THE ORDOVICIAN CONODONT *TRAPEZOGNATHUS* LINDSTRÖM, 1955 IN THE ANDEAN BASIN, ARGENTINA

Carlorosi, Josefina M. T and **Heredia, Susana E.,** Argentina

With 5 figures and 1 table

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Abstract: The central Andean basin is characterized by the presence of Ordovician deposits, distributed mainly in Northwestern Argentina. Conodonts from the Lower and Middle Ordovician were recovered from several outcrops from the *Trapezognathus diprion* Zone, *Baltoniodus* cf. *B. triangularis, Baltoniodus triangularis* Zone, and among them the genus *Trapezognathus* is highlighted. This paper describes and illustrates two species of this genus: *T. diprion* (Lindström) and *T. quadrangulum* Lindström. In addition we report that the conodont association suggests faunal affinity with Baltica and South China.

Key words: Ordovician, *Trapezognathus*, Conodont, Andean Basin.

INTRODUCTION

The central Andean basin is characterized by the presence of Palaeozoic outcrops, distributed mainly in Northwestern Argentina. There the Ordovician siliciclastic are cropping out in many geological well studied regions of the Eastern Cordillera that were mentioned by HARRINGTON & LEANZA (1957).

Lower Ordovician conodont faunas from the Eastern Cordillera were previously mentioned and described by RAO (1994, 1999); RAO & HÜNICKEN (1995); RAO et al. (1991, 1994); MANCA et al. (1995); ALBANESI & ORTEGA (2002); ORTEGA & ALBANESI (2005), among others. Upper Floian conodonts were studied by RAO et al. (1994) who described and figured the new species *Trapezognathus argentinensis* RAO & HÜNICKEN 1994. ACEÑOLAZA et al. (2008) and CARLOROSI (2011, 2012) reviewed this last species described in Rao et al. (1994) pointing out that it is composed by a mixture of two species of *Trapezognathus*.

This paper deals with the stratigraphical record of the genus *Trapezognathus* in the Eastern Cordillera, describing the two species *T. diprion* (LINDSTRÖM 1955) and *T. quadrangulum* LINDSTRÖM 1955.

REGIONAL GEOLOGICAL SETTING

The Lower Paleozoic Central Andean Basin is developed in a large area covering southern Perú and the Eastern Cordillera and Subandean areas of Bolivia and Argentina. It is represented by a highly fossiliferous succession of siliciclastic material–dominated by sandstone and shale that has been considered as the most meaning Ordovician sequence worldwide, with over 10 km in thickness (SUÁREZ SORUCO 1992; ERDTMANN et al. 1995; EGENHOFF 2000) (Fig. 1).

This Ordovician basin was bounded by the Brazilian Shield to the east and the Pampean shield to the south-east. Sequences have provided abundant fossils whose chronostratigraphical resolution was relevant for an accurate international correlation. During the last 20 years an important amount of data has been put together and nowadays, a fairly acceptable general picture of the strata, fossils and ages is available (GAGNIER et al. 1996; SUÁREZ SORUCO 2000; ACEÑOLAZA 2002; BENEDETTO 2003; ERDTMANN et al. 1995).

Among the different paleontological elements, conodonts have to be highlighted due to their importance in the studies of the Cambro-Ordovician strata in South America. In the present work the studied conodonts were recovered from 1) the Zenta Range, 2) the Purmamarca region, 3) the Altos de Lipán section 4) Los Colorados, 5) Espinazo del Diablo and 6) the Mojotoro Range; all locations are in the Jujuy and Salta provinces, Argentina (Fig. 1).

Figure 1

Zenta

Conodonts have been recorded in the Acoite Formation at the 23°17´59,3´´S and 65°01´08´´W coordinates, where *Trapezognathus diprion* is accompanied by a conodont fauna composed by *Erraticodon* sp. and *B.* cf. *B. triangularis* (LINDSTRÖM 1955) among others. Conodonts are not abundant and preservation is variable, with frequent broken cusps and processes. This association has allowed dating the succession at Laguna Verde section (upper part) as late Lower to early Middle Ordovician. The Acoite Formation at this locality comprises sandstone associated to randomly interbedded coquinoid lenses and carbonate-cemented sandstone bearing conodonts and broken inarticulate brachiopods (HEREDIA & ACEÑOLAZA 2005) (Fig. 2).

Purmamarca – La Ciénaga

The studied section is located at 23° 42’ 01´´S and 65° 32’ 33´´W, near to the Purmamarca Village (Jujuy). There the Cieneguillas Formation (*ca*. 300 m thick) is cropping out, and the last 50 m is assigned by ACEÑOLAZA et al. (2008) to the Sepulturas Member. It is composed by greenish-yellow siltstone and grey-greenish sandstone which are pale yellow in outcrop, intercalated are levels of whitish quartz sandstone with brachiopods, nautiloids, and trilobites. Conodonts were recovered from these fossiliferous strata (CARLOROSI 2012). The presence of *T. diprion* and *Oepikodus intermedius* SERPAGLI 1974 indicated a Floian age for these deposits (ACEÑOLAZA et al. 2008) (Fig. 2).

Altos de Lipán

This section is cropping out in the eastern flank of the Altos de Lipán, Purmamarca (Jujuy), at 23º41´50´´S, 65º40´35´´W coordinates. There the strata are composed by sandstone with carbonate cement and siltstone alternated. ACEÑOLAZA et al. (2010) mentioned the Upper Ordovician ichnospecies *Phycodes flabellum* (MILLER AND DYER 1878) which appears along with reworked conodonts (Fig. 2).

Los Colorados

The strata cropping out at Los Colorados (Jujuy) has provided well preserved conodonts from the Acoite and Alto del Cóndor formations. The section is located at 23°31’56, 4´´S and 65°40’04, 3´´W. The succession is 2500 m thick but only the uppermost 300 m of the Acoite Formation and 120 m of Alto del Cóndor Formation have been studied.

The Acoite Formation is composed by alternating grey-greenish sandstone and green siltstone, to the top strata of grey sandstone are thicker with coquinoid levels and levels of siltstone are thin and few (Sandy Member of ASTINI & WAISFELD 1993). Trilobites, graptolites and conodonts are frequent (WAISFELD 1995; TORO 1997; CARLOROSI 2012). *T. diprion* and *Baltoniodus* cf. *B. triangularis* are uppermost Floian key species (Lower Ordovician) (CARLOROSI 2012) (Fig. 2).

The Alto del Cóndor Formation: The lower member is composed by a heterolithic succession of thick yellow sandstone and pale green siltstone. ASTINI et al. (2004)

interpreted these strata as deposited in estuarine environment. Bivalves and conodonts are present in the section (SÁNCHEZ & BENEDETTO 2007; CARLOROSI 2012). *Baltoniodus triangularis* (LINDSTRÖM 1955) indicates an early Dapingian age for this formation. *T. diprion* (late stage) and *T. quadrangulum* (early stage) were recovered from the same sample (MS4) (Fig. 2).

Espinazo del Diablo

The section at the Espinazo del Diablo is located at 23°12'57´´S and 65°36'34, 4´´W. There, the Acoite Formation is cropping out near the Las Colas stream with *ca*. 80 m thick of dark grey sandstone with carbonate cement, dark grey sandstone and green siltstone alternating with coquinoid lenses (brachiopods, conodonts, nautiloids and trilobites). At the top fossiliferous sandstone strata are intense purple red color (CARLOROSI 2012). *T. diprion* characterizes these strata, indicating an upper Floian age (Fig. 2).

Mojotoro Range

Southwards in the Mojotoro Range of the Salta province (Fig. 2), Ordovician sandstone and siltstone of the Santa Gertrudis Formation yield conodonts (SARMIENTO & RAO 1987, MOYA et al. 2003). This conodont fauna has been assigned as Middle-Upper Ordovician by ALBANESI et al. (2007); later CARLOROSI et al. (2011) proposed this deposit as reworked due the presence of early Middle Ordovician conodont species with the Sandbian conodont *Erismodus quadridactylus* (STAUFFER 1935) (SARMIENTO & RAO 1987). *T. quadrangulum* is a common species among the conodont fauna. This conodont fauna is under study.

Figure 2

CONODONTS

Elements of *Trapezognathus diprion* and *T. quadrangulum* documented in this contribution were recovered from 20 samples (Table 1) from sections mentioned above (Fig. 2). Most of the elements recovered are well preserved (non altered) with a CAI of 1.5 - 2 (See

EPSTEIN et al. 1977 for explanation of index); a few conodont elements from the lower member of the Alto del Cóndor Formation are bleached and are texturally altered due to the original depositional environment, which is interpreted as result of an strong environmental restriction and subaerial exposition (ASTINI et al. 2004; MESTRE & CARLOROSI 2011).

The following species are accompanying specimens of *Trapezognathus* in different sections, including *Baltoniodus triangularis* (LINDSTRÖM 1955), *Baltoniodus* cf. *B. triangularis* (LINDSTRÖM 1955), *Baltoniodus* sp. A, *Drepanodus arcuatus* PANDER 1856, *Drepanodus* sp., *Drepanoistodus basiovalis* (SERGEEVA 1963), *Drepanoistodus costatus* (Abaimova, 1971), *Drepanoistodus forceps* LINDSTRÖM 1955, *Drepanoistodus* sp. A, *Drepanoistodus.* sp. B, *Erraticodon patu* COOPER 1981, *Gothodus costulatus* LINDSTRÖM 1955, *Oistodus* sp., *Triangulodus* sp. and *Triangulodus*? sp. These species allow recording the late Lower Ordovician with the *T. diprion* Zone and the early Middle Ordovician by the presence of the key conodont *Baltoniodus triangularis* (Lindström 1955) (CARLOROSI 2012) (Table 1).

Table 1

An analysis of the conodonts recorded in the studied sections suggests affinities with the Faunal Provinces of Baltica and South China (*Baltoniodus triangularis, Baltoniodus* cf. *B. triangularis*, *Trapezognathus diprion* and *T. quadrangulum*), which integrate the Shallow-Sea Realm of the Temperate-Cold Domain (ZHEN & PERCIVAL 2003). The presence of *Erraticodon patu* reveals a peculiar Australian Province affinity (Cooper 1981, Zhen et al. 2003), whereas the additional forms such as *Gothodus costulatus*, *Drepanodus* sp., *Drepanoistodus basiovalis*, *Oistodus* sp. and *Triangulodus* sp., among others have cosmopolitan distributions.

SYSTEMATIC PALAEONTOLOGY

Conventional notation system was used in the systematic research (SWEET 1981, 1988), which presents the spatial positions M, S and P, from the anterior extreme to the posterior one of the multielemental apparatus. Corresponding subpositions of the symmetry were also considered, and do not necessarily reflects location within the oral cavity of the conodont animal

All illustrations shown in Figures 3 and 4 are SEM photomicrographs of conodonts captured digitally. Collections are related to their localities in Table 1. Figured specimens are deposited in the Collection of Lillo-conodonts microvertebrates under the symbol CML-C. Sample localities are shown in Figure 1; further details of these sites were provided earlier in the paper.

Class Conodonta PANDER 1856

Order Prioniodontida DZIK 1976

Family Balognathidae LINDSTRÖM 1971

Genus *Trapezognathus* LINDSTRÖM 1955

Type species*:* *Trapezognathus quadrangulum* LINDSTRÖM 1955

Diagnosis: The multielement apparatous of the genus *Trapezognathus* Lindström was described by STOUGE & BAGNOLI (1990): “The *Trapezognathus* Lindström apparatus is septimembrate, with pectiniform P elements, geniculate M elements and a complete series of S elements (alate, tertiopedate, bipennate, quadriramate). P elements are adenticulated to weakly denticulated. M element is adenticulated to denticulated and the cusp forms an angle about 90º with the upper margin of the base. S elements are stubby, with a base higher than the cusp, weakly denticulated to denticulated. All elements are albid and have a deep basal cavity and large basal sheath”.

Remarks: When STOUGE & BAGNOLI (1990) and BAGNOLI & STOUGE (1997) organized the apparatus of this genus, they recognized Pa and Pb elements virtually indistinguishable from each other. LÖFGREN & ZHANG (2003) described Pa elements of *T. quadrangulum* following VIIRA et al. (2001), proposing that the origin of a lineage of platform-equipped conodonts began with *Trapezognathus*. This statement confirms that the apparatus of *Trapezognathus* includes a pastiniscaphate element (Pa) which was not recognized by BAGNOLI & STOUGE (1997).

Following this interpretation, we identify the Pa element which is described below for each of the species. On the other hand the Pb element adheres strictly to that described by STOUGE & BAGNOLI (1990) and BAGNOLI & STOUGE (1997) as Pa and Pb elements. These authors did not report these Pa forms in their Baltic collections and they based their classification of P elements on subtle morphological differences.

The synonymic lists applied to both species described in this paper are based on STOUGE & BAGNOLI (1990) and BAGNOLI & STOUGE (1997), introducing the mention of studies related to the elements reconsidered as part of these species.

Trapezognathus diprion (LINDSTRÖM 1955)

Fig. 3

1955 *Prioniodina diprion* n. sp. LINDSTRÖM, p. 587, pl. 5, fig. 43.

1971 *Gothodus costulatus* Lindström - LINDSTRÖM, pp. 54-55 (*partim*), pl.1, figs 1-3 only.

1974 *Prionodus navis* Lindström - VAN WAMEL, pp. 89-90 (*partim)*, pl. 8, figs 13, 15 only.

1977 *Baltoniodus crassulus* (Lindström); LINDSTRÖM *in* Ziegler, pp. 69-70 (*partim*), *Baltoniodus* pl. 1, fig. 3 only.

1994 *Trapezognathus argentinensis* Rao & Hünicken, RAO et al., p.73, lám. III, figs 7, 14.

1997 *Trapezognathus diprion* (Lindström); BAGNOLI & STOUGE, pp. 159-160, pl. 7, figs 1-8.

1999 *Trapezognathus argentinensis* Rao & Hünicken, RAO, p. 46, pl. 9, fig. 6.

2008 *Trapezognathus diprion* (Lindström); ACEÑOLAZA et al., p.152, fig. 4, A-B.

2010 *Trapezognathus diprion* (Lindström); LI et al., p. 119-120, pl. I, figs. 4, 11, 13?

Material*:* 10 Pa, 27 Pb, 37 Sa, 28 Sb, 19 Sc, 48 Sd, 48 M, 1 fragment of P, 4 fragments of S elements and 2 of M elements. CML-C 5030 (1-7), 5016 (1-6), 5021(1-3), 5023(1), 5033(1-3), 5042(1-30), 5051(1), 5055(1), 5059(1-2), 5061(1), 5064(1-8), 5066(1-3), 5069(1), 5074(1-2), 5089(1-139), 3001(1-3). The species occurs in the Sepulturas Member of the Cieneguillas Formation, upper part of Acoite Formation and the upper and lower members of the Alto del Cóndor Formation (Fig. 2). This species characterizes the *Trapezognathus diprion* Zone, Upper Floian (Lower Ordovician) and it is recorded in the *Baltoniodus triangularis* Zone, Dapingian (Middle Ordovician) in this report. This species is also recorded in same interval in the Huanghuachang region by LI et al. (2010).

Description*:* Pa element: pectiniform scaphate form. It presents a thin and triangular cusp from which three processes are developed, one anterior, one lateral and one posterior. The anterior and the lateral process have an angle of about 80° in primitive forms (Fig. 3C- D) to 120° in advanced forms (Fig. 3G); both processes have well-marked ribs but they differ in length; the anterior one being longer. The posterior process, which is the most developed one among the three, has small denticles that become more pronounced distally. The three processes are connected by the basal sheath. The basal cavity is deep which decreases in advanced forms, running through the three processes internally (Fig. 3B-E, G, I, J).

Pb element: This element is pectiniform and characterized by a proclined, small and robust cusp, there are three different ribs that are developed in to processes, the posterior one is short and concave from a posterior view and can has denticles at the end, the lateral process is longer and is directed backwards while the anterior one is curved at the junction between the apex and base and continues straight downward. The basal cavity is wide and the basal sheath is wavy and connects the three processes (Fig. 3A, F, H, K, L).

M element: This element displays a straight and proclined cusp with a sharp angle of 90º relative to the base. In anterior view, a well-defined rib extends along the cusp, projecting as a short anterior process. In posterior view, a small rib emerges where the base starts and undulates with the basal sheath. The basal cavity is wide. The upper anterior and posterior edges bear denticles on either one or both sides (Fig. 3M).

S elements

Sa element: Element with a stubby and proclined cusp from which emerge two lateral ribs that creates two processes under the base line, they are finely denticulate. The posterior margin has a weak rib (Fig. 3N).

Sb element: Element with a curved and elongated cusp, from which two lateral ribs are developed that originates two processes with a few small denticles. On the inner side of the element, the upper margin of the base has well-developed denticles. The base is wide and the basal sheath connects the processes (Fig. 3O).

Sc element: This element shows a shorter cusp than in the Sb element previously described, and is widely curved backward. From this cusp emerges lateral ribs that develop into finely denticulate lateral processes; the anterior margin of the cusp projects into a short process; the basal cavity is wide (Fig. 3P).

Sd element: Presents a short and small cusp, curved backwards, four ribs cut across the cusp and extend beyond the aboral margin forming finely denticulate processes; these processes provide the element with a quadrate section. The basal sheath links them all (Fig. 3Q).

Figure 3

Trapezognathus quadrangulum LINDSTRÖM 1955

Fig. 4

1955 *Trapezognathus quadrangulum* nov. sp. Lindström p. 598 (*partim*), pl. 5, fig. 38, 39 only.

1955 *Prioniodus triangularis* nov. sp. LINDSTRÖM, pp. 591-592 (*partim*), pl. 5,fig. 45 only.

?1955 *Prioniodus navis* nov. sp. LINDSTRÖM, pp.590-591, (*partim*), pl. 5, figs. 31, 32, only.

1974 *Prionodus navis* Lindström, VAN WAMEL, pp. 89-90, pl. 8, figs 10, 11.

1978 *Prionodus* (*Baltoniodus*) *triangularis* Lindström, LÖFGREN, pp. 81-82, pl. 12, figs 1-7.

1990 *Trapezognathus quadrangulum* Lindström, STOUGE & BAGNOLI, pp. 26-27, pl. 10, figs 1-5, 7-10. Complete synonymy herein.

1994 *Trapezognathus argentinensis* Rao & Hünicken, RAO et al., p.73, lám. III, figs 11 a, 9 a-c, lám. VII, figs 1, 3, 5.

1995? *Lenodus* sp. A, LÖFGREN, fig. 9, j-n.

1997 *Trapezognathus quadrangulum* (Lindström); Bagnoli & Stouge, p. 160, pl.8, figs 1-8.

2001 *Trapezognathus quadrangulum* Lindström, VIIRA et al., fig. 6 c-f.

Material*:* 4 Pa, 6 Pb, 38 Sa, 60 Sb, 33 Sc, 38 Sd and 29 M elements, plus 1 S fragment. Occurrence: obtained from the Alto del Cóndor Formation, Chamarra Creek (sample MS4). CML-C 5090(1-201). Altos de Lipán section (sample L14), CML-C 1035 (1-2). Santa Gertrudis Formation (samples SG3, SG5 and SG7), CML-C 5100 (1-6) (Fig. 2). Middle Ordovician – Dapingian. According to LÖFGREN & ZHANG (2003), the vertical range of this species is from the *B. navis* Zone to the *L. antivariabilis* Zone; this report expands the record to the lower part of the *B. triangularis* Zone appearing in coexistence with its direct predecessor *T. diprion*.

Description: Pa element is pectiniscaphate with a short and stubby cusp and indistinct in plan view. Three well-defined ribs extend as short processes (lateral, anterior and posterior) from the base of the cusp: the lateral process is shortest and the posterior is longest. The upper edges of the processes show evidence of denticles. A fourth rib forms a small lobe on the postero-lateral side. The basal sheath is expanded, linking the processes and giving the element a rectangular shape in plan view. The basal cavity is excavated and extends as grooves under the processes.

From the study areas were recovered primitive forms and advanced forms. Primitive pastiniscaphate Pa element (Fig. 4A, B) was recovered from the Alto del Cóndor Formation (MS4), *B. triangularis* Zone. Advanced Pa elements (Fig. 4C, D) were recovered from Altos de Lipán section and Santa Gertrudis Formation. These elements are also pastiniscaphate but the basal sheath has lower amplitude mainly in its middle part than in the stratigraphically older Pa element described above; besides the lateral lobe is further developed, the posterior process is longer and has blunt denticles. This element has similar characters to the Pa element figured by VIIRA et al. (2001).

Pb element: This element has a robust, short and straight cusp with an angle of about 100° between the upper edge of the base and the inner side of the cusp. Three strong ribs emerge from the apex of the cusp and form a lateral, an anterior and a posterior process. The first is relatively long and has a keel at the upper margin, the anterior is shorter, with a keel denoted by rudimentary denticles on its upper edge, whereas the posterior is the longest, and is directed backward. The basal cavity is wide, deep and reaches the apex of the cusp. The basal sheath is well developed and links the three processes with a well-marked undulation (Fig. 4E- H).

M element: This is a particular element because its morphology is very similar in the species of the genus *Trapezognathus* and also *Baltoniodus* cf. *B. triangularis* and *B. triangularis* (LI et al. 2010; CARLOROSI 2012). It is a geniculate element with a short and stubby cusp from which emerges extensions anteriorly and posteriorly, which may or may not have denticles on their edges, presenting the possibility that only the posterior has it, just the anterior or both. The basal cavity is excavated and concave (Fig. 4I).

S elements: These elements are characterized by serrated edges of the processes, or evident denticles, their cusps are thin and graceful.

Sa element: This element has a slender and thin strongly recurved cusp. Fine ribs run down it from the apex and persist as small extensions beyond the aboral margin. Each of these (anterior, posterior and lateral extensions) has multiple blunt denticles. The basal cavity is deep and has a triangular cross-section; the basal sheath connects the processes. This element is almost indistinguishable from the Sa element of *Trapezognathus diprion* (Fig. 4J).

Sb element: This element is similar to the Sa element, with a curved cusp bearing three ribs that form three processes that extend beyond the basal margin. These extensions are denticulate and are connected by the basal sheath. The Sb elements differ by virtue of their slight asymmetry and lateral compression from those described above (Fig. 4K).

Sc element: Element with proclined to curved cusp, two ribs are developed at the sides of the cusp that originate the lateral processes bearing denticles directed inwards. The element has a strong curvature so that the outer side is convex and the inner is concave. The base has a higher development than the cusp and is deeply excavated. The basal sheath connects the processes (Fig. 4L).

Sd element: This element has a recurved cusp, furrowed by four ribs that extend basally to form four denticulate processes connected laterally by the basal sheath. The element has a slight asymmetry (Fig. 4M).

Figure 4

Discussion on Taxonomy

BAGNOLI & STOUGE (1997) defined the apparatus of this genus as composed of elements P, S and M. The Pa elements figured and described by these authors are however, different from those recovered in the areas of study of this work, mainly in terms of pastiniscaphate Pa element of both species described here. LÖFGREN & ZHANG (2003) recognized pastiniscaphate Pa elements in their collections from Sweden which follow the same architectural design in the Pa element of *T. quadrangulum* figured by VIIRA et al. (2001).

The morphological features presented by the elements linking the genus *Trapezognathus* to the Balognathidae family confirms the idea proposed by STOUGE & BAGNOLI (1999). This work suggests that Pa and Pb forms can be used as diagnostic for recognition of the *T. diprion* and *T. quadrangulum* species.

Late Pa elements of T. *diprion* (Fig. 5) have been recovered from the upper member of the Alto del Cóndor Formation suggesting a morphological transition to Pa elements of *T. quadrangulum.* As it is referred in previous paragraphs, the recovered Pa element of *T. quadrangulum* from the Alto de Cóndor Formation suggests primitive characters when compared to the Pa elements from Altos de Lipán section and Santa Gertrudis Formation (Fig. 5). We compared our material to those figured by VIIRA et al. (2001) concluding that this Baltic Pa element represents a more advanced form. LÖFGREN & ZHANG (2003) proposed that *Trapezognathus* is the ancestor of one group of platform equipped conodonts such as *Lenodus-Yangtzeplacognathus-Eoplacognathus* from Middle Ordovician strata.

Figure 5

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Addresses of the authors:

DR. CARLOROSI JOSEFINA, INSUGEO-CONICET. Miguel Lillo 205, (4000) Tucumán, Argentina. josefinacarlorosi77@gmail.com

DR. HEREDIA SUSANA, CIGEOBIO-CONICET and Instituto de Investigaciones Mineras, Facultad de Ingeniería, Universidad Nacional de San Juan. Urquiza y Libertador, (5400) San Juan, Argentina. sheredia@unsj.edu.ar

Figures

Fig. 1. Location map of the studied localities and others mentioned in text. The gray areas represent Lower Paleozoic sequences.

Fig. 2. Stratigraphic sections mentioned in text. Collected and studied samples at right. Samples ED from the Acoite Formation, Espinazo del Diablo section; samples Ac from the Acoite Formation in Chamarra section in Los Colorados locality; samples MI and MS from the Alto del Cóndor Formation in Los Colorados locality; sample L14 no nominate unit in Altos de Lipán section; samples SG from the Santa Gertrudis Formation in Sierra de Mojotoro; samples PcF from La Ciénaga section in Purmamarca locality; sample LV from the Acoite Formation in Zenta.

Table 1: Recovered key species from sections mentioned above.

Fig. 3. **A-Q**. SEM Microphotographs of *T. diprion* (LINDSTRÖM 1955) All specimens with bar scale 0.1 mm. A-F *Trapezognathus diprion* Zone, Cieneguillas and Acoite formations, upper Floian. G-H, M-Q *Baltoniodus triangularis* Zone, Alto del Cóndor Formation, lower Dapingian. I-L *Baltoniodus* cf. *B. triangularis* Zone, Zenta, Upper Floian. A- Pb element, lateral view, sample PcF1, Sepulturas Member, Cieneguillas Formation, La Ciénega locality 1015(1); B- Pa element, upper view, sample PcF 1, Sepulturas Member, Cieneguillas Formation, La Ciénega locality 1015(2); C- Pa element, upper view, sample ED1, Acoite Formation, Espinazo del Diablo 5030(1); D- Pa element, upper view, sample ED5, Acoite Formation, Espinazo del Diablo, CML-C 5033(2); E- Pa element, lateral view, sample ED1, Acoite Formation, Espinazo del Diablo, CML-C 5030(2); F- Pb element, lateral view, sample ED1, Acoite Formation, Espinazo del Diablo, 5030(3); G-Pa element, upper view, sample MS4, Alto del Cóndor Formation, Los Colorados, CML-C 5088(1); H- Pb element, lateral view, sample MS4, Alto del Cóndor Formation, Los Colorados, CML-C 5088(4). I, J- Pa element, upper and antero-laterl view,sample LV12, Acoite Formation, Zenta, CML-C 3001(3); K- Pb element, lateral view, sample LV12, Acoite Formation, Zenta, CML-C 3001(1); L- Pb element, lateral view, sample LV12, Acoite Formation, Zenta, CML-C 3001(2); M- M element, lateral view, sample MS4, Alto

del Cóndor Formation, Los Colorados, CML-C 5088(16); N- Sa element, posterior view, sample MS4, Alto del Cóndor Formation, Los Colorados, CML-C 5089(56); O- Sb element, lateral view, sample MS4, Alto del Cóndor Formation, Los Colorados, CML-C 5089(89); P- Sc element, lateral view, sample MS4, Alto del Cóndor Formation, Los Colorados, CML-C 5089(112); Q- Sd element, lateral view, sample MS4, Alto del Cóndor Formation, Los Colorados, CML-C 5089(125).

Fig. 4. A-M- SEM Microphotographs of *Trapezognathus quadrangulum* LINDSTRÖM 1955. All specimens with bar scale 0.1 mm. *B. triangularis* Zone, Alto del Cóndor Formation, Los Colorados region, Altos de Lipán section, and Santa Gertrudis Formation, Mojotoro Range, (Middle-¿Upper Ordovician). A, B- Primitive Pa element, upper views, sample MS4, Alto del Cóndor Formation, Los Colorados, CML- C 5090(1); C, D- Pa elements, upper views, sample L14, Altos de Lipán section, CML-C 1035(1-2); E, F- Pb elements, postero-lateral and lateral views, sample MS4, Alto del Cóndor Formation, Los Colorados, CML-C 5090(2); G, H- Pb elements, lateral and latero-anterior views, sample SG 3, Santa Gertrudis Formation, Mojotoro Range, CML-C 5100(1-2); I- M element, lateral view, sample MS4, Alto del Cóndor Formation, Los Colorados, CML-C 5090(4); J- Sa element, postero-lateral view, sample MS4, Alto del Cóndor Formation, Los Colorados, CML-C 5090(34); K- Sb element, postero-lateral view, sample MS4, Alto del Cóndor Formation, Los Colorados, CML-C 5090(94); L- Sc element, postero-lateral view, sample MS4, Alto del Cóndor Formation, Los Colorados, CML-C 5090(127); M- Sd element, postero-lateral view, sample MS4, Alto del Cóndor Formation, Los Colorados, CML-C 50 90(166).

Fig. 5. Proposed evolution from base to top of diagram of the Pa element of the genus *Trapezognathus* in the uppermost Lower Ordovician and lower Middle Ordovician of the Andean basin. Scheme of *T. quadrangulum* at the top, this element was recovered from the Altos de Lipán section (ACEÑOLAZA et al. 2008).

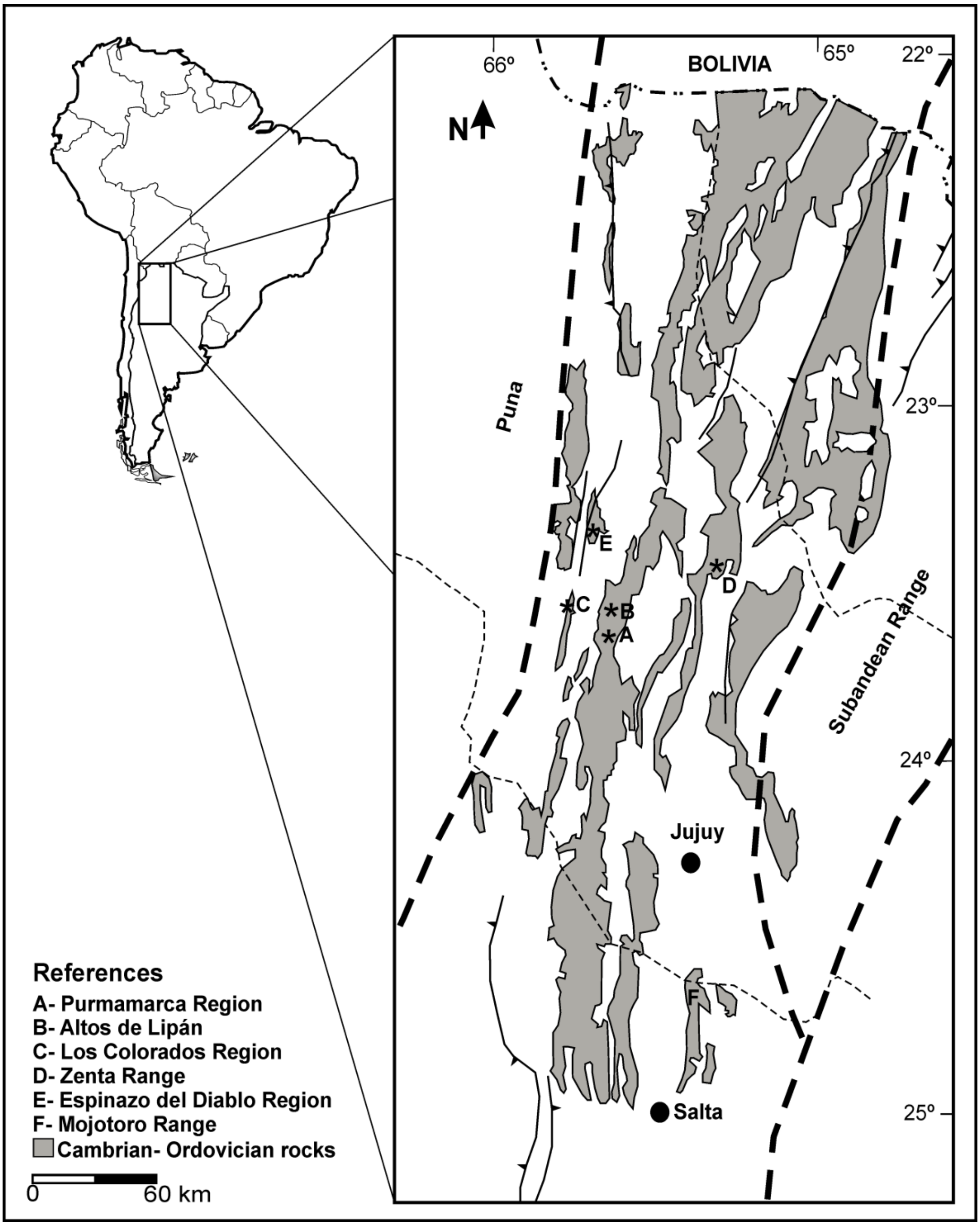

Fig. 1 – Carlorosi & Heredia.

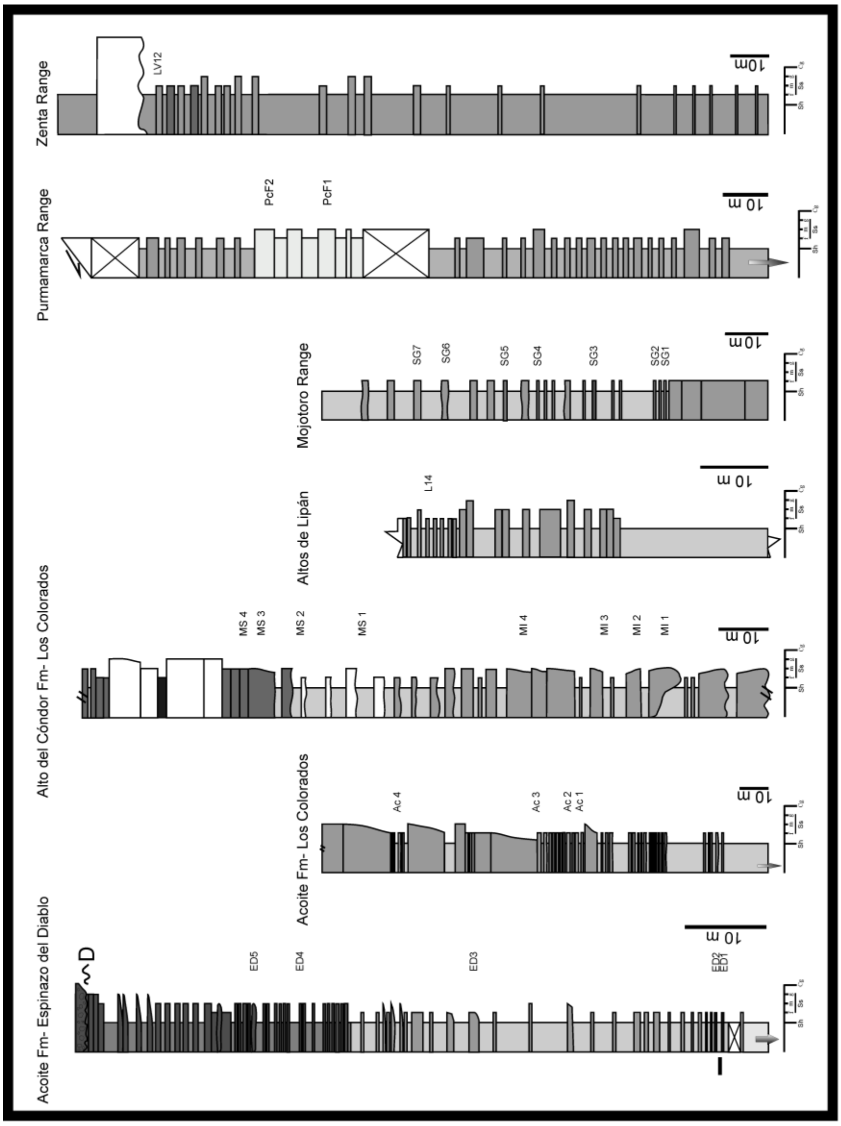

Fig. 2 - Carlorosi & Heredia

Samples	key species				
	Baltoniodus sp. A	*Baltoniodus* cf. *B. triangularis*	*Baltoniodus triangularis*	*T. diprion*	*T. quadrangulum*
ED1				8	
ED2				6	
ED3				3	
ED4				1	
ED5	3			3	
Ac1		2		30	
Ac2				1	
Ac3				1	
Ac4				2	
Pcf1				3	
Pcf2				1	
MI1				1	
MI2			1	1	
MI3				3	
MI4				1	
MS1		2	5	3	
MS4		27	319	139	201
L14			2		2
SG7			12		3
SG3			3		3
LV12		1	1	4	

Table 1 - Carlorosi & Heredia

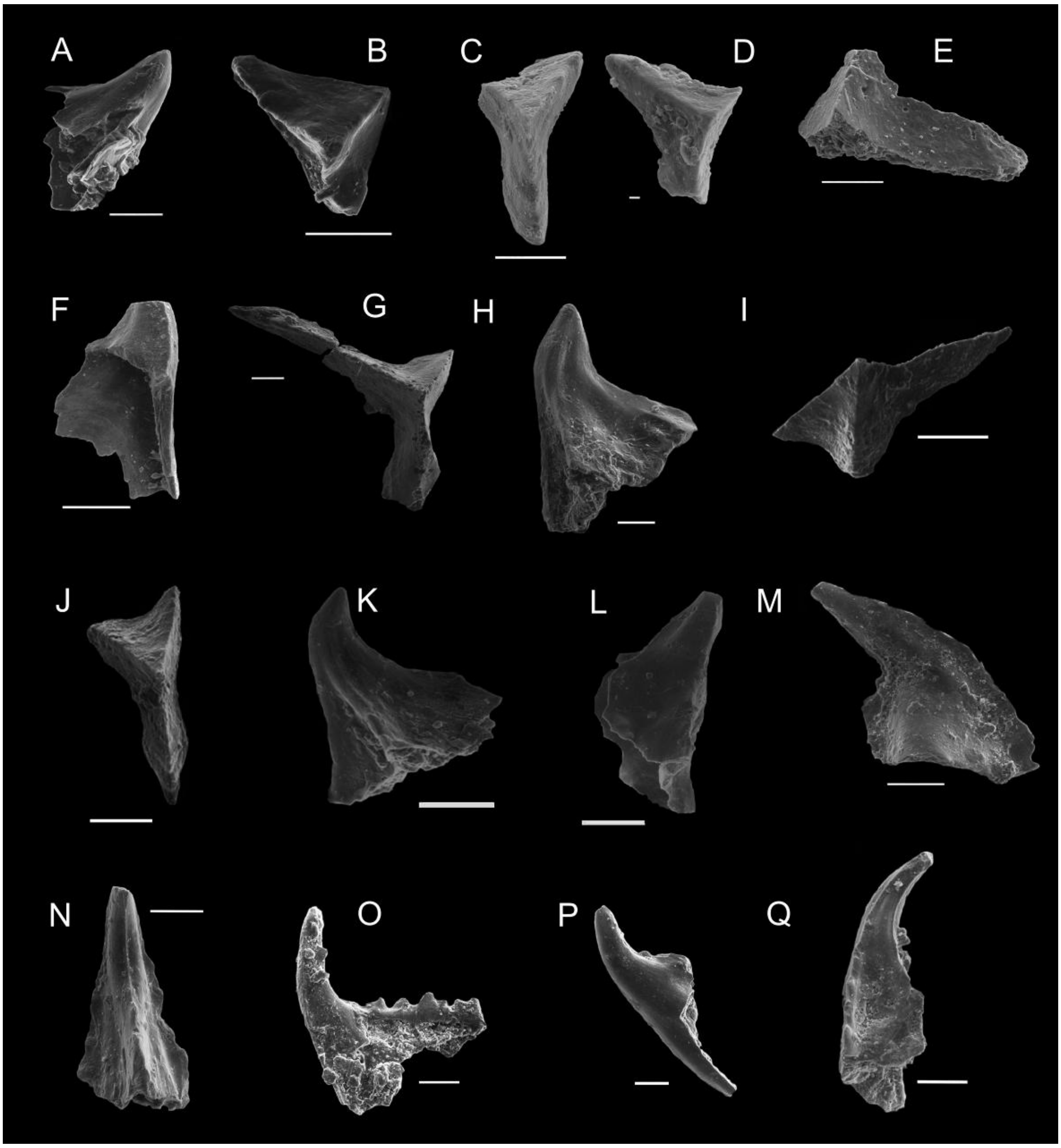

Fig. 3 – Carlorosi & Heredia

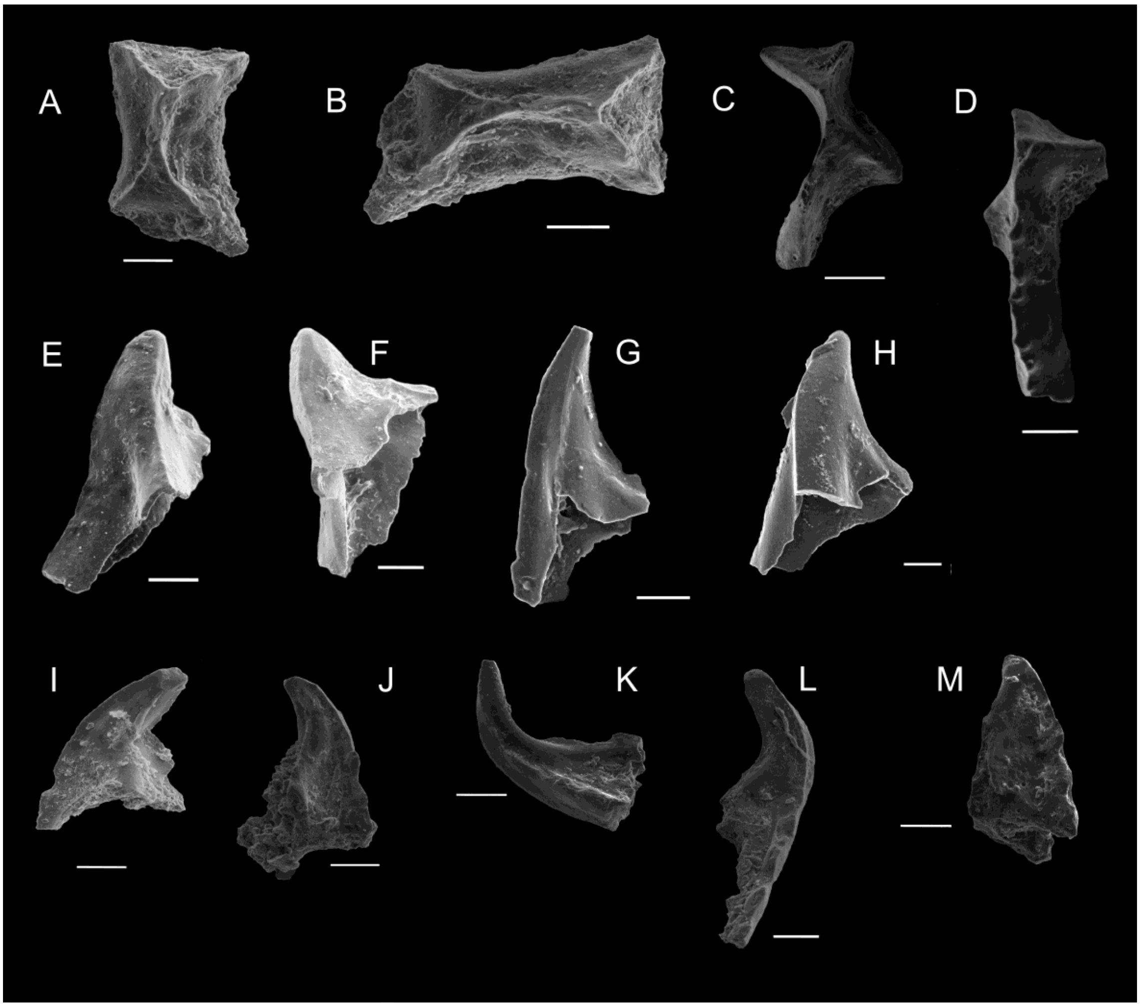

Fig. 4 – Carlorosi & Heredia

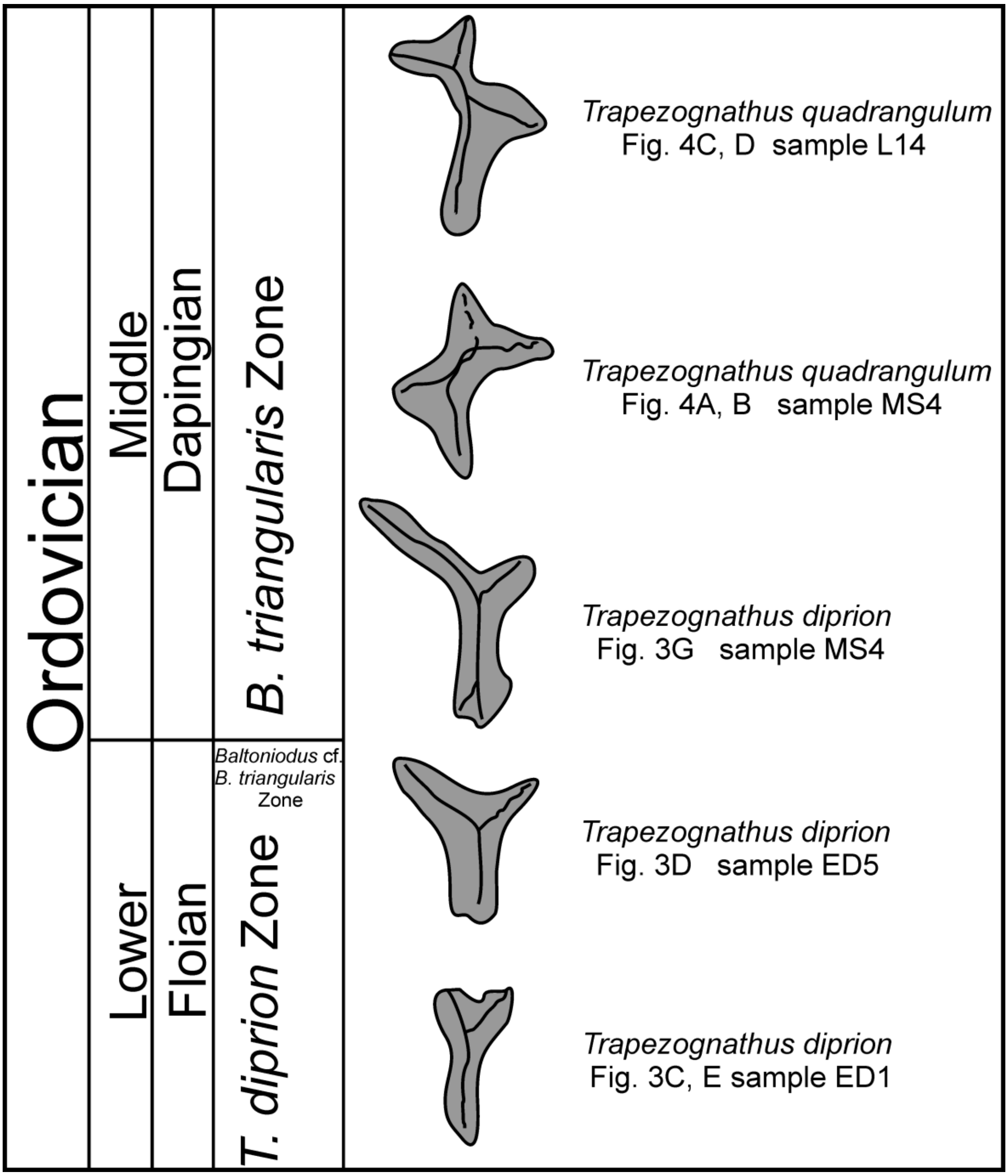

Fig. 5 – Carlorosi & Heredia