle Devonian rocks in the Holy Cross Mountains, Poland. Stockholm Contributions in Geology 17, 1–109.

Ahlfeld, F., Braniša, A.L., 1960. Geología de Bolivia. La Paz. 245 pp.

Amenábar, C.R., Di Pasquo, M., Carrizo, H.A., Azcuy, C.L., 2006. Palynology of the Chigua (Devonian) and Maliman (Carboniferous) formations in the Volcan range, San Juan Province, Argentina. Part I. Paleomicroplankton and acavate smooth and ornamented spores. Ameghiniana 43, 339–375.

Amenábar, C.R., 2009. Middle Devonian Microfloras from the Chigua Formation, Precordillera Region, Northwestern Argentina. Geological Society, London. Special Publications 314, pp. 177–192.

Amenábar, C.R., Di Pasquo, M., Carrizo, H.A., Azcuy, C.L., 2007. Palynology of the Chigua (Devonian) and Malimán (carboniferous) formations in the Volcán range, San Juan Province, Argentina. Part II. Cavate, pseudosaccate and cingulizonate spores. Ameghiniana 44, 547–564.

Astini, R.A., 1990. Formación Punta Negra: un abanico submarino o un complejo deltaico de plataforma? Actas III Reunión Argentina de Sedimentología, pp. 19–24.

Astini, R.A., 1991. Sedimentología de la Formación Talacasto: plataforma fangosa del Devónico precordillerano, provincia de San Juan. Revista de da Asociación Geológica Argentina 44, 277–294.

Baldis, B.A., 1967. Some Devonian trilobites of the Argentine Precordillera. International Symposium of Devonian System Proceeding, 789–796.

Baldis, B.A., 1973. Variaciones de facies en la Formación Punta Negra (Devónico) de la Precordillera sanjuanina. Revista de la Asociación Geológica Argentina 28, 147–155.

Baldis, B.A., 1975. El Devónico Inferior en la Precordillera Central. Parte I: Estratigrafía. Revista de la Asociación Geológica Argentina 30, 53–83.

Baldis, B.A., Rossi de García, E., 1975. Ostracodes Devoniens Argentins Associes a la Faune Malvinokafrique. V African Coloquium on Micropaleontology, 57–91.

Baldis, B.A., Longobucco, M., 1977. Trilobites devónicos de la precordillera noroccidental (Argentina). Ameghiniana 14, 145–161.

Bandel, K., Becker, G., 1975. Ostracoden aus paläozoischen pelagischen Kalken der Karnischen Alpen (Silurium bis Unterkarbon). Senckenbergiana Lethaea 56, 1–83.

Becker, G., Bless, M., Theron, J., 1994. Malvinokaffric ostracods from South Africa (Southern Cape; Bokkeveld Group, Devonian). CFS 169, 239–259.

Benson, R.H., Berdan, J.M., van den Bold, W.A., Hanai, T., Hessland, I., Howe, H.V., Kesling, R.V., Levinson, S.A., Reyment, R.A., Moore, R.C., Scott, H.W., Shaver, R.H., Sohn, I.G., Stover, L.E., Swain, F.M., Sylvester-Bradley, P.C., 1961. Systematic description. In: Moore, R.C., Pitrat, C.W. (Eds.), Treatise on Invertebrate Paleontology, Q (Arthropoda 3 Crustacea Ostracoda), pp. Q99–Q421.

Blieck, A., Gagnier, P.Y., Bigey, F., Edgecombe, G., Janvier, P., Loboziak, S., Rachebuf, P., Sempere, T., Steemans, P., 1996. New Devonian fossil localities in Bolivia. Journal of South American Earth Sciences 4, 295–308.

Bouček, B., 1936. Die ostracoden des Böhmischen Ludlows (Stufe). Neues Jahrbuch Für Mineralogie, Geologie Und Paläontologie 76, 31–98.

Boucot, A.J., 1971. Malvinokaffric devonian marine community distribution and implication for Gondwana. Anais da Academia Brasileira de Ciencias 43, 23–49.

Boucot, A.J., Johnson, J.G., Talent, J.A., 1967. Lower and middle devonian faunal provinces based on Brachiopoda. Proceeding International Symposium Devonian System II, 1239–1254.

Braniša, L., 1965. Los fósiles guías de Bolivia: I Paleozoico. Boletín del Servicio Geológico de Bolivia, 1–282.

Bustos, U.D., Astini, A.R., 1997. Formación Punta Negra: análisis secuencial y evolución de la Cuenca Devónica Precordillerana. Revista de la Asociación Argentina de Sedimentología 4, 97–111.

Bustos, U.D., 1996. Modelo sedimentario alternativo para el Devónico de la Precordillera central sanjuanina: Formación Punta Negra. Revista de la Asociación Argentina de Sedimentología 3, 17–30.

Casier, J.-G., 1987. Etude biostratigraphique et paléoécologique des ostracodes du récif de marbre rouge du Hautmont à Vodelée (partie supérieure du Frasnien, Bassin de Dinant, Belgique). Revue De Paléobiologie 6, 193–204.

Coryell, H.N., Malkin, D.S., 1936. Some Hamilton ostracodes from Arkona, Ontario. American Museum Novitatis. 891, 20.

Edwards, D., Poiré, D.G., Morel, E.M., Cingolani, C.A., 2009. Plant assemblages from SW Gondwana: further evidence for high-latitude vegetation in the Devonian of Argentina. In: Basset, M.G. (Ed.), 2009. Early Palaeozoic Peri-Gondwana Terranes, vol. 325. The Geological Society, London, pp. 233–255.

González Bonorino, G., 1975. Acerca de la existencia de la Protoprecordillera de Cuyo. 6 Congreso Geológico Argentino Actas 1, 107.

González Bonorino, G., Middleton, G.N., 1976. A Devonian submarine fan in western argentina. Journal of Sedimentary Petrology 46, 56–69.

Grahn, Y., 2002. Upper Silurian and Devonian Chitinozoa from central and southern Bolivia, central Andes. Journal of South American Earth Sciences 15, 315–326.

Henningsmoen, G., 1953. Classification of Paleozoic straight-hinge ostracods. Norske Geologische Tidsskrift 31, 185–288.

Herrera, Z.A., 1991. Taxonomía, Bioestratigrafía y Paleobiogeografía de los braquiópodos de la Formación Talacasto (Devónico) de Precordillera Argentina. Ph.D thesi, 283.

Herrera, Z.A., 1993. Nuevas precisiones sobre la edad de la Formación Talacasto (Precordillera Argentina) en base a su fauna de braquiópodos. 12 Congreso

Geológico Argentino y 2 Congreso de Exploración de Hidrocarburos. Actas 2, 289–295.

Herrera, Z.A., 1995a. The first notanopliid brachiopod from the South American Devonian sequence. Geobios 28, 337–342.

Herrera, Z.A., 1995b. The Lower Devonian chonetoidean brachiopods from the Argentine Precordillera. In: Racheboeuf, P. (Ed.), 1995b. Four Contributions to the Study of Chonetoidean Brachiopods, vol. 136. Centre des Sciences de la Terre, Université Claude-Bernard-Lyon I, Lyon, pp. 101–147.

Herrera, Z.A., Bustos, U.D., 2001. Braquiópodos devónicos de la Formación Punta Negra, en el perfil del Río de las Chacritas, Precordillera Argentina. Ameghiniana 38, 367–374.

Herrera, Z.A., Salas, M.J., Giolitti, J.A., 1998. Chilidiopsoidea (Brachiopoda) del Devónico Inferior de la Precordillera Argentina. Revista Española de Paleontología 13, 149–166.

Hessland, I., 1949. Lower Ordovician Ostracods of the Siljan District, Sweden, vol. 33. Bulletin Geological Institution of the University of Uppsala, 97–408.

Holloway, D., Rustán, J.J., 2011. The trilobite Reedops (Phacopidae) in the Lower Devonian of Argentina (Malvinokaffric Realm). Journal of Paleontology 86, 253–257.

Le Hérissé, A., Rubinstein, C., Steemans, P., 1996. Lower Devonian palynomorphs from the Talacasto formation, Cerro del Fuerte section, San Juan Precordillera, Argentina. Acta Universitatis Carolinae, Geologica 40, 497–515.

Isaacson, P.E., 2007. Mid-Paleozoic biogeography of the Central Andes: endemic faunas, immigrants, and paleogeography. Cuadernos del Museo Geominero, n° 8. In: Díaz-Martínez, E., Rábano, I. (Eds.), 4th European Meeting on the Palaeontology and Stratigraphy of Latin America. Instituto Geológico y Minero de España, Madrid, pp. 213–218.

Keidel, J., 1921. Observaciones geológicas en la Precordillera de San Juan y Mendoza. Anales Del Ministerio de Agricultura, Sección Geología. Mineralogía y Minería 15, 7–102.

Kesling, R.V., Chilman, R.B., 1987. Dimorphic Middle Devonian Paleocopan Ostracoda of the great Lakes region. Papers on Paleontology 25, 1–227.

Kozłowski, R., 1923. Faune devonienne de Bolivie. Annales de Paleontologie 12, 1–112.

Leanza, A.F., 1968. Acerca del descubrimiento de amonoideos devónicos en la República Argentina (Tornoceras baldisi n.sp.). Revista de la Asociacion Geologica Argentina 23, 326–330.

Lethiers, F., Racheboeuf, P.R., Baudin, F., Vaccari, E., 2001. A typical malvinokaffric givetian ostracod fauna from Bolivia. Revue de Micropaléontologie 44, 301–317.

Olempska, E., 1994. Ostracods of the Mójcza Limestone. In: Dzik, J. (Ed.), Ordovician Carbonate Platform Ecosystem of the Holy Cross Mountains, Poland. Palaeontologia Polonica, vol. 53, pp. 129–212.

Olempska, E., 2002. The Late Devonian Upper Kellwasser Event and entomozoacean ostracods in the Holy Cross Mountains, Poland. Acta Palaeontologica Polonica 47, 247–266.

Padula, E.L., Rolleri, E.O., Mingramm, A.R.G., Roque, P.C., Flores, M.A., Baldis, B.A., 1967. Devonian of argentina. International Symposium on the Devonian System 2, 165–199.

Peralta, S.H., 2005. Extensional tectonic controlling the silurian and Lower Devonian basin of San Juan Precordillera, western argentina. Gondwana 12: Geological and Biological Heritage of Gondwana Abstracts 288.

Peralta, S.H., Ruzycki de Behrenstein, L.J., 1990. Icnofacies asociadas a facies turbidíticas de la Formación Punta Negra (Devónico medio-superior?), en el perfil de los Caracoles, Precordillera Central sanjuanina, Argentina. 3 Reunión Argentina de Sedimentología. Actas, 334–338.

Pinto, A., Purper, G., 1981. New lower Palaeozoic ostracodes from Bolivia. Anais Do II Congresso Latino-Americano de Paleontología, Porto Alegre, 45–59.

Pinto Bosetti, E., Grahn, Y., Horodyski, R.S., Mendlowicz Mauller, P., Breuer, P., Zabini, C., 2010. An earliest Givetian "Lilliput Effect" in the Paraná Basin, and the collapse of the Malvinokaffric shelly fauna. Paläontologische Zeitschrift 85, 49–65.

Pinto Bosetti, E., Grahn, Y., Scalise Horodyski, R., Mendlowicz Mauller, P., 2012. The first recorded decline of the Malvinokaffric Devonian fauna in the Paraná Basin (southern Brazil) and its cause; taphonomic and fossil evidences. Journal of South American Earth Sciences.

Poiré, D., Morel, E., 1996. Procesos sedimentarios vinculados a la depositación de niveles con plantas, en sucesiones siluro-devónicas de la Precordillera Argentina. 6 Reunión Argentina de Sedimentología. Actas, 205–210.

Přibyl, A., 1984. Ostracodes from the Ordovician and Silurian of Bolivia. Časopis Pro Mineralogii a Geologii 29, 353–368.

Racheboeuf, P.R., Casier, J.-G., Plusquellec, Y., Toro, M., Mendoza, D., Pires de Carvalho, M., Le Hérissé, A., Paris, F., Fernandez-Martinez, E., Tourneur, F., Broutin, J., Crasquin, S., Janvier, P., 2012. New data on the Silurian–Devonian palaeontology and biostratigraphy of Bolivia. Bulletin of Geosciences 87, 269–314.

Racheboeuf, P.R., Herrera, Z.A., 1994. On some new malvinokaffric Silurian and Devonian chonetacean brachiopods and reclassification of others. Neues Jahrbuch Für Geologie Et Paläontologie 9, 541–560.

Racheboeuf, P.R., Le Hérissé, A., Paris, F., Babin, C., Guillocheau, F., Truyols-Massoni, M., 1993. El Devonico de Bolivia: bio y cronoestratigrafia. Bulletin Institute Frances de Étude Andines 22, 645–655.

Richter, R., Richter, E., 1942. Die Trilobiten der Weismes – Shichten am Hohen Venn, mit Bemerkungen über die Malvinocaffrische Provinz. Senckenbergian 25, 156–279.

Rossi de García, E., Proserpio, C., 1975. Ostrácodos Devónicos de la zona de Jáchal, Provincia de San Juan. I Congreso Argentino De Paleontología y Bioestratigrafía. Actas 1, 241–254.

Rustán, J.J., 2011. Los trilobites devónicos de precordillera argentina: sistemática, filogenia, paleobioestratigrafía y bioestratigrafía. Tesis doctoral. pp. Universidad Nacional de Córdoba, Córdoba.

Rustán, J.J., Vaccari, N.E., 2010. The aulacopleurid trilobite Maurotarion Alberti, 1969, in the silurian-devonian of Argentina: systematic, phylogenetic and paleobiogeographic significance. Journal of Paleontology 84, 1082–1098.

Salas, M.J., 2002a. Ostrácodos binodicopas del Ordovícico de la Precordillera de San Juan, Argentina. Ameghiniana 39, 41–58.

Salas, M.J., 2002b. Ostrácodos podocopas del Ordovícico de la Precordillera de San Juan, Argentina. Ameghiniana 39, 129–149.

Salas, M.J., 2003. Ostrácodos palaeocopas, leiocopas y eridostracas del Ordovícico de la Precordillera de San Juan, Argentina. Ameghiniana 40, 345–360.

Salas, M.J., 2007. Assessing the biodiversity of Ordovician ostracods from the Argentine Precordillera. Journal of Paleontology 81, 1442–1453.

Salas, M.J., 2011. Early Ordovician (Floian) ostracods from the Cordillera Oriental, Northwest Argentina. Geological Journal 46, 637–650.

Salas, M.J., Vaccari, N.E., 2012. New insights into the early Diversification of the Ostracoda: Tremadocian ostracods from the Cordillera Oriental, argentina. Acta Palaeontologica Polonica 57, 175–190.

Salas, M.J., Vannier, J.M.C., Williams, M., 2007. Early Ordovician ostracods from Argentina: their bearing on the origin of binodicope and palaeocope clades. Journal of Paleontology 81, 1384–1395.

Sars, G.O.1, 1866. Oversigt af norges marine Ostracoder. Forhandlinger i Videnskabs-Selskabet i Christiania 1865, 1–130.

Schallreuter, R.E.L., 1972. Drepanellacea (Ostracoda, Beyrichiida) aus mittelordovizischen Backsteinkalkgeschieben IV. Laterophores hystrix sp. n., Pedomphalella germanica sp. n. und Easchmidtella fragosa (Neckaja). Berichte Deutschen Gesellschaft Geologischen Wissenschaften 17, 139–145.

Schallreuter, R.E.L., 1996. Ordovizische Ostracoden Argentiniens II. Mitteilungen Aus Dem Geologisch-Paläontologischen Institut Der Universitat Hamburg 79, pp. 139–169.

Schallreuter, R.E.L., Siveter, D.J., 1985. Ostracodes across the Iapetus ocean. Palaeontology 28, 577–598.

Siveter, D.J., Vannier, J.M.C., Palmer, D., 1991. Silurian Myodocopes: pioneer pelagic ostracods and the chronology of an ecological shift. Journal of Micropalaeontology 10, 151–173.

Troth, I., Marshall, J.E.A., Racey, A., Becker, R.T., 2011. Devonian sea-level change in Bolivia: a high palaeolatitude biostratigraphical calibration of the global sea-level curve. Palaeogeography, Palaeoclimatology, Palaeoecology 304, 3–20.

Ulrich, E.O., Bassler, R.S., 1908. New American Paleozoic Ostracoda. Preliminary revision of the Beyrichiidae, with descriptions of new genera. Proceedings of the United States National Museum 35, 277–340.

Ulrich, E.O., Bassler, R.S., 1923. Paleozoic Ostracoda: Their Morphology, Classification and Ocurrence. Maryland Geological Survey, Silurian, 271–391.

Vannier, J.M.C., Racheboeuf, P.R., Benedetto, J.L., 1995. Silurian-early Devonian ostracodes from South America (Argentina, Bolivia): preliminary investigations. Journal of Paleontology 69, 752–772.

Vannier, J.M.C., Siveter, D.J., Schallreuter, R.E.L., 1989. The composition and palaeogeographical significance of the Ordovician ostracode faunas of southern Britain, Baltoscandia, and Ibero-Armorica. Palaeontology 32, 163–222.

Wolfart, R., 1968. Die Trilobiten aus dem Devon Boliviens und ihre Bedeutung für Stratigraphie und Tiergeographie. In: Wolfart, R., Voges, A. (Eds.), 1968. Beiträge zur Kentniss des Devon von Bolivien, vol. 74, pp. 5–201.