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Tremadocian Graptolite-Conodont Biostratigraphy of the South American Gondwana margin (Eastern Cordillera, NW Argentina)

G. ORTEGA and G.L. ALBANESI

CONICET- Museo de Paleontología, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de Córdoba
Av. Vélez Sarsfield 299, Casilla de Correo 1598, 5000 Córdoba, Argentina
Ortega E-mail: gcortega@arnet.com.ar Albanesi E-mail: galbanes@com.uncor.edu

ABSTRACT

The Tremadocian graptolite and conodont faunas of the Gondwana Margin recorded at the Eastern Cordillera (EC) of Salta and Jujuy provinces (northwestern Argentina) are studied. The previous data and the new provided information indicate that a "no nominated interval" and several graptolite zones (*Anisograptus matanensis, Rhabdinopora flabelliformis anglica, Bryograptus, Kiaerograptus, Kiaerograptus supremus, Araneograptus murrayi*, and *Hunnegraptus copiosus* zones), as well as several conodont zones (*Iapetognathus*, *Cordylodus angulatus*, *Paltodus deltifer*, and *Acodus deltatus - Paroistodus proteus* zones) occur in the Ordovician successions studied. New or reappraised data from sections such as Angosto del Moreno, Angosto de Lampazar, Parcha-Incamayo-Incahuasi area, and Cajas range (EC western margin), and Alfarcito area and Mojotoro range (EC eastern margin), provide new information on the composition of the fossil faunas. A composite graptolite-conodont biostratigraphic framework, including records of key trilobites as external control group, is proposed for the Tremadocian of the South American margin of Gondwana. Both fossil groups are generally recorded from outer platform to ocean basin environments, showing significant similarities with the Baltoscandian faunas. Nevertheless, particular shallow-water facies include either specific forms or species associations that are common to the epeiric shallow-water seas of Laurentia. This fact demonstrates an important interplay between faunas of different regions of the Iapetus Ocean during the Tremadocian.

KEYWORDS | **Graptolites. Conodonts. Biostratigraphy. Tremadocian. Eastern Cordillera. Argentina.**

INTRODUCTION

Fossiliferous sedimentary sequences of Tremadocian age are widespread in the Eastern Cordillera (EC; "Cordillera Oriental" by original designation) of northwestern Argentina. Several localities from Salta and Jujuy provinces (such as the classical Santa Victoria, Humahuaca, Alfarcito, Purmamarca, Mojotoro, San Bernardo, Parcha, El Moreno, Cajas and El Aguilar; Fig. 1) include important sections, which were deposited in diverse Tremadocian sedimentary settings (Harrington and Leanza, 1957; Turner, 1960a; Aceñolaza et al., 1999; Moya, 1999; Astini, 2003; Brussa et al., 2003). An estimated thickness of several thousand meters for the whole Ordovician basin succession, most of it corresponding to the Tremadocian Stage, has been suggested. Nevertheless,

the real thickness has not been determined due to the intense tectonic deformation affecting these sequences (Mon et al., 1993). There are no complete, uninterrupted Tremadocian successions in this region. In fact, the basin depositional record includes a complex mosaic of siliciclastic facies that correspond to diverse settings. By reconstructing the basin infill architecture and establishing the sequence stratigraphy, Buatois and Mángano (2003) and Mángano and Buatois (2004) have suggested that Tremadocian sequences comprise an array of fluvial and tide-dominated estuarine environments evolving to open-marine settings affected by waves. The studied Tremadocian sequences are overlain by the Acoite Formation (Turner, 1960a) and either by equivalent Arenig units or by younger deposits, where the *Tetragraptus phyllograptoides* is recorded. Current understanding suggests that the contact between Tremadocian and Arenig successions is an unconformity or a tectonized boundary.

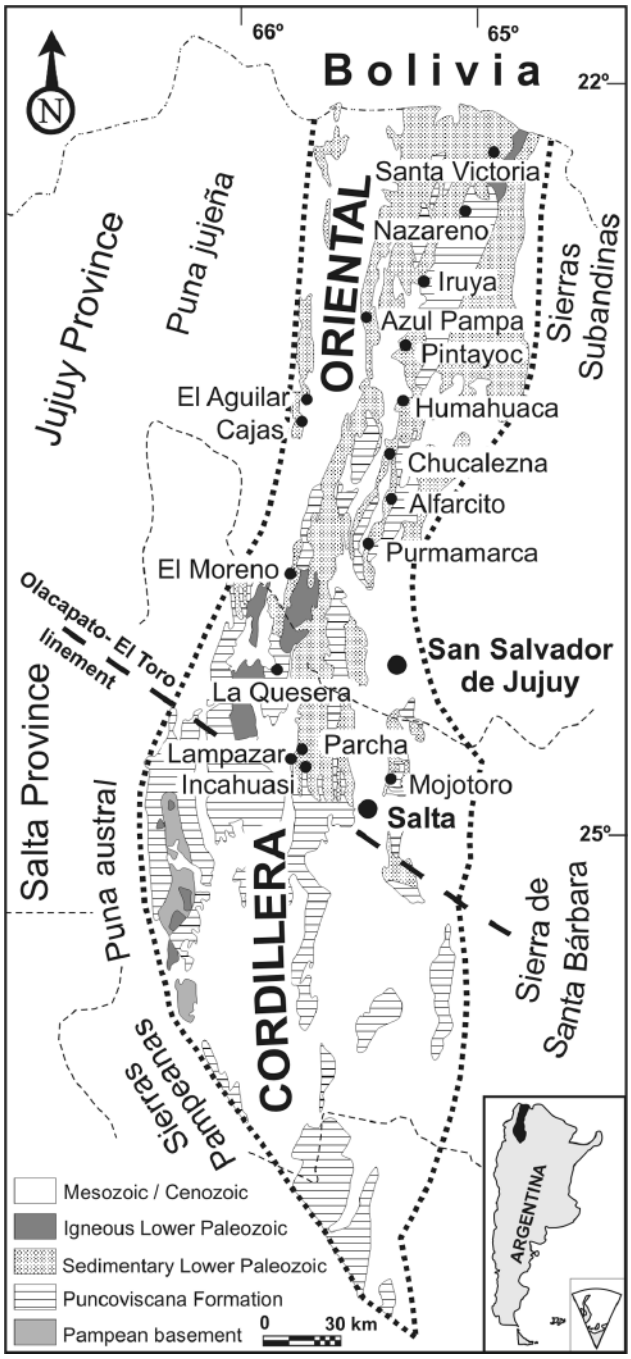


FIGURE 1| **Location and geological sketch of the Argentine Eastern Cordillera ("Cordillera Oriental" by original designation). The location of the Tremadocian fossiliferous localities discussed in the text is shown.**

Trilobites are among the most frequently studied fossils from Tremadocian rocks of northwestern Argentine basins. The Trilobite biostratigraphy of this stage (Harrington and Leanza, 1957) comprises the following biozones: *Parabolina* (*Neoparabolina*) *frequens argentina*, *Kainella meridionalis*, *Bienvillia tetragonalis - Conophrys minutula*, and *Notopeltis orthometopa* zones. These trilobite faunas have been thoroughly revised by Waisfeld and Vaccari (2003). In spite of the existence of some levels where preservation of graptolites has been enhanced, these fossils are not abundant through diverse facies. Nevertheless, after the comprehensive pioneer work of Turner (1960b), a fairly complete biostratigraphy has been developed as a reference for regional and intercontinental correlation. The conodont biostratigraphy of the Eastern Cordillera shows a parallel degree of development, from the first documentation of Ordovician conodonts from outcrops near La Ciénaga, Jujuy Province. (Youngquist and Iglesias, 1951; see a recent review by Albanesi and Ortega, 2002). A combined conodont-graptolite biostratigraphy, with biozones linked by biohorizons that correspond to critical bioevents and take into account the record of key trilobites species as an external control, provides the most reliable biostratigraphic framework for global correlation of the Tremadocian Stage and its internal subdivisions.

STRATIGRAPHIC SETTING: TREMADOCIAN FOSSIL LOCALITIES

Diverse areas with Tremadocian sections include highly fossiliferous rocks. In particular, the localities described below present important sections that yielded significant conodont and graptolite assemblages (Figs. 1 and 2). A biostratigraphical scheme for the Tremadocian Stage of NW Argentina is developed on the base of the well-documented species range records from these localities and their regional and intercontinental correlation (Figs. 2 and 3).

Santa Victoria Range

The Santa Rosita Formation (Turner, 1960a) represents the lower Upper Cambrian - Tremadocian succes-

sion of the Santa Victoria Group that crops out in this classical study area (a succession equivalent to the Angosto and Santa Cruz formations of Harrington and Leanza, 1957). The lower part of this unit consists of a thick basal conglomerate, which is overlain by a thick package (ca. 2300 m in thickness as originally estimated by Nesossi, in Turner, 1960a, 1960b, 1964) of major sandstones and black shales. This unit yielded abundant trilobites of the *P. (N.) frequens argentina, Kainella meridionalis* and *Notopeltis orthometopa* zones (Harrington and Leanza, 1957) and rhabdosomes of *Rhabdinopora* (Turner, 1960a, 1960b, 1964). *Araneograptus murrayi (= Dictyonema yaconense)* remains described by Turner (1960b) in the Santa Victoria river section and Trigo Huayco were referred to as Arenig in age, but a revision of the species ranges suggests a late Tremadocian age for these strata.

Nazareno

Manca et al. (1995) reported at this locality a conodont association derived from the Santa Rosita Formation. The authors assigned the fauna to the *Paltodus deltifer* Zone. Notwithstanding that they cite *Acodus deltatus deltatus* (LINDSTRÖM) as integrating the association. Following the intercontinental correlation of the upper Tremadocian (Löfgren, 1993; Ross et al., 1997) these strata most probably correspond to the *Acodus deltatus - Paroistodus proteus* Zone.

Iruya

Remains of *Rhabdinopora* spp. were identified by Turner (1960a) from samples collected from the Santa Rosita Formation at Colorada Creek.

Pintayoc

A heterolithic succession of sandstones and graptolitic shales with *R. f. flabelliformis* EICHWALD crops out at La Casa stream, northwest of the Hornaditas locality, Quebrada de Humahuaca. It was referred to the Santa Rosita Formation by Aceñolaza (1996). This unit conformably overlies the Chalhualmayoc Formation (Upper Cambrian) and lies in tectonic contact with the Salta Group (Cretaceous-Tertiary).

Aguilar Range

Alonso et al. (1982) and Martín et al. (1986, 1987) described the Ordovician stratigraphic succession of the Aguilar range, reporting the presence of the Despensa, Padrioc (including Lampazar), Cardonal, and Acoite formations. The Ordovician sequence with SEDEX type deposits is intruded by the Cretaceous Aguilar and Abralaite granites (Sureda and Martín, 1990). Martín et al. (1986, 1987) recorded *R. flabelliformis* from the upper part of the Padrioc Formation (Lampazar Formation) together with *P.* (*N.*) *f. argentina* (KAYSER), an association indicating an early Tremadocian age. Lately, Rao and Flores (1998) recovered conodonts from the *Paltodus deltifer* Zone (upper Tremadocian) from metamorphosed calcareous strata of the Cardonal Formation.

Cajas Range

The Padrioc, Lampazar, Cardonal and Acoite formations compose the Cambrian-Ordovician succession of the Cajas range (Aceñolaza, 1968). In accordance with recent regional investigations, the Tremadocian succession apparently does not correspond to the nominated units originally proposed by Aceñolaza (1968). The *P.* (*N.*) *f. argentina* and *K. meridionalis* zones were recorded in this study area, in the Lampazar (Upper Cambrian) and Cardonal (lower Tremadocian) formations, respectively (Aceñolaza, 1968; Tortello et al., 1999). The sequence includes abundant calcareous levels (coquinas and calcarenites) that yielded conodonts of the *Cordylodus caboti, C, intermedius, C. lindstromi*, and *C. angulatus* zones (Hünicken et al., 1985; Rao, 1999; Rao and Hünicken, 1995; Tortello et al., 1999). Conodonts are associated with graptolites herein referred to the "no nominated interval" (= Association 1 of Ortega and Rao, 1995), *Anisograptus matanensis* Zone, and probably the *Rhabdinopora f. anglica* Zone.

Chucalezna

The conodont fauna of the Rupasca Formation at Chucalezna section was recently studied by Albanesi and Aceñolaza (2005). Calcareous coquinas from the upper part of the sandy sequence exposed at the rail cut section yielded the species *Paltodus deltifer pristinus* (VIIRA), which represents the lower interval of the *Paltodus deltifer* Zone. The key species is associated to *Drepanodus arcuatus* PANDER, *Drepanoistodus chucaleznensis* ALBANESI and ACEÑOLAZA, *Paltodus* cf. *subaequalis* (PANDER), *Rossodus tenuis* MILLER, *Teridontus nakamurai* (Nogami), and *Utahconus humahuacensis* ALBANESI and ACEÑOLAZA.

Alfarcito

Important Upper Cambrian – Lower Ordovician sequences crop out in the Alfarcito area at Casa Colarada, Rupasca and San Gregorio localities, east of Tilcara (Harrington and Leanza, 1957; Zeballo et al., 2003, and Zeballo et al., 2005a, b). These sequences conformably overlie the Mesón Group (Late Cambrian) and are, in tectonic contact with the Salta Group (Cretaceous – Cenozoic). The sequence is one of alternating black and green shales and sandstones, that bear a rich trilobite fauna of the *P.* (*N.*) *f. argentina, K. meridionalis* and *Bienvillia*

tetragonalis-Conophrys minutula zones (Harrington and Leanza, 1957; Zeballo et al., 2003, and Zeballo et al., 2005). A few calcarenite levels and conquinas of the Alfarcito and Rupasca formations yielded conodonts of the *C. angulatus* and *Paltodus deltifer* zones (*P. d. pristinus* Subzone). Moreover, a sandy horizon with ripple marks, close to the top of the Alfarcito Formation bears abundant well-preserved specimens of *R. f. flabelliformis* (Zeballo et al., 2005). The Cambrian-Ordovician boundary may be located within the Alfarcito Formation, in coincidence with a transgression recorded in the middle part of this unit (Mángano and Buatois, 2004).

Purmamarca

The Tremadocian succession crops out at diverse localities (e.g., Salto Alto, Coquena, Chalala creeks) nearby Purmamarca town. The previously defined formations (Purmamarca Shale, Chañarcito Limestone, and Coquena Shale; Harrington and Leanza, 1957) are bounded by tectonic contacts. The fossil content consists mainly of trilobites and ichnofossils (Harrington and Leanza, 1957; Mángano et al., 1996). Conodonts and graptolites also occur (Rao et al., 1994; Rao and Hünicken, 1995) but they are not so widespread. The lower Tremadocian *Jujuyaspis keideli* Subzone (*P.* (*N.*) *f. argentina* Zone) as well as the *Notopeltis orthometopa* Zone (Harrington and Leanza, 1957; Tortello et al., 2002) of the upper Tremadocian are well represented in Purmamarca. A conodont assemblage lacking significative species was recorded in association with trilobites of the *N. orthometopa* Zone at Chalala creek suggesting a late Tremadocian age (Rao et al., 1994).

Mojotoro Range

The La Pedrera, San José, Caldera, Floresta, Áspero, and San Bernardo formations compose the Upper Cambrian – Tremadocian succession of the Mojotoro range (Harrington and Leanza, 1957; Moya, 1998). These units are located in diverse localities, i.e. San Bernardo, Floresta, Miraflores, cuesta de La Pedrera, Finca San José, La Caldera, and Mojotoro Village, among others. The La Pedrera and San José formations bear *J. keideli* (*P.* (*N.*) *f. argentina* Zone). The *K. meridionalis* fauna, localized in sandstones of the Caldera Formation and the Floresta Shale, includes the *N. orthometopa* fauna. The San Bernardo Formation contains a rich graptolite association of the late Tremadocian *Aorograptus victoriae* Zone (Monteros and Moya, 2002, 2003) and, in its upper part, graptolites of the early Arenig (e.g., Loss, 1951; Moya et al., 1994). The Potrero Castillo river section in Yacones records a fauna with *A. murrayi*, which was originally referred to as *Dictyonema yaconense* by Turner (1960b) and assigned to the earliest Arenig. However, this fauna corresponds probably to the late Tremadocian located in strata that are equivalent to the San Bernardo Formation.

Lampazar - Parcha – Incahuasi

Extensive outcrops in this area extend from Angosto de Lampazar to the eastern flank of the Incamayo creek, including the Abra de Sococha section, Parcha locality, La Predera and Barranca creeks, and Incahuasi sections. The Tremadocian sequences include mostly green and black shales and sandstone packages that belong to seve-

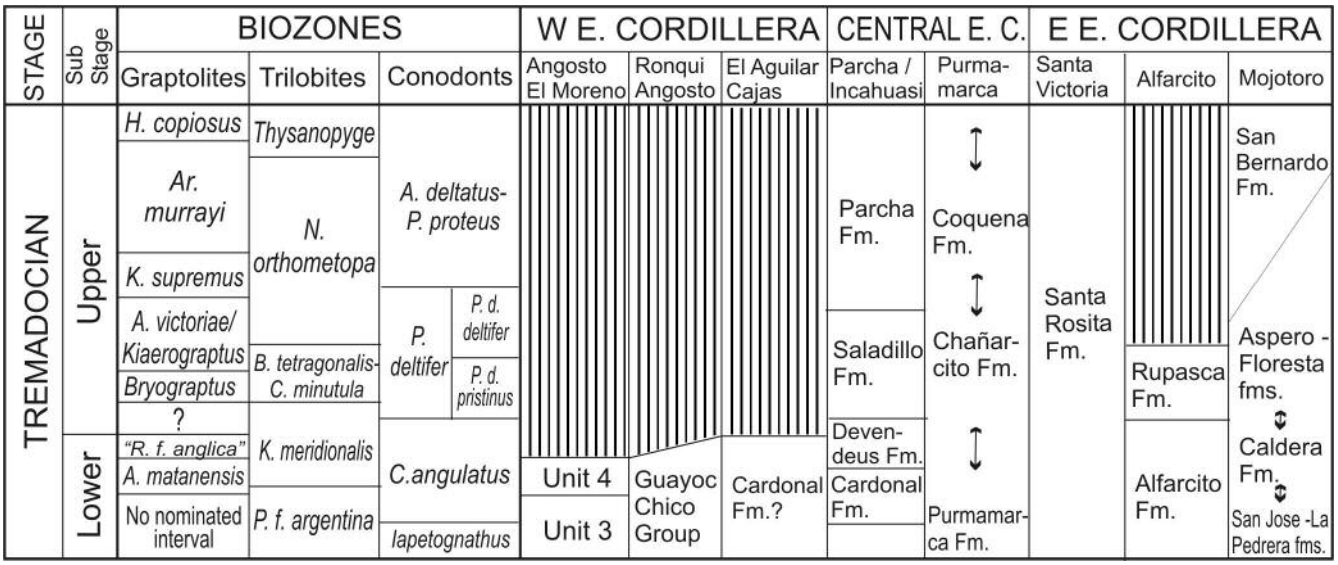


FIGURE 2 | **Correlation chart of the lithostratigraphic units from the Eastern Cordillera (western, central and eastern belts) in the Salta and Jujuy provinces, NW Argentina. Correlation data after Aceñolaza (1968), Albanesi and Ortega (2002), Astini (2003), Buatois et al. (2003), Harrington and Leanza (1957), Mángano and Buatois (2004), Monteros and Moya (2003), Moya (1999), Moya et al. (2003), Ortega and Albanesi (2003), Rao and Flores (1998), Rao (1999), and Zeballo et al. (2003).**

ral systems tracts. These successions overly the sandstones of the Meson Group (Upper Cambrian), and are covered by Cretaceous or younger rocks. The Upper Cambrian – Lower Ordovician Lampazar, Cardonal, Saladillo, and Parcha formations are therein exposed (Keidel, 1943; Harrington and Leanza, 1957). Trilobites are particularly abundant in the latter formations. The *P.* (*N.*) *f. argentina* Zone corresponds to the Lampazar Formation and lower part of the Cardonal Formation and the *K. meridionalis* Zone extends through the upper part of the Cardonal Formation and base of the Saladillo Formation (Harrington and Leanza, 1957; Tortello and Rao, 2000). The *Bienvillia tetragonalis-Conophrys minutula* and *N. orthometopa* zones were mentioned by Harrington and Leanza (1957) as occurring in the Saladillo Formation. Nevertheless, they were not found locally by later investigations. Tortello and Rao (2000) recorded conodonts of the *C. angulatus* Zone in the upper part of the Lampazar Formation and a particular association including *Acanthodus lineatus* (FURNISH) in the shallower water, basal strata of the Saladillo Formation. Apparently, this fauna either correlates with the *Rossodus manitouensis* Zone or is equivalent to the upper *C. angulatus* Zone of other schemes, suggesting a late early Tremadocian age. An early late Tremadocian age would be attributed to the ichnofossil levels of the *Cruziana-Skolithos* ichnofacies, where rhabdosomes of *Bryograptus* sp. become frequent. Graptolites of the *Bryograptus* and *Kiaerograptus* zones were identified in the Saladillo Formation, and the *Kiaerograptus supremus, Araneograptus murrayi,* and *Hunnegraptus copiosus* zones are present in the Parcha Formation, indicating a late Tremadocian (Ortega and Albanesi, 2002, 2003). The *Thysanopyge* fauna, recorded in the Parcha Formation, was considered a long-standing indicator of Arenig age for the bearer strata (Harrington and Leanza, 1957). Notwithstanding that *H. copiosus* ranges through most of the upper part of the section and indicates a latest Tremadocian age, as it can be verified in particular profiles (La Pedrera creek). At this study area, a light grey sandstone sequence completes the succession covering the dark shales of the Parcha Formation.

Angosto del Moreno

The Santa Victoria Group that crops out in Angosto del Moreno was divided into four informal units by Moya et al. (2003) and Buatois et al. (2003). Units 1-3 are mostly sandstones and include trilobites of the *P.* (*N.*) *f. argentina* Zone. Conodonts of the *Cordylodus proavus* Zone were recorded in unit 2. Unit 4 begins as a transgressive event, and its lower part includes the first records of *Anisograptus matanensis* and *Rhabdinopora flabelliformis* sp., associated with a trilobite fauna that is characterized by the presence of *Saltaspis* sp. According to Gutiérrez-Marco (2005) *Rhabdinopora flabelliformis acenolazai* is present at this unit as well. The uppermost Tremadocian part of the Angosto del Moreno is preserved in a relatively small outcrop located to the south. This sequence interbeds coquinas with the *K. meridionalis* fauna (Gómez Martínez et al., 2002) and conodonts of the *C. angulatus* Zone (Moya and Albanesi, 2000; Moya et al., 2003). The association of *A. matanensis* and *Rhabdinopora flabelliformis* ssp. continues to the top of the section, which is separated from the Acoite Formation (Arenig) by the Tumbaya unconformity (Moya, 1999).

Angosto de La Quesera

The conglomerate body that occurs between the Cardonal and Saladillo formations is made up by calcareous clasts that have yielded conodonts of the *Cordylodus angulatus* Zone (upper lower Tremadocian) including

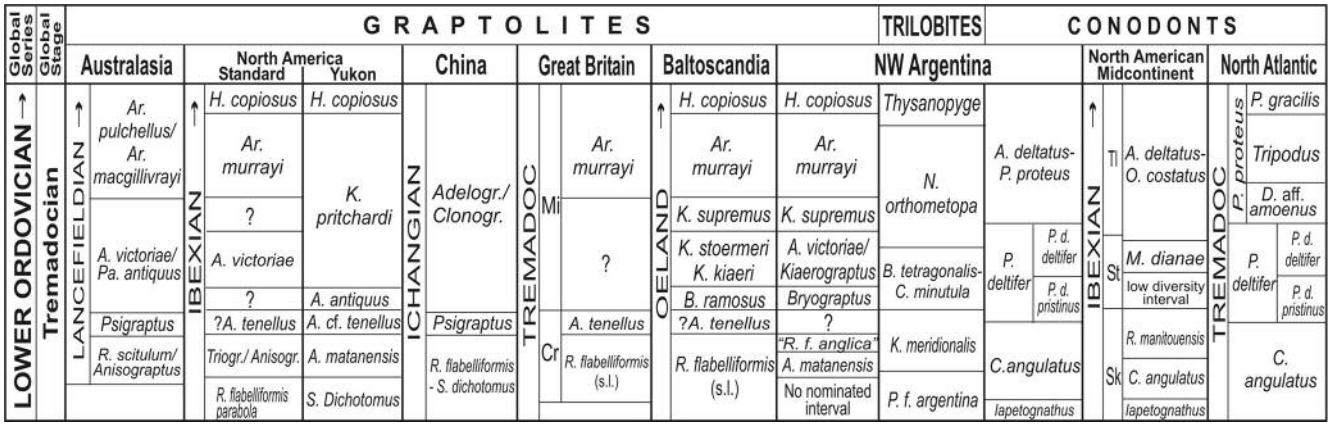


FIGURE 3 | **Comparison between the general graptolite-conodont biostratigraphic correlation charts and the graptolite, conodont, and trilobite biozones of the Argentine Eastern Cordillera (modified from Harrington and Leanza, 1957, and Albanesi and Ortega, 2002). Graptolite correlation chart: Australasia, China, and Great Britain after Webby et al. (2004); North America standard (NW Newfoundland, Quebec, and Texas) after Maletz (1999), Yukon after Jackson and Lenz (2003), and Baltoscandia after Lindholm (1991a, b) and Maletz (1999). Conodont correlation chart: North American Midcontinent after Ross et al. (1997), North Atlantic after Löfgren (1993, 1994, 1997).**

Oneotodus cf. *simplex* (FURNISH), *Problematoconites perforatus* MÜLLER, *Teridontus nakamurai* NOGAMI, *Scolopodus filosus* ETHINGTON and CLARK, *Drepanoistodus* sp., *Nogamiconus* sp., and *Variabiloconus* sp. (Aceñolaza et al., 2003). The carbonate matrix of the conglomerate bears a low diversity conodont fauna that is tentatively assigned to the *Paltodus deltifer* Zone (lower upper Tremadocian), whilst *Drepanoistodus chucaleznensis* ALBANESI and ACEÑOLAZA, *Teridontus nakamurai* and *Variabiloconus variabilis* (LINDSTRÖM) are also recorded (Albanesi, in Moya et al., 2003).

GRAPTOLITE BIOSTRATIGRAPHY

The intercontinental correlation of the following graptolite biostratigraphic units of the Eastern Cordillera is presented in Fig. 2, and particular key taxa representing these units are illustrated in Fig. 4.

No nominated interval

Rhabdinopora specimens collected in the lower part of the Cardonal Formation (*sensu* Aceñolaza, 1968) at Amarilla creek, Cajas range, were identified as *R. f. parabola* (BULMAN) (Ortega and Rao, 1995). Detailed studies suggest that these specimens can be compared with *R. f. canadensis* (LAPWORTH). Based on the absence of *Anisograptus matanensis* RUEDEMANN, these specimens are tentatively included within the "no nominated interval", probably equivalent to the *R. f. parabola* Zone of other schemes. However, the lack of records of *A. matanensis* might be attributable to sampling biases in a rock sequence with scarce fossils.

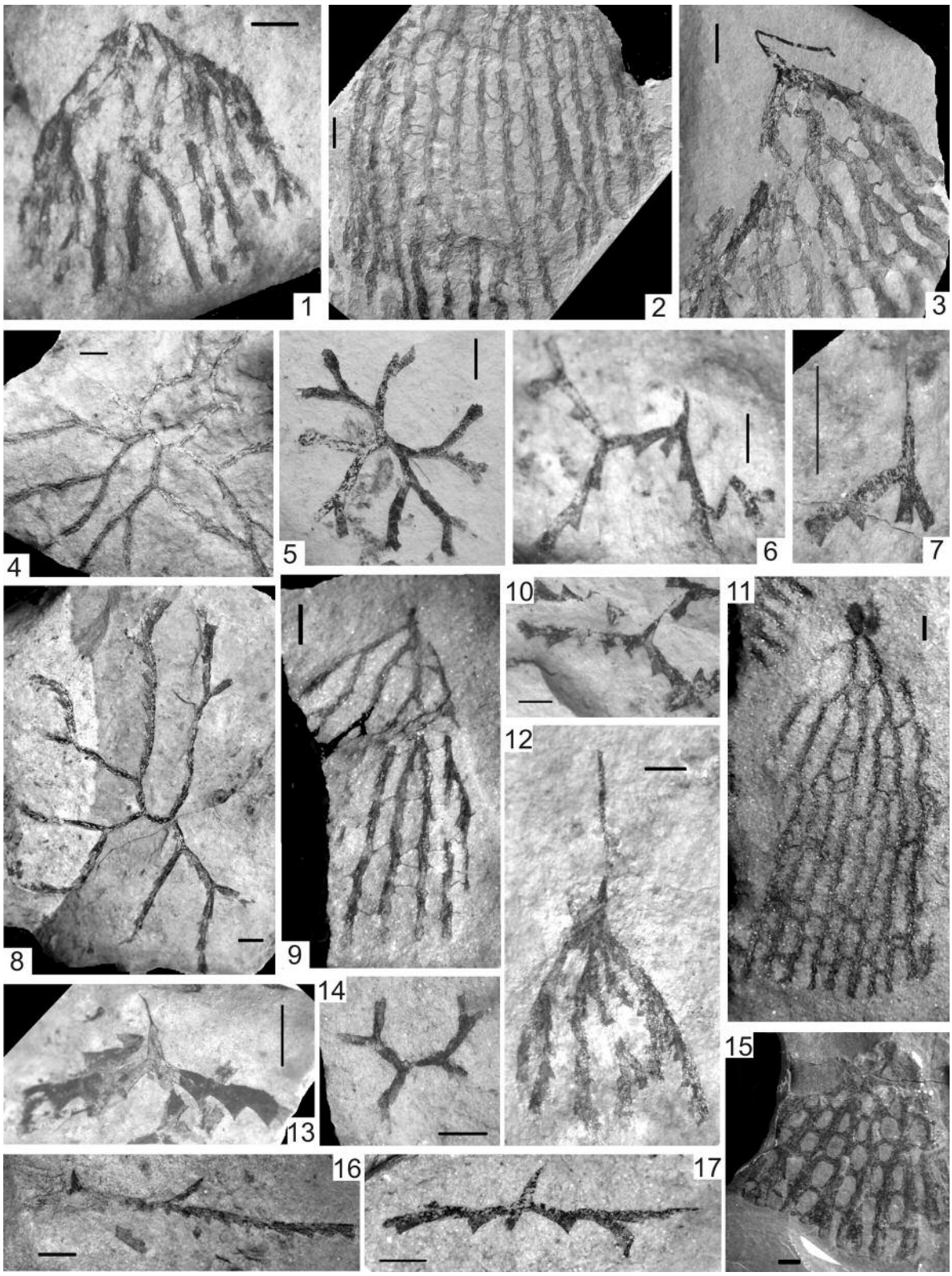
Anisograptus matanensis Zone

Anisograptus matanensis was recorded at Angosto del Moreno (Moya et al., 2003) and Cajas range. At the former locality, the taxon is recorded at the base of rock unit 4 as defined by Buatois et al. (2003) and Moya et al. (2003). Specimens of *A. matanensis* are associated to *Rhabdinopora flabelliformis* ssp., a form with thick stipes and frequent nemal threads. This fauna extends throughout unit 4, where it is associated with the common trilobite *Saltaspis* sp. at the base, and together with *Kainella meridionalis* in the upper part of the unit (Moya et al., 2003). Specimens of *R. flabelliformis acenolazai* were identified at this unit by Gutiérrez-Marco and Esteban (2005). In Cajas range, *A. matanensis* first appears in the middle part of the Cardonal Formation (*sensu* Aceñolaza, 1968), a few meters above the lowest records of *Rhabdinopora* cf. *canadensis*. The association of these two forms is maintained throughout the section, whilst *R.* cf. *canadensis* disappears in the upper part of the section, being replaced by a new *Rhabdinopora* compared with *R. f. anglica* (BULMAN). Ortega and Rao (1995) missidentified juvenile forms of *A. matanensis*, where the triradiate pattern was not apparent. These forms, derived from the lower part of the formation, were incorrectly classified as *Adelograptus tenellus* (LINNARSSON) and referred to the lower upper Tremadocian. The first appearance datum (FAD) of *A. matanensis* was still not registered in the studied sections. At Angosto del Moreno, the first specimens appear just above the shallow water sandy sequence (unit 3 of Buatois et al., 2003), which is barren of graptolites. At Cajas range, graptolites are scarce in the lower part of the Tremadocian sequence, which makes it difficult to verify if the absence of this fossil is an artefact due to collection bias.

Rhabdinopora flabelliformis anglica Zone

It is probable this biozone is represented in the upper few meters of the Tremadocian sequence, as exposed in the Amarilla creek, Cajas range, where *A. matanensis* was recently found associated with specimens of *Rhabdinopora flabelliformis* cf. *anglica*. Nevertheless, the collected material is scarce and incomplete, which precludes determining whether the subspecies is actually present, or if it may be considered as an intermediate form between *R. f. flabelliformis* and *R. f. anglica*.

FIGURE 4 | **Representative Tremadocian graptolites from the Eastern Cordillera. 1, 2, 9) *Rhabdinopora flabelliformis* cf. *canadensis* (LAPWORTH). No nominated interval, Cardonal Fm, Amarilla creek, Cajas range. 1: Juvenile rhabdosome. CORD-PZ 21436-A; 2: Mature rhabdosome showing mesh character. CORD-PZ 18138-A; 9: Narrow juvenile rhabdosome. CORD-PZ 21466. 3) *Rhabdinopora flabelliformis* ssp. *Anisograptus matanensis* Zone, unit 4, Angosto del Moreno. Proximal part of a mature rhabdosome. CORD-PZ 22822-B. 4, 5, 14) *Anisograptus matanensis* RUEDEMANN. 4: Mature specimen, *Anisograptus matanensis* Zone, unit 4, Angosto del Moreno. CORD-PZ 23072; 5: Juvenile, *Anisograptus matanensis* Zone, unit 4, Angosto del Moreno. CORD-PZ 23038; 14: Juvenile showing triradiate development, *Anisograptus matanensis* Zone, Cardonal Fm, Amarilla creek, Cajas range. CORD-PZ 18179. 6, 7, 8) *Adelograptus* cf. *altus* WILLIAMS and STEVENS. 6: Inmature specimen with isolated metasicula, *Kiaerograptus* Zone, San Bernardo Fm, La Ciénaga dam, Mojotoro Range. CORD-PZ 23800; 7: Proximal end showing sicula and first three thecae, *Kiaerograptus* Zone, San Bernardo Fm, La Ciénaga dam, Mojotoro Range. CORD-PZ 23802; 8: Horizontal rhabdosome with preserved thecae in distal stipes, *Kiaerograptus* Zone, Saladillo Fm, Angosto de Lampazar. CORD-PZ 19205. 10, 13) *Kiaerograptus* cf. *kiaeri* (MONSEN). *Kiaerograptus* Zone, Saladillo Fm, Angosto de Lampazar. 10: Specimen showing typical isolated metasicula. CORD-PZ 19848. 13: Proximal part of a mature rhabdosome, *Kiaerograptus* Zone. CORD-PZ 19207. 11) *Rhabdinopora f. flabelliformis* (EICHWALD). Mature specimen with nematic vane structure. *Rhabdinopora f. anglica* Zone? Alfarcito Fm, San Gregorio creek, Alfarcito area. CORD-PZ 30801. 12) *Bryograptus* sp. Juvenile with long nema. *Bryograptus* Zone, Saladillo Fm, Angosto de Lampazar. CORD-PZ 20231. 15) *Araneograptus murrayi* (HALL). Fragmentary rhabdosome, *A. murrayi* Zone, Saladillo Fm, El Tigre creek, Incahuasi area. CORD-PZ 18672. 16) *Hunnegraptus copiosus* LINDHOLM. Incomplete specimen with first-order stipes. *H. copiosus* Zone, Parcha Fm, Angosto de Lampazar. CORD-PZ 19090-A. 17) *Kiaerograptus* sp. Horizontal rhabdosome with pendent metasicular portion. *Kiaerograptus* Zone, San Bernardo Fm, La Ciénaga dam, Mojotoro Range. CORD-PZ 23807. Scale bar of all figures: 1 mm.**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Bryograptus Zone

Colonies of the *Bryograptus* genus were recorded from Angosto de Lampazar and Mojotoro range sections, Salta Province. Original mention was by Harrington and Leanza (1957, p. 28) for the former locality. *Bryograptus* aff. *kjerulfi* LAPWORTH was lately identified in the Mojotoro range, by González Barry and Alonso (1984) from the upper part of the homonymous formation. These authors document occurrences of the taxon for the Parcha area, herein referred to as Angosto de Lampazar, and proposed the *Bryograptus* aff. *kjerulfi* Zone, indicating a late Tremadocian age. The presence of *B. kjerulfi* defines the "Asociación Graptolítica V" of Moya et al. (1994), which was identified in the Floresta (Mojotoro range) and Saladillo (Angosto de Lampazar) formations, Salta Province. Moya et al. (1994) and Moya (1998) documented the appearance of the species in the La Floresta and Miraflores localities, Mojotoro range. Specimens of *Bryograptus* sp. from the Saladillo Formation at Angosto de Lampazar (Ortega and Albanesi, 2002, 2003) apparently differ from *B. kjerulfi* by possessing more closely spaced thecae. Strata bearing these forms were referred by the authors to the *Bryograptus* Zone, where trilobites of the *Kainella meridionalis* Zone were recorded (Tortello and Rao, 2000).

Aorograptus victoriae and *Kiaerograptus* Zones

The *Aorograptus victoriae* Zone was recorded in the lower part of the San Bernardo Formation, Mojotoro range, Salta Province (Monteros and Moya, 2002, 2003). The association consists of *Aorograptus victoriae* (T.S. Hall), *Paradelograptus onubensis* ERDTMANN, MALETZ and GUTIÉRREZ-MARCO, *P. mosseboensis* ERDTMANN, MALETZ and GUTIÉRREZ-MARCO, *Paratemnograptus isolatus* WILLIAMS and STEVENS, and *Adelograptus* sp., among others. A correlative fauna referred to the *Kiaerograptus* Zone is located in the middle part of the Saladillo Formation, at Angosto de Lampazar (Albanesi et al., 2001; Ortega and Albanesi, 2002, 2003). This fauna appears about 70 m above the last occurrence of *Bryograptus* sp., with an intervening barren interval of grey shales. The biozone presents the first records of the kiaerograptid fauna (*sensu* Maletz, 1999), whose most conspicuous elements are *Kiaerograptus* cf. *kiaeri* (MONSEN) and *Adelograptus* cf. *altus* WILLIAMS and STEVENS associated with diverse forms of the genus *Paradelograptus*. This biozone is partly equivalent to the *A. victoriae* Zone as defined by Monteros and Moya (2002, 2003) in the Mojotoro range. This correlation is evidenced by the recent finding of *Kiaerograptus* cf. *kiaeri* and *Kiaerograptus* sp. (Fig. 4:17) in the San Bernardo Formation, near La Ciénaga dam, Mojotoro range. *Kiaerograptus* cf. *kiaeri* was also registered in the Chiquero Formation, in the western flank of El Cobre range, eastern Puna of Jujuy Province, associated to specimens of the genera *Paradelograptus* and *Clonograptus* (Benedetto et al., 2002). Graptolite faunas of the *A. victoriae* and *Kiaerograptus* zones indicate an early late Tremadocian age, and can be accurately correlated with graptolitic intervals of western Newfoundland (Williams and Stevens, 1991), Yukon (Jackson and Lenz, 2000, 2003), Australia (Cooper, 1999), Scandinavia (Maletz, 1999), and Bolivia (Maletz and Egenhoff, 2001).

Kiaerograptus supremus Zone

This unit is represented by a brief interval (ca. 30 m), present in the basal part of the Parcha Formation, as exposed in the Abra de Sococha, between the *Kiaerograptus* and *Araneograptus murrayi* zones. It is characterized by the first records of the nominate taxon, species of *Paradelograptus*, and probably didymograptid forms (Ortega and Albanesi, 2003). The *K. supremus* Zone was originally defined in Scandinavia by Lindholm (1991a, 1991b) indicating a late Tremadocian age. The guide species was lately identified in Bolivia, in the *A. murrayi* Zone (Maletz and Egenhoff, 2001). The finding of *K. supremus* in the San Bernardo Formation, associated with the *A. victoriae* fauna (Monteros and Moya, 2003), suggests the *K. supremus* Zone could well be represented in that formation.

Araneograptus murrayi Zone

First records of *A. murrayi* (HALL) from Eastern Cordillera were documented by Turner (1960b) under the name of *Dictyonema yaconense* TURNER. The author referred this form to the early Arenig, indicating its presence in Yacones locality, Mojotoro range, and the Santa Victoria river, and Trigo Huayco, Salta Province. Later studies on this taxon by Gutiérrez-Marco and Aceñolaza (1987) indicated the true identity of *D. yaconense*. This species was later identified in the volcaniclastic sequence of the Tolillar Formation (Zappettini et al., 1994) to the south of Salar de Pocitos, in the southern Puna (Zimmermann et al., 1999). The FAD of *A. murrayi* is recorded in the lower part of the Parcha Formation (Abra de Sococha), ca. 35 m above the base of the unit (Albanesi et al., 2001; Ortega and Albanesi, 2002, 2003). The species range extends through ca. 50 m of micaceous sandstones and calcarenites, up to the appearance of *Hunnegraptus copiosus* LINDHOLM, where a turnover of the fauna is evidenced. Possible remains of didymograptids were found associated with the nominate taxon. The age of the graptolite fauna in the Parcha Formation is latest Tremadocian, but it is probable that some records of *A. murrayi* correspond to the early Arenig in other places of the Eastern Cordillera.

Hunnegraptus copiosus Zone

This fossil was recently discovered in the Chiquero Formation, eastern Puna of Jujuy (Benedetto et al., 2002) and the Parcha Formation, in the western border of the Eastern Cordillera (Albanesi et al., 2001; Ortega and Albanesi, 2002, 2003). At the former section, *H. copiosus* is associated with specimens of *Paradelograptus* sp. and *Tetragraptus* sp. In the Parcha Formation, the first appearance of *H. copiosus* is recorded at ca. 80 m above the base of the unit, in association with *Paradelograptus* cf. *onubensis* ERDTMANN, MALETZ and GUTIÉRREZ-MARCO, and *P. rallus* JACKSON and LENZ. The biozone extends through the middle to upper part of the cited unit, which is located in the eastern and western flanks of the Incamayo creek, nearby Parcha locality. The total range of the biozone is not known due to the intense tectonism that affects the major part of the Parcha Formation. In the upper part of the biozone, specimens of *Paradelograptus* (*P. onubensis, Paradelograptus* spp.) are frequent, but also recorded are *Hunnegraptus novus* (BERRY), *Hunnegraptus*? sp., and remains of deflexed didymograptids. In same strata trilobites of the *Thysanopyge argentina* fauna are present, which were referred to the lower Arenig by Harrington and Leanza (1957). The record of graptolites indicates, however, that the age of the bearer levels is latest Tremadocian, permitting a precise correlation with the *H. copiosus* Zone of Scandinavia (Lindholm, 1991a, 1991b) and Bolivia (Maletz and Egenhoff, 2001), and northern Yukon (Jackson and Lenz, 2003). Likewise, the presence of *H. novus* suggests a correlation with the lower part of the Marathon Limestone in west Texas (Berry, 1960; Maletz, 1999).

CONODONT BIOSTRATIGRAPHY

In the following discussion conodont biozones of the Eastern Cordillera are compared with the intercontinental correlation presented in Fig. 2. Particular conodont species representing each unit are illustrated in Fig. 5.

Iapetognathus Zone

The base of this biozone defines the Cambrian-Ordovician boundary at a global scale (Cooper et al., 2001), but it is still not recognized in the Eastern Cordillera sequences. At present, following the works of Rao and Hünicken (1995), Rao (1999), and Tortello et al. (1999), the system boundary is close to the base of the *Cordylodus lindstromi* Zone, as it was previously applied to the definition of the global stratotype in the Green Point section, western Newfoundland, Canada (Barnes, 1988). Nevertheless, the presence of species of the genus *Iapetognathus* in the *C. angulatus* Zone, in the Cardonal Formation, as exposed in the Amarilla creek, Cajas range, Eastern Cordillera, Jujuy Province, suggests the eventual finding of the guide species *I. fluctivagus* will ultimately permit a definition of the base of the biozone (Ross et al., 1997; Miller et al., 2003). Other localities of Eastern Cordillera and Puna, with previous studies that present adequate intervals to establish the system boundary, include the sections of the Angosto del Moreno (Moya and Albanesi, 2000; Moya et al., 2003) and the Las Vicuñas Formation (Rao et al., 2000), respectively. In the Famatina System, the *Iapetognathus* Zone is defined, *sensu lato*, by the FAD of the eponymous genus in the middle part of the Volcancito Formation, La Rioja Province (Albanesi et al., 1999, 2005). The system boundary, which coincides with the base of the biozone, can also be precisely established in the intermediate carbonate successions of the La Silla Formation, western Argentine Precordillera (Lehnert, 1995).

Cordylodus angulatus Zone

The conodont species that characterizes this zone was documented for the first time by Suárez Riglos et al. (1982) in strata of the Cajas Range, in the Eastern Cordillera of Salta. At this locality, Rao and Hünicken (1995) recognized the zone in the Cardonal Formation, exposed at the Amarilla creek. Rao (1999) and Tortello and Rao (2000) identified the biozone in the lower part of this formation, although, other studies by the same authors (Rao and Tortello, 1998, and Tortello et al., 1999) indicate that the boundary is located in the upper part of the formation. The Casa Colorada and San Gregorio sections, in the Alfarcito area, to the east of Tilcara, include the biozone (Zeballo et al., 2003, 2005), where the nominate taxon is associated in the upper part of the interval with the conodont *Rossodus manitouensis*. The record of the FAD of this species might eventually be considered in the defining of the homonymous base, with a more precise record, following the North American scheme of the Great Basin, Nevada (Ross et al., 1997; Miller et al., 2003). The *C. angulatus* Zone was also identified in the unit 4, cropping out at Angosto del Moreno area, Eastern Cordillera of Jujuy (Moya and Albanesi, 2000; Moya et al., 2003). Its presence is also inferred for the Lampazar section (Tortello and Rao, 2000; Ortega and Albanesi, 2003), Eastern Cordillera, Salta Province.

Paltodus deltifer Zone

This biozone was recognized in the Eastern Cordillera, in diverse localities where the lower and upper interval of the biozone can be identified. In sections of the Alfarcito area, to the east of Tilcara, Zeballo et al. (2003, 2005) identified the subspecies *Paltodus deltifer pristinus* (VIIRA), which characterizes the lower interval, where *Paltodus deltifer deltifer* (LINDSTRÖM) is still absent. Other key taxa, such us *Cordylodus angulatus,*

have their last records in this interval. *P. d. pristinus* has been identified by Albanesi and Aceñolaza (in press) in strata that correspond to the Rupasca Formation at Chucalezna section, Eastern Cordillera of Jujuy. *Paltodus d. deltifer,* which represents the upper interval of the biozone was recorded by Rao and Flores (1998) in correlative sequences of the El Aguilar range. An interval of equivalent age has been identified in the Saladillo Formation, Abra de Sococha section, at Parcha area by Ortega and Albanesi (2003), and the basal strata of the same formation are exposed in the La Quesera creek, both localities being in the Eastern Cordillera of Salta Province. The *P. deltifer* Zone was referred by Manca et al. (1995) to the Santa Rosita Formation, in outcrops from the Nazareno area (see discussion under this locality), Eastern Cordillera of Salta. The lower and upper intervals herein recognized for the biozone follow the concept of Löfgren (1997) with the original designations of the lower *P. deltifer pristinus* and upper *P. deltifer deltifer* subzones, respectively.

Acodus deltatus - Paroistodus proteus Zone

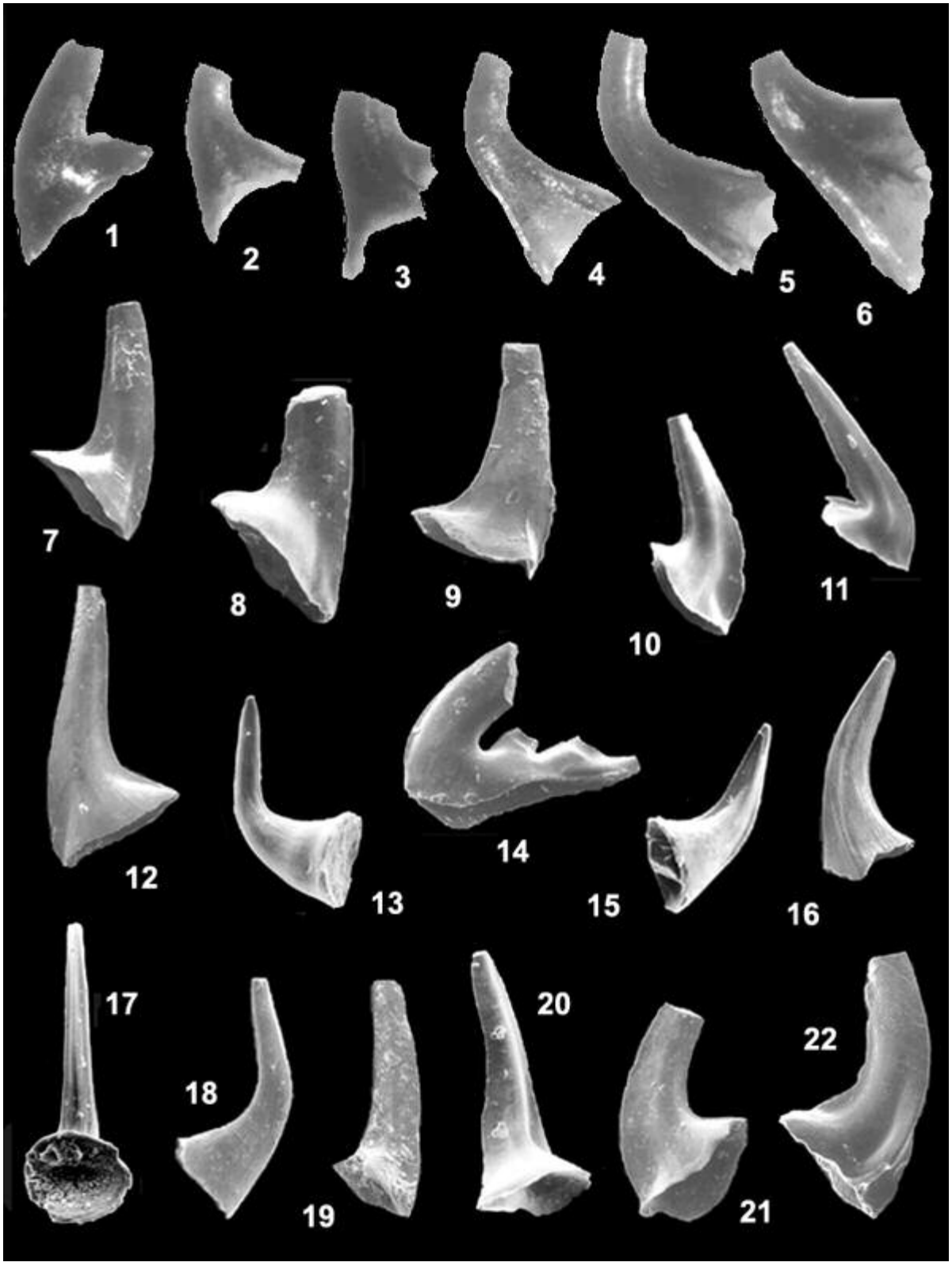
The beds bearing the conodont fauna that correspond to this biozone have, apparently, limited areal distribution in the Eastern Cordillera. At present, they have only been recognized in the Parcha-Incahuasi area (Albanesi et al., 1997). In sections of this area, diagnostic conodonts; i.e., *Acodus deltatus* LINDSTRÖM *sensu lato* and *Paroistodus proteus* (LINDSTRÖM), are associated with graptolites of the *Araneograptus murrayi* Zone through the lower part of the Parcha Formation (Ortega and Albanesi, 2003). It is interesting to note that recovered specimens of *Acodus deltatus sensu lato*, are more precisely identified with North American forms (Ethington and Clark, 1981) and with early forms of the Baltic region, such as that determined as *Acodus* aff. *deltatus* by Löfgren (1993). Following this author, the early form characterizes the lowest interval of the fourfold division of the *Paroistodus proteus* Zone*,* in the biostratigraphical scheme of the Hunneberg area. The typical forms of *Acodus deltatus* appear in the next subdivision of the scheme proposed by Löfgren (1993, 1994). This is the most frequent form recorded in the Baltoscandian region (e.g., Bagnoli et al., 1988; Stouge and Bagnoli, 1998; Löfgren and Bergström, 2002), but it has still not been found in the Eastern Cordillera.

PALEOENVIRONMENTAL AND PALEOBIOGEOGRAPHICAL REMARKS

Graptolite faunas

At the Cajas range (Figs. 1 and 2) a fauna composed by *Rhabdinopora flabelliformis* cf. *canadensis* that appears below the first occurrence of *A. matanensis* is associated with conodonts and trilobites of the *C. lindstromi* and *P.* (N.) *f. argentina* zones, respectively. Following Cooper et al. (1998), *R. f. canadensis* ranges through the upper part of the *R. f. parabola* Zone and the lower part of the *A. matanensis* Zone, and is restricted to slope environments (Cooper, 1999). At Cajas locality, *R. flabelliformis* cf. *canadensis* ranges through the uppermost part of the *A. matanensis* Zone, where it is replaced by *R. flabelliformis* cf. *anglica*. This is one of the few sections where faunas more ancient than the *A. matanensis* Zone are recorded in the Eastern Cordillera. A majority of early Tremadocian graptolites from this geological province correspond to *R. f. flabelliformis*, usually comprising monospecific faunas. It is interesting to note that *Rhabdinopora* specimens occur usually on ripple marked surfaces (Alfarcito area, Zeballo et al., 2005), that may correspond to shallow-water facies. Particular forms such as *R. f. flabelliformis*, *R. f. anglica*, *Bryograptus* sp., and *A. murrayi*, are considered to be members of the

FIGURE 5 | **Characteristic Tremadocian conodonts from the Eastern Cordillera. 1 to 6) *Acodus deltatus* LINDSTRÖM, *sensu lato. Acodus deltatus – Paroistodus proteus* Zone, Parcha Fm, Parcha area (abra de Sococha). 1: M element, outer lateral view. CORD-MP 10169, x 60; 2: Sc element, outer lateral view. CORD-MP 10170, x 60; 3: Sb element, outer lateral view. CORD-MP 10171, x 60; 4: Sd element, outer lateral view. CORD-MP 10172, x 60; 5: Sa element, outer lateral view. CORD-MP 10173, x 60; 6: P element, outer lateral view. CORD-MP 10174, x 60. 7 to 9) *Paltodus deltifer pristinus* (VIIRA). *Paltodus deltifer pristinus* Subzone (*P. deltifer* Zone), Alfarcito and Rupasca Fms, Alfarcito and Chucalezna areas. 7: M element, outer lateral view. CORD-MP 10063, x 75; 8: M element, outer lateral view. CORD-MP 8124/1, x 55; 9: Sa element, outer lateral view. CORD-MP 10062, x 100. 10, 12) *Drepanoistodus alfarcitensis* ZEBALLO, ALBANESI and ORTEGA. *Paltodus deltifer pristinus* Subzone (*P. deltifer* Zone), Rupasca Fm, Alfarcito area. 10: M element, outer lateral view. CORD-MP 10060, x 70; 12: Sa element, outer lateral view. CORD-MP 10059, x 70. 11) *Drepanoistodus chucaleznensis* ALBANESI and ACEÑOLAZA. M element, outer lateral view. *Paltodus deltifer pristinus* Subzone (*P. deltifer* Zone), Rupasca Formation, Chucalezna area. CORD-MP 8129/1, x 40. 13) *Semiacontiodus minutus* ZEBALLO, ALBANESI and ORTEGA. *c* element, lateral view (specular image). *Paltodus deltifer pristinus* Subzone (*P. deltifer* Zone), Rupasca Fm, Alfarcito area. CORD-MP 8094/36, x 100. 4) *Cordylodus angulatus* PANDER. S element, outer lateral view (specular image). *Cordylodus angulatus* Zone, Alfarcito Fm, Alfarcito area. CORD-MP 8015/1, x 50. 15, 16) *Utahconus humahuacensis* ZEBALLO, ALBANESI and ORTEGA. *Paltodus deltifer pristinus* Subzone (*P. deltifer* Zone), Rupasca Fm, Alfarcito area. 15: *f* element, inner view (specular image). CORD-MP 8101/1, x 85; 16: *f* element, outer lateral view. CORD-MP 10067, x 90. 17, 18) *Teridontus nakamurai* (NOGAMI). *Paltodus deltifer pristinus* Subzone (*P. deltifer* Zone), Alfarcito and Rupasca Fms, Alfarcito and Chucalezna areas. 17: *c* element, posterior view. CORD-MP 8092/70, x 100; 18: *a* element, lateral view. CORD-MP 10065, x 100. 19, 20) *Rossodus tenuis* (MILLER). *Paltodus deltifer pristinus* Subzone (*P. deltifer* Zone), Rupasca Fm, Alfarcito and Chucalezna area. 19: *b* element, posterior view. CORD-MP 10061, x 100; 20: *b* element, inner view (specular image). CORD-MP 8100/1, x 100. 21) *Drepanodus arcuatus* PANDER. *f* element, inner lateral view. *Paltodus deltifer pristinus* Subzone (*P. deltifer* Zone), Rupasca Fm, Chucalezna area. CORD-MP 10064, x 120. 22) *Paltodus* cf. *subaequalis* (LINDSTRÖM). Pa element, outer lateral view. *Paltodus deltifer pristinus* Subzone (*P. deltifer* Zone), Rupasca Fm, Chucalezna area. CORD-MP 10068, x 130.**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epipelagic biotope (Cooper, 1999) and can occur possibly to be found either in shallow or deep water environments. Other graptolites recorded in Tremadocian rocks of the Eastern Cordillera correspond to the isograptid (ocean restricted) facies. According to the biofacial scheme of Cooper (1999), *A. matanensis* is recorded from outer shelf to ocean floor sequences, whilst other taxa, such as *P. onubensis, A. victoriae,* and *H. copiosus* are restricted to deeper environments (lower slope to ocean floor facies).

At the moment, the *Rhabdinopora praeparabola* Zone has not been recorded in the Eastern Cordillera, and the *Rhabdinopora f. parabola* interval is not clearly defined (Figs. 2 and 3). Because of this situation, we refer to the "no nominated interval" to all graptolite assemblages that appear below the *A. matanensis* Zone. The *A. matanensis* Zone is also located in the lower part of the upper member of the Volcancito Formation, Famatina System, western Argentina (Turner, 1960b; Gutiérrez-Marco and Esteban, 2003). This unit has a widespread paleogeographical distribution, with the record of *R. f. flabelliformis*. Some colonies, typically *R. f. canadensis,* are restricted to the basal part of the biozone, while others, such as *R. f. norvegica*, may range through the whole interval in shallow shelf environments (Cooper, 1999). In Argentina, the *A. matanensis* Zone contains, apart from the nominate taxon, rhabdinoporinid graptolites, that are more frequent and diverse in the Volcancito Formation (Gutiérrez-Marco and Esteban, 2003, 2005).

The association of *A. matanensis* with forms similar to *R. f. anglica* in the Cajas range, suggests the presence of the *R. f. anglica* Zone in the Eastern Cordillera. This biozone is also documented for the upper member of the Volcancito Formation (Aceñolaza and Durand, 1984; Gutiérrez Marco and Esteban, 2003). The *R. f. anglica* Zone is consistently placed in shelf and slope sequences from Newfoundland, Estonia, and Great Britain (Bulman, 1927, 1954; Cooper et al., 1998; Cooper, 1999).

The *Adelograptus* interval (or the equivalent *Psigraptus* interval in deeper facies) has still not been identified in the Eastern Cordillera. In the Baltoscandian region, the records of *Bryograptus* spp. (*B. kjerulfi, B. broeggeri*) occur above the *Adelograptus tenellus* Zone, in association with *R. flabelliformis norvegica* (KJERULF) (Westergård, 1909). This taxon was included in the *Paradelograptus antiquus* Zone of Cooper (1999). It is possible that the *Bryograptus* Zone of northwestern Argentina and southern Bolivia has the same position. However, this assumption has not been verified due to the lack of records through the lower/upper Tremadocian boundary interval.

The succession of late Tremadocian zones (i.e., *Bryograptus, Kiaerograptus, K. supremus, A. murrayi*, and *H. copiosus*), as exposed in the Lampazar-Parcha section (Figs. 1 and 2), show a close similarity with that from the Baltoscandic region (Fig. 3; Lindholm, 1991b; Maletz, 1999), and the southern Bolivia basin (Suárez Soruco, 1975; Maletz and Egenhoff, 2001), which is a continuation of the Argentine Eastern Cordillera.

Conodont faunas

Early Tremadocian conodont faunas of the Eastern Cordillera (*Cordylodus angulatu*s Zone) do not include typical Midcontinent Realm shallow-warm water forms as frequent components, such as occurs in the epicratonic basins of Laurentia, Australia, North China (e.g., Miller, 1984; Chen and Gong, 1986; Ji and Barnes, 1994), or in the carbonate facies of restricted environments from the Argentine Precordillera (Lehnert et al., 1997). These faunas lack a significant amount of paraconodonts in association with euconodonts as it is present in high latitude environments of the North Atlantic Realm, i.e, Baltica (e.g., Viira et al., 1987; Müller and Hinz, 1991). Most frequent conodont associations of lower Tremadocian biozones from northwestern Argentina present a biofacial composition typical of peripheral environments (Rao, 1999; Albanesi et al., 2005), similar to those from particular sections of Newfoundland, as analysed by Bagnoli et al., 1987; Barnes, 1988; Fåhraeus and Roy, 1993, among others, or from northwestern Canadian basins (Landing et al., 1980; Pyle and Barnes, 2002). They are comparable, in general terms, to the faunas of outer platform to open ocean environments such as those described by Dubinina (1991, 2000) for Kazakhstan. In shallow water environments, in particular the *Cruziana-Skolithos* ichnofacies from the lower part of the Saladillo Formation, at Angosto de Lampazar (*Cordylodus angulatus* Zone), conodont faunas include genera that characterize shallow-water environments of Laurentia; e.g., *Acanthodus, Polycostatus, Ulrichodina* and *Utahconus* (Tortello and Rao, 2000). This particular situation apparently shows that even in the late early Tremadocian (up to the important extinction event of the North American "Low Diversity Interval") there was no marked paleobiogeographical partitioning as that developed through most of the Ordovician Period.

Conodont faunas of the upper Tremadocian (*Paltodus deltifer* and *Acodus deltatus – Paroistodus proteus* zones) from northwestern Argentina (e.g., Rao and Flores, 1998; Ortega and Albanesi, 2002, 2003; Zeballo et al., 2005; Albanesi and Aceñolaza, 2005) combine endemic and coeval forms of the Baltoscandian region or the North Atlantic Realm, e.g., *Paltodus, Paroistodus* (Löfgren, 1997; Tolmacheva, 2001), with the genera *Rossodus* and *Utahconus,* which are typical elements of the Midcontinent realm (Repetski, 1982; Ji and Barnes, 1994; Miller et al., 2003). At present, a section covering continuous records through the upper Tremadocian has not been do-

cumented. However, considering successive conodont associations, it is probable that the biostratigraphic interval represented by a major part of the *Paltodus deltifer* Zone corresponds to the "Low Diversity Interval" of North America (Ross et al., 1997). During this time span, a progressive shallowing cycle ("*Ceratopyge* Regressive Event") apparently induced an extinction event of global significance from which only low diversity communities survived (Ethington et al., 1987; Barnes et al., 1996; Albanesi and Bergström, 2004). The local faunal composition would then be the result of a complex interplay of faunal dynamics from different regions, leading to mixing of the faunas for the Eastern Cordillera basin of the Gondwanan margin, before the beginning of faunal partitioning and biogeographical segregration of warm and cold water faunas at the latest Tremadocian (Miller, 1984).

Apparently, the neighboring and coeval basins represented by the Volcancito and Bordo Atravesado formations of the Famatina System underwent similar environmental changes (Albanesi et al., 1999, 2005). Late Tremadocian faunas of the Argentina Precordillera or Cuyania terrane (e.g., Lehnert, 1995; Albanesi et al., 1998; Albanesi et al., 2003) are dominated by taxa representing the warm-shallow environments of the Midcontinent realm, e.g., *Paltodus spurius* ETHINGTON and CLARK, *Laurentoscandodus, Loxodus,* and *Ulrichodina* (= *Colaptoconus*), among other taxa (cf., Ji and Barnes, 1994; Miller et al., 2003). The recurrent appearance of species of *Variabiloconus* in diverse sedimentary facies of northwestern Argentine basins, Argentine Precordillera, Laurentia and Baltica, reflects the adaptation of particular organisms to dwelling in the Iapetus Ocean and connecting to more distant regions during the Tremadocian (Löfgren et al., 1998).

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