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# A new species, *Ozarkodina huenickeni*, from the upper Silurian - Lower Devonian in San Juan Precordillera, South America

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**Abstract**

The study on Silurian-Devonian conodonts from the Precordillera has shown a significant increase in the last 5 years. In the new conodont collections, particular specimens of *Ozarkodina* were obtained from the middle and upper parts of the Los Espejos Formation in the Talacasto region. The taxonomic study allows us to propose a new species of the genus *Ozarkodina*, named *Ozarkodina huenickeni* sp. nov., which shows three different morphotypes,  $\alpha$ ,  $\beta$  and  $\gamma$ , respectively, based on the presence of ornamentation above the platform lobes. The species ranges from the *Pedavis latialata*-*Ozarkodina snajdri* interval Zone to the *Icriodus hesperius* Zone, Ludfordian to early Lochkovian in age. The phylogenetic analysis of *Oz. huenickeni* sp. nov. allows us to propose that this species could belong to the *bohémica* lineage, probably representing a South American endemic taxon.

**Keywords:** *Ozarkodina*; Precordillera; New species; Silurian; Phylogeny.

## 1. Introduction

The generic denomination *Ozarkodina* was assigned for the first time to an angulate element (*Ozarkodina typica*) defined by Branson & Mehl (1933) in their extensive study on Silurian conodonts from Bainbridge of Missouri. Later this element was included as P2 element in the multielement apparatus of the genus *Ozarkodina* (Sweet, 1981). The genus *Ozarkodina* has a seximembrate apparatus that is composed of carminate P1 element, angulate P2 element, dolabrate or bipennate M elements, and a transition series of alate, extensiform digyrate and bipennate elements in S0, S1 and S2 positions, respectively (Sweet, 1988; Purnell et al. 2000). The genus *Ozarkodina* presents a great number of species with significant biostratigraphic value from the Llandovery to Middle Devonian, showing a wide record in Europe, North America, and Australia.

The Silurian-Devonian strata from Precordillera are well exposed in several areas of the Central Precordillera, but for a long time, the information about conodonts has been relatively scarce. The studies on Silurian and Devonian conodonts have experimented significant progress in the last 5 years (Gómez, 2015; Mestre et al. 2017; Gómez et al. 2019) providing new perspectives on biostratigraphy and diversity of conodont associations which will be developed in future studies.

In our conodont collections from the Silurian and Lower Devonian strata from the Precordillera, we have recognized specimens belonging to the genus *Ozarkodina*, whose elements exhibit distinctive features that allow us to propose a new species, probably endemic, for South America. The aim of this contribution is to develop a taxonomic study, as well as to determine the origin and lineage of this new species of the genus *Ozarkodina*.

## 2. Geological settings

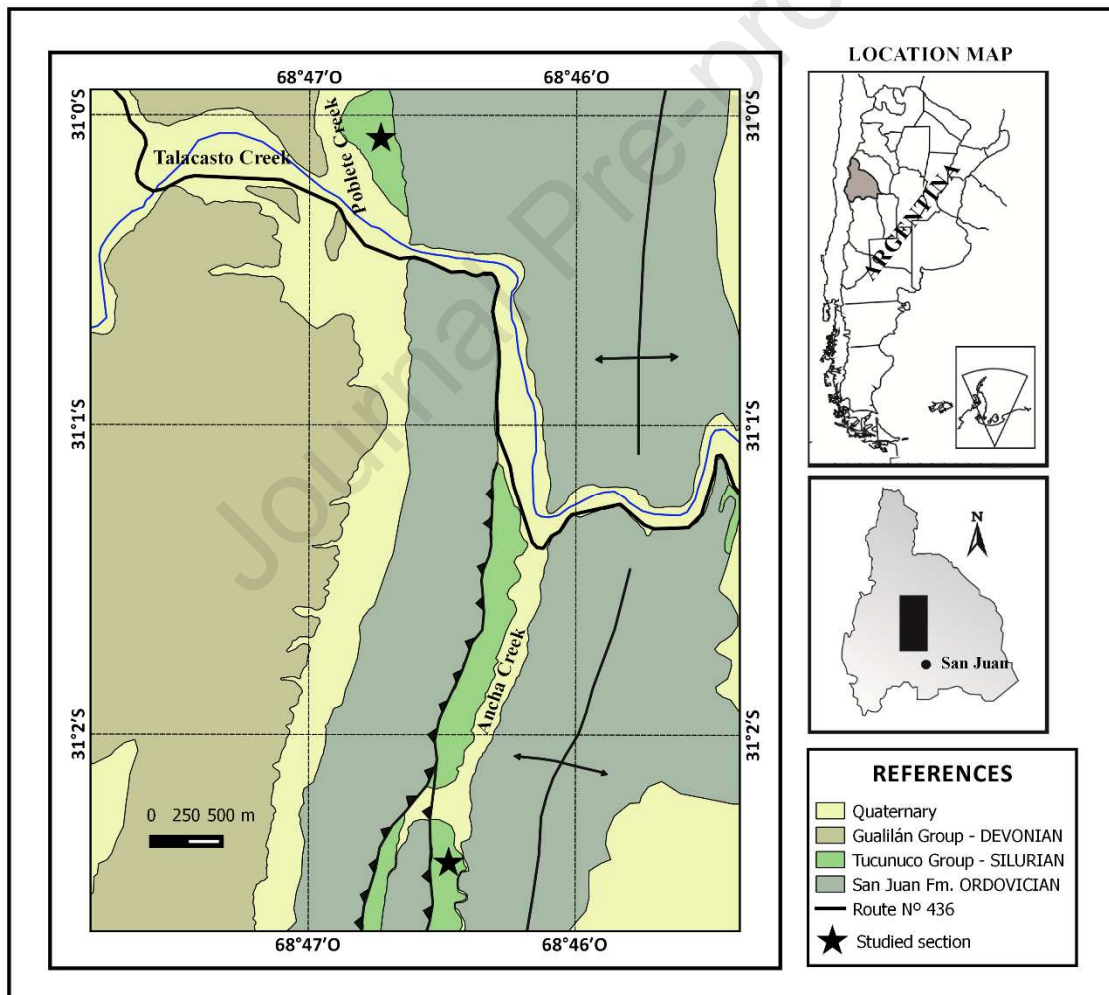
The Silurian and Lower Devonian strata in the Central Precordillera are represented by the La Chilca (Hirnantian-Wenlock) and Los Espejos (Wenlock-lower Lochkovian) formations, which are included in the Tucunuco Group (Cuerda, 1965). The boundary between these units has been interpreted as a paraconformity, as well as the upper boundary of the Los Espejos Formation, also identified as a paraconformity to the overlying Talacasto Formation (Lower Devonian).

The Los Espejos Formation is composed of marine siliciclastic rocks, mainly green shale, green to brown sandstone, and green siltstone, decreasing its thickness from 510 m in the north to 40 m in the south (Astini & Piovano, 1992). This unit was interpreted as deposited on storm-dominated clastic shelf from offshore to shoreface settings (Astini & Maretto, 1996; Rodríguez et al. 2010). Beds with abundant fossils (brachiopods, conodonts, trilobites, tentaculitids, crinoids, gastropods, corals and palynomorphs) are present in the middle and upper parts of this unit, where the graptolites *Monograptus uncinatus notouncinatus* Cuerda and *Saetograptus argentinus* Cuerda are usually present, tentatively assigned to Ludlow age (Baldis et al. 1984; Albanesi et al. 2006; Rickards et al. 1996). The ichnological association in the middle and upper parts of the unit is characterized mainly by the *Cruziana* Ichnofacies (Aceñolaza & Peralta, 1985; León et al. 2016).

In the upper part of this unit, the sandstone beds become thicker showing shell-beds and hummocky cross-stratification (HCS) structures that are associated with storm deposition (Astini & Maretto, 1996). Synsedimentary deformation structures, such as slumps, ball and pillow, and load casts are found in the uppermost part of the formation (Astini & Maretto, 1996).

## 2.1. The Poblete and Ancha creek sections

The Poblete and Ancha creeks sections represent classical localities for studying the Silurian and Lower Devonian deposits in the Precordillera (Fig. 1). There, the La Chilca and Los Espejos formations are well exposed. These sections are located about 70 km NW of San Juan city, at coordinates  $31^{\circ}00'06''$  S,  $68^{\circ}46'31''$  W (Poblete) and  $31^{\circ}02'52''$  S,  $68^{\circ}46'08''$  W (Ancha creek), respectively. The samples studied were collected from the middle and upper parts of the Los Espejos Formation in both sections.



**Figure 1.** Geographical location and geological maps showing the study areas (stars).

In the sections studied, the Los Espejos Formation shows a coarsening-up and thickening-up succession from the lower to the middle part (Fig. 2). The lower part of the Los Espejos Formation is predominantly composed of reddish and greenish phosphate-rich bioturbated mudstone and shale. In the middle part, the shaly succession includes thin sandstone beds bearing shelly fauna and abundant trace fossils of the *Cruziana* Ichnofacies. This shelly fauna is composed of brachiopod belonging to the genera *Harringtonina*, *Clarkeia*, and *Australina*, among others, which are associated with trilobites, nautiloids, ostracods, and crinoids.

The upper part of the Los Espejos Formation is characterized by fossiliferous burrowed mudstone interbedded with coquinoids sandstone. These sandstone beds turn thicker and show hummocky cross-stratified structures, which are associated with storm and shell-beds. The syndimentary deformation structures, such as slumps, balls and pillows, and load casts are well developed in the uppermost part of this unit in both sections.

### 3. Material and Methods

The conodont collection from the Los Espejos Formation includes about 5,000 conodont elements recovered from 16 samples from the upper Silurian to the Lower Devonian.

The studied collection includes specimens recovered from 7 samples collected from the middle and upper parts of the Los Espejos Formation at Poblete and Ancha creek sections (Fig. 2) (Table 1). All the samples have been processed using conventional formic acid technique (Stone, 1987). Residues have been sifted with 40, 80 and 120  $\mu\text{m}$  sieve and picked using a binocular microscope. More than 9 kg of calcareous sandstone yielded 62 P1 elements and 1 P2 element of ozarkodinids (Table 2); the state of preservation is fair, being the elements commonly broken. The selected specimens have been photographed using a scanning electronic microscopy (SEM) of the “Instituto de Investigaciones Mineras” (IIM) of San Juan University.

Sample /Taxon	Ancha Creek				Poblete		
	QA2	QA2p	QA5	QA7	YP8	YP9	YP10
<b>Sample weight (Kg)</b>	1.675	0.415	1.990	1.955	0.920	1.250	1.100
<i>Coryssognathus dubius</i>			X				
<i>Dapsilodus obliquicostatus</i>	X	?	XX				
<i>Icriodus cf. hesperius</i>						X	
<i>Oulodus</i> sp.	XX	XX	XX	X	X	X	
<i>Oulodus e. elegans</i>	X	X	X				
" <i>Ozarkodina</i> " <i>eosteinhornensis</i> s.s.			XX		XX		X
" <i>Ozarkodina</i> " <i>eosteinhornensis</i> s.l.					X		
<i>Ozarkodina</i> sp.			?				
<i>Ozarkodina huenickeni</i> nov. sp. $\alpha$	X	X	XX	X	XX	X	X
<i>Ozarkodina huenickeni</i> nov. sp. $\beta$			X		X		
<i>Ozarkodina huenickeni</i> nov. sp. $\gamma$			X		X		
<i>Panderodus unicostatus</i>			XX		X	X	
<i>Pseudooneotodus beckmanni</i>	X		X	X	XX	X	X
<i>Pseudooneotodus b. bicornis</i>	XX	X	XX		XX	X	
<i>Pseudooneotodus b. contiguus</i>	XX	XX	XX	X	XX		
<i>Wurmiella excavata</i>	XX		X		X	X	X

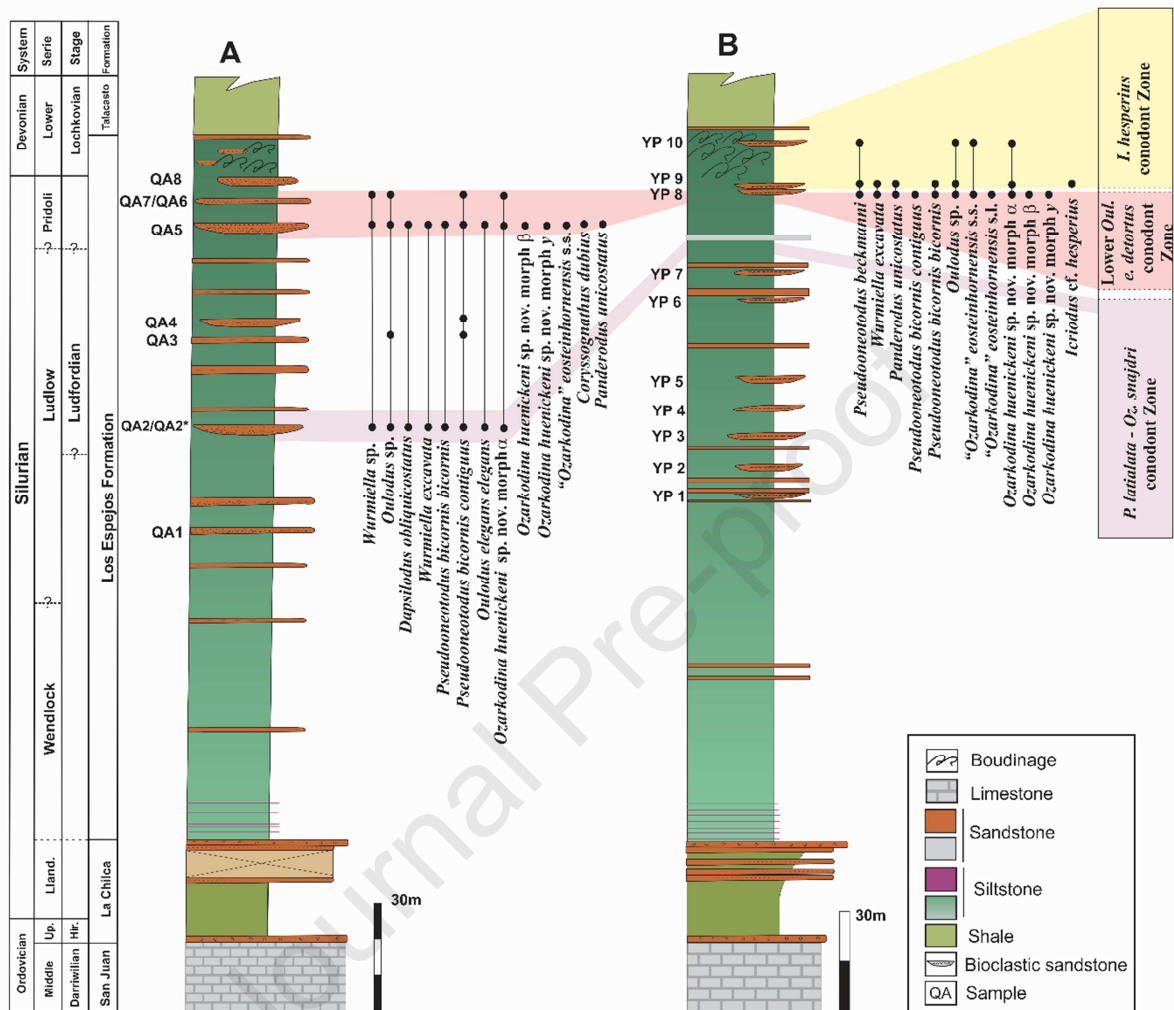
**Table 1:** Occurrence of conodont species in samples from the Ancha creek and Poblete sections. Abbreviations: X: present, XX: very frequent, ?: presence uncertain.

Species / Samples	Ancha Creek				Poblete			Total
	QA 2	QA2p	QA 5	QA 7	YP8	YP9	YP10	
<i>Ozarkodina huenickeni</i> $\alpha$ morph	1	2	15	5	12	4	3	42
<i>Ozarkodina huenickeni</i> $\beta$ morph			6		6			12
<i>Ozarkodina huenickeni</i> $\gamma$ morph			4		5			9
<i>Total</i>	1	2	25	5	23	4	3	<b>63</b>

**Table 2:** Occurrence of *Ozarkodina huenickeni* nov. sp. morph  $\alpha$ , morph  $\beta$  and morph  $\gamma$  in samples from the Ancha creek and Poblete sections.

The phylogenetic study was carried out using the data analysis PAST program with unweighted data displayed in Table 3 and the algorithm Branch-and-Bound was implemented with optimization Wargen.





**Figure 2:** Stratigraphic sections of the Los Espejos Formation in the Ancha creek (A) and Poblete (B), showing the occurrence of conodont species within the vertical distribution of the morphotypes of *Ozarkodina huenickeni* sp. nov., and conodont zones. The sample numbers are marked on the left side of the column.

#### 4. The *Ozarkodina* species from the Precordillera

The first study of Silurian conodonts from the Precordillera was carried out by Hünicken (1975), who reported the morphoelements *Hindeodella* sp. and *Plectospathodus* sp., from the Los Espejos Formation at the Loma de Los Piojos section suggesting a Wenlock age. Then,

Hünicken and Sarmiento (1986) obtained Ludlow conodont assemblages from the Los Espejos Formation that were referred to as undifferentiated *P. siluricus*-*P. latialata* Zone. Lehnert et al. (1999) described a Llandovery conodont association from the La Chilca Formation at Cerro del Fuerte recording the *Distomodus kentuckyensis* Zone; among other taxa, this association includes *Ozarkodina oldhamensis* (Rexroad).

In the middle and upper parts of the Los Espejos Formation at Ancha creek section, Albanesi et al. (2006) recorded the *K. v. variabilis* Zone (Gorstian), identifying *Ozarkodina* cf. *confluens* (Branson and Mehl) in this conodont assemblage. Subsequently, the Los Espejos Formation in Cerro del Fuerte, yielded a conodont association with *Ozarkodina* cf. *confluens* and *Ozarkodina* sp. from the *K. v. variabilis* Zone (Heredia et al. 2007).

Recently, Voldman et al. (2017) reported a poorly preserved late Homerian–early Gorstian fauna from Sierra Chica de Zonda (eastern Precordillera), including a few elements identified as “*Ozarkodina*” aff. *snajdri* and “*Ozarkodina*” sp.

In the Central Precordillera recent contributions on the Silurian-Devonian conodont biostratigraphy (Gómez, 2015; Garcías, 2016; Gómez et al. 2017; Mestre et al. 2017) represent an important progress in the knowledge of Argentina and South American conodonts for this time interval. In the Silurian-Lower Devonian conodont collections from Precordillera an ozarkonid specimens that show particular features was recognized. The taxonomical study on these specimens allows proposing a new species for the genus *Ozarkodina* from the Argentine Precordillera.

#### **4.1.Silurian - Lower Devonian conodont fauna from Poblete and Ancha creek sections**

Recently, Mestre et al. (2017) and Gómez et al. (2019) have recognized six conodont biozones from the lower Ludlow to the lower Lochkovian in the Los Espejos Formation from

the Central Precordillera, which, in ascending order, are *K. v. variabilis* interval Zone, *P. siluricus*, *Oz. eosteinhornensis* s.l. interval Zone, Lower *O. e. detortus*, Upper *O. e. detortus* (*Oz. eosteinhornensis* s.s. horizon) and *I. hesperius* conodont zones.

In the Ancha creek section the *Oz. huenickeni* sp. nov. was recovered from four samples (Fig. 2A, Tab. 1, 2). Samples QA2 and QA2\* yielded an association composed of *Dapsilodus obliquicostatus* (Branson and Mehl, 1933), *Oulodus elegans elegans* (Walliser, 1964), *Oulodus siluricus* (Branson and Mehl, 1933), *Pseudooneotodus beckmanni* (Bischoff and Sannemann, 1958), *Ps. bicornis bicornis* (Drygant, 1974), *Ps. b. contiguus* (Corradini, 2008), *Wurmiella excavata* (Branson and Mehl, 1933). The presence of *Oul. e. elegans* suggests an age not older than the upper part of the *Pe. latialata*-*Oz. snajdri* interval conodont Zone (Corradini et al. 2015). The samples QA5 and QA7 are assigned to the “*Oz.*” *eosteinhornensis* s.s. horizon of the Lower *O. e. detortus* Zone due to the occurrence of *Coryssognathus dubius* (Rhodes, 1953), *D. obliquicostatus*, *Oul. e. elegans*, *Oul. siluricus*, *Panderodus unicostatus* (Branson and Mehl, 1933), *Ps. beckmanni*, *W. excavata*, *Zieglerodina* cf. *zellmeri* (Carls et al. 2007), *Zieglerodina* sp. and “*Oz.*” *eosteinhornensis* s.s. (Walliser, 1964). All the morphotypes of *Oz. huenickeni* are present only in sample QA5, whereas only morph  $\alpha$  is present in the other samples.

In the Poblete section, *Oz. huenickeni* sp. nov. morphs  $\alpha$ ,  $\beta$  and  $\gamma$  were recovered from sample YP8 (Fig. 2B, Tab. 1, 2) together with *Oulodus* sp., *Oz. eosteinhornensis* s.l., “*Oz.*” *eosteinhornensis* s.s., *P. unicostatus*, *Ps. beckmanni*, *Ps. b. contiguus*, *W. excavata* and *Zieglerodina* sp. (Garcías, 2016). This level is assigned to the “*Oz.*” *eosteinhornensis* s.s. horizon of the Lower *O. e. detortus* Zone.

*Ozarkodina huenickeni* sp. nov. morph  $\alpha$  is also recovered from samples YP9 to YP10 (Fig. 2B, Table 2) in association with the youngest conodont fauna which is composed of *Icriodus* cf. *hesperius* (Klapper and Murphy, 1975), *Oulodus* sp., *Ozarkodina* sp., *P. unicostatus*, *Ps.*

*beckmanni* and *W. excavata* (Garcías, 2016). The presence of elements of *Icriodus* allows us to assign this level to the lowermost Devonian *I. hesperius* conodont Zone.

The morphotypes of *Oz. huenickeni* sp. nov. have different stratigraphic distribution: morph  $\alpha$  has the same range as the species, whereas morphs  $\beta$  and  $\gamma$  co-occur in the Lower *O. e. detortus* conodont Zone (“*Oz.*” *eosteinhornensis* s.s. horizon). This biostratigraphic distribution of the *Oz. huenickeni* sp. nov. morphotypes, could have a significant value for the regional correlation, but this hypothesis must be verified in future studies.

## 5. Systematic Paleontology

The conventional notation system with space positions M, S, and P, from the anterior to the posterior end of the multi-element apparatus (Sweet 1988; Purnell et al. 2000) is applied in this conodont taxonomical study. The material studied is housed in the collection of the INGEO at Universidad Nacional de San Juan, Argentina, under the code MP.

Phylum Chordata Bateson, 1886

Class Conodonta Pander, 1856

Order Ozarkodinida Dzik, 1976

Family Spathognathodontodae Hass, 1959

Genus *Ozarkodina* Branson &Mehl, 1933

*Type species:* *Ozarkodina typica* Branson &Mehl, 1933, from the Bainbridge Formation of Missouri, Silurian.

*Ozarkodina huenickeni* sp. nov.

Figures 3A-M.

*Derivation nominis:* In honor to Dr. Mario Hünicken, who studied Silurian conodonts from the Precordillera for the first time.

*Holotype:* P1 element INGEO-MP-5030 (1) illustrated in Fig. 3B1, B2.

*Paratypes:* Figured P1 elements INGEO-MP-5007 (1), INGEO-MP-5015 (1), INGEO-MP-5029 (1), INGEO-MP-5029 (3), INGEO-MP-5030 (2), INGEO-MP-5225 (1), INGEO-MP-5031(1), INGEO-MP-5043 (1), INGEO-MP-5015 (1), INGEO-MP-5043 (2); figured P2 element INGEO-MP-5015 (2). Not figured P1 elements INGEO-MP-5029 (2, 4-15), INGEO-MP-5043 (1, 3-5), INGEO-MP-5030 (3-6), INGEO-MP-5031 (1-4), INGEO-MP- 5229 (1-12), INGEO-MP- 5230 (1-4), INGEO-MP-5225 (2-3), INGEO-MP- 5231 (1-6), INGEO-MP-5232 (1-5).

*Type locality:* Ancha Creek section, Central Precordillera, Argentina.

*Type stratum:* Level of sample QA5, located about 160 m above the base of the Ancha Creek section.

*Material:* 63 P1 (42 morph  $\alpha$ , 12 morph  $\beta$  and 11 morph  $\gamma$ ) and 1 P2 elements from samples QA 1, QA 2, QA 5, QA 7, YP 8, YP 9 and YP 10. For further details, see Tables 1 and 2. All the elements are stored in the Collection of *Instituto de Investigaciones Mineras* at *Universidad Nacional de San Juan* under the code INGEO MP.

*Diagnosis:* The carminate P1 element is characterized by a discrete leaf-shaped platform expanded to reach almost the posterior end of the element. The cusp is equal in size to the adjacent denticles.

*Description:* The P1 element consists of a blade straight to slightly curved to the anterior part of the element. The platform shows a leaf-shaped morphology, slightly asymmetrical, that almost reaches the posterior end of the element and occupies more than half the length of the blade. The lobes of the platform may or may not be ornamented by nodes and/or ridge. The height of the posterior blade is relatively reduced compared to the anterior blade, but still quite high. The posterior end of the blade is gently flexed downwards. The cusp is small and not differentiable from the other denticles. The denticles on the anterior part of the blade are triangular and fused to the base, showing regular sizes in an alternate pattern. In the middle part of the blade, the denticles have the same height or they are fused. The posterior blade bears up to four discrete wide denticles. The basal cavity occupies the posterior half of the element.

Based on the occurrence of ornamentation above the platform, we can distinguish three morphotypes of *Oz. huenickeni*: morph  $\alpha$  is not ornamented (Fig. 3A, C, E, G, I-J, L-M), morph  $\beta$  is characterized by a single node or a small transverse ridge above one of the platform lobes (Fig. 3B, D, H) and morph  $\gamma$  has a node or a transverse ridge on both sides of the platform (Fig. 3F). In morphotypes  $\beta$  and  $\gamma$  nodes or ridges are located laterally on the cusp and connected to the main blade.

The angulate P2 element (Fig. 3K) shows the anterior and posterior processes approximately of the same length. The two processes are crowned by nearby denticles, sometimes fused. The triangular shaped cusp is high, robust and is inclined to the posterior process and has striae.

*Remarks:* *Ozarkodina huenickeni* sp. nov. presents a strong morphological affinity with other Wenlockian and Ludlowian species of *Ozarkodina*.

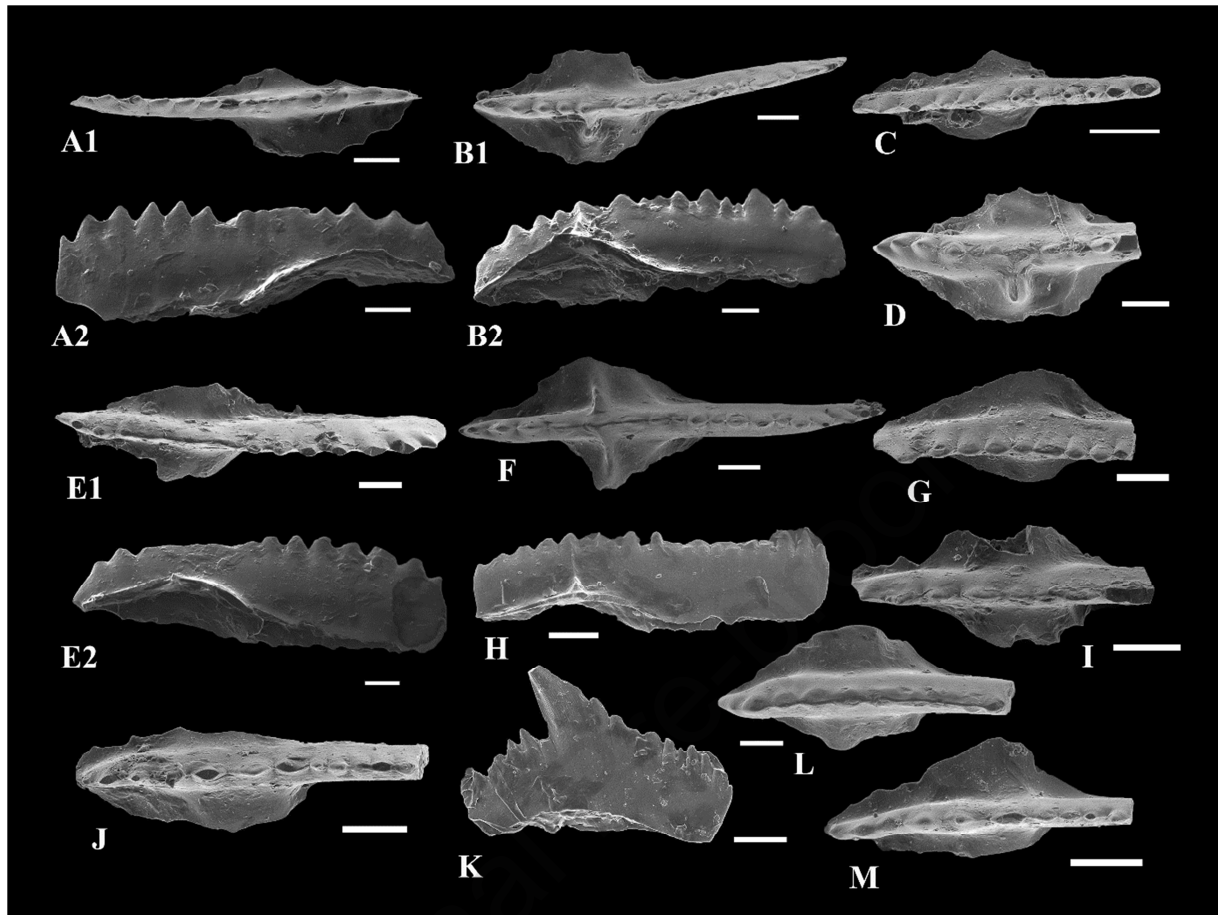
*Ozarkodina sagitta* (Walliser, 1964) is the oldest species that bears a resemblance with *Oz. huenickeni* sp. nov. They differ in the shape of the basal cavity, which is more pointed and arrow-like in the former taxon, and because in the lateral view posterior process it is higher in *Oz. huenickeni* than in *Oz. sagitta*. The main morphological difference between *Oz. huenickeni* sp. nov. and *Oz. bohémica* (Walliser, 1964) is that the tip of the basal cavity is placed more to the posterior position in *Oz. huenickeni* sp. nov. than the *Oz. bohémica*.

*Ozarkodina snajdri* (Walliser, 1964) and *Oz. parasnajdri* Viira and Aldridge, 1998 differ from *Oz. huenickeni* sp. nov. because the latter one has the basal cavity more posteriorly placed and elongated. *Ozarkodina huenickeni* sp. nov. is distinguished from *Oz. crispa* (Walliser, 1964) because in the former the posterior process does not reach the distal end of the element, and because *Oz. huenickeni* sp. nov. has a more elongate and leaf-shaped platform.

Voldman et al. (2017, figs 3.1-3.4, 4.1-4.4) described a few elements from the eastern Precordillera as *Ozarkodina* aff. *snajdri*, those elements recall *Oz. huenickeni* sp. nov., but differ in the less posteriorly expanded platform.

*Stratigraphic and geographical range:* Los Espejos Formation, Central Precordillera, San Juan Province, Argentina, South America. Ludfordian to lower Lochkovian. The species ranges from the *Pe. latialata*-*Oz. snajdri* interval Zone to the *I. hesperius* Zone. Morphotype  $\alpha$  is documented in the full range of the species, whereas morphotypes  $\beta$  and  $\gamma$  occur only in *Oz. eosteinhornensis* s.s. horizon (*Oz. eosteinhornensis* s.l. interval Zone).





**Figure 3:** Microphotographs of selected conodonts at scanning electron microscope. (A-M) *Ozarkodina huenickeni* nov. sp. (A, C, E, G, I-M) *Ozarkodina huenickeni* nov. sp. Morph  $\alpha$ , (B, D, H) *Ozarkodina huenickeni* nov. sp. morph $\beta$ , (F) *Ozarkodina huenickeni* nov. sp. Morph  $\gamma$ . (A) P1 element, sample QA5, INGE0-MP-5029 (1) (A1) upper view, (A2) lateral view. (B) P1 element, sample QA5, INGE0-MP-5030 (1), (B1) upper view, (B2) lateral view. (C) upper view of P1 element, sample QA7, INGE0-MP- 5043 (1). (D) upper view of P1 element, sample QA5, INGE0-MP-5030 (2). (E) P1 element, sample YP10, INGE0-MP-5225(1), (E1) upper view(E2) lateral view. (F) upper view of P1 element, sample QA5, INGE0-MP-5031(1). (G) upper view of P1 element, sample QA7, INGE0-MP 5043 (2). (H) lateral view of P1 element, sample QA5, INGE0-MP-5029 (3). (I) upper view of P1 element,



sample QA2, INGE0-MP-5007 (1). **(J)** upper view of P1 element, sample QA2\*, INGE0-MP-5015 (1). **(K)** lateral view of P2 element, sample QA2\*, INGE0-MP-5015 (2). **(L)** upper view of P1 element, sample QA5, INGE0-MP-5029 (2). **(M)** upper view of P1 element, sample QA5, INGE0-MP-5029 (3). The bar indicates 100  $\mu\text{m}$ .

## 6. Phylogenetic analysis

The use of the cladistic method in conodont phylogenetic studies experienced an increasing application in the phyletic reconstructions of the different lineages of this fossil group (e.g., Donoghue, 2001; Zhen, 2001; Zhang and Barnes, 2004; Wickström and Donoghue, 2005; Donoghue et al. 2008; Zhen et al. 2009). In order to assess the phylogenetic relationship of *Oz. huenickeni* sp. nov. with the other species of *Ozarkodina* morphologically similar, we used the cladistics methods of the PAST program (Ryan et al. 1995; Hammer et al. 2001). The data matrix is composed of 10 discrete morphological characters of the P1 element, coded using a reductive coding strategy. Characters that are inapplicable to some taxa are represented with (?) in the data set (Table 3).

Outgroup: *Oz. confluens* (Branson and Mehl, 1933) and *W. excavata* have been selected as outgroup in this cladistic analysis because they are supposedly closely related to the species included in the ingroup or were previously included into the genus *Ozarkodina*.

Ingroup: it is composed of the following species of the genus *Ozarkodina*: *Oz. sagitta* (Walliser), *Oz. bohémica* (Walliser), *Oz. snajdri* (Walliser), *Oz. crispa* (Walliser) and *Oz. huenickeni* sp. nov. *Ozarkodina sagitta* is included because it is considered as supposedly an ancestor of the *bohémica* lineage (Helfrich, 1975). *Ozarkodina bohémica*, *Oz. snajdri* and *Oz. crispa* are considered because they are included in the *bohémica* lineage as was corroborated by Viira and Aldridge (1998). All these species show strong morphological affinities among them. We processed the analysis at the species level, therefore, we did not consider any

subspecies other than the nominal one. Thus, *Oz. sagitta rhenana* (Walliser), *Oz. bohémica longa* Jeppsson, and *Oz. snajdri parasnajdri* Viira and Aldridge were not included in the analysis.

Characters and codes:

**Character 1-** General morphology: coniform (0) spathognathodontidae (1), inapplicable (?).

**Character 2-** Posterior position of the basal cavity: absent (0), present (1), inapplicable (?).

**Character 3-** Morphology of the platform. semicircular (0), leaf-shaped (1), inapplicable (?).

**Character 4-** Wide platform: absent (0), present (1), inapplicable (?).

**Character 5-** Ornamented platform with one node or ridge. absent (0), present (1), inapplicable (?).

**Character 6-** Ornamentation on each platform lobe. absent (0), present (1), inapplicable (?).

**Character 7-** Blade straight to slightly curved. absent (0), present (1), inapplicable (?).

**Character 8-** The posterior end of the blade comes out to the platform. absent (0), present (1), inapplicable (?).

**Character 9-** Denticles on the anterior process are triangular and fused. absent (0), present (1), inapplicable (?).

**Character 10-** Denticles on the posterior process are wide and discrete. absent (0), present (1), inapplicable (?).

Taxa	Characters									
	1	2	3	4	5	6	7	8	9	10
<i>Wurmiella excavata</i>	1	?	?	0	?	?	0	?	?	?
<i>Ozarkodina confluens</i>	1	0	?	0	0	0	0	0	0	0
<i>Ozarkodina huenickeni</i> nov. sp.	1	1	1	0	1	1	1	1	0	1
<i>Ozarkodina snajdri</i>	1	1	1	1	1	0	1	1	0	1
<i>Ozarkodina crispa</i>	1	1	1	1	1	1	1	0	0	1
<i>Ozarkodina sagitta</i>	1	0	0	0	0	0	0	1	1	0
<i>Ozarkodina bohémica</i>	1	1	1	0	0	0	1	1	0	1

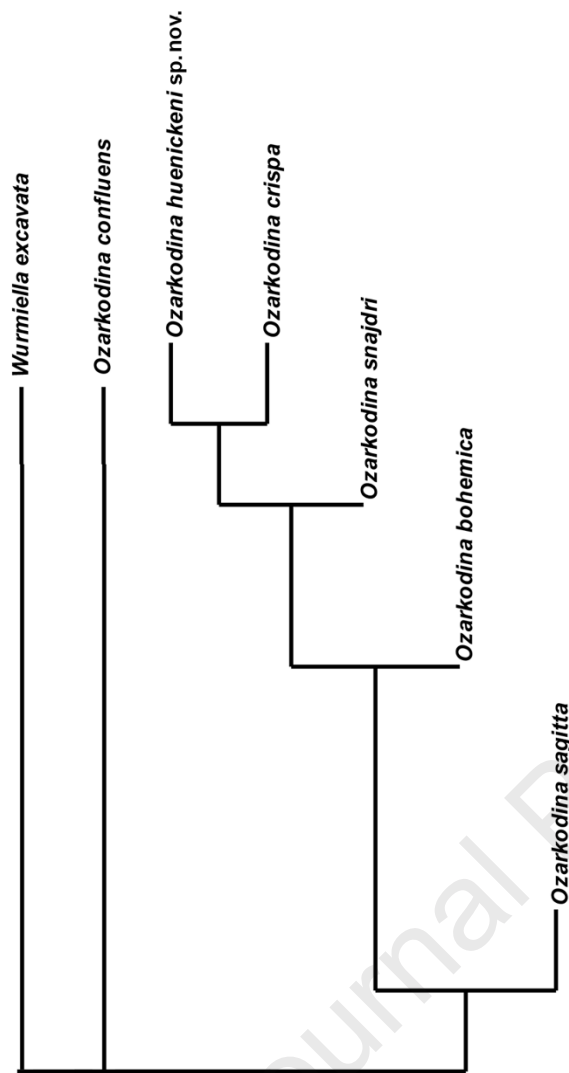
**Table 3:** Data matrix for the five species of *Ozarkodina* that conform the ingroup, and outgroup are composed by *Wurmiella excavata* and *Ozarkodina confluens* (reductive coding, with 10 binary characters, (?) designates inapplicable). For Descriptions of Characters 1-10 see text.

## 7. Discussion

*Ozarkodina huenickeni* sp. nov., *Oz. sagitta*, *Oz. bohémica*, *Oz. snajdri* and *Oz. crispa* belong to a monophyletic group as showed, by sharing several synapomorphic characters (Table 3; Fig 4). *Ozarkodina huenickeni* sp. nov. and *Oz. crispa* seem to be the most derived taxa and *Oz. sagitta* would occupy a basal position within this monophyletic group. *Wurmiella excavata* and *Oz. confluens* probably share a common ancestry with the group that includes *Oz. huenickeni* sp. nov., *Oz. sagitta*, *Oz. bohémica*, *Oz. snajdri* and *Oz. crispa*, because they are connected in the base of the cladogram. In fact, the lack of a root in the cladogram would not allow linking them to a common ancestor (Fig. 4).

Walliser (1964) included *Oz. bohémica* as a subspecies of *O. sagitta* and suggested that *Oz. snajdri* may be a descendant of *W. excavata*. *Ozarkodina snajdri* has been considered the ancestor of *Oz. eosteinhornensis* (Walliser) by Pollock and Rexroad (1973) and Mehrtens and Barnett (1976). On the other hand, Helfrich (1975) identified ‘*Spathognathodus sagitta bohemicus*’ lineage, or *bohémica* lineage, based on the morphological variation trend of the P1 elements and multielement patterns, including *Oz. bohémica*, *Oz. bicornuta* (Helfrich), *Oz. snajdri*, *Oz. tillmani* (Helfrich) and *Oz. crispa*. The basal cavity is closed before the posterior tip of the blade in stratigraphical older forms but extends further posteriorly relative to the posterior blade in successively younger species, as well as a tendency towards fusion of the denticles above the basal cavity. Viira and Aldridge (1998) recognized a succession of conodonts from Saaremaa comparable with the *bohémica* lineage identified by Helfrich (1975) and also proposed a new subspecies of *Oz. snajdri*, referred to as *Oz. snajdri parasnajdri*, that appears above the last occurrence of *Oz. crispa* and has a closer affinity with *Oz. snajdri*. Later, *Oz. parasnajdri* was documented in older levels in Bohemia by Slavík and Carls (2012), who distinguished a *parasnajdri* Zone just below the *crispa* Zone.

The phylogenetic analysis of *Oz. huenickeni* sp. nov., allows us to include the species in the *bohémica* lineage, which probably represents a South American endemic taxon that evolved from this group during the Ludlow times.



**Figure 4:** The cladogram shows the inferred phylogenetic relationships generated from data set 1 (Table 3) by using data analysis program PAST.

## 8. Conclusion

The most significant findings of this work may be summarized as follows:

- The new species *Ozarkodina huenickeni* is described from the Los Espejos Formation of the Argentine Precordillera.
- Three morphotypes are distinguished on the basis of the occurrence of ornamentation on the platform lobes, morph  $\alpha$  is not ornamented, morph  $\beta$  has a single node or a small

transverse ridge above one of the platform lobes, and morph  $\gamma$  has a node or a transverse ridge on both sides of the platform.

- *Ozarkodina huenickeni* sp. nov. ranges from the upper Ludfordian (*Pe. latialata*-*Oz. snajdri* interval Zone) to the lowermost Lochkovian (*I. hesperius* Zone).
- Morphotypes  $\beta$  and  $\gamma$  have great biostratigraphic value due to the fact that they are limited to the “*Oz.* *eosteinhornensis* s.s. horizon, Lower *O. e. detortus* conodont Zone.
- The phylogenetic analysis demonstrate that *Oz. huenickeni* belongs to the “*bohemia* lineage” and probably represents an endemic South American species.

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- The taxonomic study allows us to propose a new species of the genus *Ozarkodina*.
- The carminate P1 element is characterized by a discrete leaf-shaped platform expanded.
- The lobes of the platform may or may not be ornamented by nodes and/or ridge.
- In the middle part of the blade, the denticles have the same height or they are fused.

**Declaration of interests**

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: