

## Biofacies and palaeoenvironments of conodonts in Cambro-Ordovician sequences of the Quebrada de Humahuaca, Cordillera Oriental of Jujuy, Argentina

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The taxa frequencies and cluster analysis of 10 837 conodonts recovered from the Santa Rosita Formation on the eastern flank of the Quebrada de Humahuaca, Cordillera Oriental of Argentina, were carried out for palaeoenvironmental interpretations. The first type of analysis allowed us to identify three conodont biofacies: *Variabiloconus-Teridontus*, *Utahconus-Acanthodus* and *Tilcarodus-Drepanoistodus*, and the cluster analysis helps define respective sub-biofacies. The first biofacies is not constrained to a particular environment, the second biofacies, which is characterized by typical Laurentian genera, is related to sandstones from shallow-water environments, while the third one is better represented in deeper water siliciclastic lithofacies. A nektonic mode of life is suggested for *Utahconus* and *Acanthodus*, but a pelagic behaviour is apparent for the rest of the taxa, well adapted to off-shore biotopes in particular cases (proto- and paraconodonts). The faunal composition reveals a mixture of Baltic and Laurentian taxa, as well as endemic forms that define the Southwestern Gondwana Province from the Cold Domain in the Shallow-Sea Realm. The presence of typical species from low latitudes (e.g. Australia) confirms the installation of an oceanic perigondwanian corridor, which was open to faunal migration during the late Cambrian–early Ordovician. Copyright © 2012 John Wiley & Sons, Ltd.

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### 1. INTRODUCTION

Palaeoecological studies of conodonts have been carried out by a number of authors since the first contributions as theoretical models in the early 1970's (e.g. Seddon and Sweet, 1971; Barnes and Fåhræus, 1975; Ji and Barnes, 1994; Albanesi, 1998; Zhang and Barnes, 2004). They postulated different lifestyles for this fossil group, currently being accepted that some genera had a pelagic habit, while other taxa have a nektonic mode of life (Pohler and Barnes, 1990). However, synecological aspects of a large amount of conodont faunas from Gondwana are still unknown.

The percentage composition of genera and species, and the link between themselves and their sedimentological environment were analyzed to determine the distribution of biofacies, and to deduce the composition of the conodont communities in the palaeoenvironments of the study area. For this purpose, different graphs are presented:

relative frequency, cluster analysis, and a three-dimensional palaeoenvironmental model proposed.

The term 'biofacies' is used in this work as an association of taxa that are recorded together in a rock whose presence has palaeoenvironmental connotations (cf. Ludvigsen *et al.*, 1986). Therefore, its relationship with the lithology and stratigraphy is extremely close, but does not necessarily reflect an ecological association. The term 'community', on the other hand, is an ecological association of taxa that lived relatively close together under particular environmental conditions (cf. Zhang and Barnes, 2004).

The studied lithostratigraphic unit corresponds to the Santa Rosita Formation and equivalent units in the Tilcara Range and Alfarcito Hills, on the eastern flank of the Quebrada de Humahuaca, in the Cordillera Oriental of Argentina (Figure 1). The age for these outcrops ranges from late Furongian to middle Tremadocian (Tr2) (late Cambrian to Early Ordovician) (Figure 2). The Santa Rosita Formation is composed of six members, from bottom to top: the Tilcara, Casa Colorada, Pico de Halcón, Alfarcito, Rupasca and Humacha members. The Tilcara and Pico de Halcón members were deposited in a fluvio-estuarine environment

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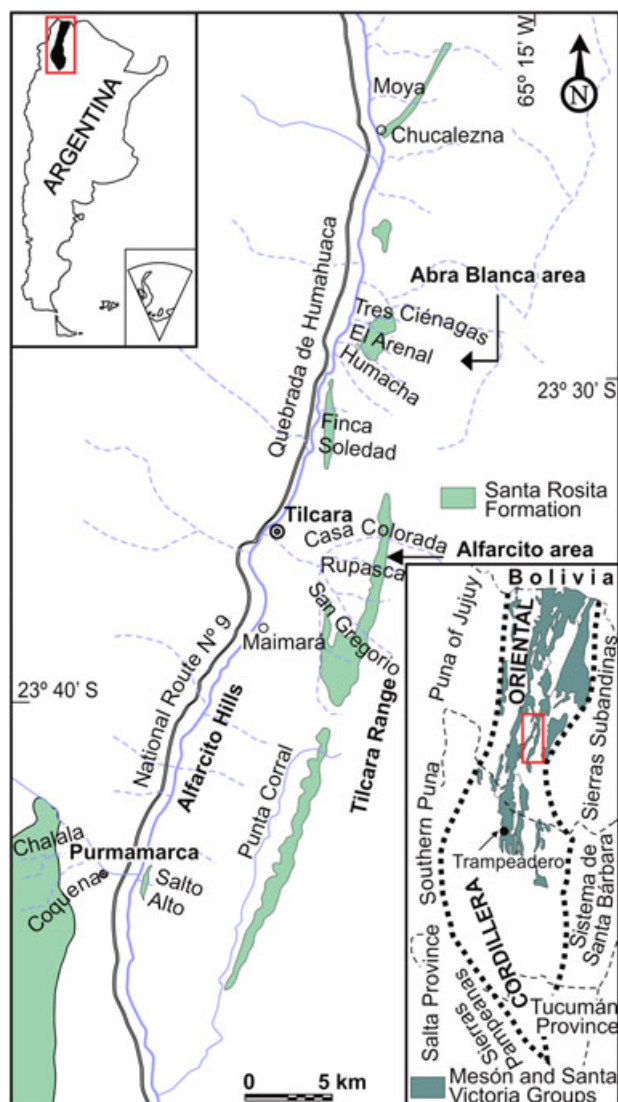


Figure 1. Location map of the study area and analyzed sections for conodont palaeoenvironments, with outcrops of the Santa Rosita Formation in light green. Map of the Argentine Cordillera Oriental, with Cambro-Ordovician outcrops in dark green. This figure is available in colour online at [wileyonlinelibrary.com/journal/gj](http://wileyonlinelibrary.com/journal/gj)

and the remaining units were deposited under open sea conditions, in a shallow-water platform. The upper three members were productive for conodonts, consequently in this contribution we analyzed the association of conodonts from the Alfarcito, Rupasca and Humacha members. The Alfarcito Member is a heterolithic succession of siltstones and sandstones with intercalated calcarenites and coquinas. The Rupasca Member is mainly a shaly-silty unit with scarce and thin levels of sandstones and coquinas, and the Humacha Member consists of sandstones with hummocky cross-stratification and trace fossils, and scarce siltstones. Each lithostratigraphic unit is made up of transgressive–regressive cycles of different magnitude; on the other hand, the regressive cycles

are represented by sandy levels and accumulation of diverse types of bioclasts. These cycles were tentatively correlated with global transgressive–regressive events: the Basal House Lowstand (BHL), *Acerocare* Regressive Event (ARE), Black Mountain Eustatic Event (BMEE), *Peltocare* Regressive Event (PRE) and *Ceratopyge* Regressive Event (CRE) (Figure 2).

A detailed stratigraphic and palaeoenvironmental analysis of the Santa Rosita Formation has been carried out by Buatois and Mángano (2003), Mángano and Buatois (2004) and Buatois *et al.* (2006), among others. Furthermore, biostratigraphic studies for this unit were accomplished by Zeballo *et al.* (2005, 2008, 2011), and Zeballo and Albanesi (2013).

## 2. MATERIAL AND METHODS

The studied collection consists of 10 837 conodonts (see Appendix, Tables 1 and 2) from the Moya, Angosto de Chucalezna, Tres Ciénagas, El Arenal, Humacha, Casa Colorada, San Gregorio, Punta Corral and Salto Alto sections (abbreviated Moya, Chuc, TrCi, ElAr, Hum, CC, SG, PtaCorral and Purm, respectively; Figure 1). The Abra Blanca area comprises the Tres Ciénagas, El Arenal and Humacha creeks. Also, we included conodont collections from the Coquena, Chalala (Purmamarca area) and Trampeadero creeks (Parcha area) (abbreviated Coq, Chal, and Tramp, respectively), which are control sections outside the Tilcara Range (Figures 3 and 4).

In the analysis of the relative frequencies, the relative percentages of conodont genera in three of the most complete sections of the study area (El Arenal, Humacha and San Gregorio creeks) are plotted. The samples containing less than three elements are dismissed because they produce abnormal frequency peaks.

For the cluster analysis we follow the methodology used by Zhang and Barnes (2004). To this purpose, the study area is divided into two minor geographic areas: northern (including the Moya, Angosto de Chucalezna, Tres Ciénagas, El Arenal and Humacha sections) and southern (corresponding to the Casa Colorada, San Gregorio, Punta Corral, Salto Alto, Coquena, Chalala and Trampeadero sections) (Figure 1).

Double clusters were made, Q and R types (organized according to the similarity between samples or the coexistence of taxa, respectively), for the northern and southern areas. The assembly of the clusters was performed using the Paired Group or Unweighted Pair-Group Moving Average (UPGMA) algorithm and the similarity measure used was the Pearson correlation coefficient ( $r$ ). The dendrograms were performed using the program PAST version 2.01 (Hammer *et al.*, 2001), with absolute abundances of each sample, obtained after dividing the number of elements of each species by the weight of each sample. In turn, there were created frequency intervals of <1, 1–4, 5–9, 10–24, 25–49, 50–99 and >100 conodonts/kg of rock, plotted by circles of different sizes.





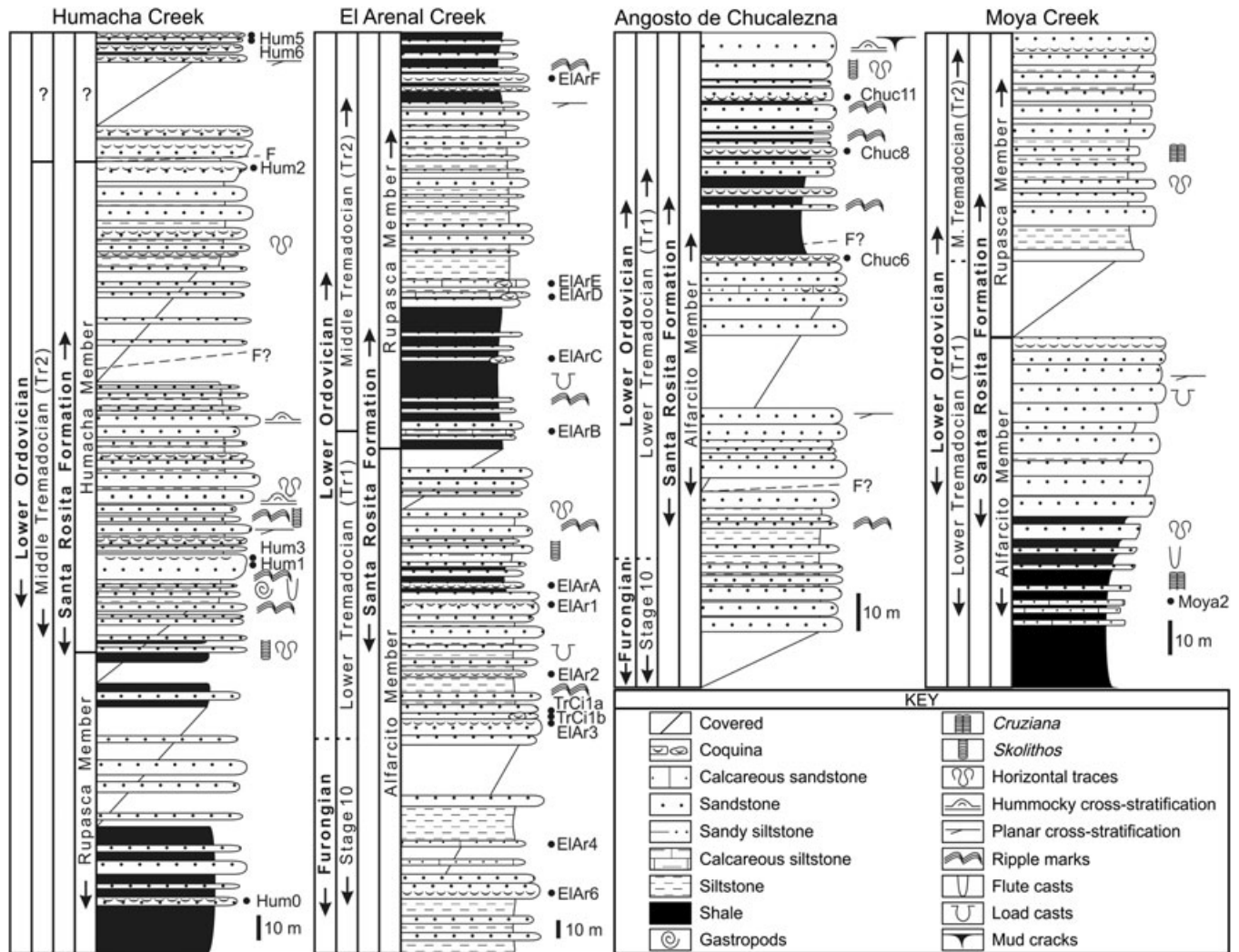


Figure 3. Stratigraphic columns of the Santa Rosita Formation in the northern area and location of the productive samples.

### 3. RELATIVE FREQUENCY OF GENERA AND RECOGNITION OF BIOFACIES

The relative frequency of genera allows to visualize the variation in the composition of conodont faunas in a single section through geological time and in correspondence with environmental changes. We selected the El Arenal and Humacha (Figure 3) and San Gregorio (Figure 4) creeks for this analysis, in the north and in the south of the study area, respectively, because they exhibit the most complete biostratigraphic records.

Figures 5 and 6 show a predominance of the genera *Variabiloconus* and *Teridontus* in the lower Alfarcito Member (samples ElAr6, TrCi1a, TrCi1b and ElAr3 in the Abra Blanca area, and samples SG1, SG2 and SG4 in the Alfarcito area), with a lower participation (*ca.* 30% in the San Gregorio section and *ca.* 20% in the El Arenal section) of the genera

*Striatodontus*, *Cordylodus* and *Drepanoistodus*, like proto- and paraconodonts at the same levels.

From the sample ElAr1, corresponding to the top of the second transgressive–regressive cycle of the Alfarcito Member, the appearance of the genus *Utahconus* is apparent. This genus also appears in the sample SG7A, which corresponds to the top of the third cycle of the same member (Figure 2). This latest transgressive–regressive cycle shows differences between the two sections studied: in the northern section, in the sample ElArA, *Utahconus* was recorded with 35% and *Acanthodus* with 31% of the total conodont fauna, while in the southern section, the latter taxon was recorded with a very low frequency in contemporary levels, with *Utahconus* the dominant genus (67%). At the same time, *Teridontus* dramatically decreases in the El Arenal section and *Variabiloconus* does so in the San Gregorio section. These two taxa are, therefore, mutually exclusive (Figures 5 and 6).

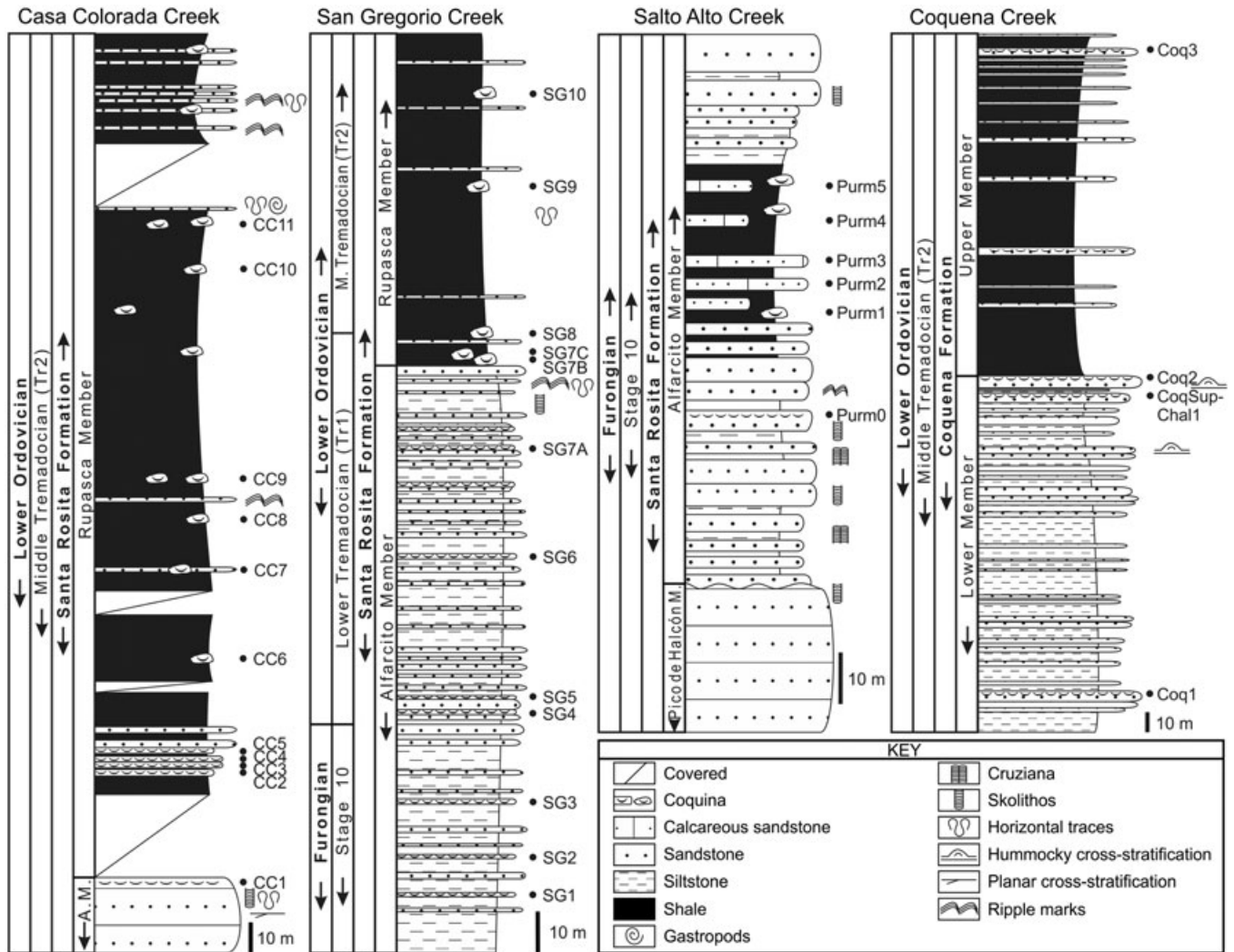


Figure 4. Stratigraphic columns of the Santa Rosita and Coquena formations in the southern area and location of the productive samples.

Relative frequency analysis also verifies the presence of other taxa in a subordinate way, such as *Rossodus*, *Kallidontus*, *Ulrichodina* and *Phakelodus*, the latter included within proto- and paraconodonts in the sample ElArA. At this level, the first appearance of *Tilcarodus* and *Paltodus* occurs, although in smaller proportion than in younger levels. The base of the Rupasca Member shows an increase in diversity of taxa in both sections, with the emergence of genera such as *Drepanodus*, *Kallidontus*, and a significant increase of *Semiacontiodus* in the sample SG7B. The contemporary level at the El Arenal Creek, ElArB sample, corresponds to a particular calcareous silty level, with a fauna that is only recorded in this horizon, including the genera *Coelocerodontus*, *Filodontus* and ca. 3% of *Kallidontus*, the highest percentage of this taxon recorded in the entire area. Also, the frequency of proto- and paraconodonts reaches ca. 10%, including the genera *Granatodontus*, *Phakelodus* and *Furnishina*. The

overlying levels are related to the end of the regression that occurs in the basal Rupasca Member (*Peltocare* Regressive Event, PRE, Figure 2), and the corresponding samples are SG7C and ElArC. The latter repeated the association of the genera *Acanthodus* and *Utahconus*, although to a lesser extent than in the upper Alfarcito Member (ca. 50% between the two taxa), while in the sample SG7C, *Utahconus*, with 29% of the total fauna, is followed in abundance by *Semiacontiodus*, with ca. 16%, although the best represented genus is *Tilcarodus*, with 34%. In both areas there has been a progressive increase in the frequency of *Drepanoistodus*, *Tilcarodus* and *Paltodus* in the rest of the Rupasca Member, becoming the main components of the conodont fauna. At the same time, *Teridontus* dominates over *Variabiloconus* in the middle part of this unit, while the ratio is reversed at the top. The Humacha Member is only present in the

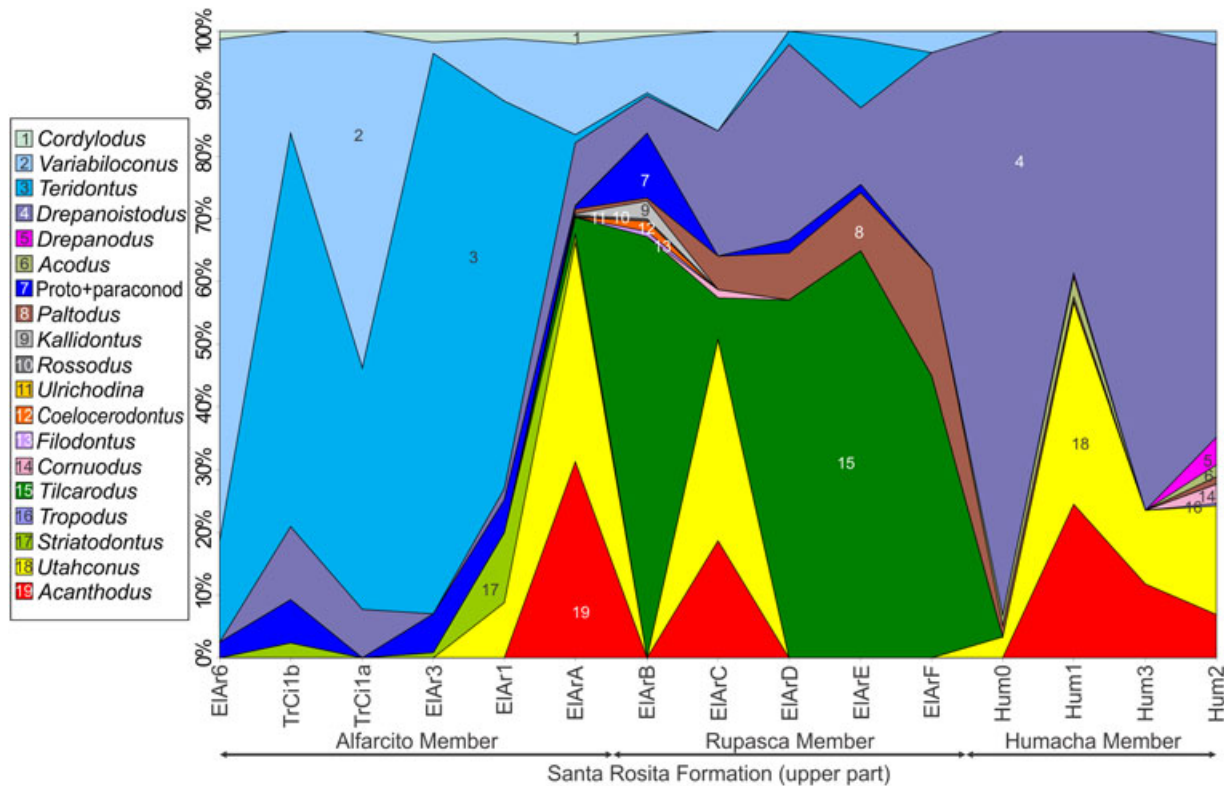


Figure 5. Relative frequencies of conodont genera recorded in the Abra Blanca area (TrCi: Tres Ciénagas, ElAr: El Arenal and Hum: Humacha creeks). X axis: samples in stratigraphic order (oldest to the left, ranges of the lithostratigraphic units not to scale), Y axis: relative frequencies (expressed in percentages). This figure is available in colour online at [wileyonlinelibrary.com/journal/gj](http://wileyonlinelibrary.com/journal/gj)

eponymous section of the northern area, and begins in Hum1 with the association *Acanthodus* and *Utahconus*, as recorded previously. That association reaches 73% of the total fauna, followed by *Drepanoistodus*, and minor components such as *Paltodus*, *Acodus*, *Cornuodus*, *Drepanodus*, *Tropodus* and *Variabiloconus*.

The peaks of the two most abundant genera of conodonts in Figures 5 and 6 determine assemblages defined as biofacies, although as few as one or two taxa can be present. These biofacies are (i) *Variabiloconus*–*Teridontus*, (ii) *Utahconus*–*Acanthodus* and (iii) *Tilcarodus*–*Drepanoistodus*. The discussion of these biofacies is presented below, together with the analysis of the whole samples and sections.

#### 4. CLUSTER ANALYSIS AND RECOGNITION OF SUB-BIOFACIES

Cluster analysis verifies the occurrence of certain species associated with particular lithologies and environments, while other taxa are distributed in different types of rocks. These associations define sub-biofacies, which bear the specific names of taxa that are more abundant or characteristic of a

palaeoenvironment. Moreover, samples with conodonts are grouped into clusters with similar faunal content, representing different palaeoenvironments (Figures 7 and 8). The three conodont biofacies are divided into the following respective sub-biofacies:

- (i) *Variabiloconus*–*Teridontus* Biofacies: related to diverse shallow-water environments, from shoreface to lower off-shore. It consists of three sub-biofacies: *Variabiloconus datsonensis*–*Teridontus gallicus* Sub-biofacies, *Variabiloconus crassus*–*Teridontus gallicus* Sub-biofacies, and *Teridontus gallicus* Sub-biofacies.
- (ii) *Utahconus*–*Acanthodus* Biofacies: related to shallow-water environments (shoreface to off-shore transition). The six sub-biofacies are: *Utahconus tortibasis*–*Acanthodus raqueli* Sub-biofacies, *Utahconus scandodiformis*–*Acanthodus humachensis* Sub-biofacies, *Utahconus purmamarcensis*–*Acanthodus raqueli* Sub-biofacies, *Utahconus* sp.–*Acanthodus raqueli* Sub-biofacies, *Utahconus* sp.–*Acanthodus* sp. Sub-biofacies, and *Utahconus tortibasis*–*Semiacontiodus* spp. Sub-biofacies.
- (iii) *Tilcarodus*–*Drepanoistodus* Biofacies: related to moderate to deep-water environments (upper to lower off-shore). It comprises a single *Tilcarodus humahuacensis*–*Drepanoistodus chucaleznsensis* Sub-biofacies.



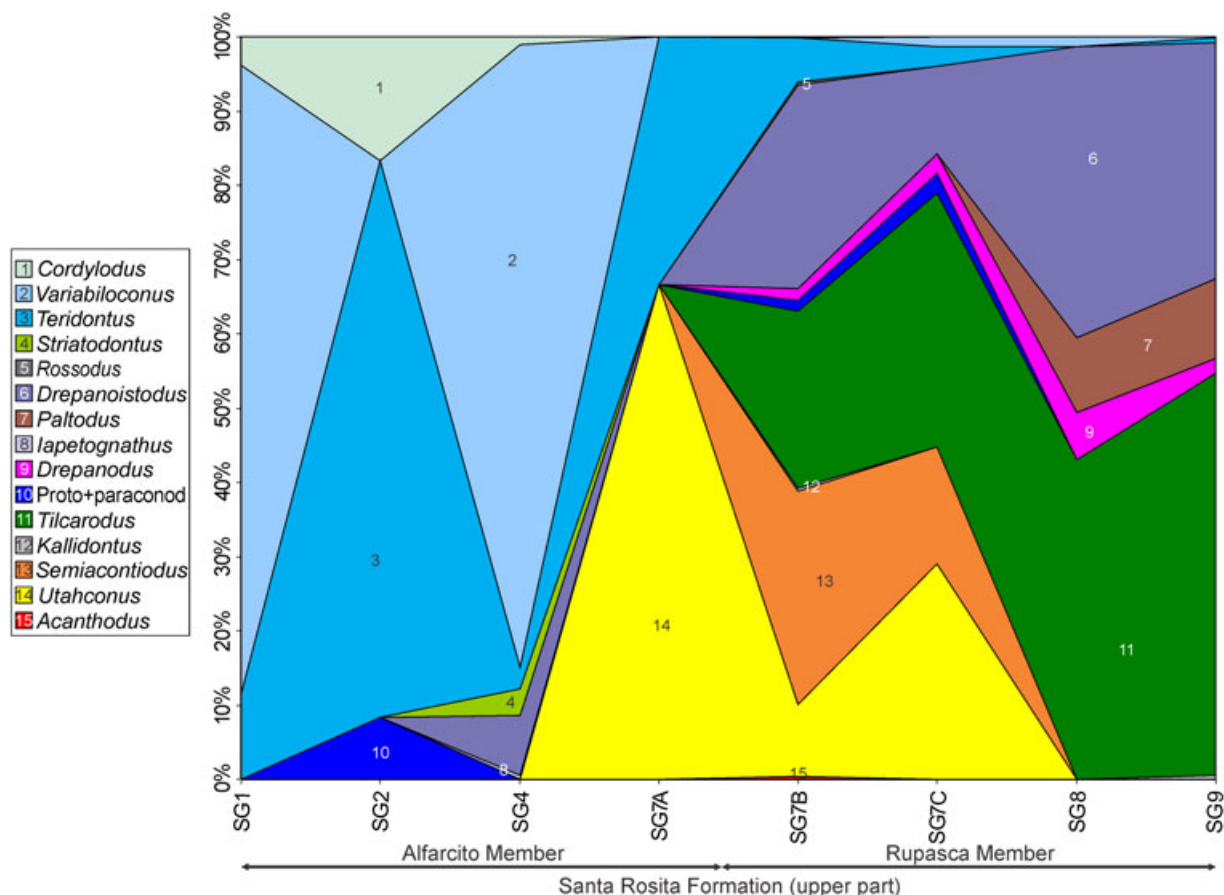


Figure 6. Relative frequencies of conodont genera recorded in the San Gregorio (SG) creek. X axis: samples in stratigraphic order (oldest to the left, ranges of the lithostratigraphic units not to scale), Y axis: relative frequencies (expressed in percentages). This figure is available in colour online at [wileyonlinelibrary.com/journal/gj](http://wileyonlinelibrary.com/journal/gj)

#### 4.1. Sub-biofacies of the *Variabiloconus*–*Teridontus* Biofacies

##### 4.1.1. *Variabiloconus datsonensis*–*Teridontus gallicus* Sub-biofacies

This sub-biofacies is represented in the El Arenal section by samples ElAr6 and ElAr4, and in the Salto Alto section by samples Purm1', Purm2, Purm2', Purm3, Purm3' and Purm3'', together with the samples PtaCorral3 and SG2, from Punta Corral and San Gregorio sections, respectively. It is mainly composed of *Variabiloconus datsonensis* (Druce and Jones) and *Teridontus gallicus* Serpagli, Ferretti, Nicoll and Serventi, which contribute ca. 96% in ElAr6 sample and ca. 65% in Purm3 sample, with minor participation of other taxa, e.g. *Variabiloconus bicuspatatus* (Druce and Jones). In the 'Purmamarca Shales', Salto Alto Creek, the association consists of diverse species of *Cordylodus* (e.g. *C. proavus* Müller, *C. caboti* Bagnoli, Barnes and Stevens, *C. cf. andresi* Viira and Sergeyeva), although with a very low proportion. *Hirsutodontus galerus* Tolmacheva and Abaimova and *Hirsutodontus simplex* (Druce and Jones) are recorded in

this section, as well as the highest frequency of para- and protoconodonts of the study area, such as *Albiconus postcostatus* Miller, *Phakelodus elongatus* (Zhang), *P. tenuis* (Müller), *Problematoconites perforatus* Müller and *Westergaardodina polymorpha* Müller and Hinz. The environment to which this sub-biofacies is related is lower to upper off-shore, and eventually shelf.

##### 4.1.2. *Variabiloconus crassus*–*Teridontus gallicus* Sub-biofacies

This sub-biofacies is identified in the uppermost levels of the Alfarcito Member, in samples TrCi1a, TrCi1b, ElAr1, Chuc6, Chuc8, Chuc11 and Moya2, of the northern area, and in samples CC2, CC3, CC5 and SG4, from the southern area, together with Tramp3. Together with the nominal taxa, the species *Cordylodus angulatus* Pander, *Drepanoistodus alfarcitensis* Zeballo, Albanesi and Ortega, *Problematoconites perforatus*, *Semiacontiodus minutus* Zeballo, Albanesi and Ortega, *Striatodontus* sp. and *Utahconus* sp., are associated in a significant number. *Variabiloconus crassus* Zeballo and Albanesi plus *Teridontus gallicus* compose ca. 93% of the

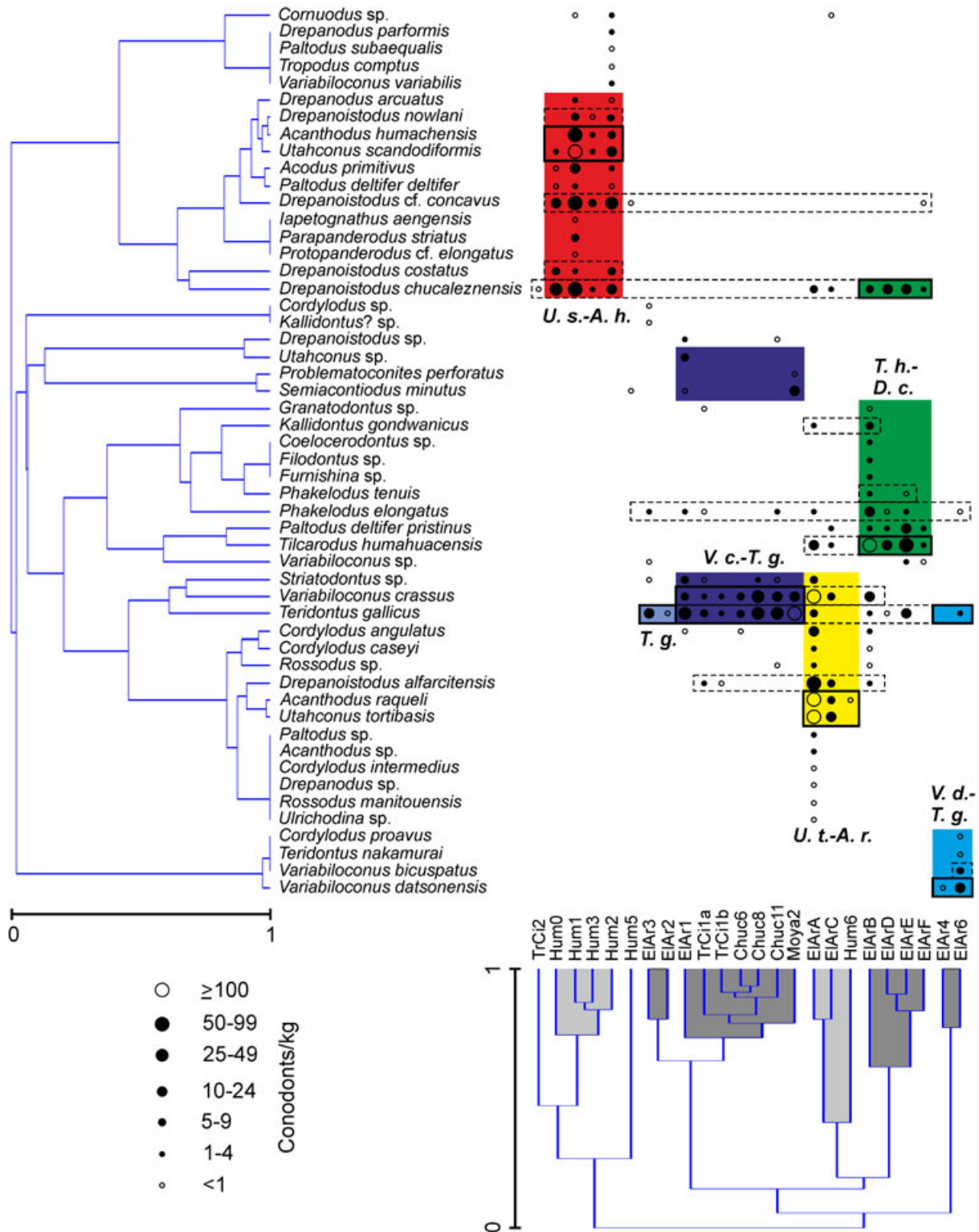


Figure 7. Cluster analysis of the northern area (U. s.-A. h.: *Utahconus scandodiformis*-*Acanthodus humachensis* Sub-biofacies, V. c.-T. g.: *Variabiloconus crassus*-*Teridontus gallicus* Sub-biofacies, U. t.-A. r.: *Utahconus tortibasis*-*Acanthodus raqueli* Sub-biofacies, T. h.-D. c.: *Tilcarodus humahuacensis*-*Drepanoistodus chucaleznensis* Sub-biofacies, V. d.-T. g.: *Variabiloconus datsonensis*-*Teridontus gallicus* Sub-biofacies). This figure is available in colour online at [wileyonlinelibrary.com/journal/gj](http://wileyonlinelibrary.com/journal/gj)



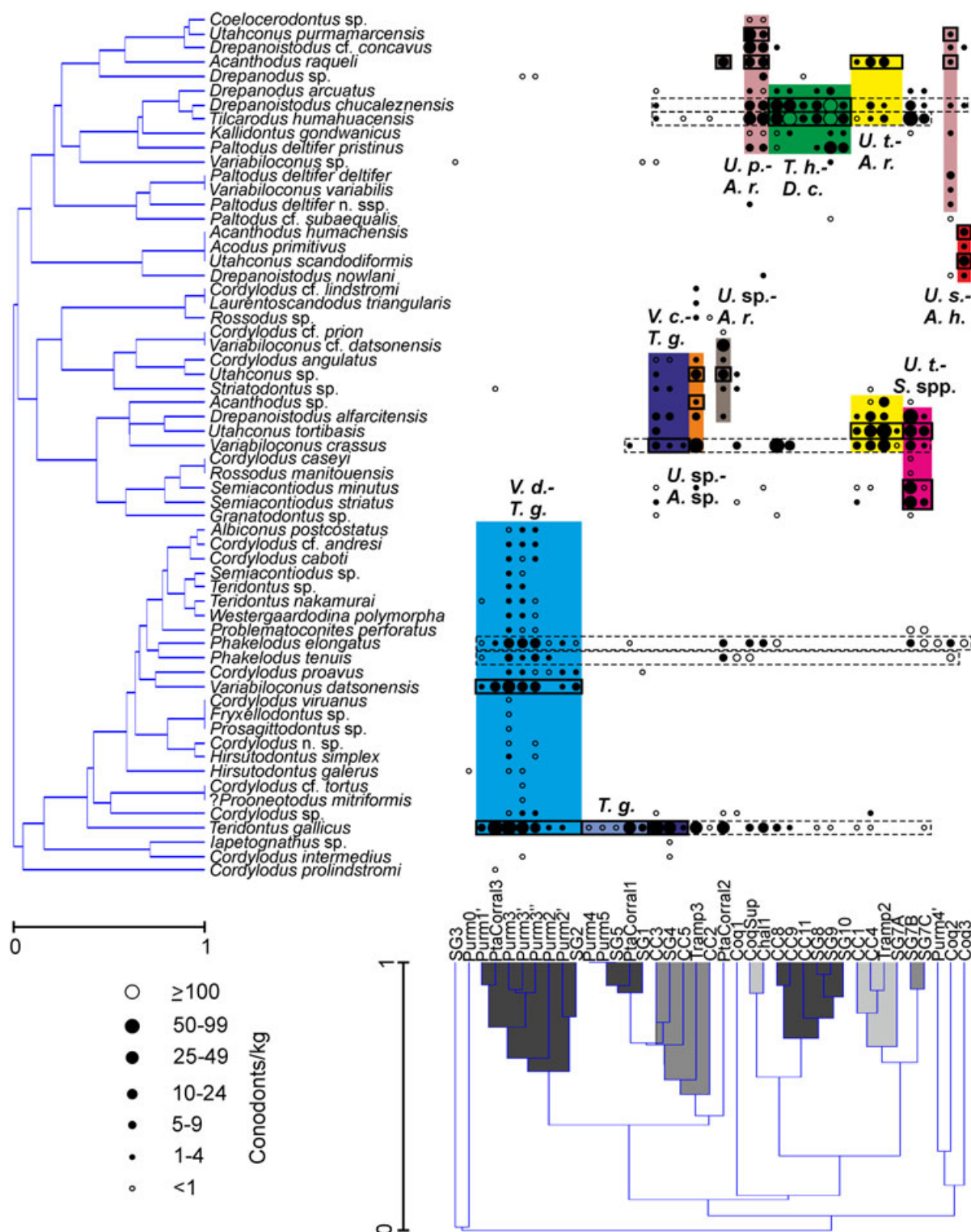


Figure 8. Cluster analysis of the southern area (*U. s.*–*A. h.*: *Utahconus scandodiformis*–*Acanthodus humahuacensis* Sub-biofacies, *V. c.*–*T. g.*: *Variabiloconus crassus*–*Teridontus gallicus* Sub-biofacies, *U. t.*–*A. r.*: *Utahconus tortibasis*–*Acanthodus raqueli* Sub-biofacies, *T. h.*–*D. c.*: *Tilcarodus humahuacensis*–*Drepanoistodus chucalezensis* Sub-biofacies, *V. d.*–*T. g.*: *Variabiloconus datsonensis*–*Teridontus gallicus* Sub-biofacies, *U. sp.*–*A. r.*: *Utahconus sp.*–*Acanthodus raqueli* Sub-biofacies, *U. sp.*–*A. sp.*: *Utahconus sp.*–*Acanthodus sp.* Sub-biofacies, *U. t.*–*S. spp.*: *Utahconus tortibasis*–*Semiacontiodus* spp. Sub-biofacies, *U. p.*–*A. r.*: *Utahconus purmamarcensis*–*Acanthodus raqueli* Sub-biofacies). This figure is available in colour online at [wileyonlinelibrary.com/journal/gj](http://wileyonlinelibrary.com/journal/gj)

fauna in sample Moya2, in the northern area, and ca. 68% in sample CC3, in the southern area. The samples belonging to this sub-biofacies come from a variety of lithologies, which were deposited from shoreface to lower off-shore.

#### 4.1.3. *Teridontus gallicus* Sub-biofacies

This third sub-biofacies of the *Variabiloconus*–*Teridontus* Biofacies is identified in the samples ElAr3, ElAr2 from the northern area, and samples SG1, SG5, PtaCorral1, Purm4 and Purm5 from the southern area. The diversity of taxa found is the lowest of all sub-biofacies of the study area, with *Teridontus gallicus* being the dominant taxon, followed by a low frequency of *Phakelodus elongatus*, *Cordylodus proavus*, *Variabiloconus crassus* and *Variabiloconus* sp. The depositional environment is lower to upper off-shore. Although the sample ElAr3 was obtained from the top strata of the lower Alfarcito Member, it corresponds to a lens of calcarenite interbedded between sandstone that could have come from deeper levels of the basin.

### 4.2. Sub-biofacies of the *Utahconus*–*Acanthodus* Biofacies

#### 4.2.1. *Utahconus tortibasis*–*Acanthodus raqueli* Sub-biofacies

Within the *Utahconus*–*Acanthodus* Biofacies, this sub-biofacies is distinguished by the nominal taxa which represent ca. 50% of the total fauna, followed by *Variabiloconus crassus*, *Tilcarodus humahuacensis* (Albanesi and Aceñolaza), *Drepanoistodus alfarcitensis*, *D. chucaleznsis* Albanesi and Aceñolaza and *Cordylodus angulatus*. In a lower proportion *Teridontus gallicus*, *Phakelodus elongatus* and *Paltodus deltifer pristinus* (Viira), are recorded. The samples related to this sub-biofacies are ElArA, ElArC and Hum6, in the northern area, and CC1, CC4, SG7A and Tramp2 in the southern area; the environment where these rocks were deposited is shallow, from shoreface to off-shore transition, corresponding to sandstones with hummocky cross-stratification structures from the third cycle of a transgressive–regressive interval of the Alfarcito Member, and to the regressive event in the lower part of the Rupasca Member. The sample ElArC probably has some reworked specimens from nearshore environments, since it intercalates with lower off-shore shales.

#### 4.2.2. *Utahconus scandodiformis*–*Acanthodus humachensis* Sub-biofacies

This sub-biofacies is another shallow-water association (shoreface to off-shore transition) which is also recorded in the sandstones of the Humacha Member. Such a biofacial unit is located in the samples Hum0, Hum1, Hum2, Hum3, from the Humacha Creek and the sample Coq3, in the Coquena Creek. The species *Utahconus scandodiformis* Zeballo and Albanesi and *Acanthodus humachensis* Zeballo

and Albanesi combined represent ca. 55% of the total fauna in the sample Hum1, with an important proportion of the genus *Drepanoistodus* (reaching 38%), through the species *D. chucaleznsis*, *D. cf. concavus* (Branson and Mehl), *D. costatus* (Abamoiva) and *D. nowlani* Ji and Barnes. The index fossil *Paltodus deltifer deltifer* (Lindström) and the species *Acodus primitivus* Zeballo and Albanesi are found represented proportionally in a lower amount, as well as other taxa, such as *Cornuodus* sp., *Drepanodus arcuatus* Pander, *D. parformis* Löfgren and Tolmacheva, *Parapan-derodus striatus* (Graves and Ellison), and *Variabiloconus variabilis* (Lindström).

#### 4.2.3. *Utahconus purmamarcensis*–*Acanthodus raqueli* Sub-biofacies

This sub-biofacies is recorded to the west of the study area, in the Coquena and Chalala creeks (samples CoqSup, Coq2 and Chal1). *Utahconus purmamarcensis* Zeballo and Albanesi and *Acanthodus raqueli* Zeballo and Albanesi are represented with ca. 32% of the fauna in the sample CoqSup, while the absolute frequency of *Tilcarodus humahuacensis* and *Drepanoistodus* spp. (*D. chucaleznsis*, *D. cf. concavus* and *D. nowlani*) is significant. *Teridontus gallicus*, *Paltodus deltifer* ssp. (*P. d. pristinus*, *P. d. deltifer* and *P. deltifer* n. ssp.) and *Phakelodus elongatus* are recorded, although with lower percentages than the mentioned taxa. The samples are coquinas from interbedded sandstone strata of shallow-water deposits (shoreface) that occur at the top part of the lower member of the Coquena Formation.

#### 4.2.4. *Utahconus* sp.–*Acanthodus raqueli* Sub-biofacies

This sub-biofacies is also related to another regressive event, but from the top of the lower interval of the Alfarcito Member, the level PtaCorral2 that was sampled in the Punta Corral Creek. It represents the oldest record of the *Utahconus*–*Acanthodus* Biofacies. The species that accompany *Utahconus* sp. and *Acanthodus raqueli* are *Variabiloconus* cf. *datsonensis*, *Teridontus gallicus*, *Striatodontus* sp., *Cordylodus angulatus*, and in a lower proportion *Drepanoistodus alfarcitensis*, *Phakelodus elongatus*, *P. tenuis* and *Cordylodus* cf. *prion* Lindström.

#### 4.2.5. *Utahconus* sp.–*Acanthodus* sp. Sub-biofacies

This sub-biofacies is present in sample Tramp3, from the Trampeadero section. The association is composed of the nominal taxa, together with *Variabiloconus crassus*, *Teridontus gallicus* and *Drepanoistodus alfarcitensis*, while *Cordylodus* cf. *lindstromi* Druce and Jones, *Laurentoscandodus triangularis* (Furnish) and *Semiacontiodus minutus* appear scarcely in this association.

#### 4.2.6. *Utahconus tortibasis*–*Semiacontiodus* spp. Sub-biofacies

In the San Gregorio Creek, in the upper interval of the Alfarcito Member (SG7B and SG7C), is recorded the association *Utahconus tortibasis* Zeballo and Albanesi with *Semiacontiodus minutus* and *Semiacontiodus striatus* Zeballo, Albanesi and Ortega, which give the name to the sub-biofacies. The latter genus reaches 29% of the conodont fauna in the sample SG7B, followed in lower proportion by *Drepanoistodus* (*D. alfarcitensis* and *D. chucaleznsensis*) and *Tilcarodus humahuacensis*, and the remaining *Utahconus tortibasis* with ca. 10%. The relationship is reversed in the sample SG7C, where this taxon represents 29% and *Semiacontiodus minutus* + *S. striatus* combined only constitute 16% of the total fauna. This biofacial unit is not found currently in other sections.

#### 4.3. Sub-biofacies of the *Tilcarodus*–*Drepanoistodus* Biofacies

##### 4.3.1. The *Tilcarodus humahuacensis*–*Drepanoistodus chucaleznsensis*

This sub-biofacies is the only sub-unit of the *Tilcarodus*–*Drepanoistodus* Biofacies, for which the description of both is convergent. Although *Tilcarodus humahuacensis* and *Drepanoistodus chucaleznsensis* are also recorded in other sub-biofacies, in this biofacies they represent the highest percentages (86% in sample SG9 and 77% in sample ElArE). Some associated species are *Coelocerodontus* sp., *Cordylodus angulatus*, *C. caseyi* Druce and Jones, *Drepanodus arcuatus*, *Kallidontus gondwanicus* Zeballo and Albanesi, *Paltodus deltifer pristinus* and *Granatodontus* sp., among others, as well as *Variabiloconus crassus* and *Teridontus gallicus*, which are also present in the previously mentioned sub-biofacies. It is particularly interesting to note the faunal composition in the sample ElArB (the calcisilt-rich strata intercalated in the basal Rupasca Member), at El Arenal Creek, with a significant increase of para- and protoconodonts (e.g. *Phakelodus elongatus*, *P. tenuis*, and *Furnishina?* sp.). The euconodont *Filodontus* sp. is recorded with scarce elements only in this sample, while the genera *Utahconus* and *Acanthodus* which characterize the homonymous biofacies, are not recognized herein, but they occur in the underlying and overlying levels, revealing a sharp environmental change in this stratigraphic interval. The palaeoenvironment, as suggested by the lithofacies, is shelfal to off-shore.

## 5. BIOFACIAL INTERPRETATION: CONODONT COMMUNITIES

From the observations made in the above figures, it appears that the genera *Variabiloconus* and *Teridontus* would be

pelagic in life habit, probably epipelagic, as they were recovered from coquinas and calcarenites interbedded in a wide variety of rocks, deposited in shoreface to lower offshore settings. In turn, the relationship between the two taxa is antithetical, i.e. at the same time the percentage of a genus increases while the other one decreases. This fact is more evident in the upper part of the Alfarcito Member and in the lower part of the Rupasca Member at the El Arenal and San Gregorio creeks, respectively. The water depth appears to be the controlling factor in a relationship where *Teridontus* occupy a more distal position than *Variabiloconus*. Zhang and Barnes (2004) found a similar antithetical relationship between *Teridontus nakamurai* (Nogami) and *Phakelodus tenuis*, where *Teridontus* dwell in shallower waters than *Phakelodus*, a protoconodont of pelagic habit, in preference to deeper and/or more distal water (slope). Therefore, the segregation from the coast to offshore of these taxa would be: *Variabiloconus*–*Teridontus*–*Phakelodus* (the latter also associated with paraconodont taxa) (Figure 9).

The dominant biofacies in the lower-half of the Alfarcito Member is that of *Variabiloconus*–*Teridontus*, with no observed nektobenthic communities, probably due to a high sea level and conditions of oxygen restriction on the bottom. Mángano *et al.* (2005) noted that often the sediments deposited during maximum flooding events are associated with low oxygen conditions in the environment. The presence of black shales deposited under dysoxic conditions occur at the basal Alfarcito Member in the Salto Alto section, where they would have occurred at the maximum flooding levels of the unit.

Moreover, the upper part of the Alfarcito Member and the regressive episode at the base of Member Rupasca are dominated by the *Utahconus*–*Acanthodus* Biofacies. This biofacies is recurrent and is confined to regressive episodes in the study area, and also identifies sandstones in the top of both members of the Coquena Formation, in the Humacha Member, the Devendeus Formation and, exceptionally, in the top of the lower interval of the Alfarcito Member, at Punta Corral section. *Utahconus* and *Acanthodus* species from the various sub-units of the biofacies occur in chronostratigraphic order (*Utahconus* sp.–*U. tortibasis*–*U. purmamarcensis*–*U. scandodiformis* and *Acanthodus* sp.–*A. raqueli*–*A. humachenensis*) and are closely linked, implying that both genera would have had a nektobenthic habit, occupying a biotope of warm and shallow water near the coast. The preference of this assemblage for the shallow-water environments and its life habit is evidenced in contemporaneous levels at the *Paltodus deltifer pristinus* Subzone: the *Utahconus*–*Acanthodus* Biofacies only is present in sandy-regressive levels of the uppermost Lower Member of the Coquena Formation, while it is absent in deeper water strata of the Rupasca Member, Santa Rosita Formation. The Alfarcito area sections and particularly the San Gregorio section (to the south), have deeper-water lithofacies than those recorded in the Abra Blanca area (to the north),



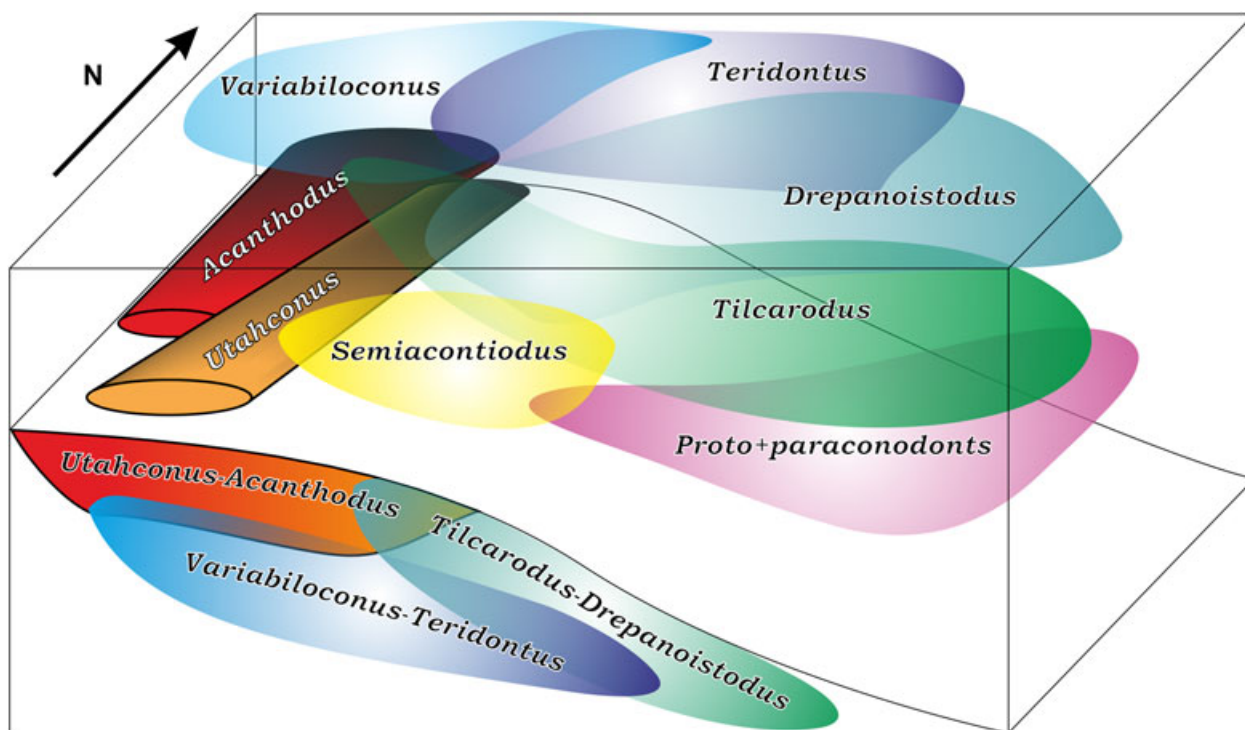


Figure 9. Palaeoenvironmental 3D model, displaying the spatial distribution of the main conodont genera recorded in the study area, at the Lower–Middle Tremadocian boundary. Upper part of the diagram with solid contour: are the nekto-benthic conodont communities, without contour are the pelagic communities, lower diagram: conodont biofacies from shallow to deep water (not to scale). This figure is available in colour online at [wileyonlinelibrary.com/journal/gj](http://wileyonlinelibrary.com/journal/gj)

where both *Acanthodus* and *Utahconus* are present. Incidentally, the R type clustering of Figure 7 (northern area) show a better association of *Utahconus*–*Acanthodus*, while the *Tilcarodus*–*Drepanoistodus* cluster is well represented in Figure 8 (southern area), reinforcing the association of these taxa to opposite lithofacies (shallower vs. deeper water environments). An exception to this association is in the San Gregorio Creek, in the basal strata of the Rupasca Member, where *Utahconus tortibasis* is associated with *Semiacontiodus minutus* and *S. striatus*, where *Acanthodus* is virtually nonexistent. The sample SG7B, with the Sub-biofacies *Utahconus tortibasis*–*Semiacontiodus* spp., is linked precisely to the largest transgressive event of the Santa Rosita Formation (and to the beginning of the deposition of the Rupasca Member; Figure 2) with a high concentration of organic matter and dysoxic conditions, to which *Acanthodus* could not adapt. Therefore, it follows that the genus *Semiacontiodus* would be pelagic (for unrestricted distribution), but with tolerance and/or preference for oxygen-deficient conditions, to which *Acanthodus* could not adapt. This inference would be reinforced by the significant increase of *Semiacontiodus minutus* in a calcarenite (distal tempestite, storm bed accumulation) associated with black shales in the Moya Creek (Moya2 sample).

*Drepanoistodus* is widely distributed in all lithofacies, so it would have pelagic habits, living probably near the water

surface (cf. Zhang and Barnes, 2004). Moreover, the new genus *Tilcarodus*, although also recorded in shallow-water environments, exhibits a marked increase seaward and south of the study area (Figure 9), where there is also a major deepening. Both taxa give the name to the biofacies, which characterizes the middle and upper Rupasca Member.

Finally, the proto- and paraconodonts are grouped into a unique community, because its components have a rather similar behaviour. It includes: *Phakelodus*, *Albiconus*, *Fryxellodontus*, *Furnishina*, *Problematoconites*, *Prosagittodontus* and *Westergaardodina*. One of the most common taxa of this group is *Phakelodus*, a cosmopolitan taxon found in a variety of facies from shallow-water environments, platform margins, slopes, but is mainly associated with black shales deposited under anoxic conditions, where only pelagic faunas inhabit (Miller, 1984). Consistent with the foregoing, in the study area, the community of proto- and paraconodonts presents a significant increase to the distal platform, such as in samples from the Salto Alto section and the base of the Rupasca Member. At the same time, there is an increase in this community to the south of the study area, where the lithofacies reflect a greater depth of the basin.

Figure 9 shows an approximate three-dimensional projection of the communities previously mentioned above, during the Lower–Middle Tremadocian (Tr1/Tr2) boundary interval, and its relationship with the recorded biofacies.

## 6. PALAEOBIOGEOGRAPHY

In the basin of northwestern Argentina, is evident a mixed conodont faunal composition (Ortega and Albanesi, 2005). The index taxa identified in the area, e.g. *Paltodus deltifer* spp., belong to the Cold Domain (low diversity and high abundance of conodonts, within which the Balto–Scandian Province is included) lacking or with exiguous amount of typical Tremadocian taxa such as *Clavohamulus*, *Loxodus* or *Rossodus* from the Tropical Domain (high diversity and endemism, within which the Laurentia, Australia and North China provinces are involved, *sensu* Zhen and Percival, 2003). Most of the genera present in the study area are cosmopolitan, e.g. *Drepanoistodus*, *Teridontus*, *Phakelodus* and *Variabiloconus*. At the same time, the new genus *Tilcarodus*, probably endemic to the western edge of Gondwana, is recorded. An important contribution of taxa

characteristic of the Tropical Domain are recognized for the first time in the basin, through the genera *Utahconus* and *Acanthodus*, albeit with new species, typical of Gondwana (Zeballo and Albanesi, 2013). Therefore, the conodont fauna of the Cordillera Oriental can be referred to a new palaeobiogeographic unit, the Southwestern Gondwana Province, within the Cold Domain of the Shallow-Sea Realm, located at middle latitudes (following the model of Zhen and Percival, 2003; see also Albanesi *et al.*, 2007).

Various palaeogeographic reconstructions located the Cordillera Oriental at mid- to high latitudes during the Furongian–Early Ordovician, around 30°S latitude (e.g. Scotese and Barrett, 1990; Cocks and Torsvik, 2002; Álvaro *et al.*, 2007, 2008) (Figure 10). In turn, Vaccari *et al.* (2006) and Benedetto and Vaccari (in Benedetto *et al.*, 2007) recognize that certain forms of trilobites recorded in the Cordillera Oriental and Argentine Puna, as *Onychopyge* from the



Figure 10. Palaeogeographic map for the Cambro-Ordovician boundary interval, with study areas and proposed patterns of ocean current (modified after Jell *et al.*, 1984, Benedetto, 2003, and Álvaro *et al.*, 2008). This figure is available in colour online at [wileyonlinelibrary.com/journal/gj](http://wileyonlinelibrary.com/journal/gj)

Furongian–basal Ordovician, are also present in northern and southern China, Australia, New Zealand and Mexico, suggesting a probable linkage between these areas. Work by other authors such as Jell (1985) and Webby *et al.* (2000) also point in this direction, noting the affinities between the faunas of Australian–New Zealand trilobites and northern Argentina from the record of the genera *Onychopyge* and *Australoharpes*; in turn, these faunal similarities also occur among the trilobites of the Cordillera Oriental and western Argentine Puna (Benedetto *et al.*, 2009). In a palaeogeographic reconstruction for the early Floian, Benedetto (2003) proposed a model of ocean circulation that would explain the exchange of faunas from Australasia to North Africa. Jell *et al.* (1984) were the first to identify this migration route through the dispersal of the gastropod *Peelerophon oehlerti* (Bergeron), which is present from the tropical terranes near to the southeastern Gondwanan platform (South China, Thailand (Sibumasu) and Tasmania) to the siliciclastic temperate to cold water platform in western Gondwana (Cordillera Oriental and southwestern France).

Furthermore, the conodont species *Variabiloconus datsonensis* and *V. bicuspatus* have been documented originally by Druce and Jones (1971) in rock successions of northeastern Australia (Ninmaroo Formation), and later in Antarctica (Robertson Bay Terrane) by Buggisch and Repetski (1987). Associated with these two taxa at the base of the Alfarcito Member is recorded *Hirsutodontus simplex*, a taxon that is also recorded from low palaeolatitudes (e.g. Australia, western United States, Siberia, northern China), as *H. galerus*, a newly recognized species in the Siberian platform by Tolmacheva and Abaimova (2009).

The geographic distribution of these taxa reinforces the proposal of a peri-Gondwanian ocean current from tropical latitudes to higher latitudes (cf. Aceñolaza and Lech, 1992; Benedetto, 2003), which contributed to faunal exchange along the continental margin, producing a mixture of faunas observed in the study area during the Furongian–Early Ordovician.

Recently, Albanesi and Bergström (2010) examined the palaeobiogeography of the Early–Middle Ordovician by cluster analysis (presence/absence of species) in various regions globally. During the *manitouensis*–*deltifer* interval, when the upper Santa Rosita Formation was deposited, two well-defined groups of clusters are evident; one gathering much of the North American basins (e.g. Ouachita Mountains, Ibex Area, and St. George Group) with the Argentine Precordillera (Figure 10), while the remaining group includes the Baltic basins and the western Gondwanian basins (Cordillera Oriental and Famatina). By the observed pattern, the authors verify that the Argentine Precordillera represents an exotic terrane with respect to the Gondwanian margin, and that during this period it has

more affinities with the Laurentian Province of the Tropical Domain. By contrast, the Cordillera Oriental is in the same cluster with localities of the Balto–Scandian Province from the Cold Domain and the Famatina System, and sections of the Cow Head Group, Newfoundland, possibly due to sampling bias or differentiation of biofacies, rather than vicariance.

## 7. CONCLUSIONS

Through graphs of generic frequency three conodont biofacies: *Utahconus*–*Acanthodus*, *Variabiloconus*–*Teridontus* and *Tilcarodus*–*Drepanoistodus* have been recognized. The first is restricted to shallow-water environments and the third is linked to moderately deep to deep-water environments. On the other hand, the *Variabiloconus*–*Teridontus* Biofacies is not confined to a particular environment, and is recorded in the absence of the above biofacies. In turn, cluster analysis has identified the *Utahconus* sp.–*Acanthodus raqueli*, *Utahconus* sp.–*Acanthodus* sp., *Utahconus tortibasis*–*Acanthodus raqueli*, *Utahconus purmamarcensis*–*Acanthodus raqueli*, *Utahconus scandodiformis*–*Acanthodus humachensis*, *Variabiloconus datsonensis*–*Teridontus gallicus*, *Variabiloconus crassus*–*Teridontus gallicus*, *Teridontus gallicus* and *Tilcarodus humahuancensis*–*Drepanoistodus chucaleznensis* sub-biofacies as integral parts of the biofacies above.

Overall, the frequency ratio between *Variabiloconus* and *Teridontus* is antithetical. The proportion of elements for the first taxon is higher in samples from shallow-water environments, unlike the second taxon, whose frequency increases in samples from deeper-water environments. It is postulated that there was a pelagic mode of life for these forms, with *Variabiloconus* being closer to the coast than *Teridontus*, although there were abnormal situations with opposite frequency ratios for these environments.

*Acanthodus* and *Utahconus* would have had a nekto-benthic mode of life in a temperate, shallow-water biotope near the coast, and *Acanthodus* disappears in a north to south direction (from El Arenal and Humada creeks to San Gregorio Creek), indicating a deepening of the basin. Moreover, *Tilcarodus* and *Drepanoistodus* being pelagic, have an increased frequency in deeper waters, such as the species grouped *sensu formae* in proto- and paraconodonts.

The base of the Rupasca Member represents a stratigraphic interval under peculiar palaeoenvironmental conditions. In a sample from the base of the Rupasca Member at the El Arenal Creek it was noted the absence of the *Utahconus*–*Acanthodus* biofacies, which is documented both below and above this level. This could be linked to the onset of a transgression and the displacement of faunas to other shallower water areas of the basin.



The conodont faunas show Baltic affinities, particularly the index taxa of the identified biozones. However, certain typically Laurentian genera such as *Acanthodus* and *Utahconus* are recorded in the shallower parts of the sequences, revealing a mixture of faunas from both regions. Other taxa such as *Tilcarodus* would be endemic forms in the Argentine Cordillera Oriental so far. The faunal association represents a new palaeobiogeographical province, the Southwestern Gondwana Province within the Cold Domain of the Shallow-Sea Realm in middle latitudes.

Some species, such as *Hirsutodontus galerus*, *H. simplex*, *Variabiloconus datsonensis* and *V. bicuspatus*, recognized only in low palaeolatitudes (Australia, United States, northern China and Siberia), were documented in the study area. These records, together with the trilobite *Onychopyge* and gastropod *Peelerophon oehlerti* in the Cordillera Oriental, confirm the existence of a perigondwanian corridor that would have allowed the connection between the Australian–New Zealand faunas and the northern Argentine faunas with those from the tropical regions farther away.

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Table 1. Absolute frequency of conodont species from the northern area

[illegible]



Table 2. Absolute frequency of conodont species from the southern area

SPECIES	SAMPLES Mass (g)	Pum1	Pum11	Pum2	Pum21	Pum3	Pum31	Pum32	Pum33	Pum4	Pum41	Pum42	Pum43	Pum44	Pum5	Cor1	Cor2	Cor3	Cha1	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	CC9	CC10	CC11	CC12	CC13	CC14	CC15	CC16	CC17	CC18	CC19	CC20	CC21	CC22	CC23	CC24	CC25	CC26	CC27	CC28	CC29	CC30	CC31	CC32	CC33	CC34	CC35	CC36	CC37	CC38	CC39	CC40	CC41	CC42	CC43	CC44	CC45	CC46	CC47	CC48	CC49	CC50	CC51	CC52	CC53	CC54	CC55	CC56	CC57	CC58	CC59	CC60	CC61	CC62	CC63	CC64	CC65	CC66	CC67	CC68	CC69	CC70	CC71	CC72	CC73	CC74	CC75	CC76	CC77	CC78	CC79	CC80	CC81	CC82	CC83	CC84	CC85	CC86	CC87	CC88	CC89	CC90	CC91	CC92	CC93	CC94	CC95	CC96	CC97	CC98	CC99	CC100	CC101	CC102	CC103	CC104	CC105	CC106	CC107	CC108	CC109	CC110	CC111	CC112	CC113	CC114	CC115	CC116	CC117	CC118	CC119	CC120	CC121	CC122	CC123	CC124	CC125	CC126	CC127	CC128	CC129	CC130	CC131	CC132	CC133	CC134	CC135	CC136	CC137	CC138	CC139	CC140	CC141	CC142	CC143	CC144	CC145	CC146	CC147	CC148	CC149	CC150	CC151	CC152	CC153	CC154	CC155	CC156	CC157	CC158	CC159	CC160	CC161	CC162	CC163	CC164	CC165	CC166	CC167	CC168	CC169	CC170	CC171	CC172	CC173	CC174	CC175	CC176	CC177	CC178	CC179	CC180	CC181	CC182	CC183	CC184	CC185	CC186	CC187	CC188	CC189	CC190	CC191	CC192	CC193	CC194	CC195	CC196	CC197	CC198	CC199	CC200	CC201	CC202	CC203	CC204	CC205	CC206	CC207	CC208	CC209	CC210	CC211	CC212	CC213	CC214	CC215	CC216	CC217	CC218	CC219	CC220	CC221	CC222	CC223	CC224	CC225	CC226	CC227	CC228	CC229	CC230	CC231	CC232	CC233	CC234	CC235	CC236	CC237	CC238	CC239	CC240	CC241	CC242	CC243	CC244	CC245	CC246	CC247	CC248	CC249	CC250	CC251	CC252	CC253	CC254	CC255	CC256	CC257	CC258	CC259	CC260	CC261	CC262	CC263	CC264	CC265	CC266	CC267	CC268	CC269	CC270	CC271	CC272	CC273	CC274	CC275	CC276	CC277	CC278	CC279	CC280	CC281	CC282	CC283	CC284	CC285	CC286	CC287	CC288	CC289	CC290	CC291	CC292	CC293	CC294	CC295	CC296	CC297	CC298	CC299	CC300	CC301	CC302	CC303	CC304	CC305	CC306	CC307	CC308	CC309	CC310	CC311	CC312	CC313	CC314	CC315	CC316	CC317	CC318	CC319	CC320	CC321	CC322	CC323	CC324	CC325	CC326	CC327	CC328	CC329	CC330	CC331	CC332	CC333	CC334	CC335	CC336	CC337	CC338	CC339	CC340	CC341	CC342	CC343	CC344	CC345	CC346	CC347	CC348	CC349	CC350	CC351	CC352	CC353	CC354	CC355	CC356	CC357	CC358	CC359	CC360	CC361	CC362	CC363	CC364	CC365	CC366	CC367	CC368	CC369	CC370	CC371	CC372	CC373	CC374	CC375	CC376	CC377	CC378	CC379	CC380	CC381	CC382	CC383	CC384	CC385	CC386	CC387	CC388	CC389	CC390	CC391	CC392	CC393	CC394	CC395	CC396	CC397	CC398	CC399	CC400	CC401	CC402	CC403	CC404	CC405	CC406	CC407	CC408	CC409	CC410	CC411	CC412	CC413	CC414	CC415	CC416	CC417	CC418	CC419	CC420	CC421	CC422	CC423	CC424	CC425	CC426	CC427	CC428	CC429	CC430	CC431	CC432	CC433	CC434	CC435	CC436	CC437	CC438	CC439	CC440	CC441	CC442	CC443	CC444	CC445	CC446	CC447	CC448	CC449	CC450	CC451	CC452	CC453	CC454	CC455	CC456	CC457	CC458	CC459	CC460	CC461	CC462	CC463	CC464	CC465	CC466	CC467	CC468	CC469	CC470	CC471	CC472	CC473	CC474	CC475	CC476	CC477	CC478	CC479	CC480	CC481	CC482	CC483	CC484	CC485	CC486	CC487	CC488	CC489	CC490	CC491	CC492	CC493	CC494	CC495	CC496	CC497	CC498	CC499	CC500	CC501	CC502	CC503	CC504	CC505	CC506	CC507	CC508	CC509	CC510	CC511	CC512	CC513	CC514	CC515	CC516	CC517	CC518	CC519	CC520	CC521	CC522	CC523	CC524	CC525	CC526	CC527	CC528	CC529	CC530	CC531	CC532	CC533	CC534	CC535	CC536	CC537	CC538	CC539	CC540	CC541	CC542	CC543	CC544	CC545	CC546	CC547	CC548	CC549	CC550	CC551	CC552	CC553	CC554	CC555	CC556	CC557	CC558	CC559	CC560	CC561	CC562	CC563	CC564	CC565	CC566	CC567	CC568	CC569	CC570	CC571	CC572	CC573	CC574	CC575	CC576	CC577	CC578	CC579	CC580	CC581	CC582	CC583	CC584	CC585	CC586	CC587	CC588	CC589	CC590	CC591	CC592	CC593	CC594	CC595	CC596	CC597	CC598	CC599	CC600	CC601	CC602	CC603	CC604	CC605	CC606	CC607	CC608	CC609	CC610	CC611	CC612	CC613	CC614	CC615	CC616	CC617	CC618	CC619	CC620	CC621	CC622	CC623	CC624	CC625	CC626	CC627	CC628	CC629	CC630	CC631	CC632	CC633	CC634	CC635	CC636	CC637	CC638	CC639	CC640	CC641	CC642	CC643	CC644	CC645	CC646	CC647	CC648	CC649	CC650	CC651	CC652	CC653	CC654	CC655	CC656	CC657	CC658	CC659	CC660	CC661	CC662	CC663	CC664	CC665	CC666	CC667	CC668	CC669	CC670	CC671	CC672	CC673	CC674	CC675	CC676	CC677	CC678	CC679	CC680	CC681	CC682	CC683	CC684	CC685	CC686	CC687	CC688	CC689	CC690	CC691	CC692	CC693	CC694	CC695	CC696	CC697	CC698	CC699	CC700	CC701	CC702	CC703	CC704	CC705	CC706	CC707	CC708	CC709	CC710	CC711	CC712	CC713	CC714	CC715	CC716	CC717	CC718	CC719	CC720	CC721	CC722	CC723	CC724	CC725	CC726	CC727	CC728	CC729	CC730	CC731	CC732	CC733	CC734	CC735	CC736	CC737	CC738	CC739	CC740	CC741	CC742	CC743	CC744	CC745	CC746	CC747	CC748	CC749	CC750	CC751	CC752	CC753	CC754	CC755	CC756	CC757	CC758	CC759	CC760	CC761	CC762	CC763	CC764	CC765	CC766	CC767	CC768	CC769	CC770	CC771	CC772	CC773	CC774	CC775	CC776	CC777	CC778	CC779	CC780	CC781	CC782	CC783	CC784	CC785	CC786	CC787	CC788	CC789	CC790	CC791	CC792	CC793	CC794	CC795	CC796	CC797	CC798	CC799	CC800	CC801	CC802	CC803	CC804	CC805	CC806	CC807	CC808	CC809	CC810	CC811	CC812	CC813	CC814	CC815	CC816	CC817	CC818	CC819	CC820	CC821	CC822	CC823	CC824	CC825	CC826	CC827	CC828	CC829	CC830	CC831	CC832	CC833	CC834	CC835	CC836	CC837	CC838	CC839	CC840	CC841	CC842	CC843	CC844	CC845	CC846	CC847	CC848	CC849	CC850	CC851	CC852	CC853	CC854	CC855	CC856	CC857	CC858	CC859	CC860	CC861	CC862	CC863	CC864	CC865	CC866	CC867	CC868	CC869	CC870	CC871	CC872	CC873	CC874	CC875	CC876	CC877	CC878	CC879	CC880	CC881	CC882	CC883	CC884	CC885	CC886	CC887	CC888	CC889	CC890	CC891	CC892	CC893	CC894	CC895	CC896	CC897	CC898	CC899	CC900	CC901	CC902	CC903	CC904	CC905	CC906	CC907	CC908	CC909	CC910	CC911	CC912	CC913	CC914	CC915	CC916	CC917	CC918	CC919	CC920	CC921	CC922	CC923	CC924	CC925	CC926	CC927	CC928	CC929	CC930	CC931	CC932	CC933	CC934	CC935	CC936	CC937	CC938	CC939	CC940	CC941	CC942	CC943	CC944	CC945	CC946	CC947	CC948	CC949	CC950	CC951	CC952	CC953	CC954	CC955	CC956	CC957	CC958	CC959	CC960	CC961	CC962	CC963	CC964	CC965	CC966	CC967	CC968	CC969	CC970	CC971	CC972	CC973	CC974	CC975	CC976	CC977	CC978	CC979	CC980	CC981	CC982	CC983	CC984	CC985	CC986	CC987	CC988	CC989	CC990	CC991	CC992	CC993	CC994	CC995	CC996	CC997	CC998	CC999	CC1000	CC1001	CC1002	CC1003	CC1004	CC1005	CC1006	CC1007	CC1008	CC1009	CC1010	CC1011	CC1012	CC1013	CC1014	CC1015	CC1016	CC1017	CC1018	CC1019	CC1020	CC1021	CC1022	CC1023	CC1024	CC1025	CC1026	CC1027	CC1028	CC1029	CC1030	CC1031	CC1032	CC1033	CC1034	CC1035	CC1036	CC1037	CC1038	CC1039	CC1040	CC1041	CC1042	CC1043	CC1044	CC1045	CC1046	CC1047	CC1048	CC1049	CC1050	CC1051	CC1052	CC1053	CC1054	CC1055	CC1056	CC1057	CC1058	CC1059	CC1060	CC1061	CC1062	CC1063	CC1064	CC1065	CC1066	CC1067	CC1068	CC1069	CC1070	CC1071	CC1072	CC1073	CC1074	CC1075	CC1076	CC1077	CC1078	CC1079	CC1080	CC1081	CC1082	CC1083	CC1084	CC1085	CC1086	CC1087	CC1088	CC1089	CC1090	CC1091	CC1092	CC1093	CC1094	CC1095	CC1096	CC1097	CC1098	CC1099	CC1100	CC1101	CC1102	CC1103	CC1104	CC1105	CC1106	CC1107	CC1108	CC1109	CC1110	CC1111	CC1112	CC1113	CC1114	CC1115	CC1116	CC1117	CC1118	CC1119	CC1120	CC1121	CC1122	CC1123	CC1124	CC1125	CC1126	CC1127	CC1128	CC1129	CC1130	CC1131	CC1132	CC1133	CC1134	CC1135	CC1136	CC1137	CC1138	CC1139	CC1140	CC1141	CC1142	CC1143	CC1144	CC1145	CC1146	CC1147	CC1148	CC1149	CC1150	CC1151	CC1152	CC1153	CC1154	CC1155	CC1156	CC1157	CC1158	CC1159	CC1160	CC1161	CC1162	CC1163	CC1164	CC1165	CC1166	CC1167	CC1168	CC1169	CC1170	CC1171	CC1172	CC1173	CC1174	CC1175	CC1176	CC1177	CC1178	CC1179	CC1180	CC1181	CC1182	CC1183	CC1184	CC1185	CC1186	CC1187	CC1188	CC1189	CC1190	CC1191	CC1192	CC1193	CC1194	CC1195	CC1196	CC1197	CC1198	CC1199	CC1200	CC1201	CC1202	CC1203	CC1204	CC1205	CC1206	CC1207	CC1208	CC1209	CC1210	CC1211	CC1212	CC1213	CC1214	CC1215	CC1216	CC1217	CC1218	CC1219	CC1220	CC1221	CC1222	CC1223	CC1224	CC1225	CC1226	CC1227	CC1228	CC1229	CC1230	CC1231	CC1232	CC1233	CC1234	CC1235	CC1236	CC1237	CC1238	CC1239	CC1240	CC1241	CC1242	CC1243	CC1244	CC1245	CC1246	CC1247	CC1248	CC1249	CC1250	CC1251	CC1252	CC1253	CC1254	CC1255	CC1256	CC1257	CC1258	CC1259	CC1260	CC1261	CC1262	CC1263	CC1264	CC1265	CC1266	CC1267	CC1268	CC1269	CC1270	CC1271	CC1272	CC1273	CC1274	CC1275	CC1276	CC1277	CC1278	CC1279	CC1280	CC1281	CC1282	CC1283	CC1284	CC1285	CC1286	CC1287	CC1288	CC1289	CC1290	CC1291	CC1292	CC1293	CC1294	CC1295	CC1296	CC1297	CC1298	CC1299	CC1300	CC1301	CC1302	CC1303	CC1304	CC1305	CC1306	CC1307	CC1308	CC1309	CC1310	CC1311	CC1312	CC1313	CC1314	CC1315	CC1316	CC1317	CC
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