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Early Tremadocian graptolites from the Arivechi area, Sonora, northern Mexico

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ABSTRACT

Graptolites from the early Tremadocian *Anisograptus matanensis* Biozone are identified from east-central Sonora, northwestern Mexico, within a carbonate-shelf succession deposited on the southwestern continental shelf margin of Laurentia. This is the second occurrence of typical anisograptid graptolites in Mexico, after its original record in the Oaxaca area, which belongs to a Gondwana-related paleogeographical realm. The graptolites from Sonora represent the second global occurrence of any member of the *Rhabdinopora flabelliformis* group in the Ordovician equatorial shelf region.

Introduction

Early Ordovician graptolites from Mexico were first reported from the lower part of the Río Salinas (=upper) Member of the Tiñú Formation, in two sections of the Nochixtlán region, Oaxaca State, where some material was illustrated and partially described by Sour and Buitrón (1987) and Landing et al. (2007). The succession includes, from base to top, a lower (but not lowermost) Tremadocian (Tr1) graptolite assemblage, dominated by *Rhabdinopora* and with possible presence of *Anisograptus*, followed by middle Tremadocian (Tr2) benthic faunas and conodont assemblages of the *Paltodus deltifer* Biozone (Landing et al. 2007). In this paper we present the discovery of early Tremadocian graptolites in a region located further north, in east-central Sonora, within a very different paleogeographical context (see below). To date, the oldest known graptolites from this region were some specimens of *Adelograptus* spp. (early Tr2), mentioned by Poole et al. (1995a) but never described or illustrated, from two localities in the El Quemado Formation exposed in the northern part of the Barita de Sonora mine area.

Geological setting

Tremadocian (Lower Ordovician) rocks in Sonora occur as scattered outcrops at several localities northwest and east of Hermosillo. These are Sierra López, Sierra Martínez, Rancho Las Norias, Cerro El Santísimo, Sierra Agua Verde, and Barita de Sonora, and the strata have been correlated by conodonts and trilobites (Almazán-Vázquez 1989; Poole et al. 1995a, 1995b; Stewart et al. 1999). They are further mentioned in syntheses on the Paleozoic of Mexico (a.o., Buitrón-Sánchez 1992; Page et al. 2012; Cuen-Romero et al. 2023).

The studied area is located in the Sierra Madre Occidental, ca 220 km east of Hermosillo and WSW of the town of Arivechi (Fig. 1). The Lower Paleozoic succession is composed of seven Cambrian and Ordovician lithostratigraphic units, in

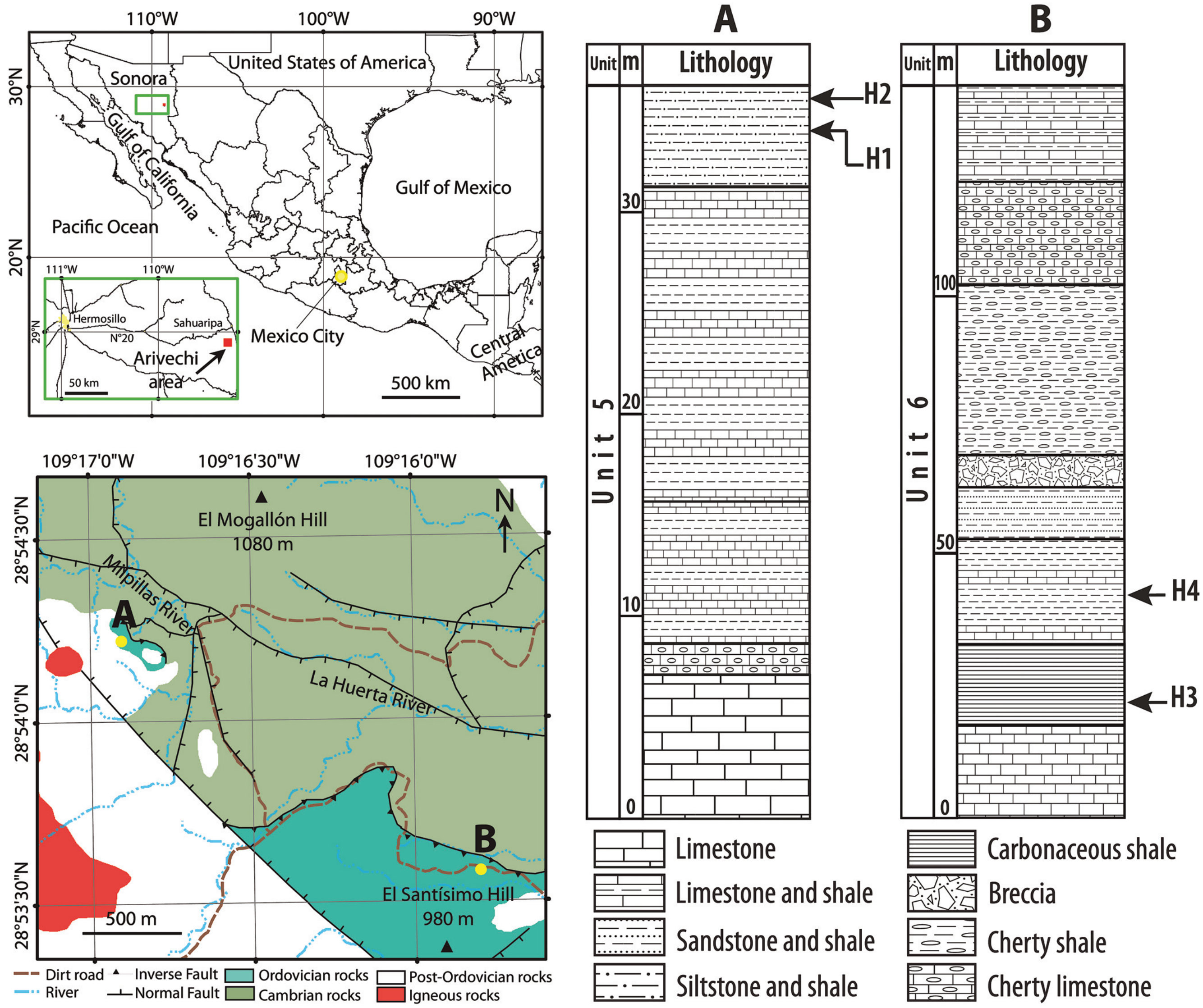

Fig. 1. Location map of the Arivechi area (above left) and geological sketch map (below) with the position of the two Early Ordovician graptolitic sections south of the Milpillas River (A) and northeast of El Santísimo Hill (B). To the right, simplified stratigraphic columns of units 5 (locality A) and 6 (locality B), showing the position of the four new graptolite horizons (H1–H4).

part informally described as formations by Almazán-Vázquez (1989). Our (unnamed) units 5 and 6 would be somewhat equivalent to a minor part of the El Santísimo Formation (Ordovician) of that author, who reported Tremadocian trilobites from the *Symphysurina* Zone in a section different from those studied here, but partly correlatable with our Unit 6 (its "member B"). Unpublished reports on Ordovician conodonts in the Arivechi area (Reyes-Montoya 2017; Becuar-Daniels 2019) come from different strata, mainly from our (here undescribed) Unit 7.

Unit 5 has been characterized on the southern slope of a hill located south of the Milpillas River (Fig. 1A on detailed map) and is a carbonate succession ca 36 m thick, dominated by thick-bedded limestone in the lower part, passing gradually to thin-bedded limestone with chert nodules, a thick alternation of medium-bedded limestone and shale, and ending with an alternation of red siltstone and shale (Fig. 1, column A). Two graptolite horizons have been located in these uppermost shales (Fig. 1, H1 and H2).

Unit 6 was characterized on the northern slope of El Santísimo Hill (Fig. 1B on detailed map) and consists of 140 m of medium- and thin-bedded limestone, alternating shale with limestone or sandstone, and also carbonaceous shale towards the lower part, some beds of sedimentary breccia towards the middle part, and shale with intercalations of bedded chert towards the upper part. Two additional graptolite horizons are in the lower third of this unit (Fig. 1, H3 and H4), whose stratigraphic relationships with Unit 5 cannot be established due to the lack of continuity between their respective outcrops. However, due to structural criteria, it is provisionally assumed that Unit 6 postdates the succession represented by Unit 5.

Paleontological results

The studied graptolite material is preserved largely as flattened tubaria, showing weathering impregnation with iron minerals in the two horizons located near the top of Unit 5 (Fig. 2A–F). Specimens from the two other horizons located in Unit 6 are also flattened but are apparently preserved as coalified organic material occurring in thin layers of black shale, as suggested by the silvery shine of their tubaria (Fig. 2G).

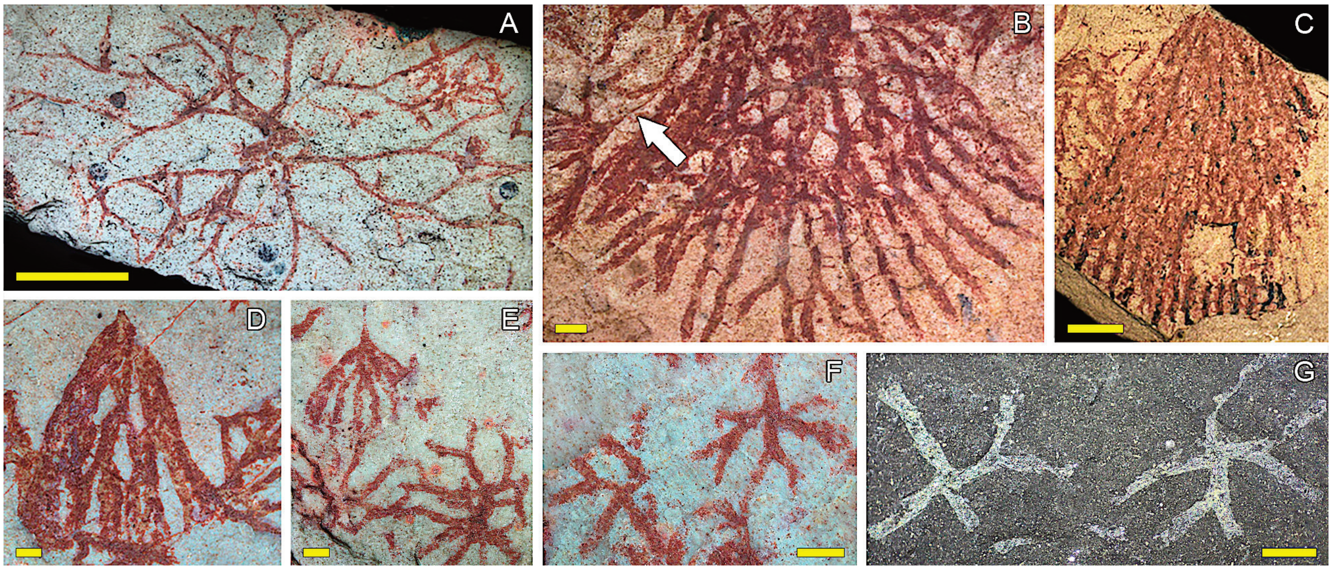

Fig. 2. Early Tremadocian graptolites from units 5 (A–F) and 6 (G): horizons H1 (B–D), H2 (A, E–F) and H3 (G). **A** – *Anisograptus matanensis* in dorsal view; **B–C** – *Rhabdinopora* cf. *canadensis* (arrow points to the nema of the left specimen); **D–F** – *Rhabdinopora* sp. (**D** – small distorted tubarium; **E–F** – small specimens in lateral and discoidal preservation, with apparent lack of dissepiments, the "pointed" sicula is visible); **G** – *Rhabdinopora*? sp., two early growth stages flattened horizontally, showing quadriradiate development. Original specimens are in the paleontological collection of the University of Sonora. Scale bars = 5 mm (A, C), and = 1 mm (B, D–G).

The graptolite assemblages recorded at horizons H1 and H2 of Unit 5 are dominated by small specimens of *Rhabdinopora* sp. They mostly consist of early growth stages in lateral and discoidal preservation, in the former case usually showing the "pointed" sicula and in the latter case the quadriradiate proximal development (Fig. 2E, F). Small distorted tubaria of conical appearance, with dissepiments obscured by torsion and flattening (Fig. 2D) are also common. Among the numerous specimens recovered, the record of *Rhabdinopora* cf. *canadensis* (Lapworth, 1898) has been established confidently based on the occurrence of specimens with a long undivided nema (Fig. 2B) and slender dissepiments irregularly arranged, with an average stipe width of ca 0.5 mm in dorsal view, and a stipe spacing of about 8–10 in 10 mm in mature parts of the mesh.

In addition to the genus *Rhabdinopora*, a triradiate anisograptid with a horizontal tubarium and 4–6 orders of stipes, with variable-spaced dichotomies and lacking dissepiments, was recorded in horizon H2. The most complete tubaria can be seen in dorsal view (Fig. 3A) and, despite the proximal ends not being entirely preserved, it can be identified as *Anisograptus matanensis* Ruedemann, 1937. Other possible *Anisograptus* remains were recorded in H1, represented by poor-quality early stages preserved in lateral view.

Graptolites from Unit 6 are less abundant and determinable than those from Unit 5. The assemblage from horizon H3 includes some small horizontal specimens showing quadriradiate proximal ends (Fig. 2G) as well as somewhat larger horizontal tubaria with a more advanced astogeny, which show diverging stipes without dissepiments. The features of the former are somewhat similar to those of the genus *Staurograptus*, although the short branching divisions allow them to be better identified as juvenile specimens of *Rhabdinopora*? sp. in discoidal preservation. Regarding the larger tubaria (not shown), despite the fact that their proximal end is not clearly visible in any specimen, its overall morphology allows a provisional identification as *Anisograptus*? sp. until a more complete and better-preserved material is available. Finally, horizon H4 has so far only provided fragments of indeterminable stipes.

Following the biochronological division of the lower Tremadocian on a global scale based on graptolite biozones (Cooper et al. 1998; Maletz 2021; and the recent review by Maletz et al. 2023), the co-occurrence of *A. matanensis* and *R.* cf. *canadensis* in horizon H2 indicates the lower part of the *A. matanensis* Biozone. If the record of *Anisograptus* in horizon H1 is confirmed by future sampling, the same biozone would begin a few meters below. Otherwise, the mere presence of *R.* cf. *canadensis* in H1 could also be indicative of the preceding *R. campanulatum* Biozone. Regarding horizon H3, the record of *Rhabdinopora*? sp. and *Anisograptus*? sp. could occur in both the *A. matanensis* and the *R. anglica* biozones, representing in the latter case the youngest graptolites of the local early Tremadocian sequence.

Concluding remarks

The occurrence of planktic graptolites from the *Anisograptus matanensis* Biozone in east-central Sonora slightly precedes the appearance of the first conodonts from the upper part of the lower Tremadocian *Rossodus manitouensis* Biozone in the Arivechi region, which are succeeded by middle and upper Tremadocian records ranging from *Scolopodus subrex* to *Paroistodus proteus* biozones (Reyes-Montoya 2017; Becuar-Daniels, 2019).

The graptolite assemblage described herein includes two species of *Rhabdinopora* and *Anisograptus* of worldwide distribution, the first of them is representative of a species of the *R. flabelliformis* group, which is recorded in a fully paleoequatorial area, such as the specimens found in the Bliss

Sandstone of New Mexico (Flower in Taylor and Repetski 1995, 136). Both occurrences of *Rhabdinopora* are unique in the Early Ordovician world if they are projected on the paleogeographical maps of Laurentia (Poole et al. 1995b; Cocks and Torsvik 2011, a.o.). At the same time, the characterization of the *A. matanensis* Biozone (but without *Rhabdinopora*) matches the earliest record of graptolites ("*Anisograptus* Zone") in classical sections of the Great American Carbonate Bank of Laurentia, such as the base of the Marathon Limestone of Texas and the Goodwin Formation of central Nevada (Erdtmann and Comeau 1980 with earlier references).

The Tremadocian graptolites from Sonora are perhaps coeval with the assemblages found in deeper-water environments in the Tiñú Formation of southern Mexico (see references above). However, the material needs a detailed taxonomic review (it seems to include more than one genus and a single species of *Rhabdinopora*). Paleogeographically, it comes from a terrane (Oaxaquia) that, although accreted to North America, was originally either an insular area in temperate latitudes or was situated in a Gondwanan or peri-Gondwanan position in pre-Silurian times (Landing et al. 2007; Cuen-Romero et al. 2023).

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