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CONODONTS AND GRAPTOLITES OF THE SANTA ROSITA FORMATION (TREMADOCIAN) AT THE NAZARENO AREA, SANTA VICTORIA RANGE, CORDILLERA ORIENTAL OF SALTA, ARGENTINA



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THE Nazareno area is located to the southeast of the Santa Victoria range in the Cordillera Oriental of Salta, Argentina, with extensive exposures of Ordovician rocks (Ortega and Albanesi, 2002; Brussa *et al.*, 2003; Astini, 2003; Albanesi *et al.*, 2008, and references therein). At this area a thick siliciclastic succession of the Santa Rosita Formation from the Lower Ordovician crops out (Turner, 1960) (Fig. 1).

Previous works describe a succession that consists of sandstones and shales, and subordinate calcareous rocks with abundant fossils of early Tremadocian age (*e.g.*, trilobites, braquiopods, gastropods, conodonts, acritarchs) (Harrington and Leanza, 1957; Vilela, 1961; Manca *et al.*, 1995). The *Paltodus deltifer* conodont Zone of the upper middle Tremadocian was first identified in this area by Manca *et al.* (1995), who reported the presence of *Paltodus deltifer* Lindström, *Drepanodus arcuatus* Pander, *Acodus deltatus deltatus* (Lindström), among other taxa, however, the illustrations of these specimens do not allow a definite determination.

At the Nazareno area, the Santa Rosita Formation unconformably overlies the upper Cambrian marine quartzites of the Mesón Group, and is unconformably covered by Cenozoic terrigenous deposits. The upper 216 m of the Capillas river profile begins with coarse sandstone strata, ca. 67.5 m thick, at the base of a heterolytic succession, which is predominantly sandy in its lower section, and continues with a shaly succession of grey and black shales, in the upper part. Calcareous tabular and

lensoid strata and concretions yielded a significant amount of microfossils, mainly conodonts (Figs. 2, 3). The composite stratigraphic column of the Figure 2 shows the lithology and biostratigraphy of the Grande Creek and Capillas River sections. In the Grande creek Minor *et al.* (2011) measured ca. 200 m of an heterolithic succession with the *Paltodus deltifer pristinus* Subzone, below the strata of the Capillas River section, which is studied in this paper.

The objective of this report is the definition of the conodont and graptolite assemblages collected from the upper Santa Rosita Formation, in both sections studied at Nazareno area, which refer to a middle Tremadocian age.

BIOSTRATIGRAPHY

Paltodus deltifer Zone

This biozone was defined by Lindström (1971), and later subdivided into the *Paltodus deltifer pristinus* and the *Paltodus deltifer deltifer* subzones by Löfgren (1997), both of them from the middle Tremadocian (Tr2 *sensu* Bergström *et al.*, 2009).

At Nazareno, the *P. d. pristinus* Subzone extends through the 70 m of the studied section at Grande creek (Minor *et al.*, 2011) (Fig.2). The conodont species recognized are: *Paltodus d. pristinus* (Viira), *Drepanoistodus chucaleznensis* Albanesi and Aceñolaza, *Tilcarodus humahuacensis* Albanesi and Aceñolaza, *Teridontus gallicus* Serpagli, Ferretti, Nicoll and Serventi, *Acanthodus raqueli* Zeballo and Albanesi, *A. humachensis* Zeballo

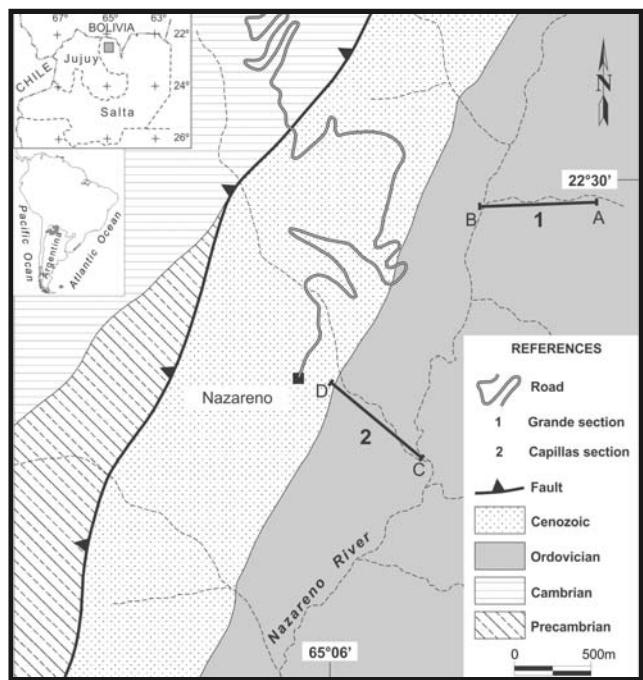


Figure 1. Location map of the study area and geology of the Nazareno locality with the study section.

and Albanesi, *Utahconus purmamacensis* Zeballo and Albanesi, *U. tortibasis* Zeballo and Albanesi, *Paroistodus numarcuatus* (Lindström), *Variabiloconus variabilis* (Lindström), *Teridontus* sp. and *Variabiloconus?* sp.

The *P. d. deltifer* Subzone ranges through the middle and upper part of the investigated section. The conodont association is composed of *P.deltifer deltifer* (Lindström), *Drepanostodus chucaleznensis* Albanesi and Aceñolaza, *Tilcarodus humahuacensis* Albunesi and Aceñolaza, *Teridontus gallicus* Serpagli, Ferretti, Nicoll and Serventi, *Acanthodus raquelii* Zeballo and Albunesi, *A. humachensis* Zeballo and Albunesi, *Utahconus purmamacensis* Zeballo and Albunesi, *U. tortibasis* Zeballo and Albunesi, *U. scandodiformis* Zeballo and Albunesi, *Kalidontus gondwanicus* Zeballo and Albunesi, *Drepanodus arcuatus* Pander, *Phakelodus elongatus* (Zhang in An et al., 1983), *Paroistodus numarcuatus* (Lindström), *Variabiloconus crassus* Zeballo and Albunesi, *V. variabilis* (Lindström), *Phakelodus tenuis* Müller,

Cordylodus hastatus Barnes, *Cordylodus proavus* Müller, *Paltodus deltifer* n. ssp., *Acanthodus* sp., *Cordylodus* sp., *Filodontus* sp. and *Variabiloconus* sp.

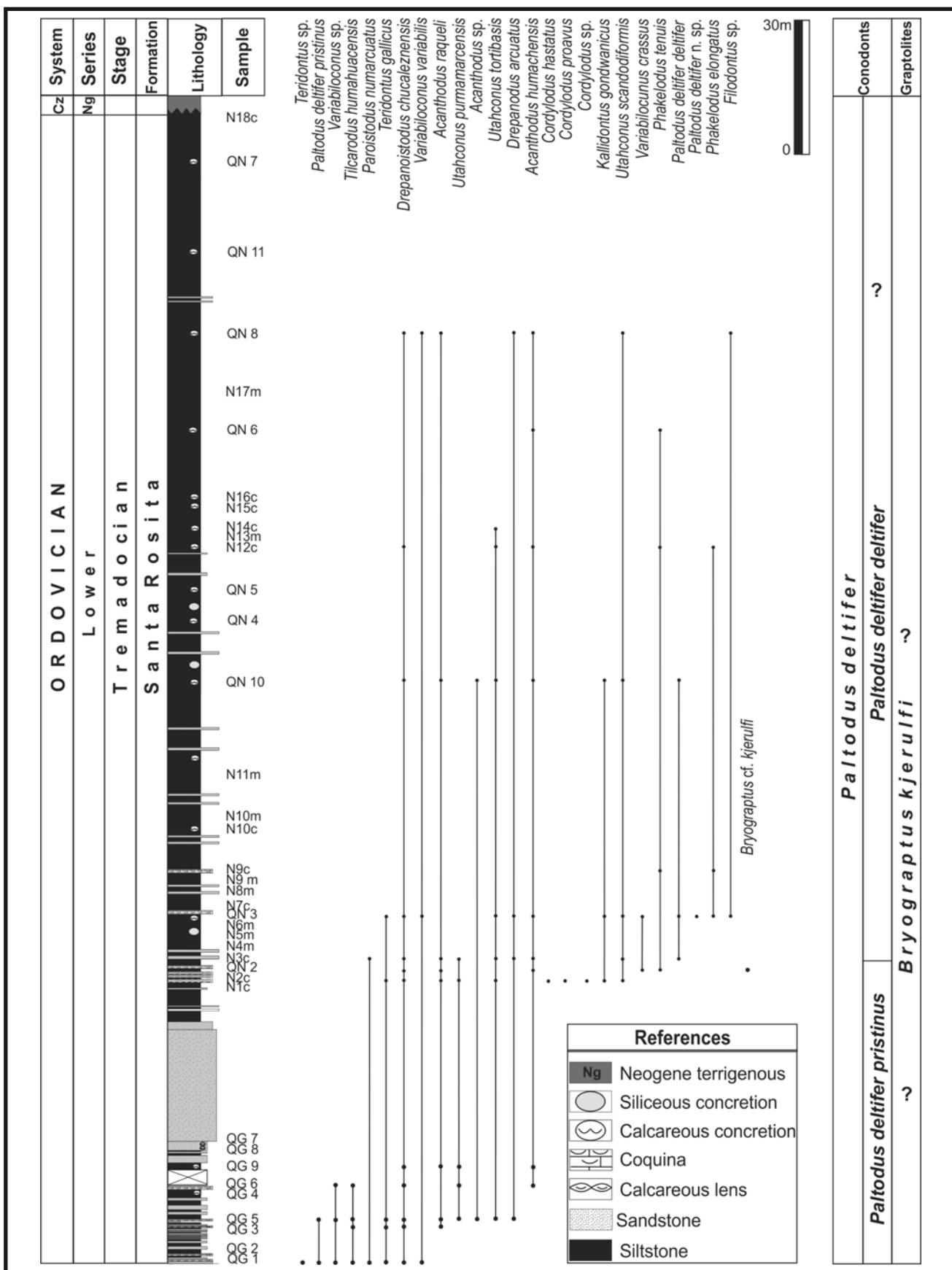
The *Paltodus deltifer* Zone *sensu lato* was first documented in the Santa Rosita Formation at the Nazareno area by Manca et al. (1995). A related conodont association from correlative strata of the region was reported more recently from the Angosto de Chucalezna section, at the Quebrada de Humahuaca (Albanesi and Aceñolaza, 2005). The fossiliferous succession, which also provided trilobites, phosphatic brachiopods, echinoderms, and diverse trace fossils correspond to the Rupasca Member of the Santa Rosita Formation, following the stratigraphic descriptions and new formations definition given by Buatois et al. (2006).

At the Nazareno section, the two subzones of the *Paltodus deltifer* Zone are clearly identified by means of the appearance of the eponymous subspecies; furthermore, the presence of conodont *Cordylodus proavus* Müller verifies its last appearance in the lower subzone of the *P. deltifer* Zone, together with the record of the graptolite *Bryograptus cf. kjerulfi*.

Bryograptus kjerulfi Zone

Graptolite remains were collected from black and grey siltstones, with abundant shelly fauna, corresponding to the sample QN2 in the lower part of the investigated profile, just overlying a remarkable coquinoid level in the Capillas river section, at the upper part of the Santa Rosita Formation (Fig. 2). The assemblage contains flattened growth stages and juvenile and mature pendent rhabdosomes. The initial angle of divergence of the stipes produces open cones to more parabolic forms of rhabdosome. The presence of a triradiate proximal end, autothecae and bithecae, a pendent rhabdosome, and the absence of dissepiments allow for referring this material to genus *Bryograptus* Lapworth (Fig. 4). The slender sicula with 1.5-1.7 mm length resembles to *B. kjerulfi* Lapworth. However, the delayed dichotomies and closer thecal spacing (16-17 thecae in 10 mm) could correspond to *B. bröeggeri* Monsen. The specimens, flattened and incomplete, are provisionally referred to as *Bryograptus cf. kjerulfi*.

Figure 2. Composite stratigraphic column of the Santa Rosita Formation from the Nazareno section with ranges of recorded taxa and biozonation. Ng: Neogene. QG and QN correspond to the samples studied by Minor et al. (2011), and samples with the prefix N were taken by two of the authors (MEG and GLA).



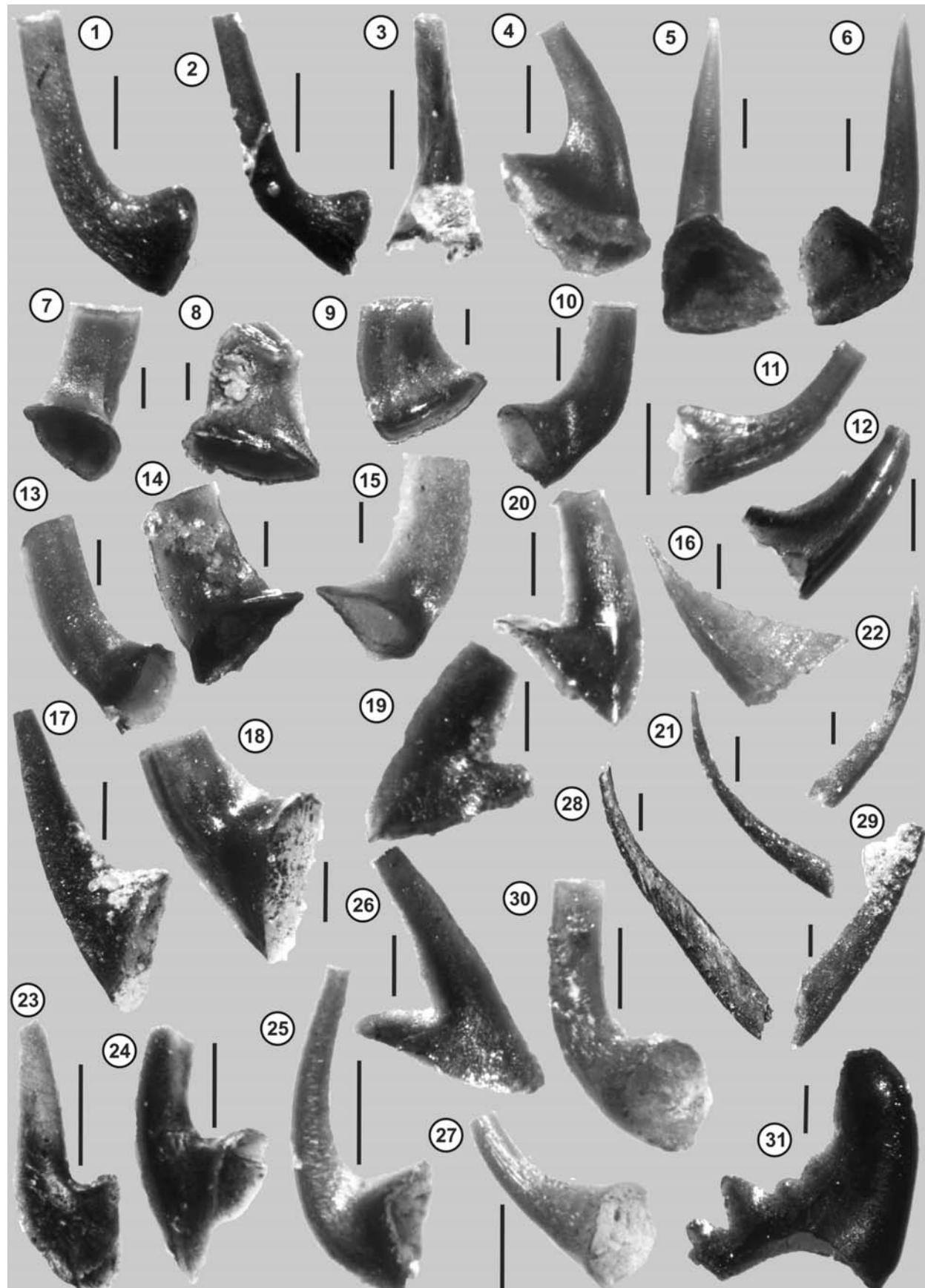


Figure 3. Tremadocian (*Paltodus deltifer* Zone) conodonts from the Nazareno locality, Cordillera Oriental, Salta Province, Argentina. **1**, *Acanthodus humachensis* Zeballo and Albaresi, P element (CORD-MP 28135/1-14). **2-3**, *Acanthodus raqueli* Zeballo and Albaresi, M and P elements (CORD-MP 28092/1-5). **4-6**, *Variabiloconus variabilis* (Lindström), **4**, Pb element (CORD-MP 28121/1), **5, 6**, Pa elements (CORD-MP 28080/1). **7-9**, *Utahconus tortibasis* Zeballo and Albaresi, M elements (CORD-MP 28115/1-15). **10**, *Utahconus purmamacrancensis* Zeballo and Albaresi, M element (CORD-MP 28090/1-3). **11-12**, *Tilcarodus humahuacensis* (Albaresi and Aceñolaza), M and Pa elements (CORD-MP 28089/1-15). **13-15**, *Utahconus scandodiformis* Zeballo and Albaresi, 13, Pa element, **14**, M element, **15**, S element (CORD-MP 28117/1-8, CORD-MP 28125/1). **16**, *Kallidontus gondwanicus* Zeballo and Albaresi, Sb element (CORD-MP 28113/1-10). **17-18**, *Paltodus deltifer pristinus* (Viira), M elements (CORD-MP 28087/1-15). **19**, *Paltodus deltifer* n. ssp., M element (CORD-MP 28120/1). **21-22**, *Phakelodus tenuis* (Müller) (CORD-MP 28156/1-3, CORD-MP 28162/1-7). **23-24**, *Drepanoistodus chucaleznensis* Albaresi and Aceñolaza, M and P elements (CORD-MP 28086/1-117). **25**, *Drepanodus arcuatus* Pander, Pa element (CORD-MP 28119/1-5). **20, 26**, *Paltodus deltifer deltifer* (Lindström), M element (CORD-MP 28109/1-10). **27**, *Filodontus* sp. (CORD-MP 28114/1-2). **28-29**, *Phakelodus elongatus* (Zhang in An et al., 1983) (CORD-MP 28157/1-3). **30**, *Teridontus gallicus* Serpagli, Ferretti, Nicoll and Serventi, S element (CORD-MP 28091/1-3). **31**, *Cordylodus hastatus* Barnes, P3 element (CORD-MP 28142/1). Scale bar: 0.1 mm.

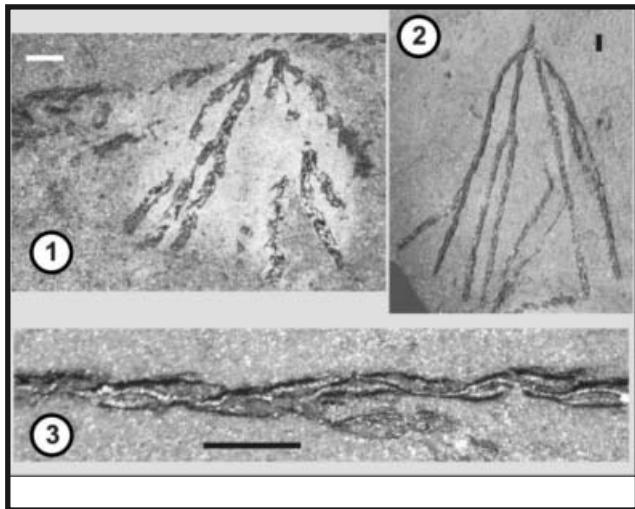


Figure 4. Tremadocian graptolites (*Bryograptus kjerulfi* Zone) from the Nazareno locality, Cordillera Oriental, Salta Province, Argentina. 1-3. *Bryograptus cf. kjerulfi* Lapworth; 1, juvenile rhabdosome (CORD-PZ 33102-1); 2, mature rhabdosome (CORD-PZ 33102-2); 3, magnified branch showing dendroid stipe structure (CORD-PZ 33102-2). Scale bar: 1mm.

The record of these fossils in the Nazareno area extends the distribution of the horizon with *Bryograptus* (*B. kjerulfi* Zone sensu Moya et al., 1984, and Maletz et al., 2010; *Bryograptus* Zone from Ortega and Albaresi, 2005) in the Cordillera Oriental, in association with conodonts of the *Paltodus deltifer* Zone, indicating a middle Tremadocian age.

This biozone, identified in various sections of the Cordillera Oriental (González-Barry and Alonso, 1984; Albaresi and Ortega, 2002; Ortega and Albaresi, 2003, 2005; Moya and Monteros, 2011, and references therein), is characterized by a monotonous graptolite fauna usually composed of the nominal species (Albaresi et al., 2008; Maletz et al., 2010). This biostratigraphic unit is approximately equivalent to the *Bryograptus ramosus* Zone of the Baltoscandian region (Maletz et al., 2010).

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