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NEW FAUNAL RECORDS AND HOLOSTRATIGRAPHIC CORRELATION OF THE HASSELBACHTAL D/C-BOUNDARY AUXILIARY STRATOTYPE (GERMANY)

R. Thomas BECKER [1]

(5 figures, 3 tables & 3 plates)

1. Institut für Paläontologie, Freie Universität Berlin, Malteserstr. 74-100, Haus D, 12249 Berlin, Germany

ABSTRACT. Detailed work in the last six years has increased significantly the macrofaunal record of the Hasselbachtal Auxiliary Stratotype. The number of ammonoid taxa has been almost doubled. *Balvia (Balvia)* n. sp. aff. *globularis* and *Rectimitoceras* n.gen. are introduced. *Kenseyoceras* Selwood and *Mayneoceras* Selwood are re-established as valid subgenera of *Balvia*. *Acutimitoceras* Librovich is subdivided into four subgenera: *Ac. (Acutimitoceras)*, *Ac. (Sulcimitoceras)* Kusina, *Ac. (Stockumites)* n.subgen., and *Ac. (Streeliceras)* n.subgen. The internal ventral furrow of *Sulcimitoceras* is a morphological feature of doubtful significance but the taxon may be kept as a subgenus for species with ribbed early stages. In the Rhenish Slate Mountains eight ammonoid zones and subzones can be distinguished within the Wocklumian. The international correlation of all biostratigraphically useful organism groups, eustatic fluctuations, global hypoxic events and sequence stratigraphy enables the separation of 23 holostratigraphic intervals around the Devonian-Carboniferous boundary (Wocklumian to Balvian). So far 19 of these have been recognized at Hasselbachtal.

KEYWORDS. Devonian, Carboniferous, ammonoids, biostratigraphy, taxonomy, holostratigraphy, Rhenish Slate Mountains.

RESUME. Nouveaux enregistrements de faunes et corrélation holostratigraphiques du stratotype auxiliaire de la limite D/C de la Hasselbachtal (Allemagne). Un travail détaillé dans les six dernières années a augmenté significativement l´enregistrement de macrofaune dans le stratotype auxiliaire de la Hasselbachtal. Le nombre de taxa d´ammonoides a été pratiquement doublé. *Balvia (Balvia)* n. sp. aff. *globularis* et *Rectimitoceras* n. gen. sont introduits. *Kenseyoceras* Selwood et *Mayneoceras* Selwood sont réétablis comme sous-genre valide de *Balvia*. *Acutimitoceras* est subdivisé en quatre sous-genres: Ac. *(Acutimitoceras)*, *Ac. (Sulcimitoceras)* Kusina, *Ac. (Stockumites)* n.subgen., et *Ac. (Streeliceras)* n.subgen. Le sillon ventral interne de *Sulcimitoceras* est un trait morphologique de signification douteuse, mais le taxon peut être conservé comme un sous-genre pour des espèces avec des stades précoces présentant des côtes. Dans le Massif Schisteux Rhénan, huit zones et sous-zones d´ammonoides peuvent être distinguées au sein du Wocklumien. La corrélation internationale de tous les groupes d´organismes utiles en biostratigraphie, les fluctuations eustatiques, les événements hypoxiques globaux et la stratigraphie séquentielle rendent possible la séparation de 23 intervalles holostratigraphiques autour de la limite Dévonien/Carbonifère (Wocklumien à Balvien). 19 de ceux-ci ont été reconnus jusqu´ici dans la Hasselbachtal.

MOTS-CLES. Dévonien, Carbonifère, ammonoides, biostratigraphie, taxonomie, holostratigraphie, Massif Schisteux Rhénan.

1. INTRODUCTION

The search for an international Devonian-Carboniferous Boundary stratotype has greatly encouraged high-resolution stratigraphic work in many sections all over the world. This has led to an enormous wealth of knowledge about precise taxon ranges, co-occurence of various fossil groups, regional and local facies developments across the boundary, sea-level fluctuations and extinction, survival and radiation patterns in relation to the global Hangenberg Event. The progress of research is well documented in special volumes on D-C boundary problems (Paproth & Streel, eds., 1984; Flajs *et al.*, eds, 1988; Streel *et al.*, eds, 1993; Korn *et al.*, eds, 1994) as well as in monographs on specific sections (e.g. Hou *et al.*, 1985; Yu, ed., 1988; Ji, ed., 1989; Schönlaub *et al.*, 1992). For a deeper understanding of later discussions the reader is referred to these publications.

The Hasselbachtal Auxiliary Stratotype is one of the sections which has been intensively investigated in the last decade and a review of literature and latest results were given by Becker & Paproth (1993). The macrofaunal record has been extended since original descriptions by Becker *et al.* (1984) and Becker (1988) but details were only presented in an unpublished field guide to the 1993 Liege Meeting of the Subcommission on Carboniferous Stratigraphy (Becker *et al.*, 1993). Publication of new faunal evidence with special emphasis on ammonoids herein gives the opportunity for taxonomic and stratigraphical discussions.

The time has come to proceed with the integration of globally assembled data. Available correlations of zones will be used here to establish briefly a holostratigraphical scheme for the latest Devonian to basal Carboniferous (Wocklumian, ud VI to Balvian = Lower Tournaisian, cu I). To a large extent it also builds on the reconstruction of sea-level changes by Bless *et al.* (1993) and on sequence stratigraphic approaches such as Van Steenwinkel (1993). Application to the Hasselbachtal Auxiliary Stratotype shows how well its sedimentary and faunal succession can be integrated in the global record of environmental and biotic changes around the boundary of the systems.

2. NEW FAUNAL RECORDS FROM HASSELBACHTAL

Intensive field work in the last six years has produced additional material from both the southern and northern slope of the brook cut which not only includes many completely new records for the section but also a new species of *Balvia*. By continued sampling in the Wocklum Limestone the ranges of previously recorded taxa were extended and records in intervening beds (e.g. Beds 12 and 14) illustrate that the current patchy record is mostly a collecting artefact. Generally it can be expected that still more species known from neighbouring sections along the Remscheid-Altena-Anticline also occur at Hasselbachtal. Remarkable is the present lack of any Glatziellidae. New material (housed in the Paleontological Institute of the Free University Berlin) collected since Becker (1988) consists of the following (Figs. 1 and 2):

Southern Slope Section

Bed 1
Rectimitoceras cf. *alternatum* Korn, SMF 51007 (det. cf. *globosum* in Becker, 1988)

Bed 8
Cyrtoclymenia ?lateseptata Schindewolf, Oc 1796 (no suture)

Bed 10
Cymaclymenia sp., Oc 1924/1-2
Kosmoclymenia sp., Oc 1925
orthocones indet., Oc 1926

Bed 12
Kosmoclymenia sp. indet., Oc 1872, 1889/1-2
Kosmo. (Muessenbiaergia) ?galeata (Wedekind), Oc 1890/1-3 (Pl. 2: 6 & 7)
Kosmo (Muess.) ?sublaevis sublaevis (Münster), Oc 1891 (no trace of ventral band on concave whorl zone)
Kalloclymenia sp., Oc 1873
Cyma. costellata (Münster), Oc 1871
Mimimitoceras cf. *liratum* (Schmidt), Oc 1892
prionoceratid indet, Oc 1874
?Arkonoceras sp., Oc 1894 (with lateral lobes; Pl.3: 13 &14; compare loose Oc 2016)
orthocones indet., Oc 1893/1-2
crinoid fragment, Os 36

Bed 14
Kosmo. (Kosmo.) undulata ssp., Oc 1897/1-3, 1876, 1898, ?1927
Kosmo. (Muess.) ?bisulcata colubrina (Lange), Oc 1877
Kallo. pessoides (v. Buch), Oc 1895
Kallo. cf. *subarmata* (Münster), Oc 1896/1-2
Cyrto. lateseptata, Oc 1900
?Cyrtoclymenia sp., Oc 1870
Cyma. cf. *striata* (Münster), Oc 1875/1-2, 1901/1-4 (with constrictions)
Cyma. cf. *costellata*, Oc 1903
Cymaclymenia sp. indet., Oc 1797/1-2, 1878, 1902
Mim. geminum Korn, Oc 1904, ?1928, 1929
Mim. ?liratum, Oc 1906

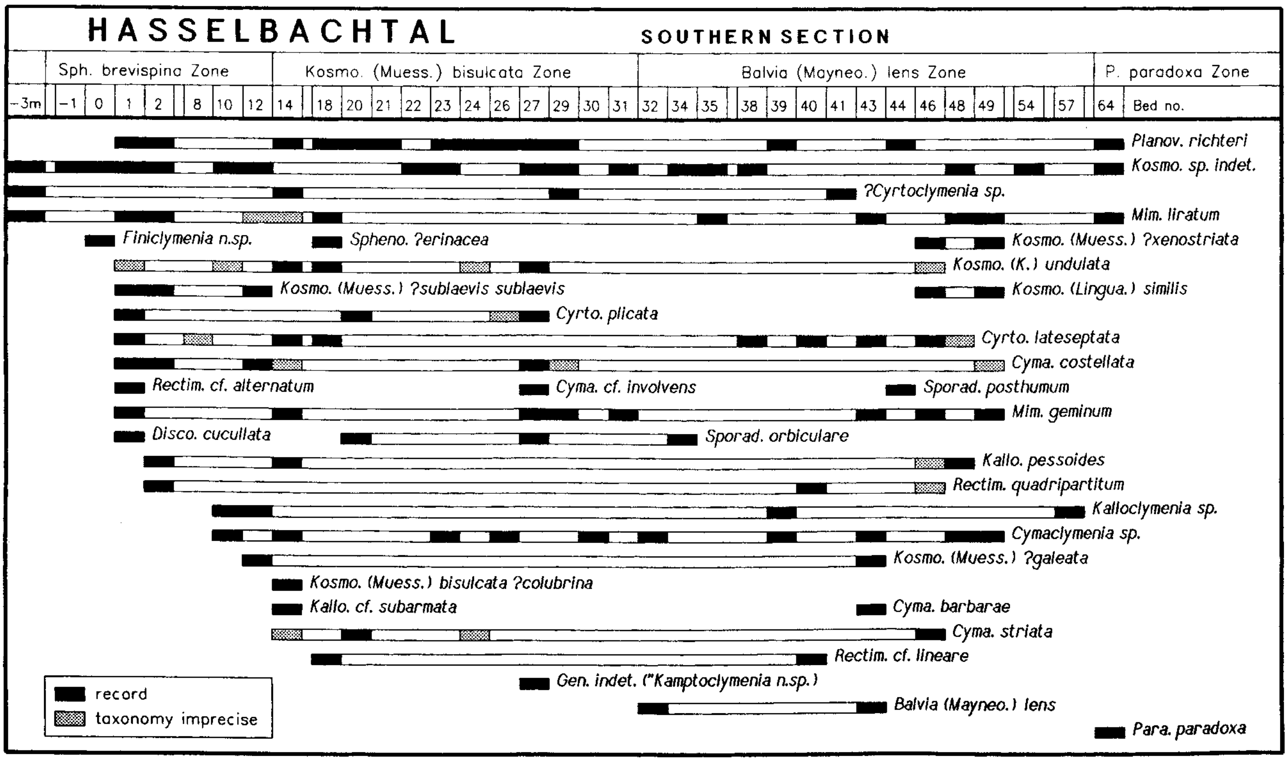

Figure 1. Ranges of ammonoids and important associated fossil groups in the southern slope succession. Lithological log see Becker (1988).

Mimimitoceras sp. indet., Oc 1905
orthocones indet., Oc 1908/1-2, 1930
breviconic nautiloid, Oc 1907/1-2
Planovatirostrum richteri (Oppenheimer) auct., Ob 70/1-3
Loxonema cf. *arcuata* (Münster), Og 9
Neaxon regulus (Rh. Richter), Ok 18 (given to D. Weyer)

Bed 16
orthocones indet., Oc 1922

Bed 20
Cyrto. plicata (Münster), Oc 1910
Sporadoceras orbiculare (Münster), Oc 1911
orthocones indet., Oc 1912
phacopid thorax indet., Ot 91
Planov. richteri auct., Ob 47, 71

Bed 21
Planov. richteri auct., Ob 72

Bed 22
Kosmoclymenia sp., Oc 1913

Bed 23
Planov. richteri auct., Ob 73

Bed 24
Cyma. ?striata, Oc 1914
Kosmo. (Kosmo.) ?undulata (Münster), Oc 1915
orthocones indet., Oc 1916
Planov. richteri auct., Ob 74

Bed 26
Cyrto. cf. *plicata*, Oc 2000 (with typical broad whorls)
Cymaclymenia sp. indet., Oc 2001/1-3
Planov. richteri auct., Ob 83/1-2

Bed 27
Cyrto. plicata, Oc 2002
Kosmo. (Kosmo.) undulata undulata, Oc 2003
Sporad. orbiculare, Oc 2004/1-2
breviconic nautiloid indet, Oc 2005
orthocones indet, Oc 2006/1-4

Bed 32
Cymaclymenia sp., Oc 1798
Balvia (Mayneoceras) lens Korn, Oc 1799 (Pl. 1: 8 & 9)

Bed 39
Cymaclymenia sp., Oc 1870
Kalloclymenia sp., Oc 1800
Planov. richteri auct., Ob 56

Bed 40
Cyrto. lateseptata, Oc 1778 (Pl. 2, Fig. 17-18)
Rectim. cf. *lineare* (Münster), Oc 1964 (loose around Bed 40)

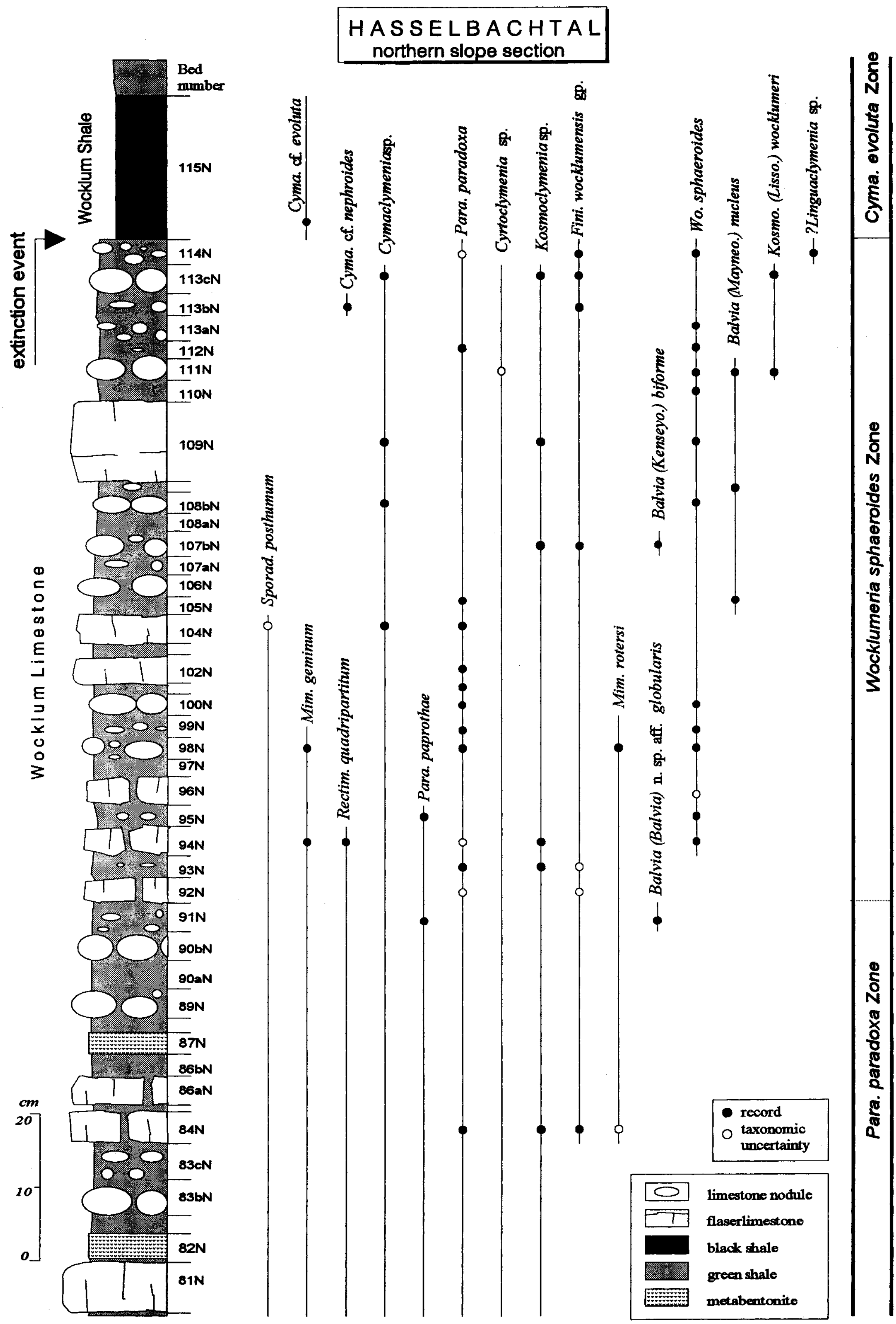

Figure 2. Ranges of ammonoids and important associated fossils in the topmost Devonian of the northern slope section.

Bed 43
Cymaclymenia sp., Oc 1803
Kosmo. (Muess.) ?galeata, Oc 1802
Mim. cf. *liratum* (Schmidt), Oc 1804
Mim. geminum juv., Oc 1805
Balvia (Mayneo.) lens, Oc 1801 (Pl. 1: 6 & 7)

Bed 44
Sporad. posthumum Wedekind, Oc 1806 (Pl. 2: 3 & 4)
Planov. richteri auct., Ob 48

Bed 46
Cyma. striata, Oc 1782/1-2
Cyrto. lateseptata, Oc 1783
Kosmo. (Kosmo.) ?undulata, Oc 1781/1-3
Kosmo. (Linguaclymenia) similis (Münster), Oc 1779 (Pl. 2: 13 & 14)
Kosmo. (Muess.) ?xenostriata Korn & Price, Oc 1780 (Pl. 2: 5)
Kallo. ?pessoides, Oc 1784/1-2
Mim. geminum, ?Oc 1807, 1785
Rectim. quadripartitum? (Münster), Oc 1807 (badly preserved)

Bed 49
Cyma. cf. *costellata*, Oc 1788
Cymaclymenia sp. indet., Oc 1789
Kosmo. (Lingua.) similis, Oc 1786
Kosmo. (Muess.) ?xenostriata, Oc 1787
Mim. liratum juv., Oc 1791
Mim. geminum juv., Oc 1790
orthocones indet., Oc 1909/1-2

Bed 54
Kosmoclymenia sp., Oc 1792

Bed 57
Kalloclymenia sp. (see Luppold *et al.*, 1994)

Northern Slope Section

In 1988, Korn (see Becker *et al.*, 1993; Luppold *et al.*, 1994) was able to dig out the upward continuation of the southern section and reached the top of the Wocklum Limestone (Bed 114) and the black Wocklum Shale (sensu Krebs, 1979; = Hangenberg Black Shale auct.) with *Cyma.* cf. *evoluta* (Bed 115) at the base of the Hangenberg Shale after additional 2.5 m. Soon after its excavation this important part of the section was covered again and will not be accessible in the near future. After degradation of the roots of the cut tree on the northern slope a complete section from the upper Wocklum Limestone to the basal Hangenberg Shale now can also be given (Fig. 2). By counting individual nodule layers and with the help of marker units such as bentonites and thick nodular limestones it was possible to transfer Korn´s bed numbering (based on an original log distributed to members of the IUGS D/C-Boundary Working Group which is more precise then the slightly simplified Fig. 3 in Luppold *et al.*, 1994). To allow a clear distinction an "N" will be added to northern slope beds. Since identical numbers have again partly been used in the Hangenberg Limestone (Becker *et al.*, 1984), beds above the Hangenberg Shale will be given the affix "H" in the future. New records are as follows:

Bed 83N
orthocone indet., Oc 1995

Bed 84N
Finiclymenia sp. (Lange), Oc 1931 (fragment with suture)
Kosmoclymenia sp., Oc 1932
Parawocklumeria paradoxa (Wedekind), Oc 1933
Mim. cf. *rotersi* Korn, Oc 1999 (ww/dm = 72.7 at 30 mm dm)

Bed 91N
Para. paprothae Korn, Oc 1935 (Pl. 2: 11 & 12)
Balvia (Balvia) n. sp. aff. *globularis* Schmidt, Oc 1934 (Pl. 3: 1-3)
prionoceratid indet., Oc 1936

Bed 92N
Parawocklumeria sp., Oc 1937
Wocklumeria sphaeroides (leg. D. Weyer)
Finiclymenia sp., Oc 1983

Bed 93N
Para. paradoxa, Oc 1938
Kosmoclymenia sp., Oc 1998
Finiclymenia sp., Oc 1997
orthocone indet., Oc 1996
part of crinoid stem, Os 37

Bed 94N
Kosmoclymenia sp. indet., Oc 1942/1-2
Para. cf. *paradoxa*, Oc 1941
Wo. sphaeroides Rh. Richter ssp., Oc 1943/1-4
Wo. sphaeroides aperta Schindewolf, Oc 1984
Mim. geminum, Oc 1940
Rectim. quadripartitum, Oc 1939
orthocones indet., Oc 1944/1-4
chonetid, Ob 75

Bed 95N
Wo. sphaeroides, Oc 1979/1-2
Para. paprothae, Oc 1980 (Pl. 2: 9 & 10)

Bed 96N
?Wo. sphaeroides, Oc 1978

Bed 98-99N, "*Parawocklumeria* Bed"
Wo. sphaeroides sphaeroides, Oc 1946/1-2

Para. paradoxa, Oc 1948/1-10
Mim. ?geminum, Oc 1947
Mim. rotersi, Oc 1945 (ww/dm 71.3 at 24 mm dm)
auloporid, Ok 19 (growing on a *Wocklumeria*)

Bed 100N
Wo. sphaeroides aperta Schindewolf, Oc 1949
Para. paradoxa, Oc 1982/1-4

Bed 101N
Para. paradoxa, Oc 1977

Bed 102N
Para. paradoxa, Oc 1950, 1976 (Pl. 2: 8)

Bed 104N
Cymaclymenia sp., Oc 1953/1-3 (with constrictions)
Para. paradoxa, Oc 1951
Sporad. cf. *posthumum*, Oc 1952

Bed 105N
Para. paradoxa, Oc 1955
Balvia (Mayneoceras) nucleus (Schmidt), Oc 1954 (Pl. 3: 4 & 5)

Bed 108bN
Cymaclymenia sp., Oc 1956
Wo. sphaeroides sphaeroides, Oc 1985/1-2

Bed 108cN
Balvia (Mayneo.) nucleus, Oc 1986

Bed 109N
Wo. sphaeroides sphaeroides, Oc 1974/1-3
Cymaclymenia cf. *striata*, Oc 1975
Kosmoclymenia sp. indet., Oc 1973
orthocone indet., Oc 1988

Bed 110N
Wo. sphaeroides sphaeroides, Oc 1987

Bed 111N
Wo. sphaeroides juv., Oc 1971/1-5
Kosmo. (Lissoclymenia) wocklumeri (Wedekind), Oc 1972
??*Cyrtoclymenia* sp. juv., Oc 1957
Balvia (Mayneo.) nucleus, Oc 1970/1-2
Hypsomyonia cf. *pauciplicata*. (Grünenberg), Ob 76/1-2

Beds 106N to 113N (= former collecting level from the upper Wocklum Limestone in Becker, 1988)
Para. paradoxa, Oc 1793/1-2, 1920
Wo. sphaeroides sphaeroides, Oc 1794 (Fig. 3a), 1917, 1958 (juv.)
Wo. sphaeroides plana Schindewolf, Oc 1795 (Fig. 3b)
Finiclymenia cf. *wocklumensis*, ?Oc 1919, 1959 (with slight marginal ribs)

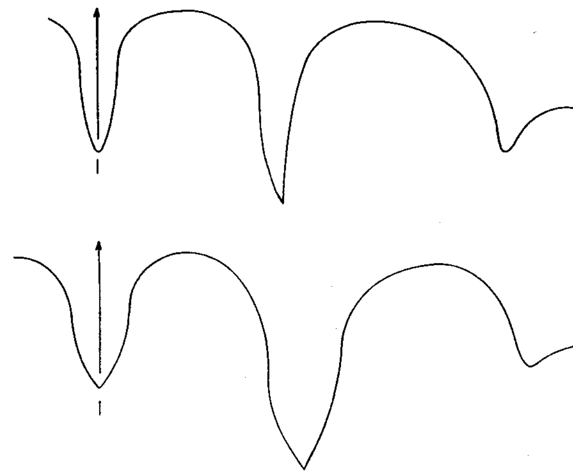

Figure 3. Comparison of outer sutures of *Wo. sphaeroides sphaeroides* (a; at ca. 22.5 mm dm, Oc 1794, reverted for comparison) and *Wo. sphaeroides plana* (b; at ca. 24 mm dm, Oc 1795) from the topmost Wocklum Limestone of the northern section.

Cyrtoclymenia sp., Oc 1918
Kosmoclymenia sp. indet., Oc 1869/1-2, 1879
crinoid ossicle, Os 32
Richterina (Richterina) striatula (Rh. Richter) (on shale surfaces)
Neaxon regulus, Ok 16 (given to D. Weyer)

Bed 110-114N
Wo. sphaeroides sphaeroides, Oc 2007/1-2
Mimimitoceras sp. indet., Oc 2008

Bed 112N
Wo. sphaeroides sphaeroides, Oc 1989, 1990
Para. paradoxa, Oc 1991

Bed 113aN
Wo. sphaeroides ssp., Oc 2010/1-3

Bed 113bN
orthocones indet., Oc 2009/1-3 (2009/1 with strong lateral sinus of growth lines as in *Pseudobactrites*)
?*Plicochonetes* sp., Ob 84; crinoid ossicle
Cryphops? wocklumeriae Richter & Richter, Ot 99
Cyma. cf. *nephroides* Korn, Oc 2018
Richterina (Richterina) striatula and other
Wo. sphaeroides sphaeroides, Oc, 2015/1-2

Bed 113cN
Kosmo. (Lisso.) wocklumeri, Oc 1992 (large fragment)
Cymaclymenia sp. indet., Oc 1993 (cross-section)

Bed 113
Wo. sphaeroides (see Korn in Luppold *et al.*, 1994)
Fini. cf. *woclumensis* (see Korn in Luppold *et al.*, 1994)

Bed 114N
Wo. sphaeroides, Oc 1994, ?1967
Parawocklumeria sp., Oc 1981
?*Finiclymenia* sp. juv., Oc 1968
Linguaclymenia sp., Oc 1966
Mimimitoceras sp. juv., Oc 1969/1-2
Haasia cf. *antedistans*, Oc 98
?*Buchiola* sp. indet., Ol 86

Bed 115N
Cyma. cf. *evoluta* (Schmidt), Oc 1960 (compare Korn in Luppold *et al.*, 1994)
prionoceratid indet., Oc 1961
orthocone indet., Oc 1962
Guerichia div. sp., Ol 82-83

Bed 85H
Ac. (Stockumites) sp. juv. (leg. Kürschner, pyritized ammonitellae)
Ac. (Stock.) cf. *subbilobatum* (Münster), SMF 51079/1 (see Becker, 1988: Fig. 6), questionable material from 40-50 cm below bed top, Geological Survey NRW
Ac. (Stock.) cf. *prorsum* (GS-NRW)
Acutimitoceras sp., WMfN P 17626 (see Korn in Luppold *et al.*, 1994: Fig. 4C), material GLA NRW Krefeld (40-50 cm below top, 9-11 cm below top)
Ac. (Ac.) cf. *acutum* (Schindewolf), WMfN P 17624 (see Korn in Luppold *et al.*, 1994: Fig. 4A)
juvenile orthocones (leg. Kürschner, pyritized)
?*Naticopsis* sp. (leg. Kürschner, pyritized)
"Oxydiscus cyrtolites" (Hall), WMfN P 17625 (see Korn in Luppold *et al.*, 1994: Fig. 4B)
Guerichia div. sp. (see Zakowa in Becker *et al.*, 1984)

Bed 83H
Guerichia div. sp.

Bed 82H
Guerichia div. sp. (abundant), e.g. Ol 84
"Spiriferina" tarpata Schmidt, Ob 78 (squoshed)
chonetids, Ob 77, 79
Semiproetus (Macrobole) funirepa gp. (common, given to R. Feist)
ostracods

Bed 81H
Acutimitoceras sp. indet., Oc 1963
Semiproetus (Macrobole) funirepa gp. (det R. Feist)
solitary rugose coral indet., Ok 20
Orbiculoidea sp.
"Spiriferina" tarpata, Ob 85 (Pl. 3: 15-19)
Guerichia div. sp., e.g. Ol 85 (common)
crinoid fragments, Os 38

Bed 73H
Ac. (Stockumites) sp. indet., Oc 1809
Gattendorfia sp. indet., Oc 1810/1-2
orthocones indet., Oc 1808

Old collections of A. Denckmann and H. Schmidt

The Museum für Naturkunde of the Humboldt University in Berlin keeps additional material which was collected by Denckmann as early as in 1904. Attached identifications were probably given subsequently by H. Schmidt and, in the case of trilobites, by the Richter couple. The fauna is as follows (number of specimens in brackets):

Cyma striata (2 + 1?)
Cyrto. ?inflata (Münster) (1, without suture; Pl. 3, Fig. 22-23)
Kosmo. (Kosmo.) ?undulata (1)
Kosmo. (Muess.) bisulcata ssp. (1)
Kalloclymenia sp. (det. "*Gonioclymenia biimpressa*", leg. H. Schmidt)
Mim. liratum (2, det. „*Aganides sulcatus*")
prionoceratid indet. (1, det. "*Aganides quadripartitus*")
orthocones indet.
breviconic nautiloid (det. "*Orthoceras angustiseptatum*")
Dianops griffithides (Rud. & E. Richter) (1 + 1?)
Helioproetus cf. *subcarintiacus* (Rud. Richter) (1)
Planov. richteri auct. (3, det. "*Liorhynchus subcurvatus*")

3. WOCKLUMIAN TO BALVIAN AMMONOID ZONATION

Wocklumian to Balvian ammonoid biostratigraphy was reviewed by Becker (1988) and recently by Korn (1993). A short review including latest updates was given in Luppold *et al.* (1994). However, in the Wocklumian there is still a lack of precisely documented taxon ranges and the pioneer work of Schindewolf (1937) still remains a major source of comparatitive data but which needs further revision. In this light the very detailed Hasselbachtal succession becomes a valuable additional data base for the current ammonoid chronology. An international genozone succession was introduced by Becker (1993a) but in the Rhenish Massive the application of the "standard zonation" is preferred. Generally it is recommended to name zones as far as possible after their defining species. This rule will be strictly followed here and is in agreement with the International Stratigraphic Guide (Hedberg, 1976) which recommends to use the most useful and not the oldest named biostratigraphic units. The straightforward correlation of a "transparent" nomenclature with Korn´s terminology is illustrated in Tab. 1.

Following the revision of Price & Korn (1989) the base of the Wocklumian (UD VI-A) is defined by the entry of *Sphenoclymenia brevispina* (Lange) which,

Table 1. Lithostratigraphy in the northern Rhenish Massif, chronostratigraphy and ammonoid zonations after Korn (1986, 1992a), Becker (1993a) and proposed herein.

		genozones (Becker, 1993a)		standard zones and subzones	zonation sensu Korn (1986,1992a)	lithostratigraphy Rhenish Massif
CARBONIFEROUS	Balvian	I-D	*(Paralytoceras)*	*Paragattendorfia patens*	*patens* Zone	Hangenberg Limestone
CARBONIFEROUS	Balvian	I-C	*Pseudarietites*	*Pseudarietites westfalicus*	*westfalicus* Zone	Hangenberg Limestone
CARBONIFEROUS	Balvian	I-B	*Paprothites*	*Paprothites dorsoplanus*	*dorsoplanus* Zone	Hangenberg Limestone
CARBONIFEROUS	Balvian	I-A	*Gattendorfia*	*Gattendorfia subinvoluta*	*Ac. acutum* Zone	Hangenberg Limestone
DEVONIAN	Wocklumian	VI-F	*Acutimitoceras*	*Ac. (Stockumites) prorsum* *Ac. (Stock.) subbilobatum*	? *prorsum* Zone	Stockum Limestone Hangenberg Shale and Sandstone
DEVONIAN	Wocklumian	VI-E	*Cymaclymenia*	*Cymaclymenia evoluta*	upper *paradoxa* Zone	Wocklum Shale (sensu Krebs)
DEVONIAN	Wocklumian	VI-D	*Wocklumeria*	*Wocklumeria sphaeroides*	upper *paradoxa* Zone	Wocklum Limestone
DEVONIAN	Wocklumian	VI-C	*Parawocklumeria*	*Parawocklumeria paradoxa*	lower *paradoxa* Zone	Wocklum Limestone
DEVONIAN	Wocklumian	VI-C	*Parawocklumeria*	*Parawocklumeria paprothae*	lower *paradoxa* Zone	Wocklum Limestone
DEVONIAN	Wocklumian	VI-B	*Balvia*	*Balvia (Mayneoceras) lens*	upper *subarmata* Zone	Wocklum Limestone
DEVONIAN	Wocklumian	VI-A	*Linguaclymenia*	*Kosmo. (Muess.) bisulcata*	upper *subarmata* Zone	Wocklum Limestone
DEVONIAN	Wocklumian	VI-A	*Linguaclymenia*	*Sphenoclymenia brevispina*	lower *subarmata* Zone	Wocklum Limestone

unfortunately, is a relatively rare species. Alternative index forms are obviously earliest representatives of *Kosmo. (Linguaclymenia)*, *Kosmo. (Kosmo.) undulata undulata* (see practice in Clausen *et al.*, 1989) and some prionoceratids (see Korn, 1992a). The boundary between the UD V and UD VI may be more easily recognizable by the complete disappearance of typical Dasbergian taxa, especially *Gonioclymenia*. The naming of the *Sph. brevispina* Zone as "Lower *Subarmata* Zone" by Korn (1986, 1993 etc.) is confusing since the name-giving taxon already occurs in the late Dasbergian (Simakov *et al.*, 1983; Price & Korn, 1989; Korn, 1993). New records of *Kalloclymenia* in the famous and much quarried *Gonioclymenia* Bed of the Tafilalt (Southern Morocco) confirm the idea that the entry of the genus is a suitable genozone marker for the topmost ammonoid zone of the UD V (see discussion in Becker, 1993a). The "standard" index species *Piriclymenia piriformis* (Schindewolf) of the UD V-C is still an endemic of the Rhenish Slate Mountains and therefore cannot be used for interbasinal comparison.

In the Rhenish Massive and possibly also in other regions a *Kosmo. (Muess.) bisulcata* Zone can be distinguished (Korn & Luppold, 1987; *Kosmo. galeata* is here regarded as a distinctive species).

The entry of *Balvia (Mayneo.) lens* Korn and related early *Balvia*-species (all without ventrolateral furrows) marks the beginning of the international UD VI-B (Becker, 1993a). This interval can be recognized in the Rhenish Slate Mountains, Thuringia (Bartzsch & Weyer, 1982), in the Moroccon Meseta (unpublished material from Ben Slimane), in the Mader of Southern Morocco and perhaps in further regions such as the Carnic Alps and Southern China. This level, which is also characterized by the entry of *Glatziella*, is recognized by Korn (1992a, 1993) as an upper subdivision of his "Upper *Subarmata* Zone".

Since revisionary work by Clausen *et al.* (1989a) the base of the Upper Wocklumian is defined by the first appearance of *Para. paprothae* and some other open umbilicate Parawocklumeriidae. In the Rhenish Slate Mountains, and probably also in the Carnic Alps (Korn, 1992b), the *Parawocklumeria* Genozone (UD VI-C) or "Lower *Paradoxa* Zone" sensu Korn can be subdivided into *Para. paprothae* and *Para. paradoxa* Subzones (see scheme in Luppold *et al.*, 1994). *Kamptoclymenia endogona* Schindewolf is a rare form and therefore not a very useful zonal marker. *Kosmo. (Lissoclymenia) wocklumeri* (Wedekind) enters already within the *Para. paradoxa* Subzone (Korn, 1993 contra Korn & Price, 1987).

The *Wo. sphaeroides* Zone (UD VI-D) equals the lower part of the "Upper *Paradoxa* Zone" sensu Korn (1986). *Epiwocklumeria applanata* Schindewolf has so far only been found at Oberrödinghausen and its possible restriction to the upper part of the *Wo. sphaeroides* Zone (Schindewolf, 1937) does not at present justify a subzonal distinction (compare Schindewolf, 1937; Luppold *et al.*, 1994). *Finiclymenia wocklumensis* cannot be used as an alternative marker for the level of *Wocklumeria* as suggested by data in Schindewolf (1937), Price & Korn (1989) and Korn (1993) but occurs already in the upper part of the *Para. paradoxa* Subzone. New Hasselbachtal material also proves an overlap of the range of *Para. paprothae* with its descendent *Para. paradoxa* (Bed 91N) and even with earliest *Wo. sphaeroides* (Bed 95N). *Balvia (Mayneo.) nucleus* and *Balvia (Kenseyoceras) biforme* (Schindewolf) are indicative of the latest *Para. paradoxa* and of the *Wo. sphaeroides* Zones. The naming of *Balvia nucleus* as marker for the UD VI-B in Becker (1993a) is based on a printing error. In the text the entry of the „*Balvia nucleus* group" is correctly quoted and this refers to all *Balvia (Mayneoceras)* in the definition used herein (see chapter 6.).

New material from neighbouring localities extends the ranges of some species. A well preserved *Mim. geminum* (Pl.2, Fig. 1-2) has been found in the uppermost part of the Wocklum Limestone (*Wo. sphaeroides* Zone) at Oese. In the Oberrödinghausen road section *Glatziella glaucopis* Renz was found in association with *Wocklumeria* and *Finiclymenia*. The extinction of *Glatziella* obviously coincided with that of most other clymenids.

As proposed by Becker (1988), the *Cyma. evoluta* Zone (UD VI-E) is defined by the extinction of most clymenids and goniatites at the top of the Wocklum Limestone. The same level is recognized in Korn's scheme as marker for the upper subdivision of his tripartite "Upper *Paradoxa* Zone" (Luppold *et al.*, 1994). Records of *Cyma. evoluta* in the topmost *Wo. sphaeroides* Zone (Korn, 1988) at Drewer show that the *Cyma. evoluta* Zone is only a partial range zone. At present no better index form is available from the black Wocklum Shale immediately overlying the last Wocklum Limestone bed. *Cyma. nigra* Korn has so far only been reported from levels above the *Acutimitoceras*-bearing Hangenberg Sandstone (Korn, 1991) and falls into the terminal Devonian part of the *Acut. prorsum* Zone (UD VI-F). The "*evoluta-prorsum*-Interregnum" was emphasized by Becker (1988) as provisionary level until better faunas from the main Hangenberg Shale become available. Objections by Clausen *et al.* (1989b) were therefore unjustified. In the meantime the presence of early (often indeterminate) *Acutimitoceras* in the Hangenberg Shale and Sandstone and their equivalents such as the Bedford Shale of Ohio (House *et al.*, 1986) or the "Upper Quarzit" of Thuringia has been accepted (e.g. House, 1993; Korn, 1993; Luppold *et al.*, 1994). These improvements of the faunal record make the interregnum obsolete. The oldest (Hangenberg and Bedford Shale) acutimitoceratids are probably related to *Ac. (Stock.) subbilobatum* (Luppold *et al.*, 1994) and this species may in the future replace *prorsum* as zonal index. *Ac. carinatum* enters also very early (in the Hangenberg Sandstone; Korn *et al.*, 1994).

A formal subdivision of the *Acut. prorsum* Zone which straddles the boundary is still not possible. Advanced acutimitoceratids such as *Acut. (Streeliceras) caesari* (Korn) and early oxyconic *Acutimitoceras* s.str. enter probably in the upper half of the zone. The somewhat doubtful *Acut. (Acut.) acutum* from Bed 85 at Hasselbachtal (Korn, 1993; in Luppold *et al.*, 1994) shows that the base of the traditional *Gattendorfia subinvoluta* Zone at the very base of the Hangenberg Limestone is better defined by the name-giving species. Alternative index forms are other species of *Gattendorfia*, the *Ac. (Stock.) antecedens* Group and first *Eocanites*. In the higher part of the Lower Tournaisian, Vöhringer's (1960) subdivision remains unchanged but as in Luppold *et al.* (1994) full zonal status is given to each of his levels.

4. HOLOSTRATIGRAPHY AROUND THE D-C BOUNDARY

In the last decade more than seventy D-C boundary sections and successions around the world have been studied in fine detail and available space does not allow their review here. For further data see this volume and quoted literature. Of special interest is recently published evidence on the presence of Hangenberg Event beds (s.l.) in the Polar Urals (Nemirovskaya *et al.*, 1993), in the Moscow Syncline (Alekseev *et al.*, 1994) and in Nova Scotia of Atlantic Canada (LN Zone conglomerates resting on Cambro-Ordovician; Martel *et al.*, 1993). The holostratigraphic scheme outlined has to be seen as a starting point since there is still insufficient integration of shallow-water and terrestrial successions as well as of fossil groups such as ostracods, microvertebrates, foraminifera and brachiopods which could lead to the recognition of additional widespread time markers. The estimated duration of 4-5 ma for the investigated period gives an average time discrimination in the order of 200 ka. This unusual precision (for the Paleozoic) can be significantly increased by the future recognition

Table 2. Correlation of ammonoid, conodont, trilobite and miospore stratigraphy and eustatic sealevel fluctuations around the Devonian-Carboniferous boundary showing the position of 23 holostratigraphic intervals. Hypoxic events are indicated by shading (Erd. = Erdbachian).

		ammonoid zonation	conodont zonation	miospore zonation	trilobite succession	eustatic and hypoxic events	holostr. interval
CARBONIFEROUS	Erd.	*Goniocyclus* sp.	*Siph. crenulata*	HD	*Liobolina nebulosa*	(shaded)	23
CARBONIFEROUS	Balvian	*Paragattendorfia patens*	*Siphonodella sandbergi*	HD	*Liobolina nebulosa*	Lower Alum Shale Event	22
CARBONIFEROUS	Balvian	*Pseudarietites westfalicus*	*Siphonodella cooperi* Morph. 1	- - - -	*Liobolina nebulosa*		21
CARBONIFEROUS	Balvian	*Paprothites dorsoplanus*	*Siphonodella cooperi* Morph. 1; *Siphonodella duplicata* Morph. 1	VI	*Liobolina submonstrans*		20, 19
CARBONIFEROUS	Balvian	*Gattendorfia subinvoluta*	*Siphonodella duplicata* Morph. 1; *Siphonodella sulcata*	VI	*Liobolina submonstrans*	Hangenb. Lst.	18, 17
CARBONIFEROUS / DEVONIAN	Balvian / Wocklumian	*Ac. (Stockumites) prorsum*	*Protognathodus kuehnei*; *Protognathodus kockeli*; Middle *praesulcata* Zone	VI / LN	*Belgibole abruptirhachis*	Stock. Lst.; Hangenb. Sdst	16, 15, 14, 13, 12, 11
DEVONIAN	Wocklumian	*Cymaclymenia evoluta*	Middle *praesulcata* Zone (extinction of *Pa. gonioclymeniae*)	LN	(faunal gap)	(shaded)	10, 9
DEVONIAN	Wocklumian	*Wocklumeria sphaeroides*	*Siphonodella praesulcata*	LE	*Chaunoproetus palensis* etc.	Hangenberg Black Shale Event	8, 7
DEVONIAN	Wocklumian	*Parawocklumeria paradoxa*	*Siphonodella praesulcata*	LE	*Chaunoproetus palensis* etc.		7, 6
DEVONIAN	Wocklumian	*Parawocklumeria paprothae*	*Siphonodella praesulcata*	LE	*Chaunoproetus palensis* etc.		6, 5
DEVONIAN	Wocklumian	*Balvia (Mayneoceras) lens*	*Siphonodella praesulcata*	LE	*Chaunoproetus palensis* etc.	(legend: ← regression, → transgression)	5, 4
DEVONIAN	Wocklumian	*Kosmo. (Muess.) bisulcata*	Upper *expansa* Zone	LL			3
DEVONIAN	Wocklumian	*Sphenoclymenia brevispina*	Upper *expansa* Zone (with *Pseudopolygnathus marburgensis trigonicus*)	LL		Strunian transgression	2, 1

of Milankovich Cycles which are well manifested in the shale-nodular limestone rhythmicity of pelagic facies (compare Thuringian sections of Bartzsch & Weyer, 1982). The following holostratigraphic levels are currently recognizable (starting in the late Famennian; compare Bless *et al.*, 1993; Tab. 2):

1. Entry of *Sphen. brevispina, Linguaclymenia* etc. and extinction of typical Dasbergian ammonoids at the base of the Wocklumian (UD VI). The start of the "Strunian transgression" has been correlated with the base of the Wocklum Limestones (Dreesen *et al.*, 1989). The earliest appearance of *Pseudopolygnathus marburgensis trigonicus* Ziegler seems to be useful to recognize the base of the Wocklumian in conodont successions (e.g. Clausen *et al.*, 1989b; Luppold *et al.*, 1994) but the species sometimes enters much later (e.g. Kürschner *et al.*, 1993).

2. Entry of *Kosmo. (Muess.) bisulcata*. *Protognathodus meischneri* Ziegler may appear at about the same time but a more precisse correlation has to await additional data (e.g. the fixing of the base of the *Kosmo. (Muess.) bisulcata* Zone at Oberrödinghausen).

3. Entry of *Siphonodella praesulcata* Sandberg.

4. Entry of *Balvia (Mayneoceras)* and *Glatziella.*

5. Entry of *Para. paprothae* and other open umbilicate "triangular clymenids" (*Triaclymenia, Kamptoclymenia*). This level still needs much better documentation in Wocklum Limestone successions.

6. Entry of *Para. paradoxa*. The earliest occurences of *Fini. wocklumensis* and *Kosmo. (Lisso.) wocklumeri* may allow the recognition of an upper subdivision.

7. Entry of *Wo. sphaeroides.*

8. Final extinction of *Palmatolepis gonioclymeniae* Müller at an interval of increased shallowing leading to increased condensation and rare sandstone intercalations with the first *Cyma. evoluta.* Correct recognition of the Middle *praesulcata* Zone seems to require very careful search for this often rather rare faunal element (see discussion in Kürschner *et al.*, 1993). *Epiwo. applanata* appears at Oberrödinghausen above the last *Pa. gonioclymeniae.*

9. Extinction of almost all goniatites, clymeniids, trilobites, many conodonts, deep-water Rugosa and other faunal groups (e.g. *Maternella hemisphaerica* (Rh. Richter) among entomozoaceans) at the

change from (Wocklum) limestone to hypoxic or anoxic shale (Hangenberg Black Shale Event). The transgressive pulse led to the spread of opportunistic *Cyma.* cf. *evoluta* in the otherwise neritic succession of the Ardenne Shelf and Velbert Anticline. Recently, the LN Zone has been recognized in mixed miospore assemblage of the Wocklum Shale (= Hangenberg Black Shale; Higgs & Streel, 1995).

10. Start of a major global eustatic fall causing reworking, sedimentary gaps and the basinward discharge of clastic sediments such as the Hangenberg and Bedford Shales and of the lower part (Beds 70-80) of the La Serre oolites. Miospore floras of the LN Zone are typical at this level (e.g. Coleman & Clayton, 1987; Bless *et al.*, 1993).

11. Peak of regression, marked by the incoming of coarse detritus such as the Hangenberg Sandstone, Seiler Conglomerate, Berea Sandstone of North America, thick quartzites of Southern and Hercynian Morocco, the Upper Quarzite of Thuringia, and the siliciclastic-calcareous unit (Beds 81-84) at La Serre. Approximately in this interval falls the occurence of earliest *Acutimitoceras* (*Ac. (Stock.).* cf. *subbilobatum* and *Ac. carinatum*).

12. Latest Devonian transgression and hypoxic event causing a second spreading of ammonoids into shallow-water areas (e.g. Moravia, Kalvoda & Kukal, 1987; Kolyma Basin, Gagiev & Kononova, 1990; Louisiana Limestone of Missouri; SW England, Matthews, 1983). The entry of *Protogn. kockeli* (Bischoff) characterizes the "Lower *Protognathodus* fauna" which may be associated with acutimitoceratids including oldest *Ac. (?Sulc.) prorsum, Ac. (Streeliceras)* and youngest cymaclymeniids. Carboniferous-type trilobites such as *Belgibole abruptirhachis* (Richter & Richter) and various *Semiproetus (Macrobole)*, Carboniferous-type ahermatypic rugose corals (Weyer, 1994) and Carboniferous-type ostracods (G. Becker *et al.*, 1993) begin to radiate.

13. Miospore extinction at the boundary between LN and VI Zones. Deposition of the famous Stockum Limestone of the type locality began at this time (Clausen *et al.*, 1994).

14. Minor regression immediately at the Devonian-Carboniferous boundary (defined by the entry of *Siph. sulcata*) leading to shale or oolite deposition (unit 10 in Bless *et al.*, 1993; La Serre: top of Bed 88 to Bed 89)

15. "Upper *Protognathodus* faunas" with *Protogn. kuehnei* Ziegler & Leuteritz, *Polygnathus purus purus* Voges and *Pseudopolygnathus primus* Branson, but very poor in siphonodellids. This level is again characterized by rich acutimitoceratid faunas. A single last *Cymaclymenia* has been found at Müssenberg (Korn, 1989). The presence of *Siph. sulcata* can only rarely be proven, e.g. in Bed 3A at Muessenberg (= "3 unten" at Section 4; Luppold *et al.*, 1984), at Oese (Luppold *et al.*, 1994) and at Berchogur (sample 3/5; Barskov *et al.*, 1984).

16. Minor regression leading to shale deposition and erosion of the Stockum Limestone interval (= interval 12-14 herein; e.g. at Oberrödinghausen).

17. Second post-extinction adaptive radiation of ammonoids during the gradual transgression at the base of the Hangenberg Limestone: first entries of *Ac. (Stock.) antecedens* Gp., *Gattendorfia* and *Gattenpleura*. The conodont biofacies returns to faunas with more abundant siphonodellids and trilobite assemblages with *Liobolina submonstrans* Richter & Richter appear (Leuschner, 1994).

18. Entry of earliest *Eocanites nodosus* Group (Becker, 1993b), followed by *Siphonodella duplicata* (Branson & Mehl) Morphotype 1 (defining the base of the Lower *duplicata* Zone), *Nicimitoceras* s.str. and *Voehringerites*.

19. Entry of *Paprothites* and *Glob. globiforme* Vöhringer, followed by oldest *Paragattendorfia*.

20. Entry of *Siph. cooperi* Hass Morphotype 1, *Siph. duplicata* sensu Hass and *Siph. carinthiaca* Schönlaub which characterize the Upper *duplicata* Zone.

21. Entry of *Pseudarietites*, the *Eoc. supradevonicus* Group, *Gatt. crassa* (slightly later) and first trilobite assemblages (Brauckmann *et al.*, 1993) with (amongst others) *Liobolina nebulosa* (Richter & Richter).

22. Entry of *Siph. sandbergi* and *Paragattendorfia patens* Vöhringer; extinction of *Pseudarietites.*

23. Extinction of practically all remaining Lower Tournaisian goniatite species at the boundary between *Siph. sandbergi* and *Siph. crenulata* Zones (transgressive and hypoxic Lower Alum Shale Event of Becker, 1993b).

5. HOLOSTRATIGRAPHIC DATING OF THE HASSELBACHTAL SUCCESSION

New samples and data supplied recently by other authors (e.g. Kürschner *et al.*, 1993; Higgs *et al.*, 1993) have improved the dating of many levels of both Hasselbachtal sections. Nineteen of the distinguished holostratigraphic levels can be currently recognized with various precision.

1. The base of the Wocklumian is not yet precisely placed on the southern slope but *Finiclymenia* n.sp. (= *Kalloclymenia* n.sp. in Becker, 1988) from Bed 0 is closest to *Fini. pachydiscus* from Kia (southern Urals) from the latest Dasbergian. The base of the UD VI is to be expected somewhat below Bed 0. Beds 1 and 2 have typical Wocklumian forms (Schindewolf, 1937; Korn & Price, 1987; Korn, 1994) such as *Mim. geminum*, *Rectim.* cf. *alternatum*, *Kosmo. (Kosmo.) ?undulata* and *Kallo. pessoides* (used here for partly ribbed forms with ww > wh).

2. Based on a single fragment, the *Kosmo. (Muess.) bisulcata* Zone is recognized in Bed 14. The presence of the index species (and zone) at Hasselbachtal is confirmed by a loose specimen in the Denckmann Collection.

3. *Siph. praesulcata* was first found in Bed 18, in the same position within the overall faunal sequence as at Oberrödinghausen (Kürschner *et al.*, 1993) or at Müssenberg (Clausen *et al.*, 1989a). In the light of the revision of Price & Korn (1989) the compressed "*Kallo.* cf. *wocklumensis*" from Bed 18 now has to be referred questionably to *Spheno. erinacea* Price & Korn (or to another unknown similar species). The same probably applies to a *Kallo.* cf. *wocklumensis* mentioned by Korn (in Clausen *et al.*, 1979) from the lower Wocklumian of the Warstein area. *Kamptoclymenia* n.sp. from Bed 27 is too badly preserved to allow any reliable stratigraphical conclusions and, based on its compressed whorl profile, may belong to a different genus. Korn's (1994) opinion that the suture is that of a juvenile *Kalloclymenia* is not accepted. Available kalloclymeniids of the same size already have fully elaborate sutures and the slight corrosion of the specimen cannot account for the observed difference. Reported specimens of *Wo. sphaeroides* and *Para. paradoxa* from Bed 31 were collected from weathered rock right above the outcropping nodule layer on the top part of the slope. In the present morphological situation downslope or downstream transport could be excluded. The revised higher sequence as discussed below, however, suggests that this material must have been derived in subrecent time from outcrop which is now completely eroded.

4. The base of the *Balvia (Mayneo.) lens* Zone can be placed at Bed 32. Higher parts of the zone (Beds 48 and 57; see Pl. 3, Fig. 20-21) so far gave the youngest representatives of *Kalloclymenia*.

6. The earliest *Parawocklumeria* from Bed 64 has already a practically closed umbilicus (Becker, 1988: Pl. 1, Fig. 7) and indicates therefore the *Para. paradoxa* Subzone. The specimen was collected in situ and there is no reason to assume that it was loose (Korn, 1994). A higher level with *Finiclymenia* lies above the second bentonite (Bed 82N) which, as with the other volcanic marker layers, is not marked well in Korn's (1994) illustration of the upper part of the southern slope section.

7. The base of the *Wo. sphaeroides* Zone is currently placed at the base of Bed 92N (above the third Wocklumian bentonite marker Bed 87N) and the species is more common slightly higher in Bed 94N.

8. The Middle *praesulcata* Zone was identified by Stoppel (in Becker *et al.*, 1984) and Kürschner *et al.* (1993) in the top 20 cm of the Wocklum Limestone (= Beds 109N to 114N). Ostracod faunas with only *Richterina* belong to the *Hemisphaerica-Latior*-Interregnum. A shale unit within the upper half of the *Wo. sphaeroides* Zone (probably around Bed 107N which includes the thickest shale) yielded an LE Zone miospore flora (Higgs & Streel, 1984). Shallowing is indicated by facies change from mudstones to more fossiliferous, crinoid-rich and brachiopod-bearing bioclastic wackestones (e.g. Beds 113bN, 114N) which contain oculated phacopids (*Cryphops*?) and proetids (*Haasia*). Both genera are recorded here for the first time from the Letmathe area (see review of regional trilobite faunas by Becker & Schreiber, 1994).

9. The black shale with *Cyma.* cf. *evoluta* is well-developed both in the southern (now covered) and northern section (Bed 115N). Updating earlier results (e.g., in Becker et al., 1984), Higgs & Streel (1995) recognize the LN Zone now already in mixed assemblages of the black shale.

10-11. Significant shallowing is documented by the thick wedge of typical, unfossiliferous, green Hangenberg Shale. A peak of regression is not distinctive and hence there is no clear sequence boundary developed.

12. Bed 85 represents a minor deepening and hypoxic event causing pyritic preservation of juvenile *Acutimitoceras*, orthocones and gastropod faunas. Among other acutimitoceratids, flattened material rarely included the index form of the *Ac. prorsum* Zone (specimen with typical biconvex constrictions on the flanks). Correlation with Upper *praesulcata* Zone faunas is indirectly shown by latest LN Zone floras.

13. The boundary between LN and VI miospore zones is precisely placed at 14 cm below the top of Bed 85H (Higgs & Streel, 1984). The single record of *Ac. (Ac.)* cf. *acutum* by Korn (1994) came from

Table 3. Thickness comparison of latest Devonian stratigraphical intervals between Hasselbachtal, Oberrödinghausen and Müssenberg.

Stratigraphical interval	**Hasselbachtal**	**Oberrödinghausen**	**Müssenberg**
Sph. brevispina Zone			ca. 150 cm
Kosmo. (Muess.) bisulcata Zone	ca. 80-90 cm	within ca. 140 cm of the lowest UD VI	ca. 110 cm
Balvia (Mayneo.) lens Zone	< 100 cm	83 cm	ca. 80 cm
Para. paradoxa Zone	170 cm	ca. 110 cm	107 cm
Wo. sphaeroides Zone	ca.80 cm	80 cm	ca. 60 cm
Lower *Praesulcata* Zone to top Wocklum Limestone	400 cm	300-315 cm	285 cm

above (10 cm below Bed 84) and therefore postdates slightly the Stockum Limestone goniatite faunas from the type area described by Korn (1984) and Clausen *et al.* (1994) which is from below the first VI zone floras (Clausen *et al.*, 1994).

14. Immediately at the D-C-boundary the turbiditic and oolitic Bed 84H with *Siph. sulcata* and *Protogn. kuehnei* indicates a minor regressive episode.

15. "Upper *Protognathodus* faunas" characterize Beds 83H to 81H (the latter also with *Po. purus purus*). Ecostratigraphic correlation with parts of the Stockum Limestone of Schmidt (1924) is indicated by the presence of *"Spiriferina" tarpata* (resembling *Brachythyris*). Trilobite faunas with *Belgi. abruptirhachis* and *Semiproetus (Macrobole) funirepa* gp. are also characteristic.

16. A minor shallowing interval is only tentatively indicated by shales of Bed 80H and the bentonite (Bed 79H) which yielded the radiometric date of 353 ma 4.0 ma (Claoué-Long *et al.*, 1992).

17. The specimen of *Acut. (Stock.)* cf. *antecedens* reported by Becker (1988; cf. added due to its bad preservation) from Bed 78H gives clear evidence for the *Gatt. subinvoluta* Zone. The change from protognathid to more *Siphonodella*-rich conodont faunas is well developed (Kürschner *et al.*, 1993) and *Siph. praesulcata* is still present pointing to a still relatively low position in the *sulcata* Zone.

18. The base of the Lower *duplicata* Zone falls into the interval of Beds 77H to 72H. The *Gattendorfia* sp. from Bed 73H have probably still a latest *subinvoluta* Zone age.

20. The Upper *duplicata* Zone is recognized first in Bed 67H (Stoppel in Becker *et al.*, 1984). Korn (1994) neglected the earlier published presence of several goniatites such as *Ac. (Stock.) intermedium* (Bed 57H) in the Hangenberg Limestone.

21. The *Pseud. westfalicus* Zone has tentatively been identified by a questionable *Eoc. spiratissimum* in Bed 55H (Becker *et al.*, 1984). The *Gatt. crassa* Schmidt described by Schmidt (1924) from Hasselbachtal ("Henkhausen") as "*Aganides* n.sp." (Weyer, 1965: 447) gives further evidence for the local presence of ammonoid faunas of the *Pseud. westfalicus* Zone. *Siph. cariantiaca* occurs above Bed 49H (Claoué-Long *et al.*, 1992), but this level could still belong to the Upper *duplicata* Zone. Currently there is no evidence for the *Paragattendorfia patens* or *Siph. sandbergi* Zones.

23. The transition from the Hangenberg Limestone to the overlying Lower Alum Shale Formation was observed in the Hasselbachtal Well (Luppold *et al.*, 1994).

The following Kieselkalk is well exposed in a series of still unstudied old quarries to the North and NW and in a roadcut to the NE. The only macrofauna which has been found so far are rare crinoid ossicles (Os 30) and tiny chonetids (Ob 41).

The new dating of many beds now allows a comparison of thicknesses of individual ammonoid zones of the Wocklum Limestone with neighbouring localities such as Oberrödinghausen (Schindewolf, 1937), and Müssenberg (see Luppold *et al.*, 1994). Measurements are surprisingly similar but Hasselbachtal has the largest thickness, e.g. for the interval from the base of the Lower *Praesulcata* Zone to the top of the Wocklum Limestone. In detail, however, this difference is mostly based on two rather thick shaly intervals within the *Para. paradoxa* Zone (Beds 76 and 72 of the southern slope) which alone account for a difference of about 70 cm. For further comparison see Tab. 3.

6. TAXONOMY

Abbreviations. Dm = diameter, uw = umbilical width, wh = whorl height, ah = apertural height, ww = whorl widths, A = adventitious lobe, MNHU = Museum für Naturkunde der Humboldt-Universität, SMF = Forschungsinstitut Senckenberg, BSPHG = Bayrische Staatssammlung für Paläontologie und Historische Geologie.

Kosmoclymenia Schindewolf

Following the revision of Korn & Price (1987) the identification of kosmoclymenids not showing their sculpture has become very difficult. The Hasselbachtal collections include only few specimens with growth-lines and ventral band preserved (e.g. Oc 1876, 1898). Internal moulds can only tentatively be referred to species based on certain morphological criteria (cross-section, umbilical width, development of longitudinal furrows) in combination with the known stratigraphical age. Small-sized linguaclymenids are easy to recognize and there are two *Kosmo. (Lingua.) similis* from the southern slope (e.g., Pl. 2: 13 & 14). Specimens (and fragments, e.g. SMF 51003/1, 51029/1, 51018) with flattened flanks, an uw/dm-ratio of ca. 50 % and a venter which does not become flattened before ca. 70 mm dm probably belong to *Kosmo. (Kosmo.) undulata* and this seems to be the most common species. The closely related *Kosmo. (Kosmo.) parundulata* Korn & Price differs (as internal mould) only by its earlier (at 40-50 mm dm) tabulate ventral side. A few specimens (SMF 51003/2, 51012/1 and Oc 1802) have relatively narrow umbilici and rounded venters and are referred with reservation (?) to *Kosmo. (Muess.) sublaevis sublaevis*. In the younger *Kosmo. (Kosmo.) schindewolfi* Korn & Price flanks are rounded, not flattened. Two small specimens (e.g., Pl. 2: 5) are very evolute and have already oval cross-section as in *Kosmo. (Muess.) xenostriata*. However, there is the chance of some diagenetic distortion of the lateral sides. In the moderately evolute (< 50 % dm) *Kosmo. (Muess.) galeata* the venter becomes tabulate at ca. 35 mm dm. Three fragments (Oc 1890/1-3) from Bed 12 show somewhat similar whorl form (e.g., Pl. 2: 6 & 7). In the presence of a concave lateral body chamber constriction, however, they are more similar to the Dasbergian *Kosmo. (Muess.) inaequistriata inaequistriata* (Münster) and *Kosmo. (Muess.) sublaevis diversa* Korn & Price. A single fragment from Bed 14 (Oc 1877) shows the typical keel of *Kosmo. (Muess.) bisulcata colubrina* (Lange) at 10 mm wh.

Cyrtoclymenia Hyatt

Currently there are three species of *Cyrtoclymenia* at Hasselbachtal and *Cyrto. lateseptata* is the dominating form which was well illustrated in the northern Rhenish Slate Mountains by Schmidt (1924) under the name of *Cyrto. lata* (Münster; see Becker, 1988). There is no possibility to confuse this species with any other described contemporaneous cyrtoclymenid and *Cyrto. angustiseptata* is completely lacking in available faunas. Korn's view (in Luppold *et al.*, 1994) that the Hasselbachtal material is unidentifiable is not followed. The best preserved new specimen (Oc 1778, Pl. 2: 17 & 18) shows widely spaced, weak and slightly prorsiradiate, straight ribs around the umbilicus. As illustrated by Schmidt (1924), the growth lines are more or less rectiradiate and possess a high ventrolateral and a lower, rather short, subumbilical salient (see Pl. 2: 15 & 16). In this resepect the apertural margin differs significantly (as in most *Cyrtoclymenia* s.str.) from the earlier (Hembergian) *Cyrto. involuta* Group. This distinction should be recognized taxonomically (Becker, 1992). The *Cyrto. pinnata* Group is better placed in *Protactoclymenia* Wedekind. The search for type material of Schindewolf's species at Marburg was unsuccesful. Consequently a neotype from the Saalfeld region has to be designated. A convolute clymenid with subrectangular whorl profile, collected by H. Schmidt in 1909 (MNHU c.1217), has shell parameters (51.7 mm dm, 20.8 mm wh, 20 mm ww = 38.7 % dm, uw 17.5 mm = 33.8 % dm, wh/ww = 1.04) which are similar to the lectotype (designated herein as BSP AS VII 536) of *Cyrto. inflata* (Münster). The umbilical shoulders show widely spaced weak ribbing (Pl. 3: 22 & 23).

Balvia Lange

As stated in the original diagnosis of Lange (1929) and as is evident in the revision of Korn (1994), the type species, *Balvia globularis,* is characterized by evolute inner whorls while all other species described so far have closed (punctiform) umbilici throughout ontogeny. In the case of other prionoceratid groups this feature serves to distinguish genera or even subfamilies. The discovery of a second species that keeps an open umbilicus even in the adult shows that there is an evolutionary lineage leading to increasingly evolute forms which was eliminated by the Hangenberg Event. Proterogenetic shell evolution in the Prionoceratidae was evidently not restricted to the post-event phase of adaptive radiation.

Selwood (1960) placed involute species which are currently (Korn, 1992a, 1994) included in *Balvia* in his new *Kenseyoceras* and *Mayneoceras*. New rich collections from Launceston/Cornwall fully confirm Selwood's taxonomic concepts. Both his taxa can be recognized at least at the subgeneric level. *Mayneoceras* comprises the majority of species with regularly spaced constrictions and episodically developed parabolic ears throughout ontogeny. Ventrolateral furrows developed later independently in strongly compressed, tegoid/suboxyconic (*lens*), subglobose (*minutulum* Korn - *obesum* Ruan) and compressed (*falx* Korn - *nucleus*) forms. *Kenseyoceras* differs markedly by its strongly biform shell with an extended imitoceratid-type early stage (Selwood, 1960). Constrictions are lacking completely until the adult where a single constriction marks the starting point for the formation of a strong keel and ventral rostrum (Pl. 3: 6 & 7). The contrast between juvenile and adult shells somewhat resembles the characteristic ontogenetic development in *Prolobites* which is taken here as the ancestor of all Prionoceratidae (see Wedekind, 1913). A typical representative of *Kenseyoceras* has been referred by Korn (1994: Fig. 24E) to adult *Balvia (Balvia) globularis* in which, however, constrictions are always present (his Fig. 24D on the other side is not a *Kenseyo. biforme* SCHINDEWOLF).

Balvia (Balvia) n.sp. aff. *globularis* Lange
Pl. 3: 1-3

Description. The only available specimen is a partly corroded mould which does not display the suture. The conch is very thickly discoidal with broad subrectangular whorls. The wide venter is gently curved, the umbilical wall well-rounded. At 12 mm diameter the still widely open umbilicus becomes gradually closed by overlap of the last half whorl over the umbilical opening. There are four very irregularly spaced, sinuouse constrictions which first form relative low ventrolateral salients. From ca. 11 mm dm on a very pronounced but flat keel appears rather suddenly.

Dimensions. Oc 1934: 12 mm dm, 4.8 mm wh, 1.6 mm ah, 2 mm uw; 10 mm ww, wh/dm = 0.4, ah/dm = 0.133, uw/dm = 0.167, ww/dm = 0.833.

Remarks. In *Balvia (Balvia) globularis* the umbilicus closes much earlier and at the same size there is only a punctiform opening left (Korn, 1994). Additionally the keel is much less prominent. In this respect the Hasselbachtal specimen shows some homoeomorphy to *Glatziella glaucopis* Renz. Due to the bad preservation of the only available specimen open nomenclature is applied.

Balvia (Mayneoceras) lens Korn
Pl. 1: 6-9

Material. Oc 1801 (Pl. 1: 6 & 7) and Oc 1799 (Pl. 1: 8 & 9), *Balvia (Kens.) lens* Zone (UD VI-B) = upper part of „Upper *Subarmata* Zone" sensu Korn (1986).

Description. Oc 1801 is a complete, slightly weathered mould with strongly converging outer flanks which give a lenticular cross-section. The aperture is very low. There are three constrictions which run almost straight across the inner parts of the whorl and which bend sharply forwards at the flank margin. They smooth out without the formation

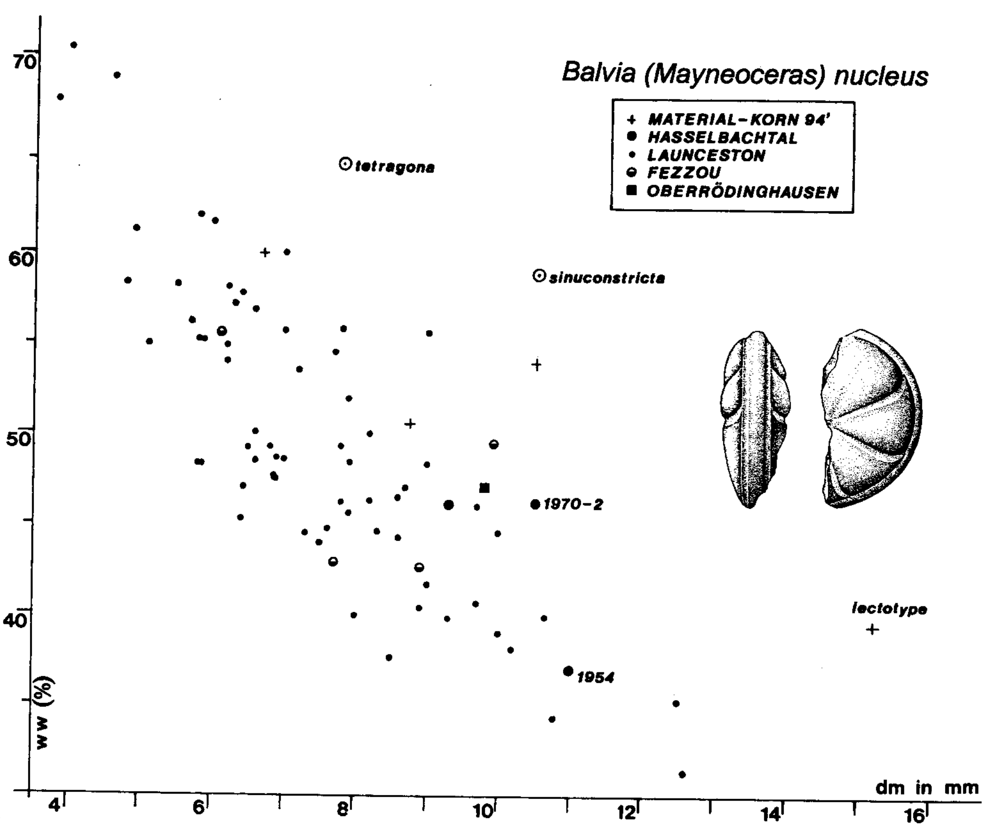

Figure 4. Intraspecific variability of relative whorl width in *Balvia (Mayneoceras) nucleus* based on a large population from Launceston (Cornwall) on material from the Rhenish Slate Mountains (specimens figured by Korn, 1944, a specimen from Oberrödinghauisen, new Hasselbachtal collections leg. Becker & Weyer) and on a few specimens from Fezzou (Maider, Southern Morocco; leg. Ebbighausen). Types of *Balvia tetragona* and *sinuconstricta* are plotted for comparison.

of longitudinal grooves and do not cross the venter. The A-lobe appears to be rounded but the smaller Oc 1799 is less eroded and possesses a bell-shaped, pointed lobe on the flank. The ventral lobe is very deep and lanceolate.

Dimensions. Oc 1801: 16 mm dm, 8.8 mm wh, 3 mm ah, 6.2 mm ww, wh/dm = 0.55, ah/dm = 0.188, ww/dm = 0.388; Oc 1799: 10.5 mm dm, 5.6 mm wh, 2 mm ah, 4.5 mm ww, wh/dm = 0.553, ah/dm = 0.19, ww/dm = 0.423.

Remarks. Extreme compression and the lack of ventrolateral furrows in the adult are different from typical *Balvia (Kens.) lens* as described by Korn (1992a, 1994). Observations on the wide intraspecific variability of *Balvia (Mayneo.) nucleus*, however (see below), suggest that it is wise not to put too much weight on such differences. Until the variability of the species is better understood, the more compressed morphotypes which occur at Hasselbachtal are not seperated taxonomically.

Balvia (Mayneoceras) nucleus (Schmidt)
Fig. 3, Pl. 3: 4 & 5

Remarks. Oc 1954 from Bed 105N is extremely compressed and its ww/dm ratio of only 0.37 at 11 mm dm differs significantly from the dimensions and illustrations of five specimens from various localities given by Korn (1994). More closely related forms have been illustrated by Selwood (1960: especially Pl. 28: 17) from Cornwall and by Petter (1959: Fig. 57) from North Africa. The revision of *Balvia* by Korn (1992a, 1994) lacks data on intraspecific variability, and he gave too strict shell parameter figures in his species diagnosis. A large population of *Balvia. (Mayneo.) nucleus* from Launceston (Fig. 4) illustrates the significant variation in absolute and relative shell thickness ranging from extremely compressed to thickly discoidal forms. The general shell shape with flat flanks remains constant. However, both *Balvia tetragona* Lange and *sinuconstricta* Selwood lie well outside the main field of variation. *Balvia tetragona* is regarded as valid species. All specimens from Hasselbachtal fall in the range of variability of the Cornwall population.

Rectimitoceras n.gen.

Derivation of name. Since this is the group which Schindewolf (1923) had mostly in mind when he introduced *Imitoceras*.

Type-species: *Goniatites linearis* Münster, 1832; see revision in Korn (1994); compare Fig. 5.

Diagnosis. Compressed to subglobose, involute throughout ontogeny, median and adult stages without shell constrictions, internal shell thickenings do not cause a regular shell tripartition or are completely absent: brevidomic, ventral lobe lanceolate and at least as deep as the asymmetric and relatively wide adventitious lobe.

Other species:
Mimimitoceras alternatum Korn, 1992 (= *alternum* Korn, 1994 nom. vad.)
Imitoceras altisellatum Schindewolf, 1923
Imitoceras angustilobatum Kusina, 1980
Imitoceras bertchogurense Balashova, 1953
Brancoceras Denckmanni Wedekind, 1918 (nom. dub.)
Imitoceras disciforme Schindewolf, 1926
Imitoceras n. sp. aff. *disciforme* Weyer, 1977
Imitoceras discoidale Schindewolf, 1926 (NON Smith; = *disciforme*)
Prionoceras felix Korn, 1994
Imitoceras globosum Schindewolf, 1923 (= *lineare*)
Goniatites quadripartitus Münster
Imitoceras karagandense Bogoslovskiy, 1971 (= *quadripartitum*)
Imitoceras kiense Bogoslovskiy, 1971
Imitoceras obsoletum Kusina, 1980
Mimimitoceras nageli Korn, 1992 (?= *subsulcatum* = *lineare*)
Imitoceras Pompeckji Schindewolf, 1923
Prionoceras rotundum Petter, 1959
Brancoceras Stillei Wedekind, 1918 (= *lineare*)
Goniatites substriatus Münster, 1840
Goniatites subsulcatus Münster, 1832 (= *lineare*)

Pr. felix is brevidomic (Korn, 1994: Fig. 5C) and its internal shell thickenings which are deepest on the venter are utterly different from all other prionoceratids in which constrictions always start at the umbilicus. Early stages have not been described but the form seems to be the oldest *Rectimitoceras*. Characteristics given by Korn (1992a, 1994) are insufficient to allow at present a distinction of *Mim. nageli* from *Gon. subsulcatus* which again is taken here as a subjective synonym of the genotype. Korn (1994) did not illustrate the suture of *Mim. alternatum* and therefore no proper comparison with the similar *Rectim. kiense* is possible. In contrast to Korn (1994: Fig. 8B), a suture diagram drawn by M.R. House from the Munich holotype of *Rectim. lineare* (Fig. 5) shows a pattern which is identical to that in *Rectim. kiense*. Both species are therefore closely related and differ only in slight differences in whorl thickness.

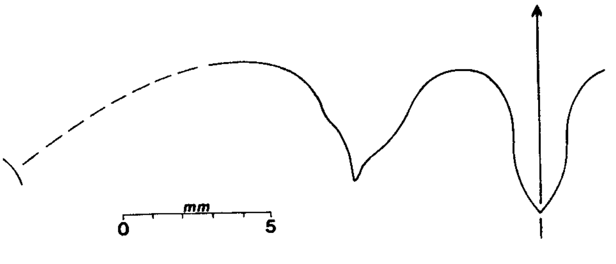

Figure 5. Suture line of the holotype of *Rectimitoceras lineare* at 22 mm dm, BSHGP As VII 23, based on a drawing supplied by M.R. House (compare somewhat diverting illustration in Korn, 1994: Fig. 8B).

In a range of inprecisely dated Chineese species (e.g. *Im. folliforme* Ruan and *Im. sinense* Sun & Chen) the shell ontogeny is unknown and such taxa could either belong to *Rectimitoceras* or *Acutimitoceras*. Further revisionary work is needed to clarifiy the possible presence of any *Rectimitoceras* species in the Middle Tournaisian of North America. *Aganides sulcatus* var. *biimpressa* Schmidt (1924) is not a prionoceratid or rectimitoceratid but a valid species of *Cyrtoclymenia*, characterized by very narrow umbilicus and subglobular, well-rounded whorl form (see Pl. 3: 11 & 12).

Remarks. An important but neglected difference between *Prionoceras* and imitoceratids (in a traditional sense) is the longer body chamber (more than one whorl) of the former (see already Wedekind, 1913). Internal moulds of imitoceratids show normally at least one or more septa although the total body chamber length may have amounted to just one full whorl. The more longidomic shell of *Prionoceras* seems to be a relict of its prolobitid ancestors.

Korn (1988) named the brevidomic *Imitoceras varicosum* Group" of Vöhringer (1960) and Becker (1988) as a new genus *Mimimitoceras*, characterized by shell constrictions bordered by ridges and by the distinctive shell tripartition similar to that in triangularly coiled parawocklumerids (see Pl. 1: 1-3). Regular spacing of constrictions and internal thickenings is already present in *Prionoceras* and is also seen (Pl. 3: 4 & 5) in *Balvia (Mayneoceras)*. Small specimens often have only two constrictions per whorl. Recently Korn (1992a, b, 1994) found *Mimimitoceras*-type constrictions in the juveniles of various other imitoceratids and consequently expanded the use of his taxon to include all Famennian and a few Lower Tournaisian imitoceratids. The Middle to early Upper Tournaisian *Imitoceras* s.str. differs in the shortened ventral lobes with slightly swollen base (Price & House, 1984; Becker, 1993b; House, 1993). In agreement with observations of many previous authors (e.g. Schindewolf, 1924, 1937; Schmidt, 1924; Vöhringer, 1960) available collections from various localities confirm the distinction between typical *Mimimitoceras* and the *Im. lineare* Group (Becker, 1993; Gen. nov. B in House, 1993), based on differences of median (> ca. 15 mm dm) to adult stages. In *Rectimitoceras* n.gen. all specimens apart from early juveniles have no shell constrictions at all (or only neglible traces of them; compare e.g. Pl. 2: 1 & 2 with Pl. 3: 8), no shell ridges, and internal shell thickenings do not cause a regular shell tripartition or are lacking completely. The Balvian *Globimitoceras* differs in its extremely rounded whorls, narrow adventitious lobe and the lack of constrictions of shell and moulds even early in ontogeny. Latest ontogenetic stages of *Prionoceras* may lose their characteristic shell constrictions (see Korn, 1994) and without knowledge of stratigraphical age, shell ontogeny and body chamber length isolated specimens may become difficult to distinguish from adult *Rectimitoceras*. Most species of the latter, however, have significantly faster expanding whorls (higher apertures) than *Prionoceras*. Some authors may prefer to recognize *Mimimitoceras, Globimitoceras* and *Rectimitoceras* only as subgenera. The distinction between *Rectimitoceras* and *Mimimitoceras* is of great significance in relation to the understanding of the drastic ammonoid faunal change just before the Devonian-Carboniferous boundary. The two genera represent the only independent lineages which survived the Hangenberg mass extinction and which gave rise to new forms during the subsequent Balvian adaptive radiation.

Korn (1994) regarded *Gon. quadripartitus* as a subjective synonym of *Gon. linearis* but a comparison of conch parameters does not support this view. *Rectim. quadripartitum* is more compressed at all stages (Pl. 3: 9 & 10), has flattened flanks and is probably conspecific with *Rectim. karagandense*. In preservation as internal moulds it can be distinguished from similarly compressed *Mim. geminum* and *lentum* by their tripartite shells, somewhat higher apertures and by biconvex constrictions at late stages of *Mim. geminum*. A specimen assigned by Korn (1994: Fig. 11B) to the latter is consequently assigned here to *Rectim. quadripartitum*.

Mimimitoceras Korn

After separation of *Rectimitoceras* the following species remain in *Mimimitoceras*: *fuerstenbergi* Korn (? = *Aganides infracarbonicus* Paeckelmann, 1913 which has priority), *geminum* Korn (= aff. *liratum* Becker, 1988; Pl. 2: 1 & 2), *hoennense* Korn, *lentum* Korn, *liratum* (Schmidt), *rotersi* Korn, *trizonatum* Korn and *varicosum* (Münster; Pl. 1: 4 & 5). *Mim. rotersi* and *trizonatum* have already slightly evolute early stages. *Mim. rotersi* is represented at Hasselbachtal by poorly preserved subglobular moulds with (tripartite) constrictions from the *Para. paradoxa* Subzone and *Wo. sphaeroides* Zone. The deformed lectotype of *Mim. liratum* (MNHU c.1200, Pl. 1: 10) from Drewer has fine convex growth lines (8-10/mm) which are bundled to 1-2 mm wide stripes. The estimated ww ratio is ca. 60 % at 30 mm dm. In the case of adult stages the diagnosis given by Korn (1994: 20), without knowledge of the type, has to be corrected. *Mim. geminum* is obviously the most common species at Hasselbachtal. The presence of the very closely related or even conspecific *Mim. lentum* with rectiradiate ornament (Pl. 1: 11) and straight constrictions is based on Korn (1994: Fig. 18F).

Two previous subspecies of *Mim. liratum* of Vöhringer (1960), *Im. liratum simile* and *Im. liratum exile*, were placed by Korn (1994) in *Acutimitoceras* although they do not show typical evolute inner whorls (see also Weyer, 1965: Pl. VIII: 2). In Lower Carboniferous *Mimimitoceras* shell constrictions often appear to be more irregularly developed. *Mim. simile* is apparently very close to the contemporaneous *Mim. hoennense*.

Acutimitoceras Librovitch

In recent years *Acutimitoceras* has been used for all terminal Wocklumian to Balvian imitoceratids with evolute inner whorls and closing umbilicus at adult stages. This large group, however, comprises several well-defined phylogenetic lineages with diverting trends of morphological evolution. All groups are also typical for specific stratigraphical intervals. The following subdivision into subgenera is proposed:

Acutimitoceras (Acutimitoceras) Librovitch

Type-species: *Imitoceras acutum* Schindewolf (1923).

Diagnosis. Strongly compressed, oxyconic at adult stages, ventral lobe deep and often wide, adventitious lobe asymmetric, with shell and mould constrictions.

Remarks. As already emphasized by Becker (1993b) and House (1993) the strict use of the generic name should be for oxyconic forms. This group is not just an agglomerate of species with similar shell form, but represents an evolutionary series in which distinctive morphologies are developed. The sharpening of the venter occured close to the D-C-Boundary progressively at earlier stages: *Ac. (Ac.)* sp. Kusina (oxyconic at 15 mm dm), *Ac. (Ac.) acutum* (oxyconic at 10 mm dm). In the latter, as well as in *Ac. (Ac.)* n. sp. aff. *acutum* Weyer and in *Ac. (Ac.) wangyuense* Sun, wide ventral lobes and unique asymmetric A-lobes appeared. Finally the lineage led to *Voehringerites* with a subdivided ventral lobe. The systematic position of the suboxyconic *Ac. carinatum* is uncertain; the species has shortened ventral lobes as in *Ac. (Streeliceras)* n. subgen.

Acutimitoceras (Stockumites) n. subgen.

Derivation of name. After the main level of distribution, the Stockum Limestone and equivalents.

Type-species: *Imitoceras intermedium* Schindewolf (1923); see revision in Korn (1994).

Diagnosis. Compressed to globular, venter always rounded, ventral lobe deep and narrow, variably with or without shell or mould constrictions.

Other species:

Imitoceras prorsum antecedens Vöhringer (?n.subgen.)
Imitoceras (Imitoceras) applanatum Ruan, 1981
Aganides compressus Moore, 1928 (= adult *louisianensis*)
Imitoceras prorsum convexum Vöhringer, 1960
?*Mimimitoceras crestaverde* Korn, 1992 (probably related to *pulchrum*)
Imitoceras depressum Vöhringer, 1960
Imitoceras gracile Vöhringer (? n.subgen.)
Aganides Gürichi Frech, 1902 (= *subbilobatus*)
?*Imitoceras inequalis* Sun & Chen, 1965
Acutimitoceras kleinerae Korn, 1984
Goniatites louisianensis Rowley, 1895
Acutimitoceras mugodzharense Kusina, 1984
Imitoceras multisulcatum Vöhringer (?n.subgen.)
Acutimitoceras procedens Korn, 1984
Imitoceras (Acutimitoceras) pulchrum Kusina, 1985
Imitoceras rotiforme Librovich, 1940
Imitoceras sphaeroidale Vöhringer, 1960
Acutimitoceras stockumensis Korn, 1984
Goniatites subbilobatus Münster

Korn (1994) recognized *Ac. louisianensis* while he placed the probably synonymous *Aganides compressus* from the same level (Louisiana Limestone) in *Imitoceras*. As discussed by Becker (1993b), the Upper Tournaisian *Imitoceras werriense* Campbell & Engel (1963) with evolute inner whorls probably represents a new genus with *Zadelsdorfia*-type ventral lobes.

Remarks. Within this subgenus there are again two subgroups with (*stockumensis* group) or without (*intermedium-kleinerae* group) shell constrictions. At present there is no clarity about phylogenetic relationsships which would allow further taxonomic changes. *Ac. (Stockumites)* n.subgen. embraces the majority of forms known from the Stockum Limestone but several species survived into the Hangenberg Limestone and gave rise to younger species such as *Ac. (Stock.) undulatum, depressum, convexum* etc. This proves continuing evolution within a relative conservative remaining stock. *Ac. antecedens, gracile* and *multisulcatum* differ from all other *Ac. (Stockumites)* by extension of their evolute stage. Obviously the umbilicus does not close completely even at maturity (Vöhringer, 1960; Korn, 1994: Fig. 49). The *antecedens* Group is therefore intermediate between *Ac. (Stockumites)* and *Gattendorfia* and it is an important index for the *Gattendorfia* Stufe. *Ac. antecedens* is most likely also the ancestor of the distinctive *Gatt. molaria* Group which led to *Gattenpleura*. Recognition of the *antecedens* Group as additional fifth subgenus may be warranted but needs further studies.

Acutimitoceras (Streeliceras) n. subgen.

Derivation of name. In honour of **Prof. Dr. M. Streel** who has contributed so much to advances in stratigraphy around the Devonian-Carboniferous boundary.
Type species: *Imitoceras heterolobatum* Vöhringer, 1960; detailed description see Vöhringer (1960) and Korn (1994).
Diagnosis: Shell discoidal, adult stages with closed umbilicus, parallel-sided ventral lobe significantly shorter than A-Lobe.
Other species:
Acutimitoceras caesari Korn, 1984
Imitoceras (Imitoceras) crassum Ruan, 1981
Imitoceras (Imitoceras) pilatum, Ruan, 1981
Imitoceras planolobatum Sun & Chen, 1965
Imitoceras yangi Sun & Chen, 1965
Remarks. The new subgenus is a sidebranch of *Ac. (Stockumites)* with some trends of morphological specialisation as in the homeomorphic *Nicimitoceras* (= *Nimitoceras* Korn, 1993 nom. vad.) and *Imitoceras* which differ both by their involute early stages (compare Korn, 1994: Fig. 59A-C to 59D-F and 37H; Vöhringer, 1960: Figs. 2a and 15a). Apart from the conch ontogeny *Nicimitoceras* shows a trend to diverging adventitious lobes (e.g. in *Nic. subacre* and *acre*). Other changes eventually led to the more specialised ventral sutures of early Karagandoceratidae (Bartzsch & Weyer, 1988). *Nicimitoceras* sensu Korn (1993, 1994) is polyphyletic since the *trochiforme-acre*-lineage was certainly derived from the Balvian *Rectim.* n.sp. aff. *disciforme* Weyer or close relatives with still deep lanceolate ventral lobe while *Ac. (Streel.) caesari* was already part of the rapidly radiating latest Devonian *Acutimitoceras* faunas (Korn, 1984).

Acutimitoceras (Sulcimitoceras) Kusina emend.

Type-species: *Sulcimitoceras yatskovi* Kusina (1985).
Remarks. The validity of Kusina´s genus is highly questionable although additional sulcate juveniles from the type Stockum Limestone were described by House (1993). Median spiral shell thickenings of the venter seem to come and go in only some specimens of certain taxa. Such patterns which are restricted to phragmocones were already recognized in the last century by Würtenberger & Würtenberger (1866). A pronounced internal ventral shell ridge was described by Manger & Saunders (1980) in their population of *Cancelloceras huntsvillense*. Dr. L.F. Kusina (Moscow) kindly showed a furrowed specimen of *Im. brevilobatum* Miller & Collinson from the Northview Shale of Missouri which in every other aspect is identical to co-occuring normal representatives of the species. Also, only the adapical half of the the last, still chambered whorl of the holotype of *"Protocanites" gurleyi* (Smith) from the same formation has a median internal depression (Miller & Collinson, 1951). Such an irregular occurence, in completely unrelated taxa, of the same association strongly speaks against its taxonomic use. Similar features are known as "siphonale Innenleisten" (siphuncular internal ridges) in Jurassic lytoceratids (Grandjean, 1910), phylloceratids, amaltheids, perisphinctids (Quenstedt, 1886/87) and haploceratids (Quenstedt, 1858), and seem to be formed in conjunction with variations in the attachment and a slight displacement of the siphuncular tube (Hölder, 1954). In ceratites ventral furrows of ca. 0.5 % of a population often almost reach the aperture (Mundlos, 1969). Rein (1988) showed that such rather variable interior thickenings of a basically different type must have been formed by the anterior mantle which secreted the hypostracum.

Discarding the ventral furrow as diagnostic feature it seems sensible to re-define *Ac. (Sulcimitoceras)* by the ribbing of early stages of the type-species which would match Gen. nov. D of House (1993). In such emended sense the subgenus perhaps also includes *Ac. prorsum* but not the sulcate juveniles of House (1993).

7. ACKNOWLEDGEMENTS.

This study takes advantage of research results of various collegues and is presented in honour of Maurice Streel, with whom the author has much enjoyed collaboration and discussion in the past. D. Weyer (Magdeburg) supplied his recent Hasselbachtal collections. Corrections of my English, comments and the original suture drawing of Fig. 5 by M.R. House (Southampton) were greatly appreciated. J. Helms and the late H. Jaeger (Humboldt-University, Berlin) made originals of the Museum für Naturkunde available. H. Keupp (Berlin) supplied important literature on median furrows in Mesozoic ammonoids. G. Schreiber (Berlin) prepared several specimens. Research was financed within a habilitation grant of the Deutsche Forschungsgemeinschaft.

8. REFERENCES

ALEKSEEV, A.A., LEBEDEV, O.A., BARSKOV, I.S., BARSKOVA, M.I., KONONOVA, L.I. & CHIZHOVA, V.A., 1994. On the stratigraphic position of the Famennian and Tournaisian fossil vertebrate beds in Andreyevka, Tula Region, Central Russia. *Proc. Geol. Ass.*, 105: 41-52.

BARSKOV, I.S., SIMAKOV, K.V, ALEKSEEV, A.S., BOGOSLOVSKY, B.I., BYVSHEVA, T.V., GAGIEV, M.H., KONONOVA, L.N., KOCHETKOVA, N.M., KUSINA, L.F. & REITLINGER, E.A., 1984. Devonian-Carboniferous transitional deposits of the Berchogur section, Mugodzhary, USSR (preliminary report). *Cour. Forsch.-Inst. Senck.*, 67: 207-230.

BARTZSCH, K. & WEYER, D., 1982. Zur Stratigraphie des Untertournai (*Gattendorfia*-Stufe) von Saalfeld im Thüringischen Schiefergebirge. *Abh. Ber. Naturkd. Vorgesch.* XII (4): 3-54.

BARTZSCH, K. & WEYER, D., 1988. Die unterkarbonische Ammonoidea-Subfamilia Karagandoceratinae. *Freib. Forsch.-H.*, C419: 130-142.

BECKER, G., CLAUSEN, C.-D. & LEUTERITZ, K., 1993. Verkieselte Ostracoden vom Thüringer Ökotyp aus dem Grenzbereich Devon/Karbon des Steinbruchs Drewer (Rheinisches Schiefergebirge). *Cour. Forsch.-Inst. Senck.*, 160, 131 p.

BECKER, R.T., 1988. Ammonoids from the Devonian-Carboniferous boundary in the Hasselbach Valley (Northern Rhenish Slate Mountains). *Cour. Forsch.-Inst. Senck.*, 100: 193-213.

BECKER, R.T., 1992. Zur Kenntnis von Hemberg-Stufe und *Annulata*-Schiefer im Nordsauerland (Oberdevon, Rheinisches Schiefergebirge, GK 4611 Hohenlimburg). *Berl. geowiss. Abh.*, E3: 3-43.

BECKER, R.T., 1993a. Anoxia, eustatic changes, and Upper Devonian to lowermost Carboniferous global ammonoid diversity. *Syst. Ass. Spec. Vol.*, 47: 115-163.

BECKER, R.T., 1993b. Analysis of ammonoid palaeobiogeography in relation to the global Hangenberg (terminal Devonian) and Lower Alum Shale (Middle Tournaisian) events. *Ann. Soc. géol. Belg.*, 115 (2): 459-473.

BECKER, R.T. & PAPROTH, E., 1993. Auxiliary stratotype sections for the Global Stratotype Section and Point (GSSP) for the Devonian-Carboniferous boundary: Hasselbachtal. *Ann. Soc. géol. Belg.*, 115 (2): 703-706.

BECKER, R.T. & SCHREIBER, G., 1994. Zur Trilobiten-Stratigraphie im Letmather Famennium (nördliches Rheinisches Schiefergebirge). *Berl. geowiss. Abh.*, E13: 369-387.

BECKER, R.T., BRAUCKMANN, C., FRIMAN, L., HIGGS, K., KEUPP, H., KORN, D., LANGER, W., PAPROTH, E., RACHEBEUF, P., STOPPEL, D., STREEL, M. & ZAKOWA, H., 1984. Hasselbachtal, the section best displaying the Devonian-Carboniferous boundary beds in the Rhenish Massif (Rheinisches Schiefergebirge). *Cour. Forsch.-Inst. Senck.*, 67: 181-191.

BECKER, R.T., KORN, D., PAPROTH, E. & STREEL, M., 1993. Beds near the Devonian-Carboniferous boundary in the Rhenish Massif, Germany. *Guidebook IUGS Com. Strat., Subcom. Carb. Strat. (SCCS)*, 86 p., Liege.

BLESS, J.M., BECKER, R.T., HIGGS, K., PAPROTH, E. & STREEL, M., 1993. Eustatic cycles around the Devonian-Carboniferous boundary and the sedimentary and fossil record in Sauerland (Federal Republic of Germany). *Ann. Soc. géol. Belg.*, 115 (2): 689-702.

BOGOSLOVSKIY, B.I., 1971. Devonskie Ammonoidei. II. Goniatity. *Trudy Pal. Inst.*, 191, 122 p.

BRAUCKMANN, C., CHLUPAC, I. & FEIST, R., 1993. Trilobites at the Devonian-Carboniferous boundary. *Ann. Soc. géol. Belg.*, 115 (2): 507-518.

CAMPBELL, K.S.W.& ENGEL, B.A., 1963. The faunas of the Tournaisian Tulcumba Sandstone and its members in the Werrie and Belvue Synclines, New South Wales. *J. Geol. Soc. Austr.*, 10: 55-122.

CLAOUÉ-LONG, J.C., JONES, P.J., ROBERTS, J. & MAXWELL, S., 1992. The numerical age of the Devonian-Carboniferous boundary. *Geol. Mag.*, 129 (3): 281-291.

CLAUSEN, C.D., KORN, D. & UFFENORDE, H., 1979. Das Devon/Karbon-Profil am alten Schießstand bei der Bilstein-Höhle (Blatt 4515 Hirschberg, Warsteiner Sattel, Rheinisches Schiefergebirge). *Aufschluß, Sonderband*, 29: 47-68.

CLAUSEN, C.D., KORN, D., LUPPOLD, F.W. & STOPPEL, D., 1989a. Untersuchungen zur Devon/Karbon-Grenze auf dem Müssenberg (Nördliches Rheinisches Schiefergebirge). *Bull. Soc. belge Géol.*, 98 (3/4): 353-369.

CLAUSEN, C.D., LEUTERITZ, K., & ZIEGLER, W., 1989b. Ausgewählte Profile an der Devon/Karbon-Grenze im Sauerland (Rheinisches Schiefergebirge). *Fortschr. Geol. Rheinld. u. Westf.*, 35: 161-226.

CLAUSEN, C.D., KORN, D., FEIST, R., LEUSCHNER, K., GROOS-UFFENORDE, H., LUPPOLD, F.W., STOPPEL, D., HIGGS, K. & STREEL, M., 1994. Die Devon/Karbon-Grenze bei Stockum. *Geol. Paläont. Westf.*, 29: 71-95.

DREESEN, R., PAPROTH, E. & THOREZ, J., 1989. Events documented in Famennian sediments (Ardenne-Rhenish Massif, Late Devonian, NW Europe). *Can. Soc. Petr. Geol., Mem.*, 14 (II): 295-308.

FLAJS, G., FEIST, R. & ZIEGLER, W., Eds., 1988. Devonian-Carboniferous Boundary - Results of recent studies. *Cour. Forsch.-Inst. Senck.*, 100, 245 p.

GAGIEV, M.H. & KONONOVA, L.I., 1990. The Upper Devonian and Lower Carboniferous Sequences in the Kamenka River Section (Kolyma River Basin, the Soviet North-East). Stratigraphic Description. *Cour. Forsch.-Inst. Senck.*, 118: 81-103.

GRANDJEAN, F., 1910. Le siphon des Ammonites et de Belemnites. *Bull. Soc. géol. France*, 4 (10): 496-519.

HEDBERG, H.D., 1976. International stratigraphic guide - A guide to stratigraphic classification, terminology and procedure. 200 pp, New York, Wiley-Interscience Publication.

HIGGS, K. & STREEL, M., 1984. Spore stratigraphy at the Devonian-Carboniferous boundary in the northern "Rheinisches Schiefergebirge“, Germany. *Cour. Forsch.-Inst. Senck.*, 67: 157-179.

HIGGS, K. & STREEL, M., 1995. Palynological age for the lower part of the Hangenberg Shale in Sauerland. *Ann. Soc. géol. Belg.*, 116 (2): 243-247.

HIGGS, K., STREEL, M., KORN, D. & PAPROTH, E., 1993. Palynological data from the Devonian-Carboniferous boundary beds in the new Stockum Trench II and the Hasselbachtal Borehole. Northern Rhenish Massif, Germany. *Ann. Soc. géol. Belg.*, 115 (2): 551-557.

HÖLDER, H., 1954. Über die Sipho-Anheftung bei Ammoniten. *N. Jb. Geol. Pal., Mh.*, 1954: 372-379.

HOU, H., JI, Q., WU, X., XIONG, J., WANG, S., GAO, L., SHENG, H., WEI, J. & TURNER, S., 1985. Muhua sections of Devonian-Carboniferous boundary beds. 226 p. + 46 pls., Beijing, Geological Publishing House.

HOUSE, M.R., 1993. Earliest Carboniferous goniatite recovery after the Hangenberg Event. *Ann. Soc. géol. Belg.*, 115 (2): 559-579.

HOUSE, M.R., GORDON, M. jr. & HLAVIN, W.J., 1986. Late Devonian ammonoids from Ohio and adjacent states. *J. Pal.*, 60 (1): 126-144.

JI, Q., Ed., 1989. The Dapoushang Section. An excellent section for the Devonian-Carboniferous Boundary Stratotype in China. 165 p., Beijing, Science Press. [in Chinese]

KALVODA, J. & KUKAL, Z., 1987. Devonian-Carboniferous boundary in the Moravian Karst at Lesni Lom Quarry, Brno-Lisen, Czechoslowakia. *Cour. Forsch.-Inst. Senck.*, 98: 95-117.

KORN, D., 1984. Die Goniatiten der Stockumer *Imitoceras*-Kalklinsen (Ammonoidea; Devon/Karbon-Grenze). *Cour. Forsch.-Inst. Senck.*, 67: 71-89.

KORN, D., 1986. Ammonoid evolution in late Famennian and early Tournaisian. *Ann. Soc. géol. Belg.*, 109: 49-54.

KORN, D., 1988. Oberdevonische Goniatiten mit dreieckigen Innenwindungen. *N. Jb. Geol. Paläont., Mh.*, 1988 (10): 605-610.

KORN, D., 1989. *Cymaclymenia* aus der *Acutimitoceras*-Fauna (*prorsum*-Zone) vom Müssenberg (Devon/Karbon-Grenze; Rheinisches Schiefergebirge). *Bull. Soc. belge Géol.*, 98 (3/4): 371-372.

KORN, D., 1991. Threedimensionally preserved clymeniids from the Hangenberg Black Shale of Drewer (Cephalopoda, Ammonoidea; Devonian-Carboniferous boundary, Rhenish Massif). *N. Jb. Geol. Pal., Mh.*, 1991 (9): 553-563.

KORN, D., 1992a. Heterochrony in the evolution of Late Devonian Ammonoids. *Acta Palaeont. Pol.*, 37: 21-36.

KORN, D., 1992b. Ammonoideen aus dem Devon/Karbon-Grenzprofil an der Grünen Schneid (Karnische Alpen, Österreich). *Jb Geol. B.-A.*, 135 (1): 7-19.

KORN, D., 1993. The ammonoid faunal change near the Devonian-Carboniferous boundary. *Ann. Soc. géol. Belg.*, 115 (2): 581-593.

KORN, D., 1994. Devonische und karbonische Prionoceraten (Cephalopoda, Ammonoidea) aus dem Rheinischen Schiefergebirge. *Geol. Paläont. Westf.*, 30, 85 p.

KORN, D. & LUPPOLD, W., 1987. Nach Clymenien und Conodonten gegliederte Profile des oberen Famenniums im Rheinischen Schiefergebirge. *Cour. Forsch.-Inst. Senck.*, 92: 199-223.

KORN, D. & PRICE, J.D., 1987. Taxonomy and Phylogeny of the Kosmoclymeniinae subfam. nov. (Cephalopoda, Ammonoidea, Clymeniida). *Cour. Forsch.-Inst. Senck.*, 92: 5-75.

KORN, D., CLAUSEN, C.D. & LUPPOLD, F.W., Eds., 1994. Die Devon/Karbon-Grenze im Rheinischen Schiefergebirge. *Geol. Paläont. Westf.*, 29, 221 p.

KREBS, W., 1969. Über Schwarzschiefer und bituminöse Kalke im mitteleuropäischen Variscikum. *Erdöl und Kohle, Erdgas, Petroch.*, 27: 2-6, 62- 67.

KÜRSCHNER, W., BECKER, R.T., BUHL & VEIZER, J., 1993. Strontium isotopes in conodonts: Devonian-Carboniferous transition, the northern Rhenish Slate Mountains, Germany. *Ann. Soc. géol. Belg*, 115 (2): 595-621.

KUSINA, L.F., 1985. K revizii roda *Imitoceras* (Ammonoidea). *Pal. Zh.*, 1985 (3): 35-48.

LANGE, W., 1929. Zur Kenntnis des Oberdevons am Enkeberg und bei Balve (Sauerland). *Abh. preuß. geol. L.-Anst., N.F.*, 119, 132 p.

LEUSCHNER, K., 1994. Trilobiten aus dem Devon/Karbon-Grenzbereich und aus der *Gattendorfia*-Stufe des Profiles NF/G von Drewer (Rheinisches Schiefergebirge). *Geol. Paläont. Westf.*, *29*: 149-175.

LUPPOLD, F.W., HAHN, G. & KORN, D., 1984. Trilobiten-, Ammonoideen- und Conodonten-Stratigraphie des Devon/Karbon-Grenzprofils auf dem Müssenberg (Rheinisches Schiefergebirge). *Cour. Forsch.-Inst. Senck.*, 67: 91-121.

LUPPOLD, F.W., CLAUSEN, C.D., KORN, D. & STOPPEL, D., 1994. Devon/Karbon-Grenzprofile im Bereich von Remscheid-Altenaer Sattel, Warsteiner Sattel, Briloner Sattel und Attendorn-Elsper Doppelmulde (Rheinisches Schiefergebirge). *Geol. Paläont. Westf.*, 29: 7-69.

MANGER, W. & SAUNDERS, B., 1980. Lower Pennsylvanian (Morrowan) ammonoids from the North American midcontinent. *J. Paleont., Mem.*, 10, 56 p.

MARTEL, A.T., McGREGOR, D.L. & UTTING, J., 1993. Stratigraphic significance of Upper Devonian and Lower Carboniferous miospores from the type area of the Horton Group, Nova Scotia. *Can. J. Earth Sci.*, 30: 1091-1098.

MATTHEWS, S.C., 1983. An occurence of Lower Carboniferous (*Gattendorfia*-Stufe) ammonoids in southwest Ireland. *N. Jb. Geol. Pal., Mh.*, 1983 (5): 293-299.

MUNDLOS, R., 1969. Medianrinne auf Ceratiten-Steinkernen. *N. Jb. Geol. Pal., Abh.*, 132 (2): 309-316.

NEMIROVSKAYA, T., CHERMNYKH, V.A., KONONOVA, L.I. & PAZUKHIN, V.N., 1993. Conodonts of the Devonian-Carboniferous boundary section, Kozhim, Polar Urals, Russia. *Ann. Soc. géol. Belg.*, 115 (2): 629-647.

PAPROTH, E. & STREEL, M., Eds., 1984. The Devonian-Carboniferous Boundary. *Cour. Forsch.-Inst. Senck.*, 67, 258 p.

PETTER, G., 1959. Goniatites dévoniennes du Sahara. *Publ. Serv. Carte géol. Algérie, n.s., Paléont.*, 2, 313 p.

PRICE, J.D. & HOUSE, M.R., 1984. Ammonoids near the Devonian-Carboniferous boundary. *Cour. Forsch.-Inst. Senck.*, 67: 15-22.

PRICE, J.D. & KORN, D., 1989. Stratigraphically important clymeniids (Ammonoidea) from the Famennian (Late Devonian) of the Rhenish Massif, West Germany. *Cour.Forsch.-Inst. Senck.*, 110: 257-294.

QUENSTEDT, F.A., 1858. Der Jura. - 842 p., Tübingen.

QUENSTEDT, F.A., 1886/1887. Die Ammoniten des Schwäbischen Jura. 1136 p., Stuttgart.

REIN, S., 1988. Rinnen-, Rillen- und Furchenbildungen auf Ceratitensteinkernen. *Veröff. Naturkundemus. Erfurt*, 1988: 66-79.

SCHINDEWOLF, O.H., 1923. Beiträge zur Kenntnis des Paläozoicums in Oberfranken, Ostthüringen und dem Sächsischen Vogtlande. I. Stratigraphie und Ammoneenfauna des Oberdevons von Hof a. S. *N. Jb. Min. Geol. Pal., Beil.-Bd.*, 49: 250-509.

SCHINDEWOLF, O.H., 1937. Zur Stratigraphie und Paläontologie der Wocklumer Schichten. *Abh. preuß. geol. L.-Anst., N.F.*, 178, 132 pp.

SCHMIDT, H., 1924. Zwei Cephalopodenfaunen an der Devon-Carbongrenze im Sauerland. *Jb. preuß. geol. L.-Anst.*, 44: 98-171.

SCHÖNLAUB, H.P.ATTREP, M., BOECKELMANN, K., DREESEN, R., FEIST, R., FENNINGER, A., HAHN, G., KLEIN, P., KORN, D., KRATZ, R., MAGARITZ, M., ORTH, C.J. & SCHRAMM, J.-M., 1992. The Devonian/Carboniferous Boundary in the Carnic Alps (Austria) - A Multidisciplinary Approach. *Jb. geol. B.-A.*, 135 (1): 57-98.

SELWOOD, E.B., 1960. Ammonoids and trilobites from Upper Devonian and Lowest Carboniferous of the Launceston area of Cornwall. *Palaeont.*, 3 (2): 153-185.

SIMAKOV, K.V., BOGOSLOVSKIY, B.I., GAGIEV, M.K., KONONOVA, L.I., KOCHETKOVA, N.M., KUSINA, L.F., KULAGINA, E.I., ONOPRIENKO, U.I., PAZUKHIN, V.N., RADINOVA, E.P., RASINA, T.P., REITLINGER, E.A., SIMAKOVA, L.V. & YANOULATOVA, M.G., 1983. Biostratigrafiya pogranichnikh otloszheniy Devona i Karbona. Kharakteristikye pogranichnikh otloszheniy Devona i Karbona Mugodzhar. 51 p., Akad. Nauk, Magadan.

STREEL, M., SEVASTOPOULO, G. & PAPROTH, E., Eds., 1993. Devonian-Carboniferous Boundary. *Ann. Soc. géol. Belg.*, 115 (2): 405-708.

VAN STEENWINKEL, M., 1993. The Devonian-Carboniferous boundary: Comparison between the Dinant Synclinorium and the northern border of the Rhenish Slate Mountains. A sequence-stratigraphic view. *Ann. Soc. géol. Belg.*, 115 (2): 665-681.

VÖHRINGER, E., 1960. Die Goniatiten der unterkarbonischen *Gattendorfia*-Stufe im Hönnetal. *Fortschr. Geol. Rheinld. Westf*, 3 (1): 107-196.

WEDEKIND, R., 1913. Beiträge zur Kenntnis des Oberdevon am Nordrande des Rheinischen Gebirges. 2. Zur Kenntnis der Prolobitiden. *N. Jb. Min. Geol. Pal.*, 1: 78-95.

WEYER, D., 1965. Zur Ammonoideen-Fauna der *Gattendorfia*-Stufe von Dzikowiec (Ebersdorf) in Dolny Slask (Niederschlesien), Polen. *Ber. geol. Ges. DDR*, 10 (4): 443-464.

WEYER, D., 1994. Korallen im Untertournai-Profil von Drewer (Rheinisches Schiefergebirge). *Geol. Paläont. Westf.*, 29: 177-221.

WÜRTENBERGER, F.J. & WÜRTENBERGER, I., 1866. Der Weiße Jura im Klettgau und angrenzendem Randgebirge. *Verh. naturwiss. Ver. Carlsruhe*, 2.

YU, C., Ed., 1988. Devonian-Carboniferous Boundary in Nanbiancun, Guilin, China - Aspects and Records. 379 p. + 87 pls., Beijing, Science Press.

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PLATE 1

Prionoceratidae from various sections of the Rhenish Massif

Mimimitoceras liratum (Schmidt), SMF 51059, Hasselbachtal, Bed 48, x 3
1. Lateral view showing the shell trilobation by deep constrictions of the internal mould similar as in homoeomorphic *Parawocklumeria* and *Epiwocklumeria*. Constriction show a typical slight ventrolateral projection but do not form "parabolic ears".
2. Adoral view showing the very low aperture.
3. Ventral view showing the slight median sinus of a constriction.

Mimimitoceras varicosum (Schindewolf), MNHU c.1208, leg. H. Schmidt, Oberrödinghausen railway cut, x 3.
4. Lateral view showing the typical narrow ridges associated with shell constrictions.
5. Ventral view illustrating the asymmetric course of a constriction.

Balvia lens Korn, Oc 1801, Hasselbachtal, Bed 43, adult, somewhat corroded specimen, x 3.
6. Lateral view showing rounded adventitious lobes and typical constrictions. Shallow ventrolateral depressions are probably missing due to bad preservation.
7. Adoral view; cross-section more compressed than in Korn´s type material, aperture very low.

Balvia lens Korn, Oc 1799, Hasselbachtal, Bed 32, uncorroded small specimen, x 3.
8. Ventral view showing the presence of typical "parabolic ears" with a median interruption at an relative early growth stage.
9. Lateral view with pointed adventitious lobes.

Mimimitoceras liratum (Schmidt), lectotype, MNHU c.1210, original of Schmidt (1924: Pl. 6, Fig. 5), leg. A. Denckmann, Drewer, x 1.5
10. Lateral view showing growth sculpture and shell constrictions causing a regular conch tripartition. [Preservation does not allow to illustrate a meaningful ventral or adoral view]

Mimimitoceras lentum Korn, MNHU c.1212, original of Schmidt (1924: Pl. 6, Fig. 8; det. *Aganides quadripartitus*), Burg, Borkewehr Quarry (sheet Balve), x 1.5.
11. Lateral view showing rectiradiate growth sculpture, shell constrictions and associated small ridges.

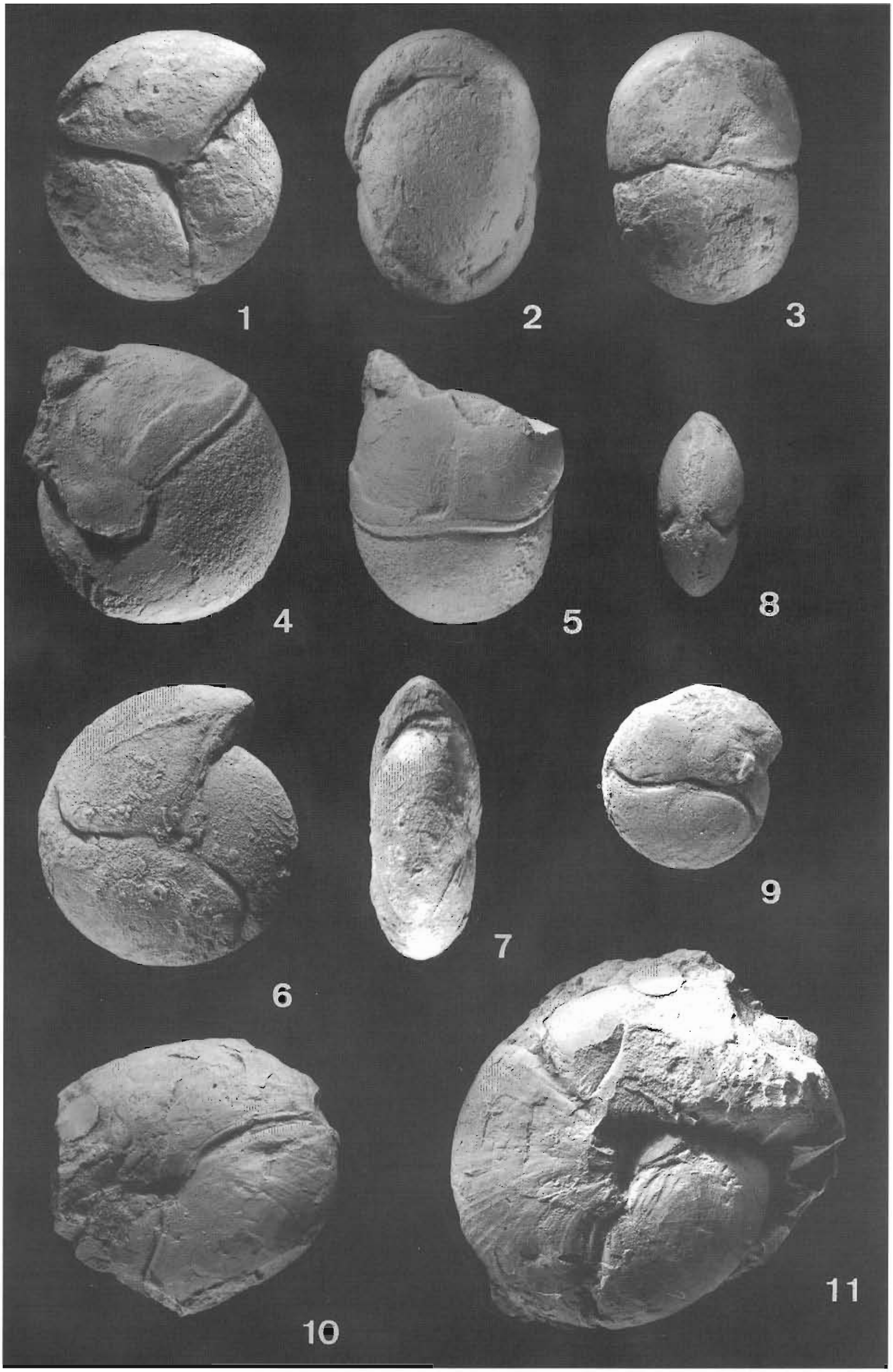
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PLATE 2

Mimimitoceras geminum Korn, Oc 1885, Oese, 30 cm below top of Wocklum Limestone (*Wocklumeria sphaeroides* Zone), x 1.
1. Lateral view with rursiradiate, biconvex ornament and shell constrictions.
2. Ventral view.

Sporadoceras posthumum Wedekind, Oc 1806, Hasselbachtal, Bed 44, x 1.5.
3. Adoral view showing part of a septal face with typical connection of the mid-flank (A_1-A_2) and dorsal saddle.
4.Lateral view with sutures.

Kosmoclymenia (Muessenbiargia) ?xenostriata Korn & Price, Oc 1780, Hasselbachtal, ca. Bed 46, x 1.5.
5. Lateral view showing the strong shell evolution.

Kosmoclymenia (Muessenbiaegia) ?galeata, Oc 1890/1, Hasselbachtal, Bed 12, x 1.
6. Ventral view showing flattening (tabulate cross-section) at relatively small size.
7. Lateral view.

Parawocklumeria paradoxa (Wedekind), Oc 1976, leg. D. Weyer, adult specimen, Hasselbachtal, Bed 102N, x 1.5.
8. Lateral view with suture lines.

Parawocklumeria paprothae Korn, Oc 1980, leg. D. Weyer, Hasselbachtal, Bed 95N (*Wocklumeria sphaeroides* Zone), x 3.
9. Lateral view with the small, open umbilicus.
10. Ventral view.

Parawocklumeria paprothae Korn, Oc 1935, Hasselbachtal, Bed 91N (*Parawocklumeria paradoxa* Subzone), x 3.
11. Lateral view.
12. Ventral view showing the high, undivided ventral saddle of a suture.

Kosmoclymenia (Linguaclymenia) similis (Münster), Oc 1779, Hasselbachtal, Bed 46, x 1.5.
13. Lateral view with typical ventrolateral furrows and sutures.
14. Keeled ventral view.

Cyrtoclymenia cf. *lateseptata* Schindewolf, Oc 2014, Oberrödinghausen road section, *Wocklumeria sphaeroides* Zone, x 1.
15. Adoral view; shell slightly more compressed than in typical *Cyrto. lateseptata*.
16. Lateral view showing biconvex growth lines close to the aperture.

Cyrtoclymenia lateseptata Schindewolf, Oc 1778, Hasselbachtal, Bed 40, x 2.
17. Lateral view with widely spaced septa and slight subumbilical ribbing.
18. Adoral view.

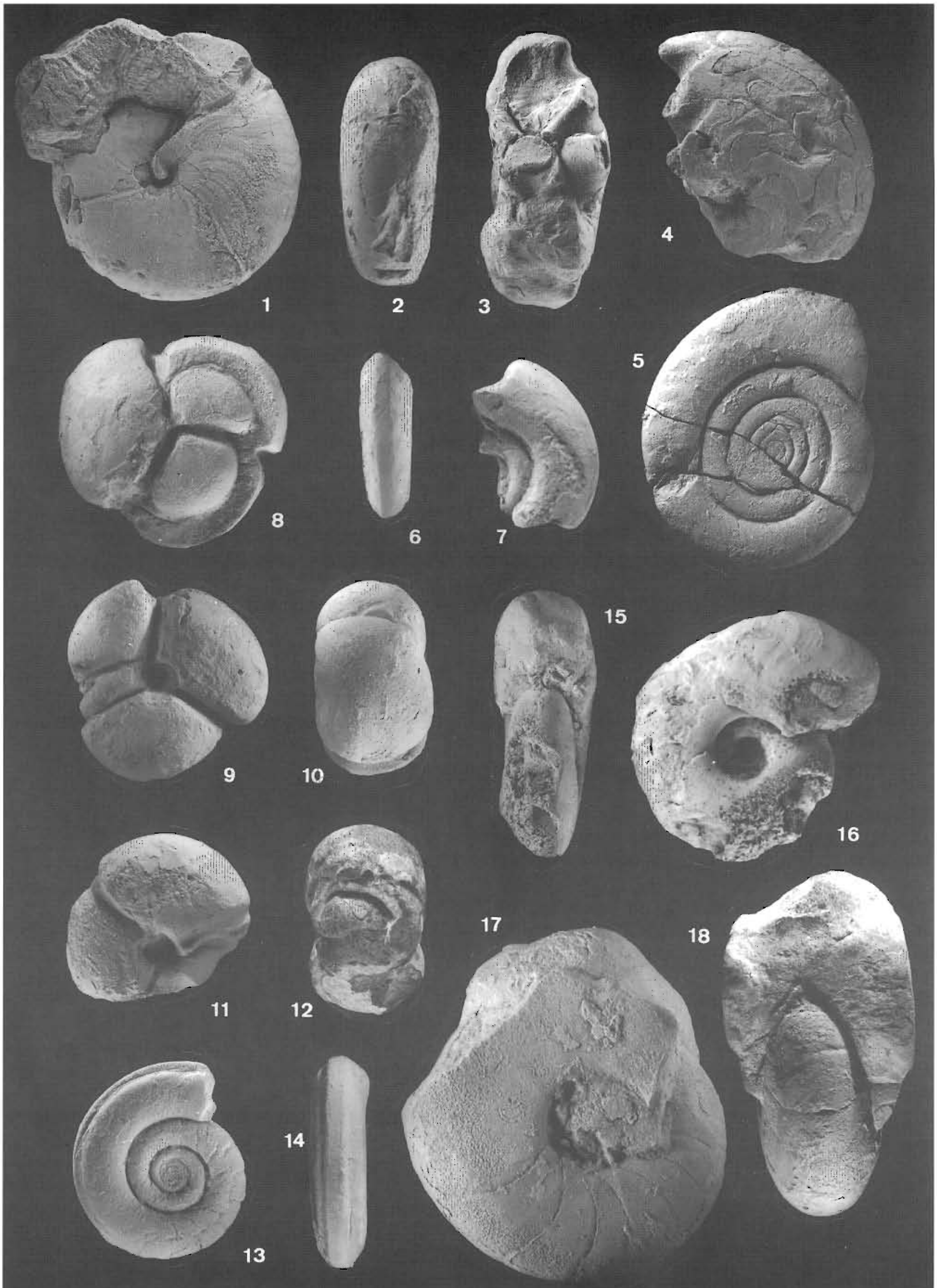
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PLATE 3

Balvia (Balvia) n. sp. aff. *globularis* Schmidt, Oc 1934, Hasselbachtal, Bed 91N, x 3.
1. Lateral view with irregularly spaced parabolic constrictions and open umbilicus.
2. Adoral view showing constrictions and the strongly developed late ontogenetic keel.
3. Ventral view with constrictions and broad, flat keel.

Balvia (Mayneoceras) nucleus (Schmidt), Oc 1954, Hasselbachtal, Bed 105N, x 3.
4. Lateral view with regularly spaced parabolic constrictions and ventrolateral furrows; umbilicus closed.
5. Ventral view with strong keel.

Balvia (Kenseyoceras) biforme (Schindewolf; = *rostrata* Selwood) Oc 2011, leg. E.B. Selwood, Stourscombe Beds, Launceston, Northern Cornwall, relatively large, adult specimen, x 3.
6. Lateral view emphasizing the biform conch ontogeny with a smooth early stage and an adult stage with a strong keel forming a pronounced rostrum which begins at a parabolic constriction.
7. Ventral view with constrictions, furrows and the projecting rostrum which does not embrace a hyponomic sinus.

Rectimitoceras lineare (Münster), Oc 2012, Effenberg, loose specimen, x 1.
8. Lateral view with undulose, convex growth ornament and without any traces of shell constrictions already at 15 - 25 mm dm.

Rectimitoceras quadripartitum (Münster), Oc 247, Oese, loose specimen, Wocklum Limestone, x 1.
9. Lateral view with four constrictions and sutures. Adventitious lobes are narrower than in *Rectim. lineare* (see Text-Fig. 5).
10. Adoral view (aperture at base) with ventral lobes, showing the strong shell compression as im *Rectim. karagandense*.

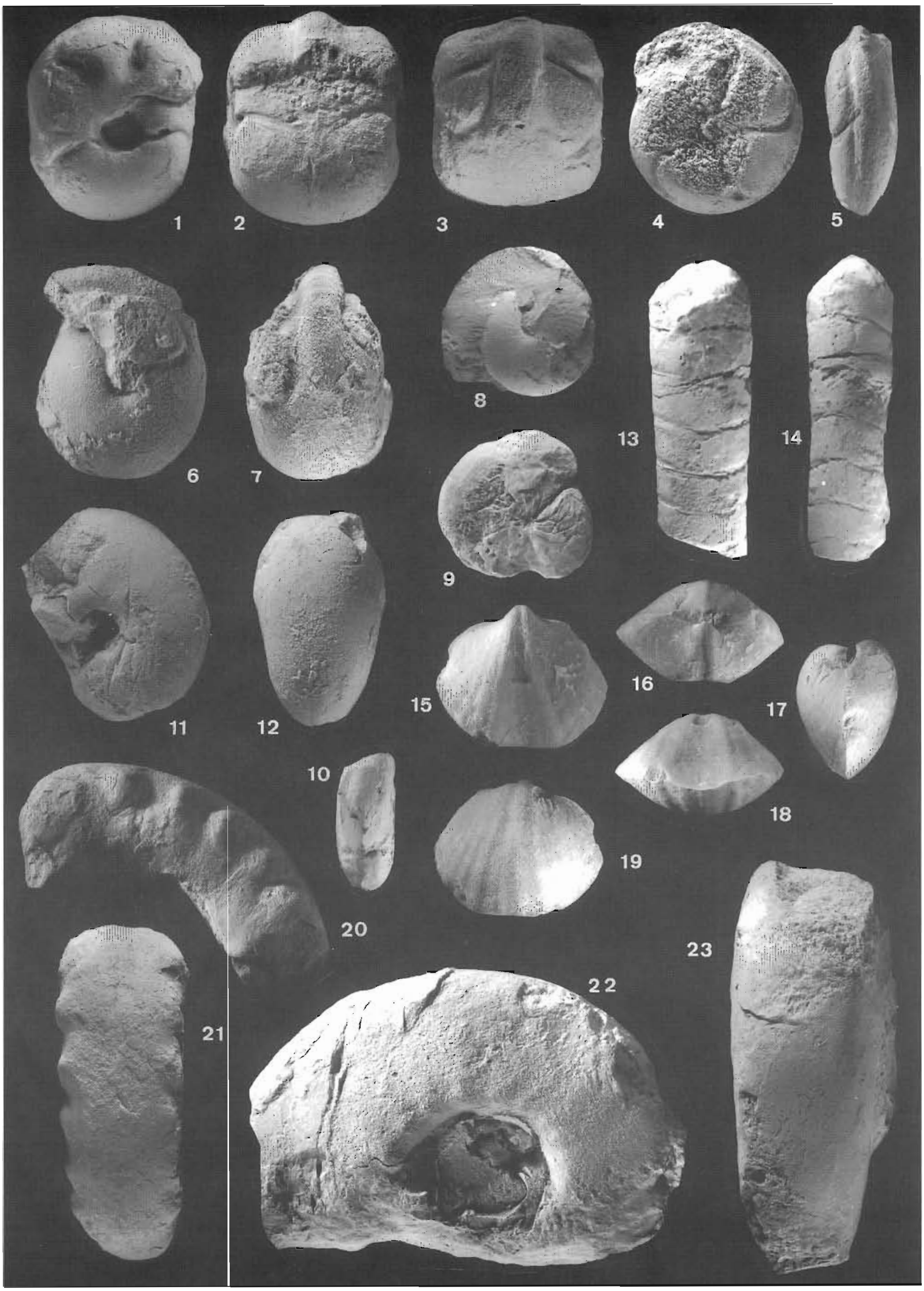
Cyrtoclymenia biimpressa (Schmidt), MNHU c.1211, lectotype, original Schmidt (1924: Pl. 6, Fig. 6; det. *Aganides sulcatus* var. *biimpressa*), Wildungen, age doubtful, x 3.
11. Lateral view showing the very narrow, open umbilicus and faint traces of biconvex growth ornament impressed on the body chamber.
12. Ventral view illustrating the well-rounded, broad whorl form.

?Arkonoceras sp., Oc 1894, Hasselbachtal, Bed 12, x 1.
13. Lateral view with wide and shallow lateral lobes of widely spaced septa.
14. Compressed dorsal or ventral view with marked saddle of sutures.

"Spiriferina" tarpata Schmidt, Ob 85, Hasselbachtal, Bed 81H, x 3.
15. Ventral view of pedicle valve with pronounced sinus.
16. Apical view (pedicle valve at the base).
17. Lateral view.
18. Frontal view (pedicle valve on top).
19. Dorsal view of pedicle valve with equal ribbing.

Kalloclymenia pessoides (v. Buch), SMF 51058, Hasselbachtal, Bed 48, x 2.
20. Lateral view with node-like parabolic ribbing.
21. Ventral view showing the relative broad whorl form (ww > wh) in comparison e.g. to *Kallo. subarmata* (with wh > ww).

Cyrtoclymenia ?inflata (Münster), MNHU c.1217, leg. E. Schmidt, 1904, det. *Cyrtoclymenia?*, Hasselbachtal, horizon unknown, x 1.5.
22. Lateral view showing traces of umbilical ribbing and biconvex growth ornament.
23. Ventral view with rounded ventrolateral edges.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