# EARLY ORDOVICIAN CONODONTS FROM THE SOUTHERN CUYANIA TERRANE (MENDOZA PROVINCE, ARGENTINA)

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Lower Ordovician dolomites and limestones of the Ponon Trehue Formation (Mendoza Province, Argentina) have been sampled for conodonts. The documented conodont faunas indicate a Late Tremadoc through Late Arenig age and are comparable with those from the Precordillera to the north. Composition of the faunas and sedimentological features show that the two areas were connected and demonstrate that the outcrops of San Rafael and the Precordillera are part of the same terrane. The faunas show a trend from Midcontinent shallow-water conodonts in the lower part of the succession to temperate-water faunas in the middle part. Pandemic faunas, together with elements of the cold-water group are present in the uppermost interval of the Ponon Trehue Formation and mirror a remarkable sea-level rise.

Key words: Conodonta, biostratigraphy, paleogeography, Early Ordovician, Cuyania Terrane, western Argentina.

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## INTRODUCTION

The Precordillera of San Juan, La Rioja, and Mendoza and other outcrops of Early Paleozoic platform carbonates in western Argentina, together with the basement of the western Sierras Pampeanas, represent fragments of a Laurentia-derived "Cuyania Terrane" (RAMOS 1995). In the Precordillera, approx. 2100 m thick tropical carbonate platform deposits (KELLER 1997) were deposited from the late Early Cambrian to the Early Llanvirn in a miogeoclinal setting. This terrane with its Cambro-Ordovician carbonate platform is unique in South America. It has a possible extension of 1000 km by 600 to 800 km (RAMOS 1995; KELLER 1997).

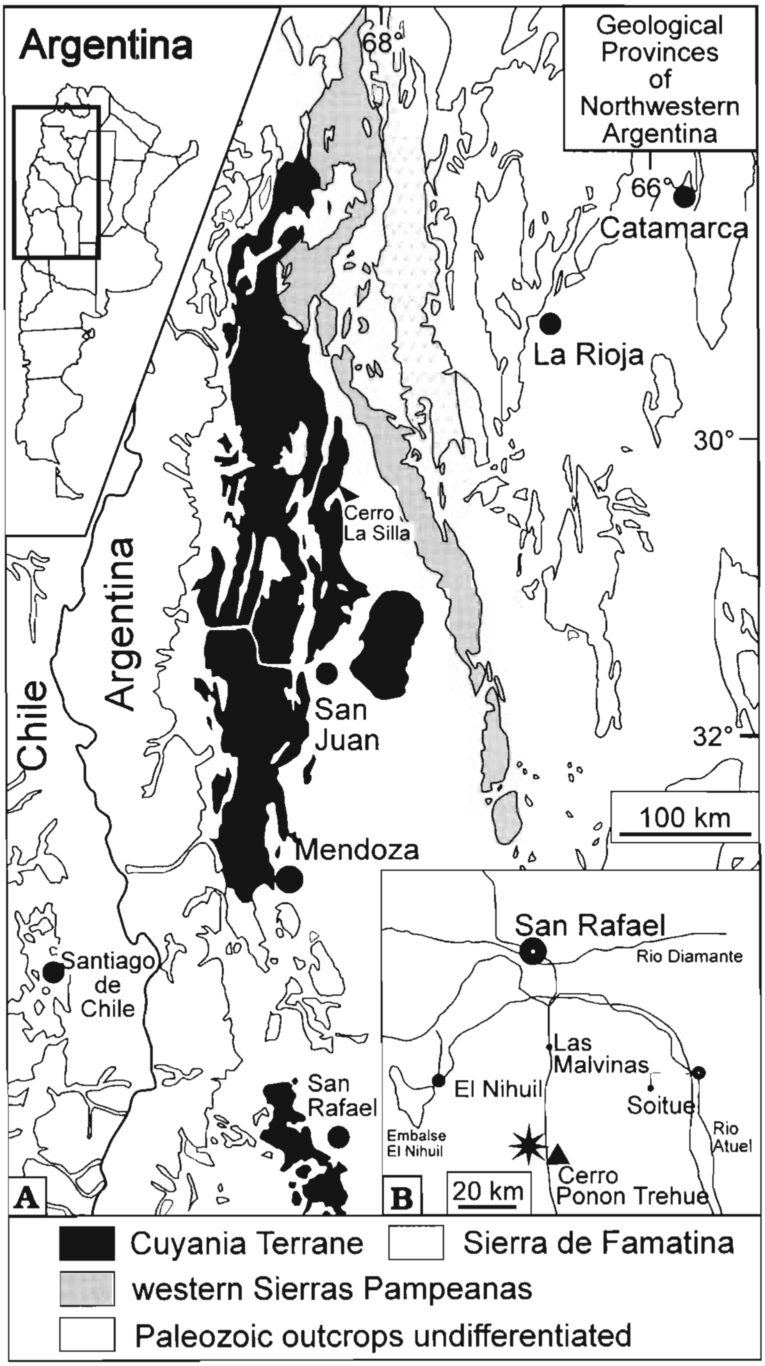

Fig. 1

**A**. Location of the "Cuyania Terrane" in western Argentina (modified from KELLER 1997). **B**. The study area (Fig. 2), south of the city of San Rafael, is marked by a star.

Ramos *et al.* (1986) pointed out strong sedimentological and faunal affinities between the Precordillera and the Appalachians. Consequently, Ramos *et al.* (1986) and Ramos (1988) interpreted the Precordillera as an exotic terrane of possible Laurentian provenance. Recent investigations suggest that this terrane originated in the Ouachita embayment at the southern margin of Laurentia (Dalla Salda *et al.* 1992a, b; Dalziel *et al.* 1994; Astini *et al.* 1995, Keller and Dickerson 1996).

In the study area (Figs 1, 2), crystalline basement of Grenvillian age (Ramos personal communication 1996) composed of siliciclastic metasediments, gneisses, and granitoids is exposed. North of the Ponon Trehue Creek, these Precambrian rocks (Cerro La Ventana Formation, Fig. 2) are overlain by Lower Ordovician carbonates of the Ponon Trehue Formation. South of the creek, the basal sedimentary succession consists of Middle to Late Ordovician (Llanvirn–Caradoc) deposits dominated by siliciclastics (Lindero Formation; Fig. 2). Wichmann (1928) was the first who compared the carbonates of the San Rafael area with Ordovician outcrops in the northern part of the Mendoza Province. Ordovician fossils from San Rafael have been first described by Nuñez (1962). Baldis and Blasco (1973) reported Llanvirnian to Caradocian? trilobites. Levy and Nullo (1975) described Llanvirnian to Llandeilian brachiopods. Only one short paper (Heredia 1982) dealt with the occurrence of conodonts (*Pygodus anserinus*); however, the sample locality is not given in that paper. Other publications dealing with this area are those of Padula (1951), Criado Roque and Ibañez (1979), and Nuñez (1979).

The purpose of this study is to document for the first time the conodont faunal succession of a cratonal part of the Cuyania Terrane. Additionally, the data indicate that sea-level changes in the San Rafael area were simultaneous with those known from the miogeoclinal setting to the north. Also, we discuss here the onlap of the carbonates onto the craton and the strong condensation of the carbonate sequence. Finally, the new data support the suggestions of various authors that the terrane was derived from Laurentia.

In the discussion of faunal affinities we will follow the terminology of Bagnoli and Stouge (1991) for the paleogeographical distribution of Arenig conodonts. These authors distinguished five different groups in two major realms (Midcontinent, North Atlantic): a pandemic group, a cold water group (North Atlantic Province), a warm water group (Midcontinent province), a temperate water group, and a warm water China group (China and Korea endemics). The specimens figured (IANIGLA PI 710–762) are deposited in the repository "Paleontología de Invertebrados del IANIGLA" (Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales; Departamento de Geología y Paleontología) in Mendoza, Argentina.

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## THE SECTION AND THE CONODONTS

The Ponon Trehue Formation has been recently redefined by Bordonaro *et al.* (1996). In its type section at Cerro Ai Sol (Fig. 2), the succession was subdivided into 4 informal units.

*Striatodontus prolificus* (Pl. 1: 1) has been obtained from a level 3 m above the base of the dolomites of unit 1 (sample CAS 1 – see Fig. 2). Unfortunately, sample CAS 2 from the thick-bedded dolomites which form the upper part of this basal unit yielded brachiopod fragments only. No data were obtained from unit 2 composed of biolaminites and microbial boundstones. The dolomites and microbial carbonates of the two basal units represent deposits of a peritidal environment.

In unit 3 of the Ponon Trehue Formation, different lithologies and open-marine macrofaunas are present. *S. prolificus* (Pl. 1: 2–4, 7, 8), *Colaptoconus quadraplicatus*, and *Eucharodus parallelus* (Pl. 1: 5) have been recovered from sponge-algal mounds at the base of this unit (sample CAS 3). These conodonts represent Midcontinent warm-water species, typical of coeval shallow-water deposits in the Precordillera. Grainstones and packstones with cherts, bioclasts, and intraclasts are associated with those mounds.

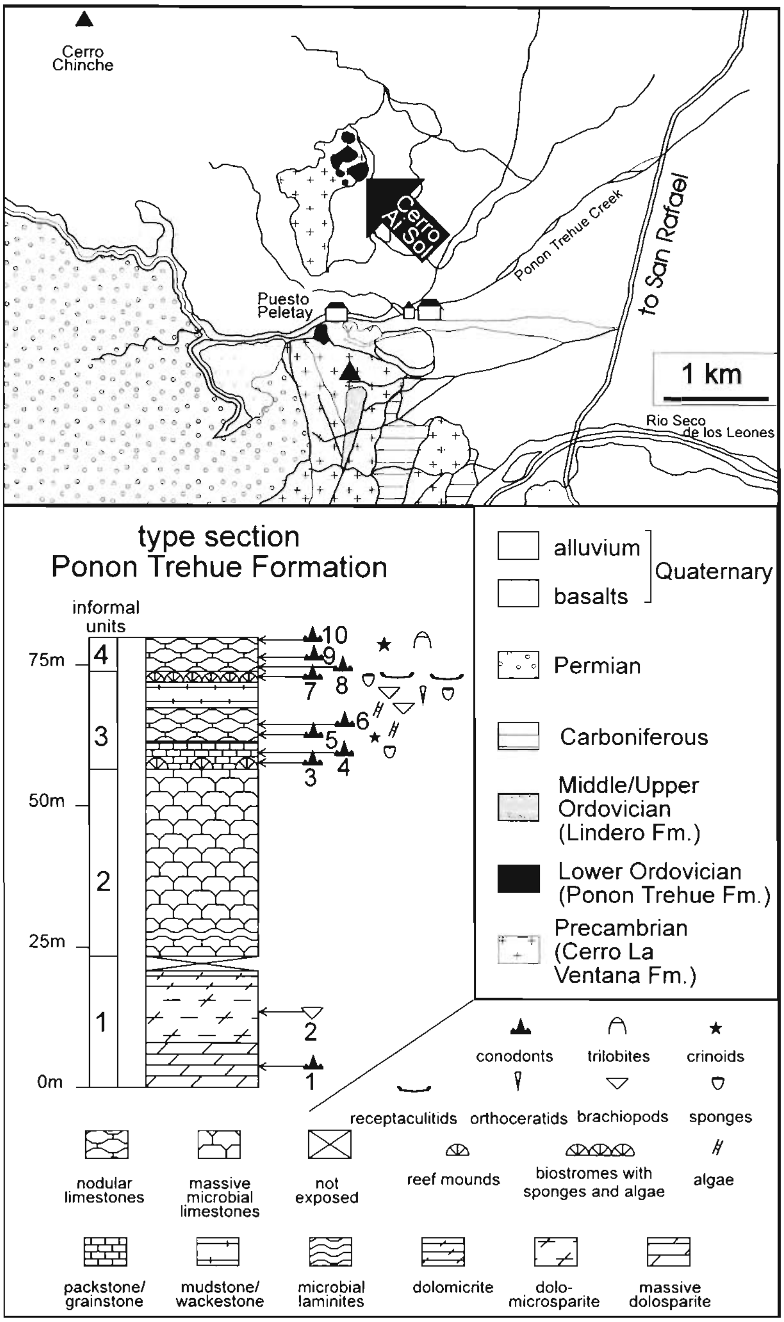

Fig. 2
Distribution of Ordovician deposits north and south of Ponon Trehue Creek and type section of the Ponon Trehue Formation (Cerro Ai Sol), modified from Bordonaro *et al.* (1996). Sampled horizons (samples CAS 1–10) are indicated by arrows.

Approximately 4 m above the base of this unit, "*Drepanodus*" *gracilis* has been found in a grainstone sample (CAS 4; Pl. 1: 6). The next two samples (CAS 5 and CAS 6, Fig. 2) from the overlying nodular wackestones yielded the first Early Arenig faunas with elements of the temperate-water group (*Bergstroemognathus*) and the pandemic group (*Tropodus, Oepikodus*). Brachiopods, algae, and echinoderm fragments are abundant. In sample CAS 5, *Bergstroemognathus extensus* (Pl. 1: 14, 19), *Juanognathus jaanussoni* (Pl. 1: 9), *Scolopodus* cf. *rex* (Pl. 1: 10, 11), *Tropodus sweeti* (Pl. 1: 12, 13, 15), *Scolopodus krummi* (Pl. 1: 20; Pl. 2: 4, 9), *Oepikodus communis* (Pl. 1: 17), and *Drepanodus arcuatus* (Pl. 1: 18) have been found. Also, sample CAS 6 contained one element of the deeper-water species *Paracordylodus gracilis* (Pl. 1: 16). This is the lowermost occurrence of a cold-water group genus in the section. The upper part of unit 3 consists of thick-bedded wackestones with biostromes of large receptaculitids, *Fischerites camacho* (NITECKI and FORNEY), and sponges. At the top of unit 3 (sample CAS 7), the first elements of *Periodon flabellum* (Pl. 2: 3, 6), another open-marine element of the cold-water group, are present together with the pandemic *Oepikodus evae* (Pl. 2: 1, 5, 7). In addition, the temperate-water genus *Bergstroemognathus* (*B. extensus*, Pl. 2: 2) has been found. However, *Fahraeosodus marathonensis* (Pl. 2: 8), also occurring at this level, represents a species typical of tropical environments of Laurentia (e.g., FINNEY and ETHINGTON 1992).

The top of the sequence exposed at Cerro Ai Sol is composed of dark gray nodular wackestones and grainstones (unit 4: 6 m thick) that reveal a sea-level rise and remarkable deepening of the environment. Three samples have been taken from these limestones (CAS 8–CAS 10), 1 m, 3.5 m, and 6 m above the base of unit 4. *P. flabellum* (Pl. 2: 12, 13, 17) and *Protopanderodus gradatus* (Pl. 3: 4, 5) are present in all three samples. *Paroistodus originalis* (Pl. 2: 10; Pl. 3: 15) and the hyolithelminthid *Phosphannulus universalis* (Pl. 3: 14) have been found in CAS 8 and CAS 10. *Erraticodon*? *balticus* (Pl. 2: 14; Pl. 3: 3), *Drepanoistodus forceps* (Pl. 3: 13), *O.* aff. *lanceolatus* (Pl. 2: 11; Pl. 3: 2, 9, 16), and *Pteracontiodus cryptodens* (Pl. 2: 15, 16; Pl. 3: 10) were obtained from samples CAS 9 and CAS 10. Additionally, *O.*? *tablepointensis* (Pl. 3: 1, 11) and *Drepanoistodus basiovalis* (Pl. 3: 6, 12) are present in sample CAS 10.

## AGE AND CORRELATION

For a detailed discussion of the intercontinental correlation of the assemblage zones established in the coeval sections of the Precordillera (La Silla and San Juan Formations; LEHNERT 1993, 1995) and as applied here, the reader is referred to LEHNERT (1995). HARRIS and REPETSKI (cited in HARRIS *et al.* 1995) established a correlation between SWEET's (1984) chronozones, which are based on graphic correlation of North American successions, and BERGSTRÖMS (1971) biozones described from Baltoscandic sediments (Fig. 3). The correlation of the faunas discussed in this paper with the standard zonations in the Baltic area and North America is shown in Fig. 3.

A discussion of the age of the lowermost part of the Ponon Trehue Formation is based on the presence of *Striatodontus prolificus.* This species is first found in the *Glyptoconus floweri/Glyptoconus bolites* shallow-water zone and is an index fossil of the overlying *S. prolificus/S. lanceolatus* shallow-water zone of JI and BARNES (1994) in western Newfoundland. The latter zone approximately correlates with the lower *Acodus deltatus–M. dianae* interval of ETHINGTON and CLARK (1982) and the *M. dianae* Zone of ROSS *et al.* (1993). In North American sections, *S. prolificus* is first present in the Low Diversity Interval and ranges up into the *Acodus deltatus–Oneotodus costatus* Zone. At the top of this zone, there are transitional forms to *Parapanderodus striatus* (J.E. REPETSKI, written communication). According to REPETSKI (personal communication), the earliest occurrence of typical elements of *P. striatus* can be dated for the *O. communis* Zone. Based on the presence of *S. prolificus*, we conclude that carbonate sedimentation at Cerro Ai Sol did not start before the Low Diversity Interval (Fig. 3).

Unit 1 to basal unit 3 correlate with strata of the upper La Silla Formation and lowermost San Juan Formation in the Precordillera (*Parapanderodus striatus/Colaptoconus quadraplicatus* assemblage zone). The contact between unit 2 and unit 3 marks a first deepening which corresponds to the change in sedimentology from the La Silla Formation to San Juan Formation in the Precordillera. The abrupt change from restricted-marine facies to limestones with open-marine and diverse faunas (KELLER *et al.* 1994), that can be observed at the contact, also reflects a deepening event. Unfortunately, *C. quadraplicatus* and *Eucharodus parallelus,* together with *S. prolificus* in the reef mounds at the base of unit 3, represent long-ranging taxa (Low Diversity Interval–*Reutterodus andinus* Zone; ROSS *et al.* 1993) and do not permit a more precise assignment. *"Drepanodus" gracilis*, found in a grainstone 2 m higher up in the section, is also known from North America where it is first present in the upper Fauna D of ETHINGTON and CLARK (1971), the *Acodus*? *deltatus–Oneotodus costatus* interval of ETHINGTON and CLARK (1982), or the *Acodus deltatus–Oneotodus costatus* Zone of ROSS *et al.* (1993). Thus, the grainstones from 2 m up to 5 m above the base of unit 3 may roughly be correlated with those zones. This part of the succession correponds to the *A.*? *deltatus–P. proteus* assemblage zone of LEHNERT (1995). The overlying strata of the Ponon Trehue Formation are coeval with the time-interval of the *O. communis/P. elegans* assemblage zone. In correlative strata of the San Juan Formation, *B. extensus*, *O. communis*, and *Scolopodus krummi* have been found.

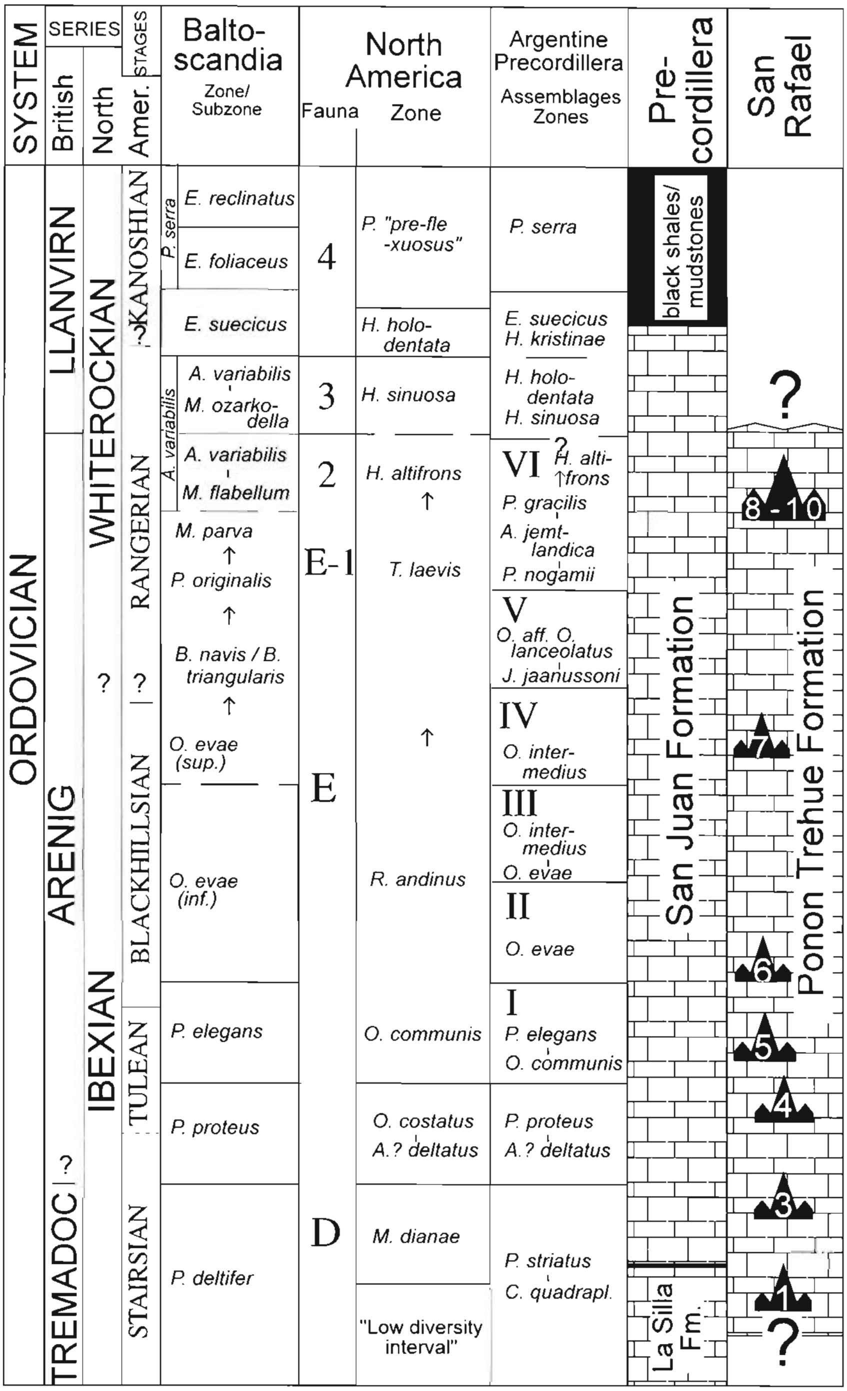

Fig. 3
Correlation of the Early Ordovician Ponon Trehue Formation with coeval strata in the Precordillera to the north (La Silla and San Juan formations). Sources of conodont zonations: Baltoscandia – LINDSTRÖM (1971), BERGSTRÖM (1971), LÖFGREN (1978); North America – ETHINGTON and CLARK (1971, 1982), Sweet *et al.* (1971), SWEET (1984), ROSS *et al.* (1993); Precordillera – LEHNERT (1993, 1995).

Other species obtained from unit 3 such as *P. gracilis, Scolopodus* cf. *rex*, *D. arcuatus*, and *T. sweeti* are already present in older beds at Cerro La Silla.

The biostromal horizons at the top of unit 3 formed during the *O. evae* chron, as indicated by the presence of the zonal index fossil. In these horizons, the abundance of the large receptaculitid *Fischerites camacho* is interesting. In the Precordillera, this receptaculitid is present in the upper *O. evae* Zone in the Niquivil section (approx. 10 km SSW' of Cerro La Silla).

The age determination for the top of the Ponon Trehue Formation (unit 4) is hampered by the lack of zonal index fossils. Therefore, the San Rafael faunas have to be indirectly correlated mainly by comparison with coeval strata in the Precordillera, from where the index fossils have previously been described. The presence of *P. originalis* indicates that this fauna is not older than the *P. originalis* Zone. In the Precordillera, however, the association of *P. cryptodens*, *P. originalis*, and *D. basiovalis* is only present in the *Amorphognathus variabilis* Zone and the overlying *E. suecicus* Zone (LEHNERT 1995; ORTEGA *et al.* 1995). In the *E. suecicus* Zone, this assemblage is associated with *H. kristinae* and *E. suecicus*. Because *P. flabellum*, which is present at the top of the Ponon Trehue Formation, is replaced by *Periodon aculeatus* within the *A. variabilis* Zone, the top of the succession cannot be younger than the lower part of the *A. variabilis* Zone. Another line of evidence although suggests a correlation with the lower *A. variabilis* Zone. *P. cryptodens* is a typical species of the following units: (1) *Histiodella altifrons* Zone; (2) the *M. flabellum/T. laevis* and *P. cryptodens/Histiodella altifrons/Multioistodus auritus* interval of ETHINGTON and CLARK 1982; and (3) Midcontinent faunas 1 and 2 (SWEET *et al.* 1971). All these units are correlated with the lower *A. variabilis* Zone.

In conclusion, the faunas in the uppermost horizons of unit 4 discussed so far represent elements which are typical of the upper San Juan Formation. In the Precordillera, these faunas are attributed to the Late Arenig (LEHNERT 1995). By comparison with the strata in the Precordillera, we attribute the sediments at the top of the Ponon Trehue Formation also to the Late Arenig. Critical to this assignment is the presence of *Oistodus*? *tablepointensis*. This species has been reported so far only from Late Whiterockian/Early Llanvirnian strata in Newfoundland (STOUGE 1984), where it has only a short range from the lower *Histiodella tableheadensis* phylozone (= *Histiodella holodentata*) to the lower part of the *Histiodella kristinae* phylozone of STOUGE (1984: fig. 18). This interval correlates with the upper *A. variabilis* to lower *E. suecicus* Zone in the Baltoscandic area (Fig. 3). The presence of *Oistodus*? *tablepointensis* indicates either that the strata at the very top of the Ponon Trehue are younger than we assume from the accompanying faunas or that the taxon appeared slightly earlier in the Cuyania Terrane than in Newfoundland. An assignment to the Late Arenig is also corroborated by the presence of *Protopanderodus gradatus* and *Paroistodus originalis* which are replaced by their successors during the *A. variabilis* Zone.

## DISCUSSION

Biostratigraphic correlations of the Upper Tremadoc to Upper Arenig strata near San Rafael with coeval miogeoclinal strata in the Precordillera (Cerro La Silla section) permit a comparison of faunal compositions and sedimentology between both successions.

In both successions, there is a trend in composition of conodont faunas of the warm-water group in the lower part to pandemic and temperate-water faunas in the younger strata. In the Ponon Trehue Formation, this trend is reflected in the sediments of unit 1 to basal unit 3. In the Precordillera, this trend is present from the upper part of the La Silla Formation to the lower part of the San Juan Formation. Additionally, in both areas representatives of the cold-water group come in with the global transgression of *O. evae* Zone (upper unit 3 of the Ponon Trehue Formation). This eustatic event represents the most extensive sea-level rise during Early Ordovician times (e.g., BAGNOLI 1994). The lower biostromal succession (base of unit 3) corresponds to the lower reef mound horizon at Cerro La Silla as described by CAÑAS and CARRERA (1993). The upper biostromal complex (top of unit 3) tentatively is compared with the upper reef mound horizon in the San Juan Formation. Both formed during an initial relative sea-level rise. The pronounced sea-level rise (nodular limestones of unit 4) in the upper part of the Ponon Trehue Formation is reflected by the common occurrence of open-marine elements such as *Periodon flabellum*. The same event is also observed in the sections of the Precordillera (KELLER 1997). This deepening during the Late Arenig finally led to the drowning of the Precordilleran carbonate platform during Early Llanvirn times.

When compared with the sections of the carbonate platform in the Precordillera (BORDONARO *et al.* 1996), the carbonates exposed in the San Rafael area represent a strongly reduced succession. About 80 m of carbonates near San Rafael correspond to more than 300 m of limestones in the miogeoclinal succession (Fig. 4). Furthermore, more than 1500 m of Cambrian and Early Ordovician sediments were deposited on this carbonate platform (La Laja Formation, Zonda Formation, La Flecha Formation, and the lower part of the La Silla Formation) until the first carbonates onlapped the basement in the Ponon Trehue area (Fig. 4). Strongly reduced sediment thicknesses, together with the Ordovician onlap onto the basement, indicate that the outcrops at Ponon Trehue represent a cratonal setting, the only cratonal section known from the Cuyania terrane so far.

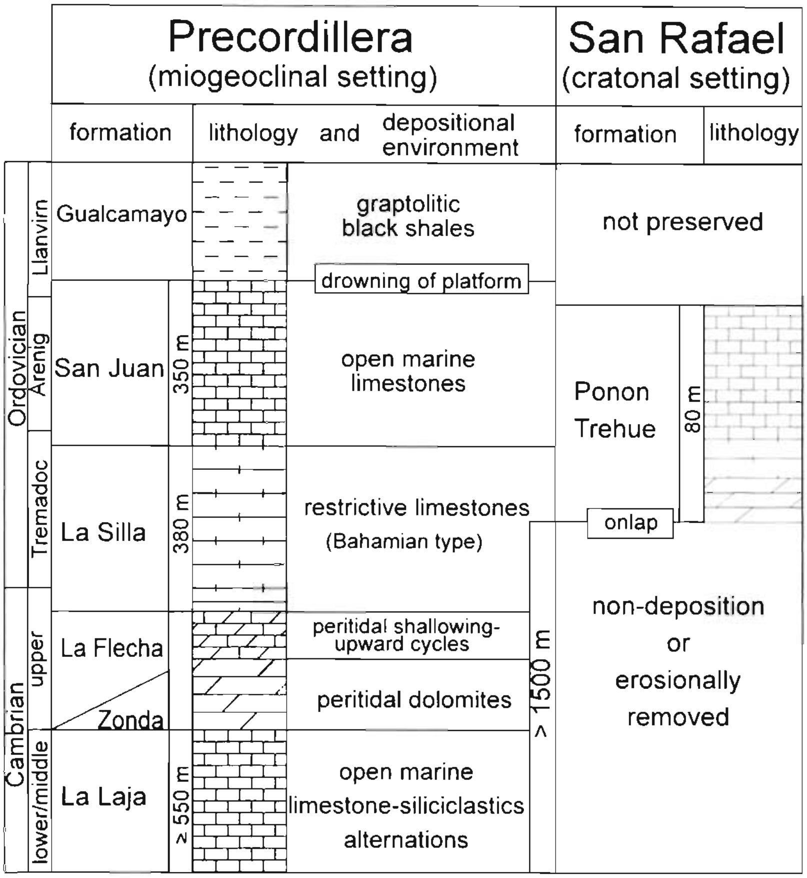

Fig. 4

Stratigraphy and depositional environments of the Cambro-Ordovician carbonate platform succession in the Precordillera (modified from Keller *et al.* 1994; thicknesses according to Keller 1997). Note that more than 1500 m of platform sediments are preserved in the miogeoclinal setting until the onlap onto the craton is recognized near San Rafael.

Ordovician conodont paleobiogeography and provincialism have been discussed and documented in various papers. Aspects of the Early Ordovician have been stressed by Ethington and Repetski (1984), Miller (1984), Bergström (1990), and Bagnoli and Stouge (1991, 1996). The conodonts from unit 1 to basal unit 3 as well as the faunas from the La Silla Formation and the lower San Juan Formation (Lehnert 1997) are typical of the North American Midcontinent Faunal Province. The presence of these conodonts together with almost identical, coeval reef structures from the San Juan Formation (Cañas and Carrera 1993; Cañas and Keller 1993) agrees with the interpretation that the San Rafael region is a part of the Cuyania Terrane. Faunal composition and sedimentology of the Ponon Trehue Formation are in agreement with a derivation of the terrane from the southern margin of Laurentia (e.g., Dalla Salda *et al.* 1992a, b; Dalziel *et al.* 1994; Astini *et al.* 1995; Dalziel 1997; Keller 1997).

## TAXONOMIC AND BIOSTRATIGRAPHIC REMARKS

The conodonts from San Rafael show a high thermal maturation. The conodont elements exhibit a high Color Alteration Index (CAI of Epstein *et al.* 1977) of about 6. According to Rejebian *et al.* (1987), this suggests a thermal heating between 360 and 550°C. Unfortunately, the conodonts are partly recrystallized and fragmented, but the faunal elements can be well compared with those described from the Argentine Precordillera (La Silla Formation and San Juan Formation).

The species mentioned in the text are well known from many other areas including the Precordillera proper. Therefore, they are listed only with reference to their original descriptions and to descriptions in the scope of multielement taxonomy or detailed synonymy lists. The occurrences in the Precordillera are not specifically discussed in this paper, but are added only for stratigraphic information. Unless otherwise stated, we always refer to the standard Cerro La Silla section, the type section for both the La Silla Formation and the San Juan Formation as defined by KELLER *et al.* (1994).

***Bergstroemognathus extensus* (GRAVES *et* ELLISON, 1941).** — *Oistodus extensus* sp. n. – GRAVES and ELLISON 1941: p. 13, pl. 1: 16, 28 (M element); *Bergstroemognathus extensus* (GRAVES *et* ELLISON, 1941) – SERPAGLI 1974: pp. 40–43, pl. 9: 1a–8c; pl. 21: 1–7; text-fig. 7 (synonymy of multielement species until 1974), STOUGE and BAGNOLI 1988: p. 113, pl. 1: 6–13 (synonymy until 1988), LEHNERT 1995: p. 75, pl. 5: 20, 21; pl. 20A: 6; pl. 20B: 2 (synonymy until 1994).

The species is present in samples CAS 5 to CAS 7 (unit 3). In the Precordillera, it is common in the lower part of the San Juan Formation where it first appears in the *P. elegans/O. communis* assemblage zone.

***Colaptoconus quadraplicatus* (BRANSON *et* MEHL, 1933).** — *Scolopodus quadraplicatus* sp. n. – BRANSON and MEHL 1933: p. 63, pl. 4: 14, 15; *Glyptoconus quadraplicatus* (BRANSON *et* MEHL) – KENNEDY 1980: pp. 61–63, pl. 1: 39–45 (detailed description and synonymy), STOUGE and BAGNOLI 1988: p. 120, pl. 3: 20, 21 (synonymy until 1988); LEHNERT 1995: pp. 89–90, pl. 1: 10, 12, pl. 2: 15–16, 18 (synonymy until 1994).

The species was found in sample CAS 3 (reef mounds, basal unit 3). In the Precordillera, it is observed from the upper La Silla Formation to the *P. elegans/O. communis* assemblage zone of the San Juan Formation.

***Drepanodus arcuatus* PANDER, 1856.** — LÖFGREN 1978: pp. 51–53, pl. 2: 1, 2, 4–8, non 3 (*D. planus)* (description and synonymy until 1978), STOUGE and BAGNOLI 1988: pp. 115–116, pl. 2: 1–6 (detailed synonymy until 1988), STOUGE and BAGNOLI 1990: p. 14, pl. 9: 7–10 (synonymy until 1990), LEHNERT 1995: p. 82, pl. 3: 15, 16 (synonymy until 1994).

The species is present in sample CAS 5 (unit 3). In the Precordillera, it is common in the San Juan Formation first occurring in the *A. ?deltatus/P. proteus* assemblage zone.

**"*Drepanodus*" *gracilis* (BRANSON *et* MEHL, 1933) *sensu* LINDSTRÖM, 1955 s.f.** — *Drepanodus*? *gracilis* BRANSON *et* MEHL – LINDSTRÖM 1955: pp. 562–563, pl. 4: 44, pl. 5: 6, 7; *Drepanodus gracilis* (BRANSON and MEHL 1933) *sensu* LINDSTRÖM 1955 – ETHINGTON and CLARK 1982: pp. 37–38, pl. 3: 7, text-fig. 10 (description and synonymy until 1981).

***Drepanoistodus basiovalis* (SERGEEVA, 1963).** — *Oistodus basiovalis* sp. n. – SERGEEVA 1963: pp. 96–98, pl. 7: 6, 7; text-fig. 3; STOUGE and BAGNOLI 1990: p. 15, pl. 5: 18–24 (synonymy until 1990); LEHNERT 1995: pp. 85–86, pl. 9: 9; pl. 10: 5, 12 (synonymy until 1994).

The species was found in sample CAS 10 (unit 4, top of Ponon Trehue Formation) and in the Precordillera in the uppermost part of the San Juan Formation where it replaces its precursor *D. forceps* in strata which are correlated with the *A. variabilis* Zone.

***Drepanoistodus forceps* (LINDSTRÖM, 1955).** — *Oistodus forceps* sp. n. – LINDSTRÖM: p. 574, pl. 4: 9–13, text-fig. 3M; *Drepanoistodus forceps* (LINDSTRÖM) – LÖFGREN 1978: pp. 53–55, pl. 1: 1–6; text-fig. 26A (detailed description and synonymy until 1978), STOUGE and BAGNOLI 1990: p. 16–17, pl. 5: 6–9 (synonymy until 1990), LEHNERT 1995: p. 86, pl. 3: 20; pl. 6: 2 (synonymy until 1994).

The species was obtained from samples CAS 9 and CAS 10 (unit 4). In the Precordillera, it is present from the *O. evae* Zone up to the top of the San Juan Formation (*A. variabilis* Zone).

***Erraticodon*? *balticus* DZIK, 1978.** — ?*Erraticodon balticus* sp. n. – DZIK 1978: p. 66, pl. 15: 1–3, 5, 6; text-fig. 6 (description); ?*Erraticodon balticus* DZIK – LEHNERT 1995: pp. 87–88, pl. 9: 13, 16 (synonymy until 1994).

The *Erraticodon* elements present in samples CAS 9 and CAS 10 (unit 4) most probably correspond to *Erraticodon balticus*. However, the preservation of the fragmented material does not permit an unequivocal determination. One **M** element of an *Erraticodon* with a long process is not typical of this species (DZIK personal communication). This element is figured as *Erraticodon* sp. (Pl. 2: 14). *E. balticus* is found in the uppermost part of the San Juan Formation (SARMIENTO 1990).

***Eucharodus parallelus*** **(BRANSON *et* MEHL, 1933).** — *Drepanodus parallelus* sp. n. – BRANSON and MEHL 1933: p. 59, pl. 4: 17; *Eucharodus parallelus* (BRANSON *et* MEHL) – KENNEDY 1980: pp. 58–60, pl. 1: 35–38 (detailed description and synonymy until 1980), STOUGE and BAGNOLI 1988: p. 118, pl. 3: 14 (synonymy until 1988), SMITH 1991: pp. 33–34, text-fig. 19d–f (detailed synonymy until 1991), LEHNERT 1995: p. 88, pl. 2: 15, 16, 18 (synonymy until 1995).

The species was obtained from sample CAS 3 (unit 3). It is also present in the lowermost part of the San Juan Formation (*G. quadraplicatus/P. striatus* to basal *P. elegans/O. communis* assemblage zone).

***Fahraeosodus marathonensis*** **(BRADSHAW, 1969).** — *Gothodus marathonensis* sp. n. – BRADSHAW 1969: p. 1151, pl. 137: 13–15, text-fig. 3S–U; *"Mikrozarkodina" marathonensis* (BRADSHAW) – ETHINGTON and CLARK 1982: pp. 55–56, Taf. 5: 14, 19, 20, 23, 24, 27 (detailed description of multielement species and synonymy until 1981); *Fahraeosodus marathonensis* (BRADSHAW) – STOUGE and BAGNOLI: p. 119, pl. 4: 15–17 (synonymy until 1988), LEHNERT 1995: p. 89, pl. 7: 19, pl. 8: 1 (synonymy until 1994).

The species is present in sample CAS 7. It represents a rare element of the San Juan faunas (*O. evae* zone to Assemblage VI in the upper part of the Niquivil section; LEHNERT 1993).

***Juanognathus jaanussoni*** **SERPAGLI, 1974.** — *Juanognathus jaanussoni* sp. n. – SERPAGLI 1974: pp. 50, 51, pl. 11: 8a–12c; pl. 23: 1a–5b; text-fig. 9 (detailed description and synonymy until 1974), LEHNERT 1995: p. 92, pl. 3: 2, 3 (synonymy until 1994).

The species is found in sample CAS 5 (unit 3). It is common in the middle and upper part of the San Juan Formation.

***Oepikodus communis*** **(ETHINGTON *et* CLARK, 1964).** — *Gothodus communis* sp. n. – ETHINGTON and CLARK 1964: pp. 690, 692, pl. 114: 6, 14; text-fig. 2F; *Oepikodus communis* (ETHINGTON and CLARK) – STOUGE and BAGNOLI 1988: p. 121, pl. 5: 8–12 (synonymy until 1988), LEHNERT 1995: pp. 98–99, pl. 5: 22, 27–29; pl. 8: 19–24 (synonymy until 1995).

The species was obtained from sample CAS 5 (unit 3). In the San Juan Formation, it is present from the upper *P. elegans/O. communis* to the *O. evae* Zone.

***Oepikodus evae*** **(LINDSTRÖM, 1955).** — *Prioniodus evae* sp. n. – LINDSTRÖM 1955: p. 589, pl. 6: 4–10; *Prioniodus (Oepikodus) evae* LINDSTRÖM – SERPAGLI 1974: pp. 67–69, pl. 15: 9a–13; pl. 26: 1–10; pl. 31: 1 (description and synonymy until 1974), LÖFGREN 1978: pp. 79, 80, pl. 9: 7–11, 17A, B (synonymy until 1978); *Oepikodus evae* (LINDSTRÖM) – STOUGE and BAGNOLI 1988: pp. 121, 122, pl. 5: 1–7 (synonymy until 1988), LEHNERT 1995: pp. 99–100, pl. 20B: 1 (synonymy until 1994).

The pandemic species was obtained from sample CAS 7 (top of unit 3). It is abundant in the *O. evae* Zone in the Precordillera (references compiled by SARMIENTO and GARCIA-LOPEZ 1993).

***Oistodus*** **aff. *lanceolatus*** **PANDER, 1856.** — ?*Oistodus* aff. *lanceolatus* PANDER – STOUGE and BAGNOLI 1988: p. 123, pl. 6: 1–8; LEHNERT 1995: p. 101, pl. 8: 6–8; pl. 20B: 12 (description and synonymy).

The species was found in samples CAS 9 and CAS 10 (unit 4) and is mainly associated with other shallow-water species in the reef mound horizons of the upper San Juan Formation (assemblages V and VI of LEHNERT 1993).

***Oistodus? tablepointensis*** **STOUGE, 1984.** — *Oistodus? tablepointensis* sp. n. – STOUGE 1984: pp. 75–76, pl. 14: 2–12 (description and synonymy).

***Paracordylodus gracilis*** **LINDSTRÖM, 1955.** — *Paracordylodus gracilis* sp. n. – LINDSTRÖM 1955: p. 584, pl. 6: 11–12 (S element); LÖFGREN 1978: pp. 67–68, pl. 9: 15A–16B (synonymy of the multielement species until 1978); LEHNERT 1995: p. 105, pl. 4: 3 (synonymy until 1994).

The species was found in sample CAS 6 (unit 3). *P. gracilis* is always represented by a few individuals only. However, this species is widely distributed on the San Juan platform. This distribution was discussed by SARMIENTO and GARCIA-LOPEZ (1993). *P. gracilis* is observed in the *P. elegans/O. communis* assemblage zone at Cerro La Silla and in the *P. elegans* and *O. evae* assemblage zones in Niquivil (LEHNERT 1993).

***Paroistodus originalis*** **(SERGEEVA, 1963).** — *Oistodus originalis* – SERGEEVA 1963: p. 98, pl. 7: 8, 9; text-fig. 4; *Paroistodus originalis* (SERGEEVA) – LÖFGREN 1978: pp. 69–71, pl. 1: 22–25; text-fig. 28 (description and synonymy until 1978), STOUGE and BAGNOLI 1990: p. 22, pl. 7: 5–10 (synonymy until 1990), LEHNERT 1995: pp. 109, 110, pl. 7: 2, 3; pl. 13: 5 (synonymy until 1994).

***Periodon flabellum*** **(Lindström, 1955).** — *Periodon flabellum* (Lindström) – Löfgren 1978: pp. 72–74, pl. 11: 1–11, text-fig. 29 (pars) (description and discussion, synonymy until 1978), Lehnert 1995: p. 112, pl. 7: 8, 10, 11 (synonymy until 1994).

The species is present in samples CAS 8 to CAS 10 (unit 4). *P. flabellum* is common in the San Juan Formation, ranging from the *O. evae* Zone to the top of the San Juan Formation (approx. *M. parva* Zone – first transitional forms into *P. aculeatus zgierzensis* Dzik, typical elements of *P. aculeatus* Hadding are found at the top of the San Juan Formation).

***Protopanderodus gradatus*** **Serpagli, 1974.** — *Protopanderodus gradatus* sp. n. – Serpagli 1974: pp. 75–77, pl. 15: 5a–8b; pl. 26: 11–15; pl. 30: 1a, b; text-fig. 17 (description and synonymy until 1974), Lehnert: p. 117, pl. 3: 11, 12 (synonymy until 1994).

The species was obtained from samples CAS 8 to CAS 10 (unit 4). It ranges from the lower part of the San Juan Formation (*P. elegans* /*O. communis* assemblage zone) to the *A. variabilis* Zone (top of the formation at Cerro Potrerillo, north of the Rio Jáchal, Ortega *et al.* 1995).

***Pteracontiodus cryptodens*** **Mound, 1965.** — *Pteracontiodus cryptodens* sp. n. – Mound 1965: pp. 197–198, text-figs 1–2, 12, 13, Ethington and Clark 1981: pp. 88–89, pl. 14: 1–4, 6–10 (synonymy of multielement species to 1981), Lehnert: pp. 119–120, pl. 7: 7; pl. 13: 13.

The species is present in samples CAS 9 and CAS 10 (unit 4). It is a typical species of the *M. parva* and *A. variabilis* zones in the Precordillera (Ortega *et al.* 1995).

***Reutterodus andinus*** **Serpagli, 1974.** — *Reutterodus andinus* sp. n. – Serpagli 1974: pp. 79–81, pl. 17: 9a–d; pl. 28: 1–9b; text-figs 19–20 (detailed description of multielement species); *Reutterodus andinus* Serpagli – Lehnert 1995: p. 122, pl. 7: 9–13 (synonymy until 1994).

The species was obtained from sample CAS 5 (unit 3). In the Precordillera, the species is first observed in the *P. elegans*/*O. communis* assemblage zone. It is an important representative of the *O. evae* Zone.

***Scolopodus*** **cf. *rex*** **Lindström, 1955.** — cf. *Scolopodus rex* sp. n. – Lindström 1955: p. 595, pl. 3: 32; cf.1978; cf. *Scolopodus rex* Lindström – Löfgren: p. 109, pl. 1: 38–39 (detailed synonymy until 1978); *Scolopodus* cf. *rex* Lindström – Lehnert: pp. 124–125, pl. 5: 5–6.

The species is present in samples CAS 5 and CAS 6 (unit 3). In the Precordillera, it is first observed in the *A.*? *deltatus* /*P. proteus* assemblage zone and ranges up into the upper *O. evae* Zone.

***Scolopodus? krummi*** **(Lehnert, 1995).** — *Tropodus*? *krummi* sp. n. – Lehnert 1995: pp. 130–131, pl. 5: 18, 19 (detailed description).

The species is present in samples CAS 6 and CAS 7 (unit 3) and in the lower part of the San Juan Formation which corresponds to the *O. communis*/*P. elegans* assemblage zone.

***Spinodus*** **sp.** — broken fragments of *Spinodus* have been found in sample CAS 10 (top of unit 4). In the Precordillera, the oldest *Spinodus* elements [*Spinodus spinatus* (Hadding, 1913)], have been found in the upper part of the San Juan Formation correlated with the *M. parva* and *A. variabilis* zones (e.g., Sarmiento 1990; Ortega *et al.* 1995).

***Striatodontus prolificus*** **(Ji *et* Barnes, 1994).** — *Striatodontus prolificus* – Ji and Barnes 1994: pp. 61–62, pl. 20: 1–26; text-fig. 36A (detailed description and synonymy).

Elements of *S. prolificus* from the uppermost La Silla Formation and lowermost San Juan Formation have been identified by Lehnert (1995: pl. 1: 15) and Lehnert *et al.* (in press: pl. 2: 22, 23) as *Parapanderodus striatus* (Graves *et* Ellison, 1941). However, as discussed by Lehnert (1995: p. 107), the elements from the Precordillera are more robust and shorter than typical elements of *P. striatus*. In addition, they show a high content of white matter in the cusp instead of being hyaline. Similar elements have been assigned to *P. striatus* by Ethington and Clark (1982), Repetski (1982), and Ross *et al.* (1993) and therefore it should be noticed that in published charts the range of this species includes that of *S. prolificus*.

The species was found in samples CAS 1 and CAS 3 (unit 1 and basal unit 3). In the Precordillera, *S. prolificus* is present in the upper part of the La Silla Formation and in the basal San Juan Formation.

***Tropodus sweeti*** **(Serpagli, 1974).** — *"Paltodus" ?sweeti* sp. n. – Serpagli 1974: pp. 58–59, pl. 14: 13a–14b; pl. 24: 8–10; text-fig. 12 (**P** element); *Tropodus sweeti* (Serpagli) – Stouge and Bagnoli 1988: p. 142, pl. 16: 10–15 (synonymy of multielement species), Lehnert 1995: pp. 131–132, pl. 3: 17–19 (synonymy until 1994).

The species was found in sample CAS 5 (unit 3). In the San Juan Formation, *T. sweeti* is first observed in the *A.? deltatus/P. proteus* assemblage zone (Cerro La Silla section) and ranges up into Assemblage IV (Niquivil section, LEHNERT 1993).

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## EARLY ORDOVICIAN CONODONTS FROM THE SOUTHERN CUYANIA TERRANE (MENDOZA PROVINCE, ARGENTINA)

### PLATE 1

*Striatodontus prolificus* Ji *et* Barnes, 1995 . . . . . . . . . . . . . . . . . . . 57

1. Postero-lateral view, IANIGLA PI 710, sample CAS 1, × 230.
2. Postero-lateral view, IANIGLA PI 711, sample CAS 3, × 182.
3. Postero-lateral view, IANIGLA PI 712, sample CAS 3, × 202.
4. Postero-lateral view, IANIGLA PI 713, sample CAS 3, × 150.
7. Postero-lateral view, IANIGLA PI 714, sample CAS 3, × 166.
8. Postero-lateral view, IANIGLA PI 715, sample CAS 3, × 216.

*Eucharodus parallelus* (Branson *et* Mehl, 1933) . . . . . . . . . . . . . . . 56

5. Lateral view, IANIGLA PI 716, sample CAS 3, × 174.

"*Drepanodus*" *gracilis* (Branson *et* Mehl) *sensu* Lindström, 1955 s.f. . . 55

6. Lateral view, IANIGLA PI 717, sample CAS 4, × 170.

*Juanognathus jaanussoni* Serpagli, 1974 . . . . . . . . . . . . . . . . . . . . 56

9. Posterior view, IANIGLA PI 718, sample CAS 5, × 93.

*Scolopodus* cf. *rex* Lindström, 1955 . . . . . . . . . . . . . . . . . . . . . . 57

10. Postero-lateral view, fragment, IANIGLA PI 719, sample CAS 5, × 121.5.
11. Lateral view, fragment, IANIGLA PI 720, sample CAS 6, × 109.

*Tropodus sweeti* Lindström, 1955 . . . . . . . . . . . . . . . . . . . . . . . 57

12. Lateral view, fivecostate **S** element, IANIGLA PI 721, sample CAS 5, × 130.
13. Posterior view, fivecostate **S** element, IANIGLA PI 722, sample CAS 5, × 113.
15. Lateral view, **P** element, IANIGLA PI 723, sample CAS 5, × 97.

*Bergstroemognathus extensus* Serpagli, 1974 . . . . . . . . . . . . . . . . 55

14. Posterior view, **Sa** element, IANIGLA PI 724, sample CAS 5, × 117.
19. Lateral view, **S** element, IANIGLA PI 725, sample CAS 5, × 154.

*Paracordylodus gracilis* Lindström, 1955 . . . . . . . . . . . . . . . . . . . 56

16. Lateral view, paracordylodiform element, IANIGLA PI 726, sample CAS 6, × 170.

*Oepikodus communis* (Ethington *et* Clark, 1964) . . . . . . . . . . . . . . . 56

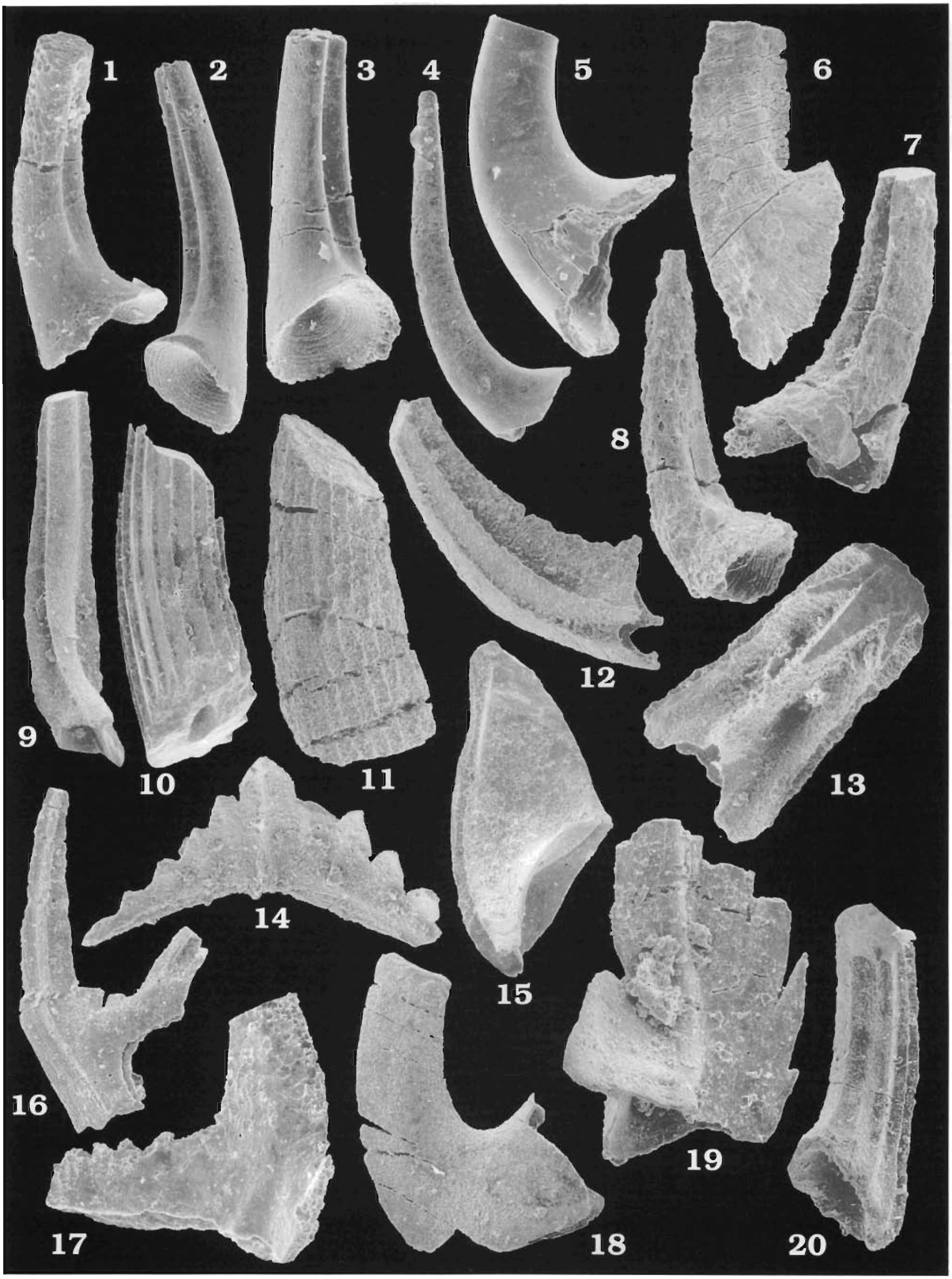
17. Lateral view, **P** element, IANIGLA PI 727, sample CAS 5, × 170.

*Drepanodus arcuatus* Pander, 1856 . . . . . . . . . . . . . . . . . . . . . . 55

18. Lateral view, **P** element, IANIGLA PI 728, sample CAS 5, × 69.

*Scolopodus*? *krummi* (Lehnert, 1995) . . . . . . . . . . . . . . . . . . . . 57

20. Posterior view, IANIGLA PI 729, sample CAS 6, × 130.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## EARLY ORDOVICIAN CONODONTS FROM THE SOUTHERN CUYANIA TERRANE (MENDOZA PROVINCE, ARGENTINA)

### PLATE 2

*Oepikodus evae* (LINDSTRÖM, 1955) . . . . . . . . . . . . . . . . . . . . . . . 56

1. Lateral view, **P** element, IANIGLA PI 730, sample CAS 7, × 150.
5. Lateral view, **S** element, IANIGLA PI 731, sample CAS 7, × 216.
7. Lateral view, **S** element, IANIGLA PI 732, sample CAS 7, × 154.

*Bergstroemognathus extensus* Serpagli, 1974 . . . . . . . . . . . . . . . . . . 55

2. Lateral view, **M** element, IANIGLA PI 733, sample CAS 7, × 77.

*Periodon flabellum* (LINDSTRÖM, 1955) . . . . . . . . . . . . . . . . . . . . . 57

3. Lateral view, **S** element, IANIGLA PI 734, sample CAS 7, × 113.
6. Lateral view, **M** element, IANIGLA PI 735, sample CAS 7, × 109.
12. Lateral view, **S** element, IANIGLA PI 736, sample CAS 9, × 117.
13. Posterior view, **S** element, IANIGLA PI 737, sample CAS 9, × 170.
17. Lateral view, **P** element, IANIGLA PI 738, sample CAS 9, × 130.

*Scolopodus? krummi* LEHNERT, 1995 . . . . . . . . . . . . . . . . . . . . . . 57

4. Posterior view, IANIGLA PI 739, sample CAS 7, × 146.
9. Posterior view, IANIGLA PI 740, sample CAS 7, × 77.

*Fahraeosodus marathonensis* (BRADSHAW, 1969) . . . . . . . . . . . . . . . 56

8. Lateral view, **P** element, IANIGLA PI 741, sample CAS 7, × 146.

*Paroistodus originalis* SERGEEVA, 1963 . . . . . . . . . . . . . . . . . . . . 56

10. Lateral view, oistodiform element, IANIGLA PI 742, sample CAS 9, × 138.

*Oistodus* aff. *lanceolatus* PANDER, 1856 . . . . . . . . . . . . . . . . . . . 54

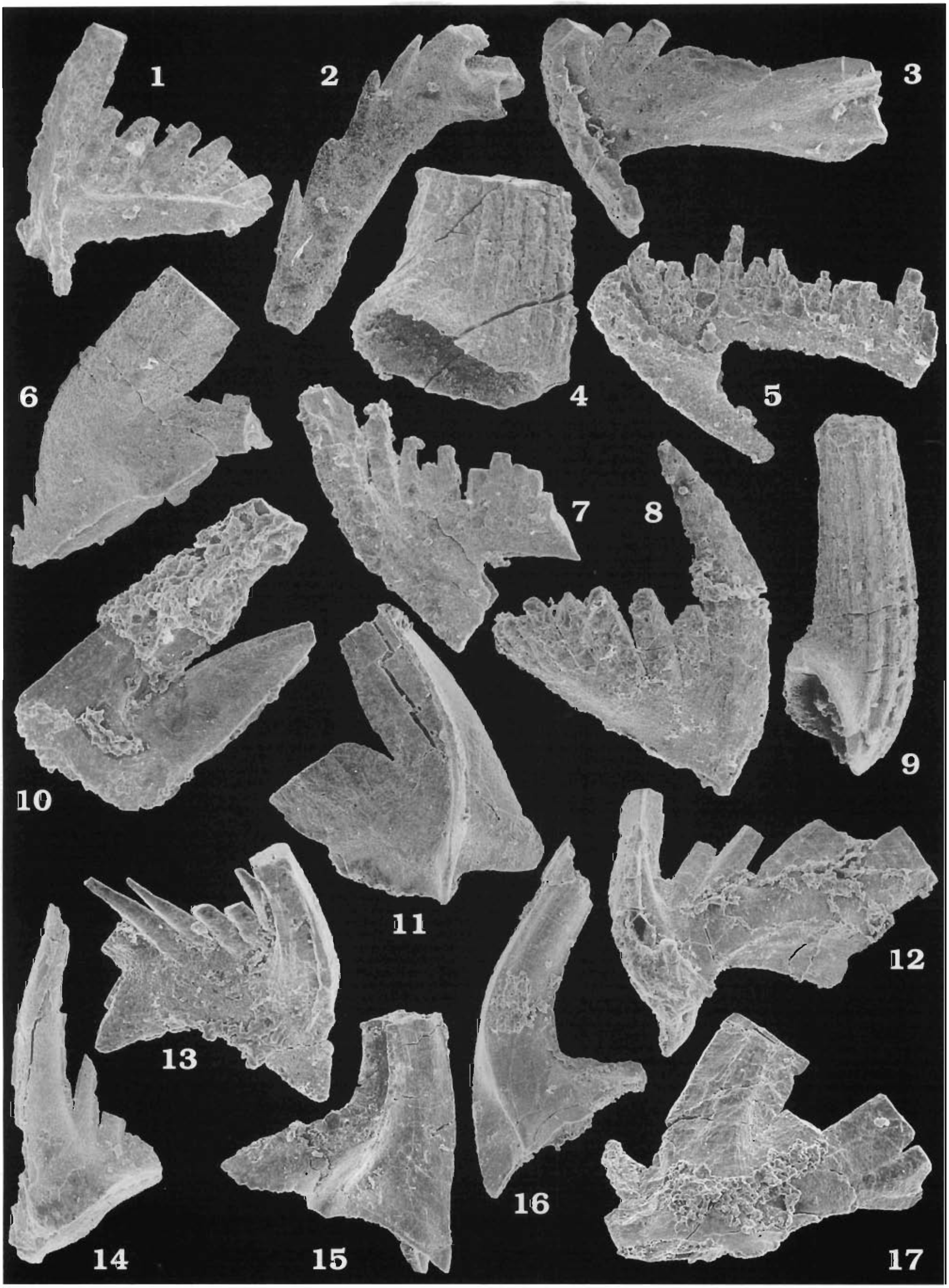
11. Lateral view, IANIGLA PI 743, sample CAS 9, × 97.

*Erraticodon* sp. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 55

14. Inner lateral view, **M** element, IANIGLA PI 744, sample CAS 9, × 73.

*Pteracontiodus cryptodens* MOUND, 1965 . . . . . . . . . . . . . . . . . . . 57

15. Lateral view, IANIGLA PI 745, sample CAS 9, × 89.
16. Lateral view, IANIGLA PI 746, sample CAS 9, × 73.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EARLY ORDOVICIAN CONODONTS FROM THE SOUTHERN CUYANIA TERRANE
(MENDOZA PROVINCE, ARGENTINA)

## PLATE 3

*Oistodus*? *tablepointensis* STOUGE, 1984 . . . . . . . . . . . . . . . . . . . . 56

1. Postero-lateral view, IANIGLA PI 747, sample CAS 10, × 97.
11. Postero-lateral view, IANIGLA PI 748, sample CAS 10, × 89.

*Oistodus* aff. *lanceolatus* PANDER, 1856 . . . . . . . . . . . . . . . . . . . . 56

2. Lateral view, IANIGLA PI 749, sample CAS 9, × 97.
9. Lateral view, **Sb** element, IANIGLA PI 750, sample CAS 10, × 89.
16. Posterior view, **Sa** element, IANIGLA PI 751, sample CAS 9, × 97.

*Erraticodon*? *balticus* DZIK, 1978 . . . . . . . . . . . . . . . . . . . . . . . 55

3. Posterior view, IANIGLA PI 752, sample CAS 9, × 146.

*Protopanderodus gradatus* SERPAGLI, 1974 . . . . . . . . . . . . . . . . . . 57

4. Lateral view, IANIGLA PI 753, sample CAS 10, × 134.
5. Lateral view, IANIGLA PI 754, sample CAS 10, × 150.

*Drepanoistodus basiovalis* (SERGEEVA, 1963) . . . . . . . . . . . . . . . . . 55

6. Lateral view, suberectiform element, IANIGLA PI 755, sample CAS 10, × 125.
12. Lateral view, oistodiform element, IANIGLA PI 756, sample CAS 10, × 113.

*Periodon flabellum* (LINDSTRÖM, 1955) . . . . . . . . . . . . . . . . . . . . 57

7. Lateral view, **S** element, IANIGLA PI 757, sample CAS 10, × 97.

*Spinodus* sp. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 57

8. Lateral view, fragment, IANIGLA PI 758, sample CAS 10, × 130.

*Pteracontiodus cryptodens* MOUND, 1965 . . . . . . . . . . . . . . . . . . . 57

10. Lateral view, IANIGLA PI 759, sample CAS 10, × 117.

*Drepanoistodus forceps* LINDSTRÖM, 1955 . . . . . . . . . . . . . . . . . . 55

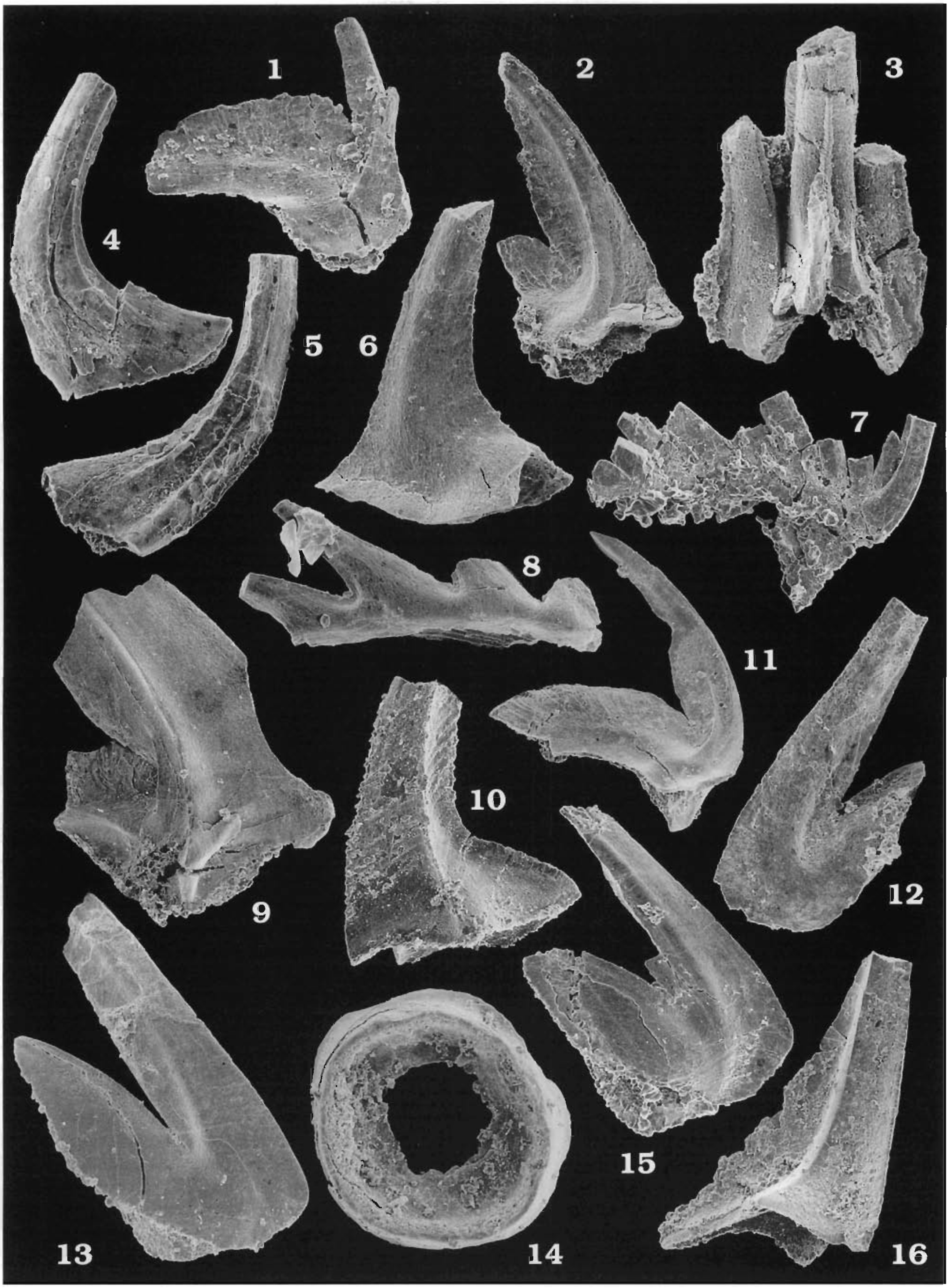
13. Lateral view, oistodiform element, IANIGLA PI 760, sample CAS 10, × 125.

*Phosphannulus universalis* MÜLLER, NOGAMI *et* LENZ, 1974 . . . . . . . . . 51

14. IANIGLA PI 761, sample CAS 8, × 154.

*Paroistodus originalis* (SERGEEVA, 1963) . . . . . . . . . . . . . . . . . . . 56

15. Lateral view, oistodiform element, IANIGLA PI 762, sample CAS 10, × 125.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