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Conodont biostratigraphy and correlation of the San Juan Formation at the Cerro La Silla section, middle Tremadocian-lower Dapingian, Central Precordillera, Argentina

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ABSTRACT: This study deals with the conodont biostratigraphy from the uppermost part of La Silla Formation (9.6 m) and the overlying San Juan Formation (264.7 m), at the Cerro La Silla section, Central Precordillera of San Juan, Argentina. The 41 samples of carbonate rocks that were digested for microfossils yielded 11,388 conodont elements corresponding to 78 species. The *Paltodus deltifer deltifer* Subzone of the *Paltodus deltifer* Zone from the Baltic biostratigraphic scheme is represented at the top stratum of the La Silla Formation and the basal part of the San Juan Formation (28.4 m), which correlates with the *Macerodus dianae* Zone (middle Tremadocian) of the Precordilleran and North American schemes. Following upwards, the *Paroistodus proteus*, *Prioniodus elegans*, *Oepikodus evae*, *Oepikodus intermedius* and *Baltoniodus triangularis-Tripodus laevis* zones (middle Tremadocian-lower Dapingian) are recorded in the San Juan Formation. The *Baltoniodus triangularis-Tripodus laevis* Zone is recognized from the second reef level (177.3 m from the base of the San Juan Formation) up to the top stratum in the section, in contrast to previous interpretations that assigned the referred interval to the *Baltoniodus navis*, *Paroistodus originalis* and *Microzarkodina parva* zones of the Baltic biostratigraphic scheme. The division of the *Oepikodus evae* Zone in subzones, according to its original definition for the Precordillera, is not applicable at the Cerro La Silla section due to the particular species distribution. The conodont elements show a brown alteration color (CAI 2-2.5), which indicates a burial paleotemperature of 60-155°C for the bearer strata.

Keywords: Biostratigraphy, Conodonts, San Juan Formation, Cerro La Silla, Ordovician, Precordillera.

RESUMEN. Bioestratigrafía de conodontes y correlación de la Formación San Juan en el cerro La Silla, Tremadociano medio-Dapingiano inferior, precordillera Central, Argentina. Este estudio presenta la bioestratigrafía de conodontes del tramo superior de la Formación La Silla (9,6 m) y la suprayacente Formación San Juan (264,7 m), en la sección del cerro La Silla, precordillera Central de San Juan, Argentina. Se procesaron 41 muestras de rocas carbonáticas para la obtención de microfósiles, las cuales proporcionaron 11.388 conodontes correspondientes a 78 especies. La subzona de *Paltodus deltifer deltifer* de la Zona de *Paltodus deltifer* del esquema bioestratigráfico de la región Baltoescandinava está representada en el techo de la Formación La Silla y en la parte basal de la Formación San Juan (28,4 m), correlacionándose con la Zona de *Macerodus dianae* (Tremadociano medio) de los esquemas de la Precordillera y Norteamérica. Las zonas suprayacentes de *Paroistodus proteus*, *Prioniodus elegans*, *Oepikodus evae*, *Oepikodus intermedius* y *Baltoniodus triangularis-Tripodus laevis* (Tremadociano medio-Dapingiano inferior) se registran en la Formación San Juan. La Zona de *Baltoniodus triangularis-Tripodus laevis* es reconocida desde el segundo nivel arrecifal (177,3 m desde la base de la Formación San Juan) hasta el tope aflorante en la sección, lo que difiere de interpretaciones previas que asignaban el intervalo referido a las zonas de *Baltoniodus navis*, *Paroistodus originalis* y *Microzarkodina parva* del esquema bioestratigráfico de la Región Baltoescandinava. La división de la Zona de *Oepikodus evae* en subzonas, según su definición original para la Precordillera, no es aplicable a la sección del cerro La Silla por su particular distribución de las especies. Los conodontes presentan una coloración parda (CAI 2-2,5), que indica una paleotemperatura de soterramiento de 60-155 °C para los estratos portadores.

Palabras clave: Bioestratigrafía, Conodontes, Formación San Juan, Cerro La Silla, Ordovícico, Precordillera.

1. Introduction

The Precordillera is located between 28°30′ and 33° S and 68°15′ and 69°45′ W, partly covering the La Rioja, San Juan and Mendoza provinces. This geological province includes extensive Paleozoic outcrops and, to a lesser extent, Mesozoic and Cenozoic rock units. On the basis of its stratigraphic and structural characteristics, the Precordillera is subdivided into three morphostructural units: Eastern (Ortiz and Zambrano, 1981), Central (Baldis and Chebli, 1969) and Western Precordillera (Baldis *et al*., 1982).

The Central Precordillera is composed mainly of carbonate platform deposits (Cerro Totora, La Flecha, La Silla, San Juan and Las Chacritas formations) that makes up a rock sequence of *ca.* 2,500 m thick. This represent an apparently continuous cycle (Baldis and Bordonaro, 1982) deposited under warm to temperate conditions, whose sedimentation began in the Cambrian and continued up to the Darriwilian.

The Cerro La Silla, in the Central Precordillera, is located 15 km southeast of Jáchal City (Figs. 1 and 2), San Juan Province. The study section can be accessed by vehicle through the National Route No. 40.

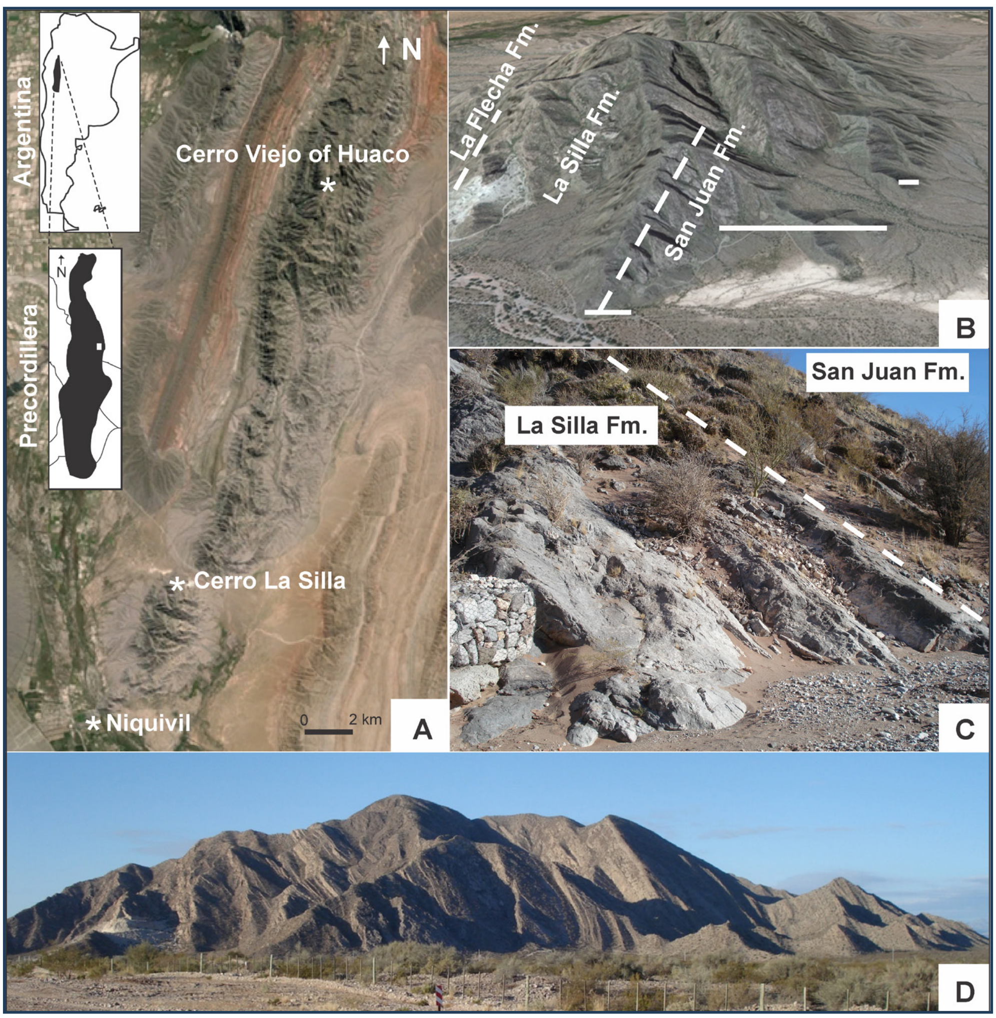

FIG. 1. **A.** Google Earth image showing the geographic location of the Cerro La Silla, Cerro Viejo of Huaco and Niquivil locality in the Central Precordillera. **B.** Google Earth image of the study area, with white lines outlining the stratigraphic sections analyzed; view to the south. **C.** Close up picture of the upper part of the La Silla Formation and the lower part of the San Juan Formation; view to the southwest. **D.** The Cerro La Silla; view to the southeast.

The section of the San Juan Formation at the Cerro La Silla (Fig. 1) is interesting to analyze due to the presence of two reefal structures in its lower and middle parts, where a stratigraphically continuous record of the conodont fauna is represented. The upper stratigraphic section, which occupies approximately one third of its actual thickness, is covered by alluvial sediments in this locality.

The conodont biostratigraphy of the San Juan Formation at Cerro La Silla was partly studied by Lehnert (1995) and Thalmeier (2014). The biostratigraphic analysis of the uppermost part of La Silla Formation and of the overlying San Juan Formation, as well as an updating to the biostratigraphic scheme of the Precordillera (Albanesi and Ortega, 2016) motivated this work.

Accordingly, the objective of this work is to study the conodont fauna of the San Juan Formation exposed at the Cerro La Silla, including the transitional interval between this unit and the uppermost strata of the underlying La Silla Formation, in order to determine the characteristics and differences of the taxonomic record and to establish the conodont biostratigraphy following the updated biozonal scheme for the Precordillera (Albanesi and Ortega, 2016), as well as its regional and global correlation.

2. The San Juan Formation

The carbonate sequence of the San Juan Formation (Keller *et al*., 1994), approximately 330 m thick, is made up of skeletal micritic limestones deposited from the upper Tremadocian up to the middle Darriwilian on a ramp topography, recording two regressive-transgressive cycles (Cañas, 1995).

The boundary between the La Silla Formation and the overlying San Juan Formation marks a major change in the configuration of the carbonate platform, with the passage from subtidal to open platform facies in a carbonate ramp geometry (Pratt *et al*., 2012). This lithofacial change is accompanied by an important faunal change.

The limestones of the San Juan Formation starts with a transgressive sequence at whose base a reef horizon consisting of calcimicrobials and sponges is developed (Cañas and Carrera, 2003).

Subsequently, high sea level sediments accumulate (mostly bioturbated skeletal wackestones) in a framework of environmental stability, which allows the development of rich subtidal communities dominated by suspension-feeding organisms, especially brachiopods and macluritacean gastropods (Cech and Carrera, 2002).

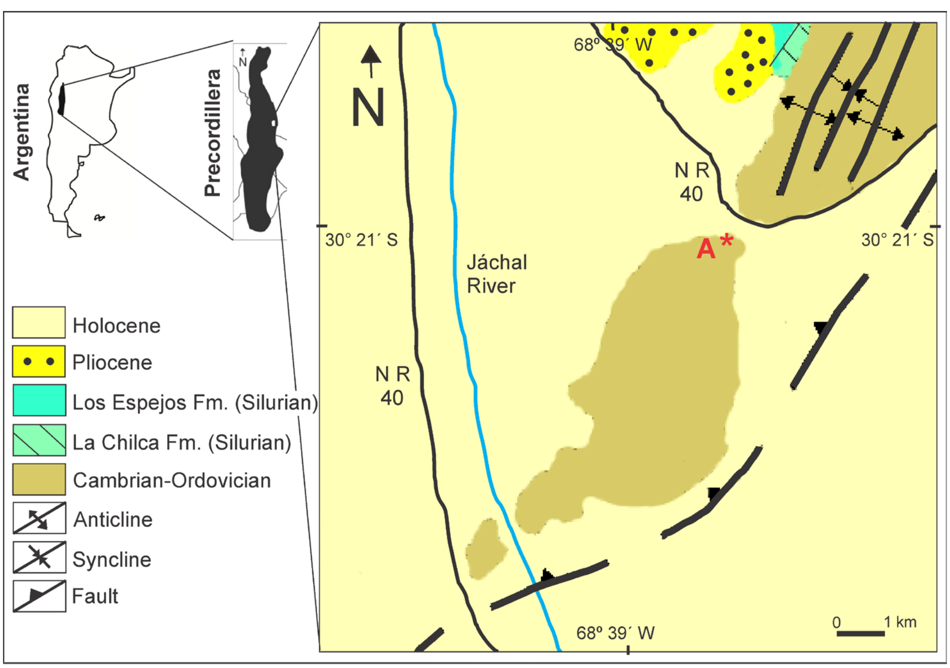

FIG. 2. Geological sketch of the study area and location of the Cerro La Silla section (A*).

A second reef horizon that consists of microbialites, receptaculitids (*Calathium*) and mainly stromatoporoids (*Zondarella*) is located in the middle part of the San Juan Formation close to the base of the Middle Ordovician (Dapingian).

During the Darriwilian, as a consequence of a relative sea level increment that led to the drowning of the platform below the photic zone, the carbonate production is suffocated. Consequently, the carbonate cycle culminates, being followed by the deposition of calcareous-shaly facies towards a predominantly pelitic sequence (Baldis and Beresi, 1981; Baldis *et al*., 1984), known as the Gualcamayo and Los Azules formations in different localities of the Precordillera.

3. Framework of the conodont biostratigraphy at the study area

Lehnert (1995) studied the conodont biostratigraphy from the lower 130 m of the San Juan Formation at the Cerro La Silla section, proposing the *Colaptoconus quadraplicatus-Parapanderodus striatus*, *Acodus? deltatus-Paroistodus proteus*, *Prioniodus elegans-Oepikodus communis*, and *Oepikodus evae* association zones.

Subsequently, Thalmeier (2014) processed nineteen rock samples (16.5 kg) from San Juan Formation at the Cerro La Silla section, recovering 344 conodont elements. From this material, she recorded the *Paroistodus proteus*, *Prioniodus elegans*, *Oepikodus evae*, *Oepikodus intermedius* and *Tripodus laevis* zones of the biostratigraphic scheme of Albanesi *et al*. (1998). It should be noted that the samples from the basal strata (samples LS 8 and LS 7) were sterile, and the first productive level obtained by the author is located above the first reef level (sample LS 6).

4. Materials and methods

The field-work consisted in the recognition of the study area and the sampling of the stratigraphic profile corresponding to the San Juan Formation at the Cerro La Silla section. There 41 limestone samples were taken, with a variable weight between 2 and 4 kg, among intervals of interest for the accomplishment of the present study. Thus, 2 samples were taken from the upper part of the La Silla Formation (uppermost 9.6 m) and 39 samples throughout the San Juan Formation (Tables 1-4)

TABLE 1. ABSOLUTE FREQUENCY OF CONODONT SPECIES FROM THE UPPER PART OF THE LA SILLA FORMATION AND THE SAN JUAN FORMATION (SAMPLES LSLS -1 TO LSSJ P), CERRO LA SILLA SECTION.

Species/Samples	LSLS -1	LSLS 0	LSSJ 0	LSSJ 1	LSSJ 2	LSSJ3	LSSJ 4	LSSJ P2	LSSJ P1	LSSJ P
Anodontus longus	1	-	-	-	-	-	-	-	-	-
Colaptoconus priscus	-	1	-	2	1	-	-	2	1	-
Colaptoconus quadraplicatus	2	31	15	7	-	1	5	1	4	4
Cornuodus longibasis	-	-	-	-	-	-	-	-	-	2
Drepanodus arcuatus	-	-	-	-	-	1	2	-	-	-
Drepanoistodus forceps	-	-	-	-	1	-	-	-	-	5
Kallidontus corbatoi	-	-	-	-	-	-	-	-	3	-
Lundodus gladiatus	-	-	-	-	-	-	-	-	-	1
Paltodus deltifer deltifer	-	1	2	-	1	3	1	-	-	-
Paltodus perrii	-	-	-	-	-	-	-	-	-	-
Paltodus subaequalis	-	1	-	-	-	-	-	-	1	5
Paroistodus proteus	-	-	-	-	-	-	-	-	1	4
Protoprioniodus simplicissimus	-	-	-	-	-	-	-	-	-	1
Scandodus furnishi	-	-	-	-	-	-	-	-	-	1
Tropodus comptus	-	-	-	-	-	-	-	-	-	1
Tropodus sweeti	-	-	-	-	-	-	-	-	-	4
Variabiloconus bassleri	-	2	-	-	-	-	-	-	-	-
Total conodont elements per sample	**3**	**36**	**17**	**9**	**3**	**5**	**8**	**3**	**10**	**28**
Amount of processed material (g)	**2,865**	**3,740**	**2,960**	**2,405**	**2,150**	**2,035**	**2,230**	**2,005**	**2,495**	**2,075**
Insoluble material (g)	**0**	**0**	**0**	**0**	**0**	**0**	**140**	**0**	**0**	**0**
Soluble material (g)	**2,865**	**3,740**	**2,960**	**2,405**	**2,150**	**2,035**	**2,090**	**2,005**	**2,495**	**2,075**

TABLE 2. ABSOLUTE FREQUENCY OF CONODONT SPECIES FROM THE SAN JUAN FORMATION (SAMPLES LSSJ O6 TO LSSJ L3), CERRO LA SILLA SECTION.

Species/Samples	LSSJ O6	LSSJ O5	LSSJ O4	LSSJ O3	LSSJ O2	LSSJ O1	LSSJ O	LSSJ N	LSSJ M	LSSJ L3
Acodus deltatus	-	1	2	-	1	-	2	2	-	-
Anodontus longus	2	-	1	2	2	-	-	2	-	-
Ansella jemtlandica	-	-	-	-	-	-	-	1	-	-
Bergstroemognathus extensus	-	-	27	-	-	-	18	9	-	11
Colaptoconus priscus	1	-	-	-	-		-	-	-	-
Colaptoconus quadraplicatus	21	-	-	-	-	-	-	2	-	-
Cornuodus longibasis	-	-	1	1	-	2	5	18	4	-
Diaphorodus russoi	3	-	9	8	3	1	88	24	4	-
Diaphorodus tovei	-	-	-	-	-	-	18	18	-	-
Drepanodus arcuatus	4	1	17	16	14	6	134	180	8	-
Drepanoistodus forceps	2	2	4	-	2	-	49	14	1	2
Gen. et sp. nov.	-	-	-	-	-	-	-	1	2	-
Juanognathus jaanussoni	-	3	-	-	-	-	-	-	-	1
Juanognathus variabilis	-	-	-	-	-	-	-	3	2	15
Jumudontus gananda	-	-	-	-	-	-	5	4	-	-
Kallidontus corbatoi	-	-	-	-	1	-	-	1	2	-
Kallidontus princeps	-	-	-	-	-	-	1	-	-	-
Kallidontus? lofgreni	-	-	-	-	-	-	1	-	-	-
Lundodus gladiatus	-	4	-	-	-	-	-	4	-	-
Oelandodus costatus	-	3	-	6	-	1	5	18	3	4
Oelandodus costatus?	-	-	-	1	-	-	-	4	-	-
Oelandodus elongatus	-	1	9	-	13	-	159	233	4	-
Oepikodus communis	-	-	-	-	-	-	7	3,444	5	-
Oistodus lanceolatus	-	-	-	-	-	-	-	-	12	-
Oistodus multicorrugatus	-	-	-	1	-	-	-	-	1	-
Paltodus perrii	-	-	3	-	-	-	4	9	-	-
Paltodus subaequalis	4	1	8	14	2	-	39	50	6	-
Paracordylodus gracilis	-	-	4	1	-	1	70	1	-	-
Parapaltodus simplicissimus	-	1	-	1	4	-	-	-	2	-
Parapanderodus paracornuformis	-	-	-	1	-	-	-	-	-	-
Paroistodus originalis	13	-	-	-	-	-	-	-	-	1
Paroistodus parallelus	1	-	-	-	-	-	2	10	4	-
Paroistodus proteus	-	2	14	9	8	-	177	405	3	-
Periodon primus	-	2	1	-	-	-	4	8	-	-
Periodon selenopsis	-	-	-	-	-	-	-	4	-	-
Prioniodus elegans	-	1	15	-	6	4	84	637	-	-
Protopanderodus elongatus	2	1	-	1	4	4	14	11	6	2

Table 2 continued.

Species/Samples	LSSJ O6	LSSJ O5	LSSJ O4	LSSJ O3	LSSJ O2	LSSJ O1	LSSJ O	LSSJ N	LSSJ M	LSSJ L3
Protopanderodus gradatus	-	-	3	-	-	-	-	47	-	-
Protopanderodus leonardii	1	-	14	7	12	-	101	36	12	9
Protopanderodus rectus	-	-	4	1	-	-	-	40	2	1
Protoprioniodus cowheadensis	-	-	-	-	-	-	-	2	-	-
Protoprioniodus simplicissimus	-	-	-	-	-	-	8	-	5	-
Reutterodus andinus	-	1	28	18	23	8	287	296	17	2
Rossodus barnesi	-	1	-	4	8	-	28	49	1	-
Scandodus furnishi	-	-	1	1	1	-	5	3	-	-
Scolopodus krummi	8	1	13	11	4	-	11	57	-	3
Semiacontiodus potrerillensis	-	2	-	-	-	-	-	-	-	-
Tripodus albanii	-	-	-	-	4	-	-	5	-	-
Tropodus australis	-	9	-	5	1	-	15	19	2	-
Tropodus comptus	-	3	-	6	7	-	13	46	1	-
Tropodus sweeti	4	1	11	16	45	21	199	3	18	-
Venoistodus venustus	-	1	-	-	-	-	-	-	-	-
Total conodont elements per sample	**66**	**42**	**189**	**131**	**165**	**48**	**1,553**	**5,720**	**127**	**51**
Amount of processed material (g)	**2,025**	**2,090**	**2,005**	**2,100**	**2,225**	**2,090**	**2,375**	**2,005**	**2,105**	**2,520**
Insoluble material (g)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Soluble material (g)	**2,025**	**2,090**	**2,005**	**2,100**	**2,225**	**2,090**	**2,375**	**2,005**	**2,105**	**2,520**

TABLE 3. ABSOLUTE FREQUENCY OF CONODONT SPECIES FROM THE SAN JUAN FORMATION (SAMPLES LSSJ L2 TO LSSJ I), CERRO LA SILLA SECTION.

Species/Samples	LSSJ L2	LSSJ L1	LSSJ K2	LSSJ K1	LSSJ K	LSSJ J1	LSSJ J	LSSJ I2	LSSJ I1	LSSJ I
Anodontus longus	-	-	-	-	-	-	-	-	-	1
Ansella jemtlandica	-	-	-	-	-	-	-	1	-	-
Bergstroemognathus extensus	12	3	10	28	11	40	10	-	-	-
Colaptoconus quadraplicatus	-	-	-	-	-	-	-	-	-	6
Cooperignathus aranda	-	-	-	-	-	-	-	1	-	2
Cornuodus longibasis	-	-	-	-	4	1	-	1	1	7
Diaphorodus russoi	-	-	2	-	3	-	1	-	-	-
Drepanodus arcuatus	7	1	21	7	29	4	3	9	26	18
Drepanoistodus basiovalis	-	-	-	1	-	-	-	-	-	-
Drepanoistodus forceps	2	-	8	-	4	-	1	2	15	24
Erraticodon patu	-	-	-	-	-	-	-	-	-	2
Fahraeusodus adentatus	-	1	-	-	-	-	-	-	-	-
Juanognathus jaanussoni	-	1	-	-	-	-	4	12	68	89
Juanognathus n. sp. A	-	-	-	2	18	-	-	-	-	11
Juanognathus variabilis	97	16	67	77	139	15	37	-	-	3

Table 3 continued.

Species/Samples	LSSJ L2	LSSJ L1	LSSJ K2	LSSJ K1	LSSJ K	LSSJ J1	LSSJ J	LSSJ I2	LSSJ I1	LSSJ I
Jumudontus gananda	-	-	-	-	-	1	-	-	-	-
Kallidontus princeps	-	-	-	1	-	-	-	-	-	-
Lundodus gladiatus	-	-	-	1	6	1	-	1	-	1
Gen. et sp. nov.	-	-	-	-	-	-	-	1	-	-
Oelandodus costatus	-	1	-	-	3	-	-	-	-	1
Oelandodus elongatus	-	1	1	-	-	-	-	-		-
Oepikodus communis	4	-	41	-	-	-	-	-	-	-
Oepikodus evae	-	-	25	10	136	3	-	-	-	-
Oepikodus intermedius	-	-	-	1	43	-	1	6	196	80
Oistodus lanceolatus	-	-	-	-	-	-	2	-	7	39
Oistodus striolatus	-	-	-	-	-	-	-	-	1	-
Paltodus subaequalis	1	1	2	3	19	4	-	1	4	3
Paltodus? jemtlandicus	-	-	-	-	-	-	-	-	-	1
Paracordylodus gracilis	-	-	-	-	1	-	-	-	-	1
Parapaltodus simplicissimus	3	1	-	1	-	-	-	-	-	-
Parapanderodus paracornuformis	-	-	-	-	-	-	-	-	-	1
Parapanderodus striatus	3	-	-	-	-	-	-	-	-	-
Paroistodus cf. P. proteus	-	-	-	-	29	-	-	-	-	2
Paroistodus originalis	-	-	2	7	-	-	-	6	20	5
Paroistodus parallelus	-	-	-	1	2	3	-	-	-	1
Paroistodus proteus	1	-	-	-	-	-	-	-	-	-
Periodon flabellum	-	-	4	-	31	-	2	5	3	72
Periodon primus	-	-	-	-	29	-	-	-	-	-
Periodon selenopsis	4	-	1	-	-	2	-	-	-	-
Prioniodus adami	-	-	-	-	-	-	-	-	4	-
Prioniodus elegans	17	-	2	-	-	-	-	-	-	-
Protopanderodus elongatus	15	1	-	7	-	-	-	-	14	2
Protopanderodus gradatus	3	1	15	-	21	16	-	7	9	94
Protopanderodus leonardii	23	1	3	14	16	7	4	-	-	14
Protopanderodus rectus	2	-	16	13	50	-	8	27	58	38
Pteracontiodus cryptodens	-	-	-	-	8	-	-	-	1	-
Reutterodus andinus	20	1	18	11	39	5	12	-	-	-
Rossodus barnesi	2	-	8	-	1	-	-	-	7	16
Scolopodus krummi	1	-	27	-	6	15	1	-	-	-
Scolopodus oldstockensis	-	-	5	5	1	4	1	-	-	2
Texania heligma	-	-	1	-	-	-	-	-	-	2
Trapezognathus diprion	-	-	-	-	-	-	-	-	1	-
Triangulodus brevibasis	-	-	-	-	-	-	-	-	-	3
Tropodus australis	10	-	-	-	1	-	-	-	-	-
Tropodus comptus	1	-	1	1	4	-	-	-	-	-
Tropodus sweeti	16	5	5	36	5	-	5	-	-	1
Total conodont elements per sample	**244**	**35**	**285**	**227**	**659**	**121**	**92**	**80**	**435**	**542**
Amount of processed material (g)	**1,975**	**2,075**	**2,140**	**2,155**	**2,080**	**2,120**	**2,055**	**2,010**	**2,105**	**2,175**
Insoluble material (g)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Soluble material (g)	**1,975**	**2,075**	**2,140**	**2,155**	**2,080**	**2,120**	**2,055**	**2,010**	**2,105**	**2,175**

TABLE 4. ABSOLUTE FREQUENCY OF CONODONT SPECIES FROM THE SAN JUAN FORMATION (SAMPLES LSSJ H4 TO LSSJ TOPE+), CERRO LA SILLA SECTION.

Species/Samples	LSSJ H4	LSSJ H3	LSSJ H2	LSSJ H1	LSSJ H	LSSJ G	LSSJ F	LSSJ D	LSSJ B	LSSJ A+7	LSSJ tope+
Anodontus longus	-	-	-	-	1	1	-	1	1	-	1
Ansella jemtlandica	-	-	-	-	-	-	-	2	-	2	-
Bergstroemognathus extensus	1	6	-	-	-	-	-	-	-	-	-
Cornuodus longibasis	1	4	-	1	-	-	2	2	-	2	-
Diaphorodus russoi	-	1	-	-	-	-	-	1	-	-	-
Drepanodus arcuatus	6	16	-	7	-	-	-	1	-	-	1
Drepanoistodus basiovalis	-	-	1	-	-	-	1	2	1	-	2
Drepanoistodus costatus	-	-	-	-	-	-	1	-	-	2	-
Drepanoistodus forceps	-	1	-	2	-	-	-	-	-	-	-
Juanognathus jaanussoni	-	12	1	1	-	1	2	8	14	18	18
Juanognathus serratus	-	-	-	-	-	-	-	-	-	3	2
Juanognathus variabilis	-	7	-	-	-	-	-	-	-	-	-
Jumudontus gananda	-	1	-	-	-	-	-	-	-	-	-
Lundodus gladiatus	-	-	-	-	1	-	1	-	-	-	-
Oelandodus elongatus	2	-	-	-	-	1	-	-	1	-	-
Oepikodus intermedius	6	7	-	1	-	-	-	2	-	-	-
Oistodus lanceolatus	6	1	-	1	-	-	-	13	-	1	-
Oistodus multicorrugatus	-	5	-	3	-	-	-	-	-	-	-
Oistodus striolatus	-	-	-	-	-	-	-	-	-	-	3
Paltodus subaequalis	3	4	-	2	-	-	-	-	-	-	-
Paltodus? jemtlandicus	-	-	-	-	-	-	-	-	-	1	-
Parapaltodus simplicissimus	-	4	-	-	-	-	-	1	-	-	2
Parapanderodus paracornuformis	-	-	-	-	-	-	-	-	-	-	8
Paroistodus originalis	6	5	-	10	-	-	-	-	-	-	-
Paroistodus parallelus	3	2	-	-	-	-	-	-	-	-	-
Periodon flabellum	2	10	-	2	-	-	1	2	1	1	-
Periodon selenopsis	-	3	-	-	-	-	-	-	-	-	-
Protopanderodus elongatus	-	7	-	-	-	-	-	-	-	-	-
Protopanderodus gradatus	15	7	1	5	-	-	-	-	-	-	-
Protopanderodus rectus	9	13	1	2	-	-	4	8	3	-	-
Pteracontiodus cryptodens	-	-	-	-	-	-	-	-	2	-	-
Rossodus barnesi	-	-	1	-	-	-	9	1	4	-	-
Scalpellodus gracilis	-	-	-	-	-	-	1	-	-	-	-
Scolopodus oldstockensis	-	-	-	-	-	-	-	2	-	-	-
Scolopodus striatus	-	-	-	-	-	-	-	1	-	-	-
Semiacontiodus potrerillensis	-	-	-	-	1	1	1	2	16	6	4
Stolodus stola	-	-	-	-	-	-	-	-	-	-	2

Table 4 continued.

Species/Samples	LSSJ H4	LSSJ H3	LSSJ H2	LSSJ H1	LSSJ H	LSSJ G	LSSJ F	LSSJ D	LSSJ B	LSSJ A+7	LSSJ tope+
Triangulodus brevibasis	-	-	1	-	-	-	-	6	-	4	-
Tripodus laevis	-	-	-	-	1	1	5	2	2	3	2
Tropodus australis	3	2	-	-	-	-	-	-	-	-	-
Tropodus comptus	-	1	-	-	-	-	-	-	-	-	-
Tropodus sweeti	-	1	-	-	-	-	1	-	-	-	-
Total conodont elements per sample	**63**	**120**	**6**	**37**	**4**	**5**	**29**	**57**	**45**	**43**	**45**
Amount of processed material (g)	**2,005**	**2,400**	**2,105**	**2,005**	**2,255**	**2,535**	**2,310**	**2,355**	**2,295**	**2,315**	**2,770**
Insoluble material (g)	**0**	**20**	**0**	**0**	**0**	**10**	**0**	**50**	**0**	**0**	**0**
Soluble material (g)	**2,005**	**2,380**	**2,105**	**2,005**	**2,255**	**2,525**	**2,310**	**2,305**	**2,295**	**2,315**	**2,770**

The laboratory work comprised the processing of rocks for the recovery of microfossils, following the method of Stone (1987) (10% formic acid). For each processed sample, insoluble residue was recovered varying in weight from 20 to 100 g, regarding the composition of the limestone. Over this residue, associated microfossils were picked up, including 11,388 conodonts specimens, which correspond to 78 species (Tables 1-4), which were illustrated by conventional optical photomicrography. The conodonts are housed in the Museo de Paleontología, Universidad Nacional de Córdoba, under repository code CORD-MP.

5. Conodonts CAI

In the present study, the conodonts recovered from La Silla and San Juan formations present a color alteration index (CAI) around 2 to 2.5, which refers to burial temperatures of 60-155°C (Epstein *et al*., 1977). These values could be explained by the Niquivil tectonic thrust; that affected the easternmost part of the Central Precordillera (Voldman *et al*., 2010), as recorded for the San Juan Formation in the Cerro Potrerillo (Albanesi *et al*., 1998), Cerro Viejo of Huaco (Ortega *et al*., 2007; Mango and Albanesi, 2018a) and the Río Las Chacritas exposures (Serra *et al*., 2015).

6. Conodont biostratigraphy and correlation

This work follows the conodont biostratigraphic scheme proposed by Albanesi *et al*. (1998, 2006, 2016) and Della Costa and Albanesi (2016), for the Argentine Precordillera, and subsequently updated by Albanesi and Ortega (2016) (Fig. 3).

6.1. *Macerodus dianae* Zone

This zone can be recorded from the lowest sample taken in the upper La Silla Formation, 9.6 m below the contact with the San Juan Formation (LSLS-1) (Fig. 4) to the sample LSSJ P1, where *Paroistodus proteus* (Lindström) appears in the record. These strata bear the index fossil *Paltodus deltifer deltifer* (Lindström) (Fig. 5) that allows to recognize the *Paltodus deltifer* Zone, *Paltodus deltifer deltifer* Subzone of the biostratigraphic scheme of Baltica, which correlates with the *Macerodus dianae* Zone of the scheme used in this work. In these samples, the record of *Paltodus deltifer deltifer*, *Colaptoconus priscus* (Ji and Barnes) and *Colaptoconus quadraplicatus* (Branson and Mehl) is frequent, and the record of *Variabiloconus bassleri* (Furnish) is scarce. The local thickness of this zone is *ca.* 38 m.

6.1.1. Regional correlation

Albanesi *et al*. (1998) reported the *Paltodus deltifer* Zone in the La Silla Formation at the Portezuelo Yanso section, and correlates its upper part with the *Macerodus dianae* Zone. Subsequently, Albanesi *et al*. (2016) studied the upper part of the La Silla Formation at the Cerro Viejo of San Roque, Central Precordillera of San Juan, and recognized the index fossils *Macerodus dianae* in the Umango section and *Paltodus deltifer deltifer* from the top stratum of the La Silla Formation in the Portezuelo Jáchal section. This work allowed to recognize the *Macerodus dianae* Zone.

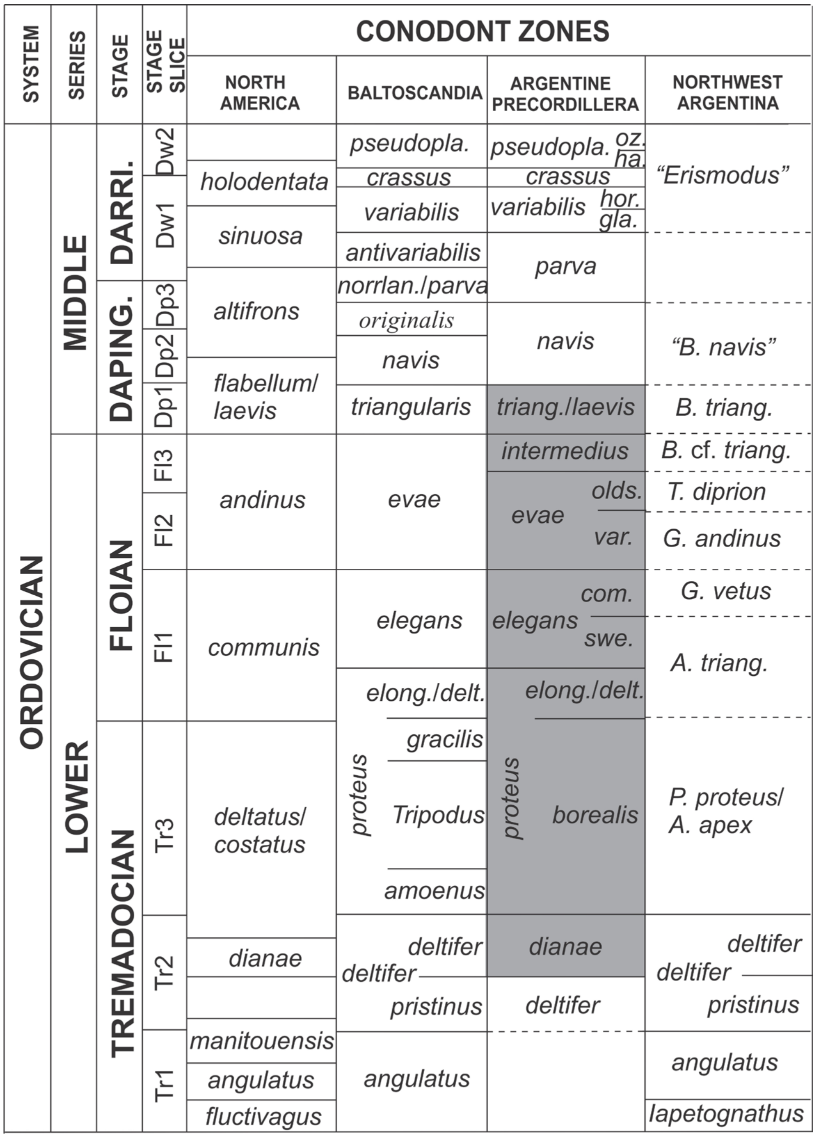

FIG. 3. Chronostratigraphic scheme of the Tremadocian-Darriwilian stages (Lower-Middle Ordovician), with conodont zones of North America, the Baltoscandian region, the Precordillera and Northwest Argentina (modified from Albanesi and Ortega, 2016). In gray the time span considered in this work.

Voldman *et al*. (2013a) analyzed the conodonts of the Santa Rosita Formation in the sections of Peña Blanca and San Felipe, Santa Victoria, Cordillera Oriental of northwestern Argentina, and recorded the upper *Paltodus deltifer* Zone (*P. deltifer deltifer* Subzone), which correlates with the *Macerodus dianae* Zone.

From the Alfarcito and Rupasca members of the Santa Rosita Formation at Nazareno, Giuliano *et al*. (2013) recognized the conodont fauna corresponding to the *P. deltifer* Zone; particularly, its upper part (the *Paltodus deltifer deltifer* Subzone) that correlates with the *Macerodus dianae* Zone.

In the San Jorge Formation, exposed in the central sector of the La Pampa Province, Albanesi *et al*. (2003) reported conodonts referred to the Baltoscandian upper *P. deltifer* Zone that correlates with the *Macerodus dianae* Zone.

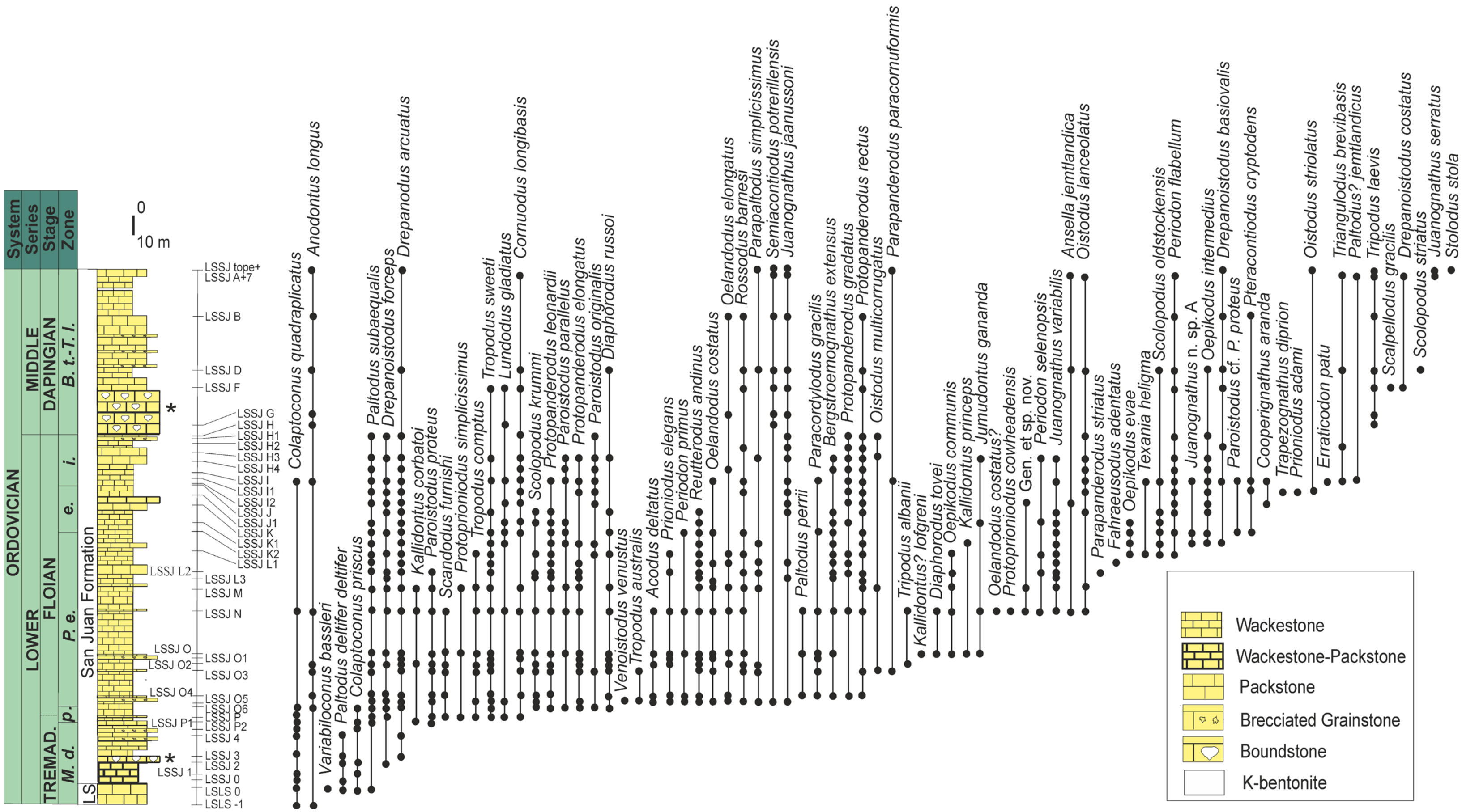

FIG. 4. Stratigraphic column from the upper part of the La Silla and San Juan formations at the Cerro La Silla sections, showing the stratigraphic distribution of conodont species (Abbreviations: **LS:** La Silla Formation; ***M.d.:*** *Macerodus dianae*; ***p.:*** *Paroistodus proteus*; ***P.e.:*** *Prioniodus elegans*; ***e.:*** *Oepikodus evae*; ***i.:*** *Oepikodus intermedius*; ***B.t.-T.l.:*** *Baltoniodus triangularis-Tripodus laevis;* ****:*** reef level).

FIG. 5. Conodonts from the upper La Silla Formation and the San Juan Formation at the Cerro La Silla section. **1-6. *Oepikodus communis* (Ethington and Clark)**; **1.** M element, sample LSSJ N, CORD-MP 64714; **2.** Sb element, sample LSSJ N, CORD-MP 64715; **3.** Sc element, sample LSSJ N, CORD-MP 64716; **4.** Sd element, sample LSSJ N, CORD-MP 64717; **5.** Pa element, sample LSSJ O, CORD-MP 64718; **6.** Pb element, sample LSSJ N, CORD-MP 64719. **7-12. *Oepikodus evae* (Lindström)**; **7.** M element, sample LSSJ K, CORD-MP 68215; **8.** Sb element, sample LSSJ K, CORD-MP 68216; **9.** Sc element, sample LSSJ K, CORD-MP 68217; **10.** Sd element, sample LSSJ K, CORD-MP 68218; **11.** Pa element, sample LSSJ K, CORD-MP 68219; **12.** Pb element, sample LSSJ K, CORD-MP 68220. **13-18. *Oepikodus intermedius* (Serpagli)**; **13.** M element, sample LSSJ I, CORD-MP 68399; **14.** Sb element, sample LSSJ I, CORD-MP 68400; **15.** Sc element, sample LSSJ I, CORD-MP 68401; **16.** Sd element, sample LSSJ I1, CORD-MP 68402; **17.** Pa element, sample LSSJ I, CORD-MP 68403; **18.** Pb element, sample LSSJ K, CORD-MP 68404. **19-21. *Oistodus striolatus* Serpagli**; **19.** Sa element, sample LSSJ tope+, CORD-MP 68824; **20.** Sc element, sample LSSJ tope+, CORD-MP 68825; **21.** P element, sample LSSJ tope+, CORD-MP 68826. **22-24. *Paltodus deltifer deltifer* (Lindström)**; **22.** M element, sample LSLS 0, CORD-MP 68828; **23.** Sa element, sample LSSJ 2, CORD-MP 68829; **24.** Sb element, sample LSSJ 3, CORD-MP 68830. **25.** *Paroistodus proteus* (Lindström), M element, sample LSSJ O, CORD-MP 69279. Scale bar: 100 µm.

6.1.2. Intercontinental correlation

The conodont associations from the Ceratopyge limestone (lower Oelandiano AIII Stage) of Västergötland and Öland, Sweden, would correspond to the *Paltodus deltifer* Zone (Lindström, 1955, 1971) that in turn correlates with the *Macerodus dianae* Zone of the Precordillera.

Szaniawski (1980) analyzed the chalcedony layers from the Holy Cross Mountains at Poland, and divided the *Paltodus deltifer* Zone into two subzones, a lower or *Paltodus deltifer pristinus* Subzone, and an upper or *Paltodus deltifer deltifer* Subzone; later, Löfgren (1996) analyzed the biostratigraphy of the Orreholmen quarry in Västergötland, Sweden, recognizing this subdivision, where the upper subzone correlates with the *Macerodus dianae* Zone.

The *Prioniodus gilberti* Zone defined by Stouge and Bagnoli (1988) for layer 8 of the Cow Head Group at Newfoundland would represent the discussed zone. A correlative interval has also been identified by Smith (1991) in Greenland, Küppers and Pohler (1992) in Montagne Noire, southern France, An *et al*. (1983) in northern China, and by Nicoll *et al.* (1993) from the units underlying the Emanuel Formation in the Canning Basin of Australia.

At the Honghuayuan Formation, Guizhou, southern China, Zhen *et al*. (2007) record an association of conodonts that compares with material from Sweden, concluding that the lower part of that association would correspond to the *P. deltifer* Zone, that is partly the *Macerodus dianae* Zone.

6.2. *Paroistodus proteus* Zone

The index fossil *Paroistodus proteus* (Figs. 5-6) is recorded between the samples LSSJ P1 and LSSJ O6 (Fig. 4), immediately below the occurrence of *Prioniodus elegans* Pander. Its appearance in this stratigraphic interval allows the recognition of the *Paroistodus proteus* Zone in this section. It shall be noted that it has not been possible to identify the subzones of this zone, because the index fossils that determine these intervals have not been found. The local thickness of this zone is 7.5 m.

The *Paroistodus proteus* Zone records a low diversity of conodonts at the base, with *Colaptoconus priscus* and *C. quadraplicatus* as recurrent species, ranging from the underlying zone. The diversity increases upwards towards the upper section, with the appearances of *Lundodus gladiatus* (Lindström), *Tropodus comptus* (Branson and Mehl), *Tropodus sweeti* (Serpagli), *Cornuodus longibasis* (Lindström), *Protoprioniodus simplicissimus* McTavish, *Kallidontus corbatoi* (Serpagli), *Diaphorodus russoi* (Serpagli), *Paroistodus parallelus* (Pander), *Protopanderodus leonardii* Serpagli, *Protopanderodus elongatus* Serpagli, *Paroistodus originalis* (Sergeeva), and *Scolopodus krummi* (Lehnert).

6.2.1. Regional correlation

Hünicken and Mazzoni (1994) reported the *Paroistodus proteus* Zone in the San Juan Formation from Guandacol River area of the northern Precordillera. In turn, Albanesi *et al*. (1998) determined the *Paroistodus proteus* Zone from the top strata of the La Silla Formation and the basal part of the San Juan Formation at the Yanso Section, Central Precordillera.

Voldman *et al*. (2016) established the *Acodus apex* Zone from the top stratum of the Santa Rosita Formation up to the basal part of the Acoite Formation, and the *Acodus triangularis* Zone from the lower part of the Acoite Formation, at the Chulpíos Creek, Santa Victoria Range, Cordillera Oriental. The *Paroistodus proteus* Zone of this study mostly correlates with the referred *Acodus apex* and *A. triangularis* zones.

6.2.2. Intercontinental correlation

Löfgren (1993) analyzed conodonts from Hunneberg, Sweden, and recognized four biostratigraphic intervals within of the *Paroistodus proteus* Zone, increasing the resolution for this part of the Ordovician; later, Löfgren (1994) formalized them as subzones, including the *Drepanoistodus* aff. *D. amoenus*, *Tripodus*, *Paracordylodus gracilis* and *Oelandodus elongatus/Acodus deltatus* subzones, from base to top, respectively.

At the Ledge Point of Head section, Cow Head Group, Newfoundland, Stouge and Bagnoli (1988) defined the *Prioniodus oepiki* and *Prioniodus adami* zones, which correlate with the upper part of the *Paroistodus proteus* Zone.

The discussed zone correlates with the successive zones of *Scalpellodus tarsus- Triangulodus* sp. aff. *T. bifidus*, *Serratognathus bilobatus* and *Serratognathus extensus* described for northern China (An *et al*., 1983; An and Zheng, 1990; Zhen *et al*., 2015a, 2016; Wang *et al*., 2018).

FIG. **6.** Conodonts from the San Juan Formation at the Cerro La Silla section. **1-6.** ***Paroistodus proteus* (Lindström)**; **1.** Sa element, sample LSSJ N, CORD-MP 69280; **2.** Sb element, sample LSSJ O, CORD-MP 69281; **3.** Sc element, sample LSSJ O, CORD-MP 69282; **4.** Sd element, sample LSSJ O, CORD-MP 69283; **5.** Pa element, sample LSSJ N, CORD-MP 69284; **6.** Pb element, sample LSSJ O, CORD-MP 69285. **7-14.** ***Prioniodus elegans* Pander**; **7.** M element, sample LSSJ N, CORD-MP 70101; **8.** Sa element, sample LSSJ N, CORD-MP 70102; **9.** Sb element, sample LSSJ N, CORD-MP 70103; **10.** Sc element, sample LSSJ N, CORD-MP 70104; **11.** Sd element, sample LSSJ N, CORD-MP 70105; **12.** Sd element, sample LSSJ N, CORD-MP 70106; **13.** Pa element, sample LSSJ O, CORD-MP 70107; **14.** Pb element, sample LSSJ N, CORD-MP 70108. **15-16.** ***Pteracontiodus cryptodens* (Mound)**; **15.** Sd element, sample LSSJ I1, CORD-MP 71732; **16.** P element, sample LSSJ B, CORD-MP 71733. **17-18.** ***Scolopodus oldstockensis* Stouge**; **17.** a element, sample LSSJ K, CORD-MP 72840; **18.** e element, sample LSSJ J, CORD-MP 72841. **19-20.** ***Triangulodus brevibasis* (Sergeeva)**; **19.** Sb element, sample LSSJ A+7, CORD-MP 72900; **20.** P element, sample LSSJ A+7, CORD-MP 72901. **21-25.** ***Tripodus laevis* Bradshaw**; **21.** Sa element, sample LSSJ B, CORD-MP 72925; **22.** Sb element, sample LSSJ D, CORD-MP 72923; **23.** Sc element, sample LSSJ tope+, CORD-MP 72924; **24.** Pa element, sample LSSJ tope+, CORD-MP 72926; **25.** Pb element, sample LSSJ H, CORD-MP 72927. Scale bar: 100 µm.

At the Honghuayuan Formation, Guizhou, southern China, Zhen *et al.* (2007) recorded an association of conodonts that compared with material from Sweden, concluding that the upper part of that association would correspond to the *P. proteus* Zone, although they did not record the index species. At slope facies of the Shijiatou and Jingshan formations, southern China, Zhen *et al*. (2015b) recorded the *Paroistodus proteus, Triangulodus bifidus* and *Serratognathus diversus* biozones, which correlate with the *Paroistodus proteus* Zone of this study.

6.3. *Prioniodus elegans* Zone

The record of *Prioniodus elegans* (Fig. 6) below the first appearance of *Oepikodus evae* (Lindström), is verified between samples LSSJ O6 and LSSJ L1 (Fig. 4), allowing for the recognition of the homonymous zone for this interval, whereas its upper limit is demarked at the sample LSSJ K2 where the *Oepikodus evae* index fossil appears. The *Prioniodus elegans-Tropodus sweeti* Subzone is recognized from sample LSSJ O6 to LSSJ O1 by the record of *Tropodus sweeti* not associated with *Oepikodus communis* (Ethington and Clark). The *Prioniodus elegans-Oepikodus communis* Subzone is recognized from the sample LSSJ O through the occurrence of *Oepikodus communis*, to the sample LSSJ K2. The local thickness of this zone is 86.6 m.

These samples yield a high diversity and abundance of conodonts, with the record of *Juanognathus jaanussoni* Serpagli, *Semiacontiodus potrerillensis* Albanesi, *Parapaltodus simplicissimus* Stouge, *Oelandodus elongatus* (Lindström), *Rossodus barnesi* Albanesi, *Reutterodus andinus* Serpagli, *Tropodus australis* (Serpagli), *Oelandodus costatus* van Wamel, *Bergtroemognathus extensus* Serpagli, *Acodus deltatus* (Lindström), *Periodon primus* Stouge and Bagnoli, *Ansella jemtlandica* (Löfgren), *Oistodus lanceolatus* Pander, *Parapanderodus paracornuformis* (Ethington and Clark), *Protopanderodus rectus* (Lindström), *Protopanderodus gradatus* Serpagli, *Paracordylodus gracilis* Lindström, *Oistodus multicorrugatus* Harris, *Periodon selenopsis* (Serpagli), *Jumudontus gananda* Cooper, *Parapanderodus striatus* (Graves and Ellison) and *Oepikodus communis*.

6.3.1. Regional correlation

Serpagli (1974) suggested the existence of the *Prioniodus elegans* Zone in the San Juan Formation, Precordillera, and proposed its correspondence with the Fauna A of the Pachaco section, based on the species association, although not determining the nominal species. This species was firstly published by Hünicken and Sarmiento (1980) from the Guandacol section, and the zone was defined by Albanesi *et al*. (1998) in the Yanso section.

Lehnert (1993, 1995) defined the correlative *Prioniodus elegans-Oepikodus communis* Association Zone for the basal levels from the San Juan Formation at the Niquivil and Cerro La Silla sections, Precordillera of San Juan.

In the Acoite Formation, Chulpíos Creek, Santa Victoria, Cordillera Oriental, Argentina, Voldman *et al.* (2016) established the *Acodus triangularis*, *Gothodus vetus* and *Gothodus andinus* zones, successively upwards. The *Prioniodus elegans* Zone applied in this work could be correlated with the upper part of the *Acodus triangularis* Zone, the *Gothodus vetus* Zone and much of the *Gothodus andinus* Zone, as defined by the referred authors.

Mango *et al.* (2016) studied samples from the Huaco Anticline, San Juan Precordillera, and recognized the *Prioniodus elegans* Zone in strata of the lower part of the San Juan Formation, based on the occurrence of the nominal species at the Río Huaco canyon.

6.3.2. Intercontinental correlation

Löfgren (1978, 1993, 1994, 1996) identified parts of this zone from different localities of Sweden. Layer 9 of the Cow Head Group contains conodonts assignable to the *Prioniodus elegans* Zone in different sections of Western Newfoundland (Fåhraeus and Nowlan, 1978; Stouge and Bagnoli, 1988; Pohler, 1994). It could also be correlated with the lower part of Fauna E proposed by Ethington and Clark (1971) for the North American biostratigraphic scheme, and with the *Oepikodus communis* Zone by Ethington and Repetski (1984).

The *Protopanderodus inconstans-Scolopodus subrex* Zone of shallow waters and *Acodus delicatus-Acodus? primus* Zone of deep water environments defined by Ji and Barnes (1994) for the Boat Harbour Formation, Saint George Group, Newfoundland, correlate with the lower *Prioniodus elegans* Zone. Its upper part corresponds to the lower *Parapanderodus carlae-Stultodontus ovatus* Zone of shallow-water facies and to the *Oepikodus communis-Protoprioniodus simplicissimus* Zone of deep-water facies as defined for the Catoche Formation by the same authors.

Seo *et al*. (1994) defined the *Paracordylodus gracilis* and *Triangulodus dumugolensis* zones for the upper South Korean Dumugol Formation, which could be partially correlated with the *Prioniodus elegans* Zone. At slope facies of the Jingshan Formation, southern China, Zhen *et al*. (2015b) also recorded the *Prioniodus elegans* Biozone.

6.4. *Oepikodus evae* Zone

This zone is recognized from the sample LSSJ K2 by the occurrence of *Oepikodus evae* (Fig. 5) to the sample LSSJ J (Fig. 4), where *Oepikodus intermedius* (Serpagli) appears not associated to *Oepikodus evae*. In this section, the species *Juanognathus variabilis* Serpagli and *Scolopodus oldstockensis* Stouge are recorded throughout the zonal interval, though according to the reference biostratigraphic scheme by Albanesi and Ortega (2016) it would correspond to the *Oepikodus evae-Scolopodus oldstockensis* Subzone of Albanesi *et al*. (1998). The division of the zone will be discussed in detail under the discussion part. The local thickness of this zone is 23.9 m.

In this interval *Periodon flabellum* (Lindström), *Drepanoistodus basiovalis* (Sergeeva), *Oepikodus intermedius*, *Scolopodus oldstockensis*, *Texania heligma* Pohler, and *Paroistodus* cf. *P. proteus* appear in the record. Additionally, the last record of *Tropodus comptus*, *Oepikodus communis*, *Prioniodus elegans* and *Periodon primus* Stouge and Bagnoli is observed.

6.4.1. Regional correlation

Lehnert (1993, 1995) proposed the *O. evae* and *O. evae./O. intermedius* zones at the Niquivil section, which correlates with the *O. evae* Zone established by Albanesi *et al*. (1998). The later zone was recognized at the Los Gatos Creek, Cerro Viejo of Huaco, Precordillera Central of San Juan, by Mango and Albanesi (2018a).

Mestre (2008) reviewed the conodont biostratigraphy of the uppermost San Juan Formation in the Buenaventura Luna Monument area, recognizing the *Oepikodus evae* Zone regardless previous studies by Lemos (1981). Subsequently, Mango *et al*. (2016) analyzed conodonts from the Huaco Anticline, recognizing conodonts of the *O. evae* Zone from the top stratum of the San Juan Formation, and the limestone dropstones that bear the basal strata of the unconformably overlying Guandacol Formation.

Species of the *Trapezognathus diprion* Zone are recognized in samples obtained from the Acoite Formation of the Cordillera Oriental, Northwest Argentina by Carlorosi and Heredia (2013), whose lower part correlates with the upper *O. evae* Zone of Albanesi *et al*. (1998).

Voldman *et al*. (2016) define the *Gothodus andinus* Zone, in the upper Acoite Formation at the Chulpíos creek, Santa Victoria, Cordillera Oriental, Argentina. The upper section could be correlated with part of the *O. evae* Zone as used in this study. At the Suri Formation of the Famatina System (Lehnert *et al*., 1997; Albanesi and Astini, 2000) and the Niquivil section (Albanesi *et al*., 2006) the *O. evae* Zone is well documented.

6.4.2. Intercontinental correlation

The *O. evae* Zone can be correlated with the upper-middle part of the *Oepikodus communis* Zone in North American biostratigraphic schemes (Ethington and Repetski, 1984).

The index fossil has an important record in the formational units of Hubei Province in China (An, 1981; An *et al*., 1985), although Stouge and Bagnoli (1988) appreciate difficulty in correlation.

The Precordilleran *O. evae* Zone can be correlated with the *O. evae* Zone of Lindström (1971) and the *O. evae* Zone and the lower *Trapezognathus diprion* Zone of Bagnoli and Stouge (1997) from the Baltoscandian region.

In limestone blocks showing evidence of transport, contained in the Rosroe Formation, Lough Nafooey Area, Western Ireland, Stouge *et al*. (2015) recognize an association dominated by *Oepikodus evae*, *Bergstroemognathus*, *Periodon* and *Protopanderodus*.

6.5. *Oepikodus intermedius* Zone

The occurrence of *Oepikodus intermedius* (Fig. 5) not associated to *Oepikodus evae* and *Tripodus laevis* Bradshaw, allows to recognize the homonymous zone from the sample LSSJ J to the sample LSSJ H (Fig. 4), where *Tripodus laevis* appears in the record. The local thickness of this zone is 30.9 m.

These samples present the first record of *Triangulodus brevibasis* (Sergeeva) and *Paltodus? jemtlandicus* Löfgren. In addition, the last record of *Colaptoconus quadraplicatus*, *Paltodus subaequalis* Pander, *Drepanoistodus forceps* (Lindström), *Scolopodus oldstockensis*, *Paroistodus parallelus*, *Juanognathus variabilis* Serpagli, *Tropodus australis*, *Protopanderodus leonardii*, *P. elongatus*, *P. gradatus*, *Texania heligma*, *Paracordylodus gracilis*, *Paroistodus originalis*, *Paroistodus* cf. *P. proteus*, *Bergstroemognathus extensus*, *Oistodus multicorrugatus*, *Juanognathus* n. sp. A, *Scolopodus krummi*, *Periodon selenopsis* and *Jumudontus gananda* is reported.

6.5.1. Regional correlation

At the Yanso section (Albanesi *et al*., 1998) and the Niquivil section (Albanesi *et al*., 2006) the referred unit would be correlated with the *O. intermedius* Zone. According to their collection of conodonts, the latter authors demonstrate that the Fauna C of the San Juan Formation (Serpagli, 1974) would represent the *O. intermedius* Zone, but not the *Baltoniodus navis* Zone as interpreted by Serpagli. At the Los Gatos Creek, Cerro Viejo de Huaco, Precordillera Central of San Juan, Mango and Albanesi (2018a) record the *Oepikodus intermedius* Zone in the San Juan Formation.

Carlorosi and Heredia (2013) analyzed samples obtained from the Acoite Formation, Cordillera Oriental, Northwestern Argentina, and recorded the *Trapezognathus diprion* Zone, and also proposed the *Baltoniodus* cf. *B. triangularis* Zone above it, which correlates with the lower and upper *O. intermedius* Zone, respectively. In the Laguna Verde section, Zenta Range, Cordillera Oriental, Northwest Argentina, Voldman *et al*. (2013b) recovered *Baltoniodus* cf. *triangularis*, with similar conclusions as Carlorosi and Heredia (2013).

6.5.2. Intercontinental correlation

The *O. intermedius* Zone could be correlated with the *O. communis* Zone (Ethington and Repetski, 1984; cf. Smith, 1991; Ji and Barnes, 1994), and with the *Protoprioniodus aranda-Juanognathus jaanussoni* interval of Ethington and Clark (1981) for the middle Wah Wah Formation of the Pogonip Group at Ibex, Utah.

The *O. intermedius* Zone correlates with the uppermost part of the *Oepikodus evae* Biozone of southern China and with the *Jumudontus ganada* Biozone of northern China (Zhen *et al*., 2015a, 2016; Wang *et al*., 2018).

In the Baltic region, it can be correlated with the upper *O. evae* Zone (Lindström, 1971) and with the *Microzarkodina* sp. A Zone of Bagnoli and Stouge (1997). Lehnert *et al*. (2013) studied the biostratigraphy of the Oslobreen Group in the Svalbard archipelago, and recognized in the Valhallfonna Formation, Olenidsletta Member, the *Oepikodus intermedius* Zone, which would correlate with the *O. intermedius* Zone and the base of the *Baltoniodus triangularis-Tripodus laevis* Zone of this work.

6.6. *Baltoniodus triangularis-Tripodus laevis* Zone

This zone is defined by the first appearance of *Tripodus laevis* (Fig. 6), without being associated with *Baltoniodus navis* (Lindström), between samples LSSJ H and LSSJ tope+ (Fig. 4), the latter corresponds to the top stratum of the San Juan Formation in the section. At these levels, *Tripodus laevis*, *Drepanoistodus costatus*, *Stolodus stola* (Lindström), *Pteracontiodus cryptodens* (Mound), *Scolopodus striatus* Pander and *Scalpellodus gracilis* (Sergeeva) are recorded. The local thickness of this zone is at least 87.4 m.

6.6.1. Regional correlation

This unit has originally been defined to as *Tripodus laevis* Zone in the Portezuelo Yanso section of the Cerro Potrerillo (Albanesi *et al*., 1998); although considering the presence of *Baltoniodus triangularis* (Lindström) at the same section and at Peña Sombría, Della Costa and Albanesi (2016) and Albanesi and Ortega (2016) emended the original definition by incorporating the latter taxon as composite name to the zone, for a broader reference. At the Niquivil section the referred biostratigraphic unit is correlated with the *Tripodus laevis* Zone (Albanesi *et al*., 2006) or *Baltoniodus triangularis-Tripodus laevis* (Mango and Albanesi, 2018b). At the Los Gatos Creek, Cerro Viejo of Huaco, Precordillera Central of San Juan, Mango and Albanesi (2018a) recorded the *Baltoniodus triangularis-Tripodus laevis* Zone in the San Juan Formation.

The conodont associations corresponding to Fauna D recorded at the Pachaco section on the San Juan River (Serpagli, 1974) could be assigned to the *Baltoniodus triangularis-Tripodus laevis* Zone.

6.6.2. Intercontinental correlation

This zone would correlate with the *Baltoniodus? triangularis* and *Microzarkodina flabellum* zones of Bagnoli and Stouge (1997), and with the *Baltoniodus triangularis* Zone of Lindström (1971) and Tolmacheva (2001), from the Baltic biostratigraphic schemes.

In North America, it correlates with the *Tripodus laevis* Zone of Ross *et al*. (1997) and with the *Microzarkodina flabellum-Tripodus laevis* Zone of Ethington and Clark (1981). Ji and Barnes (1994) defined the *Parapanderodus retractus* Zone, for shallow-water environments, and the *Pteracontiodus cryptodens* Zone for deep-water environments in the Aguathuna Formation, Saint George Group, Newfoundland, correlatives of the *Baltoniodus triangularis-Tripodus laevis* Zone.

At the Huanghuachang section, China, it could be correlated with the *Baltoniodus triangularis* Zone (Wang *et al*., 2003). Lehnert *et al.* (2013) studied the biostratigraphy of the Oslobreen Group in the Svalbard Archipelago, and recognized in the Valhallfonna Formation, Olenidsletta Member, the *Oepikodus intermedius* Zone, whose upper part correlates with the lower *Baltoniodus triangularis-Tripodus laevis* Zone of this work.

7. Discussion

The 264.7 m thickness calculated in this work for the section of the San Juan Formation at Cerro La Silla differs from the 320 m estimated by Keller *et al*. (1994) for the same section, later used by Cañas (1999), Keller (1999), and Buggisch *et al.* (2003). However, the thickness calculated from the base of the San Juan Formation up to the beginning of the *Oepikodus evae* Zone in the Cerro La Silla section is 122.5 m in the present work, which coincides with the result obtained by Lehnert (1995).

At the Cerro La Silla, the division of the *Oepikodus evae* Zone according to its original definition is not possible to apply, due to the distribution of the species recorded. At the Portezuelo Yanso section, *Scolopodus oldstockensis* appears in the record next to *Oepikodus intermedius* in the middle *Oepikodus evae* Zone (Albanesi *et al*., 1998); instead, at the Cerro La Silla section, *Oepikodus intermedius* presents its first occurrence towards the middle *Oepikodus evae* Zone, while *S. oldstockensis* has its first occurrence in older strata at the base of the mentioned zone. The absence of *S. oldstockensis* in the lower *Oepikodus evae* Zone in the Portezuelo Yanso area could be related to facies control or a bias of the laboratory procedure.

Finally, Buggisch *et al.* (2003) indicated that the upper San Juan Formation at the Cerro La Silla, would correlate with the *Baltoniodus navis*, *Paroistodus originalis*, and *Microzarkodina parva* zones of the Baltic biostratigraphic scheme. However, the present records constrain the deposits located from the base of the second reef level to the top stratum of the San Juan Formation exposed in the section (87.4 m) to the *Baltoniodus triangularis-Tripodus laevis* Zone.

8. Conclusions

The San Juan Formation at the Cerro La Silla section presents a total thickness of 264.7 m. This result differs from published measurement that indicate a thickness of 320 m for the exposed strata of the formation, a significant difference possibly due to the field technique applied for measuring the thickness of this section. However, the thickness calculated from the base of the San Juan Formation up to the beginning of the *Oepikodus evae* Zone at this section is similar to the previously published data, as a reference for the middle part of the section.

The conodonts recovered from La Silla and San Juan formations present a color alteration index (CAI) varying from 2 to 2.5, which refers to burial temperatures of 60-155 °C compatible with the Niquivil tectonic thrust, present in the easternmost belt of the Central Precordillera.

For the upper La Silla Formation and the lower part of the San Juan Formation at the Cerro La Silla, the *Paltodus deltifer deltifer* Subzone of the *Paltodus deltifer* Zone from the Baltic biostratigraphic scheme, which correlates with the *Macerodus dianae* Zone (middle Tremadocian) of the Precordillera and the North American schemes, is determined.

The San Juan Formation at the Cerro La Silla section records conodont species of the *Macerodus dianae*, *Paroistodus proteus*, *Prioniodus elegans*, *Oepikodus evae*, *Oepikodus intermedius* and *Baltoniodus triangularis-Tripodus laevis* zones (middle Tremadocian-lower Dapingian). Recovering of *Baltoniodus triangularis-Tripodus laevis* Zone from the second reef level to the top stratum in the section contradicts previous interpretations that this interval correlates with the *Baltoniodus navis*, *Paroistodus originalis* and *Microzarkodina parva* zones of the Baltic biostratigraphic scheme.

At the Cerro La Silla section, *Scolopodus oldstockensis* is recorded from older strata of the *Oepikodus evae* Zone than at the Portezuelo Yanso section, Cerro Potrerillo, where this zone was defined for the Precordillera, either because of facies control or laboratory bias. This situation precludes the application of the zonal division in the study section.

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References

Albanesi, G.L.; Astini, R.A. 2000. Bioestratigrafía de conodontes de la Formación Las Chacritas, Precordillera de San Juan, Argentina. *In* Reunión anual de comunicaciones de la Asociación Paleontológica Argentina, Resumen. Ameghiniana 37 (4): 68. Mar del Plata.

Albanesi, G.L.; Ortega, G. 2016. Conodont and graptolite bioestratigraphy of the Ordovician System of Argentina. *In* Stratigraphy & timescales (Montenari, M.; editor) 1: 61-121.

Albanesi, G.L.; Hünicken, M.A.; Barnes, C.R. 1998. Bioestratigrafía de conodontes de las secuencias ordovícicas del cerro Potrerillo, Precordillera Central de San Juan, R. Argentina. Actas de la Academia Nacional de Ciencias, Tomo XII: 7-72. Córdoba.

Albanesi, G.L.; Bergström, S.M.; Melchor, R.N. 2003. The San Jorge Formation, La Pampa Province, Argentina, dated by means of conodonts. Ameghiniana 40 (4): 77R-78R.

Albanesi, G.L.; Carrera, M.G.; Cañas, F.L.; Saltzman, M. 2006. A proposed Global Boundary Stratotype Section and Point for the base of the Middle Ordovician Series: The Niquivil section, Precordillera of San Juan, Argentina. Episodes 29: 1-15.

Albanesi, G.L.; Cañas, F.; Mango, M. 2016. Fauna de conodontes tremadocianos del techo de la Formación La Silla en el Cerro Viejo de San Roque, Precordillera Central de San Juan. *In* Jornadas de Geología de Precordillera, No. 3, Acta Geológica Lilloana 28 (suplemento): 14-20. Argentina.

An, T.-X. 1981. Recent progress in Cambrian and Ordovician conodont biostratigraphy of China. *In* Paleontology in China, 1979 (Teichert, C.; Liu, L.; editors). Geological Society of America, Special Paper 187: 209-225.

An, T.-X.; Zheng, Z. 1990. The conodonts of the marginal areas around the Ordos Basin, north China. Science Press of China: 1-101.

An, T.-X.; Zhang, F.; Xiang, W.; Zhang, Y.; Xu, W.; Zhang, H.; Jiang, D.; Yang, C.; Lin, L.; Cui, Z.; Yang, X. 1983. The Conodonts of North China and the adjacent regions. Science Press of China: 1-223. Beijing.

An, T.-X.; Du, G.; Gao, Q. 1985. Ordovician conodonts from Hubei, China. Geological Publications House: 1-64. Beijing.

Bagnoli, G.; Stouge, S. 1997. Lower Ordovician (Billingenian-Kunda) conodont zonation and provinces based on sections from Horns Udde, north Öland, Sweden. Bolletino della Società Paleontologica Italiana 35 (2): 109-163.

Baldis, B.A.J.; Chebli, G. 1969. Estructura profunda del área central de la Precordillera sanjuanina. Cuartas Jornadas Geológicas Argentinas: 47-66.

Baldis, B. A. J.; Beresi, M. 1981. Biofacies de culminación del ciclo deposicional calcáreo del Arenigiano de oeste de Argentina. *In* Congreso Latinoamericano de Paleontología, No. 2, Anais 1: 11-19. Porto Alegre.

Baldis, B.A.J.; Bordonaro, O.L. 1982. Comparación entre el Cámbrico de la "Great Basin" norteamericana y la Precordillera de San Juan, Argentina, su implicancia intercontinental. *In* Congreso Latinoamericano de Geología, No. 5, Actas I: 97-108. Buenos Aires.

Baldis, B.A.J.; Beresi, M.; Bordonaro, O.; Vaca, A. 1982. Síntesis evolutiva de la Precordillera Argentina. *In* Congreso Latinoamericano de Geología, No. 5, Actas, 4: 399-445. Buenos Aires.

Baldis, B.A.J.; Beresi, M.; Bordonaro, O.; Vaca, A. 1984. The Argentine Precordillera as a key to Andean structure. Episodes 7 (3): 14-19.

Buggisch, W.; Keller, M.; Lehnert, O. 2003. Carbon isotope record of Late Cambrian to Early Ordovician carbonates of the Argentine Precordillera. Palaeogeography, Palaeoclimatology, Palaeoecology 195 (3-4): 357-373.

Cañas, F.L. 1995. Estratigrafía y evolución paleoambiental de las sucesiones carbonáticas del Cámbrico tardío y Ordovícico temprano de la Precordillera Septentrional, República Argentina. Tesis Doctoral en Ciencias Geológicas (Unpublished), Universidad Nacional de Córdoba, Facultad de Ciencias Exactas, Físicas y Naturales: 216 p.

Cañas, F.L. 1999. Facies and sequences of the Late Cambrian-Early Ordovician carbonates of the Argentine Precordillera: A stratigraphic comparison with Laurentian platforms. *In* Laurentia-Gondwana Connections before Pangea (Ramos, V.A.; Keppie, J.D.; editors). Geological Society of America, Special Paper 336: 43-62. Boulder, Colorado.

Cañas, F.L.; Carrera, M.G. 2003. Precordilleran reefs. *In* Ordovician fossils of Argentina (Benedetto, J.L.;

editor). Secretaría de Ciencia y Tecnología, Universidad Nacional de Córdoba: 131-153.

Carlorosi, J.; Heredia, S. 2013. The conodont *Trapezognathus diprion* (Lindström) in the Acoite Formation, Eastern Cordillera, Northwestern Argentina. *In* Conodonts from the Andes. International Conodont Symposium, No. 3 (Albanesi, G.L.; Ortega, G.; editors). Asociación Paleontológica Argentina, Publicación Especial 13: 1-4.

Cech, N.; Carrera, M.G. 2002. Dinámica de las comunidades arenigianas de la Formación San Juan (Ordovícico), Precordillera Argentina. Ameghiniana 39: 21-40.

Della Costa, G.; Albanesi, G.L. 2016. Bioestratigrafía de conodontes floianos y dapingianos (Ordovícico Inferior-Medio) de la Formación San Juan en la localidad de Peña Sombría, Precordillera de La Rioja. *In* Congreso de la Asociación Paleontológica Argentina, No. 11, Resúmenes: p. 38. Río Negro.

Epstein, A.G.; Epstein, J.B.; Harris, L.D. 1977. Conodont color alteration-an index to organic metamorphism. United States Geological Survey, Professional Paper 995: 1-27.

Ethington, R.L.; Clark, D.L. 1971. Lower Ordovician conodonts in North America. *In* Symposium on conodont biostratigraphy (Sweet, W.C.; Bergström, S.M.; editors). Geological Society of America, Memoir 127: 63-82.

Ethington, R.L.; Clark, D.L. 1981. Lower and Middle Ordovician conodonts from the Ibex area, western Millard County. Utah Brigham Young, University Geology Studies 28: 1-160.

Ethington, R.L.; Repetski, J.E. 1984. Paleobiogeographic distribution of Early Ordovician conodonts in central and western United States. *In* Conodont Biofacies and Provincialism (Clark, D.L.; editor). Geological Society of America, Special Paper 196: 89-101.

Fåhraeus, L.E.; Nowlan, G.S. 1978. Franconian (Late Cambrian) to early Champlainian (Middle Ordovician) conodonts from the Cow Head Group, western Newfoundland. Journal of Paleontology 52 (2): 444-471.

Giuliano, M.E.; Albanesi, G.L.; Ortega, G.; Zeballo, F.J.; Monaldi, C.R. 2013. Conodonts and graptolites of the Santa Rosita Formation (Tremadocian) at the Nazareno area, Santa Victoria range, Cordillera Oriental of Salta, Argentina. *In* Conodonts from the Andes. International Conodont Symposium, No. 3 (Albanesi, G.L.; Ortega, G.; editors). Asociación Paleontológica Argentina, Publicación Especial 13: 39-44.

Hünicken. M.A.; Sarmiento, G.N. 1980. The Baltoscandian conodont *Prioniodus elegans* Pander (Lower Arenigian) from the San Juan Formation of the Precordillera, Guandacol River, La Rioja, República Argentina. Academia Nacional de Ciencias, Boletín 53 (3-4): 293-306. Córdoba.

Hünicken, M.A.; Mazzoni, A. 1994. La Formación San Juan en Guandacol, provincia de La Rioja, Argentina: límites, espesor y biozonas de conodontes. *In* Congreso Argentino de Paleontología y Bioestratigrafía, No. 6, Resúmenes: 60-61. Trelew.

Ji, Z.; Barnes, C.R. 1994. Lower Ordovician conodonts of the St. George Group, Port au Port Peninsula, western Newfoundland, Canada. Palaeontographica Canadiana, Geological Association of Canada and Canadian Society of Petroleum Geologists, Calgary 11: 1-149.

Keller, M. 1999. Argentine Precordillera: Sedimentary and plate tectonic history of a Laurentian crustal fragment in South America. Geological Society of America, Special Paper 341: 1-131.

Keller, M.; Cañas, F.; Lehnert, O.; Vaccari, N.E. 1994. The Upper Cambrian and Lower Ordovician of the Precordillera (Western Argentina): Some stratigraphic reconsiderations. Newsletter on Stratigraphy 31 (2): 115-132.

Küppers, A.N.; Pohler, S.M.L. 1992. Discovery of the first Early Ordovician conodonts from the Montagne Noire, southern France. *In* Global Perspectives on Ordovician Geology (Webby, B.D.; Laurie, J.R.; editors). Balkema: 487-494. Rotterdam.

Lehnert, O. 1993. Bioestratigrafía de los conodontes arenigianos de la Formación San Juan en la localidad de Niquivil (Precordillera sanjuanina, Argentina) y su correlación intercontinental. Revista Española de Paleontología 8 (2): 153-164.

Lehnert, O. 1995. Ordovizische conodonten aus der Präkordillere westargentiniens: Ihre bedeutung für Stratigraphie und Paläogeographie. Erlanger Geologische Abhandlungen 125: 1-193.

Lehnert, O.; Miller, J.F.; Repetski, J.E. 1997. Paleogeographic significance of *Clavohamulus hintzei* Miller (Conodonta) and other Ibexian conodonts in an early Paleozoic carbonate platform fades of the Argentine Precordillera. Geological Society of America Bulletin 109 (4): 429-443.

Lehnert, O.; Stouge, S.; Brandl, P. A. 2013. Conodont biostratigraphy in the Early to Middle Ordovician strata of the Oslobreen Grup in Ny Friesland, Svalbard. Z. Dt. Ges. Geowiss 164: 149-172.

Lemos, V.B. 1981. Conodontes ordovicianos da Formacào San Juan, Precordillera, Departamento Jáchal, Provincia de San Juan, República Argentina (Bioestratigrafia). Anais II Congresso Latinoamericano de Paleontologia, Porto Alegre, 1: 31-43.

Lindström, M. 1955. Conodonts from the lowermost Ordovician strata of south-central Sweden. Geologiska Föreningens i Stockholm Förhandlingar 76 (4): 517-604. doi: 10.1080/11035895409453581.

Lindström, M. 1971. Lower Ordovician conodonts of Europe. *In* Symposium on Conodont Biostratigraphy (Sweet, W.C.; Bergström, S.M.; editors). Geological Society of America, Memoir 127: 21-61.

Löfgren, A. 1978. Arenigian and Llanvirnian conodonts from Jämtland, northern Sweden. Fossils and Strata 13: 1-129.

Löfgren, A. 1993. Arenig conodont successions from central Sweden. Geologiska Föreningens i Stockholm Förhandlingar 115: 193-207.

Löfgren, A. 1994. Arenig (Lower Ordovician) conodonts and biozonation in the Eastern Siljan District, Central Sweden. Journal of Paleontology 68 (6): 1350-1368.

Löfgren, A. 1996. Lower Ordovician conodonts, reworking, and biostratigraphy of the Orreholmen quarry. Västergötland, south-central Sweden. Geologiska Föreningens I Stockholm Förhandlingar 118 (3): 169-183.

Mango, M.J.; Albanesi, G.L. 2018a. Bioestratigrafía y provincialismo de conodontes del tramo medio-superior de la Formación San Juan en el cerro Viejo de Huaco, Precordillera, Argentina. Andean Geology 45 (2): 274-299. doi: 10.5027/andgeoV45n2-3056.

Mango, M.J.; Albanesi, G.L. 2018b. Conodont biostratigraphy from the upper San Juan Formation (Middle Ordovician) at Niquivil, Argentine Precordillera. Journal of South American Earth Sciences 84: 48-55. doi: 10.1016/j.jsames.2018.03.008.

Mango, M.J.; Varini, M.; Albanesi, G. 2016. Biozonas de conodontes de la Formación San Juan (Ordovícico) y cronoestratigrafía de los cadilitos carbonáticos de la Formación Guandacol (Carbonífero) en el anticlinal de Huaco, Precordillera de San Juan. Acta Geológica Lilloana 28 (suplemento): 123-126. Argentina.

Mestre, A. 2008. Revisión bioestratigráfica del techo de la Formación San Juan (Ordovícico Inferior), en la sección del Monumento a Buenaventura Luna, Precordillera Central, San Juan. Acta Geológica Lilloana 20 (2): 127-136.

Nicoll, R.S.; Laurie, J.R.; Roche, M.T. 1993. Revised stratigraphy of the Ordovician (Late Tremadoc-Arenig) Prices Creek Group and Devonian Poulton Formation, Lennard Shelf, Canning Basin. Western Australia. Journal of Australian Geology and Geophysics 14: 65-76.

Ortega, G.; Albanesi, G.L.; Frigerio, S.E. 2007. Graptolite-conodont biostratigraphy and biofacies of the Middle Ordovician cerro Viejo succession, San Juan Precordillera Argentina. Palaeogeography, Palaeoclimatology, Palaeoecology 245: 245-263.

Ortiz, A.; Zambrano, J. 1981. La Provincia geológica Precordillera Oriental. *In* Congreso Geológico Argentino, No. 8, Actas 3: 59-74. San Luis.

Pohler, S.M.L. 1994. Conodont biofacies of Lower to lower Middle Ordovician Mega- conglomerates, Cow Head Group, Western Newfoundland. Geological Survey of Canada Bulletin 459: 1-71.

Pratt, B.; Raviolo, M.M.; Bordonaro, O.L. 2012. Carbonate platform dominated by peloidal sands: Lower Ordovician La Silla Formation of the eastern Precordillera, San Juan, Argentina. Sedimentology: 843-866.

Ross, R.J., Jr.; Hintze, L.F.; Ethington, R.L.; Miller, J.F.; Taylor, M.E.; Repetski, J.E. 1997. The Ibexian. Lowermost Series in the North American Ordovician (with a section on Echinoderm Biostratigraphy by James Sprinkle and Thomas E. Guensburg). *In* Early Paleozoic biochronology of the great basin, western United States (Taylor M.E.; editor). U.S. Geological Survey, Professional Paper 1579: 1-50.

Seo, K.-S.; Lee, H.-Y.; Ethington, R.L. 1994. Early Ordovician conodonts from the Dumugol Formation in the Baegunsan syncline, Eastern Yeongweol an Samcheog areas, Kangweon-Do, Korea. Journal of Paleontology 68 (3): 599-616.

Serpagli, E. 1974. Lower Ordovician conodont from Precordilleran Argentina (Province of San Juan). Bolletino della Societa Paleontologica Italiana 13 (1-2): 17-98.

Serra, F.; Albanesi, G.L.; Ortega, G.; Bergström, S.M. 2015. Biostratigraphy and palaeoecology of Middle-Late Ordovician conodont and graptolite faunas of the Las Chacritas River section, Precordillera of San Juan, Argentina. Geological Magazine 152 (5): 813-829.

Smith, M.P. 1991. Early Ordovician conodonts of East and North Greenland. Meddelelser om Grønland Geoscience 26: 1-81.

Stone, J. 1987. Review of investigative techniques used in the study of conodontes. *In* Conodonts: Investigative Techniques and Applications (Austin, R.L.; editor). Ellis Horwood Limited: 17-34. Chichester.

Stouge, S.; Bagnoli, G. 1988. Early Ordovician conodontes from the Cow Head Peninsula, western Newfoundland. Palaeontographia Italica 75: 89-179.

Stouge, S.; Harper, D.A.T.; Sevastopulo, G.D.; O´Mahony, D.; Murray, J. 2015. Lower and Middle Ordovician conodonts of Laurentian affinity from bloccks of limestone in the Rosroe Formation, South Mayo Trough, western Ireland and their palaeogeographic implication. Geological Journal 51 (4): 584-599.

Szaniawski, H. 1980. Conodonts from the Tremadocian chalcedony beds. Holy Cross Mountains (Poland). Acta Palaeontologica Polonica 25: 101-121

Thalmeier, M.B. 2014. Bioestratigrafía y paleoambientes de conodontes de la Formación San Juan (Ordovícico

Inferior-Medio) expuesta en el cerro La Silla, Precordillera de San Juan, Argentina. Trabajo Final en Geología (Unpublished), Universidad Nacional de Córdoba, Facultad de Ciencias Exactas, Físicas y Naturales: 1-108.

Tolmacheva, T.Y. 2001. Conodont biostratigraphy and diversity in the Lower–Middle Ordovician of eastern Baltoscandia (St. Petersburg region, Russia) and Kazakhstan. Summary in Ph.D. Thesis (Unpublished), Department of Earth Sciences, Historical Geology and Palaeontology, Uppsala University: 1-40. Sweden.

Voldman, G.G.; Albanesi, G.L.; Ramos, V.A. 2010. Conodont geothermometry of the lower Paleozoic from the Precordillera (Cuyania terrane), northwestern Argentina. Journal of South American Earth Sciences 29 (2): 278-288.

Voldman, G.G.; Albanesi, G.L.; Monaldi, C.R.; Zeballo, F.J. 2013a. An Early Ordovician conodont fauna from the Santa Rosita Formation at its type area in the Santa Victoria Range, Cordillera Oriental, Northwestern Argentina. Stratigraphy 10 (4): 301-322.

Voldman, G.G.; Albanesi, G.L.; Zeballo, F.J.; Monaldi, C.R. 2013b. Early Ordovician (Late Floian) conodonts from the Zenta Range, Cordillera Oriental, NW Argentina. *In* Conodonts from the Andes. International Conodont Symposium, No. 3 (Albanesi, G.L.; Ortega, G.; editors). Asociación Paleontológica Argentina, Publicación Especial 13: 123-128. Mendoza.

Voldman, G.G.; Albanesi, G.L.; Ortega, G.; Giuliano, M.E.; Monaldi, C. R. 2016. New conodont taxa and biozones from the Lower Ordovician of the Cordillera Oriental, NW Argentina. Geological Journal 52 (3): 394-414.

Wang, X.; LI, Z.; Chen, X.; Wang, C. 2003. The Huanghuachang section, potential as Global stratotype for the base of the Middle Ordovician Series. *In* Ordovician from Andes (Albanesi, G.L.; Beresi, M.S.; Peralta, S.H.; editors). Instituto Superior de Correlación Geológica (INSUGEO), Serie Correlación Geológica 17: 153-159.

Wang, Z.; Zhen, Y.Y.; Bergstrom, S.M.; Zhang, Y.; Wu, R. 2018. Ordovician conodont biozonation and biostratigraphy of North China. Australasian Palaeontological Memoirs 51: 65-79.

Zhen, Y.Y.; Percival, I.G.; Löfgren, A.; Liu, J.-B. 2007. Drepanoistodontid conodonts from the early Ordovician Honghuayuan Formation of Guizhou, South China. Acta Micropalaeontologica Sinica 24 (2): 125-148.

Zhen, Y.Y.; Percival, I.G.; Zhang, Y.D. 2015a. Floian (Early Ordovician) conodont-based biostratigraphy and biogeography of the Australasian Superprovince. Palaeoworld 24 (1-2): 100-109.

Zhen, Y.Y.; Zhang, Y.; Tang, Z.; Percival, I.G.; Yu, G. 2015b. Early Ordovician conodonts from Zhejiang Province, southeast China and their biostratigraphic and palaeobiogeographic implications. Alcheringa: An Australasian Journal of Palaeontology 39 (1): 109-141.

Zhen, Y.Y.; Zhang, Y.; Wang, Z.; Percival, I.G. 2016. Huaiyuan Epeirogeny-shaping Ordovician stratigraphy and sedimentation on the North China Platform. Palaeogeography, Palaeoclimatology, Palaeoecology 448: 363-370.

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