EARLY SILURIAN CONODONTS FROM THE CANTABRIAN ZONE, NW SPAIN

GRACIELA **SARMIENTO**, ISABEL **MÉNDEZ-BEDIA**, CARLOS **ARAMBURU**, MIGUEL **ARBIZU** & JAIME **TRUYOLS**

SARMIENTO G., MÉNDEZ-BEDIA I., ARAMBURU C., ARBIZU M. & TRUYOLS J. 1994. Early Silurian Conodonts from the Cantabrian Zone, NW Spain. [Conodontes du Silurien inférieur de la Zone Cantabrique, NO de l'Espagne]. [Conodontos del Silúrico Inferior de la Zona Cantábrica, NO de España]. Geobios, **27**, 4 : 507-522. Villeurbanne le 31.08.1994.

Manuscrit déposé le 24.02.1993 ; accepté définitivement le 07.07.1993.

ABSTRACT

Extensive black shale formations occur throughout most of the Lower Silurian in SW Europe. However, a wider array of facies and the presence of stratigraphic gaps in the interval covered by the Ordovician/Silurian transition, make for complications in the stratigraphic succession. Directely underlying the Silurian graptolitic black shales of the Formigoso Formation, two small intervals of carbonate rocks occur in certain localities. These are the Viodo Member of the Castro Formation, formally defined here, and the upper part of the Getino beds, both dated here for the first time. Eleven limestone samples from the Viodo Member, and one dolostone sample from the Getino beds, have yielded a relatively abundant conodont fauna of low diversity, which can be referred to the *A. petila* and *A. fluegeli* Zones, respectively. By comparison with faunas from North Greenland and the Canadian Rocky Mountains, Rhuddanian to Aeronian ages seem to be present.

KEY-WORDS : CONODONTS, LOWER SILURIAN, CANTABRIAN ZONE, VIODO MEMBER, GETINO BEDS, BIOSTRATIGRAPHY.

RÉSUMÉ

Le Silurien Inférieur du SO de l'Europe est fréquemment reconnaissable par des formations de schistes noirs. Néanmoins, la transition Ordovicien-Silurien présente des faciès très variés avec des lacunes d'une certaine importance, ce qui soulève de nombreux problèmes stratigraphiques. Dans la Zone Cantabrique, des niveaux carbonatés se placent au-dessous des schistes noirs graptolitiques de la Formation Formigoso. Ils correspondent au Membre Viodo de la Formation Castro, formellement défini dans ce travail, et à la partie supérieure des couches de Getino, l'un et l'autre d'un âge incertain jusqu'à présent. L'étude micropaléontologique des calcaires du Membre Viodo (11 échantillons) et d'un niveau dolomitique des couches de Getino a livré des associations de conodontes relativement abondantes mais peu diversifiées appartenant aux Zones *A. petila* et *A. fluegeli*. La comparaison avec des faunes similaires du Nord du Groenland et de la Cordillère Canadienne, indique un âge rhuddanien à aeronien pour l'intervalle étudié.

MOTS-CLÉS : CONODONTES, SILURIEN INFÉRIEUR, ZONE CANTABRIQUE, MEMBRE VIODO, COUCHES DE GETINO, BIOSTRATIGRAPHIE.

RESUMEN

Son bien conocidas las extensas formaciones de pizarras negras graptolíticas que dominan el Silúrico Inferior de la mayor parte del SW de Europa. El tránsito al Ordovícico es, sin embargo, origen de numerosos problemas estratigráficos, en gran parte debidos a la existencia de importantes lagunas y cambios laterales de facies. En la Zona Cantábrica, directamente bajo las pizarras negras graptolíticas silúricas de la Formación Formigoso, se localizan dos reducidos afloramientos de rocas carbonatadas, objeto de estudio en el presente trabajo. Se trata del Miembro Viodo de la Formación Castro, formalmente definido aquí, y la parte superior de las denominadas capas de Getino, ambos de una edad hasta ahora incierta. Del análisis micropaleontológico de once niveles calcáreos del Miembro Viodo y de un nivel dolomítico de las capas de Getino se obtuvo una asociación de conodontos relativamente abundante y de baja diversidad, correspondiente a las Zonas *A. petila* y *A. fluegeli*. Por comparación con faunas similares identificadas en el Norte de Groenlandia y en la Cordillera Canadiense, se establece una edad Rhuddaniense a Aeroniense para el intervalo estudiado, correspondiente a la misma base del Silúrico.

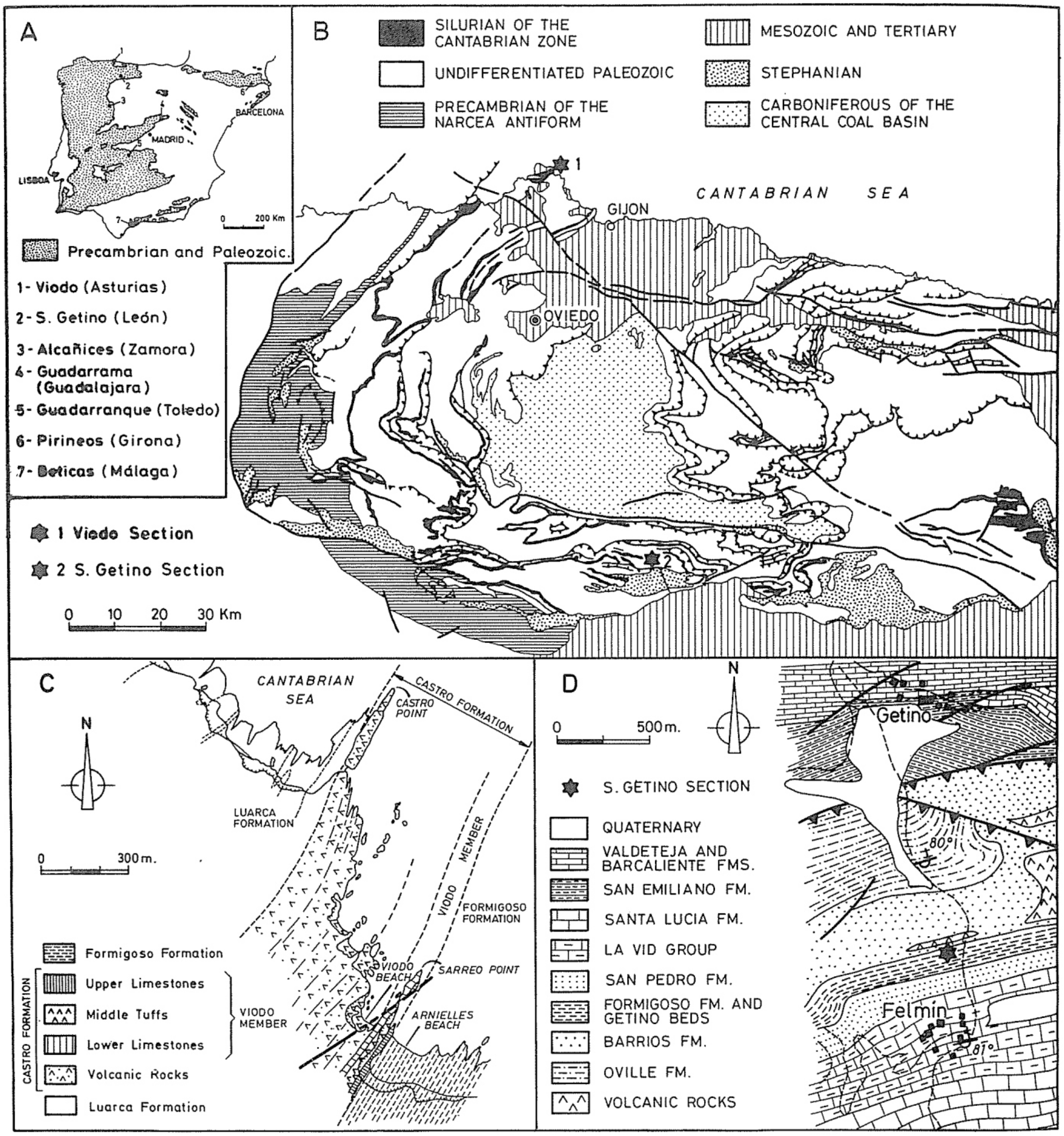


Figure 1 - Geological and geographical setting of studied sections. **A**, localities with Silurian conodonts in the Iberian Peninsula. **1** and **2**, localities from the Cantabrian Zone, this study. **3**, Alcañices Syncline (Aldaya *et al.* 1976 ; Quiroga 1980) ; **4**, Sierra de Guadarrama (Bultynck & Soers 1971) ; **5**, Guadarranque Syncline (Rodríguez Núñez *et al.* 1989 ; Sarmiento & Rodríguez 1991) ; **6**, Catalan Pyrenees (Degardin 1988) ; **7**, Betic Cordilleras (Kockel 1958 ; van den Boogaard 1965). **B**, Silurian outcrops and localities with conodonts in the Cantabrian Zone. **C**, location map of the Viodo section, after Julivert & Truyols (1973). **D**, location map of the S Getino section, after Alonso *et al.* (1991). *Situation géographique et géologique des coupes étudiées.* ***A****, localités de la Péninsule Ibérique avec des conodontes siluriens.* ***1 et 2****, localités de la Zone Cantabrique citées dans ce travail.* ***3****, Synclinal d'Alcañices ;* ***4****, Sierra de Guadarrama ;* ***5****, Synclinal de Guadarranque ;* ***6****, Pyrénées catalanes ;* ***7****, Cordillères Bétiques.* ***B****, affleurements siluriens et localités avec des conodontes de la Zone Cantabrique.* ***C****, carte de situation de la coupe de Viodo.* ***D****, carte de situation de la coupe du S Getino.*

INTRODUCTION

Although Early Silurian conodonts are very rare in the Iberian Peninsula, their occurrence has been reported from the Cantabrian Zone (Julivert & Truyols 1973) and the Central Iberian Zone (Rodríguez *et al.* 1989 ; Sarmiento & Rodríguez Núñez 1991), of the Hesperian Massif (Fig. 1, locs. 1 and 5).

A small number of localities with Late Silurian conodonts are known from the northern part of the Central Iberian Zone (Aldaya *et al.* 1976 ; Quiroga 1980 ; Bultynck & Soers 1971), the Spanish Pyrenees (Degardin 1988), the Catalonian Coastal Ranges (Walliser 1964 ; García López et al. 1990) and the Betic Cordilleras (Kockel 1958 ; van den Boogaard 1965).

In the present paper the first Lower Silurian conodonts are described. These were first identified by Lindström (*in* Julivert & Truyols 1973) from limestone bands near the top of the "vulcano-detrital succession" of these authors, on the eastern shore of Peñas Cape, North of Oviedo (Fig. 2). These limestone bands are here designated as the Viodo Member of the Castro Formation.

After a search, a new section with Early Silurian conodonts was discovered on the southern slope of the Cantabrian Mountains, at Getino (Fig. 2). A thin band of dolomitic limestone at the top of the unit mentioned as the "Transitional Beds" (van den Bosch 1969), yielded the conodonts.This is designated here as the "Getino beds".

The Viodo Member and the Getino beds are both overlain by a widespread black shale unit with graptolites (Formigoso Formation). In other areas of the Cantabrian Zone, the Formigoso Formation is found to follow directly the Arenigian quartzi-

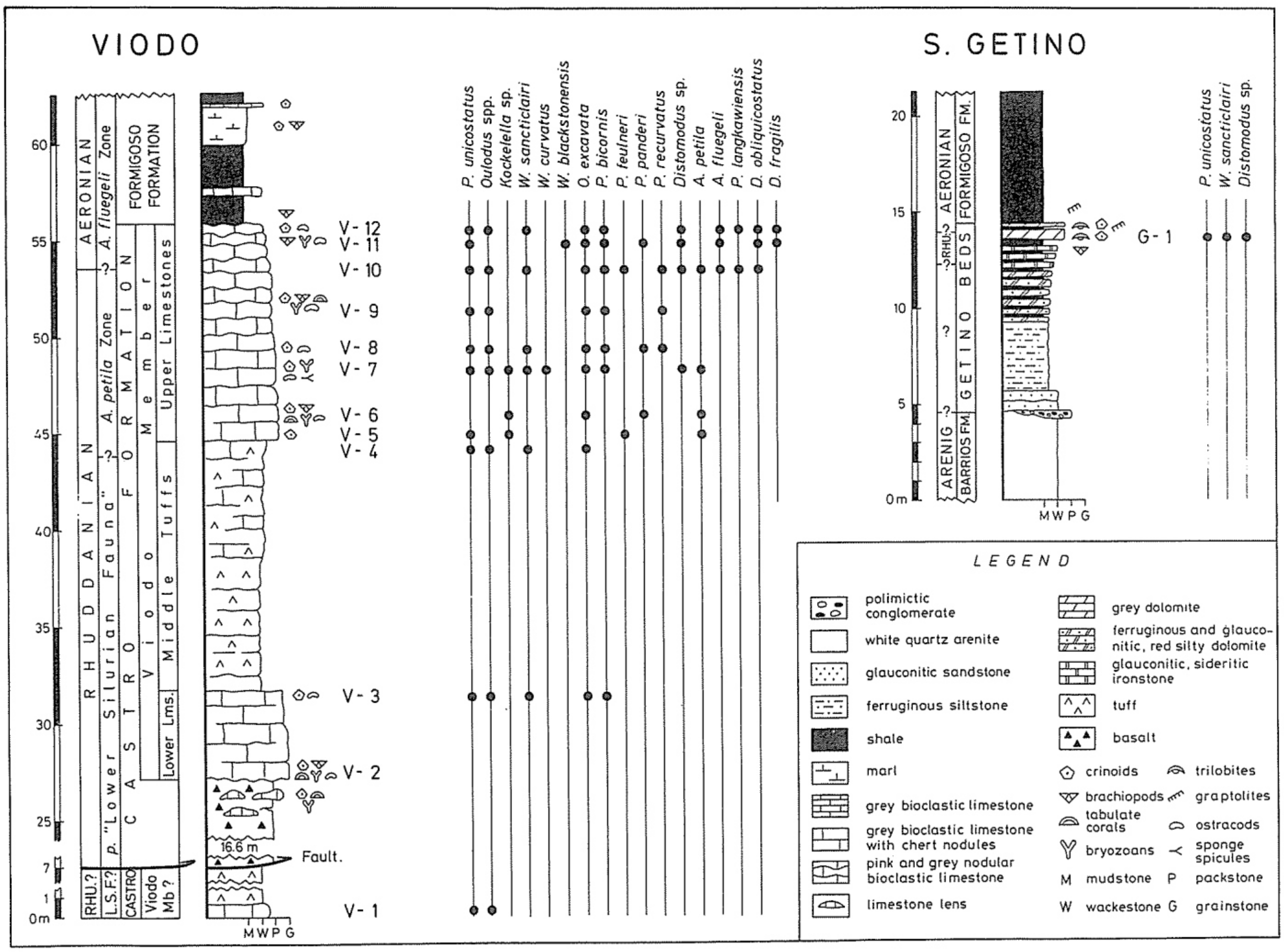


Figure 2 - Stratigraphic logs of the sections studied, showing the distribution of conodonts. *Profil stratigraphique des coupes étudiées, avec la distribution des conodontes.*

tes of the Barrios Formation. The base of the Formigoso shales apparently coincides everywhere with the *M. convolutus* graptolite Zone (late Aeronian) (Truyols *et al.* 1974 ; Truyols & Julivert 1983).

The composition of the conodont fauna shows that the Viodo Member constitutes the oldest Silurian rocks deposited in the Cantabrian Zone. On the basis of conodont biostratigraphy, a late Rhuddanian to early Aeronian age is inferred for this calcareous unit. This is consistent with the first graptolite record from the overlying Formigoso Formation, although it leaves open the possibility of a late Aeronian age for the top of the limestone. The studied material has palaeobiogeographical significance, given the rather incomplete knowledge of early Silurian (Llandoverian) conodont faunas around Gondwana, specially for the highest palaeolatitudes. Most of the data presently available (Bergström 1990) derive from areas within the palaeoequatorial belt (Scotese & McKerrow 1990). A more complete knowledge is required for the higher palaeolatitudes, so as to be able to understand the migration and evolutionary pathways of Silurian conodonts.

GEOLOGICAL SETTING

The Cantabrian Zone is one of the five Zones into which the Palaeozoic area of Northwest Spain has been divided (Julivert *et al.* 1972). This Zone constitutes a typical foreland thrust belt, characterised by unmetamorphosed sedimentary material, including a pre-orogenic Cambrian to Devonian succession and a synorogenic Carboniferous one (Pérez-Estaún *et al.* 1991). The localities with conodonts (Peñas Cape and Getino) are situated within the Fold and Nappe Region, as defined by Julivert (1967), in the western part of the Cantabrian Zone. This Region displays the most complete Palaeozoic succession of all the Zone. Eleven samples come from the Viodo Member, as exposed in the coastal cliffs of the Peñas Cape area, Asturias. An additional sample was collected from the Getino beds, south of the village of this name, in northern León (Figs. 1, 2).

LITHOSTRATIGRAPHY

VIODO LIMESTONE MEMBER

Although this unit was named and described in several different ways in the past, it was never formally characterized. A formal definition is presented here, in agreement with the recommendations of the International Stratigraphic Guide (Hedberg 1976).

Name

The geographic name of the unit derives from the village of Viodo, 2 km S of the Peñas Cape (Asturias, NW Spain). This unit formed part of the *"Schistes et quartzites de Corral"* of Barrois (1882), which included a variety of Upper Ordovician and Silurian rocks. Adaro & Junquera (1916), and later Truyols & Julivert (1976), informally named this unit as "calizas de la Punta de Sarreo" (Punta de Sarreo limestones). Llopis Lladó (1961) used the name "calizas de Viodo" for the same rocks in an informal way. Radig (1958, 1962) considered the unit as the top of his formally defined "Castro Schichten", a denomination which was not accepted at first, being known instead as "sucesión vulcano-detrítica" by Truyols & Julivert (1976). In the unpublished Ph. D. Thesis of Aramburu (1989) the calcareous unit was designated for the first time as "Formación Viodo", being differentiated from the underlying Castro Formation. A similar separation was accepted by Truyols *et al.* (1990), who designated the calcareous unit as "Sarreo Formation".
However, there is no general consensus about the suitability of recognizing this unit as a separate formation. In the present paper, it is preferred to designate it as the Viodo Member of the Castro Formation, of which it constitutes the upper part. The name Viodo is selected instead of Sarreo because the Viodo locality appears on the topographic maps to the scale of 1:50.000 ; this is not the case for Sarreo Point.

Stratotype

The type section is located on the coastal cliffs of Sarreo Point, 1 km NE of the village of Viodo, near Peñas Cape (Asturias), "Mapa Militar de España" 1:50.000, sheet n° 14 (Gijón), lat. 43°38' 55,2", long. 5°50'1,0". No other outcrops of the Viodo Member are known.

Boundaries

The lower boundary is transitional, small lenses of bioclastic limestones occurring in the last 2 m of the underlying basalt. A sharp contac definies the upper limit, where black shales of the Formigoso Formation overlie the limestone unit. However, some bands of marl and limestone are found interbedded in the lower part of the last unit.

Thickness and lateral extension

The 28.95 m thick Viodo Member is lensing, being absent at the Vidrias Cape section, ca. 18 km SW of Viodo.

Lithology

The Member is composed of two calcareous units separated by a tuffaceous intercalation in the middle.

The lower part consists of 4.7 m of grey limestones, constituted by crinoidal and tabulate grainstones at the base, and crinoidal grainstones at the top. Chert lenses occur in the upper part. Scour fills appear at the base ; these include occasional pebbles of basalt. Cross bedding occurs, but rarely. The middle part consists mainly of greenish grey tuffs. Limestones and tuffaceous limestones are interbedded near the top. Chert lenses are present at all levels. The upper part is constituted by grey nodular bioclastic limestone which is graded ; crinoidal grainstone is found at the base and packstone and wackestone with a varied macrofauna towards the top. The nodular aspect gradually increases upwards, and a pinky colour appears near the top, where occasional thin lenses of dark grey mudstone occur. Small chert lenses are common throughout. Rare pyrite nodules are present in the upper levels. The proportion of bioclasts gradually decreases upwards throughout the Member.

Palaeontology

The main palaeontological constituents are as follows : tabulate corals, brachiopods, bryozoans, crinoids and conodonts in the lower limestones ; brachiopods and trilobites in the middle tuffaceous beds (Julivert & Truyols 1973), and crinoids, ostracodes, brachiopods, bryozoans, conularids, sponge spicules, some tabulate corals and conodonts in the upper limestones.

Age

The entire Member was deposited during earliest Silurian times, as will be discussed later on in this paper. The lower and middle parts, and the base of the upper part are Rhuddanian in age. The remainder of the upper part is Aeronian.

Sedimentary environment and palaeogeography

The Viodo Member was deposited in a shallow epicontinental sea, at the commencement of a transgressive episode (Aramburu 1989). The lower limestone unit probably originated as bioclastic bars on the shoreface. The upper limestones represent a deeper, more quiet environment, situated between the fair weather wave base level and the storm wave base. The culmination of the transgression corresponds to the black shales of the Formigoso Formation, deposited below the storm wave base.

Facies and sequence interpretation conform in the main to those enunciated for the upper member of the Cambrian Láncara Formation in the Cantabrian Zone (Zamarreño 1972 ; Aramburu 1989).

The lenticular geometry of the Viodo Member is probably due primarily to limestone deposition on top of a volcanic mound similar to those described by Franke & Walliser (1983) from the Devonian and Carboniferous of Northwest Europe. Radig (1962) interpreted this unit as a reefal deposit, presumably because of its lenticular geometry. However, although corals are common, these occur as bioclasts, and not as frame builders. Since there is not sign of erosion at the top of the unit, the lenticular geometry cannot be explained in this way.

Remarks

Additional to the Viodo section, Aramburu (1989) included in his Viodo Formation two other carbonate outcrops, located at Portilla de Luna and at Getino, both in northern León. However, the limestones at Portilla de Luna differ in petrographic detail, sedimentary structures and age, and should therefore be designated as a different lithostratigraphic unit.

Although similar in age, the carbonate rocks at Getino differ from those of Viodo in lithology and sedimentary sequence. Due to their small thickness and comparable lithology, these carbonates are here included in the informal unit Getino beds, which are described below.

GETINO BEDS

In northern León and central Asturias, a heterolithic unit is recognized between the Arenigian quartzites of the Barrios Formation and the Silurian graptolitic black shales of the Formigoso Formation. It is composed of a few metres of alternating sandstones, siltstones, mudstones and carbonates (dolomite and siderite), all highly bioturbated, and frequently glauconitic and ferruginous. It represents a condensed succession of uncertain age, but possibly ranging from Arenig to Llandovery. A complete description can be found in Aramburu (1989).

In the past, these beds were commonly included within the Formigoso Formation (e.g. Kegel 1929; Comte 1959 ; Evers 1967 ; Vilas 1971). Van den Bosch (1969) included them in his "Transitional Beds", and suggested that they should be attributed formational rank. Although Aramburu (1989) suggested the name Getino Formation, in this paper the informal name "Getino beds" is preferred, since a more formal definition requires a complex explanation which is beyond the scope of the present paper.

The section giving its name to this unit is situated between the villages of Getino and Felmín, in

Sample approx. kg species	1 0,75	2 0,60	3 0,95	4 0,80	5 0,75	6 0,40	7 0,90	8 0,85	9 0,35	10 0,95	11 0,70	12 0,75
A. fluegeli												
Pa ?	-	-	-	-	-	-	-	-	-	1	-	1
Pb ?	-	-	-	-	-	-	-	-	-	-	-	1
M	-	-	-	-	-	-	-	-	-	1	-	-
Sa	-	-	-	-	-	-	-	-	-	-	-	-
Sb	-	-	-	-	-	-	-	-	-	6	2	1
Sc	-	-	-	-	-	-	-	-	-	1	3	3
A. petila												
Pa	-	-	-	-	-	-	-	-	-	-	-	-
Pb	-	-	-	-	-	-	-	-	-	-	-	-
M?	-	-	-	-	-	-	1	-	-	1	-	-
Sa	-	-	-	-	-	-	2	-	-	-	-	-
Sb?	-	-	-	-	1	3	-	-	-	-	-	-
Sc?	-	-	-	-	1	1	-	-	-	-	-	-
D. obliquicostatus												
Sym. p?	-	-	-	-	-	-	-	-	-	-	-	1
sq	-	-	-	-	-	-	-	-	-	3	1	2
r	-	-	-	-	-	-	-	-	-	-	-	-
D. fragilis												
sym. p.	-	-	-	-	-	-	-	-	-	-	-	-
sq	-	-	-	-	-	-	-	-	-	-	2	3
r	-	-	-	-	-	-	-	-	-	-	-	-
Distomodus sp.												
Pa	-	-	-	-	-	-	-	-	-	-	-	-
Pb?	-	-	-	-	-	-	-	-	-	-	2	-
M	-	-	-	-	-	-	1	-	-	3	-	1
Sa	-	-	-	-	-	-	-	-	-	-	-	-
Sb	-	-	-	-	-	-	-	-	-	-	-	-
Sc?	-	-	-	-	-	-	-	-	-	-	-	1
Kockelella sp.												
Pa	-	-	-	-	-	-	-	-	-	-	-	-
Pb	-	-	-	-	-	-	-	-	-	-	-	-
M?	-	-	-	-	-	1	-	-	-	-	-	-
Sa?	-	-	-	-	2	-	-	-	-	-	-	-
Sb	-	-	-	-	-	1	-	-	-	-	-	-
Sc?	-	-	-	-	2	-	1	-	-	-	-	-
Oulodus spp.												
Pa	-	-	-	-	-	-	-	-	-	-	-	-
Pb	-	-	-	-	-	-	-	-	-	-	-	-
M?	-	-	-	-	-	-	-	-	-	-	1	-
Sa?	-	-	-	-	-	-	-	2	-	-	-	-
Sb?	1	-	-	1	-	2	-	-	-	3	-	1
Sc	-	-	2	-	-	-	-	1	-	1	1	3

Figure 3 - Number and distribution of conodonts recovered from the Viodo Member. *Nombre et distribution des conodontes du Membre Viodo.*

northern León, on the western bank of the Torío river ("Mapa Militar de España" 1:50.000, sheet n° 103 "La Pola de Gordón", lat. 42°55,25'14,0", long. 5°32'19,2"). The unit is 10.5 m thick at this point. The proportion of carbonate gradually increases towards the top in this section. The upper 1.6 m consist of alternating grey dolostones and mudstones with crinoids, bivalves and trilobites. They have also yielded conodonts, as discussed below.

NOTES ON THE CONODONT FAUNAS

Palaeontological analysis is based on 837 specimens from 11 samples collected from the Viodo Member at Sarreo Point, and from one sample from the Getino beds in the Getino-Felmín section (Fig. 2).

The conodonts were isolated by the use of acetic acid (8%) and formic acid (6%) in which 2.5 to 3.5 kg were partially digested (Fig. 3). Identifiable conodonts were recovered from a screen mesh of 0.064, whilst only fragments were recovered on a screen of 0.032. The specimens are generally fragmentary and poorly preserved, probably as a result of tectonic deformation. CAI values of 5 suggest heating up to 300°C (Epstein *et al.* 1977) during the Hercynian and/or Alpidic orogenic cycles. The surface of the specimens shows diagenetical overgrowth, and a large number of denticles with crystal facets have been observed. The state of preservation means that a complete taxonomic study is rather difficult, particularly with regard to distinguishing species of Panderodus, where white matter is an essential diagnostic character.

The abundance of conodont elements varies from very low to moderately prolific, with a minimum found in V-1 (3 specimens) and a maximum in V-10 (281 specimens). The assemblages are dominated by coniform apparatuses with delicate ele-

Figure 3 - Suite

Sample / **approx. kg** / **species**	**1** 0,75	**2** 0,60	**3** 0,95	**4** 0,80	**5** 0,75	**6** 0,40	**7** 0,90	**8** 0,85	**9** 0,35	**10** 0,95	**11** 0,70	**12** 0,75
O. excavata												
Pa	-	-	-	1	-	2	-	-	-	-	1	-
Pb?	-	-	-	1	-	-	1	-	-	-	-	1
M?	-	-	-	-	-	-	-	-	1	-	-	-
Sa?	-	-	-	1	-	-	-	-	-	2	-	-
Sb	-	-	-	-	-	-	-	-	-	-	-	-
Sc	-	-	-	-	-	-	-	1	-	-	-	-
falciform	-	-	-	-	-	-	-	-	-	-	-	-
graciliform	-	-	-	-	-	-	-	-	-	2	-	1
P. equicostatus												
similiform?	-	-	-	1	-	-	-	-	-	-	-	-
P. langkawiensis												
graciliform	-	-	-	-	-	-	-	-	-	2	-	-
P. panderi												
arcuatiform?	-	-	-	-	1	-	-	-	-	-	-	-
falciform	-	-	-	-	-	-	-	-	-	-	-	-
graciliform	-	-	-	-	-	1	-	-	-	-	2	-
P. recurvatus												
arcuatiform?	-	-	-	-	-	-	-	-	-	1	-	-
falciform	-	-	-	-	-	-	-	1	1	2	-	-
graciliform	-	-	-	-	-	-	-	-	-	-	-	-
P. unicostatus												
arcuatiform?	-	-	2	3	7	2	42	12	4	62	18	14
falciform	-	-	1	2	10	1	18	10	23	45	11	10
graciliform	2	-	4	6	12	8	56	37	56	102	45	32
P. bicornis												
1d	-	-	-	-	-	-	-	-	-	-	-	-
2d	-	-	1	-	-	-	3	1	4	5	2	7
sl	-	-	-	-	-	-	-	-	-	-	-	-
W. blackstonensis												
aq?	-	-	-	-	-	-	-	-	-	-	2	-
W. curvatus												
sym. p	-	-	-	-	-	-	2	-	-	-	-	-
ap	-	-	-	-	-	-	1	-	-	-	-	-
aq	-	-	-	-	-	-	-	-	-	-	-	-
sq?	-	-	-	-	-	-	1	-	-	-	-	-
W. sancticlairi												
sym. p	-	-	1	3	-	-	21	-	-	9	-	23
ap	-	-	-	2	-	-	7	-	-	12	-	4
ap?	-	-	-	4	-	-	26	-	-	16	-	22
Indet. fragments	1	3	7	4	1	-	6	3	1	2	1	-

ments, *Panderodus* being the most common genus in all the samples analysed. A large number of ostracodes, bryozoans, sponge spicules, echinoderm ossicles, conularids, gastropods and brachiopods (both articulates and inarticulates) were also recovered from the insoluble residues. Species ranges are given in Fig. 3, and the biostratigraphy in Fig. 4.

Panderodus is the most common genus in all the samples analysed. Its relative abundance increases upwards within the sequence. Sweet (1988) suggested that the apparatus of fully evolved species of *Panderodus* was probably seximembrate. In our collection, only graciliform, arcuatiform and falciform elements have clearly been recognized, the former being the most frequent one.

Panderodus unicostatus (BRANSON & MEHL) (pl. 1, figs. 10, 11, 14, 15) is the most widely represented species ; *P. recurvatus* (RHODES) (pl. 1, figs. 7, 13), *P. feulneri* (GLENISTER) (pl. 1, fig. 4), *P. langkawiensis* (IGO & KOIKE) (= *P. spassovi* (STAUFFER)) (pl. 1, figs. 12), *P. panderi* (STAUFFER) and *P. equicostatus* (RHODES) (pl. 1, fig. 17) have beeen found less commonly.

Walliserodus specimens are common, although less so than *Panderodus*. All the elements are characterised by thin walls and increased thermal maturity (CAI 6). Three multielement species have been recorded : *W. sancticlairi* COOPER (pl. 2, figs. 1, 2, 3) is represented by p and q elements (*sensu* Armstrong 1990) ; *Walliserodus curvatus* (BRANSON & BRANSON) (pl. 2, fig. 4) is distinguished by the morphology of the p elements ; and *Walliserodus blackstonensis* McCRACKEN (pl. 2, fig. 5) is represented by costate elements with the characteristic narrow recurved cusps.

Dapsilodus obliquicostatus (BRANSON & MEHL) (pl. 1, figs. 1, 6) is found in low numbers and without all the elements being present. Its sq and r elements differ from those of specimens from the Brassfield Formation in southern Ohio, North America (Cooper 1975), the former having a more proclined cusp, and the latter a shorter upper margin. The characteristic striae near the anterior margin are inconspicuous in our specimens.

Small and striate cones of *Decoriconus fragilis* (BRANSON & MEHL) (pl. 1, fig. 8) have been recovered from the top of the Viodo Member. Only the sq element of this trimembrate apparatus could be identified.

Squat conical elements from the apparatus of *Pseudooneotodus bicornis* DRYGANT (pl. 1, figs. 2, 3) have been encountered. These elements are always complete, although the basal cavity is very large and the wall delicate. The specimens from the lower part of the section have a subcircular basal outline and show two small denticles ; those from the upper levels have a subtriangular design and more prominent tips.

Specimens of *Oulodus* sp., characterised by ramiform elements with large, rounded peg-like denticles, occur throughout the Viodo Member. These are listed in open nomenclature because our small collection is inadequate for a formal specific assignment.

A small number of S elements, belonging to *Kockelella* (pl. 1, fig. 16), has been found in the lower part of the section. Although well preserved, even showing the delicate denticles, a specific identification seems unwarranted.

A single species of *Ozarkodina*, i. e. *O. excavata* (BRANSON & MEHL), has been identified on the presence of the diagnostic Pa elements (pl. 2, figs. 10, 12, 15). S elements from this species also occur (pl. 2, fig. 13).

A certain number of Pa, M and S elements from the genus *Aspelundia* has been recovered from near the base of the upper limestones of the Viodo Member. Although some of them belong to *A. fluegeli* (WALLISER) emend. ARMSTRONG, 1990 (pl. 2, figs. 8, 9, 11, 14), others can be assigned to *A.*

PLATE 1

All the specimens on plates 1 and 2 are from the Viodo Member, Peñas Cape ; G. Sarmiento's collection, to be deposited in the Palaeontology Unit of the Department of Geology, University of Oviedo. *Tous les spécimens des pl. 1 et 2 appartiennent au Membre Viodo, Cap de Peñas ; ils proviennent de la collection de G. Sarmiento et seront déposés prochainement à la Section de Paléontologie du Département de Géologie, Université d'Oviedo.*

Fig. 1, 6 - ***Dapsilodus obliquicostatus*** (BRANSON & MEHL). Lateral views of sq elements. **1**. x 250, V3983, from level V-12. **6**. x 300, V4081, from level V-12. *Vue latérale des éléments sq. Les deux spécimens du niveau V-12.*

Fig. 2, 3 - ***Pseudooneotodus bicornis*** DRYGANT, squat bidentate elements. **2**. Upper view, x 130, V4082, from level V-10. **3**. Lateral view, x 100, V4002, from level V-7. *Eléments bidentés trapus.* **2**. *Vue supérieure, du niveau V-10.* **3**. *Vue latérale, du niveau V-7.*

Fig. 4 - ***Panderodus feulneri*** (GLENISTER). Lateral view of falciform element, x 190, V4003, from level V-10. *Vue latérale d'un élément falciforme, du niveau V-10.*

Fig. 5, 9, 18 - ***Distomodus*** sp. **5**. Inner-lateral view of Pb? element, x 170, V3991, from level V-11. **9**. Inner-lateral view of Sc? element, x 90, V3990, from level V-12. **18**. Inner-lateral view of M element, x 170, V3994, from level V-11. **5**. *Vue latéro-intérieure d'un élément Pb?, du niveau V-11.* **9**. *Vue latéro-intérieure d'un élément Sc?, du niveau V-12.* **18**. *Vue latéro-intérieure d'un élément M, du niveau V-11.*

Fig. 7, 13 - ***Panderodus recurvatus*** (RHODES). **7**. Lateral view of falciform element, x 200, V3993, from level V-10. **13**. Lateral view of graciliform element, x 130, V4008, from level V-10. **7**. *Vue latérale d'un élément falciforme, du niveau V-10.* **13**. *Vue latérale d'un élément graciliforme, du niveau V-10.*

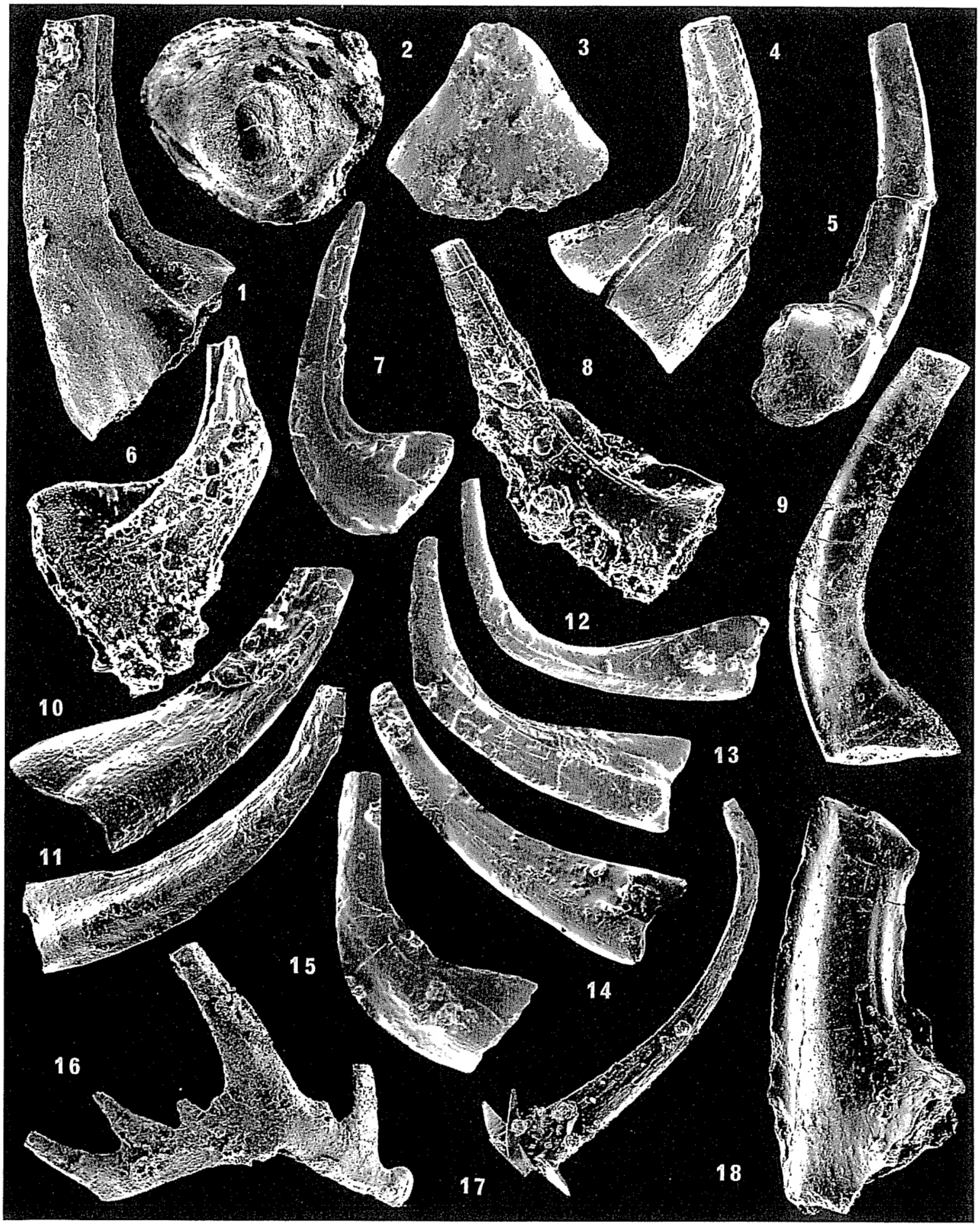
Fig. 8 - ***Decoriconus fragilis*** (BRANSON & MEHL). Lateral view of sq element, x 230, V4331, from level V-12. *Vue latérale d'un élément sq, du niveau V-12.*

Fig. 10, 11, 14, 15 - ***Panderodus unicostatus*** (BRANSON & MEHL). **10**. Lateral view of arcuatiform-graciliform element, x 230, V3971, from level V-10. **11**. Lateral view of juvenile falciform element, x 200, V4007, from level V-12. **14**. Lateral view of arcuatiform element, x 130, V4011, from level V-12. **15**. Lateral view of falciform element, x 110, V4013, from level V-10. **10**. *Vue latérale d'un élément arquatiforme-graciliforme du niveau V-10.* **11**. *Vue latérale d'un élément falciforme juvénile, du niveau V-12.* **14**. *Vue latérale d'un élément arquatiforme, du niveau V-12.* **15**. *Vue latérale d'un élément falciforme, du niveau V-10.*

Fig. 12 - ***Panderodus langkawiensis*** IGO & KOIKE. Lateral view of graciliform element, x 140, V4006, from level V-10.*Vue latérale d'un élément graciliforme du niveau V-10.*

Fig. 16 - ***Kockelella*** sp. Lateral view of Sc? element, x 130, V3987, from level V-7. *Vue latérale d'un élément Sc?, du niveau V-7.*

Fig. 17 - ***Panderodus equicostatus*** (RHODES). Lateral view of similiform? element, x 120, V3971, from level V-4. *Vue latérale d'un élément similiforme?, du niveau V-4.*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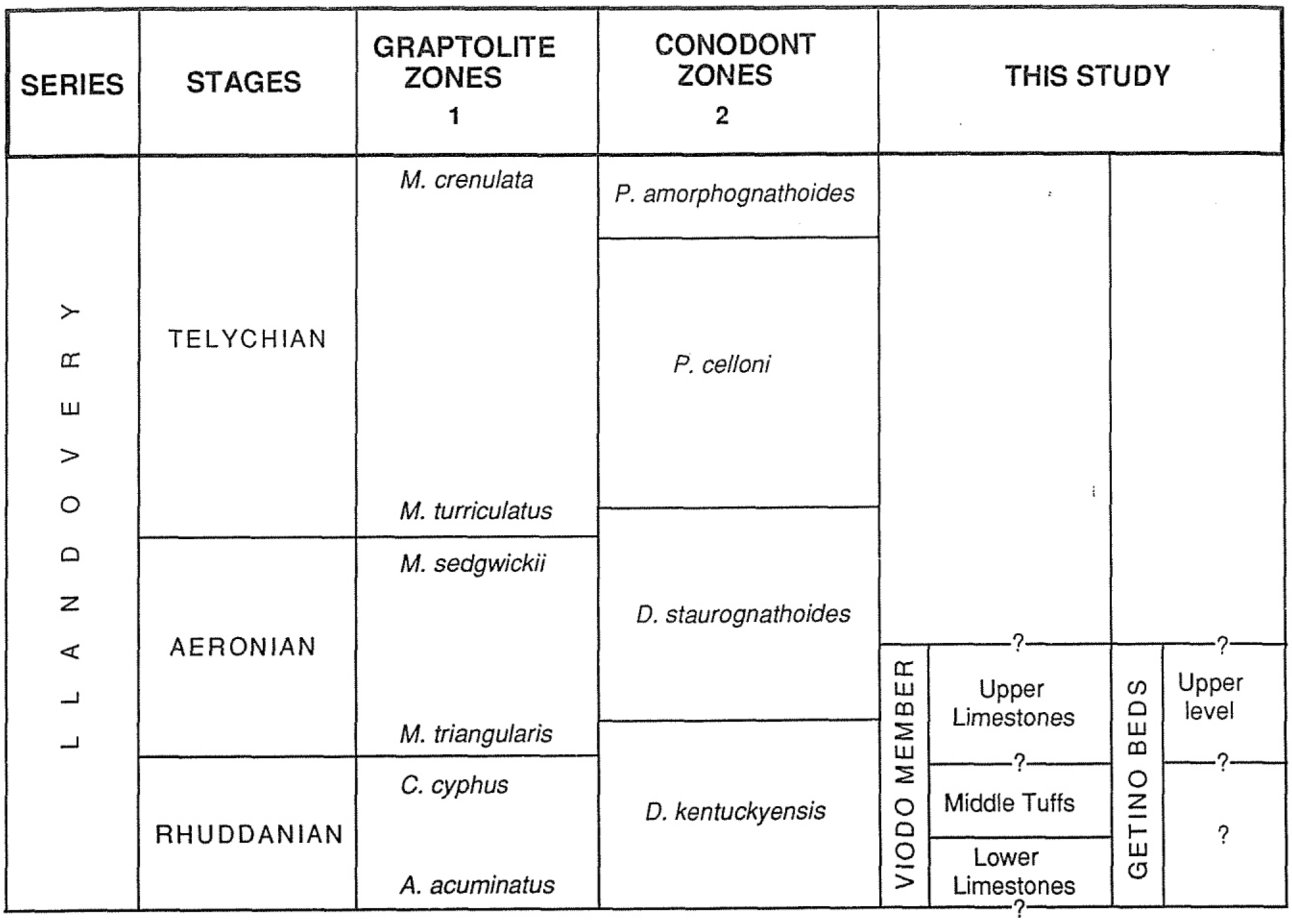


Figure 4 - Correlation of graptolite and conodont zones, with the position of stratigraphic units studied : 1, after Holland (1985) ; 2, after Aldridge & Schönlaub (1989). See text for more complete explanation. *Corrélation des unités stratigraphiques étudiées avec les zones de graptolites et de conodontes. 1, d'après Holland (1985) ; 2, d'après Aldridge & Schönlaub (1989). Voir le texte pour plus de détails.*

PLATE 2

Fig. 1, 2, 3 - ***Walliserodus sancticlairi*** COOPER. **1.** Inner-lateral view of acodiform (ap) element, X 180, V3975, from level V-4. **2.** Lateral view of acodiform (ap?) element, x 250, V3176, from level V-10. **3.** Lateral view of costate (sym. p) element, x 220, V3976, from level V-4. ***1.*** *Vue latéro-intérieure d'un élément acodiforme (ap), du niveau V-4.* ***2.*** *Vue latérale d'un élément acodiforme (ap?), du niveau V-10.* ***3.*** *Vue latérale d'un élément costé (sym. p), du niveau V-4.*

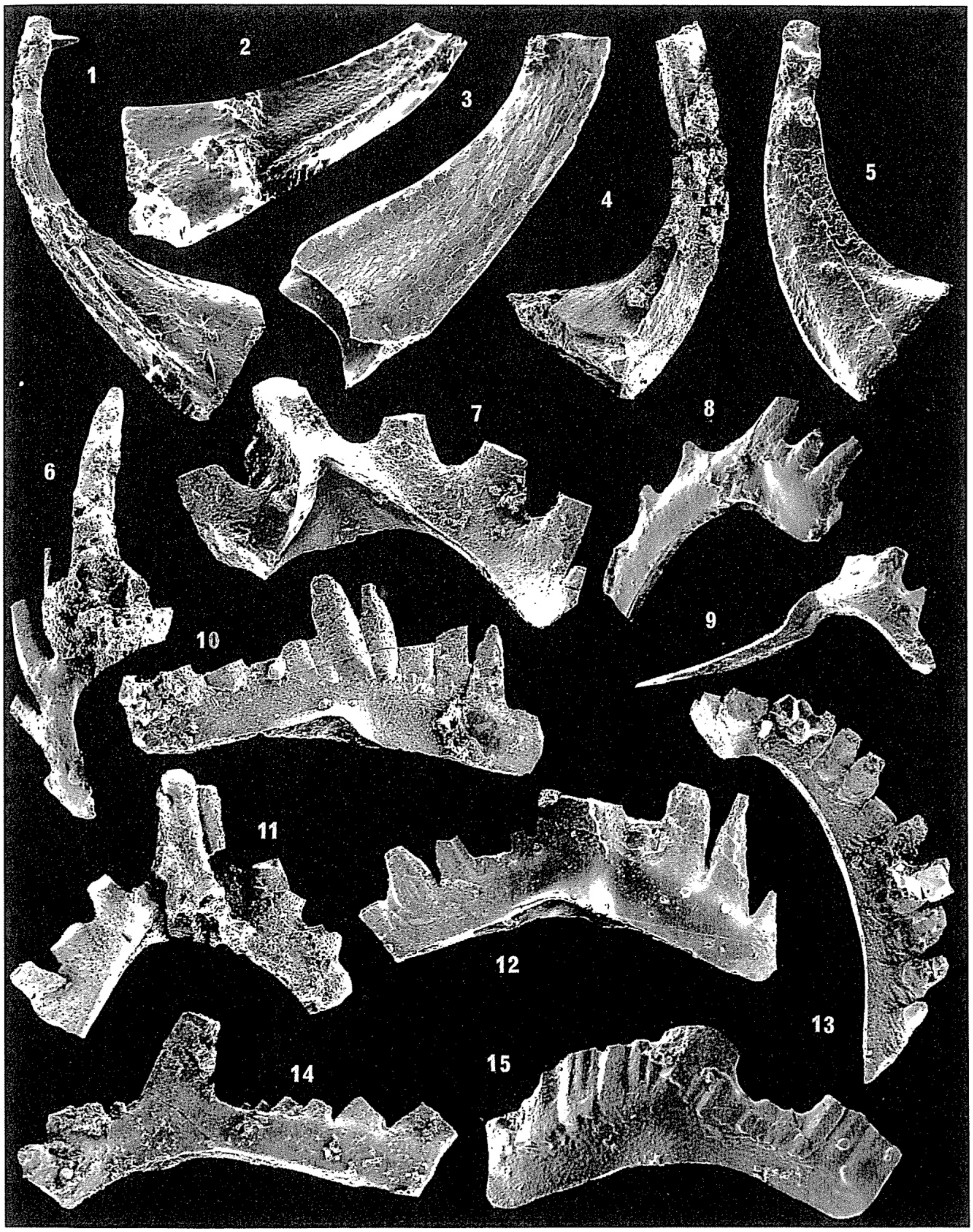
Fig. 4 - ***Walliserodus curvatus*** (BRANSON & BRANSON). Lateral view of costate (sq?) element, x 200, V3979, from level V-7. *Vue latérale d'un élément costate (sq?), du niveau V-7.*

Fig. 5 - ***Walliserodus blackstonensis***? McCRACKEN. Inner-lateral view of costate (aq?) element, x 130, V3971, from level V-11. *Vue latéro-intérieure d'un élément costé (aq?), du niveau V-11.*

Fig. 6, 7 - ***Aspelundia petila*** (NICOLL & REXROAD). **6.** Outer-lateral view of Sc? element, x 110, V3978, from level V-6. **7.** Oblique posterior view of Sb? element, x 180, V3984, from level V-6. ***6.*** *Vue latéro-extérieure d'un élément Sc?, du niveau V-6.* ***7.*** *Vue postérieure-oblique d'un élément Sb?, du niveau V-6.*

Fig. 8, 9, 11, 14 - ***Aspelundia fluegeli*** (WALLISER). **8.** Oblique posterior view of Sb element, x 100, V3956, from level V-10. **9.** Lower view of Pa? element, x 170, V3951, from level V-10. **11.** Posterior view of Sb element, x 110, V3982, from level V-10. **14.** Inner-lateral view of Sc element, x 120, V3993, from level V-11. ***8.*** *Vue postérieure-oblique d'un élément Sb, du niveau V-10.* ***9.*** *Vue inférieure d'un élément Pa?, du niveau V-10.* ***11.*** *Vue postérieure d'un élément Sb, du niveau V-10.* ***14.*** *Vue latéro-intérieure d'un élément Sc, du niveau V-11.*

Fig. 10, 12, 13, 15 - ***Ozarkodina excavata*** (BRANSON & MEHL). **10.** Inner-lateral view of Pa element, x 150, V3980, from level V-6. **12.** Inner-lateral view of Pa element, x 170, V3977, from level V-4. **13.** Posterior view of Sa? element, x 120, V3970, from level V-4. **15.** Inner-lateral view of Pb? element, x 170, V3972, from level V-8. ***10.*** *Vue latéro-intérieure d'un élément Pa, du niveau V-6.* ***12.*** *Vue latéro-intérieure d'un élément Pa, du niveau V-4.* ***13.*** *Vue postérieure d'un élément Sa?, du niveau V-4.* ***15.*** *Vue latéro-intérieure d'un élément Pb?, du niveau V-8.*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petila (NICOLL & REXROAD), (pl. 2, figs. 6, 7). McCracken (1991) offered a careful description of both species, pointing out that "the form of the elements is quite similar, and there is some morphological gradation between elements of the two species". At the same time, he showed that most elements are distinguishable. In the collection from the Cantabrian Mountains, all the elements are broken and not all the morphotypes are represented. Ramiform elements from levels V-5 to V-7 of the Viodo Member could belong to *Aspelundia petila* (NICOLL & REXROAD), since the denticles tend to be peg-like and have more excavated bases. They are also wider than those of *A. fluegeli* (WALLISER). Pa, Pb and S elements from levels V-10 to V-12 are mostly characteristic of *A. fluegeli*, but other elements cannot be attributed inequivocally.

Aspelundia petila was assigned to *A. expansa* nov. sp. by Armstrong (1990), but in McCracken's opinion *Ligonodina petila* NICOLL & REXROAD 1969 (an Sc element of this apparatus) has priority. Consequently, the valid name for this species is *Aspelundia petila* (NICOLL & REXROAD).

Fragmentary M elements attributable to *Distomodus* sp. indet. (pl. 1, figs. 5, 9, 18) occur sporadically in the Viodo Member.

BIOSTRATIGRAPHY

HISTORICAL REVIEW

Radig (1962) recorded the first Silurian fossils from the Viodo Member, identifying the trilobite *Leonaspis* sp. Spjeldnaes (1967), mentioned Silurian bryozoan and brachiopod genera from the Peñas Cape area, but did not give exact locality details. Julivert & Truyols (1973) and Villas *et al.* (1989) suggested that these fossils might have come from the Viodo Member.

Julivert & Truyols (1973) provided a detailed account of fossils from the Viodo Member, mentioning some macrofossils (*Flexicalymene, Eospirifer*, indeterminable orthids and rhynchonellids) as well as the first Silurian conodonts, as identified by M. Lindström (*op. cit.*, p. 242). These came from two different levels. The lower calcareous unit yielded *Trichonodella* cf. *symmetrica* BRANSON & MEHL and *Trichonodella* cf. *excavata* BRANSON & MEHL. From the upper calcareous unit, Lindström listed *Neoprioniodus* cf. *planus* WALLISER, *Hindeodella* cf. *equidentata* RHODES, *Lonchodina* cf. *walliseri* ZIEGLER and *Distomodus?* sp., assigned at present to *Ozarkodina, Oulodus, Aspelundia* and *Distomodus*, respectively. On the basis of this conodont fauna, Julivert & Truyols (1973) suggested a Silurian age for the whole limestone unit. However, Gutiérrez Marco (1986) noted that the sparse and imprecise conodont taxa determined from the lower level, left open the possibility that this level might still be attributed to the Ordovician.This possibility was supported by the discovery of Ashgill limestones within the Cantabrian Zone and the fact that the conodont "genus" *Trichonodella* appeared in other Ashgillian limestones in Spain (Gutiérrez Marco, pers. comm.). However, the early Silurian age is confirmed by the additional fauna reported here from these lower limestone beds.

All the faunal remains encountered in the Getino beds were collected from two localities in the upper part of this unit in northern León, i.e. at Getino-Felmín and Pontedo. Evers (1967) noted the presence of indeterminate crinoids, brachiopods and bivalves in a "black marl lens" at Felmín, which he included in the Formigoso Formation. Gutiérrez Marco (1986) and Aramburu (1989) recognized Diplograptina, *Calymene* sp. and Asaphina from the same locality and stratigraphic levels, and designated these strata as Viodo Formation. Greenish grey shales underlying the black shales of the Formigoso Formation at Pontedo have yielded *Calymene* sp., *Leonaspis* sp., *Cornulites* sp., *Pristiograptus* sp., *Metaclimacograptus* aff. *hughesi, Rastrites* sp. and *Monograptus* sp., according to Gutiérrez Marco and Rábano (*in* Aramburu 1989). The two levels referred to above, at Getino-Felmín and Pontedo, were dated by Gutiérrez Marco as early Silurian (Gutiérrez Marco 1986 ; Aramburu 1989). These are considered here to correspond to uppermost Getino beds.

BIOSTRATIGRAPHY OF THE CONODONTS

The currently available biostratigraphic zonation on conodonts has been established for low-mid latitude palaeogeographic areas (see Aldridge & Schönlaub 1989, for a review). These areas yielded a diverse fauna of platform bearing taxa, including *Distomodus* and *Icriodella*, which have been used to date early Silurian, and to erect a global standard zonation for the Rhuddanian and the Aeronian (Aldridge & Schönlaub 1989). Unfortunately, this zonation cannot be applied in the Cantabrian sections, since they lack these diagnostic taxa (Figs. 4, 5).

The predominance of simple-cone bearing taxa attributable to *Panderodus, Walliserodus, Dapsilodus*, and *Decoriconus* in the Lower Silurian of the Cantabrian Zone, and the presence of *Aspelundia*

SERIES	STAGES	GREAT BRITAIN 1	ANTICOSTI 2	ANTICOSTI 3	GREENLAND 4 shelf	GREENLAND 4 slope
LLANDOVERY	TELYCHIAN	*P. amorphognathoides*		*P. amorphognathoides*	*P. amorphognathoides*	*P. amorphognathoides*
		I. inconstans		*I. inconstans*	*P. celloni*	*P. celloni*
	AERONIAN	*H. staurognathoides*	*D. kentuckyensis*	*D. sta.*: *O. aldridgei* / *D. staurognathoides*	"Lower Silurian Fauna"	*A. fluegeli*
		I. discreta- *I. deflecta*		*I. discreta*- *I. deflecta*		
	?	?	?			
	RHUDDANIAN		*O. ? nathani*			*A. expansa*

Figure 5 - Approximate relationships between conodont zonations. 1, after Aldridge (1972, 1975) ; 2, after McCracken & Barnes (1981) ; 3, after Uyeno & Barnes (1981) ; 4, after Armstrong (1990). *Relations approximatives entre diverses zonations de conodontes. 1, d'après Aldridge (1972, 1975) ; 2, d'après McCracken & Barnes (1981) ; 3, d'après Uyeno & Barnes (1981) ; 4, d'après Armstrong (1990).*

(Fig. 2) recall the assemblages described by Armstrong (1990) from early Silurian slope-biofacies of North Greenland, and by McCracken (1991) from offshore environments of the Canadian Cordillera.

Armstrong (1990) recognized in shelf biofacies a "Lower Silurian Fauna" characterised by the presence of *Kockelella manitoulensis, Ozarkodina hassi, O. excavata* and *Panderodus unicostatus*. Conodonts from the interval below V-5 in the Viodo Member are : *P. unicostatus, Walliserodus sancticlairi, Pseudooneotodus bicornis, Ozarkodina excavata* and *Oulodus* sp.. In the absence of key species this association, coming from strata deposited in the shoreface environment, is tentatively assigned to the basal "Lower Silurian Fauna" of Armstrong (*op. cit.*). Twelve metres higher up, *Aspelundia petila* (NICOLL & REXROAD) makes its first appearance. Armstrong (1990) established the *A. expansa* (= *A. petila*) and *A. fluegeli* Zones for the pre-*P. celloni* Zone in slope and outer shelf biofacies in Greenland. The lower limit of the early Zone is close to the Ordovician-Silurian boundary, and probably within the lower *D. kentuckyensis* Zone. Accordingly, the lower limestones of the Viodo Member might correspond to the pre-*C. cyphus* graptolite Zone, of Rhuddanian age.

The presence of *Aspelundia fluegeli* (WALLISER) from the V-10 level to the top of the Viodo Member is biostratigraphically significant. The base of *A. fluegeli* Zone in North Greenland is equivalent to the *M. argenteus* graptolite Zone, of early Aeronian age (cf. Armstrong 1990) ; in northern Yukon this limit coincides with the middle to upper part of the *D. kentuckyensis* Zone (McCracken 1991).

Armstrong (*op. cit.*) mentioned that the upper part of the *A. fluegeli* Zone in Greenland can be correlated with the *Hadrognathus staurognathoides* Assemblage Zone erected by Aldridge (1972,

1975) for pre-*P. celloni* Zone strata in the Welsh Borderland. The first record of *A. fluegeli* in the Northwest Territories of Canada is within the range of the *I. discreta/D. kentuckyensis/O. nathani* to *P. amorphognathoides* Zones (Over & Chatterton 1987). *A. fluegeli,* which is partially equivalent to *Oulodus planus planus* (WALLISER), has also been reported from the middle part of the *C. cyphus* to *M. griestoniensis* graptolite Zones of New South Wales (Bischoff 1986).

Thus, the upper limestones of the Viodo Member may be correlated with the interval of the *A. petila* and *A. fluegeli* Zones, ranging from basal Rhuddanian to top Aeronian. Everywhere in the Cantabrian Zone, the graptolites at the base of the overlying Formigoso Formation belong to the *M. convolutus* Zone, the presence of the *C. gregarius* Zone being rather dubious (Truyols *et al.* 1974 ; Truyols & Julivert 1983). Consequently, conodont data confirm the early Silurian age for these rocks, established on graptolites, and suggest that the upper limestones of the Viodo Member are Rhuddanian to early Aeronian.

The small number of conodonts obtained from a single sample of the dolomitic upper part of the Getino beds, allows comparison with the fauna from the upper calcareous beds of the Viodo Member. Thus, the top of the Getino beds may be tentatively assigned either to the *A. petila* Zone or the *A. fluegeli* Zone ; late Rhuddanian or early Aeronian ages may therefore be inferred for these beds.

REMARKS ON PALAEOECOLOGY

Silurian conodonts display a high degree of palaeoenvironmental control. This has been analysed by several authors (e.g. Aldridge & Mabillard 1981 ; Barrick 1983 ; Aldridge & Jeppsson 1984).

In Britain, Aldridge (1972) used the *Icriodella* lineage for his early Silurian zonation, but this genus has not been recorded in the Cantabrian Zone. Its absence may be attributed to the fact that *Icriodella* favours nearshore high energy environments (cf. Aldridge & Jeppsson 1984). *Distomodus, Oulodus, Ozarkodina* and *Panderodus* are found associated with *Icriodella*, but in lesser proportion (Aldridge 1976).

In North Greenland, coniform genera are increasingly abundant in offshore environments. This suggests that the distribution patterns are probably depth-related (Armstrong 1990, p. 37).
Aldridge & Mabillard (1981) mentioned the high abundance of *Dapsilodus obliquicostatus* (BRANSON & MEHL) in outer platform environments. Furthermore, Barrik (1983), in an integrated study of the Wayne Formation (Tennessee), distinguished several conodont biofacies. One of these, the *Dapsilodus obliquicostatus* Biofacies, represents the farthest offshore, i.e. quiet or even deep water environments. The slope biofacies in Greenland studied by Armstrong (1990) is dominated by *D. obliquicostatus, Decoriconus fragilis* and *Aspelundia fluegeli.* A similar association in northern Yukon was identified by McCracken (1991) as *Aspelundia-Dapsilodus* fauna for offshore environments. The Cantabrian conodont fauna compares most closely to this fauna but differs in the common presence of *Panderodus* spp., whilst *Dapsilodus* is only a minor component.

A slope environment in an area close to the equator could be expected to be much cooler (a function of depth) and to be ecologically similar to shallow water environments at higher palaeolatitudes. It is therefore possible to explain in palaeoecological terms the similarity of microfaunas in areas of different palaeolatitude. Sweet (1988) concluded that temperature was a major controlling factor in conodont species.

The lower limestones of the Viodo Member yielded delicate elements from a very poorly diversified conodont assemblage. No platform or key species have been recovered. The upper limestones display a more diversified fauna, also with delicate elements, and with several taxa indicative of offshore conditions (*Dapsilodus, Decoriconus, Aspelundia*). This may represent the beginning of colonization in an area with progressive deepening, culminating with the episode of the Formigoso shales.

Acknowledgements - This article is a contribution to the projects "The Ordovician-Silurian Boundary in the Iberian Peninsula and France" (Acciones Integradas Programme between Spain and France, 1990-1992), and "Biostratigraphy of the Ordovician in the Cantabrian Zone and margin of the West Asturian-Leonese Zone" (DGICYT, Spain, PB 91-0671). We are indebted to Dr. Richard Aldridge (Leicester University) for access to his Silurian conodont collections in Great Britain. Drs. H. Armstrong (Durham) and I. Sansom (Newcastle-upon-Tyne) are thanked for their helpful discussions with regard to conodont identifications. Dr. J.C. García-Ramos (Universidad de Oviedo) is acknowledged for joint fieldwork. Critical comments to the manuscript were received from Drs. H. Armstrong, L. Fahraeus (Newfoundland University), J.C. Gutiérrez Marco (Instituto de Geología Económica and Universidad Complutense de Madrid), L. Jeppsson (Geological Institute of Lund) and M. Weyant (Université de Caen) whose contributions helped in the improvement of this paper. We thank Dr. R. H. Wagner (Jardín Botánico de

Córdoba) for his help in checking the English and comments. SEM photographs were taken at the Electronic Microscopy Center of the Universidad Complutense, Madrid.

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G. SARMIENTO
Departamento de Paleontología,
Facultad de Geología,
Universidad Complutense
28040 Madrid, España

I. MÉNDEZ-BEDIA, C. ARAMBURU, M. ARBIZU & J. TRUYOLS
Departamento de Geología
Universidad de Oviedo
33005 Oviedo, España