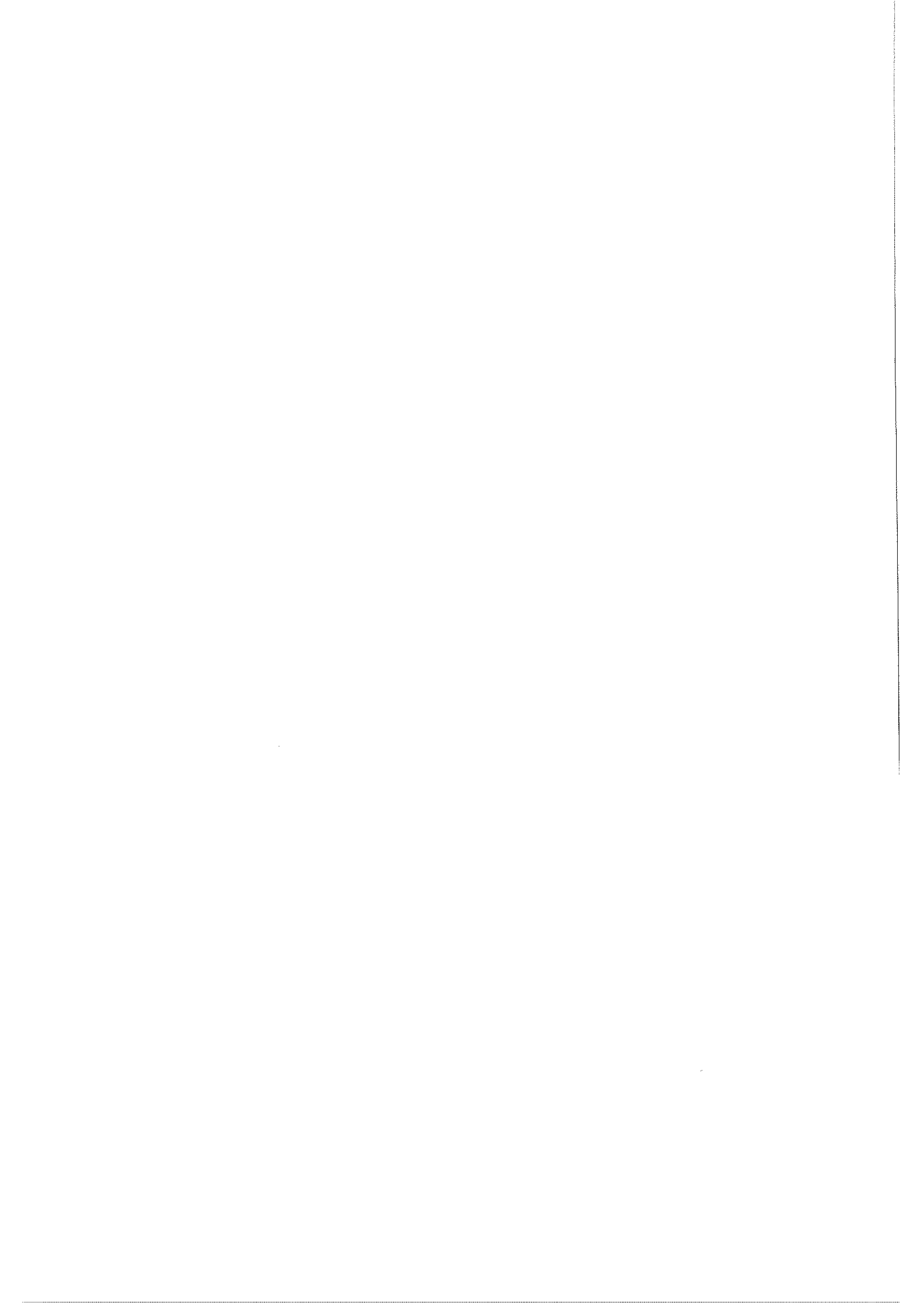


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Advantages and disadvantages of a conodont-based or event-stratigraphic Devonian-Carboniferous Boundary

MARTIN J. M. BLESS, KIRILL V. SIMAKOV & MAURICE STREEL

ABSTRACT

Review of the fossil assemblages in several sections proposed as candidates for the Devonian/Carboniferous boundary stratotype leads to the conclusion that the first (and maybe also the last) occurrences of selected taxa (including *Siphonodella sulcata*) are diachronic in these sections. Moreover, arguments are forwarded which suggest that the base of the Hangenberg Shale in the Federal Republic of Germany and the base of equivalent lithostratigraphic units elsewhere are also diachronic. This conclusion does not favour the alternative of defining an event-stratigraphic boundary at that level.

INTRODUCTION

In 1976 the IUGS Subcommittee on Stratigraphic Terminology published recommendations or guide lines for stratigraphic classification (HEDBERG (ed.), 1976). One of these recommendations is that chronostratigraphic boundaries preferably should be defined in a continuous rock sequence without any appreciable gap, and that the apparent first occurrence of a carefully selected fossil taxon should be taken for positioning the "golden nail" in that sequence.

The recognition of such a chronostratigraphic boundary in other sections is a problem of correlation. This correlation may be easier if the fossil species originally selected for defining the boundary also occurs elsewhere in as many sections as possible, if other fossil taxa occurring in the type section are widely distributed as well, and if other evidence is available (cf. HEDBERG (ed.), 1976: 86).

In order to reduce correlation problems to an acceptable minimum it has become common practice to test the vertical and lateral distribution of "critical" fossil taxa in a large number of widely spaced sections before making a selection amongst these.

This approach may be a painstaking, time-consuming one. But it guarantees that the chosen boundary can be followed somehow over large distances and through different continents.

This method has also been practiced since 1976 by the IUGS Working Group on the Devonian-Carboniferous Boundary (D/C Working Group, PAPROTH & STREEL, 1984). Recently however, a. o. WALLISER (1984, 1985) has advocated that major boundaries - defined between stages, series and systems - should coincide with "natural boundaries" produced by "global events" and presumably coinciding with worldwide major changes in fossil content and/or lithology.

For a comparison of the advantages and disadvantages of these apparently different approaches (the first one looking for boundaries within more or less uniform, uninterrupted rock sequences; the second one defining limits at more or less abrupt changes in lithology and fossil assemblages) the state of affairs of the revision of the Devonian/Carboniferous (D/C) boundary is taken as a test case.

CONODONT-BASED D/C BOUNDARY

The D/C boundary has been defined originally in 1935 by the second Heerlen Congress on Carboniferous Geology and Stratigraphy at the first occurrence of the cephalopod *Gattendorfia subinvoluta* (JONGMANS & GOTHAN, 1937). Unfortunately, this first occurrence in the classical section of Oberrödinghausen (FRG) is preceded by an important sedimentary gap

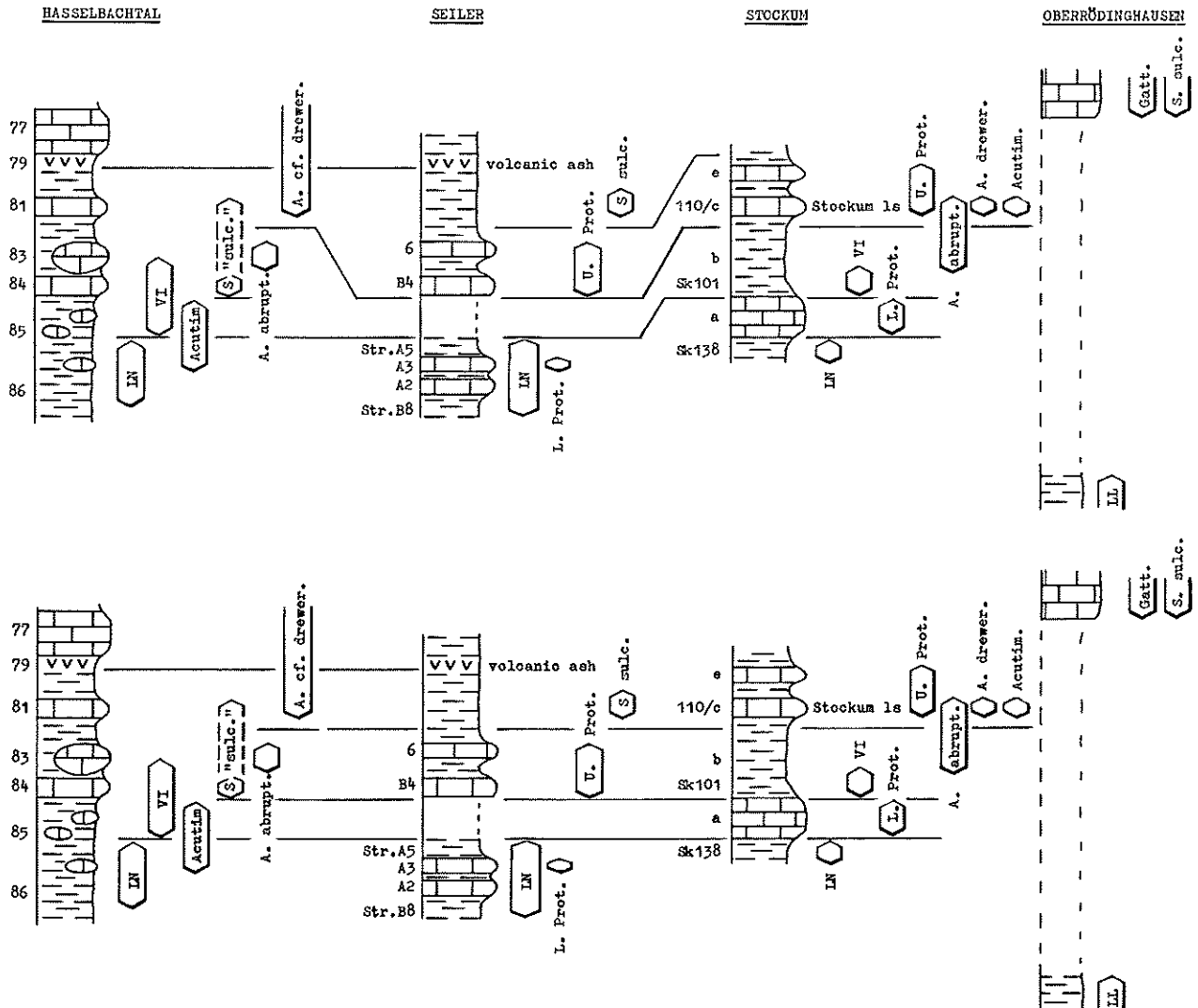


Fig. 1. Alternative biostratigraphic and lithostratigraphic correlations of Devonian-Carboniferous boundary beds in some selected sections along northern border of Rhenish Massif ("Rheinisches Schiefergebirge") in the FRG (sections not to scale!). Indicated are occurrences of miospore assemblages LL, LN and VI, goniatite assemblages with *Acutimitoceras* and *Gattendorfia*, conodont assemblages with *Siphonodella sulcata*, *Protognathodus kockeli* (Lower *Protognathodus* fauna) and *Pr. kuehni* (Upper *Protognathodus* fauna), and trilobite assemblages with *Archegonus (Waribole) abruptirhachis* and *A. (Phillibole) drewerensis*. Data for Hasselbachtal from BECKER et al. (1984), Seiler from KOCH et al. (1970), HIGGS & STREEL (1984) and ZIEGLER & SANDBERG (1984), Stockum and Oberrödinghausen from HIGGS & STREEL (1984).

(fig. 1). Because uninterrupted cephalopod-bearing sequences showing the first appearance of *Gattendorfia* could not be detected at that time, the D/C Working Group decided to look for another taxon that would appear at a level as close as possible to the original *Gattendorfia*-base in Oberrödinghausen. After some years of research and discussions a majority of the D/C Working Group members voted (in 1979) in favour of the first occurrence of the conodont species *Siphonodella sulcata* as a reliable guide for the base of the Carboni-

ferous (PAPROTH & STREEL, 1984).

This taxon is believed to have evolved directly from *Siphonodella praesulcata*, a species appearing in the uppermost Famennian or "Strunian" (SANDBERG et al., 1978). Although this proposal was not accepted unanimously, the D/C Working Group then concentrated on finding a suitable boundary stratotype that should contain both *S. praesulcata* and *S. sulcata*, and preferably also as many other fossil taxa as possible. This has not

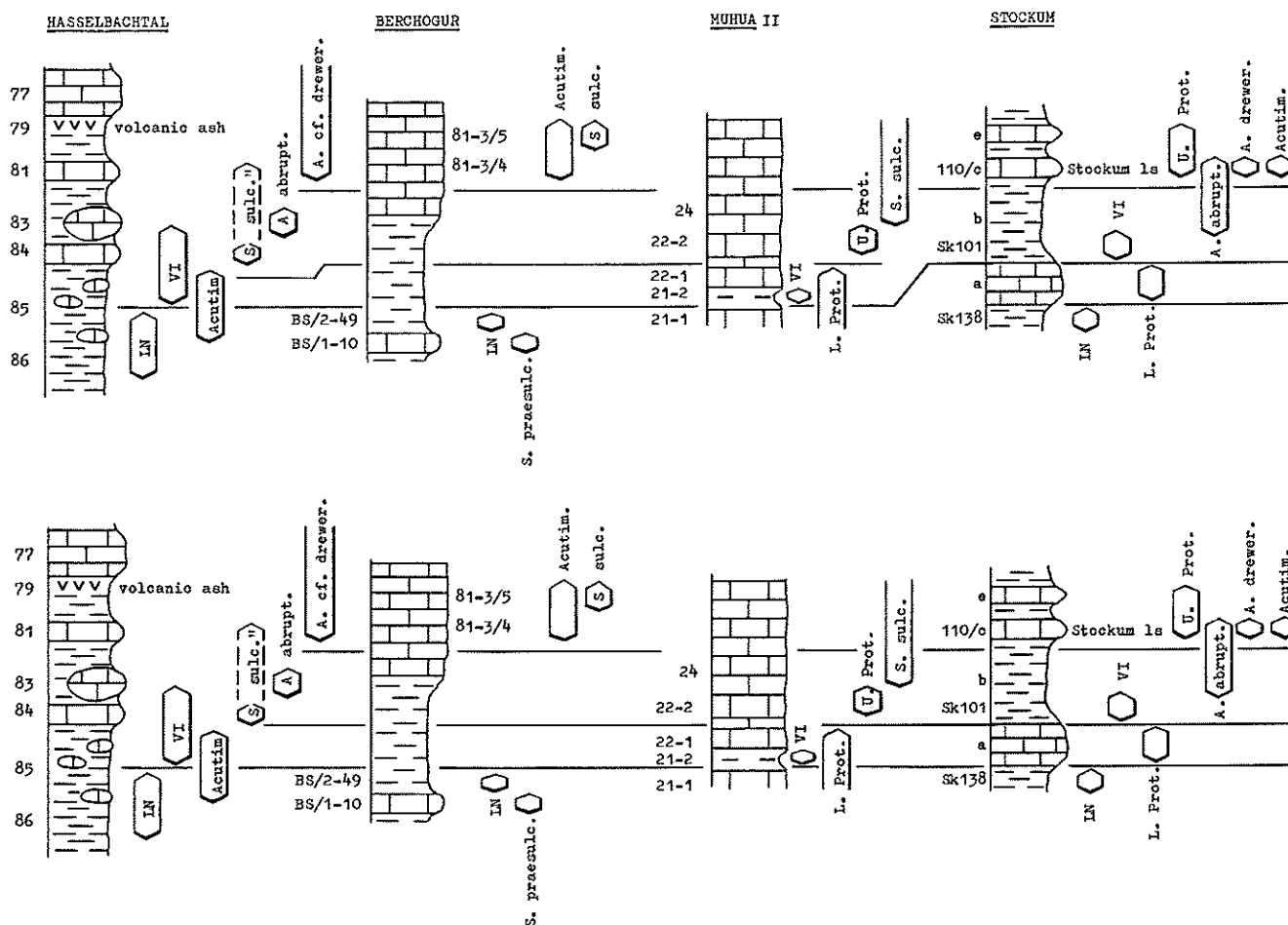


Fig. 2. Alternative biostratigraphic correlations of Devonian-Carboniferous boundary beds in some selected sections of the FRG, USSR and China (sections not to scale!). Data for Hasselbachtal from BECKER et al. (1984), Berchogur from BARS KOV et al. (1984), Muhua from HOU et al. (1984), and Stockum from HIGGS & STREEL (1984).

been an easy task. Several candidate sections have since been considered, all of these showing several shortcomings (PAPROTH & STREEL, 1984; ZIEGLER & SANDBERG, 1984).

In a preliminary vote in 1983, nine of the fifteen members of the D/C Working Group accepted a proposal to consider the Hasselbachtal section in the FRG, the Berchogur section in the USSR and the Muhua section in China as candidates for the boundary stratotype, whereas the also proposed Kiya section in the USSR was withdrawn slightly later by K. V. SIMAKOV (PAPROTH & STREEL, 1984).

Since then several more sections have been proposed as a suitable boundary stratotype (a. o. the Guilin section in southern China, YU et al., 1987). These may contain a rather continuous succession of conodont assemblages including *Siphonodella praesulcata* and *S. sulcata*. However, these sections have not yet been checked by the D/C

Working Group. Therefore we take the Hasselbachtal section as a reference for correlation in this review.

Hasselbachtal section

The critical interval in the Hasselbachtal section occurs in the about 1.25 m thick sequence between beds 86 and 77 (BECKER et al., 1984). The taxa of interest include palynomorphs (representing spore zones LN and VI), cephalopods (*Acutimitoceras*), conodonts (*Siphonodella sulcata* and species indicating *S. sulcata* or slightly younger zones) and trilobites (a. o. *Archegonus (Waribole) abruptirhachis* and *A. (Phillibole) cf. drewerensis*). Moreover a volcanic ash (metabentonite) marks bed 79.

The boundary between spore zones LN and VI is situated some 14 cm below the top of bed 85 (HIGGS & STREEL, 1984), this is within the interval with *Acutimitoceras* sp. and *A. cf. prorsum* (between 12

and 46 cm below top of bed 85; BECKER et al., 1984). *S. sulcata* is found in the upper (turbidite) part of bed 84 along with a. o. *S. praesulcata*, *Protognathodus kockeli*, *Pr. kuehni* and reworked Upper Devonian conodonts (BECKER et al., 1984). The conodont assemblage of bed 83 is indicative for the *S. sulcata* zone (a. o. *Polygnathus communis communis*, *Pr. kockeli*, *Pr. kuehni* and *Pr. meischneri*), whereas that of bed 81 may fit somewhere in the *S. sulcata* to *S. sandbergi* Zones (BECKER et al., 1984). Eventually, the first occurrence of *Archegonus* (*Phillibole*) cf. *drewerensis* in bed 81 is slightly higher than that of *A. (Waribole) abruptirhachis* in bed 83 (BRAUCKMANN & HAHN, 1984).

Seiler section

The Seiler section is situated some 5 km to the east of Hasselbachtal. It is a composed section based on data of three trenches dug out in 1969 and 1979 (KOCH et al., 1970; HIGGS & STREEL, 1984; ZIEGLER & SANDBERG, 1984). The critical interval is within the about 1.2 m thick sequence with at the base bed Str. B 8 and at the top a volcanic ash layer. The taxa of interest include palynomorphs and conodonts.

Spore zone LN has been recognized between beds Str. B 8 and Str. A 5. Within the same interval conodonts of the Lower *Protognathodus* fauna occur a. o. in bed A 3. It must be accepted that bed Str. A 5 (apparent top of LN zone) is not younger than the top of LN spore zone in Hasselbachtal some 14 cm below the top of bed 85 in that section. The Upper *Protognathodus* Fauna has been recognized in between beds B 4 and 6. According to ZIEGLER & SANDBERG (1984) the base of this conodont coincides with the base of the *S. sulcata* Zone. Therefore bed B 4 cannot be older than bed 84 in Hasselbachtal, unless it is accepted that the appearance of *S. sulcata* in bed 84 of Hasselbachtal is not the oldest one known thus far. In that case, however, the oldest *S. sulcata* must be found in a section not discussed in this review. This suggests a gap or an extremely condensed sequence between beds Str. A 5 and B 4 comprising the lower half of the VI spore zone in Hasselbachtal. The occurrence of *S. sulcata* in the predominantly shaly interval between bed 6 and the volcanic ash layer in the 1969 trench is younger than the base of the Upper *Protognathodus* fauna and thus certainly younger than the base of the *S. sulcata* zone in bed 84 of Hasselbachtal. Accepting that the tuff layer in the Seiler trenches is the equivalent of the volcanic ash layer in Hassel-

bachtal and knowing that *S. sulcata* has been found well above the tuff layer in the Seiler trenches, we suggest that this volcanic ash is within the *S. sulcata* zone and that the same holds for the conodont assemblage of bed 81 in Hasselbachtal.

Stockum section

The Stockum section occurs some 32 km to the ESE of Hasselbachtal. Like Seiler the here presented section is composed of data from several trenches and outcrops (HIGGS & STREEL, 1984; BRAUCKMANN & HAHN, 1984; KORN, 1984). The critical interval is situated between beds Sk 138 and e and is about 1.6 m thick. Taxa of interest include palynomorphs (representing spore zones LN and VI), conodonts (Lower and Upper *Protognathodus* faunas), cephalopods (*Acutimitoceras* spp.) and trilobites (*Archegonus (Waribole) abruptirhachis* and *A. (Phillibole) drewerensis*).

The correlation of the interval Sk 138 to Sk 101 with the Hasselbachtal section offers slightly different alternatives. Bed Sk 138 (with LN spore zone) is not younger than the top of the LN spore zone in Hasselbachtal. Bed a (with Lower *Protognathodus* assemblage) cannot be younger than the basal portion of bed 84 in Hasselbachtal (according to ZIEGLER & SANDBERG, 1984). Bed Sk 101 (with VI spore zone) cannot be older than the base of the VI zone in Hasselbachtal (there 14 cm below top of bed 85).

The succession of *Archegonus (W.) abruptirhachis* (beds b - c) and *A. (P.) drewerensis* (bed c) resembles that in beds 83 and 81 in Hasselbachtal. This means that the most likely correlation is that bed b of Stockum corresponds to bed 83 in Hasselbachtal, whereas bed c (the so-called Stockum *Imitoceras* Limestone lenses!) matches bed 81 in Hasselbachtal. This implies that the oldest Upper *Protognathodus* assemblage in Stockum (in bed c) is distinctly younger than the base of the *S. sulcata* zone in Hasselbachtal and maybe even younger than in Seiler. The rich goniatite assemblage of the Stockum *Imitoceras* Limestone lenses contains a diverse association of *Acutimitoceras* species (KORN, 1984). This association is much younger (well above base *S. sulcata* zone) than the poorly preserved and presumably more monotonous assemblages in the top of bed 85 (below base *S. sulcata* zone) of Hasselbachtal.

Oberrödinghausen section

This section is situated some 18 km east

of Hasselbachtal. The Devonian-Carboniferous boundary is here marked by an important gap between the spore zone LL and the base of the *Gattendorfia* goniatite zone. The section is shown here only for illustration of the length of the period without sedimentary and/or biostratigraphic record.

Berchogur section

The Berchogur section is located in the Soviet Mugodgar Mountains (Kazakh SSR north of Aral Sea). A detailed account of the fossil assemblages has been presented by BARSKOV et al. (1984). The critical interval between beds BS/1 - 10 and 81 - 3/5 is about 1,25 m thick. Taxa of interest are a. o. palynomorphs (equivalent of LN zone), conodonts (*S. praesulcata* and *S. sulcata* Zones) and cephalopods (*Acutimitoceras* assemblage).

Important for correlation with Hasselbachtal is the presence of the equivalent of the LN spore zone in bed BS/2 - 49, which cannot be younger than the top of the LN spore zone in Hasselbachtal. On the other hand the *Acutimitoceras* assemblages of beds 81 - 3/4 and 81 - 3/5 closely resemble those of the Stockum *Imitoceras* Limestone lenses (bed c) and are here correlated with these. The sequence in between beds BS/2 - 49 and 81 - 3/4 has not yielded any significant taxon for refining the correlation. The lowest observed occurrence of *Siphonodella sulcata* in bed 81 - 3/5 is anyhow much younger than in Hasselbachtal and possibly even younger than the Stockum *Imitoceras* Limestone lenses (here correlated with bed 81 of Hasselbachtal).

Muhua section

The Muhua section in the Guizhou province of southern China has been described by several authors, a. o. ZIEGLER & SANDBERG (1984) and HOU et al. (1984). The critical interval occurs between beds 22 and 24 according to HOU et al. (1984) (ZIEGLER & SANDBERG (1984) incorrectly indicated that this boundary would occur between beds 21 and 23!). Conodont assemblages (Lower and Upper *Protognathodus* faunas, *S. sulcata* Zone) form the most important taxa in this about 0.3 m thick interval.

Within an apparently uniform lithology a succession of three conodont assemblages occurs. A Lower *Protognathodus* fauna with *Pr. kockeli* marks bed 22 of HOU et al. (1984). Bed 23 contains an Upper *Protognathodus* fauna (with *Pr. kockeli* and *Pr. kuehni*). *Siphonodella sulcata* appears in bed 24. Following the arguments of ZIEGLER

& SANDBERG (1984) bed 22 of HOU et al. (1984) cannot be younger than the base of bed 84 in Hasselbachtal, whereas bed 23 cannot be older than the first occurrence of *S. sulcata* in Hasselbachtal. This implies that the first entry of *S. sulcata* in Muhua in bed 24 of HOU et al. (1984) is later than that in Hasselbachtal!

CONCLUSIONS

The first occurrences of selected taxa (including *Siphonodella sulcata*) are not synchronic in the sections surveyed here (fig. 1 - 3). This is remarkable since each one of these sections has received special attention in the (recent) past as a potential candidate for the D/C boundary stratotype.

For example, the first occurrence of *Acutimitoceras* in Hasselbachtal is much earlier than in Stockum (fig. 1), even if one would accept the correlation of the Stockum *Imitoceras* Limestone lenses (bed c) with bed 84 of Hasselbachtal (cf. BLESS & GROOS-UFFENORDE, 1984; ZIEGLER & SANDBERG, 1984). *Acutimitoceras* occurs, however, below bed 84 in Hasselbachtal (below base *S. sulcata*) and not below the Stockum *Imitoceras* Limestone lenses. In that case the first occurrences of respectively *A. (W.) abruptirhachis* and *A. (P.) drewerensis* would also be diachronic. Most likely, the low-diversity *Acutimitoceras* assemblage (with *A. cf. prorsum*) of Hasselbachtal is the latest Devonian forerunner of the high-diversity, lowermost Carboniferous *Acutimitoceras* assemblages of e. g. Stockum (with *A. prorsum*) and Berchogur.

The first occurrence of *Siphonodella sulcata* in Seiler, Berchogur and Muhua is later than in Hasselbachtal (fig. 2). In Berchogur because the appearance of *S. sulcata* is above the base of the high-diversity *Acutimitoceras* assemblage which is correlated with that of the Stockum *Imitoceras* Limestone lenses (bed c, here correlated with bed 81 of Hasselbachtal). In Seiler and Muhua because the lowest occurrence of *S. sulcata* is preceded by an Upper *Protognathodus* fauna with *Pr. kuehni* which "per definition" cannot be older than the base of the *S. sulcata* zone (cf. ZIEGLER & SANDBERG, 1984). In Hasselbachtal this assumption is correct, but in many other sections *Pr. kuehni* occurs earlier than *S. sulcata*. This leaves us with a problem that cannot be solved at the moment. Either we accept the suggestion that the base of the Upper *Protognathodus* fauna (in fact the base of *Pr. kuehni*) matches the base of *S. sulcata*, or we believe that the

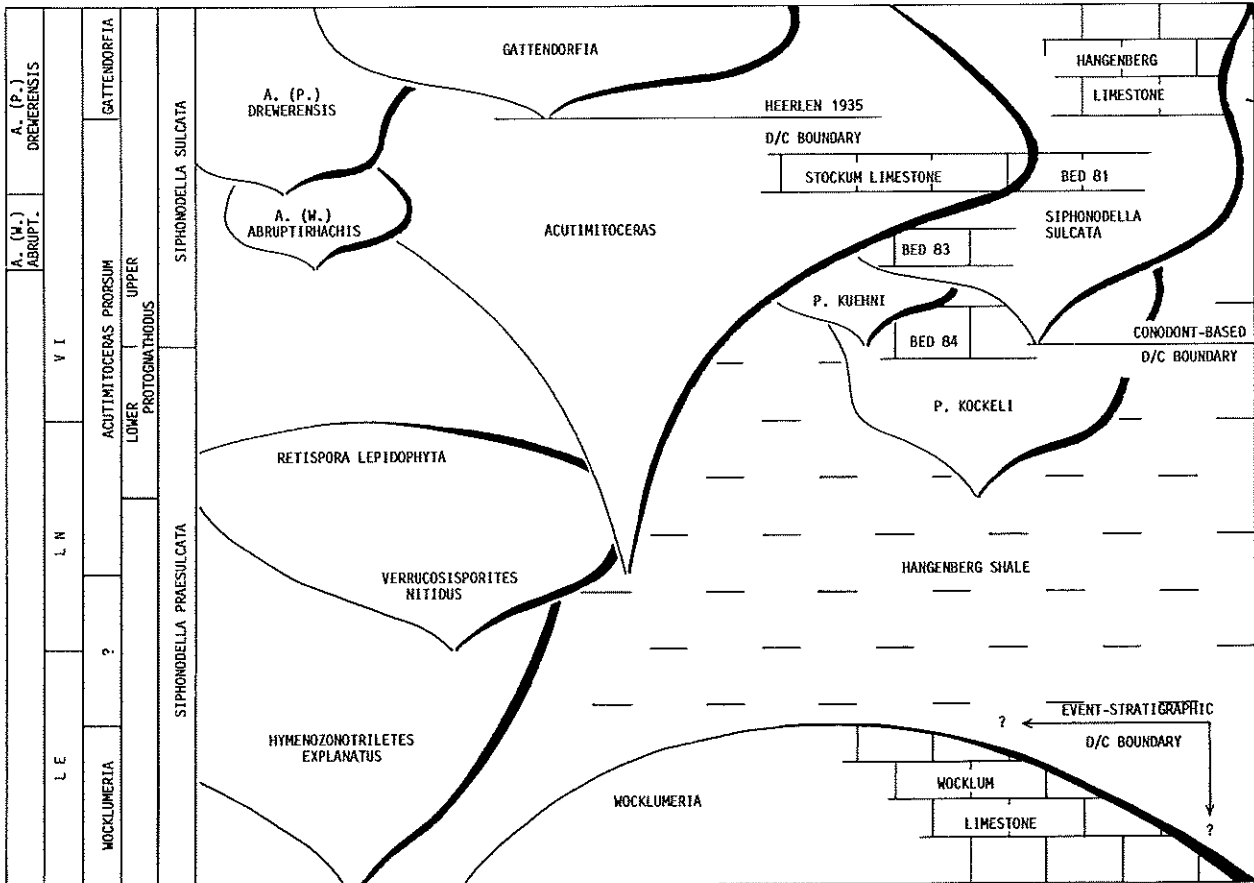


Fig. 3. Cartoon showing presumed relative chronostratigraphic appearance and disappearance of some relevant taxa near the Devonian-Carboniferous boundary along the northern border of the Rhenish Massif (FRG). Also indicated is the position of some key beds in Hasselbachtal (notably beds 84, 83 and 81), Stockum (Stockum *Imitoceras* Limestone lenses) and Oberrödinghausen (Hangenberg Limestone). Top and base of Hangenberg Shale and top of Wocklum Limestone are presumably diachronic in this area. The position of the event-stratigraphic D/C boundary seems ambiguous.

entry of *S. sulcata* is synchronic in most sections what would imply a certain diachronism for the base of the Upper *Protognathodus* assemblages.

Unfortunately, there are no objective arguments in favour of either one of these theories. Therefore, for the time being it is arbitrarily accepted that the suggestion of ZIEGLER & SANDBERG (1984) is correct, this is that the earliest appearances of *S. sulcata* and *Pr. kuehni* are synchronic.

A similar problem form boundaries based on the disappearance of taxa such as *Wocklumeria* and *Retispora lepidophyta*.

The top of the Wocklum Limestone along the northern border of the Rhenish Massif may be diachronic. This *Wocklumeria sphaeroides*-bearing limestone yielded conodonts of the Middle *costatus* zone at Apricke and conodonts of the Upper *costatus* zone at

Oese (HIGGS & STREEL, 1984).

In both sections the overlying Hangenberg Shale yielded *Cymaclymenia evoluta* (= *C. euryomphala*) and spores of the LL zone. In another section, however, Hasselbachtal, the spores in the top of the Wocklum Limestone indicate the younger LE zone (HIGGS & STREEL, 1984). Are these differences to be explained by non-sequences, erosion and/or reworking?

The disappearance of *Retispora lepidophyta* (and also of other species such as *Vallatisporites pusillites*, *Rugospora flexuosa*, etc.) marks the boundary between the spore zones LN and VI. Again the problem is that there is not sufficient information on other fossil groups to check whether this disappearance is more or less synchronic or not. In Hasselbachtal this boundary is within an interval with presumably rather early *Acutimitoceras*

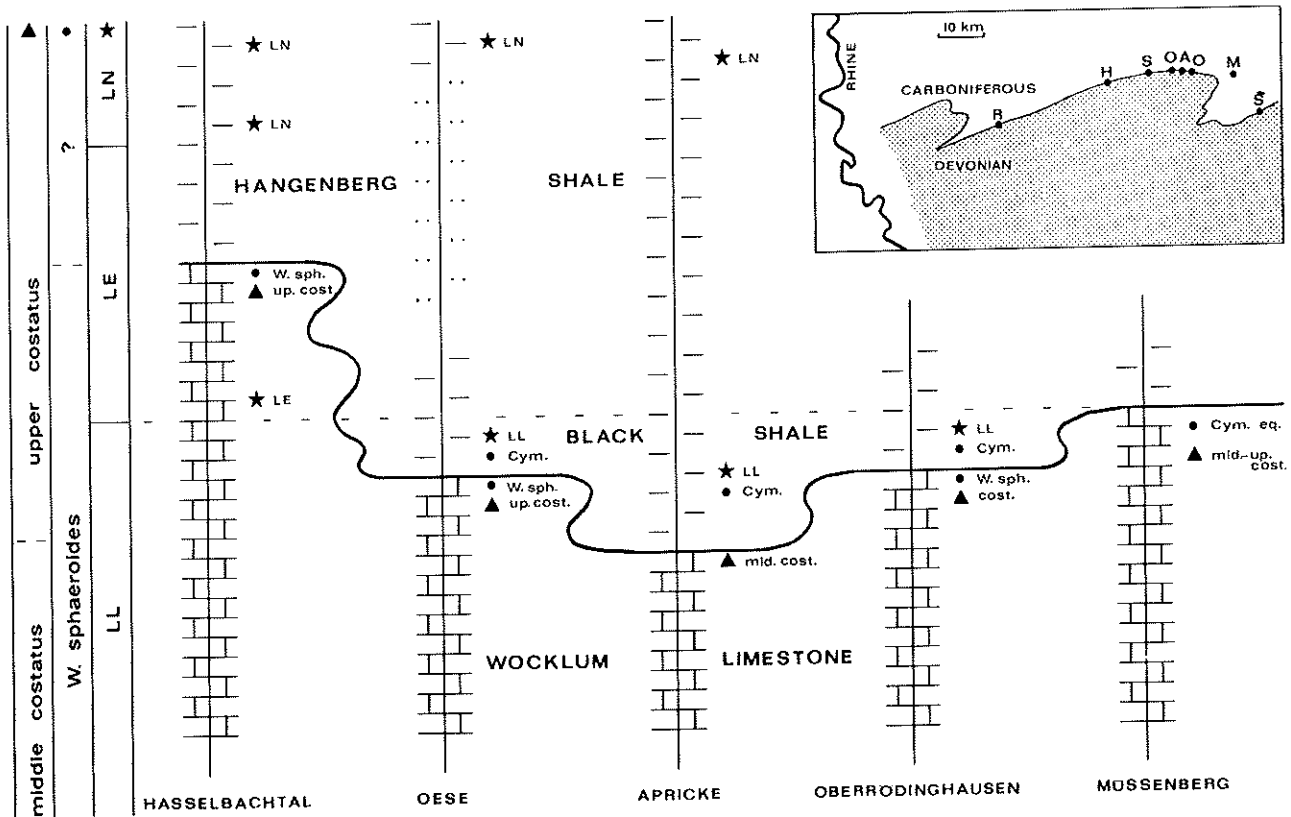


Fig. 4. Cartoon showing chronostratigraphic position of boundary between Wocklum Limestone and Hangenberg Shale in some selected sections along the northern border of Rhenish Massif (FRG). Inset map shows location of D/C boundary sections (from west to east: Riescheid, Hasselbachtal, Seiler, Oese, Apricke, Oberrödinghausen, Müssenberg, Stockum). Data for Hasselbachtal from BECKER et al. (1984), Oese, Apricke and Oberrödinghausen from HIGGS & STREEL (1984), Müssenberg from LUPPOLD et al. (1984).

and below the base of the conodont biozone of *Protognathodus kuehni* and *Siphonodella sulcata*. By inference this means that this boundary is somewhere within the interval with the Lower *Protognathodus* fauna. In Stockum the LN-VI boundary is formed by an observation gap "filled" with conodonts of the Lower *Protognathodus* facies. Reworking of *R. lepidophyta* and older spores of the LL zone is suggested for some assemblages in one of the Stockum trenches (HIGGS & STREEL, 1984) because of their anomalous position in the stratigraphic sequence and because of the anomalous composition of the assemblages wherein these occur. However, in some cases it may be difficult to distinguish between "in situ" occurrences of *R. lepidophyta* and reworked assemblages. The above examples yield ample proof to support the idea that the distribution of critical taxa around the D/C boundary is irregularly limited in time and space because of environmental influences, preservation possibilities and post-sedimentary erosion and reworking.

Notwithstanding all these shortcomings it

seems possible to achieve rather detailed correlations between the Hasselbachtal sections and other ones elsewhere in the world as far as the base of the *Siphonodella sulcata* Zone in bed 84 of Hasselbachtal is concerned. It should be emphasized, however, that this is partly due to the fact that in many sections there is an anomaly in the sedimentary record at and around the stratigraphic position of bed 84.

EVENT STRATIGRAPHY

Event stratigraphy is based on rather drastic changes in the biostratigraphic contents of rock sequences and/or interruptions of the sedimentary environment. Frequently apparent mass extinction of major taxa is noticed. The causes for these dramatic happenings are virtually unknown. In the case of the D/C boundary a major change in cephalopod evolution had since long been recognized by several authors. For this reason the Heerlen-1935 Congress decided to place the D/C boundary

Fig. 5. Bivalve molluscs or bivalve conchostracan crustaceans from the latest Devonian and earliest Dinantian. Bar represents 2 mm for complete specimens and 1 mm for details of striate ornament. Position of details on shells indicated by black dot.

A. *Cyzicus* (*Lioestheria*) sp. sensu GUTSCHICK & RODRIGUEZ (1979) from the *Syringothyris* brachiopod zone (= Middle *costatus* Zone) of Nevada (USA). Specimens occur in black shale with high organic carbon content of the middle Pilot Shale and equivalents (Leatham Formation in Utah and Sappington Member in Montana). The associated fossil assemblages include *Lingula*, *Orbiculoidea*, trilobites, brittle starfish and *Imitoceras*-type goniatites (GUTSCHICK & RODRIGUEZ, 1979).

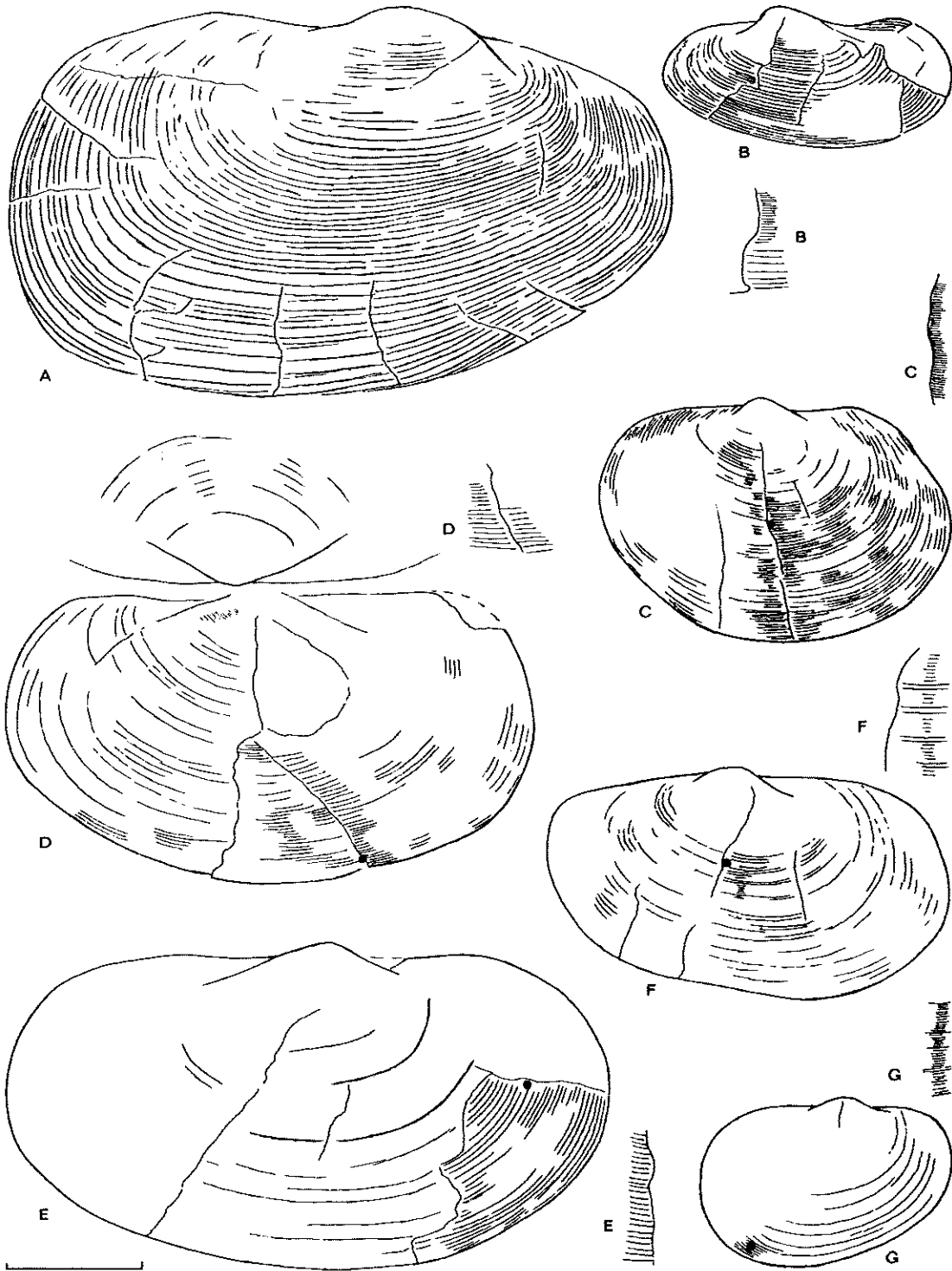
B - C. *Estherians* sensu FEIST & FLAJS (1987) from uppermost *expansa* to *sulcata* Zones of Montagne Noire (France). Specimens occur in bleached silty to clayey shales at boundary between *expansa* and *praesulcata* Zone (fig. B) and in oolitic limestone of *sulcata* Zone (fig. C). Associated fossils include trilobites (a. o. A. (W.) *abruptirhachis*) in oolitic limestone unit. FEIST & FLAJS (1987) argued that the microstructure of the shell of these specimens closely resembles that of recent conchostracans (notably *Leptoestheria dahalacensis* from Sardinia).

D - E. *Guerichia* or *Posidonia* sp. sensu BECKER et al. (1984) and sensu LUPPOLD et al. (1984) from LN spore zone (= *praesulcata* Zone) of northern border of Rhenish Massif (FRG). Specimens at Hasselbachtal (fig. D) occur in carbonaceous silty mudstones of Hangenberg Shale along with *Acutimitoceras*, spores of LN zone and plant debris. Specimens at Oberrödinghausen (fig. E) have been found in Hangenberg Shale, some 1.5 - 2 m below the top. Associated are extremely rich spore assemblages of the LL zone suggesting either nearness of the shoreline or turbiditic mass transport of the sediment into deeper parts of the basin (PAPROTH & STREEL, 1970; fig. 2). Similar specimens have been recorded also from "Stockum Limestone" (*sulcata* Zone) of Müssenbergl (LUPPOLD et al. 1984).

F - G. specimens from Muhua III section (southern Guizhou province, South China) collected by Dr. Eva PAPROTH in 1985 from carbonaceous shale (base of Gedongguan Bed) with plant debris, *Orbiculoidea*, gastropods (between 677 and 678). Post-*lepidophyta* spore assemblage sensu STREEL (1985, p. 87 - 88), presumably equivalent of LE zone.

at the base of the *Gattendorfia*-bearing Hangenberg Limestone of Oberrödinghausen. WALLISER (1984) advocated to place the event-stratigraphic D/C boundary at the base of the Hangenberg Shale as exposed e. g. in the Hönnetal section, since this matches the event-caused change in lithology (from clymenid limestone with *Wocklumeria sphaeroides* to Hangenberg Shale with at the base *Cymaclymenia evoluta* (formerly identified as *C. euryomphala*) and the practical disappearance of clymenids (except *C. evoluta*). According to WALLISER (1984) this point would coincide in these beds with the end of a latest Devonian regression and the onset of the earliest Carboniferous transgression. WALLISER (1984) pointed out that the base of the Hangenberg Shale usually consists of black, organic-rich shale. The question now arises whether this proposition would lead us to a better result or not. Or, in other words, would this proposal yield an easier recognizable and correlatable boundary that might be pinpointed with the same or with more exactness than the conodont-based D/C boundary of e. g. Hasselbachtal? The ex-

perience with the sections along the northern border of the Rhenish Massif (see above) seems to give us little hope. On the contrary, the information thus far available rather suggests that both the top of the clymenid-bearing Wocklum Limestone and the base of the Hangenberg Shale may be strongly diachronic (fig. 4; HIGGS & STREEL, 1984). Spore evidence indicates that the top of the Wocklum Limestone in Hasselbachtal (LE zone) is younger than the *Cymaclymenia evoluta*-bearing basal portion of the Hangenberg Shale at Oese, Apricke and Oberrödinghausen (LL zone). The alternative of a LL assemblage reworked in younger sediments by mass transport (HIGGS & STREEL, 1984: 163) seems less likely. For the basal black shale of the Hangenberg Shale, conodont data suggest that the top of the Wocklum Limestone at Apricke (middle *costatus* Zone) is slightly older than that at Oese, Oberrödinghausen and Müssenbergl (upper *costatus* zone). Finally, the top of the Wocklum Limestone at Müssenbergl has yielded a cephalopod assemblage that may be a time equivalent



of the basal portion of the Hangenberg Shale with *Cymaclymenia evoluta* (LUPPOLD et al., 1984). This means that the presence and absence of *W. sphaeroides* and *C. evoluta* may be facies-controlled.

This brings us to another problem: the depositional environment of the Hangenberg Shale. The Hangenberg Shale does not display a uniform lithology. Black shales occur at its base in a. o. Oese, Apricke and Oberrödinghausen (with *C. evoluta* and spores of LL zone) and in the upper portion in Riescheid (somewhere within spore zones LN, VI and HD; HIGGS & STREEL, 1984). Sandstone (Hangenberg Sandstone) has been observed a. o. at Oese. Increased carbonate contents and carbonate lenses occur rather randomly, a. o. at Apricke (somewhere in LL, LE or LN spore zones) and Hasselbachtal (in LN and VI spore zones). The bulk lithology is formed by greyish, silty shales.

This variation in lithofacies points to diversification of the palaeoenvironment in time and space during deposition of the Hangenberg Shale. Black shale (with *C. evoluta*) and Wocklum Limestone (with *W. sphaeroides*) were deposited during (late) LL time, grey shale and Wocklum Limestone during LE time, and grey shale and sandstone during late LE and/or early LN time.

There are several open-ended questions about the depositional environments of the Hangenberg Shale Sea. Relative depth, distance to the shore line and distance to the continental margin have been interpreted in rather different, sometimes contradictory ways.

Do the black shales reflect regionally limited anaerobic conditions (cf. ETTENSOHN & BARRON, 1981) or rather worldwide anoxic events (cf. WALLISER, 1984)? The answer to that question might be found in unraveling the nature of the fossil assemblages.

The fossil contents of the Hangenberg Shales is relatively monotonous. Land-derived spores and plant debris occur along with nektonic (notably cephalopods) and planktonic (entomozoan ostracodes) marine organisms. True benthonic organisms are rare or absent (except for some inarticulate brachiopods such as *Lingula* and *Orbiculoidea*). A frequently observed fossil in the Hangenberg Shale and time-equivalent shale deposits is "*Posidonia*" (fig. 5). Its rather tiny shells are marked by numerous, closely spaced growth lines. Its systematic position and palaeoecology seem to have been interpreted in quite different ways.

Some authors have considered these as lamellibranchs and attributed them to *Posidonia* (BABIN et al., 1976; LUPPOLD et al., 1984; WALLISER, 1984) or *Guerichia* (PAPROTH & STREEL, 1970; ZAKOWA in BECKER et al., 1984). Others like KOZUR & SITTIG (1981) and FEIST & FLAJS (1987) rather believe that these are conchostracan arthropods. The attribution to *Posidonia*-like lamellibranchs might imply a semipelagic way of life in open sea, the lamellibranchs having been attached to drifting algae or weed. Interpreting these as conchostracans rather suggests somehow restricted (brackish, lagoonal?) and possibly nearshore life conditions. However, one should be aware of the possibility that these fossils have been washed into deeper-water environments. "*Posidonia*"-like fossils in the Devonian-Carboniferous boundary beds of the USA (Pilot Shale of Nevada, Leatham Formation of Utah, Sappington Member of Montana) have been described as *Lioestheria* (GUTSCHICK & RODRIGUEZ, 1979). Similar fossils have been observed at many places throughout the world in black to greyish shales and even in limestones of Late Devonian to Early Permian age.

Summarizing the above observations we may conclude that there is no hard evidence for identification of the true nature of "*Posidonia*" and its life environment.

There are arguments to believe that the base of the Hangenberg Shale along the northern border of the Rhenish Massif is diachronic. Moreover, the basal black shale of the Hangenberg Shale at Oese, Apricke and Oberrödinghausen seems to be younger (Upper *costatus* Zone) than the *Lioestheria*-bearing portion of the black shales in the western USA (Middle *costatus* Zone according to GUTSCHICK & RODRIGUEZ, 1979). Most intriguing in this context is also the fact that JOHNSON et al. (1985) place the base of their IIf T - R cycle at the base of the Lower *expansa* zone in the western USA and western Canada and at the base of the Upper *expansa* Zone in Belgium (Epinette Shale) and FRG (base of Wocklum Limestone underlying Hangenberg Shale!).

Thus it seems that an event-stratigraphic boundary between Devonian and Carboniferous at the base of the Hangenberg Shale would certainly not simplify the correlation problems between widely spaced sections.

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