New Ludlovian, upper Silurian, graptolite faunas from the Los Espejos Formation, Central Precordillera, San Juan Province, Argentina: correlations and biostratigraphic remarks

FERNANDO E. LOPEZ, OSVALDO A. CONDE, ALEJANDRO R. BRAECKMAN, DIEGO G. SEGURA, JUAN M. DROVANDI, ANDREA J. BUENO, and ULISES ABARCA

Lopez, F.E., Conde, O.A., Braeckman, A.R., Segura, D.G., Drovandi, J.M., Bueno, A.J., and Abarca, U. 2024. New Ludlovian, upper Silurian, graptolite faunas from the Los Espejos Formation, Central Precordillera, San Juan Province, Argentina: correlations and biostratigraphic remarks. *Acta Palaeontologica Polonica* 69 (3): 351–370.

Graptolites represent one of the most important index fossils for the lower to middle Paleozoic biostratigraphy worldwide. Compared to other regions, graptolite faunas exhibited a marked decrease in diversity in Argentina during the Silurian, what resulted in reduced and low-varied registers and denied biostratigraphic works in its territory. This study introduces new Silurian graptolite faunas from the Los Espejos Formation, Poblete Norte section, Central Precordillera of Argentina. A total of thirteen graptolitic levels were identified, containing *Bohemograptus bohemicus*, *Lobograptus* sp., *Saetograptus argentinus argentinus*, *Saetograptus* cf. *S. varians*, *Uncinatograptus uncinatus notouncinatus*, *Uncinatograptus elsae* sp. nov., and *Uncinatograptus lisandroi* sp. nov. The occurrence of *Uncinatograptus* spp. in association with *B. bohemicus* could indicate the presence of the lower Gorstian *Neodiversograptus nilssoni* Biozone. A few meters above, the finding of *S. a. argentinus* in association with *S.* cf. *S. varians*, *U. u. notouncinatus*, and *Lobograptus* sp. suggest the presence of the lower Gorstian *Lobograptus progenitor* Biozone. The upper graptolitic beds yield specimens of *S. a. argentinus* and *B. bohemicus*, suggesting late Gorstian to early Ludfordian ages. These new graptolite faunas allow to correlate more precisely with local (Precordillera and Famatina), regional (North Western Argentina and Bolivia) and global equivalent sections. This discovery introduces new graptolite faunas, first-time recorded in South America, proposes for the first time a graptolite biostratigraphy for the Ludlow of Precordillera, and complements so far insufficient knowledge on Ludlovian graptolitic faunas of the continent in a critical time in the history of this fossil group.

Key words: Graptolithina, biostratigraphy, Gorstian Stage, Ludlow Series, Los Espejos Formation, Precordillera, Argentina, South America.

Fernando E. Lopez [felopez@unsj-cuim.edu.ar; ORCID: https://orcid.org/0000-0002-5562-7105], Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)-Departamento de Geología, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de San Juan, Ignacio de la Roza 590 (O), Rivadavia, San Juan, Argentina.
Osvaldo A. Conde [osvaldoagustin94@gmail.com; ORCID: https://orcid.org/0009-0007-5890-4300] and Juan M. Drovandi [drovandijuan@gmail.com; ORCID: https://orcid.org/0009-0004-3022-9444], Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)-Instituto y Museo de Ciencias Naturales, Universidad Nacional de San Juan, CIGEOBIO, CONICET, Av. España 400 (N), J5500DNQ, San Juan, San Juan, Argentina.
Alejandro R. Braeckman [geobraeckman@gmail.com; ORDID: https://orcid.org/0000-0003-2580-3873], Diego G. Segura [seguradiegogabriel@gmail.com; ORCID: https://orcid.org/0009-0006-3102-0735], Andrea J. Bueno [andreajesusbueno @gmail.com; ORCID: https://orcid.org/0009-0008-4973-5223], and Ulises Abarca [likogx89@gmail.com; ORCID: https://orcid.org/0009-0009-7036-9288], Departamento de Geología, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de San Juan, Ignacio de la Roza 590 (O), Rivadavia, San Juan, Argentina.

Received 8 February 2024, accepted 24 May 2024, published online 28 August 2024.

Introduction

The Silurian System is globally represented by graptolite-rich sections (e.g., Australia, Czech Republic, United Kingdom), where precise biostratigraphic chart have been established (see Zalasiewicz et al. 2009; Loydell 2012; Melchin et al. 2012, 2020; Maletz 2017; Štorch 2023), setting the foundation for paleontological studies in other countries.

In Argentina, Silurian graptolite-rich rocks have been analysed in two different geographical regions. In North

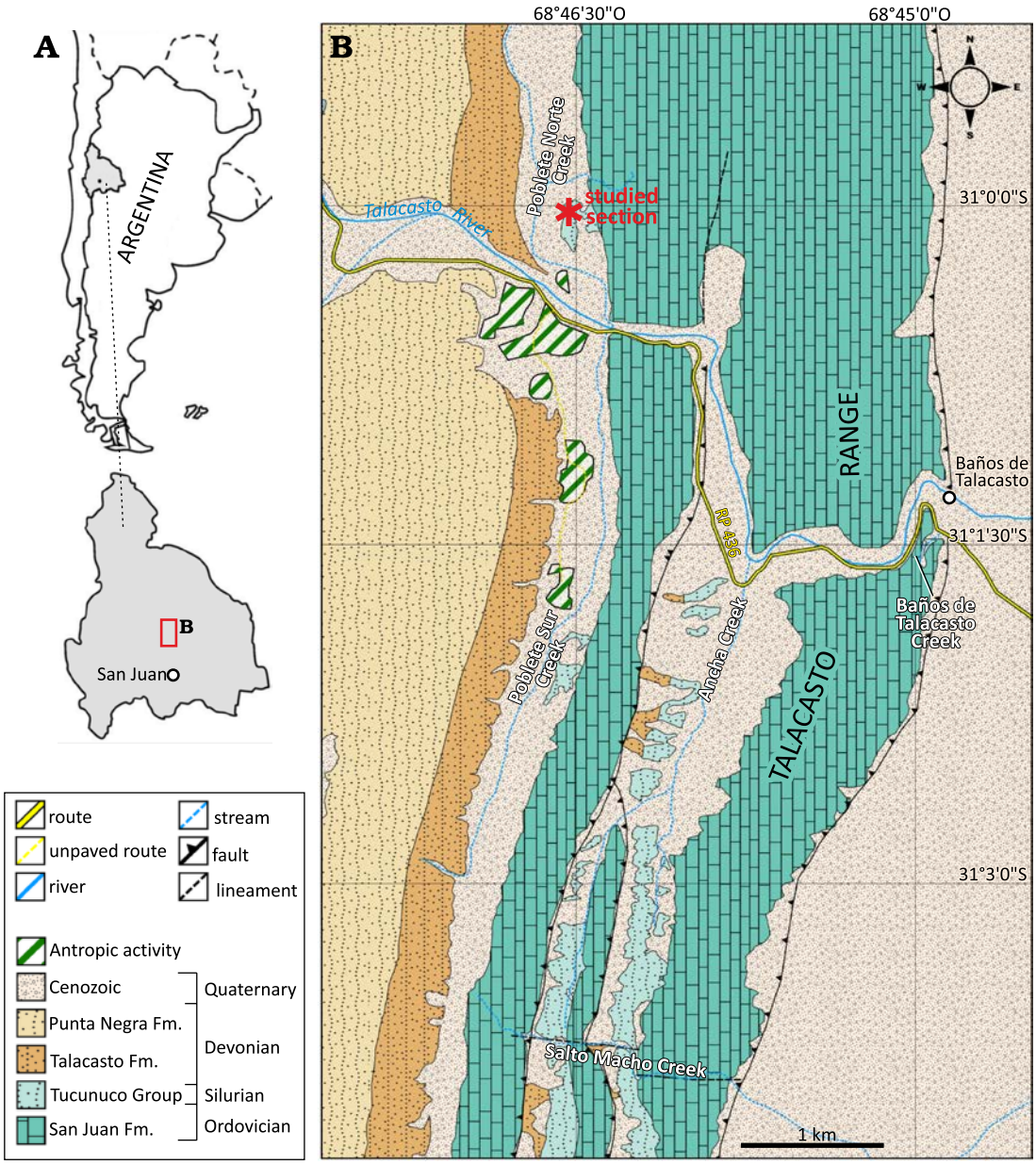


Fig 1. **A**. Maps showing location of San Juan Province in Argentina and Talacasto area (red rectangle). **B**. Geological map of the Talacasto area with studied are indicated. Abbreviation: Fm., Formation.

Western Argentina, Llandoverian to Ludlovian faunas have been described in the Lipeón Formation (Toro 1995; Maletz et al. 2002; Toro and Maletz 2018). In Precordillera, where this study was conducted, Silurian graptolites were studied in the lower Hirnantian (Ordovician) to Llandoverian Don Braulio Formation and the Wenlockian to Lower Devonian Rinconada Formation of the Eastern Precordillera (Peralta 1986, 1993; Lopez et al. 2023), and from the upper Hirnantian to lower Wenlockian La Chilca Formation and the upper Wenlockian to Lower Devonian Los Espejos Formation of the Central Precordillera (Cuerda 1969; Cuerda et al. 1988; Peralta 1984b; Lopez 2022).

In the aforementioned units, diverse and extensive graptolitic levels have been reported. However, the absence of index taxa and limited taxonomic studies hindered the recognition of most of the biozones identified in other countries. This study introduces new graptolite faunas from the lower Ludlow (Gorstian) found in the middle to upper Los Espejos Formation, Poblete Norte section (Fig. 1). It proposes, for the first time, a graptolite biostratigraphy for the Ludlow of Precordillera, enhancing the limited knowledge of Ludlovian graptolites in Argentina and South America during a crucial period in graptolite history. Additionally, it facilitates more accurate age dating and correlation of the Silurian in Precordillera with other global sections.

Institutional abbreviations.—INGEO, Instituto de Geología, Universidad Nacional de San Juan, San Juan, Argentina; UNSJ, Universidad Nacional de San Juan, San Juan, Argentina.

Other abbreviations.—2TRD, two thecae repeat distance; FAD, first appearance datum; PNN, Poblete Norte Nuevo; Th, theca(e).

Nomenclatural acts.—This study and the nomenclatural acts it contains have been registered in ZooBank: urn:lsid:zoobank.org:pub:E6FAC9E7-1740-4BDC-9C5A-AEE24B914771

Geological setting

The Los Espejos Formation (Cuerda 1965) crops-out in the Poblete Norte section, 77 km north of San Juan city, Talacasto Range, Central Precordillera of San Juan Province, Argentina (Fig. 1). This formation paraconformably overlies the upper Hirnantian to lower Wenlockian La Chilca Formation, and is generally overlain by the Lower Devonian Talacasto Formation. To the south, in the San Juan River area, the Los Espejos Formation passes laterally into the Tambolar Formation (Heim 1952).

Paleontologically, the Los Espejos Formation possesses one of the most varied and abundant Silurian fossil faunas of Argentina. The assemblage includes brachiopods, graptolites, bivalves, conodonts, tentaculitoids, crinoids, eurypterids, ostracods, cnidarian, and trace fossils, which dated the unit as late Wenlockian to Early Devonian (Cuerda 1969; Brussa and Toro 1989; Benedetto et al. 1992; Gómez et al. 2018, 2021; and studies cited therein).

Local stratigraphy.—At the Poblete Norte section, the outcrops reveal a stratigraphic sequence ranging from the Lower Ordovician to the upper Carboniferous in the mountain ranges, and Neogene and Quaternary deposits occurring in valleys and river courses (Ramos et al. 2000). The oldest unit is the San Juan Formation of Tremadocian to middle Darriwilian (Ordovician) age (Kobayashi 1937, redefined by Amos 1954). Following this, the Tucunuco Group (Cuerda 1965) is composed of the upper Hirnantian (Ordovician) to Lower Devonian La Chilca and Los Espejos formations (Cuerda 1965). Subsequently, the Gualilán Group (Baldis 1975) consist of the Lower to Upper Devonian Talacasto and Punta Negra formations (Padula et al. 1967; Bracaccini 1950). This is succeeded by the Los Gauchos Formation (lower to upper Carboniferous; Furque 1983; Vergel et al. 2009), the Albarracín Formation (Middle Miocene; Leveratto 1968), and, finally, Quaternary alluvial and colluvial deposits.

In the La Chilca Hill, Cuerda (1969) subdivided the Los Espejos Formation into three members. The Lower Member is characterized by a basal reddish oolitic sandstone, followed by green and purplish red claystones, with interbedded phosphate concretions. The Middle Member presents abundant greenish siltstones, reduced brownish sandstones, and coquinas. Finally, the Upper Member is formed by

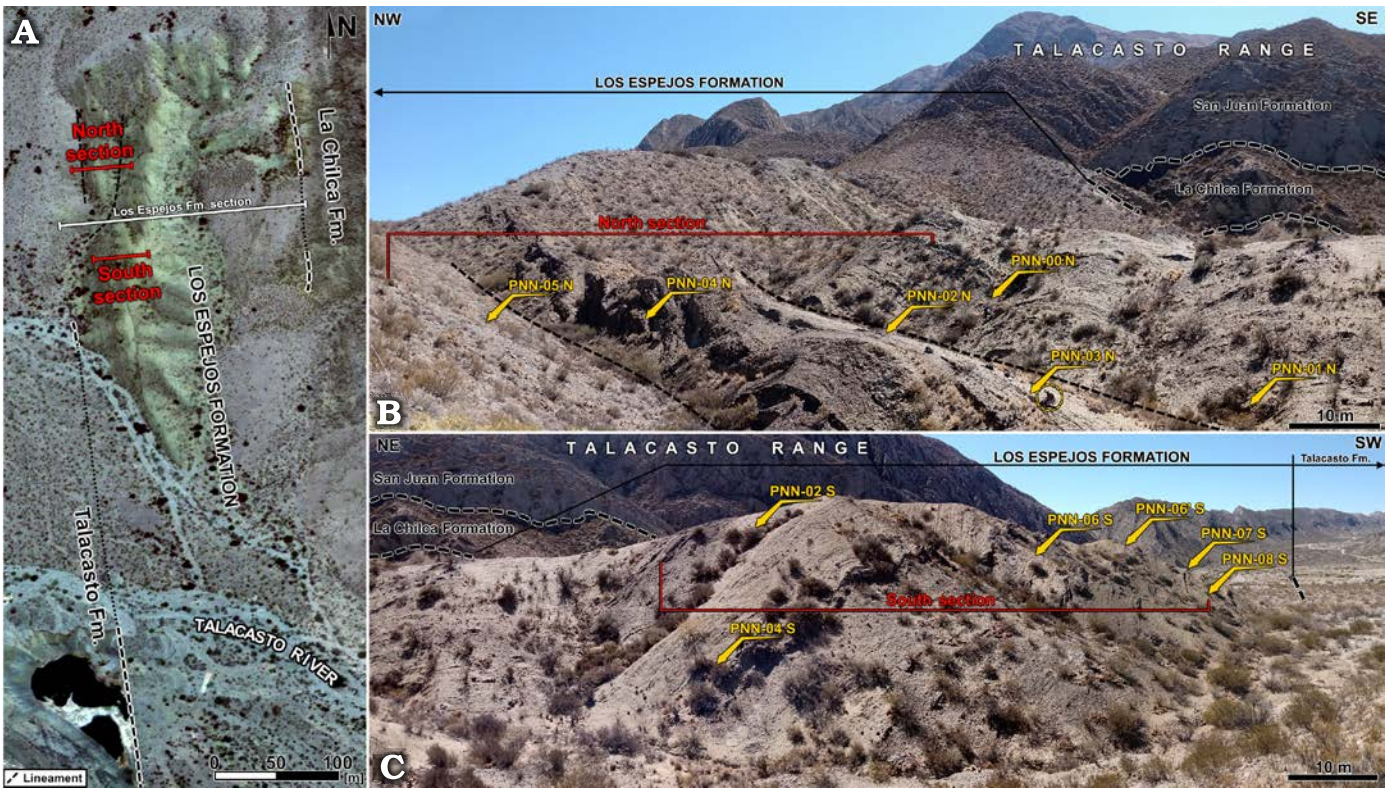


Fig. 2. Satellite and field views of the studied sections at the Poblete Norte Creek section, Talacasto Range. **A**. Satellite image showing the Paleozoic stratigraphy, the Los Espejos Formation section, and the two detailed sections (North and South). Image obtained from the free software SASPlanet, v.221122.10312 Nightly. **B**, **C**. Field photographs of the North and South sections, showing the outcropping formations, graptolitic levels and faults. Photographs provided by the authors.

abundant greenish sandstones, coquinas and subordinate siltstones, with sporadic para-conglomerates at the highest levels. These three members were later recognized in the Poblete Norte section by Lopez (2019).

Structure.—The Poblete Norte section is situated in the Central Precordillera, characterized by a thin-skinned faulted fold belt, exhibiting eastern vergence and detachment level within the Cambrian–Ordovician formations (Ramos et al. 2000).

Specifically, the Poblete Norte section displays a homoclinal and continuous sequence that commences with a faulted zone beneath the San Juan Formation to the east (see Fig. 1). Within the Los Espejos Formation section, the strata exhibit predominantly uniform tilting (ca. 45° W) and azimuth (north-south), with continuous outcropping levels. Conversely, beds located at the east of two minor creeks (pointed as lineaments in Figs. 2 and 3) were observed either vertically or overturned, with slightly turned azimuths (NNW). This variation, coupled with a mismatch of the fossiliferous levels of ca. eleven meters, might suggest the presence of left-lateral strike-slip faults. However, further structural studies are required to validate this hypothesis.

Stratigraphic sections.—The Los Espejos Formation section was traced from the topmost levels of the La Chilca Formation to the lowermost strata of the Talacasto Formation, encompassing the Los Espejos Formation with a thickness of 138.5 meters. Both formational contacts were identified as paraconformities (Fig. 3A), and within this column, the three members of the unit were recognized.

In an effort to address the structural concerns outlined in the "Structure" section, two detailed columns were examined, one to the north and another to the south of the main column. These detailed segments measured 45.26 meters (North section) and 44.93 meters (South section) in thickness, covering the upper Middle Member and the lower Upper Member of the Los Espejos Formation (Fig. 3B, C). The North section revealed six graptolitic levels (PNN-00N–05N), while the South section exhibited seven levels with graptolites (PNN-02S, 04S, 06S, 06'S, 07, 08'S and 08S; samples 01S, 03S and 05S were barren).

Graptolite faunas from the Los Espejos Formation.—Within the Los Espejos Formation only two genera have been documented, encompassing two species and three subspecies. Specimens of *Uncinatograptus uncinatus notouncinatus* (Cuerda 1969) have been recognized in the sections of La Chilca Hill, Las Chacritas River, Salto Macho Creek (Talacasto), and del Fuerte Hill (Cuerda 1969; Antonioli 1975; Baldis et al. 1984; Peralta 1984b; Rickards et al. 1996). It is noteworthy that Cuerda (1969) reported undetermined monograptids associated with specimens of *U. uncinatus notouncinatus* that were tentatively referred to the *Pristiograptus dubius* group. However, the author did not provide a detailed description or illustration of these findings.

On a different note, several specimens of *Saetograptus argentinus argentinus* (Cuerda 1969) and *Saetograptus argentinus robustus* have been described in levels situated a few meters above those yielding *Uncinatograptus uncinatus notouncinatus*. These findings were recorded in the La Chilca Hill, Salto Macho Creek, Ancha Creek, del Fuerte Hill, and Loma de Los Piojos section (Cuerda 1969; Antonioli 1975; Baldis et al. 1984; Peralta 1984b; Rickards et al. 1996; Maletz et al. 2002; Lopez 2022).

Biostratigraphy of the Los Espejos Formation.—The Los Espejos Formation has been dated based on three fossil groups. First, its brachiopod fauna was subdivided by Benedetto et al. (1992) into four assemblages: the First Association of a Wenlockian to early Ludlovian age, the Second Association of a late Ludlovian to early Pridolian age, the Third Association of a Pridolian age, and a Fourth Association of a Lochkovian (Early Devonian) age. The authors mentioned specimens of the graptolites *U. u. notouncinatus* and *S. argentinus* in the lower and middle parts of the Second Association of brachiopods, respectively.

Subsequently, the palynomorph content allowed dating the lower levels as late Wenlockian to early Ludlovian, and the upper levels as Lochkovian (Early Devonian) (García-Muro and Rubinstein 2015).

Finally, the conodont faunas studied in the Los Espejos Formation have allowed to record the Gorstian *Kockellella variabilis variabilis* Interval Biozone, the Ludfordian *Polygnathoides siluricus* and "*Ozarkodina*" *parasnajdri* zones, the Pridolian *Ozarkodina eosteinhornensis* Interval Biozone and the Lower and Upper *O. e. detortus* biozones, and the Lochkovian *Icriodus herperius* Biozone (Albanesi et al. 2006, 2017; Mestre et al. 2017; Gómez et al. 2021). Specimens of *S. argentinus* were mentioned associated with the *K. v. variabilis* Interval Biozone (Albanesi et al. 2006).

Until now, no key graptolites have been documented, precluding the biostratigraphic studies. Consequently, the levels hosting *U. u. notouncinatus*, *S. a. argentinus*, and *S. a. robustus* have been dated as Gorstian sensu lato based on phylogenetic relations or the association with other fossils (Cuerda 1969; Benedetto et al. 1992; Maletz et al. 2002; Albanesi et al. 2006; Lopez 2022).

Silurian graptolite faunas in Precordillera and South America.—In the Precordillera Geological Province, located in western Argentina, Silurian graptolites have been studied in four stratigraphic units. Llandoverian specimens were documented in the lower Salto Macho Member of the La Chilca Formation (Cuerda et al. 1982, 1988; Lopez et al. 2020; Lopez and Kaufmann 2023), as well as in the "Fangolitas Ocres" and "Ferrífero Superior" members of the Don Braulio Formation (Peralta 1985). Wenlockian graptolites were only mentioned in the upper Salto Macho Member of the La Chilca Formation (Lopez and Kaufmann 2023). Ludlovian specimens have been discovered in the "Middle Psamitic" Member of the Rinconada Formation (Peralta 1984a, 1986) and the Middle Member of the Los Espejos Formation (Cuerda 1965, 1969; Antonioli 1975; Rickards et al. 1996; Maletz et al. 2002; Lopez 2022). Lastly, early Pridolian graptolites have been

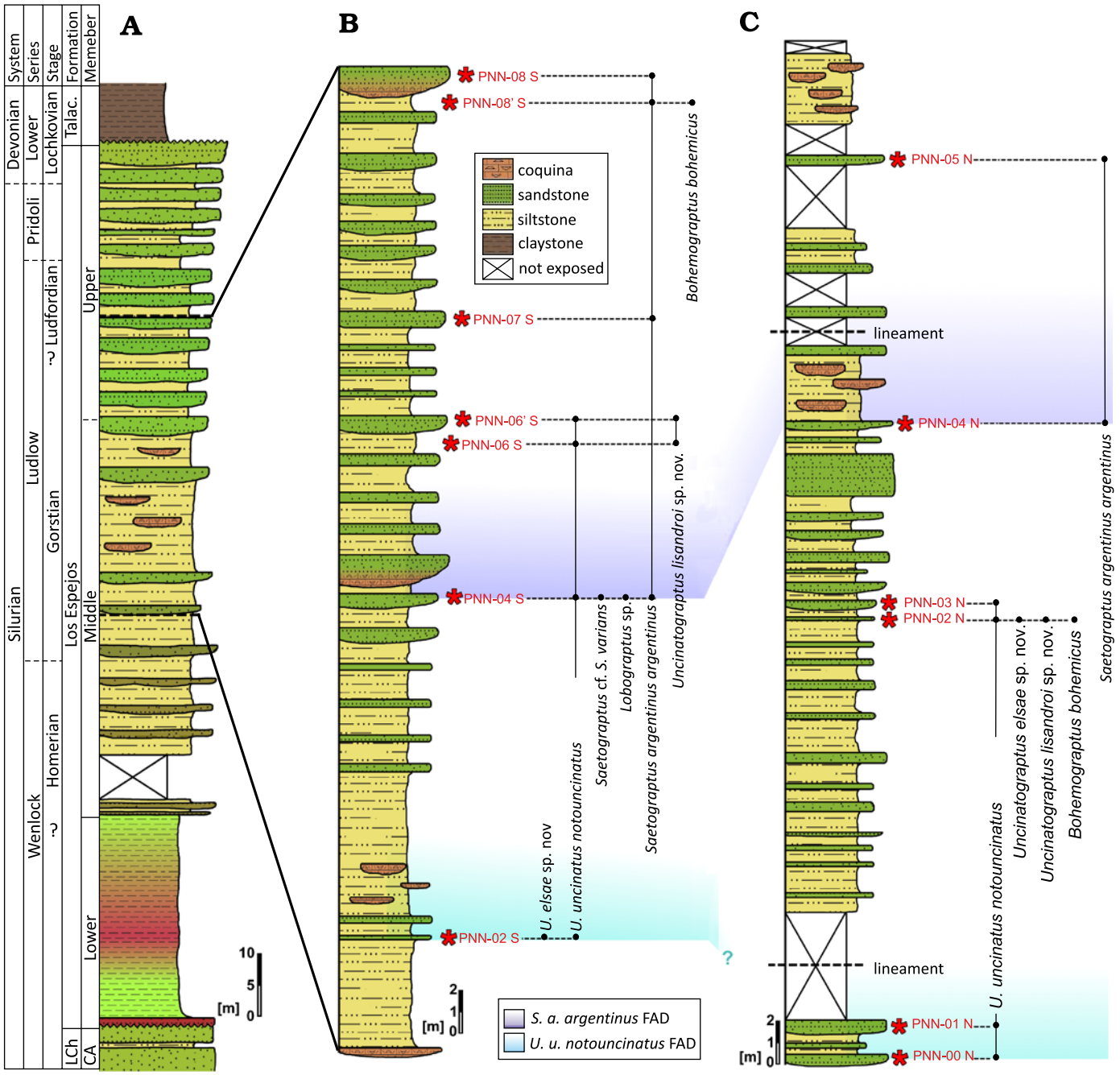
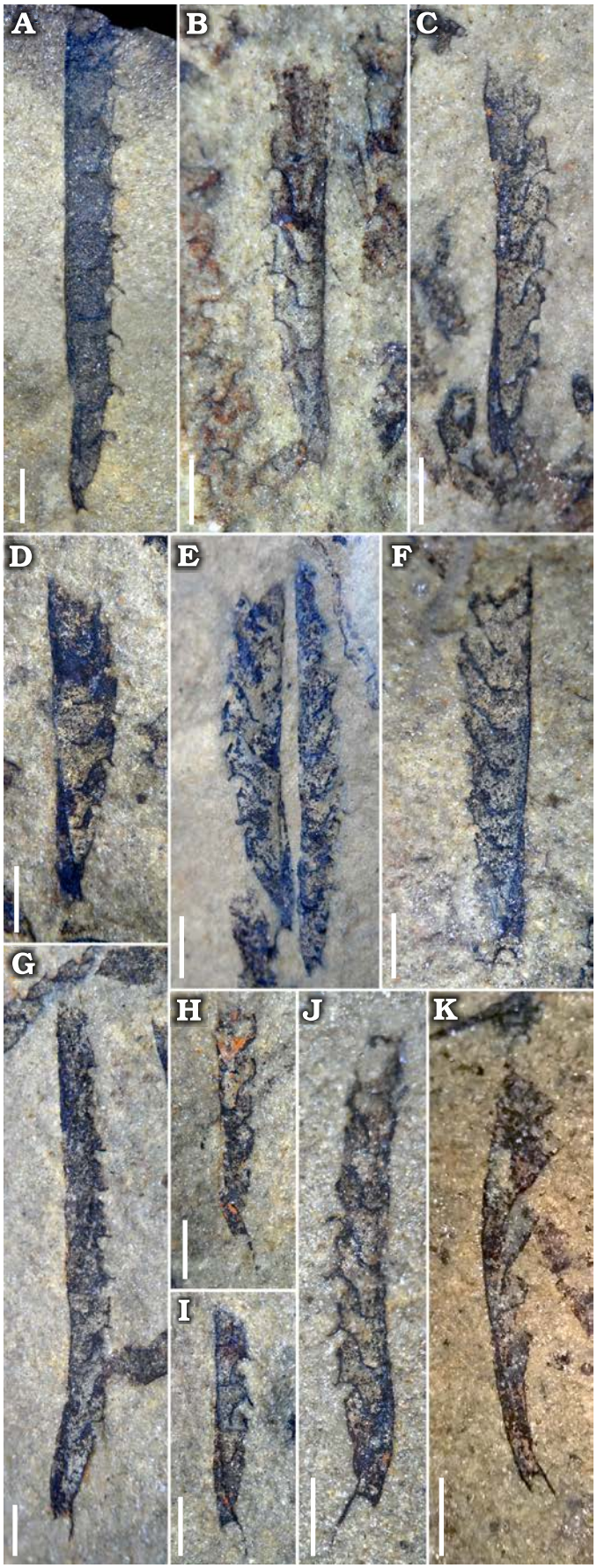


Fig. 3. Age and stratigraphic columns of the Los Espejos Formation at the Poblete Norte Creek section, Talacasto Range (**A**), with detailed South (**B**), and North (**C**) sections, showing the graptolite taxa studied herein, its biochrons, and the correlation between detailed sections. Note the two lineaments in the lower and upper sector of the North section. In both sections the graptolitic levels and the found taxa are pointed, together with the first appearances (FAD) of *Uncinatograptus uncinatus notouncinatus* and *Saetograptus argentinus argentinus.* Abbreviations: LCh, La Chilca; CA, Cuarcitas Azules; *S.*, *Saetograptus*; Talac., Talacasto; *U.*, *Uncinatograptus*.

exclusively described from the upper part of the "Middle Psamitic" Member of the Rinconada Formation (Lopez et al. 2023). As of now, no younger graptolites have been reported in South America.

The climate changes (mainly cooling) during the Silurian and Early Devonian, accompanied by the emergence of plankton predators, marked the gradual decline and subsequent extinction of the graptolites faunas worldwide (see Maletz 2017, 2023; Štorch 2023). This ongoing disappearance is also evident in South America, mainly in the Precordillera, where the most complete record has been found. In this region, the studied Llandoverian assemblages have revealed diverse graptolite faunas, with *Coronograptus*, *Lagarograptus*, *Metaclimacograptus*, *Monograptus*, *Normalograptus*, *Pristiograptus*, *Pseudoplegmatograptus*, *Stimulograptus*, *Talacastograptus*, and several other undetermined biserial and uniserial graptolites (Cuerda et al. 1988; Lenz et al. 2003; Lopez and Kaufmann 2023).



Wenlockian associations exhibit a reduced number of genera, only with *Monograptus*, *Pristiograptus*, *Retiolites*, *Stimulograptus*, and undetermined uniserial graptolites (Peralta 1985; Kerlleñevich and Cuerda 1986; Lopez and Kaufmann 2023). Ludlovian strata, up until now, have shown only two genera, *Saetograptus* and *Uncinatograptus* (Cuerda 1969; Antonioli 1975; Peralta 1986; Lopez 2022). Finally, lower Pridolian assemblages are scarce, with only one described so far, consisting of the genera *Skalograptus,* possibly *Enigmagraptus*, and undetermined monograptids (Lopez et al. 2023). The pattern outlined above displays a marked decrease in the graptolite taxonomic diversity during the Silurian in Precordillera with at least 9 genera in the Llandovery, 4 genera in the Wenlock, and only 2 genera in the Ludlow and Pridoli series.

A comparable decline in diversity has been observed in other regions of South America as well. In the North Western Argentina and south of Bolivia, *Clinoclimacograptus*, *Paraclimacograptus*, *Spirograptus*, and *Stimulograptus* of Llandoverian age have been documented (Alhfeld and Branisa 1960; Toro 1995; Rubinstein and Toro 2006). Ludlovian genera *Colonograptus*, *Monograptus*, *Neodiversograptus*, *Pristiograptus*, and *Saetograptus* were also described in the same region (Suarez-Soruco 1975; Maletz et al. 2002; Toro and Maletz 2018), with no precise biostratigraphic affiliation for those associations. Finally, in Paraguay, Llandoverian graptolites of the genera ?*Demirastrites*, *Metaclimacograptus*, *Monograptus*, *Normalograptus*, *Paraclimacograptus*, and *Stimulograptus* (Uriz et al. 2008; Tortello et al. 2012) were mentioned.

Owing to the last paragraphs, every discovery of upper Silurian graptolite faunas represents a significant paleontological window to a crucial time of the graptolite history. These findings offer insights into their presence and distribution in South America, a continent with scarce graptolite faunal lists, before their final extinction worldwide in the Early Devonian.

Material and methods

The graptolites were collected from brownish sandstones with carbonate cement, greenish massive sandstones, yellowish siltstones, and carbonate coquinas, corresponding to thirteen samples from the Los Espejos Formation, Poblete

Fig. 4. The early Gorstian (Ludlow, Silurian) graptolite fauna: *Uncinatograptus uncinatus notouncinatus* (Cuerda, 1969) (A–C), *Uncinatograptus elsae* sp. nov. (D–F), *Uncinatograptus lisandroi* sp. nov. (G–J), and *Bohemograptus bohemicus* (Barrande, 1850) (K) of the Los Espejos Formation, Talacasto Range, San Juan Province, Argentinian Precordillera. **A**. INGEO-PI-2028, level PNN-06S. **B**. INGEO-PI-2067, level PNN-02N. **C**. INGEO-PI-2122, level PNN-02N. **D**. INGEO-PI-1870, level PNN-02N. **E**. INGEO-PI-2042, level PNN-02N. **F**. INGEO-PI-2087, level PNN-02N. **G**. INGEO-PI-2134A, level PNN-02N. **H**. INGEO-PI-2048A, level PNN-02N. **I**. INGEO-PI-2133, level PNN-02N. **J**. INGEO-PI-2126, level PNN-02N. **K**. , INGEO-PI-1865, level PNN-02N. Scale bars 1 mm.

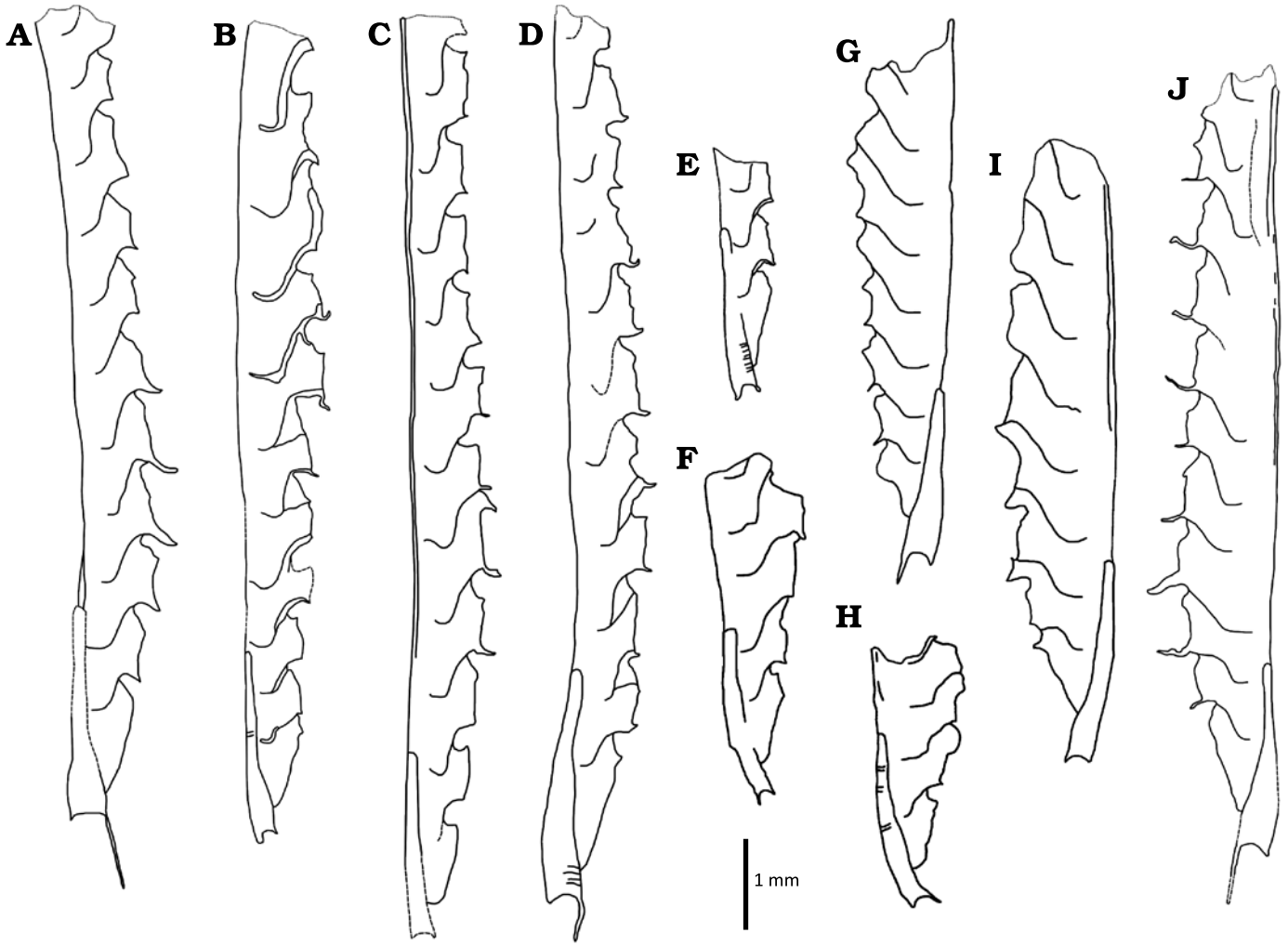


Fig. 5. Line drawings of two new graptolite taxa *Uncinatograptus lisandroi* sp. nov. (A–E) and *Uncinatograptus elsae* sp. nov. (F–J) of the Los Espejos Formation, Talacasto Range, San Juan Province, Argentinian Precordillera. **A**. INGEO-PI-2040, level PNN-02N. **B**. INGEO-PI-2062, level PNN-02N. **C**. INGEO-PI-2092, level PNN-02N. **D**. INGEO-PI-2134, level PNN-02N. **E**. INGEO-PI-2046A, level PNN-02N. **F**. INGEO-PI-2035, level PNN-02N. **G**. INGEO-PI-2087, level PNN-02N. **H**. INGEO-PI-2162, level PNN-02S. **I**. INGEO-PI-2137A, level PNN-02N. **J**. INGEO-PI-2115, level PNN-02N.

Norte section, Talacasto Range (PNN-00N–05N; PNN-02S–08S; Figs. 2 and 3). Most of the graptolite specimens are preserved in three dimensions, filled by oxidized pyrite or carbonate-sandstone/siltstone (see Figs. 4–7). In general, the tubaria are parallel to bedding or slightly oblique in siltstones, randomly disposed in coquinas (e.g., PNN-04S), and horizontal and mostly aligned in sandstones (e.g., PNN-02N).

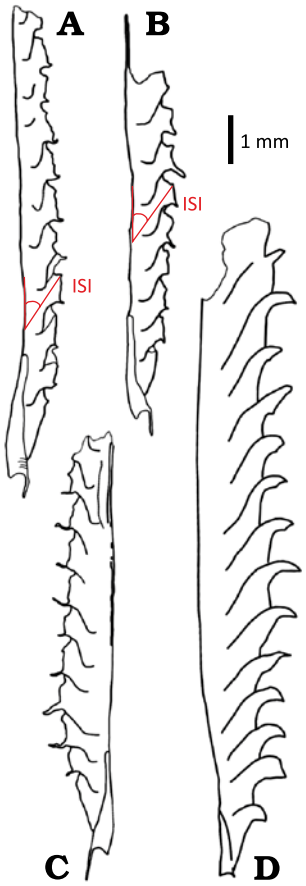
Some of the graptolites from the Los Espejos Formation were partially illustrated and described by Lopez (2019). In the present work, an updated taxonomic revision of these fossils is presented and new specimens from the same area are studied.

The values of the interthecal septum inclination in specimens of *Uncinatograptus* spp. were measured from the tubarium axis to the top end of the supragenicular wall, positioned as parallel as possible to the thecal development (given the sigmoidal nature of the interthecal septum; see Fig. 6).

The fossil specimens were illustrated using conventional stereomicroscope (Leica S9D) and with a digital camera (Nikon D3400). Material is housed at the Instituto de Geología Dr. Emiliano Aparicio, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de San Juan, under the repository code INGEO-PI-2016-2248.

Systematic palaeontology

The graptolite fauna collected is dominated by uniserial taxa, aligned (lower levels of the sections) or randomly disposed (upper levels of the sections). *Uncinatograptus* spp. and *Saetograptus argentinus argentinus* (Cuerda 1969) are abundant in specific levels, with dozens to hundreds of specimens per sample. Other graptolite taxa, such as *Bohemograptus* and *Lobograptus*, are scarce and only present in a few fossiliferous levels. The taxonomic classification of Maletz (2014) and Bates et al. (2023) is followed herein.



Characteristics \ Graptolites		A *Uncinatograptus lisandroi* sp. nov.			B *Uncinatograptus u. notouncinatus*			C *Uncinatograptus elsae*			D *Uncinatograptus uncinatus*	
		min.	main	max.	min.	main	max.	min.	main	max.	min.	max.
Width (without hood)	th1	0.49	0.52	0.69	0.56	0.62	0.63	0.64	0.70	0.80	0.54	0.70
	th2	0.52	0.62	0.78	0.60	0.70	0.81	0.72	0.79	0.89	0.59	0.85
	th3	0.49	0.64	0.78	0.73	0.75	0.86	0.83	0.91	1.05	0.67	1.00
	th5	0.60	0.71	0.79	0.74	0.80	0.87	0.89	1.05	1.21	0.86	1.25
	th7	0.63	0.73	0.78	0.83	0.87	0.94	0.82	1.03	1.18	1.00	1.47
	th10	0.61	0.61	0.62	0.86	0.88	0.88	0.74	0.80	0.90	1.24	1.41
	distal	0.45	0.51	0.70	0.84	0.99	1.02	0.97	0.98	1.06	1.36	1.56
2TRD/thecal spacing		proximal		distal	proximal		distal	proximal		distal	proximal	distal
		1.38		1.74	1.41		1.97	1.45		1.86	1.50	1.95
		5–8 in 5 mm			5–7 in 5 mm			5.5–7 in 5 mm			6.5–7 in 5 mm	
Interthecal septum inclination		32°–40°		28°	40°		30°–27°	48°–56°		40°–33°	54°	25°–20°

Fig. 6. Comparison of the three *Uncinatograptus* species found in the Los Espejos Formation, Talacasto Range, San Juan Province, Argentinian Precordillera: *Uncinatograptus lisandroi* sp. nov. (A), *Uncinatograptus uncinatus notouncinatus* (Cuerda, 1969) (B), *Uncinatograptus elsae* sp. nov. (C), and the type species *Uncinatograptus uncinatus* (Elles in Lang and Cookson, 1935) (D) showing the measurement technic of the interthecal septum (in red lines). The most important differences (widths [in mm] and interthecal septum inclination) and similarities (two thecae repeat distance [2TRD] and thecal spacing) are shown. **A**. INGEO-PI-2040, level PNN-02N. **B**. INGEO-PI-2074, level PNN-02N. **C**. INGEO-PI-2115, level PNN-02N. **D**. GSV 65160, modified from Garrat and Rickards (1984: fig. 5B). Features data taken from Garrat (1978), Garrat and Rickards (1984), Lenz and Kozłowska-Dawidziuk (2004), and Štorch et al. (2015). Abbreviations: ISI, interthecal septum inclination; max., maximum; min., minimum.

Phylum Hemichordata Bateson, 1885

Class Pterobranchia Lankester, 1877

Subclass Graptolithina Bronn, 1849

Order Graptoloidea Lapworth, 1875

Family Monograptidae Lapworth, 1873

Genus *Bohemograptus* Přibyl, 1967

Type species: *Graptolithus bohemicus* Barrande, 1850; by original designation; Ludlow of Bohemia (Czech Republic).

Bohemograptus bohemicus (Barrande, 1850)

Figs. 4K, 8A, B.

1850 *Graptolithus bohemicus*; Barrande 1850: 40, pl. 1: 15–18.
1936 *Monograptus bohemicus* (Barrande, 1850); Bouček 1936: 3–4, pl. 1: 1–3.
1958 *Pristiograptus bohemicus* (Barrande, 1850); Urbanek 1958: 77–80, figs. 46, 47, 49.
1967 *Bohemograptus bohemicus* (Barrande, 1850); Přibyl 1967: 136, pl. 1: 1–6.
1990 *Bohemograptus bohemicus bohemicus* (Barrande, 1850); Lenz 1990: figs. 3A, B.
1997 *Bohemograptus bohemicus bohemicus* (Barrande, 1850); Zhang and Lenz 1997: 1236, figs. 6M–S, 7I, 7K–M.
2002 *Bohemograptus bohemicus* (Barrande, 1850); Nilsson 2002: 16, figs. 8B, 9B, C.
2004 *Bohemograptus bohemicus bohemicus* (Barrande, 1850); Lenz and Kozłowska-Dawidziuk 2004: 32, pl. 37: 1–5, 7; pl. 44: 1–5.
2012 *Bohemograptus bohemicus* (Barrande, 1850); Sachanski et al. 2012: pl. 1e.
2014 *Bohemograptus bohemicus* (Barrande, 1850); Štorch et al. 2014: 1032, fig. 13D.

Material.—Two specimens (INGEO-PI-1865, 1879B) with sicula and firsts thecae, well preserved as carbon film and filled by carbonate siltstone from levels PNN-02N and 07S middle to upper Los Espejos Formation, lower Gorstian, lower Ludlow, upper Silurian. Poblete Norte section, Talacasto area, San Juan Province, Argentina.

Description.—Specimens moderate to strongly ventrally curved, only with sicula and firsts thecae present. The dorso-ventral width varies between 0.54–0.66 mm at Th1,

0.56–0.73 mm at Th2, 0.74–0.84 mm at Th3, 0.94–1.02 mm at Th4, and 0.94 mm at Th5. Sicula is slightly ventrally curved, 1.81–1.98 mm long, a moderately flared 0.28–0.29 mm wide aperture, and its apex reaches the Th1 aperture level or slightly above. Virgella and dorsal process visible, with 0.34–0.14 mm long and 0.05–0.16 mm long, respectively. Th1 shows a concave ventral wall in profile, whereas Th2–5 present tube-like thecae or slightly undulated ventral walls. Thecae incline 31–36° to the tubarium axis. 2TRD values range from 1.37–1.50 mm proximally, the thecal spacing counts 6 in 5 mm, and the overlap is ½.

Remarks.—Uncommon component of the Los Espejos Formation graptolite fauna. The specimens collected in the Los Espejos Formations resemble *Bohemograptus bohemicus* as described and illustrated by Berry (1964), Urbanek (1970), Lenz (1984), Nilsson (2002), Koren' and Sujarkova (2004), Lenz and Kozłowska-Dawidziuk (2004), and Wilkinson (2021). This species differs from its derivative species *Bohemograptus tenuis* (Bouček, 1936) in its greater width and thecal overlap (Lenz and Kozłowska-Dawidziuk 2004).

A possible *B. bohemicus* was mentioned but no illustrated by Suarez-Soruco (1975) in lower Ludlovian levels. This contribution presents the first description and illustration of this taxon in South America.

Stratigraphic and geographic range.—Level PNN-02N and 07S, middle to upper Los Espejos Formation, lower Gorstian, lower Ludlow, upper Silurian. Poblete Norte section, Talacasto area, San Juan Province of Argentina.

Genus *Lobograptus* Urbanek, 1958

Type species: *Monograptus scanicus* Tullberg, 1883; Ludlow of the Scania (Sweden).

Lobograptus sp.

Fig. 7D, 8F.

Material.—One specimen with mould and countermould (INGEO-PI-53A and B) well preserved in relief filled by carbonate siltstone. Level PNN-04S, middle to upper Los Espejos Formation, lower Gorstian, lower Ludlow, upper Silurian. Poblete Norte section, Talacasto area, San Juan Province, Argentina.

Description.—Straight 9.82 mm long fragment, with proximal end not recovered. The dorso-ventral width increases from 0.60 mm to 0.71 mm. Thecae inclined 10–18° to the tubarium axis. Thecae show ventral bends in its ventral wall or are slightly geniculate, giving a weakly monoclimacid-shape in profile. The thecal aperture shape is straight to sigmoidal, with orthogonal to obtuse angles to the tubarium axis. Thecal spacing counts 4 in 5 mm, the 2TRD varies 2.70–3.06 mm, and the thecal overlap is ¼ to two-fifths.

Remarks.—Very rare component of the Los Espejos Formation graptolite fauna. The specimen exhibits morphological similarities with the material described and illustrated by Palmer (1971), Lenz (1990), Zhang and Lenz (1997), Koren' and Sujarkova (2004), Lenz and Kozłowska-Dawidziuk (2004), Pashko (2020), and Wilkinson (2021) as *Lobograptus* sp. In particular, the studied specimen shares features with *L. progenitor* in thecal shape, middle to distal dorso-ventral width, thecal inclination, shape, spacing, and overlap. On the other hand, the absence of essential diagnostic characteristics (proximal end and tubarium curvature shown by Palmer 1971), does not allow for a specific determination.

The specimen of *Lobograptus* described herein represents the first record of this genus in South America.

Fig. 7. Ludlow (Silurian) graptolite fauna of the Los Espejos Formation, Talacasto Range, San Juan Province, Argentinian Precordillera: early Gorstian to early Ludfordian *Saetograptus argentinus argentinus* (Cuerda, 1969) (A, B), the early Gorstian *Saetograptus* cf. *S. varians* (Bouček, 1936) (C), and *Lobograptus* sp. (D). **A**. INGEO-PI-2195, level PNN-04S. **B**. INGEO-PI-2196A, level PNN-04S. **C**. INGEO-PI-2198A, level PNN-04S. **D**. INGEO-PI-2199A, level PNN-04S. Scale bars 1 mm.

Genus *Saetograptus* Přibyl, 1942

Type species: *Graptolithus chimaera* Barrande, 1850; original description Přibyl 1942; *Neodiversograptus nilssoni* Zone, Gorstian, Ludlow of Bohemia (Czech Republic).

Saetograptus argentinus argentinus (Cuerda, 1969)

Fig. 7A, B, 8E, I.

1969 *Monograptus argentinus*; Cuerda 1969: 231–234, pl. 1: a–d; pl. 2: 4–6.
1971 *Monograptus argentinus* Cuerda, 1969; Cuerda 1971: 399, pl. 5: 1–11, pl. 31: 4–6.
1996 *Saetograptus* (?*Colonograptus*) *argentinus* (Cuerda, 1969); Rickards et al. 1996: 120, figs. 7e–h, 11h.
2002 *Saetograptus argentinus argentinus* (Cuerda, 1969); Maletz et al. 2002: 334–336, text-fig. 2g, i–m, pl. 1: 2, 4.
2019 *Saetograptus argentinus*? (Cuerda, 1969); Lopez 2019: 77, figs. 21h–i, 22b.
2022 *Saetograptus argentinus argentinus* (Cuerda, 1969); Lopez 2022: 28–30, figs. 3.1–3, 3.5–8, 4.1–3.

Material.—Several juvenile and mature tubaria (INGEO- PI-2138–2146, 2178, 2190, 2195–2197, 2202–2203, 2206, 2208A–B, 2214–2217, 2219, 2221–2227, 2247) well preserved and filled by carbonate siltstone from levels PNN-04N, 05N, 04S, 07S, 08'S, and 08S, middle to upper Los Espejos Formation, lower Gorstian, lower Ludlow, upper Silurian. Poblete Norte section, Talacasto area, San Juan Province, Argentina.

Description.—The material found in the Los Espejos Formation possesses both juvenile and mature specimens with an absent proximal end, and a few complete tubaria preserved in relief, filled by carbonate or oxidized pyrite. Straight tubaria, with a maximum length of 26.4 mm, having thirty-one thecae and a broken proximal end. The proximal dorso-ventral width without spines is 0.82–1.11 mm at Th1, 0.93–1.39 mm at Th2, 1.07–1.44 mm at Th3, 1.11–1.36 mm at Th5, and 2.07–2.51 mm distally. Thecae possess ventrally directed lateral apertural spines up to Th3–6, with a rapid distalward transition to pristiograptid thecae with even apertures. The sicula is 2.05–2.26 mm long, and 0.25–0.46 mm wide at the aperture which possesses 0.37–0.44 mm long virgella and 0.14–0.51 mm antivirgellar spine. Sicular apex reaches up to the level of the aperture of Th2–3. The 2TRD is 1.17–1.21 mm at Th2, and 1.79–1.97 mm distally. Thecal spacing equals 5–8 thecae in 5 mm, and the thecal overlap is one half proximally to three-fifths distally. The thecal inclination decreases from 50° proximally to 36–30° distally.

Remarks.— These measures agree with those reported by Cuerda (1965), Cuerda (1969), Rickards et al. (1996), Maletz et al. (2002) and Lopez (2022) for *S. a. argentinus*. This subspecies can be differentiated from *S. a. robustus* mainly by its narrower tubarium (2.51 mm vs 3.2–3.8 mm) and much lower thecal inclination distally (30° vs 55°).

Stratigraphic and geographic range.—Levels PNN-04N, 05N, 04S, 07S, 08'S, and 08S, middle to upper Los Espejos Formation, lower Gorstian, lower Ludlow, upper Silurian. Poblete Norte section, Talacasto area, San Juan Province of Argentina.

Saetograptus cf. *varians* (Wood, 1900)

Fig. 7C, 8C, D.

Material.—Two immature specimens with sicula and firsts 7–8 thecae (INGEO-PI-2187, 2198A, B) well preserved in relief filled by carbonate siltstone from level PNN-04S, middle to upper Los Espejos Formation, lower Gorstian, lower Ludlow, upper Silurian. Poblete Norte section, Talacasto area, San Juan Province, Argentina.

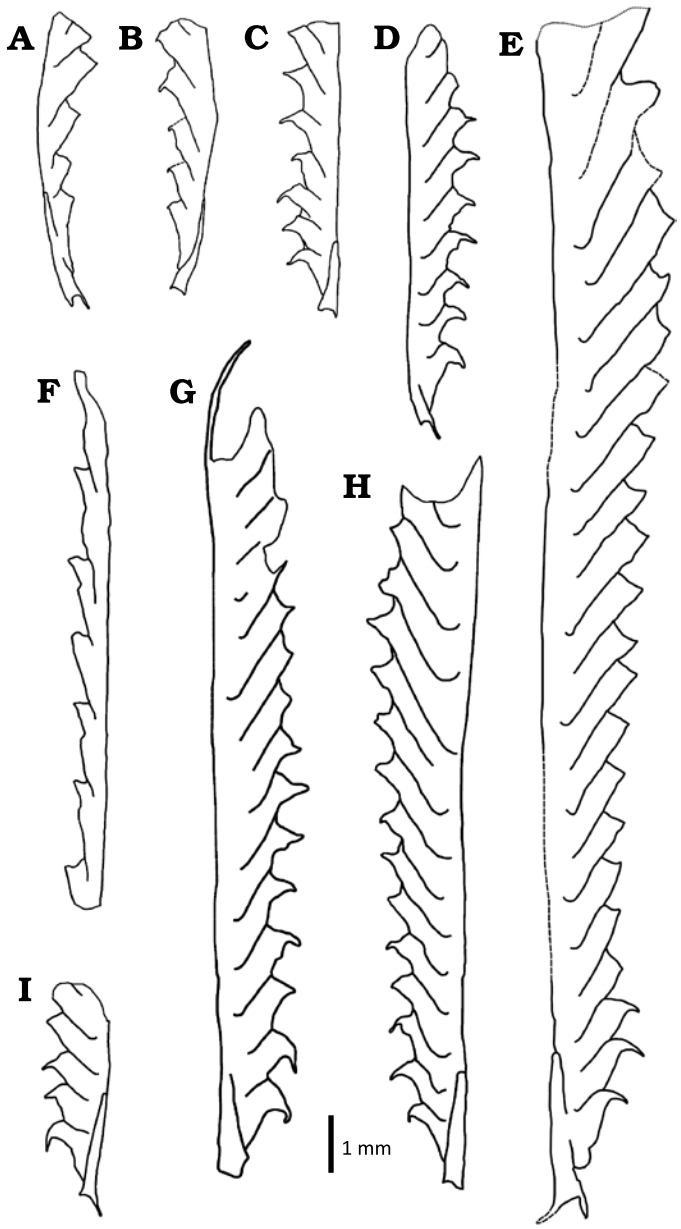


Fig. 8. Line drawings of the Ludlow (Silurian) graptolite fauna of the Los Espejos Formation, Talacasto Range, San Juan Province, Argentinian Precordillera: early Gorstian *Bohemograptus bohemicus* (Barrande, 1850) (A, B), *Saetograptus* cf. *S. varians* (Bouček, 1936) (C, D), and *Lobograptus* sp. (E), the early Gorstian to early Ludfordian *Saetograptus argentinus argentinus* (Cuerda, 1969) (F–I). **A**. INGEO-PI-1865, level PNN-02N. **B**. INGEO-PI-1879 B, level PNN-08S. **C**. INGEO-PI-2187, level PNN-04S. **D**. INGEO-PI-2198A, level PNN-04S. **E**. INGEO-PI-2144A, level PNN-05N. **F**. INGEO-PI-2199A, level PNN-04S. **G**. INGEO-PI-2195, level PNN-04S. **H**. INGEO-PI-2195, level PNN-04S. **I**. INGEO-PI-2200A, level PNN-04S.

Description.—Straight tubarium of a maximum recorded length of 7.67 mm (INGEO-PI-2198A), with a gently ven-

trally curved proximal end. The dorso-ventral width is 0.65–0.89 mm at Th1, 0.78–0.93 mm at Th2, 0.92–0.93 mm at Th3, 0.83–1.05 mm at Th4, 0.89–1.13 mm at Th5, and 0.99 mm at Th8. The sicula is slightly ventrally curved, 1.55 mm long. Sicular aperture is 0.25–0.34 mm wide. The sicular apex reaches up to the level of Th2 aperture. A 0.38 mm long virgella and 0.09–0.15 mm long antivirgellar spine are present. Thecae are biform, with Th1 to Th6–7 displaying spine-like lateral apertural lappets. Subsequent thecae gained simple pristiograptid appearance. Thecae incline at 37–39° to the tubarium axis. 2TRD values range from 1.39 mm at Th2 to 1.55 mm at Th5. Thecae number 6.5–7 in 5 mm, and overlap for three-fifths to ¾ their length.

Remarks.—The studied specimens from the Los Espejos Formation are similar to *S. varians* in its proximal width, 2TRD, thecal spacing, etc. (Hutt 1969; Lenz and Kozłowska-Dawidziuk 2004; Wilkinson 2021). On the other hand, the presence of spine-like thecal lappets in theca Th4–7, of antivirgellar spine, and lower dorso-ventral width (cf. Wilkinson 2021), suggest that the Argentinian material belongs to a different taxon, for which a reliable specific determination requires a further material.

Specimens of *S.* cf. *S. varians* and *S. varians* were mentioned by Branisa (1969) and Suarez-Soruco (1975) in Bolivian outcrops in association with *S. argentinus*. The material of the Los Espejos Formation means the first mention and description of this species in Argentina.

Genus *Uncinatograptus* Tsegelnyuk, 1976

Type species: *Monograptus uncinatus* Tullberg, 1883; 12a, lectotype, selected by Přibyl 1948: 35 (Tullberg 1883: pl. 1: 25; ?LO collection, specimen not identified); 12b–c, proximal end in lateral (3b) and ventral (3c) views; from the Ludlow of Bohemia (Czech Republic).

Uncinatograptus elsae sp. nov.

Figs. 4D–F, 5F–J, 6C.

Zoobank LSID: urn:lsid:zoobank.org:act:B90B4DF2-6ECB-4D16-8B64-0ED5DBC1FF78

Etymology: In honour of Elsa Nelly Borcia (1957–2020), mother of FEL, a woman with an exceptional affection and patience, who instilled to FEL the love for the knowledge, and to whom is greatly thankful.

Type material: Holotype: INGEO-PI-2115, almost mature relief preserved tubarium. Paratypes: INGEO-PI-1870, well preserved fragmented tubarium; INGEO-PI-2042, moderate preserved specimen; INGEO-PI-2035, proximal specimen; INGEO-PI-2137A and B, specimen with preserved hoods. All from the type locality and horizon.

Type locality: Poblete Norte Creek, Talacasto, 77 km NNW from San Juan city. Central Precordillera, San Juan, Argentina.

Type horizon: PNN-02N, North detailed section, Middle Member of the Los Espejos Formation, Poblete Norte section, Talacasto, lower Gorstian, lower Ludlow, Silurian.

Material.—13 proximal ends or complete specimens in relief (INGEO-PI-2023, 2035, 2042, 2048A, B, 2066A, B, 2069, 2082, 2087, 2088, 2091, 2111A, B, 2115, 2132A, B, 2137A, B, 2162) filled by carbonate or oxidized pyrite from levels PNN-02N and 02S, all from the type locality and horizon.

Diagnosis.—Straight, robust, and rapidly widening *Uncinatograptus* reaching a dorso-ventral width of more than 1 mm (without hood) at Th3–4, decreasing to 0.8 mm at Th10 and then continuously increasing distally, giving a half spindle-shape to the tubarium. Hoods rarely preserved. Thecal number 5.5–7 in 5 mm, the 2TRD is 1.45 mm proximally and 1.86 mm distally, and interthecal septum inclination is 48–56° proximally and 40–33° distally.

Description.—Straight tubarium of a maximum length of 9.21 mm (INGEO-PI-2115), with slightly to moderately ventrally curved proximal end. The dorso-ventral width varies 0.64–0.80 mm (0.70 mm mean value) at Th1, 0.72–0.89 mm (0.79 mm) at Th2, 0.83–1.05 mm (0.91 mm) at Th3, 0.89–1.21 mm (1.05 mm) at Th5, 0.82–1.18 mm (1.03 mm) at Th7, 0.74–0.90 mm (0.80 mm) at Th10, and 0.97–1.06 mm (0.98 mm) distally. Sicula is moderate to strongly ventrally curved, with 1.91–2.44 mm long, with 0.25–0.39 mm wide aperture, and the apex generally attaining the level of the Th2 aperture. Ventrally-directed, up to 0.68 mm long virgella and 0.05–0.16 mm long dorsal apertural process are usually seen. The distance between the sicular and Th1 apertures ranges 1.12–1.65 mm (1.32 mm in average). Thecae are of *Uncinatograptus*-type, with dorsal hoods and ventrally facing apertures. Due to taphonomy these hoods are usually not visible, giving the aspect of a pseudomonoclimacid-like thecae or apertural spines. The supragenicular ventral walls are slightly oblique proximally, to parallel medially and distally to the tubarium axis. The interthecal septum inclines 48–56° proximally, to 40–33° distally. 2TRD values range from 1.45 mm proximally to 1.86 mm distally, and the thecal spacing counts 5.5–7 in 5 mm. Thecal overlap for about half their length.

Remarks.—Common species of the lower graptolitic levels of the Los Espejos Formation (PNN-02N and 02S) preserved in different astogenetic stages. Specimens of *Uncinatograptus elsae* sp. nov. can be differentiated from other *Uncinatograptus* species by its dorso-ventral width, which initiates in near values (0.64–0.80 mm) and rapidly increases and exceeds 1 mm from Th3 (1.05 mm maximum) to Th7 (1.18 mm maximum); subsequent dorso-ventral width values decrease to less than 1 mm, to finally stabilize in values similar to those in *Uncinatograptus uncinatus notouncinatus* distally (0.97–1.06 mm). The increase-decrease width results in a half spindle-shape of mature tubaria (from Th1–10) or a conic-shape in juvenile specimens, that helps to distinguish this species from the parallel-shaped *Uncinatograptus lisandroi* sp. nov., and the steadily widening of *U. u. uncinatus* and *U. u. notouncinatus* (with maximum distal values of 1.56 mm and 1.02 mm, respectively). In addition, proximal interthecal septum tilting can be helpful to differentiate the respective species, where *U. elsae* sp. nov. shows higher values (48–56°) than *U. u. notouncinatus* (40°) and *U. lisandroi* sp. nov. (32–40°), and distal values, with *U. elsae* sp. nov. showing slightly higher angles than *U. u. uncinatus* (25–20°). Moreover, sicula length is similar

in all the species, showing only slightly higher values in sicular aperture width in *U. elsae* sp. nov. than *U. u. uncinatus* (0.22–0.26 mm; Urbanek 1958). These differences are summarized in Fig. 6. On the other hand, if the specimen shows only the firsts pair of thecae, its features will be similar between species denying a reliable taxonomic determination. It is important to mention that similar tubaria shape and sizes to *U. elsae* sp. nov. are illustrated by Garrat (1978: figs. 6A, B), classified as *Monograptus* aff. *uncinatus.*

Stratigraphic and geographic range.—Levels PNN-02N and 02S, middle to upper Los Espejos Formation, lower Gorstian, lower Ludlow, upper Silurian. Poblete Norte section, Talacasto area, San Juan Province, Argentina.

Uncinatograptus lisandroi sp. nov.

Figs. 4G–J, 5A–E, 6A.

Zoobank LSID: urn:lsid:zoobank.org:act:09E7BF7D-D620-457B-B6BA-824DDEEAB8CA

Etymology: In honour of Lisandro Lopez Gordillo (born 2022), son of FEL, a lovely little boy that gives love and kindness to everyone, and who nowadays inspires FEL to continue his research.

Type material: Holotype: INGEO-PI-2134A, mature well preserved tubarium. Paratypes: INGEO-PI-2134B, countermould of holotype; INGEO-PI-2040, 2062, 2092, mature specimens with moderate preservation; INGEO-PI-2046A, 2048A, juvenile specimens. All from the type locality and horizon.

Type locality: Poblete Norte Creek, Talacasto, 77 km NNW from San Juan city. Central Precordillera, San Juan, Argentina.

Type horizon: PNN-02N, North detailed section, Middle Member of the Los Espejos Formation, Poblete Norte section, Talacasto, lower Gorstian, lower Ludlow, Silurian.

Material.—13 proximal ends or complete specimens in relief (INGEO-PI-2023, 2029, 2040, 2042, 2044, 2046A–C, 2048A, B, 2083, 2092, 2093, 2108A–C, 2126, 2133A, B, 2134A, B, 2137A, B) filled by carbonate or oxidized pyrite. Levels PNN-02N, 06S, and 06'S, all from the type locality and horizon.

Diagnosis.—Slightly to moderately dorsally curved *Uncinatograptus*, with generally slender tubarium. Sicula and first theca gently to moderately ventrally curved. Dorso-ventral width of 0.52 mm proximally, 0.71 mm medially, and 0.51 mm distally, giving a parallel-sided shape to the tubarium. Hoods rarely preserved. Thecae number 5–8 in 5 mm, 2TRD is 1.38 mm proximally and 1.74 mm distally, interthecal septum inclination decreases from 32–40° proximally to 28° distally.

Description.—Specimens with slightly to moderately proximal ventral curvature, gently to moderately dorsally curved in the middle and distal part. The maximum length is 10.99 mm (INGEO-PI-2092). The dorso-ventral width varies from 0.49–0.69 mm (0.52 mm mean value) at Th1, 0.52–0.78 mm (0.62 mm) at Th2, 0.49–0.78 mm (0.64 mm) at Th3, 0.60–0.79 mm (0.71 mm) at Th5, 0.63–0.78 mm (0.73 mm) at Th7, 0.61–0.62 mm (0.61 mm) at Th10, and 0.45–0.70 mm (0.51 mm) distally. Sicula is moderately to strongly ventrally curved, 1.89–2.21 mm long, and its apex reaches up to the level of the Th2 aperture. Sicular aperture is 0.23–0.40 mm wide. Downwardly to slightly ventrally-directed virgella 0.14–0.75 mm long, commonly having 0.05–0.14 mm long dorsal tongue. The distance between the sicular and the Th1 apertures varies from 1.18–1.65 mm (1.28 mm mean value). Thecae of uncinatograptid-type finished with hoods and extroverted ventrally facing apertures. Due to taphonomic reasons these hoods are usually not visible or seen in cross section, giving the aspect a pseudomonoclimacid appearance or apertural spines. The supragenicular ventral walls are parallel or inclined slightly inwards to the tubarium axis. Interthecae septum inclines at 32–40° proximally, decreasing to 28° distally. The 2TRD values range from 1.38 mm proximally to 1.74 mm distally. Thecae number 5–8 in 5 mm, and overlap for mostly half their length.

Remarks.—Common components of the lower and middle graptolitic levels of the Los Espejos Formation in different astogenetic stages. Specimens of *U. lisandroi* sp. nov. can be differentiated from other *Uncinatograptus* species by its dorso-ventral width, which starts 0.49–0.69 mm at Th1, and from Th2 maintains constant values measured in the respective specimens (minimums of 0.45–0.52 mm to maximums of 0.62–0.79 mm). This width development differs from the constant growth of *U. u. uncinatus* and *U. u. notouncinatus*, and the half spindle-shape of *U. elsae* sp. nov. Furthermore, proximal interthecal septum inclinations are smaller than those showed by *U. u. uncinatus* (54°), and distal interthecal septum inclination and distal 2TRD show lower values than *U. u. notouncinatus* (40° and 1.97 mm) and *U. elsae* sp. nov. (48–56° and 1.86 mm). These minute differences are summarized in Fig. 6. On the other hand, if the tubarium presents only proximal features or belongs to a juvenile astogenetic stage, a taxonomic classification at species level will be imposible.

Stratigraphic and geographic range.—Levels PNN-02N, 06S, and 06'S, middle to upper Los Espejos Formation, lower Gorstian, lower Ludlow, upper Silurian. Poblete Norte section, Talacasto area, San Juan Province, Argentina.

Uncinatograptus uncinatus notouncinatus (Cuerda, 1969)

Figs. 4A–C, 6B.

1969 *Monograptus uncinatus notouncinatus*; Cuerda 1969: 228–231, pl. 1e–h; pl. 2: 1–3.

1971 *Monograptus uncinatus notouncinatus* Cuerda, 1969; Cuerda 1971: 396–399, pl. 5: 12–23; pl. 31: 1–3.

1975 *Monograptus uncinatus notouncinatus* Cuerda, 1969; Antonioli 1975: 212–216, pl. 1a–k; pl. 2: 1–2.

1996 *Monograptus uncinatus notouncinatus* Cuerda, 1969; Rickards et al. 1996: 114–115, figs. 6j–l, 11c–g.

2019 *Monograptus uncinatus* var. *notounciantus* Cuerda, 1969; Lopez 2019: 75–77, figs. 21a–g, j, 22a.

Material.—Several juvenile and mature tubaria (INGEO-PI-1863, 1868, 2016A, B, 2023, 2025, 2032, 2044, 2062, 2067, 2074, 2077, 2093, 2101, 2103A, B–2104A, B, 2109A–C, 2115, 2123, 2126–2127A, B, 2134A, B, 2152, 2156, 2173A, B, 2193,

2197, 2209, 2229A, B, 2235, 2238–2246) well preserved as carbon films or filled by carbonate siltstone, from levels PNN-00N–03N, 02S, 04S, 06S, and 06'S, middle to upper Los Espejos Formation, lower Gorstian, lower Ludlow, upper Silurian. Poblete Norte section, Talacasto area, San Juan Province of Argentina.

Description.—The specimens are abundant in the Los Espejos Formation and represented by both juvenile and mature tubaria. Generally, they are preserved in relief, filled by carbonate or oxidized pyrite, as carbon films or negative casts. The analysed material exhibits a straight to slightly dorsally curved tubarium, with a ventrally curved proximal end. The longest specimen with 14 thecae attained the length of 14.5 mm. The dorso-ventral width, thecal spacing, and 2TRD measures are summarized in the Fig. 6. Thecae are extroverted throughout the tubarium, although most have lost the hood as a result of preservation and simulate a hood-like aperture or the presence of spines. The suprageniculars walls are parallel or inclined with obtuse angles to the tubarium axis. The sicula is 1.75–2.32 mm long, presents an aperture of 0.28–0.36 mm long, its apex reaches the Th2 aperture, and possesses from two to seven sicular annuli. The thecal overlap is one half. The interthecal septum tilting varies from 40° proximally to 30–27° distally.

Remarks.—These features agree with those given by Cuerda (1969), Antonioli (1975), and Rickards et al. (1996) for *U. u. notouncinatus.* It is important noting that the dorso-ventral width continuously increase from the proximal (0.62 mm) to the distal area (0.99 mm), in contrast to *U. elsae* sp. nov. and *U. lisandroi* sp. nov. (Fig. 6).

Stratigraphic and geographic range.—Levels PNN-00N–03N, 02S, 04S, 06S, and 06'S, middle to upper Los Espejos Formation, lower Gorstian, lower Ludlow, upper Silurian. Poblete Norte section, Talacasto area, San Juan Province of Argentina.

Results

Graptolite faunas.—The graptolite faunas reported in this contribution represent the most diverse associations found in the upper Silurian of South America until now. In addition to the three subspecies previously described, *Uncinatograptus uncinatus notouncinatus*, *Saetograptus argentinus argentinus*, and *Saetograptus argentinus robustus*, five new taxa have been identified.

At the North section (Fig. 3B), the first appearance of *U. u. notouncinatus* corresponds to the PNN-00N and 01N samples, located in the Middle Member of the Los Espejos Formation (Fig. 3B, indicated by the sky-blue area). Upwards, and 15 m above the first lineament, the identified association is made up of *U. u. notouncinatus*, *U. elsae* sp. nov., *U. lisandroi* sp. nov., *Bohemograptus bohemicus*, and an unidentified uniserial taxon with pristiograptid thecae (level PNN-02N; Figs. 4, 5). Subsequently, one meter higher, an association of *U. uncinatus*, *U. lisandroi* sp. nov., and several plant remains was discovered (PNN-03N). Still 8.20 m upwards, the first appearance of *S. a. argentinus* was recorded in the sample PNN-04N (Fig. 3B, indicated by the blue area). Finally, 7.90 m above the last lineament, the level PNN-05N was found, showing only a few specimens of *S. a. argentinus*.

At the South section (Fig. 3A), the first appearance of *U. u. notouncinatus* was recorded in the sample PNN-02S, along with *U. elsae* sp. nov. and fragments of undetermined retiolitid lists. Higher, the sample PNN-04S, located 15.60 m above, exhibited the first appearance of *S. a. argentinus*, associated with *S.* cf. *S. varians*, *U. u. notouncinatus*, and *Lobograptus* sp. (Figs. 7, 8). This sample represents the first record of *S. a. argentinus* and *U. u. notouncinatus* in the same stratigraphic level. The samples PNN-06S and 06'S, positioned 7 and 8 m higher in the section, yield specimens of *U. u. notouncinatus* and *U. lisandroi* sp. nov. Subsequent, the sample PNN-07S is 4.60 m upwards, and yields *S. a. argentinus.* Finally, at 9.90 m (PNN-08'S) and 11.10 m (PNN-08S) of the section, specimens of *S. a. argentinus* and *B. bohemicus* were collected.

The FAD of *S. a. argentinus* is recorded in both detailed columns and reliably correlated (PNN-04N and 04S), whereas the FAD of *U. u. notouncinatus* cannot be reliably correlated due to the presence of possible strike-slip faults in the North section, which might represent repetitions or omissions in the stratigraphic column. In the latter case, a tentative correlation is proposed between the levels PNN-00N and 02S.

Associated fossils.—In the North section, graptolites were found associated with brachiopods *Australina jachalensis*, *Amosina* sp., and *Castellaroina* sp. (levels PNN-00N–04N). Specimens of *Clarkeia* sp. were observed in levels above the PNN-05N. Most of the levels presented tentaculitoids and ostracods, and a few gastropods, like *Loxonema* sp. and Bellerophontidae gen. et sp. indet., were present in the levels PNN-00N and 01N. Eurypterid plates, classified as Eurypteracea by Brussa and Toro (1989), together with spicules, crinoids, and scolecodonts were collected in the PNN-02N (Figs. 9, 10A–G). Concretions with conularid cnidarians were found in the level PNN-00N. It is worth mentioning that undetermined carbonaceous wisps were collected in the levels PNN-02N, 03N, and 05N, first-time registered in the Los Espejos Formation. Finally, in the interbedded strata, traces as *Chondrites* isp., *Conostichnus* isp., and *Planolites* isp., were observed.

In the South section, as well as the North section, the brachiopods *Australina jachalensis*, *Amosina* sp., and *Castellaroina* sp. were present in most of the levels, together with *Harringtonina australis* (PNN-02S) and *Clarkeia* sp. (PNN-04S and 08S). Specimens of *Nuculites* sp. and undetermined bivalves were collected in the levels PNN-02S, 04S, and 08S. Eurypterid plates were found in the levels PNN-02S, 04S, and 08'S. Most of the sampled levels showed

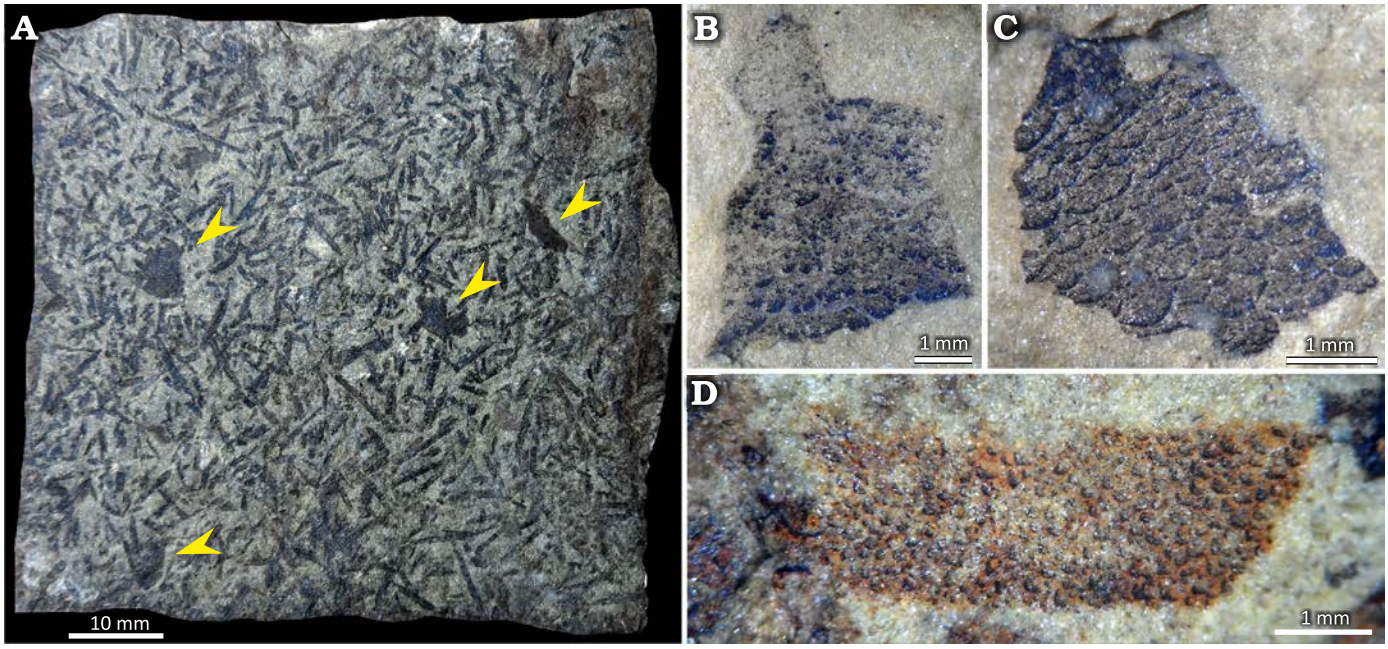


Fig. 9. Eurypterid plates of the superfamily Eurypteracea Burmeister, 1843, associated with the described graptolites, from Silurian Los Espejos Formation, Talacasto Range, San Juan Province, Argentinian Precordillera. **A**. INGEO-PI-2078, graptolitic sample with four eurypterids plates (arrows). **B**. INGEO-PI-1860, level PNN-02N. **C**. INGEO-PI-2047, level PNN-02N. **D**. INGEO-PI-2067, level PNN-02N.

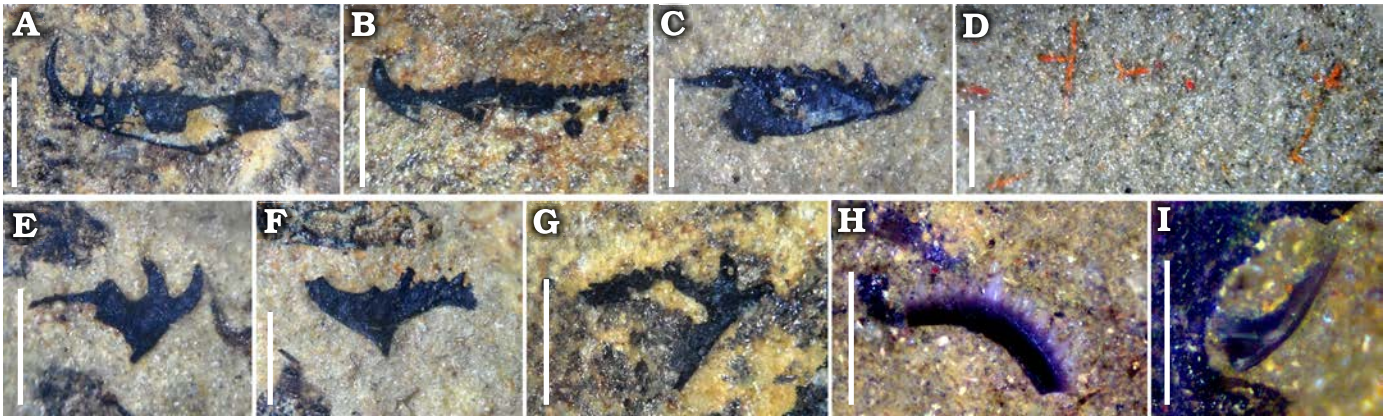


Fig. 10. Associated non-graptolite fauna of scolecodonts (A–F), spicules (G), and conodonts (H, I), from the Silurian Los Espejos Formation, Talacasto Range, San Juan Province, Argentinian Precordillera. **A**. INGEO-PI-2155, level PNN-02S. **B**. INGEO-PI-2120, level PNN-02N. **C**. INGEO-PI-2085, level PNN-02N. **D**. INGEO-PI-2050, level PNN-02N. **E**. INGEO-PI-2112, level PNN-02N. **F**. INGEO-PI-2040, level PNN-02N. **G**. INGEO-PI-2161, level PNN-02S. **H**. INGEO-PI-2176, level PNN-02S. **I**. INGEO-PI-2210, level PNN-04S. Scale bars 1 mm.

tentaculitoids and ostracods, in some cases associated with spicules (PNN-06S), scolecodonts (PNN-02S) (Fig. 10A–G), favositid cnidarians (PNN-02S), trilobites (PNN-06'S and 08S), and conodonts in bedding planes (PNN-02S and 04S) (Fig. 10H, I). In the levels PNN-02S and 04S, a few carbonaceous wisps were collected. Lastly, a similar ichnofossil association were observed in both detailed columns.

Local, regional, and global correlation.—The list of lower Gorstian graptolites in the middle–upper Los Espejos Formation allows to establish a regional correlation with other studied section of Precordillera, as del Fuerte Hill, Loma de Los Piojos section, La Chilca Hill, Las Chacritas River, and Ancha and Salto Macho creeks for the Los Espejos Formation (Cuerda 1969; Antonioli 1975; Baldis et al. 1984; Peralta 1984b; Rickards et al. 1996; Maletz et al. 2002; Albanesi et al. 2006; Gómez et al. 2018; Lopez 2022), the Villicum Range and the La Rinconada sections for the Rinconada Formation (Peralta 1984a, 1986), the San Juan River section for the Tambolar Formation (Peralta and León 1993; Mestre 2009), and the Famatina Geological Province for the Villacorta Formation (Césari et al. 2020).

A regional correlation is proposed with graptolitic levels of the upper Lipeón Formation (Argentina) and with the middle–upper levels of the Kirusillas Formation (Bolivia) (Martínez et al. 1971; Brockmann et al. 1972; Suarez-Soruco 1975; Maletz et al. 2002; Edwards et al. 2009; Aris et al. 2011; Toro and Maletz 2018).

Finally, a global correlation could be proposed with contemporaneous sections from Albania (Maletz et al. 1998; Pashko 2020), Australia (Garrat 1978; Garrat and Rickards 1984; Rickards and Sandford 1998; Rickards 2000; Talent et al. 2003), Canada (Lenz 1984, 1990, 2011; Lenz and Kozłowska-Dawidziuk 2004), China (Chen 1984; Hou and Shu 1986; Lenz et al. 1996; Rong et al. 2003), Czech Republic (Kozłowska-Dawidziuk et al. 2001; Manda et al. 2012; Štorch et al. 2015), England (Berry 1964; Rickards 1967; Cocks et al. 2003), Kyrghistan (Koren' and Sujarkova 2004), Lithuania and Latvia (Radzevičius and Paškevičius 2005), Poland (Urbanek 1958, 1960, 1966; Podhalańska 2019), Sweden (Nilsson 2002; Baarli et al. 2003), Romania (Rickards and Iordan 1975), Russia (Koren' 1973; Koren' and Sujarkova 2004; Baarli et al. 2003), USA (Berry and Satterfield 1972; Saltzman 2001; Cramer et al. 2006), and Wales (Watkins and Berry 1977).

Discussion

Biostratigraphic considerations.—Although biostratigraphic data have been obtained from other fossil groups, such as brachiopods, conodonts and palynomorphs (see Biostratigraphy of the Los Espejos Formation section), and a Gorstian age was estimated for host rocks, the described graptolite taxa could not provide a reliable age information. This issue is caused by the endemic nature of the species previously described, so far only known from South America, and by the absence of index graptolites of the Ludlow. Generally speaking, the two genera, *Saetograptus* and *Uncinatograptus*, appear in the fossil record in the lower Gorstian *Neodiversograptus nilssoni* Biozone, and disappear in the upper Ludfordian *S. leintwardiniensis* Biozone and in the Lower Devonian *U. yukonensis* Biozone, respectively (Bates et al. 2023). By comparison with other taxa worldwide, the species found in the Los Espejos Formations are consistent with a supposed Gorstian age (Cuerda 1969; Maletz et al. 2002), with the FAD of *U. u. notouncinatus* in levels slightly below those with the FAD of *S. a. argentinus* (Cuerda 1969; Benedetto et al. 1992; Rickards et al. 1996; this study).

This contribution introduces three new graptolites, generally cosmopolitan taxa, first time recorded and described in Argentina and South America. *Bohemograptus bohemicus* is a typical representative of the lower Gorstian (Go1) *N. nilssoni* and *Lobograptus progenitor* biozones, or the base of the lower Ludfordian (Lu1) *Saetograptus leintwardinensis* Biozone (Fig. 11), then replaced by *B. tenuis* (Urbanek 1970; Rickards and Wright 1999; Kozłowska-Dawidziuk et al. 2001; Nilsson 2002; Koren' and Sujarkova 2004; Lenz and Kozłowska-Dawidziuk 2004; Rickards 2012; Štorch et al. 2014; Pashko 2020).

Later, specimens of the genus *Lobograptus* have been found from the middle Homerian (Ho2) *Colonograptus praedeubeli* Zone to the lower Ludfordian (Lu1) *S. leintwardinensis* Biozone. On the other hand, the thecal morphology of the studied fragment resembles to *L. progenitor* or slightly younger species (from the *L. progenitor* or *L. scanicus* biozones), based on what a Gorstian age sensu lato can be estimated (Fig. 11) (Bates et al. 2023; and references therein).

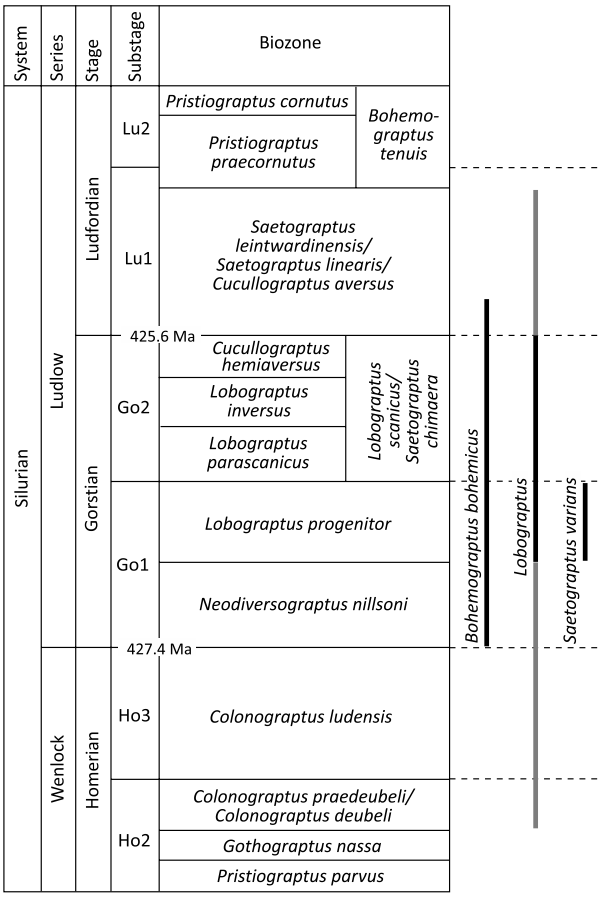


Fig. 11. Chronostratigraphic and graptolite biostratigraphic charts for the Homerian–Ludfordian (Wenlock–Ludlow) interval. The *Bohemograptus bohemicus* (Barrande, 1850), genus *Lobograptus*, and *Saetograptus varians* (Bouček, 1936) biochrons are shown. *Lobograptus* biochron is represented by the complete segment, whereas the black slice depicts the stimated age for the Precordillera's material. Chrono and biostratigraphic data from Loydell (2012) and Melchin et al. (2020).

Lastly, *Saetograptus varians* have been found as a scarce integrant only of the early Gorstian *L. progenitor* Zone in sections of Canada and Czech Republic (Fig. 11) (Lenz 1988, 1990; Lenz and Kozłowska-Dawidziuk 2004; Štorch et al. 2015).

In accordance with the aforementioned points, the FAD of *U. u. notouncinatus* in the levels PNN-00N and 02S might correspond to the lower Gorstian (Go1) *N. nilssoni* Zone, supported by the presence of *B. bohemicus* in immediately overlying levels (PNN-02N). On the other hand, the FAD of *S. a. argentinus* in the levels PNN-04N and 04S might suggest assignment to the lower Gorstian (Go1) *L. progenitor* Zone, in accordance with the presence of *S.* cf. *S. varians* and *Lobograptus* sp. The latter stratigraphic assignment is complacent with *S. argentinus* reported from

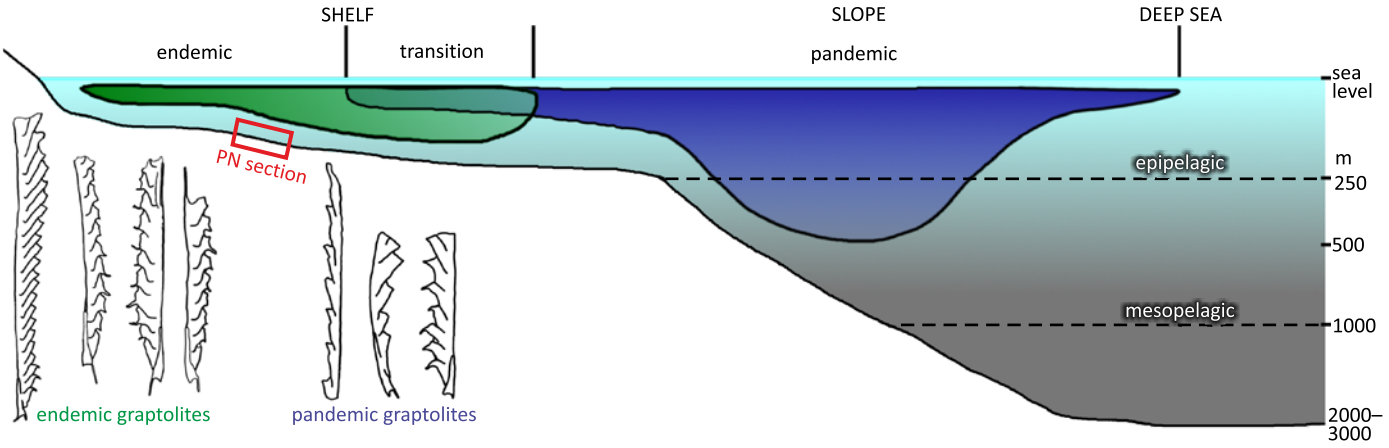


Fig. 12. Depth distribution of graptolites in a standard passive margin. The red square indicates the possible bathymetric position of the Poblete Norte section according to its graptolite faunas. The endemic graptolite group is formed by *Saetograptus argentinus argentinus* (Cuerda, 1969), *Uncinatograptus lisandroi* sp. nov., *Uncinatograptus elsae* sp. nov., and *Uncinatograptus uncinatus notouncinatus* (Cuerda, 1969); and the pandemic graptolite group is contains to *Lobograptus* sp., *Bohemograptus bohemicus* (Barrande, 1850), and *Saetograptus* cf. *S. varians* (Bouček, 1936). Graptolite illustrations not to scale. Modified from Goldman et al. (2013) and Maletz and Bates (2017).

the *K. v. variabilis* Interval Biozone by Albanesi et al. (2006). Finally, samples PNN-05N, 08'S, and 08S with *S. a. argentinus* and *B. bohemicus*, could correspond to the upper Gorstian or lower Ludfordian due to the ranges of the mentioned species, associated with brachiopods of the Ludlovian genus *Clarkeia* (Benedetto et al. 1992, 1996). These biostratigraphic considerations are the first proposed for the Ludlovian graptolite faunas of the Precordillera unit of Argentina.

On the other hand, the new species of *Uncinatograptus* described herein (i.e., *U. elsae* sp. nov. and *U. lisandroi* sp. nov.) were found in the lower to middle detailed sections, for which a Gorstian age sensu lato is assigned.

Paleoenvironmental and paleoecological remarks.— Graptolite fauna distribution has shown significant variations depending on the paleolatitude and the depth of the water column. The graptolite presence and taxonomic abundance is directly related with the water temperature and the basin location of the deposits (Boucot and Chen 2009; Goldman et al. 2013; Bates et al. 2023; and references therein), i.e., the shallower and colder the water, the poorer the taxonomic assemblage. According to the latter, Goldman et al. (2013: fig. 26.1, and references therein) subdivided a sedimentary basin into three vertical areas with regards on the graptolite fauna: endemic (shallow waters), pandemic (deeper waters) and transition zone; and two horizontal areas or biotopes: epipelagic (0–250 m deep) and mesopelagic (250–1000 m deep) (Fig. 12). Furthermore, Boucot and Chen (2009: fig. 9) delineated a water depth subdivision into four segments (1–4), and related them with the graptolite diversity.

At the local scale, the Los Espejos Formation has been associated to a transgressive-regressive marine cycle in a foreland basin, evolving from a muddy platform without wave influence, later to an inner platform with storm influence, and finally to a transitional platform dominated by storms (Astini and Piovano 1992; Astini and Maretto 1996). This basin evolution modelled a sedimentary succession characterized by heterolithic levels, which alternate shales, siltstones, sandstones, and abundant coquinas, and were deposited in progressively shallower waters with moderate to high energy (Astini and Maretto 1996). Moreover, the paleogeographic reconstruction proposed by Torsvik and Cocks (2013) and Scotese (2021) indicates that the Precordillera was located in middle to high latitudes for the Ludlow–Pridoli, ranging from 45° S to 60° S, suggesting the presence of cold waters within its basin.

The graptolite assemblage of the Los Espejos Formation, presented herein, includes endemic taxa as *Saetograptus argentinus argentinus*, *Uncinatograptus uncinatus notouncinatus*, *Uncinatograptus elsae* sp. nov., and *Uncinatograptus lisandroi* sp. nov. Furthermore, this study adds new pandemic specimens first time recorded in South America as *Bohemograptus bohemicus*, *Saetograptus* cf. *S. varians*, and *Lobograptus* sp., together with retiolitid lists and the previous possible *Pristiograptus dubius*-like tubarium recorded by Cuerda (1969). The first group is the most abundant in the graptolitic levels, reaching amounts of up to hundred specimens per sample. Conversely, representatives of the second group are extremely uncommon, with only one or a few specimens in all the sampled levels. This abundance contrast, in conjunction with the shallow water and moderate-high energy paleoenvironment of the Los Espejos Formation, and with a middle-high paleolatitude location of Precordillera during the Ludlow, would have generated a low-varied graptolite assemblage, high abundance of endemic and epipelagic graptolites, and sporadic representation of pandemic specimens in the basin. According to this, an in-shore position in the proposal of Goldman et al. (2013) or Depth 1 in Boucot and Chen (2009) can be estimated for the Los Espejos Formation levels studied in the Poblete Norte section, which is consistent with the paleoenvironmental features described for the unit (Fig. 12).

Conclusions

New graptolite faunas from the Los Espejos Formation, Poblete Norte section, Talacasto area of Central Precordillera, are presented herein, enabling more precise biostratigraphic knowledge on the Silurian of Argentina.

Two detailed section were studied and thirteen graptolitic levels were sampled. These strata presented classical examples of the Silurian succession of Precordillera, *Uncinatograptus uncinatus notouncinatus* and *Saetograptus argentinus argentinus*, associated with three worldwide taxa as *Bohemograptus bohemicus*, *Saetograptus* cf. *S. varians*, and *Lobograptus* sp., and two new species as *Uncinatograptus elsae* and *Uncinatograptus lisandroi*.

The occurrence of *U. u. notouncinatus* in association with *B. bohemicus* could indicate the presence of the lower Gorstian *Neodiversograptus nilssoni* Biozone in the lower graptolitic levels. Few meters above, the existence of *S. a. argentinus* with *S.* cf. *S. varians*, *U. u. notouncinatus*, and *Lobograptus* sp. might correspond to the lower Gorstian *Lobograptus progenitor* Biozone. The last graptolitic levels, which present specimens of *S. a. argentinus* and *B. bohemicus* could indicate upper Gorstian to lower Ludfordian ages. The new species of *Uncinatograptus* described herein, *U. elsae* and *U. lisandroi*, were found in the lower to middle detailed sections, for which a Gorstian age sensu lato is assigned. This proposal represents the first Ludlovian graptolite biostratigraphy in Precordillera, Argentina.

The discovery of these new graptolite taxa in the Los Espejos Formation enables a more precise local correlation with other sections from Precordillera and Famatina, as well as regional correlations with the Lipeón (Argentina) and Kirusillas (Bolivia) formations. Additionally, it contributes to global correlation efforts with several equivalent sections worldwide.

This study introduces new graptolite faunas from the Ludlow of Precordillera, first-time recorded in Argentina and South America, enriching insufficient knowledge on Ludlow graptolite fauna of this subcontinent in a critical time in the graptolite history.

Acknowledgements

The authors are grateful to Michael Melchin (Department of Earth Sciences, St. Francis Xavier University, Antigonish, Canada) and Petr Štorch (Institute of Geology of the Czech Academy of Sciences, Prague, Czech Republic) for their revisions and suggestions, which significantly enhance the original manuscript; to the Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) for its continuous support in the graptolite studies; and to the Instituto y Museo de Ciencias Naturales (IMCN) and Universidad Nacional de San Juan for their instrumental facility and workplace.

References

Albanesi, G.L., Banchig, A.L., Alonso, J.L., Fernández, L.P., and Cardón, R. 2017. Conodontes ludfordianos de la Formación Los Espejos, Precordillera Central de San Juan. *In*: L.M. Ibañez, P. Grosse, and M.A. Baéz (eds.), *20º Congreso Geológico Argentino, ST 6: Paleontología, Paleoecología y Bioestratigrafía*, 3. Asociación Geológica Argentina, San Miguel de Tucumán.

Albanesi, G.L., Ortega, G., and Hünicken, M.A. 2006. Bioestratigrafía de conodontes y graptolitos silúricos en la sierra de Talacasto, Precordillera de San Juan, Argentina. *Ameghiniana* 43: 93–112.

Amos, A.J. 1954. Estructura de las formaciones paleozoicas de La Rinconada, pie oriental de la sierra Chica de Zonda, San Juan. *Revista de la Asociación Geológica Argentina* 9: 5–38.

Ahlfeld, F. and Branisa, L. 1960. *Geología de Bolivia*. 245 pp. Don Bosco, La Paz.

Antonioli, J.A. 1975. Una nueva localidad con *Monograptus uncinatus notouncinatus* en la Precordillera de San Juan. *In*: C.A. Menéndez (ed.), *1º Congreso Argentino de Paleontología y Bioestratigrafía*, 209–218. Asociación Paleontológica Argentina, Tucumán.

Aris, M., Carrizo, H., Gallardo, E., Boso, M., Brandán, E., and Fernández, J. 2011. Primer registro de plantas silúricas en Argentina. Formación Lipeón, Área río Condado-río Los Toldos, Sierras Subandinas Occidentales (Provincia de Salta). *Acta Geológica* 23: 70–77.

Astini, R.A. and Maretto, H.M. 1996. Análisis estratigráfico del Silúrico de la Precordillera Central de San Juan y consideraciones sobre la evolución de la cuenca. *In*: V.A. Ramos, M.B. Aguirre-Urreta, C. Gulisano, E. Kozlowski, O. Limarino, V. Méndez, J.E. Mendía, M. Mozetic, A. Ortiz, C. Rapela, A. Riccardi, J.A. Robbiano, M.A. Turic, V.A. Vega, and M.R. Yrigoyen (eds.), *13º Congreso Geológico Argentino y 3º Congreso de Exploración de Hidrocarburos*, 351–368. Asociación Geológica Argentina, Buenos Aires.

Astini, R.A. and Piovano, E. 1992. Facies de plataforma terrígena del Silúrico de la Precordillera sanjuanina. *Revista de la Asociación Geológica Argentina* 47: 99–110.

Baarli, B.G., Johnson, M.E., and Antoshkina, A.I. 2003. Silurian stratigraphy and paleogeography of Baltica. *In*: E. Landing and M.E. Johnson (eds.), Silurian Lands and Seas: Paleogeography Outside of Laurentia. *New York State Museum Bulletin* 493: 3–34.

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

Baldis, B.A., Peralta, S.H., and Uliarte, E. 1984. Geología de la quebrada Ancha y sus alrededores en área de Talacasto, Precordillera sanjuanina. *In*: F.E. Nullo, C. Cingolani, M. Haller, J. Lage, O. Lapido, C.W. Rapela, L. Spalletti, and R. de Barrio (eds.), *9º Congreso Geológico Argentino*, 233–245. Asociación Geológica Argentina, San Carlos de Bariloche, Río Negro.

Barrande, J. 1850. *Graptolites de Bohême, VI*. 74 pp. Published by the autor, Prague.

Bates, D.E.B., Beli, E., Brussa, E.D., Cameron, C.B., Cooper, R.A., Gonzalez, P., Kozłowska, A., Lenz, A.C., Loydell, D.K., Maletz, J., Rigby, S., Riva, J.F., Steiner, M., Toro, B.A., VandenBerg A.H.M., Zalasiewicz, J.A., and Zhang, Y.D. 2023. *Treatise on Invertebrate Paleontology, Part V, Hemichordata, Second Revision, Including Enteropneusta, Pterobranchia (Graptolithina)*. 548 pp. Paleontological Institute, University of Kansas, USA.

Bateson, W. 1885. Note on the later stages in the development of *Balanoglossus kowalevskii* (Agassiz), and on the affinities of the Enteropneusta. *Proceedings of the Royal Society of London* 38: 23–30.

Benedetto, J.L., Racheboeuf, P.R., Herrera, Z., Brussa, E.D., and Toro, B.A. 1992. Brachiopodes et biostratigraphie de la formation de Los Espejos, Siluro-Dévonien de la Précordillère (NW Argentine). *Geobios* 25: 599–637.

Benedetto, J.L., Peralta, S.H., and Sánchez, T.M. 1996. Morfología y biometría de las especies de *Clarkeia* Kozlowski (Brachiopoda, Rhynchonellida) en el Silúrico de la Precordillera Argentina. *Ameghiniana* 33: 279–299.

Berry, W.B.N. 1964. Early Ludlow graptolites from the Presque Isle Quadrangle, Maine. *Journal of Paleontology* 38: 587–599.

Berry, W.B.N., and Satterfield, I.R. 1972. Late Silurian graptolites from

the Bainbridge Formation in southeastern Missouri. *Journal of Paleontology* 46: 492–498.

Bouček, B. 1936. Le faune graptolitique du Ludlowien inférieure de la Bohême. *Rozpravy II Třídy České akademie věd* 46: 137–152.

Boucot, A.J. and Chen, X. 2009. Fossil plankton depth zones. *Palaeoworld* 18: 213–234.

Bracaccini, O.I. 1950. Observaciones estratigráficas en la Precordillera Sanjuanina. *Revista de La Asociación Geológica Argentina* 5: 5–14.

Branisa, L. 1969. El sistema Silúrico en Bolivia: estratigrafía, faunas y límites. I. El límite entre el Silúrico y el Devónico. *Boletín de La Sociedad Geológica Boliviana* 12: 22–70.

Brockmann, C., Castanos, A., Suarez, R., and Tomasi, P. 1972. Estudio Geologico de la Cordillera oriental de Los Andes en la zona central de Bolivia (Region del Chapare). *Sociedad Geologica Boliviana, Boletin* 18: 3–36.

Bronn, H.G. 1849. *Index palaeontologicus: Abth. B. Enumerator palaeontologicus: systematische Zusammenstellung und geologische Entwicklungs-Gesetze der organische Reiche, Vol. 2*. 980 pp. E. Schweizerbart, Stuttgart.

Brussa, E. and Toro, B. 1989. Hallazgo del primer euryptérido silúrico de Argentina. *Ameghiniana* 26: 23–26.

Burmeister, H. 1843. *Die Organisation der Trilobiten, aus ihren lebenden Verwandtern entwickelt; nebst systematischen Uebersicht aller zeither beschriben Arten*. 148 pp. G. Reimer, Berlin.

Césari, S.N., Marenssi, S., Limarino, C.O., Ciccioli, P.L., Bello, F.C., Ferreira, L.C., and Scarlatta, L. R. 2020. The first upper Silurian land-derived palynological assemblage from South America: Depositional environment and stratigraphic significance. *Palaeogeography, Palaeoclimatology, Palaeoecology* 559: 109970.

Chen, X. 1984. The Silurian graptolite zonation of China. *Canadian Journal of Earth Sciences* 21: 241–257.

Cocks, L.R.M., McKerrow, W.S., and Verniers, J. 2003. The Silurian of Avalonia. *In*: E. Landing and M.E. Johnson (eds.), Silurian lands and seas: paleogeography outside of Laurentia. *New York State Museum Bulletin* 493: 35–53.

Cramer, B.D., Kleffner, M.A., and Saltzman, M.R. 2006. The Late Wenlock Mulde positive carbon isotope (δ^{13}_{Carbon}) excursion in North America. *GFF* 128: 85–90.

Cuerda, A.J. 1965. *Monograptus leintwardinensis* var. *incipiens* Wood en el Silúrico de la Precordillera. *Ameghiniana* 4: 171–177.

Cuerda, A.J. 1969. Sobre las graptofaunas del Silúrico de San Juan, Argentina. *Ameghiniana* 6: 223–235.

Cuerda, A.J. 1971. Monograpten des Under–Ludlow aus der Vorkordillere von San Juan, Argentinien. *Geologisches Jahrbuch* 85: 391–400.

Cuerda, A.J., Furque, G., and Uliarte, E. 1982. Graptolitos de la base del Silúrico de Talacasto, Precordillera de San Juan. *Ameghiniana* 19: 239–252.

Cuerda, A.J., Rickards, R.B., and Cingolani, C. 1988. A new Ordovician–Silurian boundary section in San Juan Province, Argentina, and its definitive graptolite fauna. *Journal of the Geological Society* 145: 749–757.

Edwards, D., Poiré, D.G., Morel, E.M., and Cingolani, C.A. 2009. Plant assemblages from SW Gondwana: further evidence for high-latitude vegetation in the Devonian of Argentina. *Geological Society, London, Special Publications* 325: 233–255.

Furque, G. 1983. *Descripción geológica de la Hoja 19c, Ciénaga de Gualilán*. 111 pp. Servicio Geológico Nacional, Buenos Aires.

García-Muro, V.J. and Rubinstein, C.V. 2015. New biostratigraphic proposal for the Lower Palaeozoic Tucunuco Group (San Juan Precordillera, Argentina) based on marine and terrestrial palynomorphs. *Ameghiniana* 52: 265–285.

Garrat, M.J. 1978. New evidence for a Silurian (Ludlow) age for the earliest *Baragwanathia* flora. *Alcheringa* 2: 217–224.

Garratt, M.J. and Rickards, R.B. 1984. Graptolite biostratigraphy of early land plants from Victoria, Australia. *Proceedings of the Yorkshire Geological Society* 44: 377–384.

Goldman, D., Maletz, J., Melchin, M.J., and Junxuan, F. 2013. Graptolite palaeobiogegraphy. *In*: D.A.T. Harper and T. Servais (eds.), Early Palaeozoic Biogeography and Palaeogeography. *The Geological Society of London, Memoirs* 38: 415–428.

Gómez, M.J., Mestre, A., Corradini, C., and Heredia, S. 2021. A new species, *Ozarkodina huenickeni*, from the upper Silurian–Lower Devonian in San Juan Precordillera, South America. *Journal of South American Earth Sciences* 108: 103174.

Gómez, M.J., Mestre, A., Garcías, Y., and Corradini, C. 2018. First documentation of the *Polygnathoides siluricus* conodont Zone (Ludfordian) in South America (Argentina) and the stratigraphic significance of the younger species of *Kockelella* (Conodonta). *Geological Journal* 54: 3455–3467.

Heim, A. 1952. Estudios tectónicos en la Precordillera de San Juan. Los ríos San Juan, Jáchal y Huaco. *Revista de La Asociación Geológica Argentina* 7: 11–70.

Hou, S. and Shu, D. 1986. The Silurian graptolite-bearing strata in China. *Geological Society, London, Special Publications* 20: 173–179.

Hutt, J. 1969. The development of the Ludlovian graptolite *Saetograptus varians*. *Lethaia* 2: 361–368.

Kerlleñevich, S.C. and Cuerda, A.J. 1986. *Monograptus priodon* (Bronn) (Graptolithina) en la Formación La Chilca, Precordillera de San Juan, Argentina. *Ameghiniana* 23: 119–126.

Kobayashi, T. 1937. The Cambro-Ordovician shelly faunas of South America. *Journal of Faculty of Science* 5: 369–522.

Koren', T.N. 1973. The Silurian and Lower Devonian graptolite-bearing strata in the USSR (a review). *Geological Magazine* 110: 1–96.

Koren', T.N. and Sujarkova, A.A. 2004. The Ludlow (late Silurian) neocucullograptid fauna from the southern Tien Shan, Kyrghizstan. *Alcheringa* 28: 333–387.

Kozłowska-Dawidziuk, A., Lenz, A.C., and Štorch, P. 2001. Upper Wenlock and Lower Ludlow (Silurian), post-extinction graptolites, Všeradice section, Barrandian area, Czech Republic. *Journal of Paleontology* 75: 147–164.

Lang, W.H. and Cookson, I.C. 1935. On a flora, including vascular land plants, associated with *Monograptus*, in rocks of Silurian age from Victoria, Australia. *Philosophical Transactions of the Royal Society of London B* 224: 421–449.

Lankester, E. 1877. Notes on the embryology and classification of the animal kingdom; com-prising a revision of speculations relative to the origin and significance of the germlayers. *Quarterly Journal of Microscopical Science* 17: 339–454.

Lapworth, C. 1873. Notes on the British graptolites and their allies. 1. On an improved classification of the Rhabdophora, Part 1. *Geological Magazine* 10: 500–504.

Lapworth, C. 1875. Description of the graptolites of the Arenig and Llandeilo rocks of St. Davids. *In*: J. Hopkinson and C. Lapworth (eds.), Descriptions of the Graptolites of the Arenig and Llandeilo Rocks of St. David's. *Quarterly Journal of the Geological Society* 31: 631–672.

Lenz, A.C. 1984. A new mid-Ludlow graptolite faunule from northern Yukon, Canada. *Canadian Journal of Earth Sciences* 21: 969–972.

Lenz, A.C. 1988. Upper Silurian and Lower Devonian graptolites and graptolite biostratigraphy, northern Yukon, Canada. *Canadian Journal of Earth Sciences* 25: 355–369.

Lenz, A.C. 1990. Ludlow and Pridoli (Upper Silurian) graptolite biostratigraphy of the central Arctic Islands: a preliminary report. *Canadian Journal of Earth Sciences* 27: 1074–1083.

Lenz, A.C. 2011. Some late Wenlock and Ludlow monograptid graptolites, Cornwallis Island, Arctic Canada. *Canadian Journal of Earth Sciences* 29: 200–207.

Lenz, A.C. and Kozłowska-Dawidziuk, A. 2004. *Ludlow and Pridoli (Upper Silurian) Graptolites from the Arctic Islands, Canada*. 141 pp. NRC Research Press, Ottawa.

Lenz, A.C., Chen, X., and Ni, Y. N. 1996. Wenlock, Ludlow, and Pridoli? graptolites from Yulin, Guangxi, China. *Canadian Journal of Earth Sciences* 33: 1390–1401.

Lenz, A.C., Cuerda, A., and Peralta, S.H. 2003. Graptolites from the Upper Llandovery of the Talacasto area, Central Precordillera, San Juan, Argentina. *Journal of Paleontology* 77: 1198–1202.

Leveratto, M.A. 1968. Geología de la zona al oeste de Ullun-Zonda, borde Oriental de la Precordillera de San Juan, eruptividad subvolcanica y estructura. *Revista de la Asociación Geológica Argentina* 23: 129–157.

Lopez, F.E. 2019. *Estratigrafía y bioestratigrafía del Paleozoico inferior y medio en la quebrada Poblete Norte, área de Talacasto, Precordillera Central, San Juan, Argentina*. 126 pp. Tesis de Licenciatura en Ciencias Geológicas (inédito). Universidad Nacional de San Juan, San Juan.

Lopez, F.E. 2022. *Saetograptus argentinus argentinus* y *S. a. robustus* (Graptolithina; Ludloviano) en la Formación Los Espejos, Precordillera Central de San Juan, Argentina. *Publicación Electrónica de la Asociación Paleontológica Argentina* 22: 25–32.

Lopez, F.E. and Kaufmann, C. 2023. New insights in the Silurian graptolite biostratigraphy of the La Chilca Formation, Poblete Norte section, Central Precordillera of San Juan, Argentina: faunal replacement and paleoenvironmental implications. *Andean Geology* 50: 201–216.

Lopez, F.E., Kaufmann, C., Drovandi, J.M., Conde, O.A., Braeckman, A.R., Arnol, J.A., Estrada, L., Pedernera, F., and Abarca, U. 2023. First record of Pridolian graptolites from South America: Biostratigraphic and paleogeographic remarks. *Gondwana Research* 119: 246–261.

Lopez, F.E., Kaufmann, C., Leon, L.I., Contreras, V.H., Conde, O.A., and Campos, M.G. 2020. Graptofaunas del Miembro Salto Macho, Formación La Chilca (Ordovícico Superior-Silúrico Inferior), en la quebrada Poblete Norte, Precordillera Central de San Juan, Argentina. *Serie Correlación Geológica* 36: 5–26.

Loydell, D.K. 2012. Graptolite biozone correlation charts. *Geological Magazine* 149: 124–132.

Maletz, J. 2014. The classification of the Pterobranchia (Cephalodiscida and Graptolithina). *Bulletin of Geosciences* 89: 477–540.

Maletz, J. 2017. The monograptids. *In*: J. Maletz (ed.), *Graptolite Paleobiology. First Edition*, 1–221. John Wiley and Sons Ltd., Hoboken.

Maletz, J. 2023. Graptolites—survival in the palaeozoic seas. *Historical Biology* [available online, https://doi.org/10.1080/08912963.2023.2231975]

Maletz, J. and Bates, D.E. 2017. Paleoecology of the Pterobranchia. *In*: J. Maletz (ed.), *Graptolite Paleobiology. First Edition*, 50–75. John Wiley & Sons Ltd., Hoboken.

Maletz, J., Königshof, P., Meço, S., and Schindler, E. 1998. Late Wenlock to Early Ludlow graptolites from Albania. *Palaeobiodiversity and Palaeoenvironments* 78: 141–151.

Maletz, J., Soruco, R.S., and Egenhoff, S.O. 2002. Silurian (Wenlock–Ludlow) graptolites from Bolivia. *Palaeontology* 45: 327–341.

Manda, Š., Štorch, P., Slavik, L., Frýda, J., Kříž, J., and Tasáryová, Z. 2012. The graptolite, conodont and sedimentary record through the late Ludlow Kozlowskii Event (Silurian) in the shale-dominated succession of Bohemia. *Geological Magazine* 149: 507–531.

Martinez, C., Suarez, R., and Subieta, T. 1971. La cadena hercinica en la parte septentrional de la cordillera oriental de los Andes bolivianos (perfil La Paz-Alto Beni). *Boletin del Servicio Geológico de Bolivia* 15: 26–35

Melchin. M.J., Sadler, P.M., and Cramer, B.D. 2012. The Silurian period. *In*: F.M. Grandstein, J.G. Ogg, M. Schmitz, and G. Ogg (eds.), *The Geological Time Scale*, 525–558. Elsevier, Oxford.

Melchin, M.J., Sadler, P.M., and Cramer, B.D. 2020. The Silurian Period. *In*: F.M. Gradstein, J.G. Ogg, M. Schmitz, and G. Ogg (eds.), *The Geologic Time Scale*, 695–732. Elsevier Press, Oxford.

Mestre, A. 2009. Primeros conodontes de la Formación Tambolar (Facies Pachaco), Silúrico de la Precordillera Argentina, y sus implicancias bioestratigráficas. *Ameghiniana* 46: 469–479.

Mestre, A., Gómez, M.J., Garcías, Y., Corradini, C., and Heredia, S. 2017. Advances on Silurian–Devonian conodont biostratigraphy in the central Precordillera, Argentina. *Cuadernos Del Museo Geominero* 22: 105–108.

Nilsson, A. 2002. Early Ludlow (Silurian) graptolites from Skåne, southern Sweden. *Examensarbete I Geologiska Vid Lunds Universitet* 165: 1–22.

Padula, E.L., Rolleri, E.O., Mingramm, A.R.G., Roque, P.C., Flores, M.A., and Baldis, B.A. 1967. Devonian of Argentina. *In*: D.H. Oswald (ed.), *Proceeding of the International Symposium on the Devonian System* 2: 165–199.

Palmer, D. 1971. The Ludlow graptolites *Neodiversograptus nilssoni* and *Cucullograptus* (*Lobograptus*) *progenitor*. *Lethaia* 4: 357–384.

Pashko, P. 2020. Upper Silurian (Gorstian, Ludfordian, Pridoli) graptolite biozonation in the Muhurr area (Albania). *Bulletin of the Geological Society of Greece* 56: 147–166.

Peralta, S.H. 1984a. Ludlowiano en la Precordillera Oriental sanjuanina. *In*: F.E. Nullo, C. Cingolani, M. Haller, J. Lage, O. Lapido, C.W. Rapela, L. Spalletti, and R. de Barrio (eds.), *9º Congreso Geológico Argentino*, 296–304. Asociación Geológica Argentina, San Carlos de Bariloche, Río Negro.

Peralta, S.H. 1984b. Nueva localidad con *Monograptus argentinus* Cuerda y *Monograptus uncinatus* var. *notouncinatus* Cuerda en la sierra de Talacasto. *In*: F.E. Nullo, C. Cingolani, M. Haller, J. Lage, O. Lapido, C.W. Rapela, L. Spalletti, and R. de Barrio (eds.), *9º Congreso Geológico Argentino*, 305–310. Asociación Geológica Argentina, San Carlos de Bariloche, Río Negro.

Peralta, S.H. 1985. El género *Retiolites* Barrande (Graptolithina) en el Silúrico de la Precordillera de San Juan. *In*: *Reunión Comunicaciones de la Asociación Paleontológica Argentina*, 80. Asociación Paleontológica Argentina, Buenos Aires.

Peralta, S.H. 1986. Graptolitos del Llandoveriano inferior en el Paleozoico inferior clástico en el pie oriental de la sierra de Villicum, Precordillera Oriental. *In*: V. Angelelli, H.H. Camacho, R. Caminos, C. Cingolani, G. Chebli, F. González Bonorino, E. González Díaz, E. Linares, N. Malumián, F. Nullo, M. Teruggi, and M.R. Yrigoyen (eds.), *1º Jornadas Sobre Geología de Precordillera*, 134–138. Asociación Geológica Argentina, San Juan.

Peralta, S.H. 1993. Estratigrafía y consideraciones paleoambientales de los depósitos marino-clásticos eopaleozoicos de la Precordillera Oriental de San Juan. *In*: R.B. Rodríguez, C. Risso, P.A. Chebli, and M.S. Vázquez (eds.), *12º Congreso Geológico Argentino y 2º Congreso de Exploración de Hidrocarburos*, 128–137. Asociación Geológica Argentina, Mendoza.

Peralta, S.H. and León, L. 1993. Estratigrafía, sedimentología y correlación de los depósitos silúricos de Pachaco, Precordillera Central sanjuanina. *In*: R.B. Rodríguez, C. Risso, P.A. Chebli, and M.S. Vázquez (eds.), *12º Congreso Geológico Argentino y 2º Congreso de Exploración de Hidrocarburos*, 142–147. Asociación Geológica Argentina, Mendoza.

Podhalańska, T. 2019. Graptolite Biostratigraphy and dating of the Ordovician–Silurian shale succession of the SW slope of the East European Craton. *Annales Societatis Geologorum Poloniae* 89: 429–452.

Přibyl, A. 1942. Revision der Pristiograpten aus den Unter-gattungen *Colonograptus* n. subg. und *Saetograptus* n. subg. *Mitteilungen der tschechischen Akademie der Wissenschaften* 52: 1–22.

Přibyl, A. 1967. Zur Gattung *Bohemograptus* gen. nov. (Graptoloidea) aus dem Böhmischen und fremden Ludlovium. *Časopis Narodniho Muzea* 3: 133–136.

Radzevičius, S. and Paškevičius, J. 2005. *Pristiograptus* (Graptoloidea) from the Upper Wenlock of the Baltic countries. *Stratigraphy and Geological Correlation* 13: 159–169.

Ramos, V.A., Vujovich, G.I., Cardó, R., Pérez, L., Pelichotti, R., Godeas, M.C., Pucci, J.C., Bercowski, F., Bordonaro, O., and Chernicoff, C.J. 2000. *Hoja Geologica 3169-IV San Juan*. 82 pp. Servicio Geológico Minero, Buenos Aires.

Rickards, R.B. 1967. The Wenlock and Ludlow succession in the Howgill Fells (north-west Yorkshire and Westmoreland). *Quarterly Journal of the Geological Society* 123: 215–249.

Rickards, R.B. 2000. The age of the earliest club mosses: the Silurian *Baragwanathia* flora in Victoria, Australia. *Geological Magazine* 137: 207–209.

Rickards, R.B. 2012. Rare and problematical bohemograptid graptoloids from the *leintwardinensis* Zone (basal Ludfordian, Silurian) of the northern Howgill Fells, Cumbria. *Proceedings of the Yorkshire Geological Society* 59: 21–24.

Rickards, R.B. and Iordan, M. 1975. Rumanian graptolites from boreholes on the Moesian Platform. *Geological Magazine* 112: 241–255.

Rickards, R.B. and Sandford, A.C. 1998. Llandovery-Ludlow graptolites from central Victoria: New correlation perspectives of the major formations. *Australian Journal of Earth Sciences* 45: 743–763.

Rickards, R.B. and Wright, A.J. 1999. Evolution of the Ludlow (Silurian) graptolite genus *Bohemograptus* Přibyl 1936. *Proceedings of the Yorkshire Geological Society* 52: 313–320.

Rickards, R.B., Brussa, E., Toro, B., and Ortega, G. 1996. Ordovician and Silurian graptolite assemblages from Cerro del Fuerte, San Juan Province, Argentina. *Geological Journal* 31: 101–122.

Rong, J.-Y., Chen, X., Su, Y.-Z., Ni, Y.-N., Zhian, R.-B., Chen, T.-E., Fu, L.-P., Li, R.-Y., and Fan, J.-X. 2003. Silurian paleogeography of China. *In*: E. Landing and M.E. Johnson (eds.), Silurian Lands and Seas: Paleogeography Outside of Laurentia. *New York State Museum Bulletin* 493: 243–298.

Rubinstein, C.V. and Toro, B.A. 2006. Aeronian (Llandovery, Lower Silurian) palynomorphs and graptolites from the Lipeón Formation, eastern Cordillera, north-west Argentina. *Geobios* 39: 103–111.

Sachanski, V., Gôncûoğlu, M.C., Lakova, I., Boncheva, I., and Saydam-Demiray G. 2012. Silurian graptolite, conodont and cryptospore Biostratigraphy of the Gülüç Section in Ereğli, Zonguldak Terrane, NW Anatolia, Turkey. *Turkish Journal of Earth Sciences* 21: 867–903.

Saltzman, M.R. 2001. Silurian $\delta^{13}C$ stratigraphy: a view from North America. *Geology* 29: 671–674.

Scotese, C.R. 2021. An atlas of Phanerozoic paleogeographic maps: The seas como in and the seas go out. *Annual Review of Earth and Planetary Sciences* 49: 679–728.

Štorch, P. 2023. Graptolite biostratigraphy and biodiversity dynamics in the Silurian System of the Prague Synform (Barrandian area, Czech Republic). *Bulletin of Geosciences* 98: 1–78.

Štorch, P., Manda, Š., and Loydell, D.K. 2014. The early Ludfordian *leintwardinensis* graptolite Event and the Gorstian–Ludfordian boundary in Bohemia (Silurian, Czech Republic). *Palaeontology* 57: 1003–1043.

Štorch, P., Manda, Š., Slavík, L., and Tasáryová, Z. 2015. Wenlock–Ludlow boundary interval revisited: new insights from the offshore facies of the Prague Synform, Czech Republic. *Canadian Journal of Earth Sciences* 53: 666–673.

Suarez-Soruco, R.S. 1975. Zonas graptolitiferas de Bolivia. *In*: C.A. Menéndez (ed.), *I Congreso Argentino de Paleontología y Biostratigrafía*, 133–148. Asociación Paleontológica Argentina, Tucumán.

Talent, J.A., Mawson, R., and Simpson, A. 2003. Silurian of Australia and New Guinea: biostratigraphic correlations and paleogeography. *In*: E. Landing and M.E. Johnson (eds.), Silurian Lands and Seas: Paleogeography Outside of Laurentia. *New York State Museum Bulletin* 493: 181–219.

Toro, B.A. 1995. Primer hallazgo de graptolitos del Silúrico (Llandoveriano) en la Cordillera Oriental, provincia de Jujuy, Argentina. *Ameghiniana* 32: 375–384.

Toro, B.A. and Maletz, J. 2018. Up-to-date overview of the Ordovician and Silurian graptolites from Bolivia. *In*: M. Suárez Riglos, A. Dalenz Farjat, and M.A. Perez Leyton (eds.), *Fósiles y Facies de Bolivia*, 59–81. Sincronía Diseño & Publicidad, Santa Cruz de la Sierra.

Torsvik, T.H. and Cocks, L.R.M. 2013. New global palaeogeographical reconstructions for the Early Palaeozoic and their generation. *In*: D.A.T. Harper and T. Servais (eds.), Early Palaeozoic Biogeography and Palaeogeography. *Geological Society of London*, *Memoirs* 38: 5–24.

Tortello, M.F., Uriz, N.J., Alfaro, M.B., Cingolani, C.A., Bidone, A.R., and Galeano Inchausti, J.C. 2012. Trilobites and graptolites from the Vargas Peña Formation (early Silurian), Paraná Basin, eastern Paraguay. *Revue de Paléobiologie* 11: 279–298.

Tsegelnyuk, P. 1976. Late Silurian and Early Devonian monograptids from the southwestern margin of the East European Platform [in Russian]. *In*: P.N. Shulga (ed.), *Paleontologia i stratigrafia verchnego dokembria i nizhnego paleozoja jugo-zapada vostocno-evropejskoj platformy*, 91–133. Naukova Dumka, Kiev.

Tullberg, L. 1883. Skanes graptoliter, 11. *Sveriges Geologiska Undersökning* 9: 1–14.

Urbanek, A. 1958. Monograptidae from erratic boulders of Poland. *Paleontologica Polonica* 9: 1–105.

Urbanek, A. 1966. On the morphology and evolution of the Cucullograptinae (Monograptidae, Graptolithina). *Acta Palaeontologica Polonica* 11: 291–544.

Urbanek, A. 1970. Neocucullograptinae n. subfam. (Graptolithina)—their evolutionary and stratigraphic bearing. *Acta Palaeontologica Polonica* 15: 1–338.

Uriz, N.J., Alfaro, M.B., and Inchausti, J.C.G. 2008. Silurian (Llandovery) monograptids from the Vargas Peña Formation (Paraná Basin, Eastern Paraguay). *Geologica Acta* 6: 181–190.

Vergel, M.M., Milana, J.P., and Araóz, L. 2009. Primer dato paleontológico (Palinológico) en la Formación Los Gauchos, Paleozoico Superior, Precordillera Central, Argentina. *In*: A.R. Prieto and M.V. Mancini (eds.), *XIV Simposio Argentino de Paleobotánica y Palinología*, 13–14. Asociación Paleontológica Argentina, Mar del Plata.

Watkins, R. and Berry, W.B.N. 1977. Ecology of a Late Silurian fauna of graptolites and associated organisms. *Lethaia* 10: 267–286.

Wilkinson, J. 2021. *Graptolites from the Ludlow Series (Silurian) of Wales and the Welsh Borderland*. 322 pp. Ph.D. Thesis (unpublished). University of Leicester, Leicester.

Wood, E.M.R. 1900. The Lower Ludlow formation and its grapolite-fauna. *Quaterlry Journal of the Geological Society of London* 56: 415–492.

Zalasiewicz, J.A., Taylor, L., Rushton, W.A., Loydell, D.K., Rickards, R.B., and Williams, M. 2009. Graptolites in British stratigraphy. *Geological Magazine* 146: 23–57.

Zhang, Y.-D. and Lenz, A.C. 1997. Uppermost Wenlock and Ludlow graptolites from southern Yunnan, China. *Canadian Journal of Earth Sciences* 34: 1220–1238.