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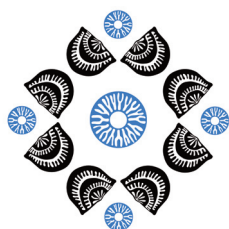
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Corresponding author:

Fernando E. Lopez
felopez@unsj-cuim.edu.ar

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New contributions to the Ordovician biostratigraphy of the Western Precordillera, Argentina

Fernando E. Lopez^{a,c}, Gladys Ortega^{b,c}, Guillermo L. Albanesi^b and Aldo L. Banchig^a

^a Departamento de Geología, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de San Juan, Ignacio de la Roza 590 (O), 5400, Rivadavia, San Juan, Argentina

^b Museo de Paleontología, CIGEA, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de Córdoba, Av. Vélez Sarsfield 299, 5000, Córdoba, Argentina

^c Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina

ABSTRACT

Upper Ordovician graptolites and conodonts are recorded from the Yerba Loca Formation in two sections, in the El Toro and Las Viudas creeks, from the El Tigre Range in the Western Precordillera of San Juan Province, Argentina. A collection of graptolites from the late Sandbian *Climacograptus bicornis* Zone and conodonts on bedding plane surfaces corresponding to the *Amorphognathus tvaerensis* Zone are presented. Graptolites apparently corresponding to the early Sandbian *Nemagraptus gracilis* Zone have also been recorded. The fossils determined allow for regional and global correlations, revealing sections suitable for future integrated studies on deep marine environments that are poorly known in the Argentine Precordillera.

Introduction

The Western Precordillera, located in the west of Argentina, has vast outcrops of siliciclastic, carbonate, and igneous rocks of Ordovician age, distributed throughout its ranges. Furthermore, the tectono-magmatic cycles that occurred in the western part of Gondwana have caused pervasive low-grade metamorphism, and the associated tectonic features make biostratigraphic studies complicated.

Several Ordovician formations have been described in the Western Precordillera with two lithological features: olistostromic mélanges, such as the Los Sombreros Formation, and turbiditic or hemipelagic deposits, such as the Alcaparrosa, Cabeceras, Cortaderas, Portezuelo del Tontal, and Yerba Loca formations.

The Yerba Loca Formation, studied herein, is composed of conglomerates, sandstones, black and gray shales, carbonates, and Ordovician intrusive-extrusive basic igneous rocks. Its main studied sections are located in the Yerba Loca, Negra, La Tranca, and El Tigre ranges (Fig. 1). The fossil content is bare, mostly composed of graptolites, conodonts, brachiopods, arthropods, and traces. Graptolites referable to the early Darriwilian *Levisograptus austrodentatus* or probably *L. dentatus* zones, and conodonts from the *Yangtzeplacognathus crassus* and *Eoplacognathus pseudoplanus* zones of middle Darriwilian age were found in the Yerba Loca Range (Albanesi et al. 2022). In the Negra Range, the early Sandbian *Nemagraptus gracilis* Zone was recorded (Blasco and Ramos 1976), and in the El Tigre Range, the late Sandbian *Climacograptus bicornis* Zone and early Katian graptolites were identified (Ortega et al. 1991; Caballé et al. 1993; Brussa 1995). Recently, Lopez et al. (2022) extended the range of the *C. bicornis* Zone to the El Toro Creek, El Tigre Range, mentioning an assemblage composed of the eponymous species, *Hallograptus* sp., *Dicellograptus* sp., and *Dicranograptus* sp. Accordingly, the biostratigraphic records constrain the age of the Yerba Loca Formation between the early Darriwilian and the late Sandbian–early Katian.

This study introduces one new Ordovician fossiliferous section for the Western Precordillera and expands the knowledge of a recently discovered section, i.e. Las Viudas and El Toro creeks, respectively, both located in the El Tigre Range in the Western Precordillera. Graptolites of the *Climacograptus bicornis* Zone

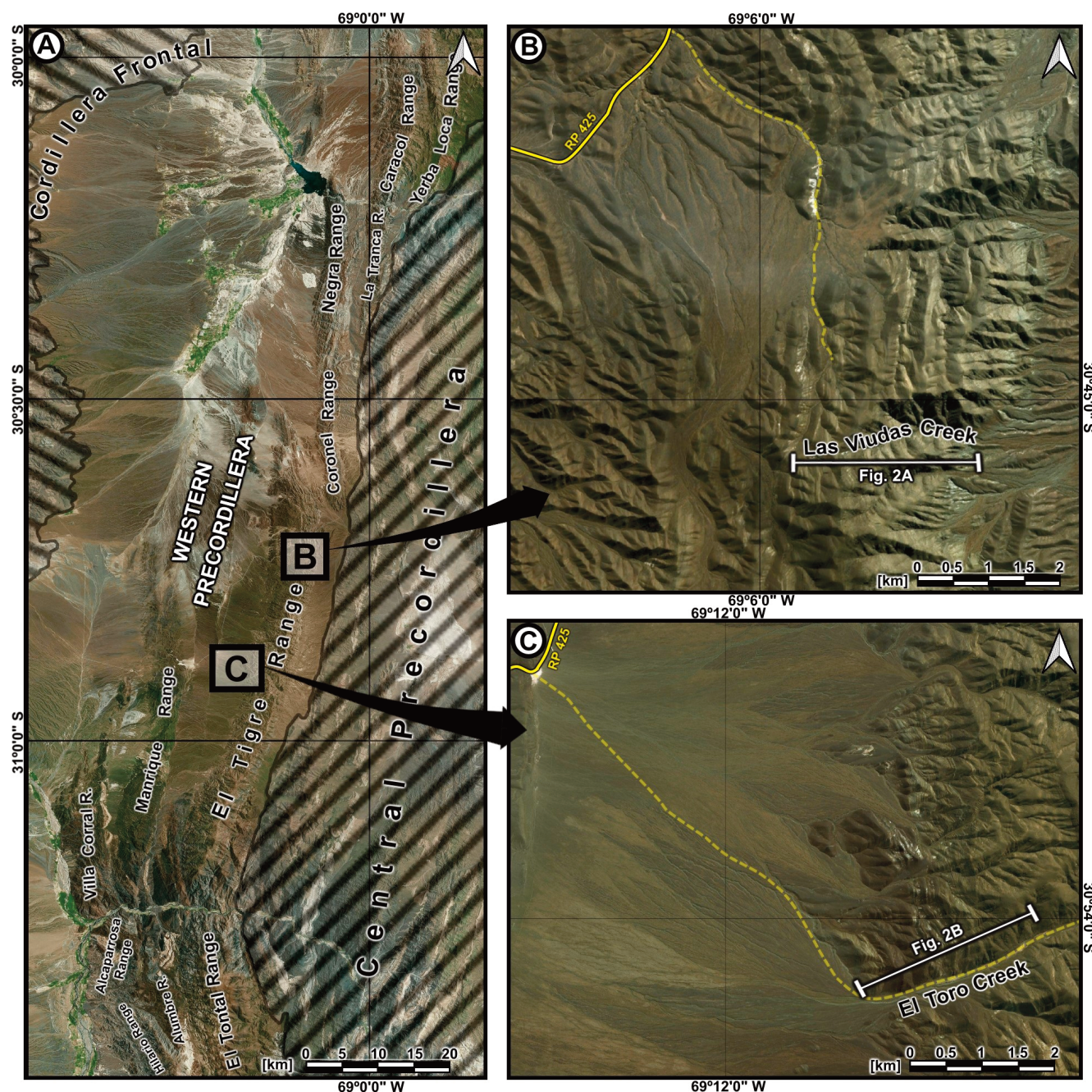


Fig. 1. **A** – location map showing the principal ranges of the Western Precordillera of San Juan; **B** – detailed map of the Las Viudas Creek section, northern area of the El Tigre Range; **C** – closer view of the El Toro Creek section, central part of the El Tigre Range.

and conodonts on bedding planes corresponding to the *Amorphognathus tvaerensis* Zone indicate a late Sandbian age. Furthermore, graptolites provisionally referred to as the *Nemagraptus gracilis* Zone (Lower Sandbian) are reported. These new sections show great potential to increase the paleontological and biostratigraphic knowledge of a critical time and place to untangle the complex geological history of the western margin of Gondwana.

Materials and methods

The graptolite samples were collected from the Las Viudas and El Toro creeks, from sandstones, gray and black shales, and present a poor to moderate preservation. Conodont elements and possible brachiopod specimens were recorded from bedding planes. All material is housed in the

Repositorio-INGEO Emiliano P. Aparicio, FCFN, Universidad Nacional de San Juan, under the acronym INGEO-PI-1988–2001.

Results and discussion

El Tigre Range sections. The first section, referred to as the Las Viudas Creek, is located on the eastern slope of the range, 30°45'21"S and 69°05'25"W, 4 km south of RP 425 (Fig. 1B). This outcrop is characterized by a west-dipping 969 m thick stratigraphic succession, with faulted base and top, composed mainly of thick beds of sandstones, gray shales, siltstones, and occasional conglomerates and calcarenite beds. Several basic Ordovician igneous bodies, sills and pillows were found across the section, which thermally affected the surrounding strata and fossil preservation. Only a few

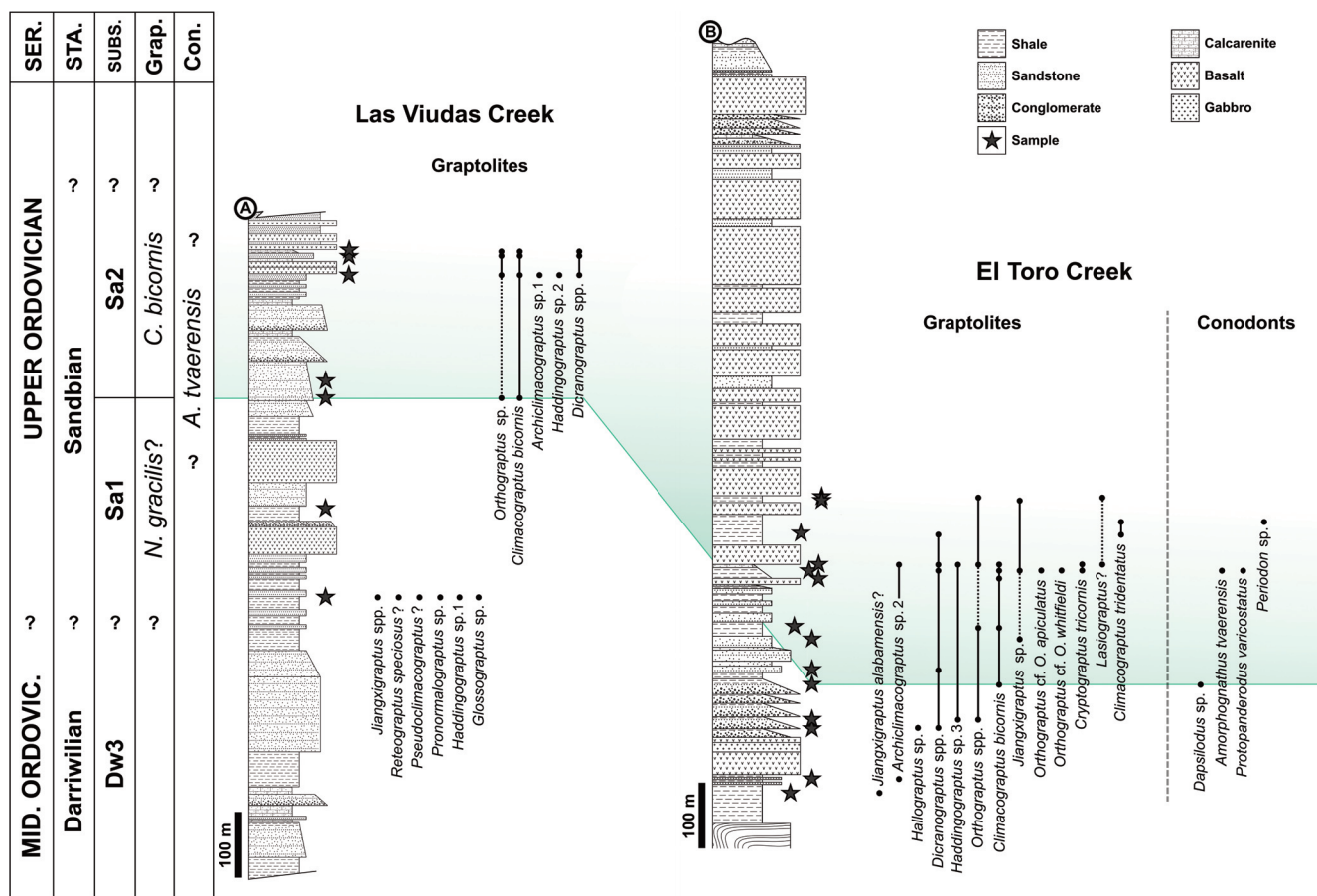


Fig. 2. Stratigraphic data of the Yerba Loca Formation in sections: A – Las Viudas Creek, northern column; B – El Toro Creek, southern column. Sample positions are indicated by the star symbol. Abbreviations: SER. – Series, STA. – Stage, SUBS. – Substage, Grap. – Graptolites, Con. – Conodonts, MID. ORDOVIC. – Middle Ordovician.

fossiliferous strata were found, including five graptolite-bearing levels (Fig. 2A).

418 m above the base of the section, the graptolite assemblage is preliminary composed of *Jiangxigraptus* spp., *Glossograptus* sp., *Haddingograptus* sp. 1, *Pronormalograptus* sp., *Pseudoclimacograptus?* sp. and *Reteograptus speciosus?*, suggesting an early Sandbian age, though a late Darriwilian age remains possible. At 729 m, the late Sandbian *Climacograptus bicornis* Zone starts with the record of the eponymous species, *Archiclimacograptus* sp. 1, *Dicranograptus* spp., *Haddingograptus* sp. 2 and *Orthograptus* sp. (Fig. 2A).

The El Toro Creek section is located in the western margin of the El Tigre Range, 30°54'15"S and 69°10'26"W, 6.5 km south-east of RP 425 (Fig. 1C). A west-dipping succession, 1266 m thick, with a folded base and covered top is described. More abundant graptolitic black shales were found interbedded between sandstones and igneous levels. The sampling provided 17 graptolite-containing layers from the base to the middle of the section (Fig. 2B).

Graptolites preliminary referred to as *Archiclimacograptus* sp. 2, *Dicranograptus* spp., *Haddingograptus* sp. 3, *Hallograptus* sp., *Jiangxigraptus alabamensis?* and *Orthograptus* spp. are recorded from the base up to the level at 212 m. This graptolite assemblage could be preliminarily referred to as the Lower Sandbian. The first occurrence of *Climacograptus bicornis* indicates the homonymous biozone

at 212 m from the base, containing *Archiclimacograptus* sp. 2, *Cryptograptus tricornis*, *Dicranograptus* spp., *Haddingograptus* sp. 3, *Jiangxigraptus* sp., *Lasiograptus?*, *Orthograptus* cf. *O. apiculatus*, *O. cf. O. whitfieldi* and *Orthograptus* spp. Tubaria of *Climacograptus tridentatus* are frequent in the upper part of this assemblage, above the range of *C. bicornis*. Additionally, conodont elements of the index species *Amorphognathus tvaerensis* preserved as casts on bedding plane surfaces are reported (Fig. 2B).

Age considerations and correlations. Preliminary studies of the two sections allow to propose a more accurate correlation with other Ordovician outcrops in the Western Precordillera. Considering the great thicknesses of both sections, the Darriwilian Stage could be represented in the barren lower part of the respective successions.

The *Nemagraptus gracilis* Zone is not recorded in the studied sections, although it was documented in the Negra Range section (Blasco and Ramos 1976) and possibly in the La Antena section, El Tontal Range (Peralta et al. 2003; Fig. 1). The graptolite assemblages collected below the strata with *C. bicornis* in the Las Viudas and El Toro sections could be assigned to the *N. gracilis* Zone, despite the fact that the nominal species is not present.

The *Climacograptus bicornis* Zone is recorded in both sections, together with the index conodont *Amorphognathus tvaerensis*, allowing the correlation of these outcrops with those in the northern area of the El Tigre Range; with the Los

Azules, Las Vacas and Sierra de La Invernada formations (Central Precordillera; Ortega and Brussa 1990; Ortega et al. 2007a; Ortega et al. 2008), the Empozada Formation (South Precordillera; Ortega et al. 2007b), the Pavón Formation (San Rafael Block; Cuerda and Cingolani 1998), and the Las Lagunitas Formation (Cordillera Frontal; Tikyj et al. 2009). Globally, a number of sections from Scandinavia, Great Britain, North America, Australasia, and China can be confidently correlated.

Conclusions

New biostratigraphic studies are presented after surveys carried out in the El Toro and Las Viudas creeks, from the El Tigre Range, Western Precordillera of San Juan Province, Argentina. Graptolites of the *Climacograptus bicornis* Zone and conodonts on bedding plane surfaces corresponding to the *Amorphognathus tvaerensis* Zone were collected, indicating a late Sandbian age for the bearer strata. Graptolites possibly referable to the early Sandbian *Nemagraptus gracilis* Zone have also been recorded. These two sections reveal important paleontological and biostratigraphic potential for the study of the Upper Ordovician in poorly known deep marine environments from the Western Precordillera of Argentina.

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