Journal of South American Earth Sciences 45 (2013) 224–234

Contents lists available at SciVerse ScienceDirect

Journal of South American Earth Sciences

journal homepage: www.elsevier.com/locate/jsames

Stratigraphical distribution of the Ordovician conodont *Erraticodon* Dzik in Argentina

S. Heredia [a,*], J. Carlorosi [b], A. Mestre [a], T. Soria [a]

[a] CONICET – CIGEOBIO – Universidad Nacional de San Juan, Facultad de Ingeniería, Instituto de Investigaciones Mineras, Urquiza y Libertador, 5400 San Juan, Argentina
[b] Instituto Superior de Correlación Geológica, (CONICET-UNT), Miguel Lillo 205, 4000 San Miguel de Tucumán, Argentina

ARTICLE INFO

Article history:
Received 31 August 2012
Accepted 22 March 2013

Keywords:
Ordovician
Conodonts
Erraticodon
Argentina

ABSTRACT

Three different species of the Ordovician genus *Erraticodon* Dzik are described and illustrated. *Erraticodon patu* Cooper is reported from the Lower–Midde Ordovician strata of the Acoite and Alto del Cóndor formations. *E.* cf. *Erraticodon balticus* and *Erraticodon hexianensis* from Middle Ordovician carbonate deposits of the San Juan Formation are analyzed and compared to specimens of these species from Australia, China, Newfoundland, and Baltica. *E. patu* and *E. hexianensis* are recorded for first time in the San Juan Formation of Precordillera. The elements of *E.* cf. *E. balticus* resemble closely *E. balticus* Dzik but lack the important denticle on the posterior process of the S elements. An evaluation of the stratigraphic occurrences of these species relative to those of key Lower and Middle Ordovician conodont species such as *Trapezognathus diprion* Lindström, *Oepikodus intermedius* Serpagli, *Baltoniodus triangularis* (Lindström), *Baltoniodus navis* Lindström, *Yangtzeplacognathus crassus* (Chen and Zhang) and *Eoplacognathus pseudoplanus* (Viira) indicates they value for biostratigraphic correlation.

1. Introduction

Hyaline conodonts of the genus *Erraticodon* belong to the Family Chirognathidae Branson and Mehl (1944), within the Order Prioniodinida Sweet (1988). The genus *Erraticodon* has been recorded in Floian to Darriwilian strata of Australia, Baltica, Midcontinent USA, South-Central China and Argentina (Zhen et al., 2003; Stouge, 1984; Zhang, 1998; Rasmussen, 2001; Albanesi, 1998; Lehnert, 1995; Mestre, 2010; Carlorosi, 2012). Therefore, it is present in several biogeographical conodont provinces. Zhen et al. (2003) analyzed the global distribution of *Erraticodon* and concluded that *Erraticodon patu* (then regarded as an exclusively Australian conodont) is the oldest species of the group, but also suggested that some specimens assigned to *E. patu* require further study. *Erraticodon* is interpreted to have had thrived in shallow and warm sea waters with sandy sea floors, because it is abundant in sandy beds with disarticulated macrofauna (Sweet, 1981; Stouge, 1984; Albanesi et al., 2005; Carlorosi, 2012).

Elements of the genus *Erraticodon* are not common in Ordovician conodont faunas of Argentina. They have been mentioned by Lehnert (1995), Albanesi (1998), Albanesi and Vaccari (1994), Sarmiento (1990), Mestre (2010), among others. Carlorosi (2012) described and illustrated *E. patu* Cooper from Floian-Dapingian strata in the Andean Basin (Eastern Cordillera).

The purpose of this paper is to report and illustrate the species of the genus *Erraticodon* that occur in several Ordovician formations of Argentina. Previous records are evaluated and reviewed following the taxonomic concepts of Zhen et al. (2003), Zhen et al. (2007) and Zhen and Pickett (2008).

2. Geological settings and previous investigations

The material examined in this study is derived from two different geological provinces in Argentina, the Andean Basin and the Precordillera, where Lower and Middle Ordovician strata are classical outcrops. Conodonts were collected from the following sections: Chamarra Creek (Los Colorados, Jujuy), Talacasto Creek (Sierra de Talacasto, San Juan), La Chilca (La Chilca Hill, San Juan) and Del Aluvión Creek (Viejo Hill, San Juan) (Fig. 1).

2.1. Andean Basin

The Lower Paleozoic Central Andean Basin covers a large area in southern Perú and the Eastern Cordillera and Subandean areas of Bolivia and Argentina. It is represented lithologically by a highly fossiliferous succession of strata of sandstone and shale, which has been considered as the most prominent Ordovician sequence

* Corresponding author. Tel.: +54 92646719653.
E-mail addresses: sheredia@unsj.edu.ar (S. Heredia), josefinacarlorosi@hotmail.com (J. Carlorosi), amestre@unsj.edu.ar (A. Mestre).

0895-9811/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jsames.2013.03.012

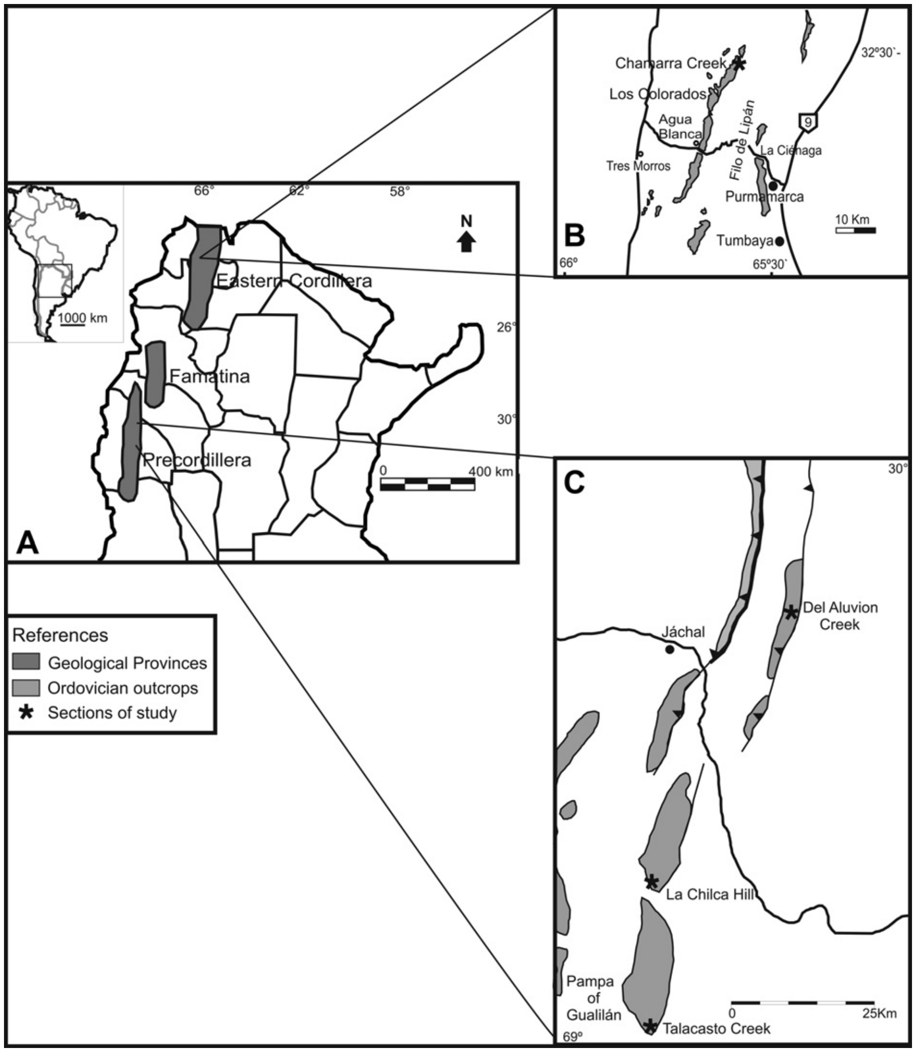

Fig. 1. Regional and location maps. A – Geological provinces of Argentina. B – Eastern Cordillera with Ordovician outcrops in grey color, study area mentioned in text. C – Precordillera with Ordovician outcrops in grey color, areas of study are mentioned in text.

worldwide, with over 10 km in thickness (Suárez Soruco, 1992; Erdtmann et al., 1995; Egenhoff, 2000) (Fig. 1).

Shallow marine sequences characterize the whole region and were deposited on a general deepening in a westward basin. This Ordovician basin is bounded by the Brazilian Shield to the east and the Pampean shield to the south–east. Lower and Upper Ordovician formations are chronostratigraphically resolved by abundant fossils, with conodonts of particular importance for 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 et al., 2002; Benedetto, 2003; Egenhoff et al., 2004; Erdtmann et al., 1995). Among the different paleontological elements, conodonts have to be highlighted due to their importance in the studies of the Cambrian and Ordovician strata in South America.

2.1.1. Chamarra Creek section (Eastern Cordillera)

The entire succession is composed by the clastic Acoite and Alto del Cóndor formations. The uppermost part of the Acoite Formation is almost 300 m thick and the entire Alto del Cóndor Formation is 120 m thick. The coordinates at the base of the measured section are 23°31′56, 4″ S and 65°40′04, 3″ W (Figs. 1 and 2). Astini et al. (2004) described the basal part of the Acoite Formation as a heterolithic succession composed by alternating green shale and grey sandstone. At the top, sandstone beds are thicker than shale beds and usually contain bioclastic levels. Astini and Waisfeld (1993) defined these strata as a sandy member in the upper part of the Acoite Formation. Sampled beds have fragments of brachiopods and trilobites. The age of the upper part of this formation is restricted to the uppermost Floian by the record of the *Trapezognathus diprion* Zone (Lower Ordovician) (Carlorosi, 2012).

The Alto del Cóndor Formation is comprised of pale yellow sandstone for the lower member, and green siltstone and red sandstone for the upper member. The age is given by conodonts of the *Baltoniodus triangularis* Zone as earliest Dapingian (Middle Ordovician) (Carlorosi, 2012).

Elements of the genus *Erraticodon* were recovered from the upper beds of the Acoite Formation and the lower and upper members of the Alto del Cóndor Formation.

The following species are present in the *T. diprion* Zone: *Drepanodus arcuatus* Pander, *Drepanoistodus basiovalis* (Sergeeva), *Drepanoistodus costatus* (Abaimova), *Erraticodon patu* Cooper, *Gothodus costulatus* Lindström, *Trapezognathus diprion* (Lindström), *Baltoniodus* sp. cf. *B. triangularis* (Lindström), *Oistodus* sp., and *Triangulodus* sp.

The following species are present in the *B. triangularis* Zone: *Baltoniodus triangularis* (Lindström), *Drepanoistodus basiovalis,*

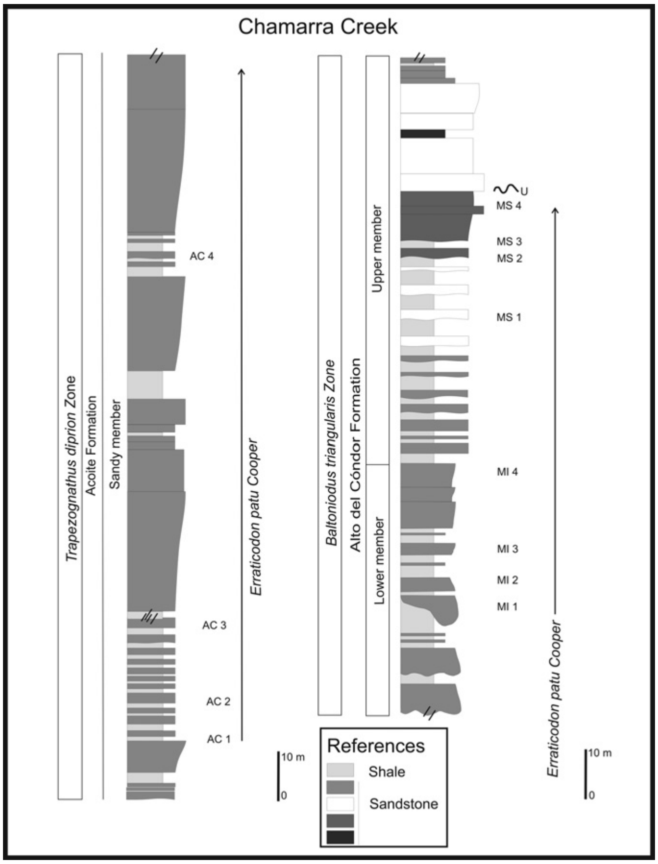

Fig. 2. Section of Acoite and Alto del Cóndor formations at the Chamarra Creek, Los Colorados region (Jujuy province) with vertical distribution of *E. patu* Cooper.

Erraticodon patu, Gothodus costulatus, T. diprion, Trapezognathus quadrangulum Lindström, *Baltoniodus* sp. cf. *B. triangularis*, *Drepanodus* sp., *Oistodus* sp., and *Triangulodus* sp. among others.

2.2. Precordillera

The Precordillera (Fig. 1) is part of a larger region, the Cuyania terrane (Ramos, 1995; Ramos et al., 1998), which is interpreted as allochthonous and did not occupy its present geographic position until mid Ordovician time (Astini, 1998; Astini and Thomas, 1999) or Devonian time (Aceñolaza et al., 2002; Finney, 2007). The Lower-Middle Ordovician carbonate succession of the Precordillera, comprising the La Silla and San Juan formations, is developed along a length of 400 km N–S with a width of 150 km E–W. Although these stratigraphic successions indicate the stability of the platform sedimentation, Middle and Upper Ordovician strata of largely siliciclastic facies show great vertical and lateral heterogeneity that has been taken as a record of tectonic and paleogeographic upheaval.

The conodont genus *Erraticodon* was mentioned previously in the San Juan Formation by several authors (Sarmiento, 1990; Lehnert, 1995; Albanesi, 1998; Mestre, 2010) and new elements of this genus were recovered in this study. Different species of *Erraticodon* were recovered from Talacasto Creek, La Chilca Hill and Del Aluvión Creek sections, where the San Juan Formation has good exposure (Fig. 1).

2.2.1. Talacasto locality

This well known and classical sector of the San Juan Precordillera was poorly studied on Ordovician conodonts, only mentioning the *Oepikodus evae* Zone (Hünicken, 1982) in the eastern outcrops of the Talacasto Creek and the *Lenodus variabilis* Zone for the uppermost San Juan Formation (Albanesi et al., 2007) in Talacasto Range.

The Talacasto section shows good and continuous exposure of the San Juan Formation. It consists of highly fossiliferous shallow-water limestone which varies from glauconitic wackestone-packstone with k-bentonites (*O. evae* Zone) to tempestitic grainstone with k-bentonites (*Oepikodus intermedius* Zone), including several firmgrounds to the top of the biozone, followed by non-fossiliferous rich chert limestone. Ten meters from the top, limestone beds contain well preserved Darriwilian fossils (Fig. 2). Few elements of *Erraticodon* were obtained from beds of the *O. intermedius* Zone, representing the first record of the genus in strata of such age in the Precordillera. The following species are present in the *O. intermedius* Zone: *Ansella jemtlandica* (Löfgren), *Bergstroemognathus extensus* Serpagli, *Erraticodon patu*, *Juanognathus variabilis* Serpagli, *O. evae* (Lindström), *O. intermedius* (Serpagli), *Periodon flabellum* (Lindström), *Protopanderodus leonardii* Serpagli, *Protopanderodus elongatus* Serpagli, *Protopanderodus gradatus* Serpagli, *Rossodus barnesi* Albanesi, *Reutterodus andinus* Serpagli, and *Scolopodus krummi* (Lehnert).

2.2.2. La Chilca Hill section

Lehnert (1995) mentioned the first conodont fauna from La Chilca section including *Erraticodon balticus*. Mestre (2010, 2012) recorded the *Eoplacognathus pseudoplanus* Zone for the last meter of San Juan Formation in this section. Recently, the record of the key conodonts *Lenodus variabilis* Sergeeva, *Yangtzeplacognathus crassus* (Chen and Zhang), and *Eoplacognathus pseudoplanus* (Viira) in this section by Heredia and Mestre (2011), Mestre and Heredia (2012), and Mestre (2012) allows modifications on the Darriwilian conodont chart zonation for the Precordillera. The Ordovician carbonates exposed in the La Chilca section are composed of grey to dark grey carbonates, marls and mixed carbonate/siliciclastic beds deposited in a ramp setting (Carrera, 1997; Mestre, 2010). The section begins with the Lower – Middle Ordovician San Juan Formation, composed mainly of fossiliferous limestone and marly limestone, 380 m thick (Keller, 1999). The San Juan Formation is conformably overlain by thin- to medium-bedded marly limestone and black shale of the Los Azules Formation, which correlates with the Middle to Upper Ordovician. The contact between the San Juan and Los Azules Formations is transitional, and the first level of black shale marks the boundary between these two units (Fig. 3).

From the *Y. crassus* Zone (Fig. 3) few elements of *Erraticodon hexianensis* and *E.* cf. *E. balticus* were recovered associated with: *A. jemtlandica*, *Cornuodus longibasis* (Lindström), *Drepanoistodus basiovalis*, *Fahraeusodus marathonensis* (Bradshaw), *Histiodella holodentata* Ethington and Clark, *Lenodus variabilis*, *Paroistodus horridus* (Barnes and Poplawski), *Periodon macrodentatus* (Graves and Ellison), *Protopanderodus rectus* (Lindström), *Pteracontiodus cryptodens* (Mound), *Rossodus barnesi*, *Scolopodus oldstockensis* Stouge, *Y. crassus*, "*Bryantodina*" aff. "*B*". *typicalis* (Stauffer), among others.

From the *E. pseudoplanus* Zone (Fig. 3), elements of *E.* cf. *E. balticus* were obtained along with the following species: *A. jemtlandica*, *Baltoniodus medius* (Dzik), *Cornuodus longibasis*, *Costiconus ethingtoni* Fåhraeus, *Drepanoistodus basiovalis*, *Drepanoistodus bellburnensis* Stouge, *Drepanoistodus costatus*, *Eoplacognathus pseudoplanus*, *Fahraeusodus marathonensis*, *Histiodella holodentata*, *Histiodella kristinae* Stouge, *Protopanderodus calceatus* Bagnoli and Stouge, *Protopanderodus graeai* (Hamar), *Parapanderodus simplicissimus* Stouge, *Paroistodus horridus*, *Periodon macrodentatus*, *Rossodus barnesi*, *Scolopodus oldstockensis* and *Microzarkodina* cf. *M. ozarkodella* Lindström, and "*Bryantodina*" aff. *B. typicalis*.

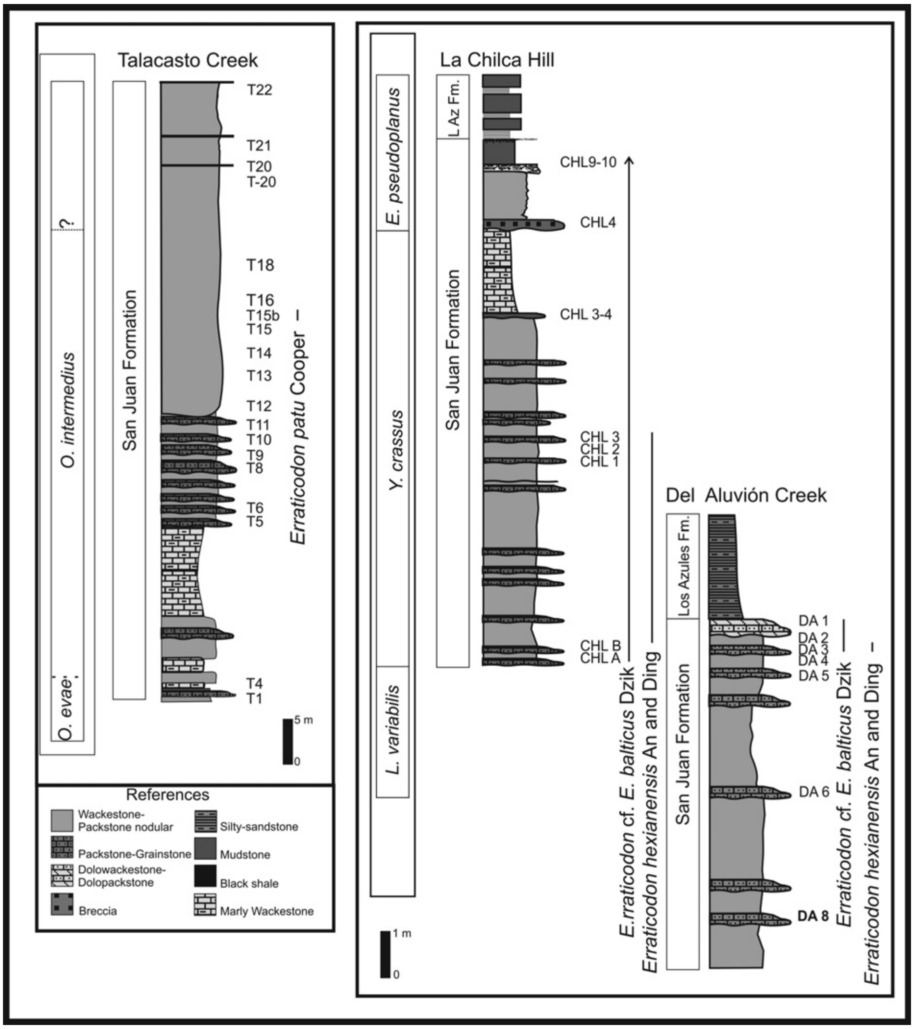

Fig. 3. Sections of San Juan Formation at Talacasto Creek, La Chilca Hill and Del Aluvión Creek (San Juan province) with vertical distribution of *E. patu* Cooper, *E. hexianensis* An and Ding, and *E.* cf. *E. balticus* Dzik.

2.2.3. Del Aluvión section

This section is located on the western flank of the Huaco anticline about 4 km southeast from La Ciénaga village (Fig. 1). There, the San Juan Formation crops out in a north-south belt with several well studied sections that cut off this belt. The most northward section of this classical site is located on Del Aluvión creek.

The San Juan Formation consists of carbonate deposits with a thickness of 330 m (Keller, 1999), assigned to a shallow ramp depositional settings, developing crinoidal barriers, hardgrounds, and several exposure surfaces in the upper part (Cañas and Aguirre, 2005 with references herein). A well-known hardground is at the top of the unit where nautiloids with giant phragmacones are present. The Los Azules Formation overlies the San Juan Formation with a contact that has been interpreted as paraconformable (Astini, 1994) (Fig. 3). Ortega et al. (2007) mentioned the presence of conodonts from the upper part of the San Juan Formation belonging to the *Lenodus variabilis* Zone that provides a Middle Ordovician (Darriwilian) age for this these outcrops. Mestre (2010) recorded the *Y. crassus* Zone for the uppermost beds of the San Juan Formation on the Del Aluvión creek. From the *Y. crassus* Zone (Fig. 3) few elements of *E. hexianensis* and *E.* cf. *E. balticus* were recovered together with *A. jemtlandica*, *Cornuodus longibasis*, *Drepanodus arcuatus*, *Drepanoistodus basiovalis*, *Drepanoistodus bellburnensis*, *Drepanoistodus tablepointensis* Stouge, *Drepanoistodus costatus*, *Fahraeusodus marathonensis*, *Parapanderodus elegans* Stouge, *Paraistodus originalis* (Sergeeva), *Periodon macrodentatus*, *Protopanderodus rectus*, *Pteracontiodus cryptodens*, *Rossodus barnesi*, *Scolopodus oldstockensis*, *Strachagnathus parvus* Rhodes, and *Y. crassus*, among others.

3. Materials and methods

Seventy-three samples (average 1.5 kg) collected in sections mentioned above yield conodonts. Laboratory procedures were the usual ones described by Stone (1987). All photographic illustrations (Figs. 4–6) are SEM digital photomicrographs. Conodont elements have different CAI grades (for explanation of CAI, see Epstein et al., 1977) depending the location of the section in the basin, which will be discussed later. The illustrated elements are deposited in collections of the INGEO at Universidad Nacional de San Juan under the code INGEO-MP and the Collection of Microvertebrates Lillo-Conodonts under the code CML-C.

The synonymy lists are condensed, mostly containing only the original citations of species names incorporated in each multielement taxon and mentions for Argentina. In the descriptions, we have used the conventional orientational terms – anterior, posterior and lateral – noting that these do not relate to the anatomical orientation of elements (see Purnell et al., 2000).

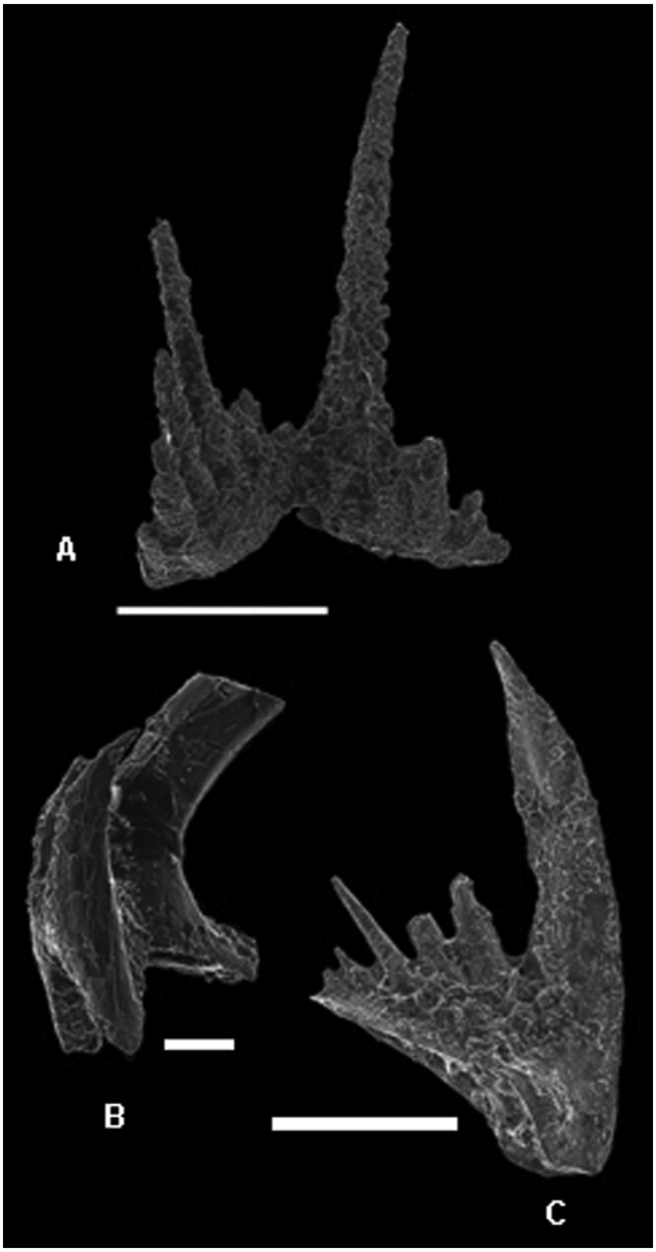

Fig. 4. Microphotograph of scanning electron microscope of *Erraticodon hexianensis* (An and Ding, 1985). The bar indicates 0.1 mm. Figured elements belong to Darriwilian beds of the Precordillera. A – lateral view of Pa element, sample DA2, Del Aluvión Creek, INGEO-MP 436 (1). B – lateral view of Sa element, sample DA3, Del Aluvión Creek, INGEO-MP 437 (1). C – lateral view of M element, sample DA3, Del Aluvión Creek, INGEO-MP 437 (2).

4. Systematic palaeontology

Class Conodonta Pander, 1856
Order Prioniodinida Sweet, 1988
Family Chirognathidae Branson and Mehl, 1944
Erraticodon Dzik, 1978

Type species. *Erraticodon balticus* Dzik, 1978

Diagnosis. Septimembrate or octomembrate apparatus with a ramiform structure including digyrate P, makellate M, alate Sa, bipennate Sb and Sc and tertiopedate Sd. Hyaline elements with long and prominent cusp, discrete denticles on the processes, and a shallow basal cavity. In this work we follow criteria applied by Zhen et al. (2003) on the element diagnosis.

Seven named species are ascribed to *Erraticodon*. Worldwide these include *E. balticus* Dzik, *E. fengxiangensis* Ni, *E. gratus* (Moskalenko), *E. hexianensis* An and Ding, *E. patu* Cooper, and *E. tangshanensis* Yan and Xu, and *E. tarimensis* Zhen et al. (2007).

Erraticodon hexianensis An and Ding, 1985
Fig. 4, A–C.
1984 *Erraticodon balticus* Dzik, Stouge, p. 84–85, pl. 17, Figs. 10, 15,18.
1998 *Erraticodon balticus* Dzik, Zhang, p. 126, pl. 9, Figs. 8, 10?–11?.
2007 *Erraticodon hexianensis* An and Ding, Zhen et al., p. 149–158, Figs. 4–9 with synonymy herein.

Material. 3 Pa, 4 Sa, 1 Sb, 1 Sc, 1 Sd, 1 M; CHLB: INGEO-MP1090 (1); CHL 3: INGEO-MP 1091 (1–3); DA1: INGEO-MP 435 (1); DA2: INGEO-MP 436 (1–3); DA3: INGEO-MP 437 (1–3).

Description. We describe Pa, M and Sa elements which are illustrated (Fig. 4). Preservation is poor in the others elements.

Pa element digyrate with a long cusp rounded in cross section. The sinuously curved lateral process has peg-like denticles on it and the short inner lateral process has three small denticles on it. The lateral process bears six denticles, two short denticles proximal to the cusp, follow by two long denticles and the rest of the denticles shorter distally from the cusp.

M element makellate with an outer lateral process bearing five denticles. Prominent cusp curved posteriorly. Basal cavity shallow, in basal view is triangular.

Sa element alate has short lateral processes bearing a single prominent, posteriorly curved short denticle. The cusp is robust and posteriorly curved with sharp costa along the posterior margin. Posterior denticulate process. The base below the lateral processes is extended downwardly.

Remarks. The *Erraticodon hexianensis* was introduced by An and Ding (1985) from the late Dawanian to early Darriwilian of South China. Zhen et al. (2007) revised this species of *Erraticodon* with an octomembrate ramiform–ramiform apparatus including M, Sa, Sb, Sc, Sd, Pa, Pb and Pc. The Pa element of *E. hexianensis* is comparable in shape and angles relation of the processes and the cusp to the corresponding element illustrated by Zhen et al. (2007). Comparisons to *E.* cf. *E. balticus* are made in remarks section of such species.

The recovered elements are comparable to those obtained from the Guniutan Formation, Yangtze Platform, south-central China (Zhang, 1998; pl. 9, Figs. 8, 10? –11?). Stouge (1984) illustrated elements of "*Erraticodon balticus*" that we propose to refer to *E. hexianensis* (pl. 17, Figs. 10, 15, 18).

Occurrence in the sections. *E. hexianensis* is restricted to the Precordillera, in the San Juan Formation, *Y. crassus* Zone (Del Aluvión Creek and La Chilca Hill).

Erraticodon patu Cooper, 1981
Fig. 5, A–I; Fig. 6, A–C.
1981 *Erraticodon patu* Cooper, p.166, pl. 32, Figs. 1–6, 8.
1987 *Erismodus quadridactylus* (Stauffer), Sarmiento and Rao, p. 90–91, pl. 1., Figs. 2–4, 7, 9, 12; pl. 2, Figs. 1–6.
1994 *Erraticodon patu* Cooper, Albanesi and Vaccari, p. 137, pl. 1, Figs. 11–16.
2007 *Erraticodon balticus* Dzik, Albanesi et al., p. 46, text. Fig. 3 A, B, C, D.
2012 *Erraticodon patu* Cooper, Carlorosi, p. 112–116, pls. 2, 3, 27 (A, F), 28 (D).

Material. Eastern Cordillera: 44 Pa, 6 Pb, 55 Sa, 154 Sb, 88 Sc, 67 Sd y 26 M, Acoite Formation, Samples AC1: CML-C 5038 (1–

Fig. 5. Microphotograph of scanning electron microscope of *Erraticodon patu* (Cooper, 1981). The bar indicates 0.1 mm. Figured elements belong to Dapingian beds of the Eastern Cordillera. A – posterior view of Pa element, sample MS4, Alto del Cóndor Formation, CML-C 5084(1). B, C – oral and lateral views of Pb element, sample MS4, Alto del Cóndor Formation, CML-C 5084(45). D, E – antero-lateral and postero-lateral views of M elements, sample MS4, Alto del Cóndor Formation, CML-C 5084(47–48). F – posterior view of Sa element, sample MS4, Alo del Cóndor Formation, CML-C 5084(73). G – lateral view of Sb element, sample MS4, Alto del Cóndor Formation, CML-C 5084(119). H – lateral view of Sc element, sample MS4, Alto del Cóndor Formation, CML-C 5084(248). I – postero-lateral view of Sd element, sample MS4, Alto del Cóndor Formation, CML-C 5084(320).

8); AC2: CML-C 5047 (1–5), AC3: CML-C 5054 (1–6), AC4: CML-C 5058 (1–5). Alto del Cóndor Formation, samples MI1: CML-C 5060 (1–5), MI2: CML-C 5063 (1–7), MI3: CML-C 5065 (1), MI4: CML-C 5067 (1–3), MS1: CML-C 5072 (1–3), MS2: CML-C 5076 (1–6), MS3: CML-C 5077 (1–3), MS4: CML-C 5084 (1–393) (39 Pa, 6 Pb, 25M, 45Sa, 129Sb, 82Sc, 67Sd). Preservation is fair but many elements are fragmented due to peculiar shape of the elements.

Precordillera: 1 Sa, 1Sb and 1Sc, San Juan Formation, Sample T15: INGEO-MP 1815 (1–3).

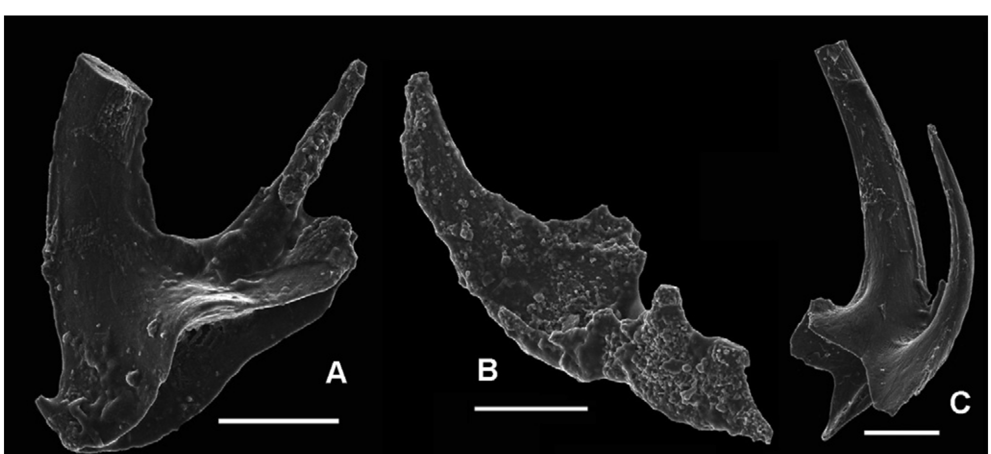

Fig. 6. Microphotograph of scanning electron microscope of *Erraticodon patu* Cooper. The bar indicates 0.1 mm. Figured elements belong to Floian beds of the Precordillera. A – postero-lateral view of M element, sample 15b, Talacasto Creek, INGEO-MP 1851 (1). B – lateral view of Sb element, sample 15b, Talacasto Creek, INGEO-MP 1851 (2). C – lateral-posterior view of Sd element, sample 15b, Talacasto Creek, INGEO-MP 1851 (3).

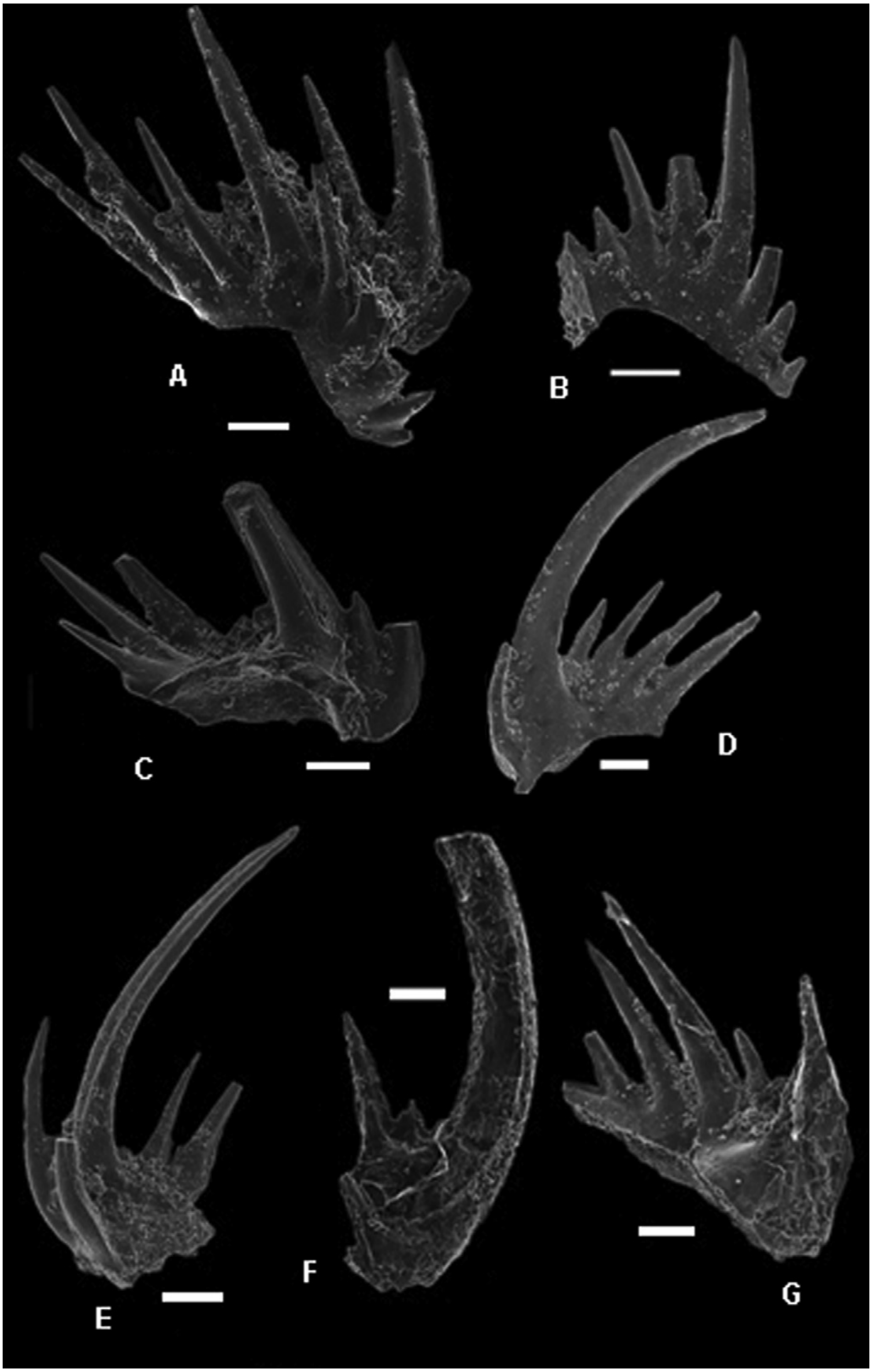

Fig. 7. Microphotograph of scanning electron microscope of *Erraticodon* cf. *Erraticodon balticus* (Dzik, 1978). The bar indicates 0.1 mm. Figured elements belong to Darriwilian beds of the Precordillera. A – anterior view of Pb element, sample DA3, Del Aluvión Creek, INGEO-MP 413 (1). B – lateral view of Pa element, sample CHL4, La Chilca Hill, INGEO-MP 1010 (1). C – posterior view of Pb element, sample CHL4, La Chilca Hill, INGEO-MP 100 (2). D – lateral view of Sc element, sample DA3, Del Aluvión Creek, INGEO-MP 413 (1). E – lateral view of Sa element, sample CHL5, La Chilca Hill, INGEO-MP 1025 (2). F – lateral view of Sb element, sample DA3, Del Aluvión Creek, INGEO-MP 413 (2). G – lateral view of M element, sample DA3, Del Aluvión Creek, INGEO-MP 413 (3).

Description. Pa element: Thin and elongated cusp where three processes appear. The anterior and posterior are arranged upright with respect to the cusp but are directed downwards. The lateral process follows the anterior process at an angle of 60°, all three processes bearing denticles. The base is deep and excavated and expands each of the processes.

Pb element: Cusp slender, straight with sharp edges like small ribs which continue laterally as processes. The internal lateral process is short and has a horizontal direction with respect to the cusp, the outer lateral process is longer and is directed downwards at an angle to the cusp of about 130°, both processes have two to three anteroposterior compressed thin denticles with sharp edges and curving back. Denticle sizes range from short in the internal lateral process to long in length to the cusp above the lateral process. The basal margin is extended and bent in the case of anterior lateral process. Basal cavity is reduced to a small pit below the apex and extends as an imperceptible groove in the all processes.

M element: This element has a long, robust, sharp margin, anteroposteriorly compressed cusp facing back, and from it emerges two processes, a small anterior process that usually carries a denticulate and a longer posterior process bearing two denticles. The denticles are short and compressed in the front to back. The basal cavity is small, excavated and extends only under the posterior process.

Sa element: Symmetrical alate element. The cusp is long and thin facing back and acute flanks. The lateral processes emerge straight from the top and carry denticles in numbers between two and four of which also have sharp margins. A short posterior process bears a denticle. The basal margin is formed by deep arches on each lateral process, whereas the basal cavity is excavated underneath the cusp.

Sb element: robust and strongly recurved cusp which is directed toward posterior, we can distinguish three well-marked ribs, two of which are continuing in lateral processes directed downward, forming at a closed arc between them, each carrying thin denticles compressed in the anterior. In the case of the denticles of the anterior lateral process they are directed backwards. The posterior process is short. The basal cavity is excavated and extends deeply in the interior of the processes.

Sc element: The cusp is enlarged near the base and tapers toward its apex, generally suberect, with sharp edges. The anterior face is concave while the back is flat, and is characteristically directed toward posterior lateral flank. From it arise two curved lateral processes carrying three downward denticles. In the case of posterior lateral process the first denticle is attached to the apex while the anterior lateral is free. The basal cavity is widely excavated and goes to each process.

Sd element: Slender and long cusp, straight to suberect. The element has three processes, two lateral and posterior bearing denticles. Both lateral processes are curve downwards at an angle of 40°.

Remarks. Originally defined by Cooper (1981) on the basis of specimens from the Horn Valley Siltstone, the Tabita Formation at Mount Arrowsmith and unnamed unit at Koonenberry Gap; subsequently subjected to review by Zhen et al. (2003). According to this last author the elements are ramiforms digyrate P, makelate M, alate Sa, Sb and Sc bipennate, and Sd tertiopedate. Zhen et al. (2003) recorded *E. patu* from the early Ordovician from New South Wales (Australia) which were especially used for comparing our material. Albanesi and Vaccari (1994) mentioned *E. patu* in Dapingian strata, that cropping out in Chaschuil (Famatina range). On the other hand, elements figured as *Erismodus quadridactylus* (Stauffer) by Sarmiento and Rao (1987) are interpreted as *E. patu*. Also, several elements assigned as *E. balticus* by Albanesi et al. (2007) are suggested as *E. patu*.

Occurrence in the sections. *E. patu* is recorded in the Acoite (upper Floian, *Trapezognathus diprion* Zone) and Alto del Cóndor formations (Dapingian, *Baltoniodus triangularis* Zone) in the Andean Basin (Carlorosi, 2012; Carlorosi et al., 2013). From the Talacasto Creek (Central Precordillera) few elements of *E. patu* have been recovered in the *O. intermedius* Zone from the San Juan Formation.

Erraticodon cf. E. balticus Dzik, 1978
Fig. 7, A–G.
1978 *Erraticodon balticus* sp. n. Dzik, p. 66, pl. 15: 2, 5 only; Fig. 6 b–d only.
1984 *Erraticodon balticus* Dzik, Stouge, p. 84–85, pl. 17, Figs. 9, 11–14,16, 17, 19 only.
1991 *Erraticodon balticus* Dzik, Sarmiento, p. 120, pl. 2, Figs. 1–2.
1995 *Erraticodon balticus* Dzik, Lehnert, p. 87–88, pl. 10, Figs. 13, 16.
1995 *Erraticodon patu* Cooper, Lehnert, pl. 10, Figs. 4, 11, 17.
1995 *Erismodus*? sp., Ortega et al., pl. 6, Figs. 1–3.
1995 *Erraticodon* aff. *balticus* Dzik, Albanesi et al., pl. 4, Figs. 1–3.
1998 *Erraticodon balticus* Dzik, Albanesi, p. 176, pl. 4, Figs. 16–18.
1998 *Erraticodon balticus* Dzik, Zhang, p. 126, pl. 9, Figs. 6–7, 13 only.
2007 *Erraticodon balticus* Dzik, Ortega et al., Fig. 6 F, G.
2008 *Erraticodon balticus* Dzik, Zhen and Pickett, Fig. 8 only.
2010 *Erraticodon balticus* Dzik, Mestre, p. 315, pl. 3, Figs. A–D.

Material. 5 Pa; 5 Pb; 3 Sa; 5 Sb; 5 Sc; 5 M elements. CHL 3: INGEO-MP 1100 (1–3), CHL A: INGEO-MP 1101 (1); CHL4: INGEO-MP 1010 (1–18), CHL5: INGEO-MP 1025 (1–4), CHL6: INGEO-MP 1036 (1), DA3: INGEO-MP 413 (1–4). They occur in the upper part of the San Juan Formation.

Description. Pa has a less prominent cusp with rounded in cross section with a sharp lateral costa on each side and basal cavity shallow, pit underneath the cusp. A long sinuously curved inner lateral process, and a long, anteriorly twisted outer lateral process, denticles on both processes also rounded.

Pb element has a slender and recurved cusp, with a sharp anterior margin with lateral costa on each side, short anterior process which bears four denticles, lateral processes on each side with denticles.

S elements: the species of *E. balticus* is characterized by having an important denticle on the posterior process of the Sa, Sb and Sc elements (Dzik, 1991; Fig. 12A). The recovered S elements from the Precordillera have not the diagnostic denticles.

Sa element alate has a large cusp with a sharp costa along its posterior margin, and long and thin denticles on the posterior process. Short lateral process on each side with a single denticle which diverge from the aboral margin of the base. Basal cavity shallow and small.

Sb element bipennate, asymmetrical, has a long cusp, with two lateral processes and a long posterior process with denticles keeled and reclined.

Sc element bipennate has a long and prominent recurved cusp, and anterior and posterior processes. The inner laterally curved anterior process bearing two to five reclined denticles. The posterior process bears four thin and separately spaced denticles. The basal cavity is shallow.

M element makellate has a robust cusp with a sharp costa along the inner lateral face without anti-cusp. The basal cavity is shallow. The outer lateral process bearing four to five separated or isolated and pointed denticles, being the second and third longer than the others; the first denticle is attached to the base of the cusp.

Remarks. The type specimens of *E. balticus* were recovered from a Quaternary glacial boulder of Baltic origin in Poland (Dzik, 1978; pl. 15:1–3,5,6; Fig. 6 a–e) among conodonts from the *E. robustus*

Subzone, *Pygodus serra* Zone. Our material is comparable in shape, angles and number of denticles to these type specimens but a detailed comparison shows that our material lack of the distinctive larger denticle on the posterior process of the S elements. Also it is broadly comparable with the elements of "*E. balticus*" from the Table Head Formation, Newfoundland (Stouge, 1984; pl. 17, Figs. 9, 11–14, 16–17, 19), and P elements of *E. balticus* from the Goonumbla Volcanics Formation, Central New South Wales, Australia (Zhen and Pickett, 2008; Figs. 6–8). These last authors described M elements of *E. balticus* with the long outer lateral process bearing four to seven pointed denticles which are more closely spaced than those observed in our material or compared to those described by Dzik (1978).

The S and M elements of *E. hexianensis* recovered for this study were compared to those of *E.* cf. *E. balticus*. The M element of *E. hexianensis* resembles M element of *E. balticus* and *E.* cf. *E. balticus* except that the first denticle of the outer lateral process is not attached to the cusp and the denticles are smaller. Sa element shows strong morphological differences with Sa elements of *E.* cf. *E. balticus*, mainly in the shape and size of the lateral processes and of the denticles that they bear.

After comparison the biostratigraphical distribution of *Erraticodon* cf. *E. balticus* (*Y. crassus* and *Eoplacognathus pseudoplanus* zones) from the San Juan Formation (Lehnert, 1995; Albanesi, 1998; this contribution, among others), and those from the Table Head Formation (Stouge, 1984) to *E. balticus* described from Baltica by Dzik (1978) and Australia by Zhen and Pickett (2008), is possible to propose that the first ones could represent the ancestors of *E. balticus*.

Lehnert (1995) distinguished *E. patu* and *E. balticus* at the top of San Juan Formation (*E. patu* pl. 4; Figs. 4, 11, 15 and 17; *E. balticus*, pl. 4, Figs. 13, 16); we assigned all these elements to *E.* cf. *E. balticus*. *E. balticus* described and illustrated by Sarmiento (1990), Albanesi (1998), Ortega et al. (2007) and Mestre (2010) are included in *E.* cf. *E. balticus* until large collections allows better studies on this species.

The elements studied here show a partial *Erraticodon* apparatus represented by 4 Pa, 5 Pb, 3 Sa, 5 Sb, 5 Sc, and 5 M elements except the Sd element which has not been recovered.

Occurrence in the sections. *E.* cf. *E. balticus* is restricted to the Precordillera, in the San Juan Formation, *Y. crassus* Zone (Del Aluvión Creek and La Chilca Hill) and *Eoplacognathus pseudoplanus* Zone (La Chilca Hill).

5. Conodont ecology and biogeography

Erraticodon patu elements Floian Acoite Formation fossil assemblages are small and fragile. The Dapingian *E. patu* assemblages yield complete sets of ontogenetic stages (juvenile, adult and mature elements) mostly by large and robust elements. It seems that *E. patu* ranges from Floian (*O. evae* Zone) to early Dapingian (*Baltoniodus triangularis* – *Baltoniodus navis* zones) (Fig. 8).

Darriwilian species of *Erraticodon* probably were not strongly controlled by the environment like Floian *Erraticodon* species because the first occupied shallow and middle ramp environments. Comparisons of *Erraticodon* specimens from these environments of the carbonate ramp (*Y. crassus* Zone) suggests that shallower settings are inhabited by robust forms of *Erraticodon* (both species) and in middle ramp settings these are smaller and delicate. *E. hexianensis* is apparently restricted to *Lenodus variabilis* – *Y. crassus* zones, meanwhile *E.* cf. *E. balticus* shared this interval extending its presence until upper Darriwilian times (Fig. 8).

Benedetto (2003) pointed out a more or less continuous biotic exchange during early Ordovician times along the Gondwana margin, from Australasia to North Africa and related south

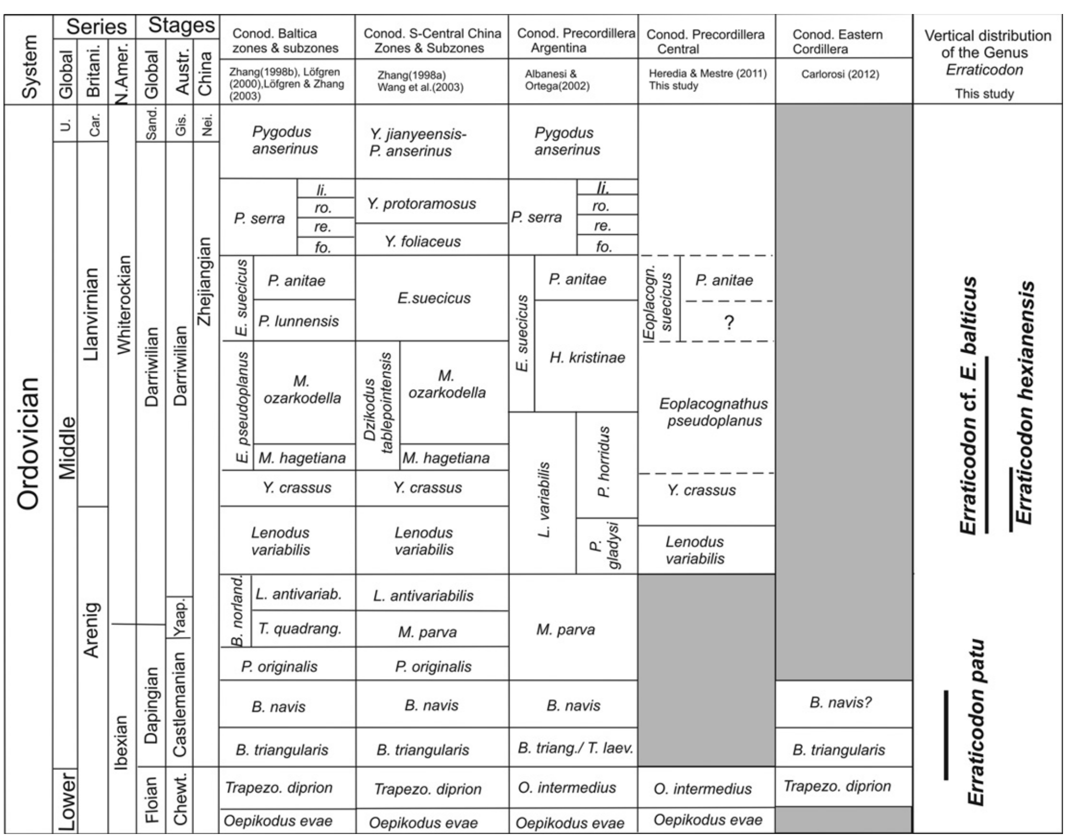

Fig. 8. Ordovician Conodont biostratigraphic chart with vertical distribution of the genus *Erraticodon* Dzik in Argentina.

European peri Gondwanan fragments following Jell et al. (1984). More evidence supporting connections between Australian, Famatinian and North Western Argentinean faunas is also presented in Benedetto (2003).

The finding of the conodont *E. patu* in Lower to early Middle Ordovician deposits in the Andean basin (Eastern Cordillera) and the Famatina range (Albanesi and Vaccari, 1994) confirms strong ties with the Australian plate. However, the presence of *E. patu* in Lower Ordovician (*O. intermedius*/*T. diprion* Zone) strata of the San Juan Formation is of great interest in connection with the Precordillera microplate because of its suspected isolation during this time, following interpretation of Astini and Thomas (1999), Benedetto (2003) and citations herein. Benedetto (2003) suggested that for Floian-Dapingian times the Precordillera was not adjacent to Gondwana due to the absence of typical Gondwanan faunas, except for the brachiopod *Niquivilia*. The presence of *E. patu* in limestone beds in the Precordillera during the late Floian suggests earlier links with Gondwana, especially with the Andean basin, contrary to the scenario what these authors proposed.

We record for first time elements of *E. hexianenesis* which occurred with *E.* cf. *E. balticus* in Darriwilian deposits of the Precordillera in the *Y. crassus* Zone. Meanwhile, *E.* cf. *E. balticus* is occurred up until *E. pseudoplanus* Zone.

In Darriwilian times several conodont species suggest fluent connections with Newfoundland and South-Central China due to the record of *E.* cf. *E. balticus* and *E. hexianensis,* along with elements of *Y. crassus*, *E. pseudoplanus* and several species of *Dzikodus* (Mestre, 2010; Heredia and Mestre, 2011; Mestre, 2012).

Acknowledgments

The authors wish to express their thanks to Argentine Research Council (Conicet) and Conicet's technician Mercedes González for her work at lab. Special thanks to Dr. Ian Percival for reviewing the original manuscript, Dr. Stan Finney and Victor Paletta for correcting the English language. We also thank to the anonymous reviewers for suggestions and useful comments that improve the original manuscript. This work was benefited from financial support of projects CGL2009-09583 (Ministerio de Ciencia e Innovación, Spain) and CIUNT–26–G401/2 (UNT, Argentina).

References

Aceñolaza, F.G., Miller, H., Toselli, A.J., 2002. Proterozoic-early Paleozoic evolution in western South America – a discussion. Tectonophysics 354, 121–137.
Albanesi, G.L., 1998. Taxonomía de conodontes de las secuencias ordovícicas del Cerro Potrerillo, Precordillera Central de San Juan, República Argentina. Academia Nacional de Ciencias 12, 101–227.
Albanesi, G.L., Vaccari, N.E., 1994. Conodontos del Arenig en la Formación Suri, Sistema del Famatina, Argentina. Revista Española de Micropaleontología 26, 125–146.
Albanesi, G.L., Ortega, G., Hünicken, M.A., 1995. Conodontes y graptolitos de la Formación Yerba Loca (Arenigiano–Llandeiliano) en las quebradas de Ancaucha y El Divisadero, Precordillera de San Juan, Argentina. Boletín de la Academia Nacional de Ciencias 60, 365–400.
Albanesi, G.L., Esteban, S.B., Ortega, G., Hünicken, M.A., Barnes, C.R., 2005. Bioestratigrafía y ambientes sedimentarios de las formaciones Volcancito y Bordo Atravesado (Cámbrico Superior-Ordovícico Inferior), Sistema de Famatina, provincia de La Rioja, vol. 8. Asociación Geológica Argentina, Serie D, Publicación Especial, Argentina, pp. 41–64.
Albanesi, G.L., Monaldi, C.R., Ortega, G., Trotter, J.A., 2007. The Capillas formation (Late Darriwilian) of Subandean ranges, Northwestern Argentina: age, correlation and environmental constraints. Acta Palaeontologica Sinica 46, 9–15.
An, T.X., Ding, L.S., 1985. Ordovician conodont biostratigraphy in Hexian, Anhui province. Geological Review 31, 1–12.
Astini, R.A., 1994. Interpretación estratigráfica de la Formación Sepulturas (Ordovícico Inferior) y unidades análogas del noroeste argentino: La Aloformación Sepulturas. In: 5° Reunión Argentina de Sedimentológica, Actas 1, pp. 9–14. Tucumán.
Astini, R.A., 1998. Stratigraphic evidence supporting the rifting, drifting and collision of the Laurentian Precordillera terrane of western Argentina. In: Pankhurst, R.J., Rapela, C.W. (Eds.), The Proto-Andean Margin of Gondwana. Geological Society of London Special Publication, vol. 142, pp. 11–33.
Astini, R.A., Thomas, W.A., 1999. Origin and evolution of the Precordillera terrane of western Argentina: a drifted Laurentian orphan. In: Ramos, V.A., Keppie, J.D. (Eds.), Laurentia-Gondwana Connections before Pangea. Geological Society of America Special Paper, vol. 336, pp. 1–20.
Astini, R.A., Waisfeld, B.G., 1993. Análisis estratigráfico y paleoambiental del Ordovícico inferior (Formación Acoite y Sepulturas) al oeste de Purmamarca, Cordillera Oriental Argentina. In: XII Congreso Geológico Argentino, pp. 96–106.
Astini, R.A., Waisfeld, B.G., Toro, B.A., Benedetto, J.L., 2004. El Paleozoico inferior y medio de la región de Los Colorados, borde occidental de la Cordillera Oriental (Provincia de Jujuy). Revista de la Asociación Geológica Argentina 59, 243–260.
Benedetto, J.L., 2003. Braquiópodos del Caradociano temprano de la Formación La Pola, sierra de Villicúm, Precordillera de San Juan (Argentina). Ameghiniana 40, 33–52.
Branson, E.B., Mehl, M.G., 1944. Conodonts. In: Shimer, H.W., Shrock, R.R. (Eds.), Index Fossils of North America. Wiley and Sons, pp. 235–246.
Cañas, F., Aguirre, H., 2005. Estratigrafía de alta resolución de la Formación San Juan (Ordovícico inferior de la Precordillera de Cuyo, San Juan, Argentina): Resultados preliminares. In: XVI Congreso de Geología Argentina. Actas, tomo III, pp. 365–370. La Plata.
Carlorosi, J.M.T, 2012. Bioestratigrafía y taxonomía de conodontes de la Formación Sepulturas (Ordovícico), Cordillera Oriental de Jujuy. PhD Thesis. Universidad Nacional de Tucumán, 310 pp. (Unpublished).
Carlorosi, J.M.T., Heredia, S., Aceñolaza, G., 2013. Middle Ordovician (early Dapingian) conodonts in the central Andean basin of NW Argentina. Alcheringa 37.
Carrera, M.G., 1997. Análisis paleoecológico de la fauna de poríferos del Llanvirniano tardío de la Precordillera Argentina. Ameghiniana 34 (3), 309–316.
Cooper, B.J., 1981. Early Ordovician conodonts from the Horn Valley siltstone, central Australia. Palaeontology 24 (1), 147–183.
Dzik, J., 1978. Conodont biostratigraphy and paleogeographical relations of the Ordovician Mójcza limestone (Holy cross Mts, Poland). Acta Palaeontologica Polonica 23, 51–72.
Dzik, J., 1991. Evolution of oral apparatuses in the conodont chordates. Acta Palaeontologica Polonica 36 (3), 265–323.
Egenhoff, S.O., 2000. Sedimentologie und Beckenentwicklung im Ordovizium in Südbolivien. Berliner Geowissenschaftliche Abhandlungen A207, 1–173.
Egenhoff, S.O., Maletz, J., Erdtmann, B.D., 2004. Lower Ordovician graptolite biozonation and lithofacies of southern Bolivia: relevance for palaeogeographic interpretations. Geological Magazine 141, 287–299.
Epstein, A.G., Epstein, J.P., Harris, L., 1977. Conodont alteration – an index to organic metamorphism. United State Geological Survey Professional Paper 995, 1–27.
Erdtmann, B.D., Kley, J., Müller, J., Jacobshagen, V., 1995. Ordovician Basin Dynamics and New Graptolite Data from the Tarija Region, Eastern Cordillera, vol. 77. The Pacific Section Society for Sedimentary Geology, Fullerton, Book, South Bolivia, pp. 69–73.
Finney, S., 2007. The parautochthonous Gondwanan origin of the Cuyania (greater Precordillera) terrene of Argentina: a re-evaluation of evidence used to support an allochthonous Laurentian origin. Geologica Acta 5 (2), 127–158.
Gagnier, P.-Y., Blieck, A., Emig, C.C., Sempere, T., Vachard, D., Vanguestaine, M., 1996. New paleontological and geological data on the Ordovician and Silurian of Bolivia. Journal of South American Earth Sciences 9 (5–6), 329–347.
Heredia, S., Mestre, A., 2011. Middle Darriwilian conodont biostratigraphy in the Argentine Precordillera. In: Gutiérrez Marco, J.C., Rábano, I., García Bellido, D. (Eds.), Ordovician of the World. Cuadernos del Museo Geominero, vol. 14, pp. 229–234.
Hünicken, M., 1982. Zona de Oepikodus evae en la Formación San Juan, Quebrada de Talacasto, Precordillera Central. In: V Congreso Geologico Latinoamericano I, pp. 797–802. Buenos Aires.
Jell, P.A., Burrett, C.F., Stait, B., Yochelson, E.L., 1984. The early Ordovician bellerophontid Peelerophon oehlerti (Bergeron) from Argentina, Australia and Thailand. Alcheringa 8, 169–176.
Keller, M., 1999. Argentine Precordillera: sedimentary and plate tectonic history of a Laurentian crustal fragment in South America. Geological Society of America Special Paper 341, 1–131.
Lehnert, O., 1995. Ordovizische Conodonten aus der Präkordillere Westargentiniens: Ihre Bedeutung für Stratigraphie und Paläogeographie. Erlanger Geologische Abhandlungen 125, 1–193.
Mestre, A., 2010. Estratigrafía y bioestratigrafía de Conodontes de la 'Transición Cuspidal' de la Formación San Juan al sur del paralelo 30°, Precordillera de San Juan. Ph.D. thesis. Facultad de Ciencias Exactas, Físicas y Naturales de la Universidad Nacional de San Juan, p. 330. (Unpublished).
Mestre, A., 2012. Bioestratigrafía de conodontes del techo de la Formación San Juan y del miembro inferior de la Formación Los Azules, Cerro La Chilca, Precordillera de San Juan. Ameghiniana 49 (2), 185–197.
Mestre, A., Heredia, S., 2012. The Darriwilian species of the genus *Histiodella* (Conodonta) in the Argentina Precordillera. Alcheringa 36, 141–150.
Ortega, G., Albanesi, G.L., Hünicken, M., 1995. Bioestratigrafía en base a conodontes y graptolitos de las formaciones San Juan (techo) y Gualcamayo (Arenigiano-Llanvirniano) en el cerro Potrerillo, Precordillera de San Juan, Argentina. Boletín de la Academia Nacional de Ciencias 60, 317–364.
Ortega, G., Albanesi, G.L., Frigerio, R.S., 2007. Graptolite-conodont biostratigraphy and biofacies of the middle Ordovician Cerro Viejo succession, San Juan, Precordillera, Argentina. Palaeogeography, Palaeoclimatology, Palaeoecology 245, 245–264.

Pander, C.H., 1856. Monographie der fossilen Fische des silurischen Systems der russisch-baltischen Gouvernements. Akademie der Wissenschaften, St. Petersburg, p. 91.
Purnell, M.A., Donoghue, P.C.J., Aldridge, R.J., 2000. Orientation and anatomical notation in conodonts. Journal of Paleontology 74, 113–122.
Ramos, V.A., 1995. Sudamérica: un mosaico de continentes y océanos. Ciencia Hoy 6, 24–29.
Ramos, V.A., Dallmeyer, R.D., Vujovich, G., 1998. Time constraints on the early Palaeozoic docking of the Precordillera, central Argentina. In: Pankhurst, R.J., Rapela, C.W. (Eds.). The Proto-Andean Margin of Gondwana, vol. 142. Geological Society, Special Publication, London, England, pp. 143–158.
Rasmussen, J.A., 2001. Conodont biostratigraphy and taxonomy of the Ordovician shelf margin deposits in the Scandinavian Caledonides. Fossils and Strata 48, 1–180.
Sarmiento, G., 1990. Conodontos ordovícicos de Argentina. Treballs del Museu de Geologia de Barcelona 1, 135–161.
Sarmiento, G., 1991. Conodontos de la Zona de Suecicus (Llanvirniano inferior) en la sierra de Villicúm, Precordillera de San Juan, Argentina. Revista Española de Micropaleontología 23 (3), 113–132.
Sarmiento, G.N., Rao, R.I., 1987. *Erismodus quadridactylus* (Conodonta) en la Formación Santa Gertrudis (Ordovícico); Provincia de Salta, Argentina. IV Congreso Latinoamericano de Paleontología. Memoria 1, 89–95.
Stone, J., 1987. Review of investigative techniques used in the study of conodontes. In: Austin, R. (Ed.), Conodonts: Investigative Techniques and Applications. Ellis Horwood Limited, Chichester, pp. 17–34.
Stouge, S., 1984. Conodonts of the middle Ordovician table head formation, western Newfoundland. Fossils and Strata 16, 1–145.
Suárez Soruco, R., 2000. Compendio de Geología de Bolivia. Revista Técnica Yacimientos Petrolíferos Fiscales Bolivianos 18 (1–2), 1–213.
Suárez-Soruco, R., 1992. El Paleozoico Inferior de Bolivia y Perú. In: Gutiérrez-Marco, J.C., Saavedra, J., Rábano, I. (Eds.), Paleozoico Inferior de Ibero-América. Universidad de Extremadura, pp. 225–239.
Sweet, W.C., 1981. Macromorphology of elements and apparatuses. In: Robinson, R.A. (Ed.), Treatise on Invertebrate Paleontology, Pt. W, Miscellanea, Supplement 2, Conodonta. Geological Society of America and University of Kansas Press, Lawrence, Kansas, pp. 5–20.
Sweet, W.C., 1988. The Conodonta: Morphology, Taxonomy, Paleoecology, and Evolutionary History of a Long-extinct Animal Phylum. Oxford Monographs on Geology and Geophysic. Clarendon Press, New York, Oxford, p. 212. s, No. 10.
Zhang, J., 1998. Conodonts from the Guniutan Formation (Llanvirnian) in Hubei and Hunan Provinces, south-central China. Stockholm Contributions in Geology 46, 1–161.
Zhen, Y.-Y., Pickett, J.W., 2008. Ordovician (Early Darriwilian) conodonts and sponges from west of Parkes, central New South Wales. Proceedings of the Linnean Society of New South Wales 129, 57–82.
Zhen, Y.-Y., Percival, I.G., Webby, B.D., 2003. Early Ordovician conodonts from western new south Wales, Australia. Records of the Australian Museum 55, 169–220.
Zhen, Y.-Y., Liu, J., Percival, I., 2007. Revision of the conodont *Erraticodon hexianensis* from the upper Meitan formation (Middle Ordovician) of Guizhou, south China. Paleontological Research 11 (2), 145–162.