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Conodont Biofacies Analysis of the Devonian/Carboniferous Boundary Beds in the Carnic Alps

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With 9 Figures and 2 Tables

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Italien
Karnische Alpen
Devon/Karbon-Grenze
Conodonten
Biofazies

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Analyse der Conodonten-Biofazies an der Devon/Karbon-Grenze in den Karnischen Alpen

Zusammenfassung

Die Arbeit präsentiert die Ergebnisse der Conodonten-Biofazies-Analyse an der Devon/Karbon-Grenze der Profile „Grüne Schneid" und „Kronhofgraben" der Zentralen Karnischen Alpen in Österreich. Die Analysen wurden an 15 Conodonten-Proben des Profils „Grüne Schneid" durchgeführt, mit einer Summe von 16.846 einzelnen Conodonten-Elementen mit einer durchschnittlichen Identifikationsrate von 52 %, und an 8 Proben vom Profil „Kronhofgraben" mit 14.345 Conodonten-Elementen und ca. 60 % identifizierter Taxa.

In beiden Abschnitten ist die ältere Schicht der *S. praesulcata*-Zone durch die palmatolepid-bispathodide (branmehlide) Biofazies charakterisiert. Die unterkarbonen Teile beider Abschnitte, d.h. die Aquivalente des untersten Tournai, repräsentieren die polygnathide Biofazies (durchschnittlich über 85 %) und zeigen erstaunliche Ähnlichkeiten in ihrer Biofazies-Evolution. Trotzdem, der Anteil der Vertreter von *Pseudopolygnathus* und *Siphonodella* ist im Profil „Kronhofgraben" weit höher; dies deutet auf eine tiefere Position hin. Einen noch größeren Unterschied zwischen beiden Abschnitten stellt das Vorkommen einer starken *Protognathodus*-Population bei der Grünen Schneid dar. Dies ist auf die Tatsache zurückzuführen, daß zur selben Zeit Schiefer (i.e. die Äquivalente der Hangenberg-Schiefer) im Kronhofgraben abgelagert wurden.

Der interessanteste Wechsel in der Biofazies findet unter der *S. praesulcata/S. sulcata*-Grenze des Abschnittes Grüne Schneid statt, i.e. zwischen den Proben 6A and 6B. Einem plötzlichen Abfall von *Palmatolepis, Pseudopolygnathus* und *Branmehla* steht ein auffallender Anstieg von *Polygnathus* und *Protognathodus* gegenüber; dies weist auf ein eustatisches Absinken des Meeresspiegels hin, wie es in vielen anderen Abschnitten kurz vor der D/C-Grenze beobachtet werden kann.

Abstract

This paper presents the results of a conodont-based biofacies analysis of the Devonian/Carboniferous boundary sections at Grüne Schneid and Kronhofgraben, Central Carnic Alps, Austria. This analysis is based on countings from 15 conodont samples from the Grüne Schneid section totalling 16.846 single conodont elements, with an average identification level of 52 %, and 8 samples from the Kronhofgraben section totalling 14.345 conodont elements, with some 60 % identified taxa.

In both sections the older part of the *S. praesulcata* Zone is characterized by a palmatolepid-bispathodid (branmehlid) biofacies. The Lower Carboniferous parts of both sections, i.e. the equivalents of the early Tournaisian Stage, are represented by a

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polygnathid biofacies (average over 85 %) and shows remarkable similarity in their biofacies evolution. There is, however, a slightly higher frequency of representatives of *Pseudopolygnathus* and of *Siphonodella* in the Kronhofgraben section when compared with the Grüne Schneid section. This suggests a slightly deeper setting of the former. An even more striking difference between both sections is the occurrence of an important *Protognathodus* population at Grüne Schneid resulting from the fact that during the same time interval, shales (i.e. the equivalents of the Hangenberg Shale) were deposited at Kronhofgraben.

The most interesting change in conodont biofacies occurs below the *S. praesulcata/S. sulcata* zonal boundary at Grüne Schneid, i.e., between samples 6A and 6B. The sudden decrease of *Palmatolepis, Pseudopolygnathus* and *Branmehla* contrasts with a striking increase of *Polygnathus* and *Protognathodus*, suggesting an eustatic sea-level drop as observed in many other sections just before the D/C boundary.

1. Introduction

The conclusions drawn in this report are based on countings of conodonts derived from limestone samples of the sections Grüne Schneid and Kronhofgraben, Carnic Alps, Southern Austria. Both sections have been extensively studied during the past years (SCHÖNLAUB, 1969; SCHÖNLAUB et al., 1988, 1991; HAHN & KRATZ, 1991). For details of the succession we refer to the former papers. All identifiable platform and ramiform conodont elements, including the broken ones were counted. The biofacies analysis is based on the platform conodont elements only. Although the absolute numbers are not so important the relative frequencies are even more relevant. The weight of the totally dissolved rock sample varies from 2.5 kg to more than 11 kg depending on the importance to recover diagnostic conodonts for individual levels, e.g., the Devonian/Carboniferous boundary. This level is defined by the first occurrence of *Siphonodella sulcata* (HUDDLE) and its coincidence with lower limits of the Dinantian, Tournaisian, Mississippian and other chronostratigraphic units (G. FLAJS et al., 1988 eds.).

In addition to the study by SCHÖNLAUB et al. (1988) of the Grüne Schneid section, a few comments with respect to the identified platform conodont species are listed below:

1) The last representatives of the late Upper Devonian genera *Palmatolepis* and *Branmehla* may occur as high as sample GS 6 C, as there were found 1 broken specimen of *Palmatolepis gracilis* and 3 specimens of *Branmehla suprema*.
2) Most of the "siphonodellids" of sample GS 3 B are doubtful and may rather belong to the yet poorly known group of *Polygnathus mehli*.

Fig. 1.
Grüne Schneid section, Central Carnic Alps, Austria.
The boundary between the Devonian and the Carboniferous lies within the 32 cm thick bed no. 6, and more precisely between samples 6C and 6D.

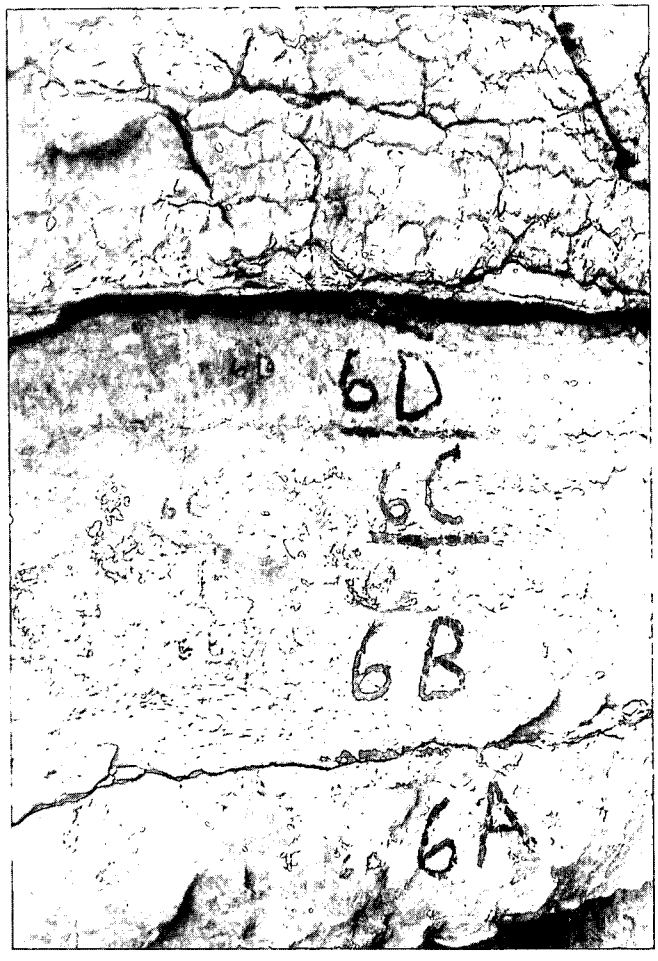

Fig. 2.
Grüne Schneid section: detail of Fig. 1 near the D/C boundary.
Note uniform cephalopod limestone development across the boundary, i.e., between samples 6C and 6D.

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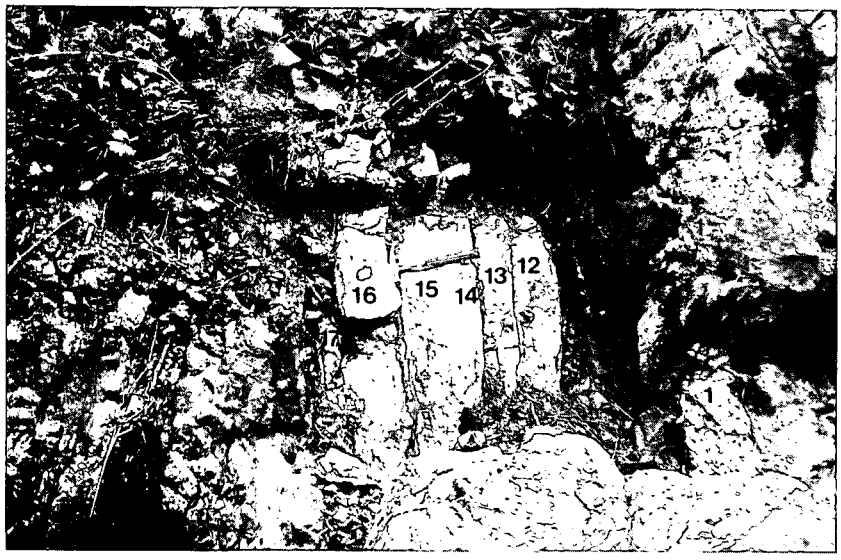

Fig. 3.
Kronhofgraben section.
The vertically dipping section displays, from the right to the left: cephalopod bearing limestones of the Upper Devonian *praesulcata* Zone (sample K1), followed by a 50 cm thick shale horizon (the equivalent of the Hangenberg Shale), and 6 limestone beds (no.12 named K12: 15 cm, K13: 13 cm, K14: 4 cm, K15: 24 cm, K16: 17 to 20 cm, K17: 5 to 7 cm). This continuous limestone succession is overlain by black radiolarian cherts (left part of the photo), in the lower part of which two small limestone lenses are intercalated (sample K19).

3) *Siphonodella sulcata* is probably present in samples GS 1, GS 2, GS 5 B and GS 5 C (the majority are broken specimens).
4) Within sample GS 3 B, a fragmentary siphonodellid showed a rather evolved anterior platform part, suggesting the presence of *Siphonodella duplicata* Morphotype 2.
5) The occurrence of the different stratigraphically important species of *Protognathodus* all together at the same stratigraphic level (for example in sample GS 4 B2) possibly points to a slight condensation within this bed.

2. Conodont Biofacies concept and Ecostratigraphy

The basis concept of lateral (coeval) conodont biofacies related to linear belts of regional paleotectonic settings which parallel the paleo-coastline, has been proposed by SANDBERG (1976) for the Lower expansa (formerly Upper *styriacus*, late Upper Devonian) Zone in the western U.S.

Each individual biofacies was named for the one or two most abundant platform conodont genera, representing at least 70 % of the population.

The original biofacies concept included five biofacies only and was applied to a single zone in the U.S. It was expanded to include a total of nine distinct biofacies and modelled through several zones in Belgium by SANDBERG & DREESEN (1984). The latter was based on a preliminary application of SANDBERG's 1976 model by DREESEN & THOREZ (1980) to the late Upper Devonian (Famennian) regressive megasequence (Psammites du Condroz) South of the London-Brabant Massif.

Recently, SANDBERG et al. (1988) added two extra biofacies which brings the total number of worldwide Late Devonian conodont facies to eleven:

Each of the outer four paleotectonic belts contains a single conodont biofacies:

I) **Palmatolepid** or **palmatolepid-bispathodid** (continental rise and lower slope).
II) **Palmatolepid-polygnathid** (middle and upper slope or outer shelf).
III) **Polygnathid-icriodid** (outer to middle shelf).
IV) **Polygnathid-pelekysgnathid** (inner shelf; tidal flats; shallow subtidal).

The inner or fifth belt contains five distinct conodont biofacies typical of varying conditions in restricted marine peritidal settings:

V) **Clydagnathid.**
VI) **Scaphignathid.**
VII) **Patrognathid.**
VIII) **Pandorinellid.**
IX) **Antognathid.**

A tenth nearshore inner-belt polygnathid biofacies (already mentioned by SANDBERG & POOLE in 1971) was formerly added by SANDBERG et al. (1988) to represent a distinct biofacies of the inner carbonate platform.

Finally, a polygnathid-ancyrodellid biofacies was introduced by SANDBERG & DREESEN (1987) to represent a special niche characterizing the seaward flanks of Frasnian reefs and mud mounds in the Frasnian of Belgium.

Similarly, SANDBERG & GUTSCHICK (1984) suggested a biofacies model for Lower Carboniferous conodont distribution from deep basin to shoreline in the *Scaliognathus anchoralis* Zone.

Already in the mid-1970's facies control was the accepted explanation for the poor correlation between the Dinantian faunas of the British Isles (carbonate platform) and those of the US and West Germany (basinal facies (AUSTIN, 1974, 1976).

A clear distinction had been recognized in the Tournaisian Series between conodonts from shelf environments characterized by *Clydagnathus* and *Patrognathus* and those from basin environments with *Siphonodella* and *Protognathodus*. A similar distinction between conodont faunas of shelf and basin was demonstrated in later Dinantian horizons by AUSTIN (1976), who described a shelf facies characterized by *Cavusgnathus, Mestognathus* and *Taphrognathus* whereas the deeper-water facies were characterized by species of *Gnathodus*. AUSTIN & DAVIES (1984) indicated that the facies control of conodonts during the Dinantian can also be demonstrated by comparing faunas from rocks deposited in similar facies but different age.

The same authors outlined the relationship between sediment types and conodont genera and went on to

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Table 1.
Grüne Schneid section. Data sheet summarizing countings of conodonts from the beds shown on Fig. 1.
Abbreviations: Sip = *Siphonodella*; Bis = *Bispathodus*; Bra = *Branmehla*; Pse = *Pseudopolygnathus*; Pro = *Protognathodus*; Pol = *Polygnathus*; Palma = *Palmatolepis*, D/C = Devonian/Carboniferous boundary.

GRÜNE SCHNEID SECTION															
	GS 1	GS 2	GS 3a	GS 3b	GS 4	GS 5c	GS 5b	GS 5a	GS 6d2	GS 6d1	GS 6c	GS 6b2	GS 6b1	GS 6a	GS 7
Sip	1	4	1	0,5	0,5	0,8	2,3	1,1	0,5	1	0	0	0	0	1
Bis	0,5	2	2	2,5	6,5	4,8	5,1	3,3	7	5,9	6,4	3,4	6,2	7,5	20
Bra	0	0	0	0	0	0	0	0	0	0	0,5	0	12	29,2	29
Pse	4	6	5	6	6	11,8	8	6	0,8	0,5	0	0	3,5	18,6	11
Pro	5	10	0	0	0	0	0,8	15,2	3,6	8	20	58,1	37,3	0	0
Pol	89,5	78	92	91	87	82,6	83,8	74,3	88	84,5	73	38,1	32	3	0
Palma	0	0	0	0	0	0	0	0	0	0	0,1	0	8,9	41,7	39
	GS 1	GS 2	GS 3a	GS 3b	GS 4	GS 5c	GS 5b	GS 5a	GS 6d2	GS 6d1	GS 6c	GS 6b2	GS 6b1	GS 6a	GS 7
Total counts	339	379	384	282	817	2584	1382	1671	975	2350	2967	486	840	1017	373
	GS 1	GS 2	GS 3a	GS 3b	GS 4	GS 5c	GS 5b	GS 5a	GS 6d2	GS 6d1	GS 6c	GS 6b2	GS 6b1	GS 6a	GS 7
% ident.taxa	67	65	63	69	58	55,7	54	43,1	39,3	42,7	42,2	30,5	26,8	71	60,2
	GS 1	GS 2	GS 3a	GS 3b	GS 4	GS 5c	GS 5b	GS 5a	GS 6d2	GS 6d1	GS 6c	GS 6b2	GS 6b1	GS 6a	GS 7
weight in gr.	2500	3000	3000	3000	7542	11738	8487	11610	3240	6410	8500	3170	6300	2500	2500

D/C

apply knowledge of environments of deposition of modern sediments to conodont distribution patterns.

In the SANDBERG & GUTSCHICK model for the late Tournaisian, seven distinct conodont biofacies were recognized (from offshore to inshore):

I) **Bispathodid** (starved basin).
II) **Scaliognathid-doliognathid** (starved basin and lower slope).
III) **Gnathodid-pseudopolygnathid** (foreslope).
IV) **Eotaphrid** (shelfedge).
V) **Hindeodellid** (outer platform).
VI) **Pandorinellid** (inner platform)
VII) Mestognathid (tidal lagoon and sabkha).

Although this biofacies model can be applied to British and Belgian Dinantian conodont faunas, the model does not extend across the carbonate platform. It might be possible that additional, shallow-platform, protected shelf and restricted marine biofacies will be added to the SANDBERG & GUTSCHICK model in future (DREESEN et al., 1986).

A formal biofacies model for the Devonian/Carboniferous boundary beds is not yet available. Obviously, it should contain elements from both the "standard" Late Devonian and Lower Carboniferous biofacies models.

With the exception of ecologically extreme niches such as: basin or deeper subtidal (dominated by either *Palmatolepis, Siphonodella* or *Gnathodus*) and intertidal or supratidal facies with higher energy and/or salinities (high frequency of *Patrognathus*), the facies control of platform conodont genera at the Devonian-Carboniferous transition is rather difficult to assess. Especially the distribution pattern and biofacies affinities of *Pseudopolygnathus* and *Protognathodus* are less clear and require further investigation.

Species such as *Polygnathus communis* and *Bispathodus stabilis* are common in most marine environments: both are thought to have inhabited the nearsurface layers of the sea, perhaps near the wave-base (AUSTIN & DAVIES, 1984; SANDBERG & GUTSCHICK, 1979).

The common presence of *Polygnathus communis* and absence of *Pseudopolygnathus* suggested that the former might have lived in the upper water layers and the latter in slightly deeper water (AUSTIN & DAVIES, 1984). Moreover, pseudopolygnathids such as *P. dentilineatus* apparently lived at somewhat greater depths than *Bispathodus aculeatus, B. stabilis* and *Pol. communis*, and hence in less agitated waters than its common associates.

In order to obtain the total percentage of *Bispathodus* for recognizing the palmatolepid-bispathodid biofacies in some faunas, morphologically similar platform genera such as *Branmehla* and *Mehlina* are counted with *Bis-*

KRONHOFGRABEN SECTION								
	K 19	K 17	K 16	K 15	K14	K 13	K 12	K1
Sip	97,3	4	8,5	0,8	1,9	2,5	2,5	0
Bis	0	0	0	0	0,2	0,9	2,9	6,3
Bra	0	0	0	0	0	0	0	54
Pse	0,8	10,6	12,2	9,9	8,9	3,2	0,3	13,3
Pro	0	0,6	1,4	0,4	1,9	2	6,8	0
Pol	1,9	84,7	77,9	88,9	87,1	91,4	87,5	1,9
Pal	0	0	0	0	0	0	0	24,5
	K 19	K 17	K 16	K 15	K14	K 13	K 12	K1
total counts	4622	874	1693	1049	2234	738	490	2645
	K 19	K 17	K 16	K 15	K14	K 13	K 12	K1
ident.taxa%	100	45	70,1	46,5	53,5	58	57	46
	K 19	K 17	K 16	K 15	K14	K 13	K 12	K1
weight dissolv.	3264	3875	3125	3465	1845	2946	24530	3000

D/C

Table 2.
Kronhofgraben section. Data sheet summarizing conodont countings.
Abbreviations as in Table 1.

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pathodus (ZIEGLER & SANDBERG, 1984). The *Bispathodus* group (sensu lato) occurs abundantly in pelagic, far offshore settings, but it is equally common in most nearshore settings. This group is interpreted to have lived in the euphotic zone in the highest part of the water column. It occurs widely, independent of bottom conditions, in all but the most nearshore, restricted biofacies.

Characteristic of the Devonian/Carboniferous boundary beds is the appearance of protognathodids: a distinct protognathodid biofacies (ZIEGLER, 1969; ZIEGLER & LEUTERITZ, 1969) interrupts worldwide, in a short stratigraphic interval, the pelagic siphonodellid or ecologically equivalent palmatolepid-bispathoid biofacies. This has been related to a brief eustatic fall in sea level just before the end of the Devonian (ZIEGLER & SANDBERG, 1984). Ecological and sedimentological arguments favour the idea of considering *Protognathodus* as the dweller of more nearshore environments or as a "shallow-water intruder".

3. Comments on the Comparative Biofacies Analysis of the Grüne Schneid (GS) and Kronhofgraben (K) Sections

(Tabs. 1,2; Figs. 4–9)

Except for slight differences in the frequencies of *Siphonodella*, there is a remarkable similarity in biofacies evolution during the oldest part of the Carboniferous (*S. sulcata* and *duplicata* Zones): in both sections we are dealing with a polygnathid biofacies (average over 85 %). In the "rest", we observe a slightly higher frequency of *Pseudopolygnathus* and of *Siphonodella* in the Kronhofgraben section as compared to the Grüne Schneid section.

A striking difference between both sections during the *S. sulcata* Zone is the occurrence of an important *Protognathodus* population in Grüne Schneid at the top of the Zone (almost 30 %). This difference obviously results from the fact that we had a deposition of shale

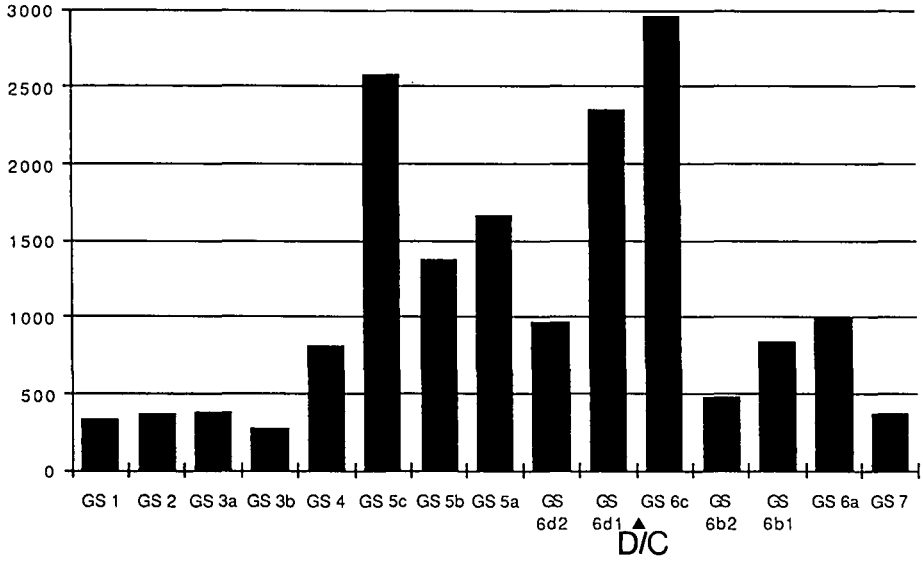

Fig. 4.
Grüne Schneid section. Total counts.
D/C = Devonian/Carboniferous boundary.

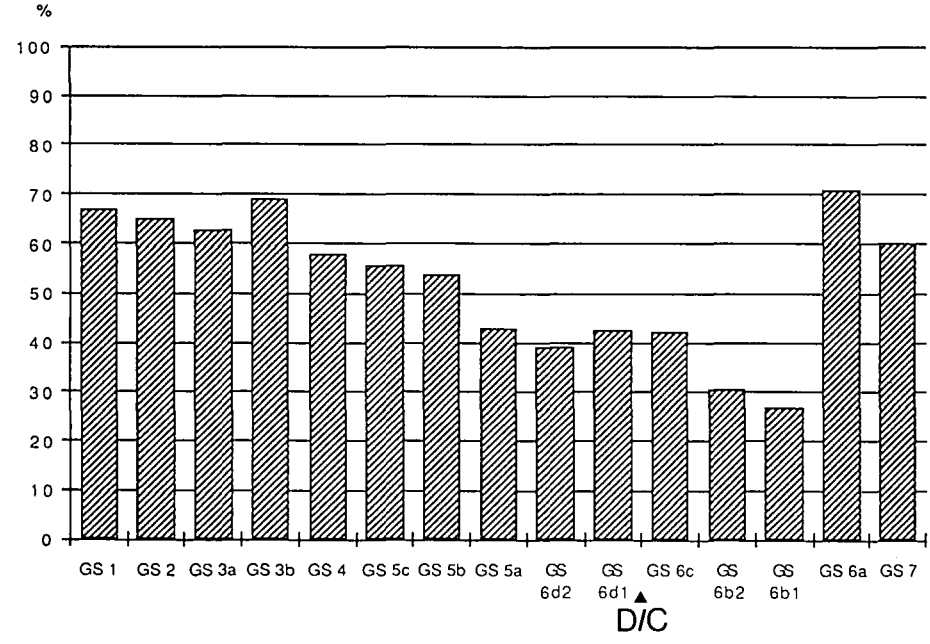

Fig. 5.
Grüne Schneid section. Percentage of identified taxa.
Data sheet summarizing countings of conodonts from the beds shown on Fig. 1.
Sip = *Siphonodella*; Bis = *Bispathodus*; Bra = *Branmehla*; Pse = *Pseudopolygnathus*; Pro = *Protognathus*; Pol = *Polygnathus*; Palma = *Palmatolepis*.
D/C = Devonian/Carboniferous boundary.

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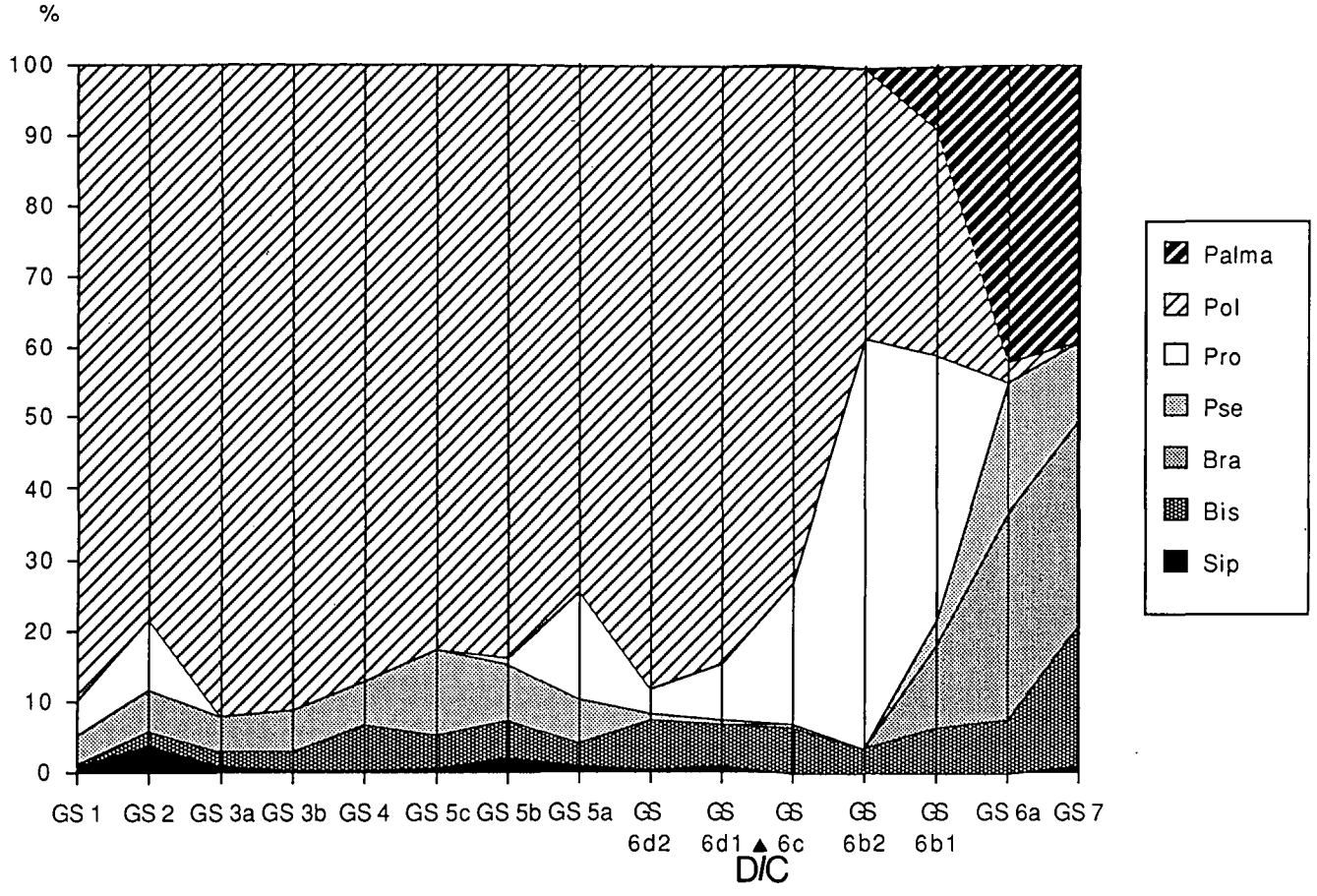

Fig. 6.
Grüne Schneid section. Computer-generated drawing showing distribution of facies related conodont taxa.
Abbreviations as in Fig. 5 and Table 1.

during that particular time interval at Kronhofgraben. The next *Protognathodus* "bloom" within the *S. duplicata* Zone (corresponding to the levels of samples 1 and 2 of the Grüne Schneid section) can possibly be correlated with the base of the chert sequence in the Kronhofgraben section (from which part no conodonts could be extracted).

Although the biofacies record for the *S. praesulcata* Zone is more complete in the Grüne Schneid section, there is a good similarity in biofacies between both sections: comparable relative frequencies of *Palmatolepis*, *Pseudopolygnathus*, and if we take *Bispathodus* and *Branmehla* as a common biofacies group, the similarity is even greater.

For both sections the oldest part of the *praesulcata* Zone is thus characterized by a palmatolepid-bispathodid (branmehlid) biofacies.

The most interesting biofacies change occurs below the *praesulcata-sulcata* zonal boundary in the Grüne

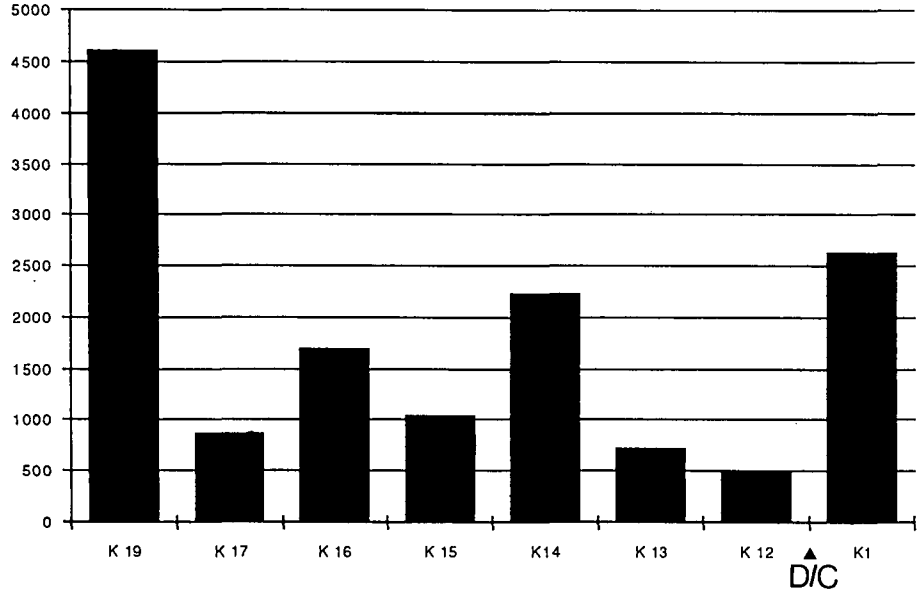

Fig. 7.
Kronhofgraben section. Total counting of conodonts from the samples shown on Fig. 3.
D/C = Devonian/Carboniferous boundary.

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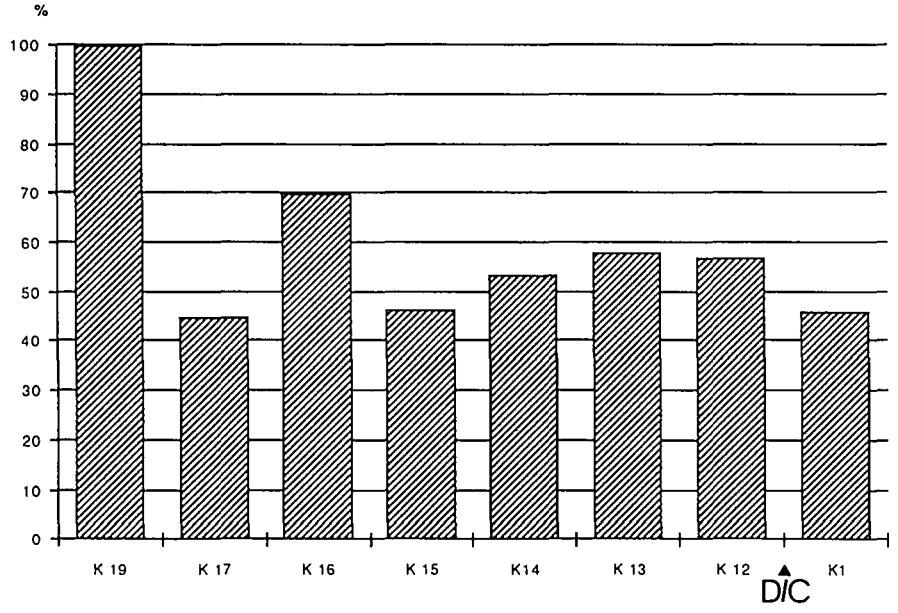

Fig. 8.
Kronhofgraben section. Percentage of identified taxa.
D/C = Devonian/Carboniferous boundary.

Schneid section: between samples GS 6A and GS 6B we observe an abrupt decrease in *Palmatolepis*, *Pseudopolygnathus* and *Branmehla*, and a sudden increase in *Polygnathus* and especially in *Protognathodus*. This would point to the eustatic sea-level drop, as observed just before the Devonian/Carboniferous boundary in other sections worldwide.

A next important observation concerns the D/C boundary located at the transition from samples 6C to 6D in the Grüne Schneid section: The last representative of the Upper Devonian genus *Palmatolepis* occurs just below that level. Interestingly, *Branmehla* disappears at the same time, whereas there is a significant drop in *Protognathodus* and a slight increase in *Polygnathus*.

Finally, a true "pelagic" Siphonodellid biofacies is present in bed K19 of the Kronhofgraben section (see Fig. 9) pointing to an important deepening event during the *S. sandbergi* Zone. This conclusion is strongly supported by the appearance of blind trilobites (HAHN & KRATZ, 1991, this volume).

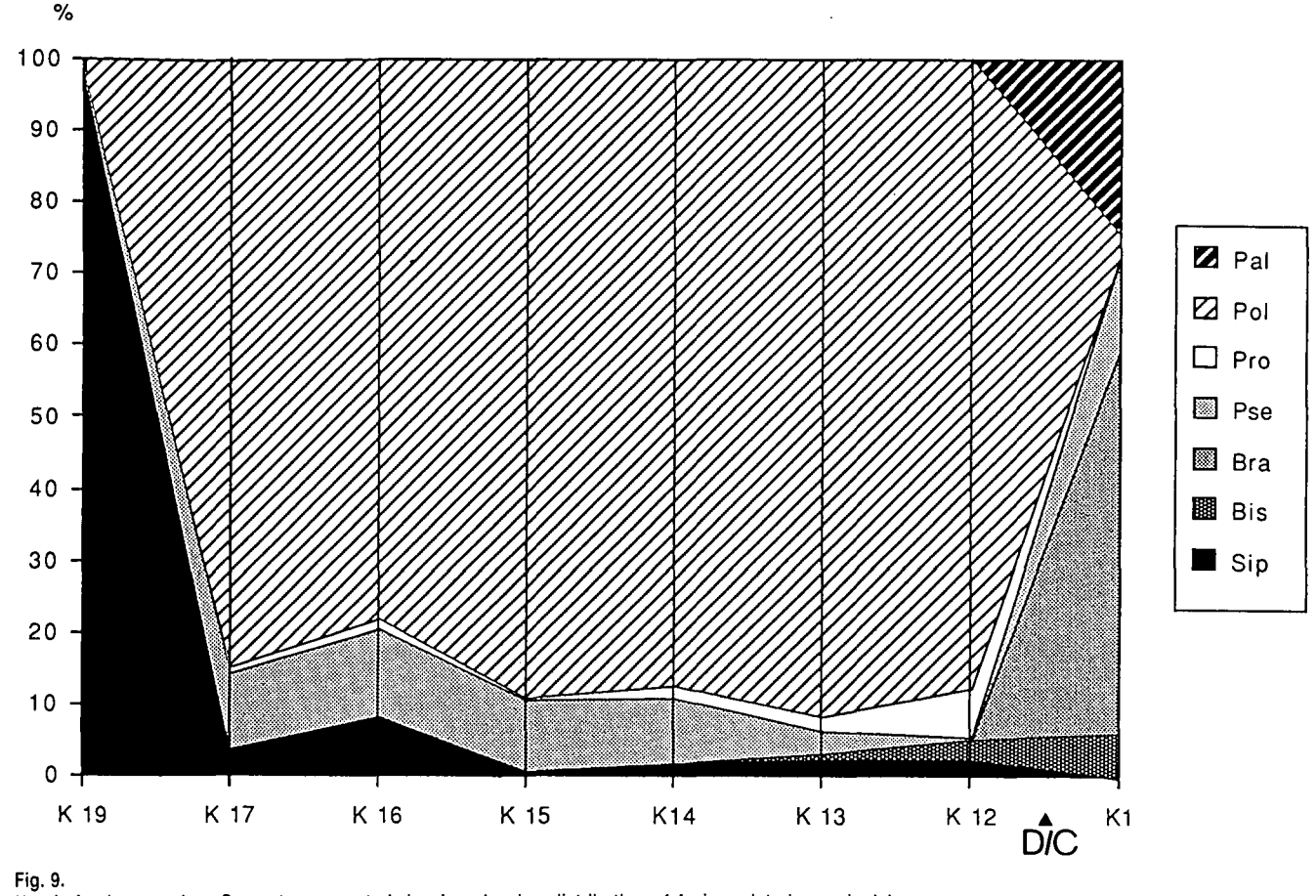

Fig. 9.
Kronhofgraben section. Computer generated drawing showing distribution of facies related conodont taxa.
Abbreviations as in Table 1.

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