

Biostratigraphic significance of Darriwilian conodonts from Sierra de La Trampa (Central Precordillera, San Juan, Argentina)

Ana Mestre* } CONICET–CIGEOBIO– Instituto de Investigaciones Mineras, Laboratorio de Micropaleontología, Facultad de Ingeniería, Universidad Nacional de San Juan, 5400 San Juan, Argentina
Susana Heredia }

ABSTRACT: The *Eoplacognathus pseudoplanus* Zone is defined by a conodont fauna composed by *E. pseudoplanus* (Viira) and *Dzikodus tablepointensis* (Stouge) among others in the Central Precordillera, Sierra de La Trampa region. We revised the biostratigraphical distribution and control biofacies of the conodonts *D. tablepointensis* and *E. pseudoplanus* in the Middle Ordovician of the Precordillera. This study confirms that these species has a similar biostratigraphical distribution to those of equivalent age in south-central China, Baltica and Midcontinent region. We also corroborate that the presence of *D. tablepointensis* is accurately positioned in the *E. pseudoplanus* Zone. In this paper we discuss for the first time the morphological affinities of *D. tablepointensis* and *E. pseudoplanus* elements from the Precordillera with those same species from south-central China and Baltica. On the other hand, we review the genus “*Polonodus*” *galerus* Albanesi and propose it as *Kallidontus? galerus* (Albanesi), extending the biostratigraphical record of the genus *Kallidontus* from the late Tremadocian to middle Darriwilian.

Key words: conodonts, *Dzikodus*, *Eoplacognathus*, Darriwilian, Precordillera

1. INTRODUCTION

The Lower-Middle Ordovician carbonate succession of the Precordillera is developed along a length of 400 km N-S with a width of 150 km E-W. Several classical localities at the Central Precordillera (Baldis and Chebli, 1969) were well studied by several authors (synthesis in Benedetto et al., 2007). The Middle Ordovician succession in the Sierra de La Trampa is characterized by carbonate and fine mixed carbonate/siliciclastic deposits (Mestre, 2010). The sections Las Chacritas River (LCHA) and the Quebrada de la Brecha (QB) are considered as the most complete and well exposed for detailed analysis of Middle Ordovician conodont biostratigraphy from western most area of Central Precordillera (Fig. 1).

The conodont taxa retrieved from the investigated sections are typical of the *E. pseudoplanus* Zone, Middle Darriwilian (Mestre, 2010; Heredia and Mestre, 2011; Heredia, 2011; Mestre, in press). The key conodonts present in this association are *Eoplacognathus pseudoplanus* (Viira) and *Dzikodus tablepointensis* (Stouge).

The focus of this paper is the stratigraphical and regional distribution of *Dzikodus tablepointensis* and *Eoplacognathus pseudoplanus* in the Central Precordillera. We evaluate the biostratigraphical and biofacial significance of these species in the Darriwilian of the Precordillera, also we consider the morphological affinities showed by the apparatuses of *D. tablepointensis* and *E. pseudoplanus* with those species from Baltica and south-central China. Finally, we present new pectiniform conodonts from the *E. pseudoplanus* Zone.

2. METHODOLOGY

Conodont samples were collected from limestone beds at 10–15 cm intervals from the uppermost part of the San Juan Formation at the Quebrada de la Brecha section and 1 m intervals at the Las Chacritas River section (Fig. 2). We showed a simplified lithological column, sampled level and stratigraphical range of conodont taxa are combined in the column (Fig. 2).

Initially, 1–2 kg of each sample was dissolved in dilute formic acid with additional material processed if needed. The insoluble fraction of each sample was picked for conodonts resulting in recovery of ca. 6770 identifiable conodont elements. All elements have a colour alteration index of 2–3 (60–200 °C) (Epstein et al., 1977). Conodonts are housed in the collection of the INGENIO at the Universidad Nacional de San Juan, under the code-MP.

3. GEOLOGICAL SETTING AND STRATIGRAPHY

The Middle Ordovician outcrops of Sierra de La Trampa have been described and discussed by several authors, the emphasis usually being placed on stratigraphy, sedimentology and microfossil biostratigraphy (Espizúa, 1968; Peralta and Baldis, 1995; Astini, 1994; Carrera, 1997; Carrera and Astini, 1998; Peralta et al., 1999a, b; Keller, 1999; Mestre, 2010).

In this region the carbonate Ordovician succession begins with the Lower–Middle Ordovician San Juan Formation, composed mainly of fossiliferous limestone and marly limestone. Its base is concealed by faulting but the exposed part

*Corresponding author: amestre@unsj.edu.ar

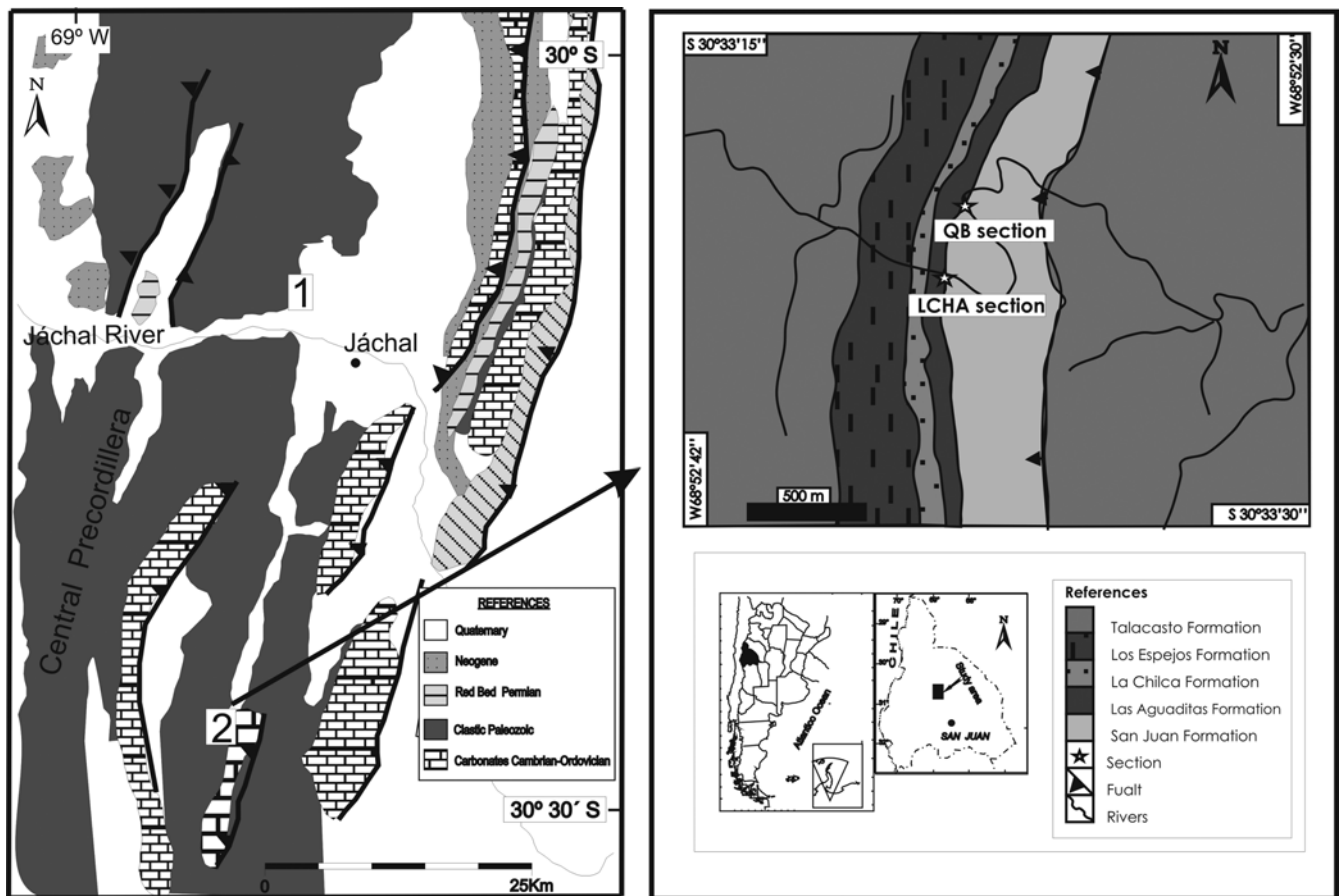


Fig. 1. Geological map of Central Precordillera. 1: Quebrada Ancaucha section (Yerba Loca Formation), 2: Sierra de Trampra, Quebrada de la Brecha section (QB) and Las Chacritas section (LCHA) (Detail map).

is 240 m thick in the area (Heredia et al., 2011). The San Juan Formation is conformably overlain by 55 m of thin- to medium-bedded marly limestone and black shale of the Las Aguaditas Formation of Middle to Late Ordovician age (Heredia et al., 2011). This latter unit consists of tabular, thin- to medium-bedded, dark mudstone, nodular fossiliferous wackestone to packstone, black shale and sparse thin beds of bentonite. The contact between the San Juan and Las Aguaditas Formations is transitional; the first level of black shale being used as the arbitrary boundary between these units.

Our biostratigraphical study focuses on the last three meters in the upper part of the San Juan Formation and the two first meters in the lower member of Las Aguaditas Formation (Fig. 2). In the both sections, the top of the San Juan Formation is characterized by dark grey grainstone and bioclastic packstone, with plates of crinoids, brachiopods, trilobites and nautiloids. A hardground is developed at the contact with Las Aguaditas Formation. The lowest level of Las Aguaditas Formation consists of unfossiliferous marly mudstone and very thin black shale levels with sporadic packstone-grainstone bioclastic strata (Fig. 2).

4. CONODONTS

Although this paper focuses on the conodont species *D. tablepointensis* and *E. pseudoplanus*, the composition of the remainder of the middle Darriwilian conodont fauna specially that of the *E. pseudoplanus* Zone, of the LCHA and QB sections, is also of interest. This consists of *Ansella jemtlandica* Löfgren, *Baltoniodus medius* Dzik, *Costiconus ethingtoni* (Fåhræus), *Cornuodus longibasis* Lindström, *Drepanodus gracilis* Branson & Mehl, *Drepanodus robustus* Hadding, *Drepanoistodus basiovalis* (Sergeeva), *Drepanoistodus pitjanti* Cooper, *Dzikodus tablepointensis* (Stouge), *Eoplacognathus pseudoplanus* (Viira), *Erraticodon balticus* Dzik, *Histiodela kristinae* Stouge, *Histiodela holodentata* Ethington & Clark, *Kallidontus? galerus* (Albanesi), *Microzarkodina* cf. *M. ozarkodella* Lindström, *Parapanderodus elegans* Stouge, *Parapaltodus simplicissimus* Stouge, *Paroistodus horridus* Barnes & Poplawski, *Periodon aculeatus zgiezrensis* (Dzik), *Protopanderodus calceatus* Bagnoli & Stouge, *Protopanderodus graeai* (Hamar), *Pteracontiodus cryptodens* Mound, Gen. et sp. indet. A and Gen. et sp. indet. B (Fig. 2).

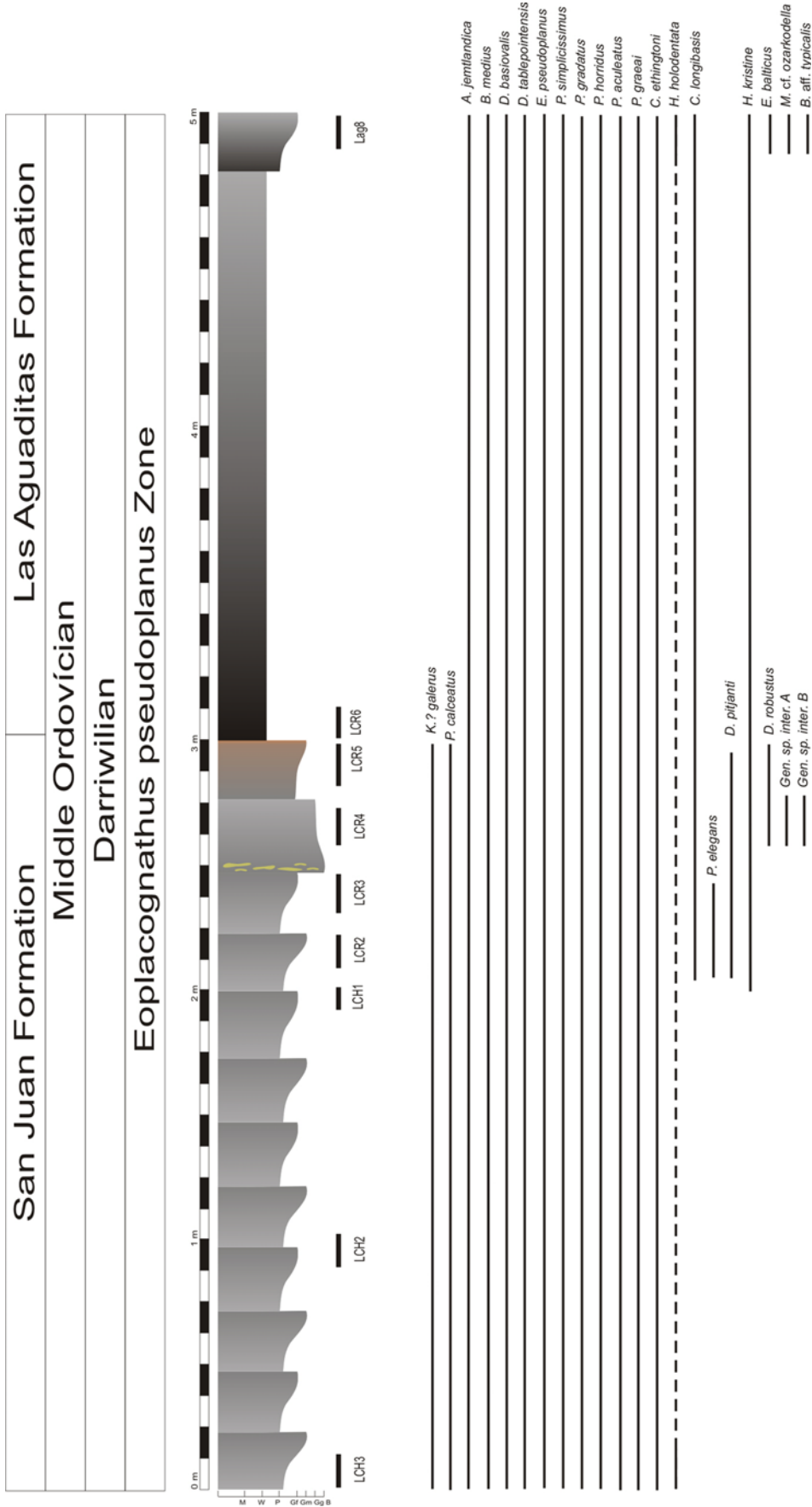


Fig. 2. Stratigraphic column of the San Juan and Las Aguaditas Formations in QB and LCHA sections, showing the samples levels and stratigraphic ranges of conodont taxa.

5. SYSTEMATIC PALEONTOLOGY

The complete apparatuses of the species *D. tablepointensis* and *E. pseudoplanus* have been described and figured by Zhang (1998) and Löfgren and Zhang (2003).

The species *D. tablepointensis* and *E. pseudoplanus* have been mentioned in several papers regarded to Middle Ordovician strata of Precordillera; however the elements of the *D. tablepointensis* apparatus have not been described and compared to specimens of other regions before. We figure for the first time the complete apparatuses of these both species discussing their morphological affinities. On the other hand, we record the genus *Kallidontus?* and new conodonts not identified previously.

We use the Pa-Pb, Sa-Sd and M terminology for notation of conodont elements in the way suggested by Sweet (1981, 1988).

Order Prioniodontida Dzik, 1976

Superfamily Prioniodontacea Bassler, 1925

Family Pygodontidae Bergström, 1981

Genus *Dzikodus* Zhang, 1998

Type species: *Polonodus tablepointensis* Stouge, 1984

Dzikodus tablepointensis (Stouge)

Figures 5a–i.

Synonymy: Complete synonymy in Zhang (1998)

2000. *Dzikodus tablepointensis* (Stouge). Löfgren, pl. 6, fig. P.

2002. *Dzikodus tablepointensis* (Stouge). Pyle and Barnes,

pp. 208, pl. 20, figs. 1–7.

2004. *Dzikodus tablepointensis* (Stouge). Löfgren, pp. 512, pl. 7, figs. x and y.

2005. *Dzikodus tablepointensis* (Stouge). Heredia et al., pp. 389, pl. 3, fig. C.

2008. *Dzikodus tablepointensis* (Stouge). Voldman et al., pp. 455, pl. 4, figs. d, k and x.

2010. *Dzikodus tablepointensis* (Stouge). Mestre, pp. 323, pl. 7, figs. A–I.

Description: Sinistral and dextral Pa elements are basically symmetric with respect with to one other. As Zhang (1998) describes, the antero-lateral process gradually forms at the outside of the anterior process, and the postero-lateral process at the inside of the posterior process. The antero-lateral process subsequently forms one secondary lateral process, and then may branch posteriorly to form another secondary lateral process. In mature specimens the anterior process develops a secondary lateral process on the outside. The anterior and antero-lateral processes are longer than the posterior and postero-lateral processes. The anterior process has a wide platform and curves inward-downwards. The denticle rows on the anterior and posterior processes are continuous and form a curved line when seen from above. The antero-lateral process is straight and has narrow platform ledges and makes an angle of about 80–100 degrees

with the anterior process. The posterior and postero-lateral processes have wide platform ledges.

According to Zhang (1998), the sinistral and dextral Pb elements of *D. tablepointensis* are unpaired and do not forms mirror images of one another, both have the four processes, the anterior and antero-lateral processes have narrow platform ledges and the posterior and postero-lateral process have wide platforms.

The surface of the Pa and Pb elements are ornamented by low nodes and transverse ridges, and both elements have large basal cavities.

The M element has a broad cusp and reclines. The anterior process presents denticles. The basal cavity is wide and shallow. The aboral margin is directed firstly top and, below, down towards later.

The Sb and Sd elements (ramiforms) have a recurved cusps (hook-shaped) and all processes are equipped with apically free denticles.

The Sa elements have a recurved cusp, all three processes are regularly denticulated and the denticles are apically free.

Remarks: Most P element in the San Juan Formation material is broken, but S and M elements have a good preservation. The Pa elements present in the Precordillera are comparable with the material of *D. tablepointensis* figured by Zhang (1998) from Guniutan Formation (pl. 7, figs. 1–6; pl. 8, figs. 1 and 2). Only one Pb element recovered completely differs from such material because the anterior process is outer-laterally curved. The M elements is identical to that figured by Zhang (1998; pl. 8, fig. 3). The Sa elements show close similarity to that figured by Zhang (1998; pl. 8, fig. 4). The Sb and Sd elements from the Precordillera show the cusps more curved than the S elements from south-central China figured by Zhang (1998; pl. 8, figs. 5–6). These S elements present strong differences with the S element figured by Rasmussen (2001; pl. 15, figs. 7–8, 12).

Discussion: Stouge (1984) defined the new species “*Polonodus tablepointensis*” which appeared in the *Histioidella kristinae* Zone in the Table Head Formation, Newfoundland. Later, Zhang (1998) redescribed the genus *Polonodus* by defining *Polonodus s.s.* and *Dzikodus*. These Ordovician platform conodonts have several species; most of them are guide taxa of worldwide distribution. Zhang (1998) also proposed a new conodont zone based on the short vertical distribution of *Dzikodus tablepointensis* in the Yangzte Platform, south-central China. The *Dzikodus tablepointensis* Zone was subdivided into two subzones, the lower *Microzarkodina hagetiana* and the upper *M. ozarkodella*.

Derivation of the defined of genus *Dzikodus* has been taxonomically complex. As noted by previous authors (Löfgren, 1978, 1990; Stouge, 1984; Zhen and Percival, 2004) *Polonodus* Dzik was based on a very limited number of platform elements from the middle Darriwilian of Estonia and Poland. Dzik (1976) originally defined *Polonodus* as “Conical conodonts with 4 lobes covered with concentric

Sistem	Series			Stages			Baltica	south-central China	Precordillera	
	Global	Britain	N.Amer.	Global	Austr.	China				
Ordovician	Middle	Llanvirnian	Whiterockian	Darrivilian	Darrivilian	Zhejiangian	Zhang(1997,1998) Bagnoli & Stouge (1997)	Zhang(1998)	Heredia & Mestre (2011)	
							<i>P. anserinus</i>	<i>P. anserinus</i>		
							<i>P. serra</i>	<i>li.</i>	<i>Y. protoramosus</i>	
								<i>ro.</i>		
								<i>re.</i>	<i>Y. foliaceus</i>	
	<i>fo.</i>									
	<i>E. suecicus</i>	<i>P. anitae</i>	<i>E. suecicus</i>	<i>E. suecicus</i>	<i>P. anitae</i>					
		<i>P. lunnensis</i>			?					
	<i>E. pseudoplanus</i>	<i>M. ozarkodella</i>	<i>Dzikodus tablepointensis</i>	<i>M. ozarkodella</i>	<i>Eoplacognathus pseudoplanus</i>					
		<i>M. hagetiana</i>				<i>M. hagetiana</i>				
<i>Y. crassus</i>	<i>Y. crassus</i>	<i>Y. crassus</i>	<i>Yangtzeplacognathus crassus</i>							
<i>Lenodus variabilis</i>	<i>Lenodus variabilis</i>	<i>Lenodus variabilis</i>	<i>Lenodus variabilis</i>							

Fig. 3. Chronostratigraphic and conodont biostratigraphic subdivision of the Middle Darrivilian sequence.

and radial rows of tubercles. Very large basal cavity.”

Löfgren (1978) noted that two types of four-branched elements were represented, one group with well developed anterior platform and the second group, which Dzik (1976) assigned to *Polonodus*. Later, basically two-group nature of the *Polonodus* plexus was further emphasized by Stouge (1984). The first of these, *P. clivosus* (Viira) sensu Löfgren (1978) and *P. newfoundlandensis* Stouge 1984, comprises polyplacognatiforms elements which have large basal cavity and outer blade-like process, but the ambalodontiforms have a restricted basal cavity. The second group comprises of two types of elements: polyplacognatiforms and ambalodontiforms, but both elements have deep and wide basal cavity.

Löfgren (1990) recognized one geniculate and three ramiforms elements and proposed these elements as part of the *Polonodus* apparatus.

Finally, Zhang (1998) proposed that genus *Polonodus* should be restricted to *P. newfoundlandensis* species group only, while genus *Dzikodus* applied to *P. tablepointensis* species group of Stouge (1984) and present the complete apparatus of this species.

Stouge and Bagnoli (1999) accepted this proposal, also assigned *Dzikodus* and *Polonodus* to different orders and families. They interpreted *Dzikodus* to compose of a seximembrate apparatus as defined by Zhang (1998), while *Polonodus* was considered as bimembrate apparatus.

The species *Dzikodus tablepointensis* was also reported in Baltoscandia (Rasmussen, 2001; Löfgren, 2004), the North America Midcontinent in Nevada and Southeast Cal-

ifornia (Harris et al., 1979), the Canadian Midcontinent in Northeastern British Columbia (Pyle and Barnes, 2002) and the Argentine Precordillera (Heredia et al., 2005; Voldman et al., 2008; Mestre, 2010).

Occurrence: San Juan Formation, LCR2, LCR3, LCR4 and LCR5 (Quebrada de la Brecha section) and LCH1 to LCH3 (Rio Las Chacritas section), *E. pseudoplanus* Zone.

Material: 8 dextral Pa, 6 sinistral Pa and 26 fragments Pa; 1 sinistral Pb and 14 fragments Pb; 12 M; 12 Sa; 5 Sb and 7 Sd.

Repository numbers: INGENO-MP LCR2: 1756 (1-17); LCR3: 1775 (1-34); LCR4: 1791(1-9); LCR5: 1807 (1-12); LCH1: 102 (1-10); LCH3: 128 (1-9); Lag 8: CML-C-3404 (1-2).

Order PRIONIODONTIDA

Superfamily PRIONIODONTACEA

Family POLYPLACOGNATHIDAE Bergström, 1971

Genus *Eoplacognathus* Hamar, 1966

Type species: *Ambolodus lindstroemi* Hamar, 1964

Eoplacognathus pseudoplanus (Viira), 1974

Figures 5j-r.

Complete synonymy in Löfgren and Zhang (2003).

1974. *Ambalodus pseudoplanus* Viira, p. 54, figs. 43-46, pl. 6, figs. 25, 29, 31.

2005. *Eoplacognathus pseudoplanus* (Viira). Heredia et al., pp. 389, pl. 3, fig. D.

2008. *Lenodus variabilis* Sergeeva. Voldman et al., pp. 455, pl. 4, fig. j.

2010. *Eoplacognathus pseudoplanus* (Viira). Mestre, pp.

321, pl. 6, figs. A–N.

Description: In the Pa elements, the posterior process is not 180° with respect to the anterolateral process, the posterior process is curved inwards, generating that the row of denticles is also curved. The Pa elements usually have a high ratio of length between the posterior process and posterolateral process.

The Pb elements have the process is curved inwards and directed downward, while the posterior process presents a wide platform similar to the elements figured by Löfgren and Zhang (2003, pl. 13, figs. 7–8, 11–13). The Pa and Pb elements have the polygonal texture on the platforms common in all the pectiform elements. The M and S elements identical with those of Löfgren and Zhang (2003).

Remarks: The Pa elements recovered present some differences with specimens described previously from Baltica (Löfgren and Zhang, 2003), but the curved posterior process allows to compare them with those described for south-central China (Zhang, 1998; pl.9, figs. 1 and 2).

Discussion: Lofgrén and Zhang (2003) discussed about the lineage relation between the Darriwilian platform-equipped conodonts, they observed strong ties between the genera *Trapezognathus*-*Lenodus*-*Yangtzeplacognathus*-*Eoplacognathus*, mainly in the shape of their septimembrate apparatuses. The similarities between the M elements, as the similarities of the S elements, almost indistinguishable in any of the four genera, as the general morphology of P forms, allow suggest that these all genera could be included in the Balognathidae family.

However, the genus *Eoplacognathus* was defined by Bergström (1971) as belonging to the Polyplacognathidae, being formed by a bimembrate apparatus (only P elements), but following the proposal mentioned above the species *E. pseudoplanus* and their direct descendant *E. suecicus* could be included in the Balognathidae. Stouge and Bagnoli (1990) assigned to *E. pseudoplanus* species to the genus *Lenodus* due to the composition of its apparatus. However, in this paper we will continue using the genus *Eoplacognathus* following Löfgren and Zhang (2003) criteria, accepting that more studies on this subject must be made.

Occurrence: San Juan Formation, LCR2, LCR3, LCR4 y LCR5 (Quebrada de la Brecha section), LCH1 to LCH3 (Río Las Chacritas section), and Lag 8, *E. pseudoplanus* Zone.

Material: 10 dextral Pa; 5 sinistral Pa; 2 dextral Pb; 4 sinistral Pb and 45 fragments P; 3 M; 24 Sa; 17 Sb y 1 Sc.

Repository numbers: LCR2: INGeo-MP 1757 (1-39); LCR3: 1776 (1-22); LCR4: 1792 (1-15); LCR5: 1808 (1-23); Lag8: CML-C 3400 (1-12).

Family Fryxellodontidae Miller, 1981

Kallidontus? galerus (Albanesi)

Figures 4d–e.

Synonymy

1987. *Polonodus tablepointensis* Stouge, 1984. Hünicken

and Ortega, pp.140–141, pl. 7.1, fig. 1.

1987. *Serratognathus?* sp. Sarmiento, pp. 307–308, pl. 36, fig. 2.

1991. *Serratognathus?* sp. Sarmiento, pp. 123–124, pl. 2, fig. 20.

1995. *Polonodus* sp. Ortega et al., pp. 362–363, pl. 6, fig. 18.

1998. *Polonodus galerus* n. sp. Albanesi, pp. 109–111, pl. 7, figs. 28–31.

1998. Gen. et. sp. indet. A. Zhang, pp. 148, pl. 20, figs. 11 and 12.

2000a. “Pyramid” form. Löfgren, pp. 58, pl. 4, fig. aa.

2000b. “Pyramid” form. Löfgren, pp. 326, pl. 5, fig. Y.

2005. *Polonodus galerus* Albanesi. Heredia et al., p. 289, pl. 3, fig. H.

Description: The apparatus consists of conical S elements and platform P elements.

P elements are crossed by transverse ridges, the basal cavity is wide and deep, and the basal margin is slightly arched. All the P elements are stout, broad based and expanded in anterior and posterior direction. The P elements have features of caplike and the anterior and the posterior faces of the cusp are convex, giving the basal margin an S-shape in oral view.

The conical S elements have deep basal cavity, and cusp tip filled with white matter. These coniform elements are simple costate forms. S elements bear a costa on the posterior face of the cusp and anterior face of the cusp is smooth. Elements are stout with small cusp tip, recurved posteriorly and filled with white matter.

Remarks: Based on the similarity between Albanesi’s material and our own material with the genus *Kallidontus* Pyle and Barnes, we proposed assigning the species *galerus* to this genus; thus, being the youngest record of the genus *Kallidontus?*

Lofgren (2000a, b) figured the conodont as pyramid form in the *B. norrlandicus* Zone (*T. quadrangulum* and *L. anti-variabilis* subzones), we interpret that probably these element are S and P elements of *K?. galerus*.

Zhang (1998) reported from the Guniutan Formation of the Maocaopu Section (south-central China) in *L. variabilis* to *E. pseudoplanus* zones, an apparatus of Gen. et. sp. indet. A assigned to P and S elements. We interpret that those S elements belong to *K?. galerus*. This species described by Zhang has a similar biostratigraphic distribution to *K?. galerus* in Argentina Precordillera.

Discussion: The genus *Kallidontus* was defined by Pyle and Barnes (2002) for the Tremadocian – Arenig of the Canadian Midcontinent in Northeastern British Columbia. *Kallidontus* was included into the Family Fryxellodontidae and present an apparatus with P and S elements. Pyle and Barnes (2002) described three species, *K. princeps*, *K. serratus* and *K. nodosus*.

Albanesi (1998) created a new species *Polonodus galerus* from Darriwilian of the Precordillera, this species consisted

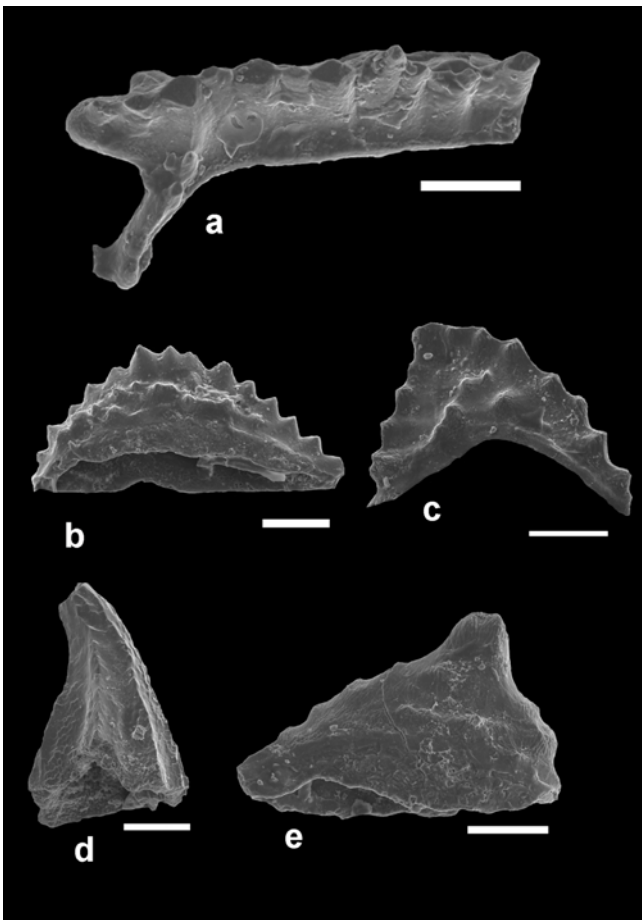


Fig. 4. Scanning Electron Microscope microphotographs of conodonts. Scale bar indicates 100 μm . All figured specimens are from the Darriwilian, San Juan and Las Aguaditas Formation, QB and CHLA section. **a.** Gen. et. sp. indet. A, P element, upper-lateral view, sample LCR4, INGEO-MP 1822 (1), **b.**, **c.** Gen. et. sp. indet. B; **b.** Pa element, lateral view, samples LCR4, INGEO-MP 1823 (1), **c.** Pb element, lateral view, sample LCR4, INGEO-MP 1823 (2); **d.**, **e.** *Kallidontus? galerus* (Albanesi); **d.** S element, antero-lateral view, sample LCR3, INGEO-MP 1781 (1), **e.** P element, lateral view, sample LCR3, INGEO-MP 1781 (2).

of multielement apparatus with P and S elements. This author mentioned the strong relationship to the Family Fryxellodontidae and recognized this species as an early form of the genus *Polonodus*, but co-occurring with late forms of *Polonodus* and *Dzikodus*. Despite this, Albanesi (1998) assigned the species “*galerus*” to genus *Polonodus*. Later, Albanesi et al. (2003) proposed the re-assignment of the ancestor of *K? galerus* in Precordillera, *Polonodus corbatoi* as *Kallidontus corbatoi*.

The *Kallidontus? galerus* is fairly scarce in the conodont-fauna analyzed with a maximum of 0.1%. The biostratigraphical distribution of the genus *Kallidontus*, previously known only from the Lower Ordovician, now can be extended up into the middle Darriwilian. On the other hand, we have reviewed the specimens present in Baltic and south-central

China without taxonomic assignment, thus we propose its assignment as *Kallidontus? galerus*.

Occurrence: San Juan Formation, samples LCR2, LCR3 and LCR5, *E. pseudoplanus* Zone.

Material: 1 P and 3 s.

Repository numbers: INGEO-MP LCR2: 1764 (1); LCR3: 1781 (1-2); LCR5 1813 (1)

Gen. et. sp. indet. A

Figure 5a.

Description: The material consists only of stelliscaphate P element. This presents a large and long pectiniform anterior process with large denticles. The cusp is the same size to the anterior denticles. Posterior process is little developed with two small denticles and shows a small lobe with row. Both distal ends of the platform ledges are blunt, also has a polygonal texture pattern on the platforms ledges.

This species has the posterior-lateral process with 4 denticles and presents an expansion of platform in the distal end, the angle between the posterior-lateral process and posterior process is wide (nearly 90°).

Remarks: Based on the morphological characteristics, we assign this specimen to the Family Polyplacognathidae Bergström, however the large anterior process suggested a more closer relationship to the Family Pygodontidae Bergström.

Occurrence: San Juan Formation, LCR4 (Quebrada de la Brecha section), *E. pseudoplanus* Zone.

Material: 1 P

Repository numbers: INGEO-MP 1822 (1)

Gen. et sp. indet. B

Figures 5b–c.

Description: The two elements have a small cusp and a very large basal cavity. The Pa element is pectiniform element with an anterior and posterior process with small denticles, it presents a inconspicuous cusp in the medial position, cusp and denticles are equal in size. The surface of platform is ornamented by low nodes. The Pb element is crest shaped, the denticles are fused and the cusp is equal size that denticles. The basal margin is bent to sinuous. The surface is ornamented by low nodes.

Occurrence: San Juan Formation LCR4 (Quebrada de la Brecha section) *E. pseudoplanus* Zone.

Material: 1 Pa and 1 Pb.

Repository numbers: INGEO-MP 1823 (1-2).

6. BIOESTRATIGRAPHICAL DISCUSSION

The middle Darriwilian conodont fauna of the LCHA and QB sections is very similar at species level to correlative faunas of the Baltic and south China regions (Sarmiento,

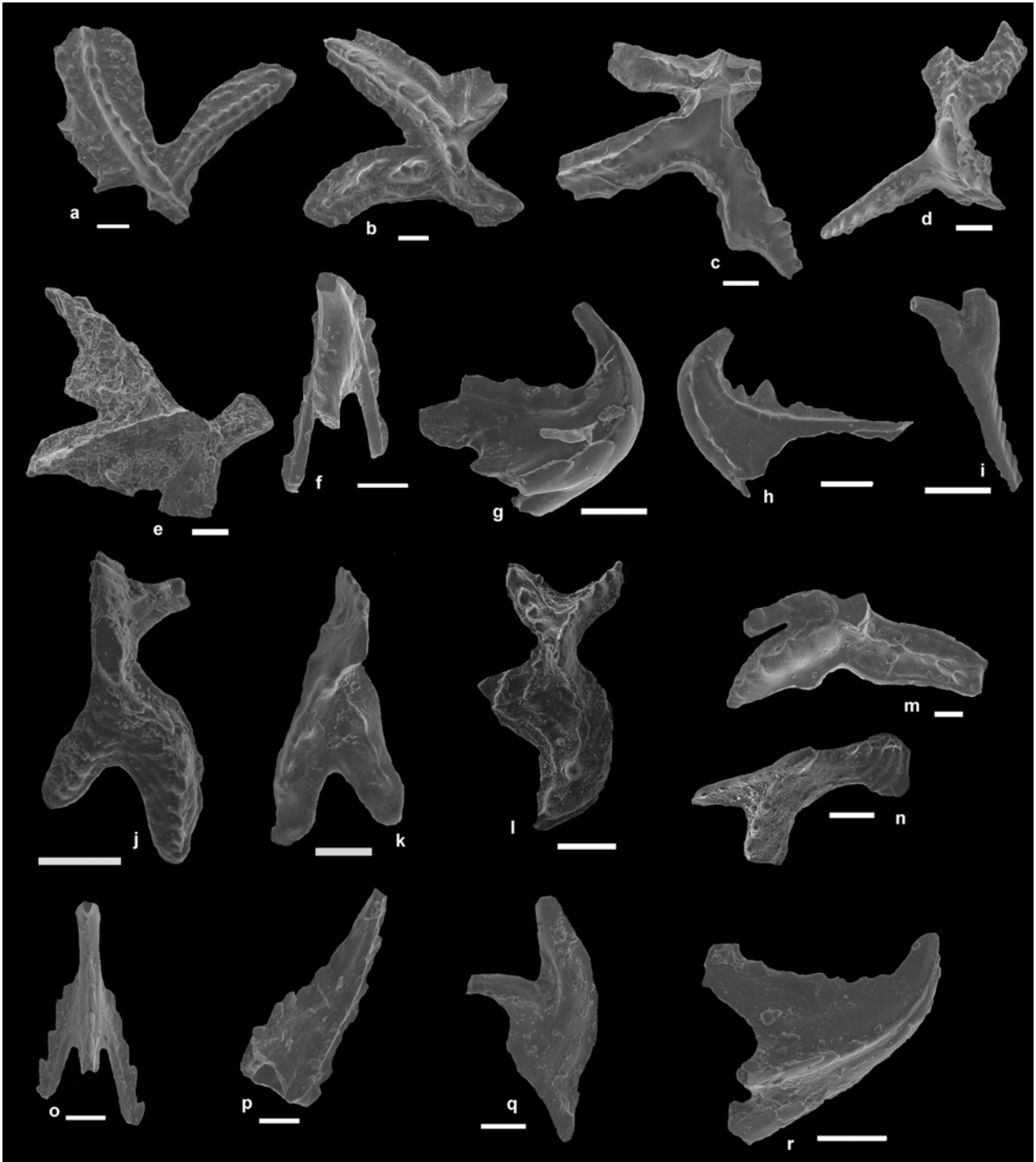


Fig. 5. Scanning Electron Microscope microphotographs of conodonts. Scale bar indicates 100 μ m. All figured specimens are from the Darriwilian, San Juan and Las Aguaditas Formation, QB and CHLA section. **a–i.** *Dzikodus tablepointensis* (Stouge); **a.** Dextral Pa element, upper view, samples LCR5, INGEO-MP 1807 (1); **b.** Sinistral Pa element, upper view, sample LCR5, INGEO-MP 1807 (2); **c.** Sinistral Pa element, anterior view, sample LCR3, INGEO-MP 1775 (1); **d.** Sinistral Pb element, upper view, sample LCR2, INGEO-MP 1756 (1); **e.** Dextral Pa element, upper view, sample LCR3, INGEO-MP 1775 (1); **f.** Sa element, posterior view, sample LCR3, INGEO-MP 1775 (2); **g.** Sb element, lateral view, sample LCR5, INGEO-MP 1807 (3); **h.** Sd element, lateral view, sample LCR5, INGEO-MP 1807 (4); **i.** M element, lateral view, sample LCR3 INGEO-MP 1775 (3); **j–r.** *Eoplacognathus pseudoplanus* (Viira), **j.** Dextral Pa element, upper view, sample LCR2, INGEO-MP 1757 (2); **k.** Sinistral Pa element, upper view, sample LCR2, INGEO-MP 1757 (4); **l.** Dextral Pa element, upper view, samples Lag8, CML-C 3400/3; **m.** Sinistral Pb element, upper view, sample LCR4, INGEO-MP 1794 (1); **n.** Dextral Pb element, anterior view, sample Lag8, CML-C 3400/ 2; **o.** Sa element, posterior view, sample LCR3, INGEO-MP 1776 (1); **p.** Sb element, lateral view, sample LCR2, INGEO-MP 1757 (5); **q.** M element, lateral view, sample LCR2, INGEO-MP 1757 (6); **r.** Sc element, lateral view, sample LCR2, INGEO-MP 1757 (7).

1985; Albanesi et al., 1998; Heredia et al., 2005a; Mestre, 2010; Heredia and Mestre, 2011). Nevertheless, the Darriwilian conodont zonation of the Precordillera does not match to those established in Baltica and south China (Albanesi and Ortega, 2002) because of the poorly resolved distribution of certain index species in the Precordillera. Recently, Heredia and Mestre (2011) proposed a new Darriwilian conodont biostratigraphical chart, which shows the close association to the Baltic and south China biostratigraphical chart (Fig. 3).

Stouge (1984) erected two phylozones from the Table Head Formation of Newfoundland, defining *H. tableheadensis* (= *H. holodentata*) and *H. kristinae* and proposed the new species "*Polonodus tablepointensis*" that appeared in the middle and upper part of *H. kristinae* Phylozone.

Zhang (1998) erected the *Dzikodus tablepointensis* Zone in south China, divided into the *M. hagetiana* and *M. ozarkodella* subzones (Fig. 3), the lower boundary of this zone coincides with the disappearance of *Yangtzeplacognathus crassus* and the upper boundary coincides with the first appearance of *E. suecicus*. In Baltica, the middle Darriwilian conodont zonation includes four successive zones (Löfgren, 2000, 2004; Löfgren and Zhang, 2003): *Lenodus variabilis*, *Yangtzeplacognathus crassus*, *Eoplacognathus pseudoplanus* (*M. hagetiana* and *M. ozarkodella* subzones) and *Eoplacognathus suecicus* (*P. lunnensis* and *P. anitae* subzones; Fig. 3). The oldest appearance of *D. tablepointensis* is at the middle part of the *M. hagetiana* Subzone, having the co-occurrence with its ancestor *D. hunanensis* Zhang. The stratigraphical considerations outlined above suggest that the base of the *E. pseudoplanus* Zone in Baltoscandia may be slightly lower than the base of the *D. tablepointensis* Zone in south-central China as proposed by Löfgren and Zhang (2003).

Heredia et al. (2005) reported *D. tablepointensis* in the uppermost level of "Las Chacritas Formation" on the LCHA section and proposed the combined zone with *E. pseudoplanus*.

Voldman et al. (2008) mentioned and figured P elements of *D. tablepointensis* on the lower levels of the Yerba Loca Formation in the Quebrada Ancaucha section (Fig. 1).

In the Argentine Precordillera *D. tablepointensis* has occurred in the LCHA and QB sections in the upper part of the San Juan Formation. On the other hand, the record of *D. tablepointensis* appeared in association with *E. pseudoplanus* (late forms), *H. kristinae*, *H. holodentata*, and *M. sp. cf. M. ozarkodella*, suggesting that all these species occurred within an interval of the *E. pseudoplanus* Zone. This represents a similar biostratigraphical distribution to that reported in Baltoscandia, south China and Midcontinent regions (Stouge, 1984; Löfgren, 2004; Pyle and Barnes, 2002; Zhang, 1998).

7. BIOFACIES

Conodont paleoecology and biofacies models have been discussed since at least the '70, when Seddon and Sweet (1971) presented a model where conodont biofacies were

based on depth-stratification of the planktic forms. In essence, this model was also used by Zhang (1998) to explain the distribution of some key forms in her Middle Ordovician sections from south-central China.

Zhang (1998) defined four biofacies from shallow to deep platform facies which are: *Periodon* Biofacies, *Protopanderodus* Biofacies, "*Walliserodus*" Biofacies and *Spinodus* Biofacies. She placed the genus *Dzikodus* in the "*Walliserodus*" Biofacies, indicative of deep oceanic water. *E. pseudoplanus*, on the other hand, probably inhabited shallower water (Viira et al., 2001).

D. tablepointensis and *E. pseudoplanus* in Precordillera have strong biofacial control, in the studied sections (Sierra de la Trampa region) they appear together, but in sections with shallower deposits of the Central Precordillera located eastward, such as the Cerro La Chilca section, only *E. pseudoplanus* is present. In the same way that occurred in Baltica and south-central China, *E. pseudoplanus* inhabited shallow middle ramp environment in the Precordillera, but it was not exclusive of this environment because it appears associated to *D. tablepointensis*, which is present in distal ramp deposits linked to oceanic water.

8. CONCLUSIONS

The *D. tablepointensis* and *E. pseudoplanus* have significant biostratigraphical value in Baltica and China. In the Middle Darriwilian of the Argentine Precordillera, these species allow to record the *E. pseudoplanus* Zone.

This biostratigraphical study reveals that the uppermost levels of the San Juan Formation and the lowermost levels of Las Aguaditas are restricted to the *E. pseudoplanus* Zone. The *D. tablepointensis* and *E. pseudoplanus* in the Precordillera present close morphological affinities with those from the Yangtze platform (south-central China).

The palaeoecology distribution of *E. pseudoplanus* is considered as being not primarily dependent on water depth, whereas *D. tablepointensis* obviously preferred deeper open oceanic water.

We have reviewed the taxonomic assignation of the species "*Polonodus*" *galerus* Albanesi, thus we propose the genus *Kallidontus?* in the Argentina Precordillera, extending the biostratigraphical record of this genus to the middle Darriwilian.

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