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THE BIOSTRATIGRAPHIC LIMITATIONS OF CONODONTS WITH PARTICULAR REFERENCE TO THE BASE OF THE CARBONIFEROUS.

by

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ABSTRACT

Lower Carboniferous conodonts from Belgium, Britain and Germany are related to the sediments in which they occur. RAMSBOTTOM (1970) showed the distribution of 7 lithofacies in the Lower Carboniferous of South West Britain. British Tournaisian conodonts are related to the lithofacies of RAMSBOTTOM. Conodonts of Lower Carboniferous age from near Tongwynlais, South Wales, are reported. British conodont faunas (dominated by *Spathognathodus* and *Patrognathus*) are typical of the shelf environment, German faunas (dominated by *Siphonodella*) are typical of the bathyal environment and the Belgian faunas contain elements (*Siphonodella* and *Patrognathus*) from both environments. Faunas from the bathyal environment are best for intercontinental correlation. Attention is drawn to the biostratigraphic limitations of conodonts at the base of the Carboniferous and in younger Dinantian sediments.

RESUME

Les conodontes du Carbonifères inférieur de Belgique, de Grande-Bretagne et d'Allemagne sont en relation avec le type

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de sédiment dans lequel ils se présentent. Ceci se vérifie notamment dans les 7 lithofaciès mis en évidence par RAMSBOTTOM (1970) dans le Carbonifère inférieur du Sud-Ouest de Grande-Bretagne.
Des conodontes sont mentionnés dans le Carbonifère inférieur des environs de Tongwynlais, au Sud du Pays de Galles.
Les faunes britanniques (dominées par *Spathognathodus* et *Patrognathus*) sont typiques du shelf. Les faunes allemandes, (dominées par *Siphonodella*) sont typiques du milieu bathyal ; les faunes belges contiennent des éléments (*Siphonodella* et *Patrognathus*) des deux faciès.
Les faunes bathyales sont les meilleurs pour les corrélations internationales.
L'attention est attirée sur les limites d'application biostratigraphique des conodontes à la base du Carbonifère et dans les sédiments dinantiens les plus jeunes.

INTRODUCTION

Successive Congresses of Stratigraphy and Geology have agreed that in the Carboniferous goniatites have priority for zonation. The base of the Carboniferous is recognised by the first appearance of *Gattendorfia subinvoluta*. This goniatite, however, is relatively rare and the I.I.U.G.S. Subcommission on Carboniferous Geology at its last meeting in Krefeld recognised that the first appearance of a conodont, *Siphonodella sulcata* approximates to the base of the Carboniferous.

The upper DEvonian and Lower Carboniferous rocks of Germany contain abundant conodonts and a series of zones have been proposed (BISCHOFF 1957, VOGES 1959 and ZIEGLER 1969, 1971). Conodonts from the Lower Tournaisian rocks of Belgium were listed by BOUCKAERT & ZIEGLER (1965) and AUSTIN et al. (1970a). RHODES et al. (1969) described conodonts from the K Zone of the British Avonian.

Subsequently, other Lower Avonian outcrops have been studied and the results form the basis of this paper.

STRATIGRAPHY AND CORRELATION

In Germany, the Lower Carboniferous (CuI) nodular limestones and intercalated, grey-green shales form the *Gattendorfia*-Kalk. Two goniatite zones are recognised in this limestone, the *subinvoluta* Zone and the succeeding *crassa* Zone (ZIEGLER 1971). The limestones rest on grey-green, calcareous shales, or marls, which form the Hangenberg-Schiefer, the upper part of the Hangenberg-Schiefer has yielded *Balvia prorsum* and the lower part contains *Cymaclymenia euryomphala*. The Hangenberg-Schiefer of latest Devonian age is underlain by nodular limestones of the *Wocklumeria*-Stufe, which contain a variety of species of *Wocklumeria* and other goniatite genera.

The passage beds from the Devonian to the Carboniferous in Belgium comprise the sous-Assise d'Etroeungt (Tn1a) and the sous-Assise d'Hastière (Tn1b). These beds have been described in detail (CONIL et al. 1964, CONIL et al. 1971, LEGRAND et al. 1966). The sous-Assise d'Etroeungt consists of an alternating sequence of limestones and shales, which contain a variety of stromatoporoids, brachiopods and corals. The sous-Assise d'Hastière consists predominately of limestones, which contain trilobites, corals and brachiopods (CONIL et al. 1971). The lowest Carboniferous (Avonian) rocks of South Wales, and the northern part of South-West England are transitional between the Old Red Sandstone below and the massive Mountain Limestone above. KELLAWAY and WELCH (1955) named these deposits the Lower Limestone Group. The Shirehampton Beds at the base consist of sandly limestone and shale with calcareous sandstone and thin red crinoidal limestone interbedded with some sandstone and red and green mudstone. The following Lower Limestone Shale (K Zone) consists of an alternating sequence of limestone and shale which contains a varied assemblage of corals and brachiopods. To the south in Devon and Cornwall the shales, sandstones and limestones contain mainly trilobites, goniatites and brachiopods. The Devonian-Carboniferous boundary in South-West England and in Wales was discussed by AUSTIN et al. (1970b).

The Lower Hastière Limestones (Tn1b) of Belgium, the Lower Avonian (K Zone) rocks of Great Britain and the Lower *Gattendorfia* Limestones (CuI) of Germany are on the evidence of macrofaunas and microfaunas of equivalent age (PAUL 1937, GOLDRING 1958, AUSTIN et al. 1970c, BOUCKAERT et al. 1971, STREEL 1969, UTTING & NEEVES 1970).

DEPOSITIONAL ENVIRONMENTS

The *Gattendorfia* Limestone is a typical "cephalopod limestone" of German authors deposited in the pelagial environment (ZIEGLER 1971, fig.1). It is thought that the "cephalopod limestones" formed under pelagic conditions on submarine rises or swells.

The Lower Carboniferous deposits of Britain and Belgium are typical of the shelf environment deposited under neritic conditions. The Upper Devonian Condroz sandstone of Belgium is a littoral deposit and is succeeded by the Etroeungt Beds (PAPROTH & STREEL 1970). GOLDRING (1962, pp. 82, 83) noted that the sequence in Belgium was similar to that in Britain. "The succession Condroz Sandstone (III - V), Etroeungt or Comblain-au-Pont Beds (VI), Hastière Limestone (Lower Carboniferous I) is very similar to the Pembroke succession Skrinkle Sandstone (VI), Lower Limestone Shale (Lower Carboniferous K, 1), Main Limestone (Lower Carboniferous Z, I) diachronously occurring one stage later".

RAMSBOTTOM (1970 figs. 2, 3) showed the distribution of seven lithofacies in the Lower Carboniferous of South West Britain. These reflect a progressive increase in water depth or distance from land (Text-fig. 1). For the purposes of this paper the bioclastic limestone of RAMSBOTTOM are not subdivided.

THE CONODONT FAUNAS

The distribution of conodonts in the *Wocklumeria* and *Gattendorfia*-Kalk of Germany has recently been revised by ZIEGLER, 1971. The *Wocklumeria* Limestone contains a variety of spathognathodids. Faunas from the upper part of the Hangenberg-Schiefer are dominated by *Protognathodus*. This genus extends into the lower part of the *Gattendorfia*-Kalk, but the characteristic genus of this limestone is *Siphonodella*. *Spathognathodus*, though common, and used as a zonal index in the underlying Devonian is relatively rare in the German Lower Carboniferous standards. The genera *Polygnathus* and *Pseudopolygnathus* are also represented in these Upper Devonian - Lower Carboniferous faunas.

Intensive investigation of the conodont faunas from the Lower Tournaisian rocks of Belgium has taken place in recent years but to date no zonal scheme has been suggested (BOUCKAERT et al. 1971). Lower Tn1a conodonts from Belgium were described by BOUCKAERT and ZIEGLER (1965). The lower part of the Etroeungt is characterised by species of *Spathognathodus* which in Germany are present in the upper part of the *Wocklumeria*-Kalk. The conodonts listed by AUSTIN et al. (1970a) from the upper part of the Etroeungt are also similar to the Upper Devonian faunas of Germany. From Royseux in beds of Tn1bα age (Huy 15, Bed 111) the oldest *Siphonodella* in Belgium was reported. From the same horizon spathognathodids similar to the Upper Devonian forms of Germany have been reported and also the genus *Patrognathus*, which is characteristic of the Lower Avonian rocks in Britain. AUSTIN and RHODES (1970) recorded *Protognathodus kockeli* in the Hastière Limestone at St. Hilaire. The genus *Siphonodella* has also been found in bed 91 of the Huy 2 section. (Royseux).

The oldest conodont zone reported by RHODES et al. (1969) from the Avonian rocks of South-West Britain was the *Patrognathus variabilis* - *Spathognathodus plumulus* assemblage Zone. Its lower limit was not identified, but it was noted that is probably corresponded to the first appearance of *Patrognathus variabilis*. The upper limit coincided with the oldest stratigraphic occurrence of *Polygnathus inornatus inornatus*, *Polygnathus lobatus lobatus* and of the genus *Siphonodella*. Specimens of *Siphonodella* are the advanced species *S. isosticha* and *S. obsoleta*. The zone was present in the lower and middle of the K Zone (samples K1 - k11 in the Avon Gorge and samples KL1 - K1 13 on the North Crop of the South Wales Coalfield). Characteristic species of the zone were *Patrognathus variabilis*, *Spathognathodus plumulus plumulus*, *Pseudopolygnathus vogesi*, *Spathognathodus plumulus shirleyae* and *Clydagnathus gilwernensis*.

A new roadside section near Tongwynlais, Glamorganshire, South Wales, shows a sequence through the non-marine Old Red Sandstone of the Devonian into the marine Lower Carboniferous Avonian rocks. The lower sandy limestones contain few conodonts. *Spathognathodus plumulus* and *Patrognathus variabilis* including forms transitional from *Spathognathodus* have been recovered. The overlying oolites contain *Clydagnathus*, *Spathognathodus* and *Pseudopolygnathus*. In the lower bioclastic limestones which follow, *Spathognathodus* and *Pseudopolygnathus* predominate with a few *Polygnathus*. In the upper bioclastic limestones polygnathids are very abundant and also forms which are similar to early *Siponodella*. The genera *Spathognathodus* and *Patrognathus* are not abundant. The intervening shales which occur in the section have not yet been investigated. The base of the *Siphonodella - Polygnathus inornatus* Asemblage Zone at Tongwynlais occurs in the upper part of the bioclastic limestone sequence. The base of this zone in other parts of South Wales and in the Avon Gorge also occurs in bioclastic limestones. Therefore the first appearance of abundant polygnathids and of the genus *Siphonodella* has stratigraphic value in the local basin, although this first appearance is a reflection of new environmental conditions.

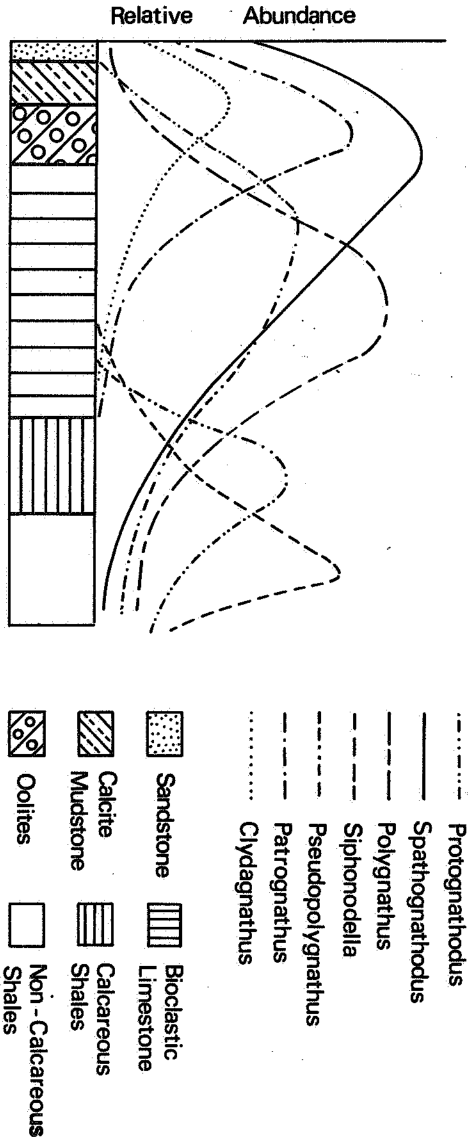
ENVIRONMENTAL INTERPRETATIONS OF CONODONT FAUNAS

ZIEGLER (1971) has indicated that the German faunas have been recovered from rocks formed when bathyal conditions predominated. In the Hangenberg-Kalk the genera *Siphonodella* and *Protognathodus* dominate the faunas. These are herein equated with the calcareous Shale and Non-Calcareous Shale lithofacies of RAMSBOTTOM (1970).

The genera *Clydagnathus* and *Patrognathus* and species of the genus *Spathognathodus* characteristic of the Lower Avonian rocks in Britain have not to date been found in the Lower Carboniferous rocks of Germany. Their absence is interpreted as a reflection of the different depositional environments.

The faunas from the Lower sous-Assise d'Hastière of Belgium are herein equated with the Bioclastic Limestone and Calcareous Shale lithofacies of RAMSBOTTOM. It is interesting to note that in the Huy 15 section (AUSTIN et al. 1970a), the first appearance of *Siphonodella* represents a facies change in the Hastière Limestone. This level also contains a British component *Patrognathus variabilis* and a German component the *Spathognathus costatus* group sensu ZIEGLER.

In Britain, the Avon Gorge, North Crop of the South Wales Coalfield and Tongwynlais exposures show a marine transgression from continental Old Red Sandstone facies into the marine Lower Carboniferous. In these regions the Sandstone,

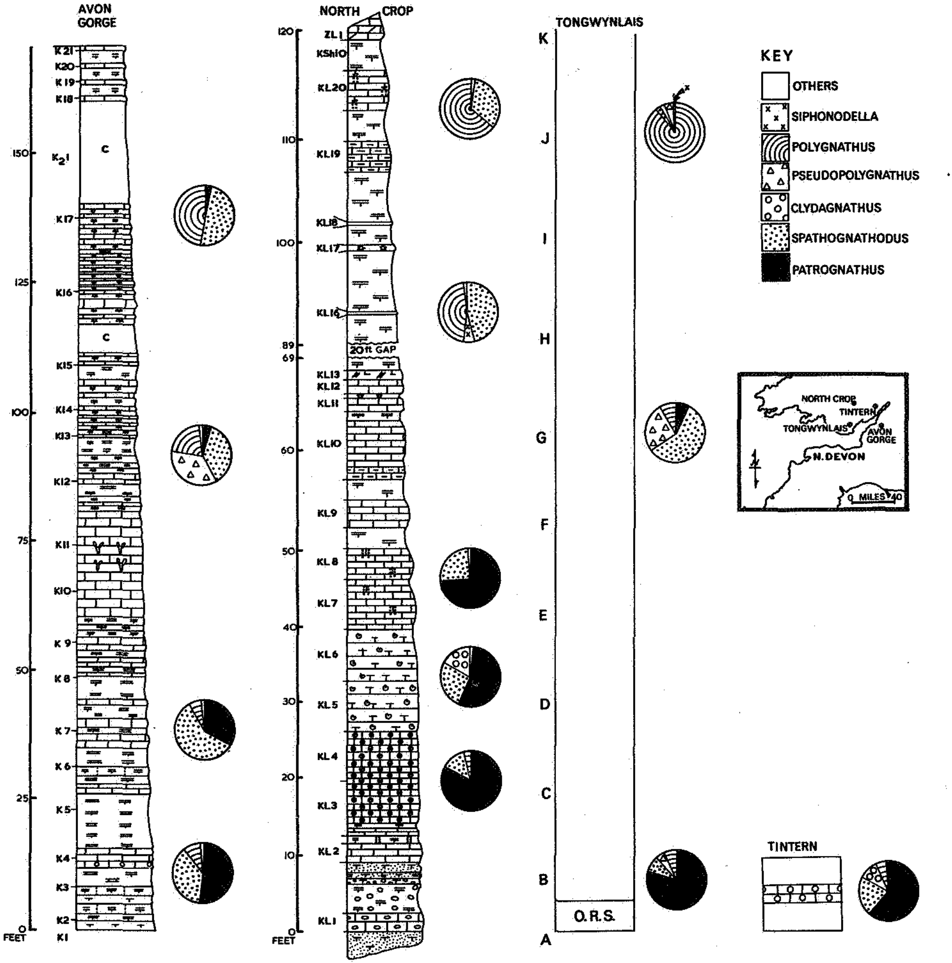


Text-fig. 1. Diagrammatic relationship of lithofacies (RAMSBOTTOM 1970) and principal conodont genera in the Lower Carboniferous.

Calcite Mudstone, Oolite, Bioclastic Limestone and Calcareous Shale lithofacies of RAMSBOTTOM (1970) are recognised. These lithofacies contain characteristic conodont genera (text.-fig.1). In the Sandstone lithofacies spathognathodids and patrognathids are the dominant elements. *Clydagnathus* is also present, but the genera *Polygnathus* and *Pseudopolygnathus* are rare. In the Calcite Mudstone lithofacies conodonts are rare, but the genera which are found in the Sandstone lithofacies also occur. The genera *Spathognathodus*, *Patrognathus* and *Clydagnathus* are most common in the Oolite lithofacies. *Clydagnathus* has its maximum abundance here. Polygnathids and pseudopolygnathids are again present, but rare. In the Bioclastic Limestones *Pseudopolygnathus* and *Spathognathodus* are abundant. *Polygnathus* and *Patrognathus* are less abundant, but *Polygnathus* increases in abundance in the Dark-thin bedded Bioclastic Limestones. In the Calcareous Shale the genera *Siphonodella* and *Polygnathus* predominate with a few spathognathodids and pseudopolygnathids (text.-fig.2).

From the Upper Devonian rocks of North America, BEINERT et al. (1971) have described a new species of ? *Clydagnathus*. KLAPPER (1971) has documented the occurrence of the genus *Patrognathus* in North America. There is evidence in these publications that the distribution of conodont species characteristic of the British Avonian in North America is related to environments similar to those found in the British Avonian.

The environmental interpretation of conodont genera outlined above is summarised in Text-fig. 1 which is strictly diagrammatic. It will be possible with more detailed numerical research to subdivide the genera into assemblages of species which reflect further environmental and/or ecological differences. It can be suggested, for example, that within the genus *Pseudopolygnathus*, the species



Text.-fig. 2. Numerical abundance of conodont genera from K Zone horizons at the Avon Gorge, the North Crop, Tintern and Tongwynlais. Lithological details of the new Tongwynlais section will be published later by Gayer, Allen, Bassett and Edwards (1973). The Tintern fauna will be published by AUSTIN and HILL (*Geologica & Palaeontologica* in preparation). Details of the Avon Gorge and North Crop succession after RHODES et al. (1969).

P. triangulus triangulus and *P. triangulus inaequalis* are characteristic of the Calcareous Shale lithofacies. *P. dentilineatus* is characteristic of the Dark-thin bedded Bioclastic Limestones and *P. vogesi* is characteristic of the Pale-thick bedded Bioclastic Limestones.

Attention is drawn to one other feature of the chart. The genus *Spathognathodus* is shown as having its maximum abundance in the shallower water environments. This is the situation in the Lower Carboniferous. In Germany the genus is relatively rare and unimportant, although it is abundant and important in other areas notably Belgium and Britain. However, the Upper Devonian *Wocklumeria*-Kalk formed in a similar environment to the *Gattendorfia*-Kalk, is characterised by abundant specimens of the genus. The lithofacies characterised by abundant *Spathognathodus* appears to have changed strikingly in the relatively short period of time from the Upper Devonian to the Lower Carboniferous.

SUMMARY

a. The German sequence of Carboniferous conodont faunas with *Siphonodella* and *Protognathodus* indicative of the bathyal (oceanic) environment are best for intercontinental correlation (Text.-fig.3).

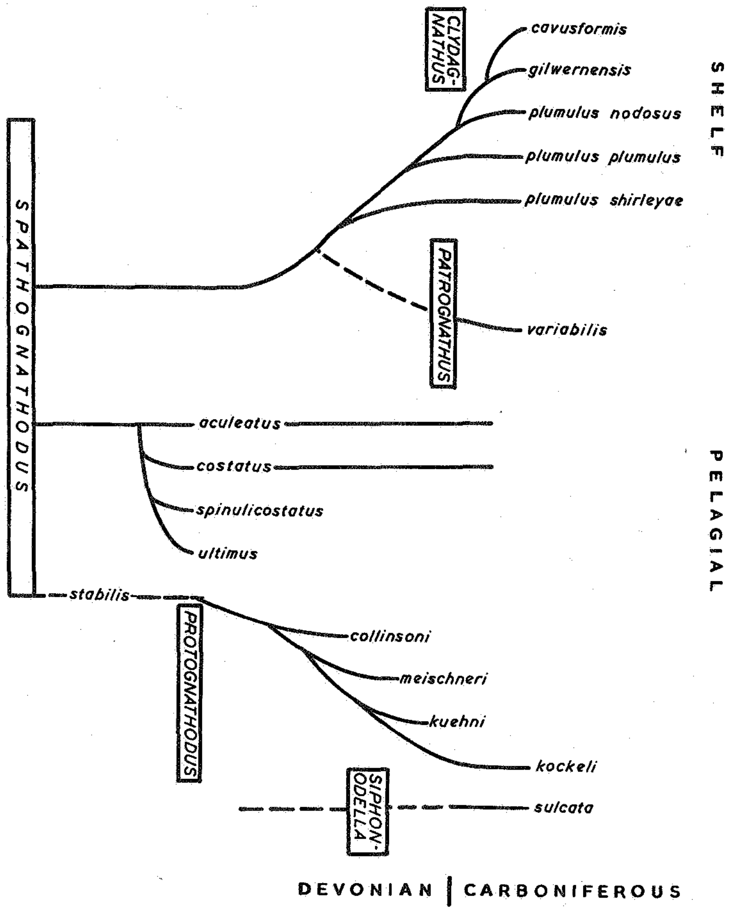
b. Faunas from the shelf environment contain only rare specimens of *Siphonodella*. It is possible to recognise two different types of conodont communities, or biofacies, in the shelf environment. A shallow, shelf environment typified by the British faunas and a deeper shelf environment illustrated by the Belgian faunas. These faunas are widespread in their occurrence and can be recognised in other shelf environments, for example parts of North America (KLAPEER 1971, BEINERT et al. 1971) and in Australia (DRUCE 1969).

c. The Belgian deeper shelf community contains the British component *Patrognathus* and the German elements *Spathognathodus costatus* sensu ZIEGLER, *Siphonodella* and *Protognathodus*.

d. A deepening of the shelf is indicated by the lithologies of the rocks in Britain (RAMSBOTTOM 1970) and in Belgium (GOLDRING 1962). This is also reflected in the conodont faunas, by the first appearance of the genus *Siphonodella* (represented by advanced species) and by the lower limit of abundant polygnathids. *S. costatus* sensu ZIEGLER, which is typical of the pelagial environment migrates into the shelf environment of Britain with the deepening of the shelf. Ancestors of this species make their first appearance in Britain in the upper part of the K Zone (RHODES et al. 1969).

e. Therefore, the base of the Carboniferous is adequately defined by the first appearance of *S. sulcata* only in those areas which have bathyal facies. Carbonate shelf areas must have alternative conodont zonations. Every effort must be made to relate these alternative conodont zonations to the German standard in order that the stratigraphy and correlation of shelf areas can be refined (text.-fig.3).

f. The biostratigraphic limitations of conodonts outlined above have particular reference to the base of the Carboniferous. Attention is, however, drawn to similar limitations in younger Dinantian sediments. The Avonian Z, C, S and D, rocks of Britain are characterised by the rare occurrence of the genus *Gnathodus* and by an abundance of *Pseudopolygnathus* and *Polygnathus* in the Lower Avonian and by an abundance of *Cavusgnathus*, *Taphrognathus* and *Mestognathus* in the Upper Avonian. The genera *Cavusgnathus*, *Taphrognathus* and *Mestognathus* are rare in the Upper Dinantian rocks of Germany, but the genus *Gnathodus* is common and abundant. The conodont zonation of North American Mississippian rocks, revised by COLLINSON et al. (1971) includes elements indicative of



Text.-fig. 3. Distribution of diagnostic conodont species of Upper Devonian and Lower Carboniferous age from the shelf and pelagial environments.

the bathyal facies (*Siphonodella* and *Protognathodus*) and of the shelf facies (*Apatognathus*, *Cavusgnathus* and *Taphrognathus*).

g. Caution is needed with conodont zones applied elsewhere in the stratigraphical column. These zones are often of no more than local significance as they are related to local environmental conditions. More attention must be paid to conodont ecology. A model of conodont ecology, in which different species are segregated by vertical stratification was advanced by SEDDON and SWEET (1971). A different model of laterally segregated conodont communities, from littoral to bathyal environments was proposed by BARNES et al. (1972), although some degree of vertical segregation was accepted. With the Carboniferous conodonts under consideration, shallow water forms (*Clydagnathus* and *Patrognathus*) do not extend into the bathyal facies as one might expect with the model of SEDDON and SWEET (1971).
Likewise, *Siphonodella* and *Protognathodus* are confined to the deeper water facies (Text.-fig. 1). Hence, the distribution of these Carboniferous conodonts favours a model of laterally segregated communitites in which vertical stratification is only one factor.

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-Feluy, Huy and St-Hilaire specimens, Université de Louvain, Inst. de Géologie et de Géographie, Dépt. Paléont., 1348 Louvain-la-Neuve. Belgium.

-Tongwynlais specimens, Department of Geology, National Museum of Wales, Cardiff. ENGLAND.

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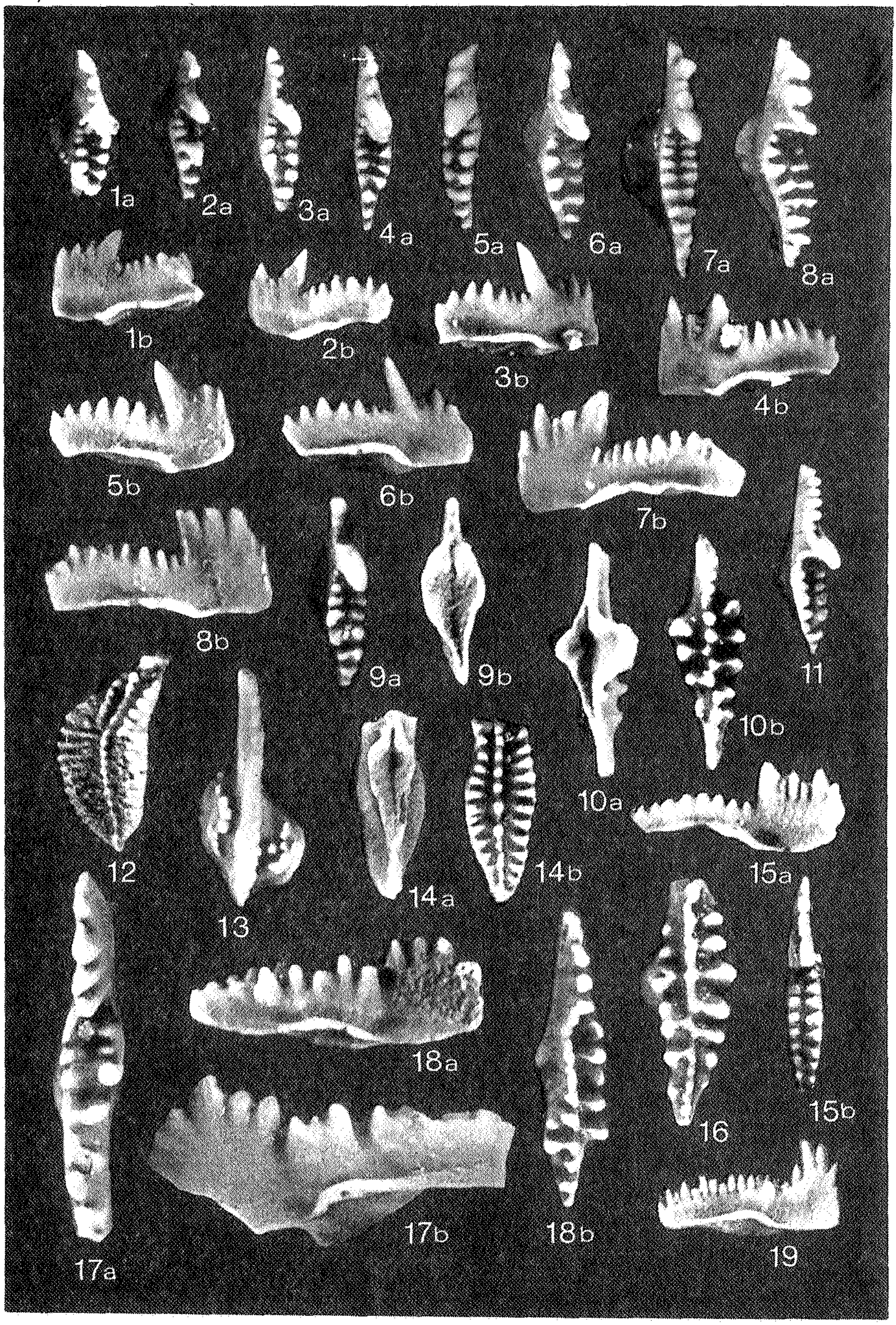
PLATE 1

(25)

	Patrognathus variabilis RHODES, AUSTIN & DRUCE
Figs. 1a, b.	1a. Oral view 1b. Lateral view. Specimen Feluy 932/21/41.
	Patrognathus variabilis RHODES, AUSTIN & DRUCE
Figs. 2a, b.	2a. Oral view 2b. Lateral view. Specimen Feluy 932/21/40.
	Patrognathus variabilis RHODES, AUSTIN & DRUCE
Figs. 3a, b.	3a. Oral view 3b. Lateral view. Specimen Feluy 83/33.
	Patrognathus variabilis RHODES, AUSTIN & DRUCE
Figs. 4a, b.	4a. Oral view 4b. Lateral view. Specimen Feluy 83/37.
	Patrognathus variabilis RHODES, AUSTIN & DRUCE
Figs. 5a, b.	5a. Oral view 5b. Lateral view. Specimen Feluy 932/21/42.
	Patrognathus variabilis RHODES, AUSTIN & DRUCE
Figs. 6a, b.	6a. Oral view 6b. Lateral view. Specimen Feluy 83/34.
	Patrognathus variabilis RHODES, AUSTIN & DRUCE
Figs. 7a, b.	7a. Oral view 7b. Lateral view. Specimen Feluy 83/31.
	Patrognathus variabilis RHODES, AUSTIN & DRUCE
Figs. 8a, b.	8a. Oral view 8b. Lateral view. Specimen Feluy 83/58.
	Patrognathus variabilis RHODES, AUSTIN & DRUCE
Figs. 9a, b.	9a. Oral view 9b. Aboral view Specimen Huy 15/111/41.
	Pseudopolygnathus dentilineatus E.R.BRANSON
Figs. 10a, b.	10a. Aboral view 10b. Oral view Specimen Tongwynlais x/38.
	Patrognathus variabilis RHODES, AUSTIN & DRUCE
Fig. 11.	Oral view. Specimen Huy 15/111/86.
	Siphonodella sp.
Fig. 12.	Oral view. Specimen Huy 15/111/87.
	Patrognathodus kockeli (BISCHOFF)
Fig. 13.	Oral view. Specimen St. Hilaire 16/1.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?Siphonodella sp.nov.

Figs.14a, b. 14a. Aboral view 14b. Oral view
Specimen Tongwynlais x/65.

Patrognathus variabilis RHODES, AUSTIN & DRUCE

Figs.15a, b. 15a. Lateral view 15b. Oral view
Specimen Tongwynlais x/37.

Pseudopolygnathus vogesi RHODES, AUSTIN & DRUCE

Fig. 16. Oral view.
Specimen Tongwynlais J/37.

Spathognathodus costatus costatus (E.R.BRANSON)

Figs.17a, b. 17a. Oral view 17b. Lateral view.
Specimen Feluy 83/56.

Spathognathodus costatus sulciferus (BRANSON & MEHL)

Figs.18a, b. 18a. Lateral view 18b. Oral view.
Specimen Feluy 83/32.

Spathognathodus plumulus shirleyae RHODES, AUSTIN & DRUCE

Fig. 19. Lateral view.
Specimen Tongwynlais G/65.

PLATE 2

(x 25)

Polygnathus symmetricus E.R.BRANSON

Figs. 1a, b. 1a. Oral view. 1b. Aboral view.
Specimen Tongwynlais J/40.

? Siphonodella sp.

Figs. 2a, b. 2a. Aboral view. 2b. Oral view.
Specimen Tongwynlais X/42.

Spathognathodus plumulus plumulus RHODES, AUSTIN & DRUCE

Fig. 3. Oral view.
Specimen Tongwynlais G/66.

? Siphonodella sp.nov.

Figs. 4a, b. 4a. Oral view. 4b. Aboral view
Specimen Tongwynlais X/39.

? Siphonodella sp.nov.

Figs. 5a, b. 5a. Aboral view. 5b. Oral view.
Specimen Tongwynlais X/63.

Siphonodella ? sulcata

Figs. 6a, b. 6a. Aboral view. 6b. Oral view.
Specimen Tongwynlais X/68.

? Siphonodella sp.nov.

Figs. 7a, b. 7a. Aboral view. 7b. Oral view.
Specimen Tongwynlais X/67.

Polygnathus symmetricus E.R.BRANSON

Figs. 8a, b. 8a. Oral view. 8b. Aboral view.
Specimen Tongwynlais X/43.

Polygnathus symmetricus E.R.BRANSON

Fig. 9. Oral view.
Specimen Tongwynlais J/40.

? Siphonodella sp.nov.

Figs.10a, b. 10a. Oral view. 10b. Aboral view.
Specimen Tongwynlais X/64.

Clydagnathus cavusformis RHODES, AUSTIN & DRUCE

Fig. 11. Oral view.
Specimen Tongwynlais 1/58.

Polygnathus symmetricus E.R.BRANSON

Figs.12a, b. 12a. Aboral view. 12b. Oral view.
Specimen Tongwynlais X/65.

Pseudopolygnathus vogesi RHODES, AUSTIN & DRUCE

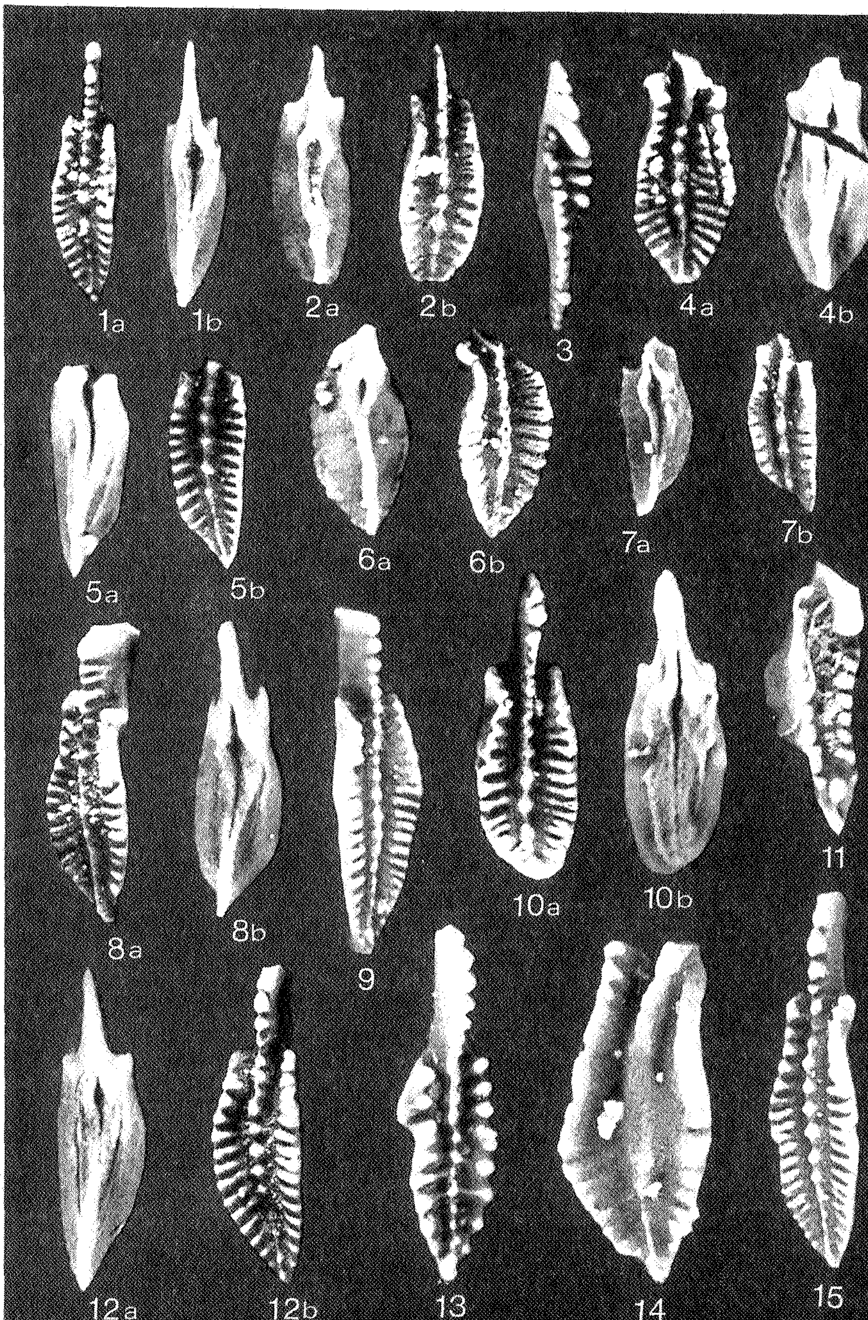
Fig. 13. Oral view.
Specimen Tongwynlais J/39.

Polygnathus inornatus rostratus RHODES, AUSTIN & DRUCE

Fig. 14. Oral view.
Specimen Tongwynlais G/60.

Polygnathus symmetricus E.R.BRANSON.

Fig. 15. Oral view.
Specimen Tongwynlais J/38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