

The Ordovician conodont *Tripodus Laevis* Bradshaw, 1969: Its taxonomic validity and biostratigraphic value in the Argentine Precordillera

ANA MESTRE¹
FLORENCIA MORENO¹
SUSANA HEREDIA¹

1. Consejo Nacional de Investigaciones Científicas y Tecnológicas (CONICET) - Centro de Investigaciones de la Geósfera y Biósfera (CIGEOBIO) - Laboratorio de Micropaleontología - Instituto de Investigaciones Mineras (IIM) - Facultad de Ingeniería, Universidad Nacional de San Juan. Avenida Libertador San Martín 1109 (Oeste), 5400 San Juan, San Juan, Argentina.

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THE ORDOVICIAN CONODONT *TRIPODUS LAEVIS* BRADSHAW, 1969: ITS TAXONOMIC VALIDITY AND BIOSTRATIGRAPHIC VALUE IN THE ARGENTINE PRECORDILLERA

ANA MESTRE¹, FLORENCIA MORENO¹, AND SUSANA HEREDIA¹

¹Consejo Nacional de Investigaciones Científicas y Tecnológicas (CONICET) - Centro de Investigaciones de la Geósfera y Biosfera (CIGEOBIO) - Laboratorio de Micropaleontología - Instituto de Investigaciones Mineras (IIM) - Facultad de Ingeniería, Universidad Nacional de San Juan. Avenida Libertador San Martín 1109 (Oeste), 5400 San Juan, San Juan, Argentina. amestre@unsj.edu.ar; florenciamorenovalez@gmail.com; sheredia@unsj.edu.ar

 AM: <https://orcid.org/0000-0002-3272-4439>; FM: <https://orcid.org/0000-0003-1225-8829>; SH: <https://orcid.org/0000-003-4960-0974>

Abstract. The conodont species *Tripodus laevis* has been used as an index conodont to mark the lower boundary of the Middle Ordovician in the Midcontinent and Precordillera conodont biostratigraphic charts, despite that *T. laevis* or specimens assignable to this species span from lower Floian to middle Darriwilian. Also, this conodont species has a complex taxonomic history. It has been located in different conodont families and its apparatus has been composed of varying conodont morphotypes. In the present contribution, we conducted a critical revision of the taxonomic history of *T. laevis*, as well as its biostratigraphic value as a key species for indicating the lower boundary of the Dapingian stage. Based on this analysis, we propose that *T. laevis sensu lato* (s. l.) should not be considered a valid species and to avoid using this species in the Argentine Precordillera. Therefore, we suggest discontinuing the first appearance datum of *T. laevis* s. l. as a marker for the lower boundary of the Middle Ordovician in this region. In light of this proposal, we suggest using a new Dapingian conodont biostratigraphic chart for the Argentine Precordillera.

Key words. Dapingian. Conodont. Argentina. Precordillera.

Resumen. EL CONODONTE ORDOVÍCICO *TRIPODUS LAEVIS* BRADSHAW, 1969: SU VALIDEZ TAXONÓMICA Y VALOR BIOSTRATIGRÁFICO EN LA PRECORDILLERA ARGENTINA. La especie de conodonte *Tripodus laevis* se ha utilizado como conodonte guía para marcar el límite inferior del Ordovícico Medio en los cuadros bioestratigráficos de conodontes de Midcontinent y Precordillera, a pesar de que *T. laevis* o especímenes asignables a esta especie se registran desde el Floiano inferior hasta el Darriwiliano medio. Además, esta especie de conodonte tiene una historia taxonómica compleja. Se ha ubicado en diferentes familias de conodontes y su aparato ha estado compuesto por distintos morfotipos de elementos conodontales. En la presente contribución se realizó una revisión crítica sobre la historia taxonómica de *T. laevis*, así como de su valor bioestratigráfico como especie guía para señalar el límite inferior del Dapingiano. Con base en este análisis, proponemos que *T. laevis sensu lato* (s. l.) no debe ser considerada una especie válida y evitar el uso de la misma en la Precordillera argentina. En consecuencia, se sugiere discontinuar la primera aparición (*first appearance datum*) de *T. laevis* s. l. como un marcador para el límite inferior del Ordovícico Medio en esta región. A la luz de esta propuesta, sugerimos el uso de un nuevo cuadro bioestratigráfico de conodontes para el Dapingiano de la Precordillera argentina.

Palabras clave. Dapingiano. Conodonte. Argentina. Precordillera.

THE CONODONT *Tripodus laevis* Bradshaw, 1969 was defined based on coniform elements recovered from the Middle Ordovician (Darriwilian) Fort Peña Formation in the Marathon Basin, USA. Through time, *T. laevis* has been located in different conodont families (Sweet, 1988; Dzik, 1994) and its apparatus has been composed of varying conodont morphotypes (Ethington & Clark, 1981; Stouge, 1984; Albanesi, 1998; Johnston & Barnes, 2000). Despite this taxonomical complexity, *T. laevis* has been used as an index conodont for Middle Ordovician in some conodont

biostratigraphic charts, especially in the Midcontinent and Precordillera regions (Ethington & Clark, 1981; Ross *et al.*, 1997; Albanesi *et al.*, 1998; Johnston & Barnes, 1999; Albanesi & Ortega, 2002, 2016; Pyle & Barnes, 2002). However, the species *T. laevis* (Johnston & Barnes, 1999; Pyle & Barnes, 2002) or specimens assignable to *T. laevis*, such as *T. laevis?* (Wang *et al.*, 2009), *Tripodus* spp. (Löfgren *et al.*, 2005) and *Tripodus combsi* (Bradsaw, 1969) (Bauer, 2010; Loch & Ethington, 2017) range from lower Floian to middle Darriwilian.

The absence of specimens assignable to *T. laevis* in our conodont collections and other collections studied by several authors in the Ordovician strata of the Argentine Precordillera (Serpagli, 1974; Sarmiento, 1990; Lehnert, 1995), as well as its complex taxonomic history and wide biostratigraphic range, led us to ask about the validity of this species and its real biostratigraphic value. In addition, Mango & Albanesi (2023) recognized that the apparatus of the *T. laevis* proposed by Albanesi (1998) did not correspond to this species in the strict sense, and based on the few elements assigned to this species in the Precordillera, it was preferred to use *T. laevis sensu lato* (s. l.). These authors suggested the possibility that specimens assigned to *T. laevis* s. l. represent a new Dapingian species from the Precordillera.

The main goal of this contribution is to develop a critical revision of the taxonomic history of the species *T. laevis* and reconsider its biostratigraphic value as a key species for pointing out the lower boundary of the Dapingian stage from the Precordillera.

RESULTS

The complex taxonomic history of *Tripodus laevis*

The type species of *T. laevis* was originally defined as having two coniform elements based on only three elements retrieved from the Fort Peña Formation (Darriwilian) in the Marathon basin, USA (Bradshaw, 1969) (Fig. 1). Within this conodont assemblage, two more species, *Scolopodus alatus* and *Acodus combsi*, were also defined based on a few coniform specimens (Fig. 1). These species are significant because they were subsequently used in the reconstruction of the *T. laevis* multielemental apparatus (Ethington & Clark, 1981; Stouge, 1984; Albanesi, 1998; Johnston & Barnes, 2000).

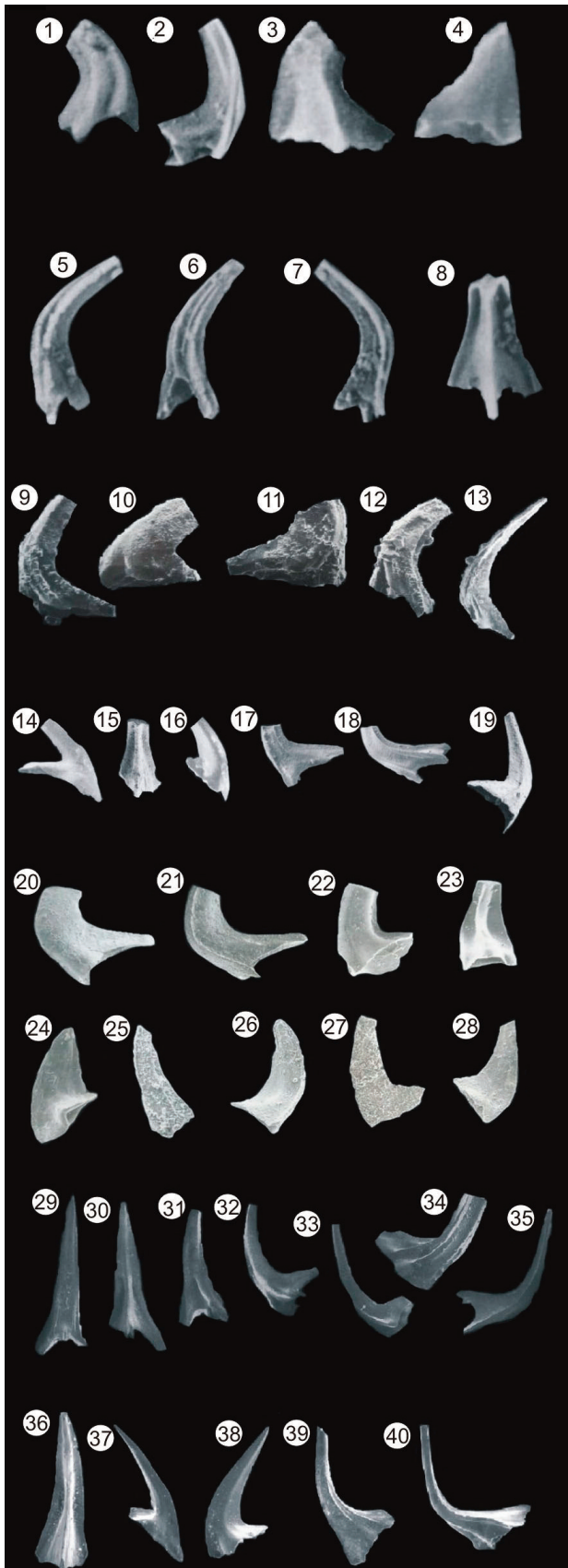
The first multielemental apparatus reconstruction of the species *T. laevis* was proposed by Ethington & Clark (1981) and included five elements: oistodiform (M), distacodiform (Sb), drepanodiform (Sc), paltodiform (Sd), and trichonodelliform (Sa) (Fig. 1). The Bradshaw's type material of the *T. laevis* corresponds to the Sb element, while the type material of the *S. alatus* comprised both Sa and Sd elements. Unfortunately, the prioniodontiform (P) element was not included in this reconstruction.

Based on the conodont assemblage retrieved from the Darriwilian Table Head Formation in Newfoundland, Stouge (1984) proposed a multielemental apparatus of the species *A. combsi* including the type species *A. combsi* as the prioniodontiform (P) element, the *T. laevis* as the tetraprioniodontiform (Sd) element, and the *S. alatus* as the trichonodelliform (Sa) element (Fig. 1). This apparatus was completed by *Distacodus* s. f. and *Oistodus* s. f. (Barnes & Poplawski, 1973) as the cordylodontiform elements (Sc and Sb), and described a new M element. Based on this material, Stouge (1984) regarded the genus *Tripodus* as a junior synonym of the genus *Acodus*.

Albanesi (1998) proposed a multielemental apparatus for the species *T. laevis* composed of seven elements: Pa, Pb, Sa, Sb, Sc, Sd, and M elements (Fig. 1). This proposal was based on a few specimens recovered from several samples, which were collected in different levels of the San Juan Formation. This author considered the Pa, Sa, Sc, Sd, and M elements belonging to the Precordilleran *T. laevis* apparatus as equivalent to the distacodiform, trichonodelliform, drepanodiform, paltodiform, and oistodiform elements described by Ethington & Clark (1981). However, Albanesi (1998) misunderstood the proposal of Stouge (1984), who considered the holotype of *A. combsi* as the P (prioniodontiform) element of the genus *Tripodus* (Stouge & Bagnoli, 1988), not the distacodiform element described by Ethington & Clark (1981). In fact, Stouge (1984) did not include the *T. laevis* specimens described by Ethington & Clark (1981) in the *A. combsi* synonymy list. Nevertheless, Albanesi (1998) retained the *T. laevis* denomination even though the Precordilleran specimens were more similar to *A. combsi* in the sense of Stouge (1984).

Johnston & Barnes (2000) illustrated and described elements of *T. laevis* that support the reconstruction proposed by Ethington & Clark (1981). The acodontiform (*A. combsi* s. f.) and oistodontiform elements were not identify (Fig. 1). In addition, these authors excluded the species *T. laevis* described for the Precordillera from the synonymy list.

The species *Tripodus combsi* from the Oil Creek Formation, USA (Darriwilian) was studied by Bauer (2010). This author proposed the apparatus redefinition of the genus *Tripodus* as having two acodontiform P elements,



oistodontiform M, acodontiform Sa, distacodontiform or paltodontiform Sb, and drepanodontiform Sc elements (Fig. 1). This apparatus is consistent with the *T. combsi* retrieved from the Antelope Valley Limestone, USA (Sweet *et al.*, 2005).

Bauer (2010) supported its reconstruction by comparing the *T. combsi* elements with specimens of *T. laevis* collected from the Whiterock Canyon section, USA (provided by Dr. Ethington). This author concluded that *T. laevis* seems to have two types of acodontiform P elements which correspond to "*Scandodus*" *robustus* Serpagli, 1974 (Ethington & Clark,

Figure 1. Comparison between the type material of the *Tripodus laevis*, *Scolopodus alatus*, and *Acodus combsi* and the different interpretations of the *T. laevis* and *A. combsi* apparatuses (modified from Bradshaw, 1969; Ethington & Clark, 1981; Stouge, 1984; Albanesi, 1998; Johnston & Barnes, 2000; Bauer, 2010). 1–2, *T. laevis* Bradshaw, 1969; 1, Paratype AC-FP-44-3, x50; 2, Holotype AC-FP-14-6, x50; 3–4, Holotype of *A. combsi* Bradshaw, 1969 CR-FP-46-6, x50; 5–8, *S. alatus* Bradshaw, 1969; 5–6, Holotype AC-FP-35-4, x50; 7–8, Paratype CR-FP-28-18, x50; 9–13, *T. laevis* Ethington & Clark, 1981; 9, Distacodontiform element UMC 1110-15, x100; 10, Oistodontiform element—~~T~~ UMC 1110-19, x100; 11, Drepanodontiform element UMC 1110-17, x100; 12, Paltodontiform element UMC 1111-11, x100; 13, Trichonodelliform element UMC 1111-3, x80; 14–19, *A. combsi* Stouge, 1984; 14, Cordylodontiform element TP66 ROM 39707, x90; 15, Trichonodelliform element TP66 ROM 39707, x70; 16, Oistodontiform element TP66 ROM 39707, x70; 17, Cordylodontiform element TP66 ROM 39707, x75; 18, Tetrapriodontiform element TP66 ROM 39707, x75; 19, Prionodontiform element TP66 ROM 39707, x100; 20–29, *T. laevis* s. l. Albanesi, 1998; 20–21, Pa element CORD-MP 3701/1-2, x41 (Distacodontiform element *sensu* Ethington & Clark, 1981); 22, Pb element CORD-MP 3653/1, x31 (Cordylodontiform element *sensu* Stouge, 1984 = Oistodus s. f. *sensu* Barnes & Poplawski, 1973); 23, Sa element CORD-MP 3678/1, x86 (Trichonodelliform element *sensu* Ethington & Clark, 1981); 24, M element CORD-MP 3678/2, x54 (Oistodontiform element *sensu* Ethington & Clark, 1981); 25, Sd? element CORD-MP 3623/1, x200 (Paltodontiform *sensu* Ethington & Clark, 1981); 26, Sb element CORD-MP 3678/3, x86 (*Distacodus?* sp. s. f. *sensu* Barnes & Poplawski, 1973); 27–28, Sc element CORD-MP 3633/1, x71 and CORD-MP 3678/4, x86 (Drepanodontiform *sensu* Ethington & Clark, 1981); respectively; 29, C element GSC 82770, x90 (Acodontiform); 30–35, *T. laevis* Johnston & Barnes, 2000; 30, C element GSC 82771, x90 (Acodontiform); 31, ~~B~~ element GSC 82772, x90 (Paltodontiform); 32, ~~A~~ element GSC 82774, x90 (Drepanodontiform element); 33–34, ~~P~~ element GSC 82773, x90 (Distacodontiform); 35, ~~C~~ element GSC 82771, x90 (Acodontiform); 36–40, *T. combsi* Bauer, 2010; 36, Sa element OSU 52109, x89 (Acodontiform); 37, M element OSU 52110, x61 (Geniculate element); 38, P element OSU 517, x59 (Acodontiform); 39, Sc element OSU 52118, x60 (Drepanodontiform element); 40, Sb element OSU 52120, x85 (Distacodontiform). Institutional abbreviations: AC-FP, Alsate creek-Fort Peña Formation, University of Texas, USA; CR-FP, Comb Ranch-Fort Peña, University of Texas, USA; CORD-MP, Museo de Paleontología, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de Córdoba, Argentina; GSC, Geological Survey of Canada, Canada; OSU, Ohio State University, USA; UMC, Utah Millard County Museum, USA.

1981, p. 94, pl. 10, fig. 1–27). It is important to note that the species “*S. robustus*” in the Precordillera was constrained to the Floian stage (*Oepikodus evae* and *O. intermedius* zones). On the other hand, this species was included in the synonymy list of *Rossodus barnesi* Albanesi, 1998 by Albanesi (1998).

The Precordilleran apparatus reconstruction of the genus *Tripodus* is strongly contrasting to the apparatus proposed by Bauer (2010). Albanesi (1998) considered the distacodiform, paltodiform and acodiform morphotypes as Pa, Sd and Sb elements, while Bauer (2010) proposed the acodontiform morphotypes as P (Pa and Pb) elements, and distacodontiform or paltodontiform morphotypes as Sb elements. In this sense, Bauer’s proposal coincided with the apparatus reconstruction of *A. combsi* proposed by Stouge (1984).

The last mentioned taxonomic misunderstandings about the apparatus reconstruction of the species *T. laevis* and *A. combsi* created several problems in the definition of these genera. Kennedy (1980) and Sweet (1988) suggested the genus *Tripodus* as valid and interpreted the genus *Acodus* as *nomen dubium*. On the other hand, several authors considered *Tripodus* and *Acodus* as two valid and different genera (Lindström, 1977; Stouge & Bagnoli, 1988; Johnston & Barnes, 2000; Zhen *et al.*, 2005).

Albanesi & Ortega (2002) suggested that the *T. laevis* specimens present in the Precordillera should be assigned to *T. laevis* s. l., considering them as forms apparently related to *T. laevis sensu stricto* (s. s.) from North America. According to this proposal, Mango & Albanesi (2023) considered the *T. laevis* specimens found in the Precordillera may not fall under the strict definition of *T. laevis*. These authors supported the idea that it could be a new conodont species, but in the absence of a sufficient number of elements to propose it as such, they decided to continue naming them *T. laevis* s. l.

Considering the intricate taxonomic history of the species *T. laevis* and the significant differences between the apparatus of the genus *Tripodus* from the Precordillera (Albanesi, 1998; Mango & Albanesi, 2023) and Midcontinent (Ethington & Clark, 1981; Stouge, 1984; Johnston & Barnes, 2000; Bauer, 2010), we propose that *T. laevis* s. l. should not be considered as a valid species. As a result, we suggest avoiding the usage of this species in the Precordillera.

Biostratigraphic use of the *Tripodus laevis* through time

The species *T. laevis* has been used as an index conodont to mark the lower boundary of the Middle Ordovician series (Dapingian), especially in the Midcontinent and Precordillera conodont biostratigraphic charts (Ethington & Clark, 1981; Ross *et al.*, 1997; Albanesi *et al.*, 1998; Johnston & Barnes, 1999; Albanesi & Ortega, 2002, 2016; Pyle & Barnes, 2002). However, the type species of *T. laevis* was recovered in co-occurrence with Darriwilian conodonts such as *Histiodella sinuosa* Graves & Ellison, 1941, *Paroistodus horridus* (Barnes & Poplawski, 1973) and *Periodon aculeatus* Hadding, 1913 (Bradshaw, 1969).

Ethington & Clark (1981) proposed for the first time to use the species *T. laevis* as a biostratigraphic marker recognizing *Microzarkodina flabellum*–*Tripodus laevis* interval in the Ibex area (Utah, USA). According to these authors, both species have short stratigraphic ranges in the Ibex region but longer ranges elsewhere. Later, Ross *et al.* (1997) introduced the *T. laevis* Conodont Zone in the Midcontinent conodont biostratigraphic scheme, proposing that the first appearance datum (FAD) of *T. laevis* indicated the base of this zone, as well as the lower boundary of the Whiterockian stage (Fig. 2).

This *T. laevis* Zone was approved as the biohorizon to define the lower boundary of the Middle Ordovician (Dapingian) since it could be globally correlated (Webby, 1998). Based on this statement, the Whiterock Narrows section (Nevada, USA) was proposed as the type section for the base of the Middle Ordovician, locating the FAD of *T. laevis* 3 m below the top of the Ninemile Formation (Finney & Ethington, 2000a, 2000b). However, graptolites data revealed that the Whiterock Narrows section is equivalent to the *Histiodella altifrons* Zone, which is registered for the upper part of the Dapingian, indicating a discrepancy in the first appearance of the *T. laevis*. As a result, *T. laevis* should be not relied upon as a biostratigraphic marker of the base of the Middle Ordovician (Mitchell, 2001).

In order to resolve this issue, the International Commission on Stratigraphy proposed two sections as potential stratotypes of the Lower–Middle Ordovician boundary. Albanesi *et al.* (2006) proposed the Niquivil section in the Argentine Precordillera as the global

stratotype for the base of the Dapingian stage (Middle Ordovician), where the FAD of *Cooperignathus aranda* Cooper, 1981 would be the alternative guide species to indicate the boundary between the Lower and Middle Ordovician series. On the other hand, Wang *et al.* (2009) proposed the Huanghuachang section at southern China, with the FAD of the species *Baltoniodus triangularis* Lindström, 1955 as a biomarker for the lower boundary of the Dapingian. The FAD of *B. triangularis* coincides with a speciation event where this species evolved from its ancestor *B. cf. B. triangularis*, matching almost exactly with the speciation event for other genera such as *Gothodus*, *Microzarkodina*, *Periodon*, and *Paroistodus*. Finally, this section was accepted as the global stratotype for the base of the Dapingian stage (Middle Ordovician) (Fig. 2). In the upper Floian strata at the Huanghuachang section, 6 m below the FAD of the *B. triangularis*, coniform specimens tentatively assigned as *T. laevis*? were recorded (Wang *et al.*,

2009). However, those specimens were illustrated and certainly assigned to *T. laevis* by Wang *et al.* (2003) and Li *et al.* (2004).

The *T. laevis* Zone was also recorded in Western Newfoundland and Northeastern British Columbia, Canada, following the proposal of Ross *et al.* (1997) (Johnston & Barnes, 1999; Pyle & Barnes, 2002) (Fig. 2).

The species *T. laevis* was synonymized with *T. combsi* by several authors, thus proposing to name *T. combsi* Zone to the first Dapingian zone of the Midcontinent conodont biostratigraphic scheme (Sweet *et al.*, 2005; Loch & Ethington, 2017). However, other authors suggested that *T. laevis* and *T. combsi* are two valid species with different biostratigraphic ranges, supporting the Dapingian *T. laevis* Zone, while the species *T. combsi* is recorded from the *Histiodela labiosa* to *Histiodela kristinae* zones in the Darriwilian time (Stouge, 1984; Bauer, 2010; Stouge, 2012) (Fig. 2).

System	Series	Stage	South China	North America	Newfoundland	Argentine Precordillera		Central Precordillera
			Wang <i>et al.</i> (2009)	Ross <i>et al.</i> (1997) Bauer (2010)	Johnston & Barnes (1999) Stouge (2012)	Albanesi & Ortega (2016)	Heredia <i>et al.</i> (2017)	Moreno (2023)
Ordovician	Middle	Darriwilian	<i>Lenodus variabilis</i>	<i>H. labiosa</i>	<i>H. holodentata</i>	<i>L. variab.</i>	<i>P. horridus</i>	
				<i>H. sinuosa</i>			<i>P. gladysi</i>	<i>L. variabilis</i>
		<i>L. antivariabilis</i>	<i>Histiodela minutiserrata</i>	<i>H. sinuosa</i>	<i>M. parva</i>	<i>L. antivariabilis</i>		
		Dapingian	<i>M. parva</i>	<i>Histiodela altifrons</i>				
			<i>P. originalis</i>		<i>Baltoniodus navis</i>			
			<i>B. navis</i>					
	<i>B. triangularis</i>	<i>Tripodus laevis</i>	<i>Tripodus laevis</i>	<i>B. triangularis/ Tripodus laevis</i>				
Lower	Floian	<i>Oepikodus evae</i>	<i>Reutterodus andinus</i>	<i>Oepikodus evae</i>	<i>Oepikodus intermedius</i>	<i>Oepikodus intermedius</i>		

Figure 2. Lower–Middle Ordovician conodont biostratigraphic chart from South China, North America, Newfoundland, and Argentine Precordillera.

Biostratigraphic value of the *Tripodus laevis* s. l. in the Argentine Precordillera

In the precordilleran Ordovician conodont biostratigraphic chart proposed by Albanesi *et al.* (1998), the *T. laevis* Zone indicates the lower boundary of the Middle Ordovician series. This zone was defined as an interval zone that ranges from the first record of the eponymous species to the FAD of the *Baltoniodus navis* (Lindström, 1955) (Albanesi *et al.*, 1998). Its stratotype was located in the Portezuelo Yanso section (Fig. 3); the lower boundary was placed at 147 m and the upper limit at 248 m from the base of the San Juan Formation. Afterwards, the *T. laevis* Zone has also been identified in the uppermost bed of the San Juan Formation and the lower strata of the Gualcamayo Formation at Los Sapitos, Peña Sombría, and Los Potrerillos creek sections (northern Precordillera) (Albanesi *et al.*, 1999) (Fig. 3). Albanesi & Ortega (2002) validated the *T. laevis* biozone but considered the specimens present in the Precordillera as *T. laevis* s. l.

Subsequently, Della Costa & Albanesi (2016) mentioned the record of *B. triangularis* at 14 m below the top of the San Juan Formation in co-occurrence with *T. laevis* s. l. in the Peña Sombría section (Fig. 3). Nevertheless, this significant finding lacks a photographic record, as well as an appropriate systematic study that allows validating those records. Based on these findings, Albanesi & Ortega (2016) proposed modifying the previous *T. laevis* Zone as *B. triangularis-T. laevis* Zone, whose lower boundary would be marked by the FAD of the eponymous species. However, this co-occurrence has not been registered in other sections of the Precordillera.

Recent studies about late Floian, Dapingian, and early Darriwilian conodont biostratigraphy showed problems in the definition of lower and upper boundaries of the Dapingian stage (Albanesi *et al.*, 2006; Soria *et al.*, 2013; Mango & Albanesi, 2018a, 2018b, 2020, 2023; Moreno *et al.*, 2020; Moreno, 2023; Mestre *et al.*, 2024).

In the Niquivil section, the first occurrence of *T. laevis* s. l. was registered 20 m below the FAD of *Triangulodus brevibasis* (Sergeeva, 1963), which allowed the record of the *B. navis* Zone in the shoal and reef facies (Albanesi *et al.*, 2006). On the other hand, Mango & Albanesi (2018a) recorded the first occurrence of *T. laevis* s. l. at least 20 m above the reef facies; additionally, these authors state

the absence of *B. navis* Zone in this section proposing the presence of the *B. triangularis-T. laevis* Zone.

In the Los Gatos creek section (Cerro Viejo), the lower boundary of the *B. triangularis-T. laevis* Zone was recognized by the first occurrence of *T. brevibasis*, which was recovered 50 m below the FAD of *T. laevis* s. l. and above these beds there is a barred interval of 40 m thick (Mango & Albanesi, 2018b) (Fig. 3). Moreover, Mango & Albanesi (2020) retrieved the species *T. brevibasis* in the *O. intermedius* Zone and registered the *B. triangularis-T. laevis* Zone from the base of the reef facies to the top of the San Juan Formation in the La Silla section by the presence of the species *T. laevis* s. l. (Fig. 3).

Recently, the *B. navis* Zone was recorded in the lowermost beds of the Gualcamayo Formation at Los Potrerillos creek (Mango & Albanesi, 2023). These authors proposed correlating those levels of the Gualcamayo Formation with the *B. triangularis-T. laevis* Zone beds from Niquivil and sterile stratigraphic interval from the Los Gatos creek. However, the equivalent strata from the La Silla section were not included in this correlation.

Based on all these issues and inconsistencies in the definition of both the lower boundary of the *T. laevis* Zone and the Dapingian stage, we suggest discontinuing the FAD of *T. laevis* s. l. as a marker for the lower boundary of the Middle Ordovician in the Precordillera.

The *O. intermedius* Zone proposed by Albanesi *et al.* (1998) represents an interval zone whose lower boundary was marked by the last appearance datum (LAD) of *O. evae* and the upper limit by the FAD of *T. laevis* s. l. Soria *et al.* (2013) and Moreno *et al.* (2020) proposed modifications in the boundaries of the *O. intermedius* Zone, considering it as an interval zone whose lower boundary is the FAD of the index conodont. Indeed, *O. evae* and *O. intermedius* co-occur during the lower interval of the *O. intermedius* Zone. However, the upper boundary stayed open since the absence of index conodonts in the younger stratigraphic strata precludes its identification. Recently, Moreno (2023) recorded the conodont species *Microzarkodina flabellum* (Lindström, 1955) 12 m above the beds with typical conodonts of the *O. intermedius* Zone in the shoal and reef facies (Mestre *et al.*, 2020) (Fig. 3). This finding allowed inferring the time interval constrained by *B. triangularis-B.*

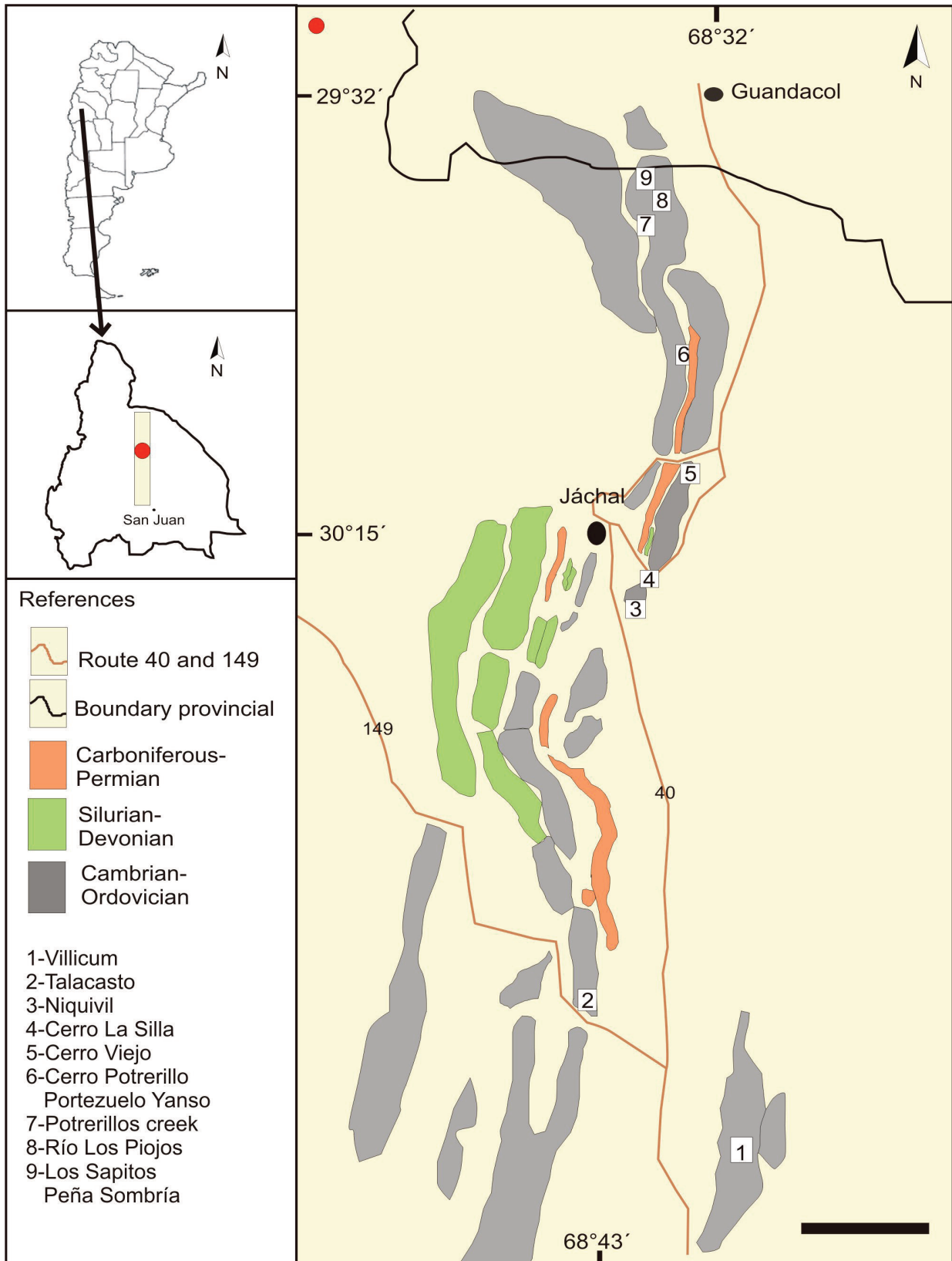


Figure 3. Regional location map and references and geological map of the Argentine Precordillera with the location of the sections (red point) mentioned in text. Scale= 25km.

navis zones for this level in the Talacasto section. In this section, 45.6 m of barred strata for conodonts were recognized above the *B. triangularis*-*B. navis* zones and in the last 8 m of the San Juan Formation, the *L. variabilis* Zone was identified by the record of *H. sinuosa* and *A. leptosomatus* An, 1983 (Moreno, 2023).

Regarding the Dapingian/Darriwilian boundary, there are some problems in its definition. The *Microzarkodina parva* Zone was proposed as part of the upper Dapingian and lower Darriwilian in two sections in the northern part of the Argentine Precordillera (Albanesi *et al.*, 1998, 1999). However, this conodont zone is absent to the south, where the upper Dapingian are nearly devoid of conodonts (Lehnert, 1995; Mango & Albanesi, 2018b; Moreno, 2023; Mestre *et al.*, 2024). In the Niquivil section, 33 m below the erosive top of the San Juan Formation, the *M. flabellum* and *Histiodela altifrons* Harris, 1962 were recovered, indicating an upper Dapingian age, and in the last 7 m of this unit, the Darriwilian brachiopod *Athiella* Biozone was registered (Lehnert, 1995). The *Lenodus antivariabilis* Zone, which represents the base of the Darriwilian, was recorded 20 m below the top of the San Juan Formation in the Río Francia section, but older stratigraphic beds hosted no conodonts (Heredia & Mestre, 2017) (Fig. 3).

Considering all the data, we suggest using the biostratigraphic proposal of Moreno (2023) for the Dapingian stage, until future studies provide more precision in the definition of boundaries of the Dapingian in the Argentine Precordillera (Fig. 2).

CONCLUSION

A critical revision of the taxonomic history of the conodont species *T. laevis* reveals notable differences between the apparatus of *T. laevis* s. l. from the Precordillera and *T. laevis* s. s. from the Midcontinent. Therefore, we recommend refraining from using this name species in the Precordillera region. In addition to the proposal of Mango & Albanesi (2023), which considered *T. laevis* s. l. as a possible new conodont species, we believe that the specimens assigned to *T. laevis* s. l. could belong to other conodont genera, such as *Juanognathus*, *Drepanoistodus*, *Diaphorodus*, and *Paltodus*, among others. This assumption provides a possible answer to the virtual absence of specimens assignable to *T. laevis* in

our conodont collections and other collections studied by several authors in the Ordovician strata from the Argentine Precordillera (Serpagli, 1974; Sarmiento, 1990; Lehnert, 1995).

Despite its historical use as an index conodont for indicating the lower boundary of the Middle Ordovician in the Precordillera, the biostratigraphic revisions and complex history of the *T. laevis* s. l. species make it an unreliable biostratigraphic marker and its random biostratigraphic range is hardly useful for age correlation. The Dapingian stage in the Southern Precordillera is represented by a thick carbonate succession with abundant k-bentonite and chert beds, while in the Northern Precordillera this stage is characterized by graptolite carbonate shales. In these levels, the fossil record is poor and has low diversity. In the same way, the Dapingian conodont record is random and meagre. These features make the Dapingian conodont record problematic for building an accurate conodont biostratigraphy chart.

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