Late Tremadocian graptolites from the Mojotoro Range, Argentine Eastern Cordillera

Julio A. MONTEROS[1] and María C. MOYA[1,2]

[1]CI-UNSa. Universidad Nacional de Salta, Facultad de Ciencias Naturales, Buenos Aires 177, 4400 Salta, Argentina. E–mail: julpaleo@ unsa.edu.ar

[2] CONICET. E–mail: crismoya @ unsa.edu.ar

Keywords: Graptolites. Late Tremadocian. Ordovician. Eastern Cordillera. Argentine.

Introduction

The aim of this contribution is to make known a graptolite assemblage from the Upper Tremadocian coming from the Mojotoro Range on the southeast part of the Argentine Eastern Cordillera (Figure 1a,b). The fossiliferous deposits correspond to the lower part of San Bernardo Formation (SBF) exposed on the hill of the same name, immediately to the east of Salta city (Figure 1b). The SBF outcrops along the park roadway up to San Bernardo; this route is one of the most important tourist attractions in the city of Salta, which assures a fast and easy access to the outcrops.

The SBF is composed of silty shales, siltstones and fine– grained olive–green wackes deposited in a marine environment of transitional facies between the inshore and offshore shelf. Sandstone and conglomerate beds assigned to storm and gravity flow deposits are interbedded in the succession of shales and fine wackes. The SBF has been assigned an Arenigian age because it contains graptolites of this age (Loss, 1951) and typical trilobites belonging to the "*Thysanopyge* Fauna" (Harrington, 1957). The forms described by Loss (1951) include, among others, *Clonograptus flexilis* (Hall), *Tetragraptus lavalensis* (Ruedemann), *T. sanbernardicus* Loss, *Didymograptus vacillans* Tullberg, *D. deflexus* Elles and Wood, D. *v–fractus* Salter and *D. nitidus* (Hall). Later on, Moya *et al.* (1994) mention *Pendeograptus fruticosus* (Hall), *Didymograptus* cf. *vacillans* Tullberg and *Schizograptus* sp. An late Tremadocian age for the beginning of the SBF deposits has been proposed by Moya (1998) and thus could potentially record the Tremadocian–Arenigian boundary. The SBF belongs to the Santa Victoria Group (SVG; Upper Cambrian–Caradocian), which is composed of an alternating succession of sandstone and shale units (Figure 1c). The SVG overlies the Meson Group (Middle?–Upper Cambrian) through a clear erosional disconformity (Figure 1c).

Late Tremadocian graptolites in the San Bernardo Formation (SBF)

The graptolite succession relevant to this contribution is considered to be continuous, it has a thickness of 45 m and it ranges through the lower part of the SBF (Figure 1c). The most representative graptolites occurring in this interval include the following forms: *Aorograptus victoriae* Hall, *Paradelograptus mosseboensis* Erdtmann, Maletz and Gutiérrez Marco, *P. onubensis* Erdtmann, Maletz and Gutiérrez Marco, *Paradelograptus* sp., *Kiaerograptus* cf. *pritchardi* (Hall), *Kiaerograptus supremus* Lindholm, *Paratemnograptus isolatus* Williams and Stevens, *Clonograptus* sp., *Adelograptus* sp. and *Bryograptus?* nov. sp. (Figure 1c). The foregoing list includes several species mentioned for the first time both from South America and especially from Argentina. The recognized forms allow the identification of the *Aorograptus victoriae Zone* (Monteros and Moya, 2002), which has been recently mentioned in south Bolivia (Maletz *et al.*, 1999).

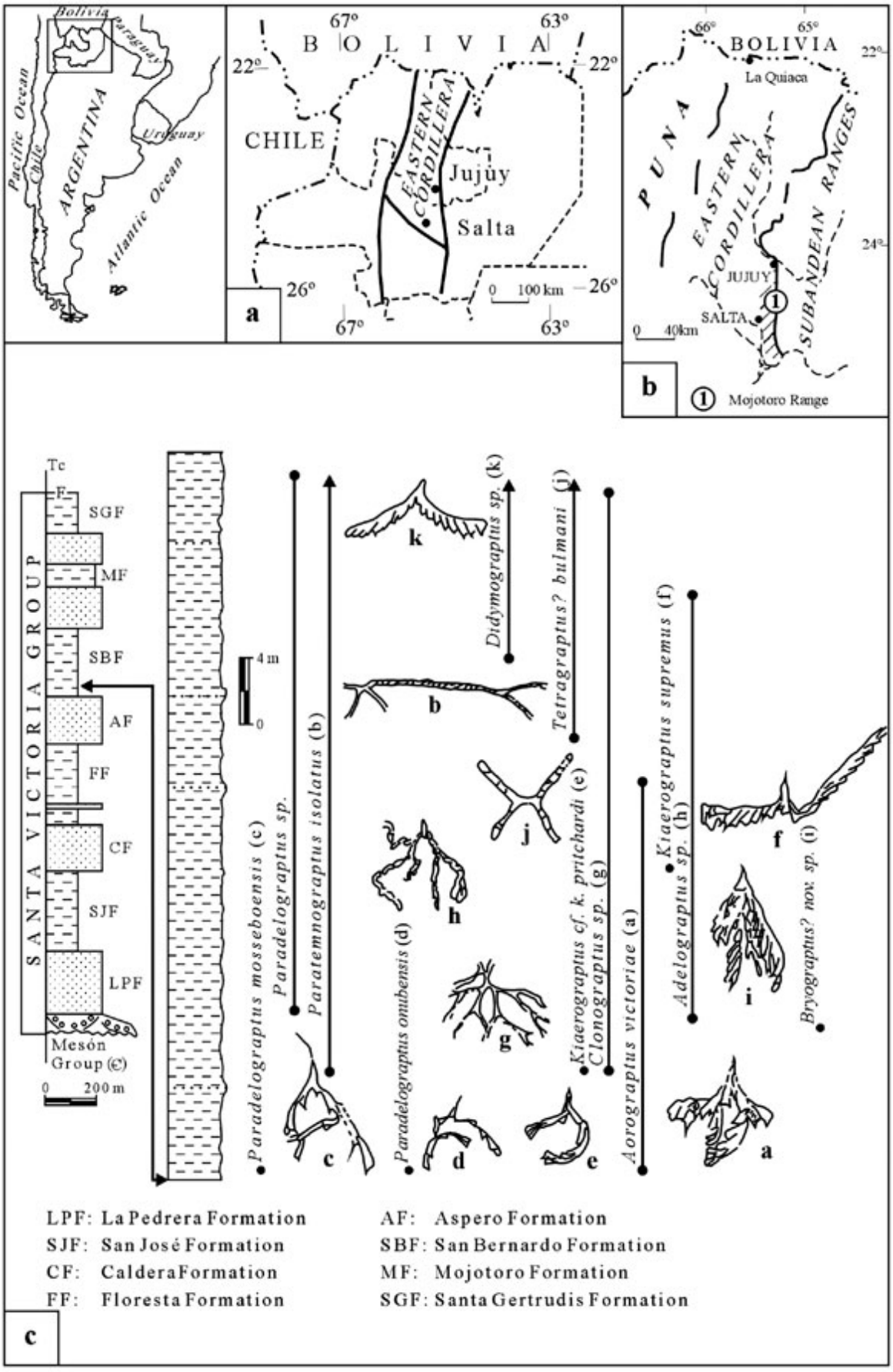

Figure 1. Location map and graptolite ocurrences of the San Bernardo Formation.

The specimens of *Aorograptus victoriae* of the SBF show a good preservation state. These show pendent or declined rhabdosomes with regular dichotomus branching. The specimens are mostly juveniles, however, they include some mature rhabdosomes preserved flattened in horizontal orientation. The sicula is large, more or less straight, measuring 1.8–2.0 mm long. The sicular aperture is 0.3 mm wide, with a pronounce rutellum.

Stipes average width 0.7 mm. Autothecae with concave ventral margin, flared aperture, thecal density 10 in 10 mm. Bithecae not observed (Figure 1c–a and Figure 2g.). CNS–I 125/790 (1–20).

This species occurrs usually together with *Paratemnograptus isolatus*. *A. victoriae* has a worldwide record. In Australia and Yukón (Canada) it appears with *P. antiquus* (Hall), featuring the lower part of the Lancefieldian 2 (La2). However, in Newfoundland it appears along with different species of *Kiaerograptus* and with *P. isolatus* (Williams and Stevens, 1991), all of which suggests a younger age inside the late Tremadocian (*fide* Cooper, 1999).

Paratemnograptus isolatus is mentioned for the first time in South America. This species is plentiful in the SBF interval herein discussed and together with *Tetragraptus? bulmani* (Thomas), its record extends until the first didymograptids appeared. *P. isolatus* is considered to be one of the most characteristic forms of the *A. victoriae Zone* in Newfoundland. The possible synonymy of *P. isolatus* with *T. decipiens* Hall has already been set forth (Williams and Stevens, 1991), though it is not yet resolved. The importance of this aspect lies in the question of the *T. decipiens* being mentioned not only in successions of the Upper Tremadocian (*A. murrayi / pulchellus* Zone), but also of the early lower Arenigian both in Australia and in North America.

P. isolatus of the SBF exhibits large rhabdosome with four to eight slightly flexuous, stipes increasing rapidly from 0.5 mm wide proximally to 1.5 mm maximum. Funicle width 2.5 mm. Thecae simple, overlap one half, thecal density 10 in 10 mm. Conspicuous three–dimensional, regularly alternated, bithecae have been observed along stipes (Figure1c–b and Figure2 h,j). CNS–I 125/793 (1–30).

Among the recovered paradelograptids, *Paradelograptus* sp. (CNS–I 125/791(5–7) is represented only by isolated stipes. However, being a very delicate form, *P. mosseboensis* and *P. onubensis* show a good preservation state and though they are not plentiful, they are recorded throughout the entire analyzed section. *P. mosseboensis* was defined in Sweden in beds corresponding to the *T. approximatus* Zone (Erdtmann *et al.*, 1987). A similar form to *P. mosseboensis* has recently been mentioned in the Argentine Precordillera, together with *T. approximatus* (Banchig and Moya, 2002). The presence of the *P. mosseboensis* inside the *A. victoriae* Zone makes the stratigraphic record of said species wider to include lower levels.

P. mosseboensis show rhabdosomes biradiate, multiramous, pendent or declined. Birfucations after first and third thecae. Sicula 2.1 mm long, more or less straight, reaching an apertural width of 0.46 mm, with a pronounce rutellum and nema. Origin of th11 from a position rather high in metasicula. The species of *P. mosseboensis* figured by Erdtmann *et al*, 1987 (Figure5 H) is identical to our specimen (Figure1c–c and Figure 2 a). CNS–I 125/791 (1).

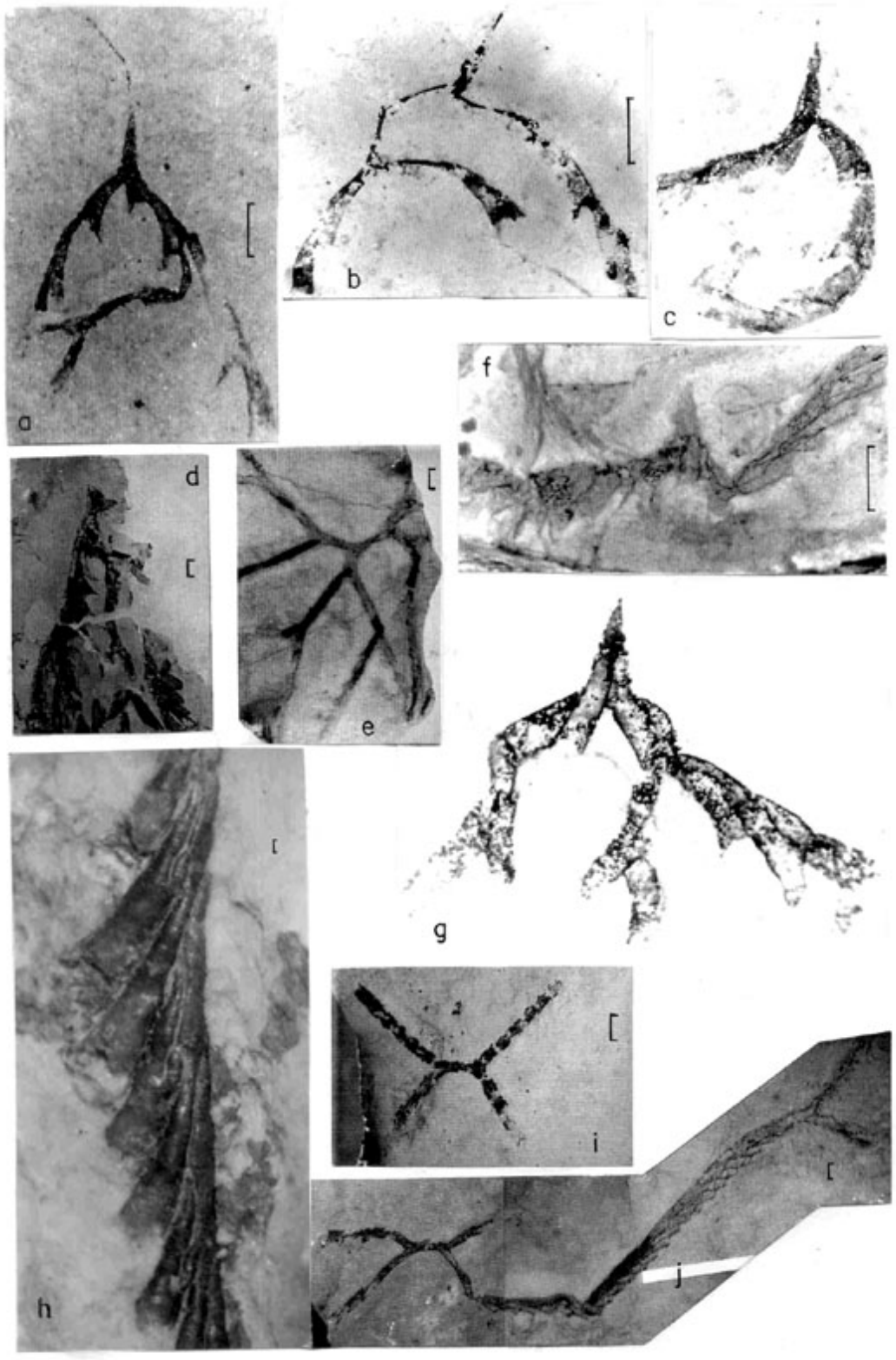

Figure 2. Graptolites of San Bernardo Formation. Scale bar : 1 mm. A, Paradelograptus mosseboensis Erdtmann, Maletz and Gutiérrez Marco. B, Paradelograptus onubensis Erdtmann, Maletz and Gutiérrez Marco. C. Kiaerograptus cf. pritchardi (Hall). D, Bryograptus? nov. sp. E, Clonograptus sp. F, Kiaerograptus supremus Linholm. G, Aorograptus victoriae (Hall). H, stipe of Paratemnograptus isolatus with bithecae. I, Tetragraptus? bulmani. J. Paratemngraptus isolatus Williams and Stevens.

Paradelograptus onubensis was recorded in Sweden together with the *T. phyllograptoides* and *T. approximatus*; however, in Spain it appears below those levels with *A. murrayi* (Hall) (Erdtmann *et al.*, 1987). The presence of *P. onubensis* in the Argentine Eastern Cordillera has recently been Formation, a lateral equivalent of the SBF. *P. onubensis* of the SBF include rhabdosomes biradiate, biramous to multiramous, declined. Sicula 0.9–1.0 mm long, 0.3 mm wide at metasicular aperture, with nema; thecae very long and slender. The prothecal portions are 0.5–07 mm long, each being continued by a 0.5–0.8 mm long metathecal portion and 0.3–0.4 mm wide at

the apertures (Figure1c–d and Figure2 b). CNS–I 125/791 (2–4).

Two species of *Kiaerograptus* have already been recognized. One of them, *K. Supremus* is herein mentioned for the first time from Argentina. The *K. supremus* is recorded in the south of Scandinavia, where it defines the homonymous zone and where it occurs together with *P. onubernsis* and *A. murrayi* (Lindholm, 1991). The same species was also discovered in the *A. murrayi* Zone in southern Bolivia (Maletz *et. al.,* 1999) *K.supremus* of the SBF show rhabdosome biradiate, composed of two reclined to declined stipes with 0.7 mm wide. Length of sicula 1.7 mm; sicular aperture width 0.38 mm. Thecal width at aperture is 0.45 mm. There are 13 thecae in 10 mm. Bitheca present at sicula, other bithecae apparently absent throughout stipes (Figure1c–f and Figure2 f). CNS–I 125/792 (2,3).

The specimens herein referred to as *Kiaerograptus* cf. p*ritchardi* include rhabdosome with two slender, gently declined stipes, 0.4–0.6 mm proximal width. The sicula is 1.5 mm long, gently curved, 0.23 mm wide at the aperture. Origin of th11 from a position rather high in metasicula. Bithecae have been observed along stipes, however sicular bitheca appear to be absent. Autothecae with slightly concave ventral margin and gently flared apertures (Figure 1c–e and Figure2c). CNS–I 125/792 (1). *Kiaerograptus pritchardi* is a worldwide form; the species was given a new definition as *Paradelograptus pritchardi* by Erdtmann *et al.* (1987).

The new form that we carefully assign to *Bryograptus?* nov. sp., stands out for the length and density of its thecae. The clonograptids and adelograptids are not frequently found, though they are present not only in the *Aorograptus victoriae* Zone, but also at higher levels, together with the *T.? bulmani* and the first didymograptids, which have not yet been analyzed in detail.

The graptolitic association mentioned above occurs together with articulate and inarticulate brachiopods, bivalves, cephalopods, gastropods, echinoderms and ostracods, and among microfossils there have been found conodonts, acritarchs and chitinozoans. We should also mention the trilobites, as all the forms found out can be considered typical examples of the "*Thysanopyge* Fauna". The species to be considered as reference forms include the following: *Thysanopyge argentina* Kayser, *Kayseraspis asaphelloides* Harrington, *K. brackebuschi* (Kayser) and *Sanbernardaspis pygacantha* Aceñolaza.

Conclusions

The temporal distribution of the main forms found, may lead us to consider a late upper Tremadocian age in the analyzed fossiliferous interval, during the time covered by the *Kiaerograptus* Zone and the lower part of the *A. murrayi/pulchellus* Zone according to the scheme of international zones suggested by Cooper (1999).

The graptolite assemblage of the SBF demonstrates a mixture of faunas, with specimens of Pacific and Atlantic affinity followed by pandemic forms and an endemic one that we carefully assign to a *Bryograptus*? nov. sp. The mixture pointed out turns out to be consistent with an intermediate paleolatitudinal position like the one generally accepted for the northwest of Argentina during the Ordovician.

The SBF interval bearing the Tremadocian graptolites herein discussed, represents the oldest record ever reported as regards to the *Thysanopyge* Fauna.

The Tremadocian–Arenigian boundary – which we hope that we can record it – would bear the interval covered between the fossiliferous succession herein discussed and the range levels of true didymograptids.

References

Banchig, A.L. and Moya, M.C. 2002. La Zona de *Tetragraptus approximatus* (Ordovícico Inferior) en la sierra del Tontal, Precordillera Occidental Argentina. *VIII Congreso Argentino de Paleontología y Bioestratigrafía, Resúmenes*, 83.

Cooper, R.A. 1999. Ecostratigraphy, zonation and global correlation of earliest Ordovician planktic graptolites. *Lethaia*, 32: 1–16.

Erdtmann, B.–D., Maletz, J. and Gutiérrez Marco, J.C. 1987. The new Early Ordovician (Hunneberg Stage) graptolite genus *Paradelograptus* (Fam. Kinnegraptidae), its Phylogeny and bioestratigraphy. *Palaontologische Zeitschrift*, 61:109–131.

Harrington, H.J. 1957. Ordovician Formations of Argentina. *In*: Ordovician Trilobites of Argentina.*University of Kansas, Special Publication*, 1: 22–39.

Jackson, D.E. and Lenz, A.C. 2.000. Some graptolites from the late Tremadoc and early Arenig of Yukon, Canada. Canadian Journal of Earth Science, 37: 1177–1193.

Lindholm, K. 1991. Ordovician graptolites from the early Hunneberg of southern Scandinavia. *Palaeontology,* 34 (2): 283–327.

Loss, R. 1951. Contribuciones al conocimiento de las faunas graptolíticas del norte argentino. I. Graptolites del cerro San Bernardo (Salta) y zona del dique La Ciénaga (Jujuy). Asociación Geológica Argentina, Revista, 6 (1): 21–61.

Maletz, J., Egenhoff, S. and Erdtmann, B.–D. 1999. Late Tremadoc to early Arenig graptolite succession of southern Bolivia. *In*: Kraft, P. and O. Fatka (eds.), *Quo vadis Ordovician?: Short papers of 8th International Symposium on the Ordovician System*, Acta Universitatis Carolinae, Geologica, Prague, 43 (1/2): 29–32.

Monteros, J.A. and Moya, M.C. 2002. La Zona de *Aorograptus victoriae* (Ordovícico Inferior) en la sierra de Mojotoro, Cordillera Oriental argentina. *VIII Congreso Argentino de Paleontología y Bioestratigrafía,Resúmenes*, 88.

Moya, M.C. 1998. El Paleozoico inferior en la sierra de Mojotoro, Salta–Jujuy. *Revista de la Asociación Geológica Argentina*, 53 (2): 219–238.

Moya, M.C., Malanca, S., Monteros, J.A. and Cuerda, A. 1994. Bioestratigrafía del Ordovícico Inferior en la Cordillera Oriental argentina basada en graptolitos. *Revista Española de Paleontología*, 9 (1): 91–104.

Ortega, G. and Albanesi, G.L. 2002. Bioestratigrafía de graptolitos y conodontes del Tremadociano Tardío de la Cordillera Oriental argentina. *XV Congreso Geológico Argentino*, *Actas*, 1: 542–547.

Williams, S.H. and Stevens, R.K. 1991. Late Tremadoc graptolites from western Newfoundland. *Paleontology*, 34:1–47.

Received: February 15, 2003

Accepted: June 15, 200