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Upper Turonian and Coniacian ammonite stratigraphy of Westphalia, NW-Germany

ABSTRACT: The Upper Turonian and Coniacian ammonite stratigraphy of the Münster Basin, Westphalia, is described in the context of the regional litho-, event- and inoceramid stratigraphy. The Upper Turonian is divided into a *Subpricyclus neptuni* Zone below and a *Prionocyclus germari* Zone above. In the Coniacian, successive zones of: (1) *Forresteria petrocoriensis*, (2) *Peroniceras* (*Peroniceras*) *tridorsatum*, (3) *Gauthiericeras margae*, (4) *Paratexanites serratomarginatus*, and (5) the lower part of the *Texanites texanus* Zone of authors are recognized. Integration of ammonite and inoceramid zones shows a discrepancy between current ammonite zonation and inoceramid-based definitions of the base of the Coniacian stage and substages proposed at the 1995 Brussels Meeting of the Subcommission on Cretaceous Stratigraphy. Rare belemnite occurrences are placed in the context of the revised ammonite stratigraphy. The correlation of the Westphalian Upper Turonian and Coniacian with that of other regions is discussed.

INTRODUCTION

New and stratigraphically refined collections of Upper Turonian and Coniacian ammonites from still extant outcrops in the Teutoburger Wald, Egge, and southern Westphalia, and revision of type material of SCHLÜTER (1867, 1871-1876), and other museum material, including that collected from mine shafts and infilled pits in southwestern Westphalia (KAPLAN & KENNEDY1994) provide the basis for a revision of the ammonite stratigraphy of the Upper Turonian to basal Santonian of this area in the context of a refined event stratigraphy and its correlation with a well-defined inoceramid zonation as well as rare belemnite occurrences.

GEOLOGICAL SETTING

In Westphalia Upper Turonian and Coniacian rocks are restricted to the Münster Basin (Text-fig. 1), which lies on the northern spur of the

Rhenish massif. The basin is bounded to the west and northwest by the Central Dutch Basin and to the north and northeast by the Lower Saxonian Basin. The southern margin of the basin is defined by Palaeozoic outcrops. Marine onlap onto the northern Rhenish Massif began in the Albian and persisted into to the late Cretaceous. Relatively nearshore Upper Turonian and Coniacian sediments are preserved only in the southwest of the Ruhr district. The predominately pelagic sediments of the southern margin of the basin suggest that the Turonian and Coniacian coastlines extended from Duisburg to the east and were situated well to the south of present outcrops of the Westphalian Upper Cretaceous (WOLANSKY 1938).

Uplift of the "Lower Saxonian Tectogen" and deepening of the Münster Basin, as a result of inversion tectonic movements, triggered submarine slides, beginning in the Turonian and becoming widespread in the

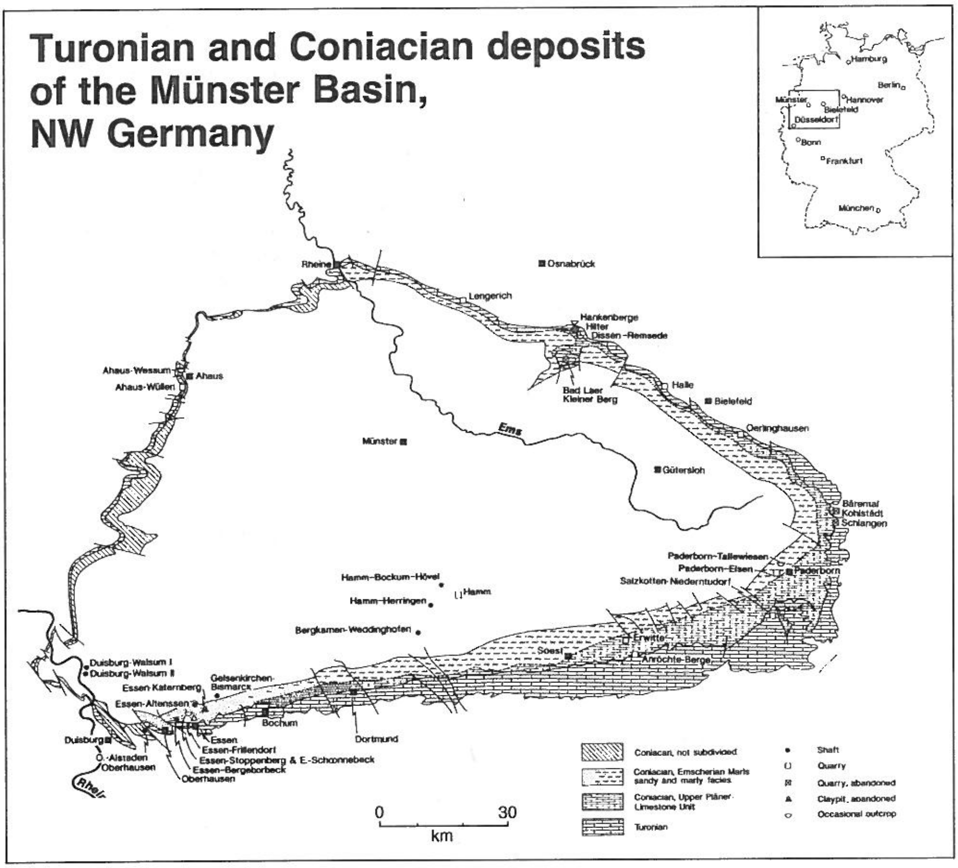
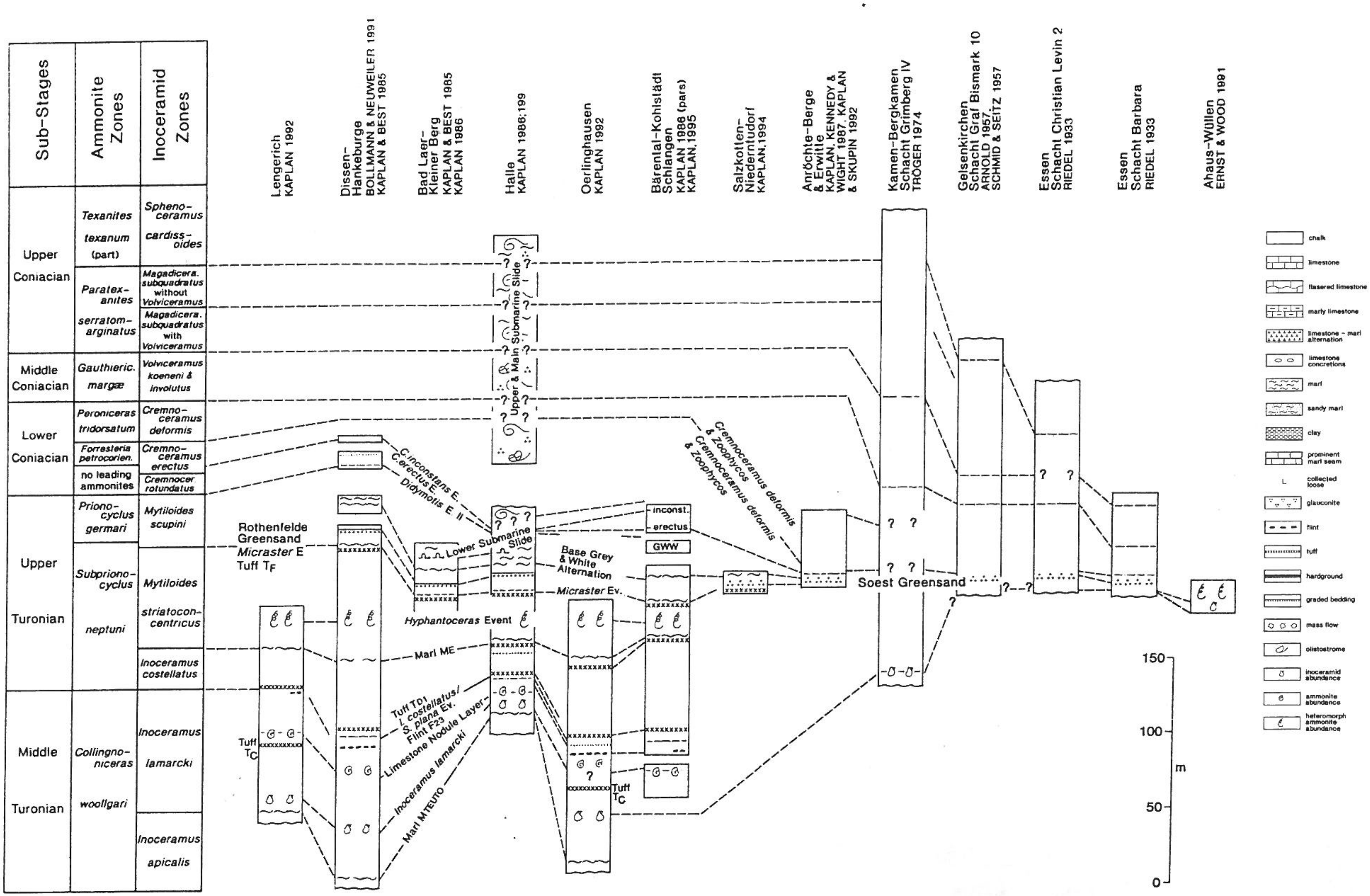


Fig. 1. The Turonian and Coniacian of the Münster Basin, Westphalia, northwestern Germany, showing localities mentioned in text (*after* HISS 1995)



Generalized correlation diagram of the Upper Turonian and Coniacian of the Münster Basin

Coniacian at the northeast boundary of the basin (VOIGT 1962, KAPLAN & BEST 1984, SKUPIN 1990). There are indications of unstable sedimentation on the northwestern boundary of the Central Dutch Basin, also beginning in the late Turonian (ERNST & WOOD 1992) and probably continuing into the Coniacian and Santonian (HISS 1995). These sedimentological anomalies indicate the beginning of the straightening of the basin and its accelerated filling.

LOCALITIES STUDIED

Stratigraphically relevant localities in the Münster Basin (Text-figs 1-2) are listed below. For further localities, ammonite occurrences, repositories of collections and additional literature see FRIEG & *al.* (1989), KAPLAN (1986, 1988, 1991, 1992), and KAPLAN & KENNEDY (1994).

Ahaus-Wessum, abandoned quarry situated northwest of the village, TK 25 Blatt 3907 Ottenstein; exact position unknown, probably lower *G. margae* Zone, *V. koeneni & involutus* Zone, infilled since the turn of the century (HOSIUS 1860, BÄRTLING 1913, BENTZ 1930).

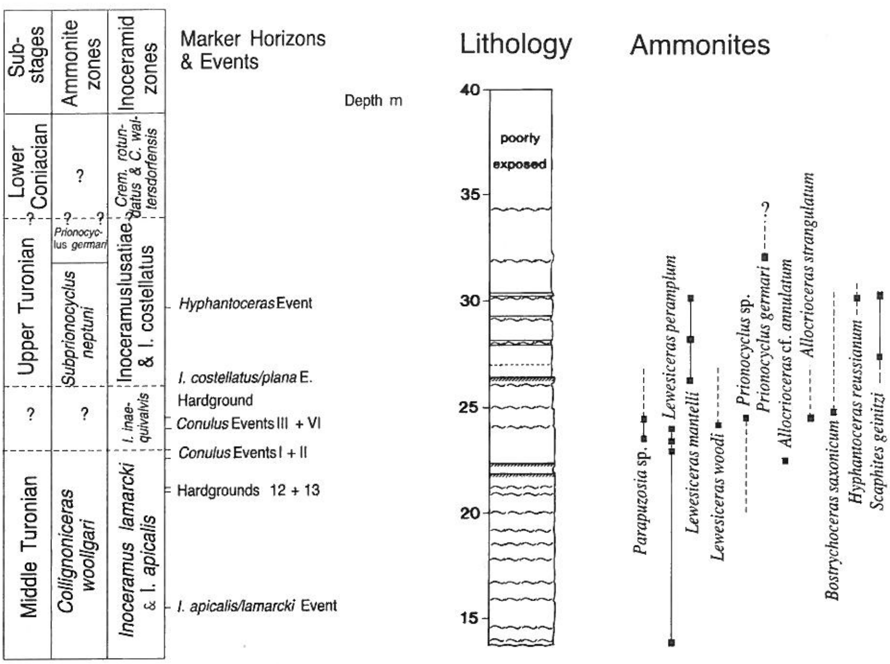


Fig. 3. Middle and Upper Turonian of Ahaus Wüllen, Hollekamp quarry, redrawn *from* ERNST & WOOD (1992)

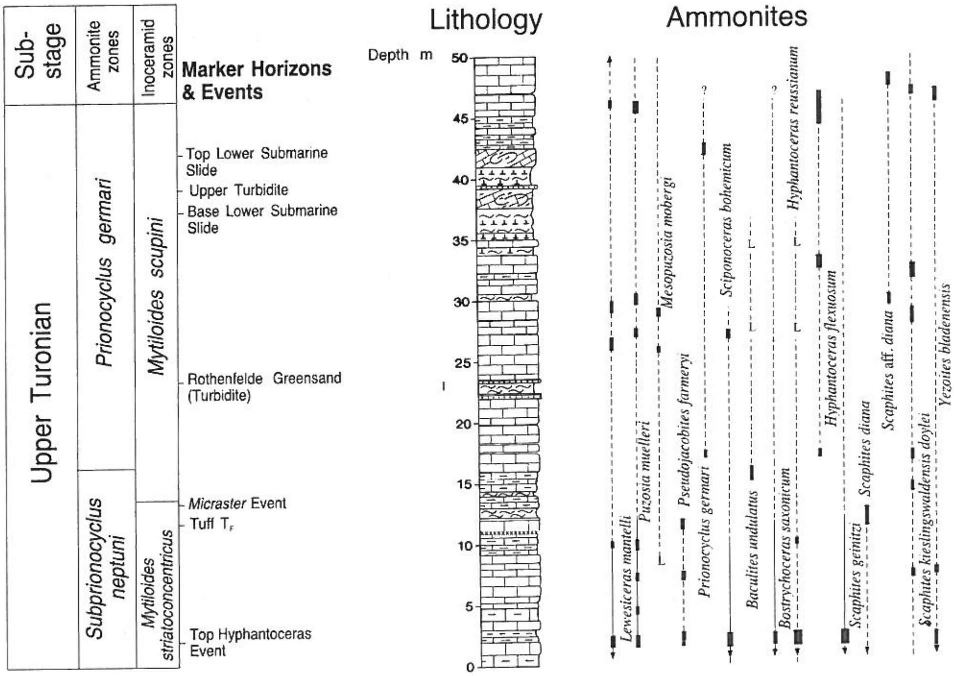


Fig. 4. Upper Turonian of Bad Laer, Kleiner Berg, abandoned Anneliese quarry, now construction rubbish tip of Dieckmann AG, Osnabrück

Ahaus-Wüllen, Hollekamp chalk quarry (Text-fig. 3), TK 25 Blatt 3907 Ottenstein, R = 25 67 550, H = 57 71 200; Upper Cenomanian to Turonian/Coniacian boundary (ERNST & WOOD 1992, LÖSCHER 1910).

Anröchte-Berge, In der Michaelishecke quarry of the Schotterwerk (macadam work) Westereiden (Text-fig. 9), TK 25 Blatt 4416 Effeln, R = 34 54 900, H = 57 15 800 (central value); Upper Turonian, *P. germari* Zone, *M. scupini* Zone to basal *P. tridorsatum* Zone, *C. deformis* Zone (KAPLAN & SKUPIN 1992, KAPLAN & KENNEDY 1994).

Bad Laer, Kleiner Berg, abandoned Anneliese quarry and currently (1995) building rubbish dump of the Dieckmann KG, Osnabrück (Text-fig. 4), TK 25 Blatt 3814 Bad Iburg, R = 34 39 900, H = 57 75 450 (central value); Upper Turonian, *S. neptuni* Zone, *Hyphantoceras* Event to *P. germari* Zone, Grey and white alternation (*Grauweiße Wechselfolge*) (KAPLAN & BEST 1984; KAPLAN 1986; WRAY & *al.* 1995).

Bärental, Horn-Bad Meinberg, forest track section on the southeastern slope of the Schierenberg (Text-fig. 6), TK 25 Blatt 4119 Horn-Bad

Meinberg Blatt, R = 34 92 950, H = 57 45 060; late Middle to Upper Turonian, *S. neptuni* Zone below marl M_E (WRAY & *al.* 1995).

Bergkamen-Weddinghofen, Grimberg coal mine, shaft IV (Text-fig. 5), TK 25 Blatt 4311 Lünen, R = 26 11 712, H 57 20 786; Upper Turonian to Lower Santonian (FALK & RIEDEL 1935, *unpubl. report*; TRÖGER 1974).

Dissen-Remsede, Arsehdehne, A 33 motorway cutting and excavations for bridges in 1993-1996 (Text-fig. 14), TK 25 Blatt 3815 Dissen am Teutoburger Wald, R = 34 43 180, H = 57 78 120; Upper Turonian, *P. germari* Zone, *M. scupini* Zone to Lower Coniacian, *F. petrocoriensis* Zone, *C. erectus* Zone (KAPLAN & KENNEDY 1994).

Dortmund-Eving, abandoned clay pit of the Dortmunder Tonwerke, TK 24 Blatt 4410 Dortmund, R = 26 03 850, H = 57 13 000; *G. margae* Zone, *V. koeneni & involutus* Zone (BÄRTLING 1913, FRANKE 1914).

Duisburg-Walsum, Walsum coal mine, Walsum I shaft = Wilhelm Roelen shaft (Text-fig. 7), TK 25 Blatt 4406 Dinslaken, R = 25 49 669, H = 57 10 760; *G. margae* Zone, *V. koeneni & involutus* Zone to *P. serratomarginatus* Zone, *M. subquadratus* Zone (KAPLAN & KENNEDY 1994).

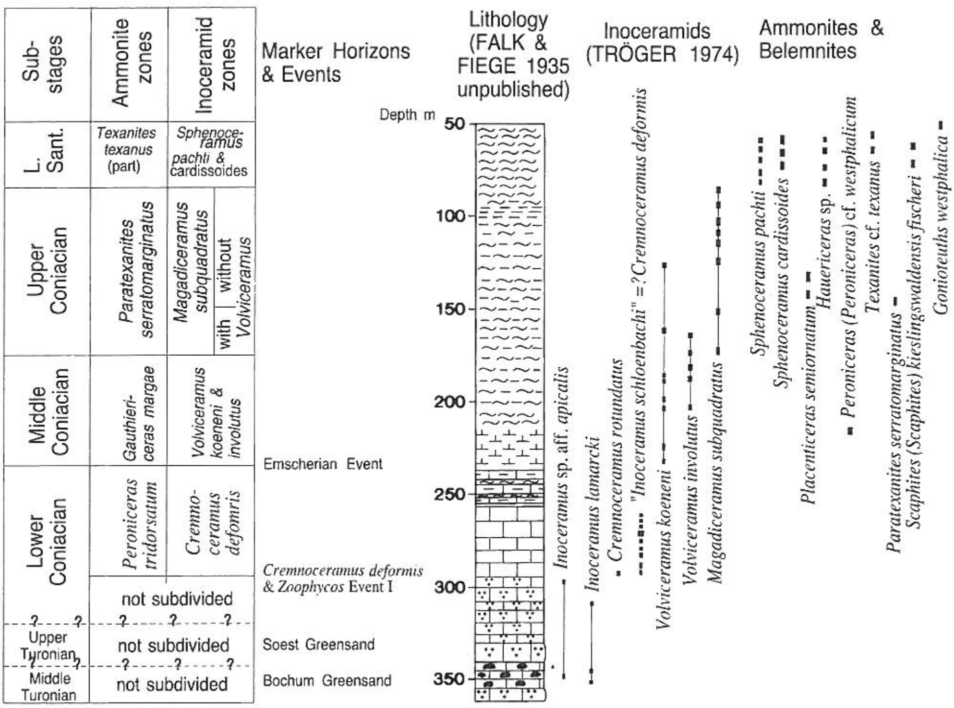


Fig. 5. Bergkamen-Weddinghofen, Grimberg coal mine, shaft IV, lithology according to FALK & FIEGE (1935), unpublished report in Geologisches Landesamt Nordrhein-Westfalen, Krefeld, and TRÖGER (1974); fossil determinations after K.-A. TRÖGER

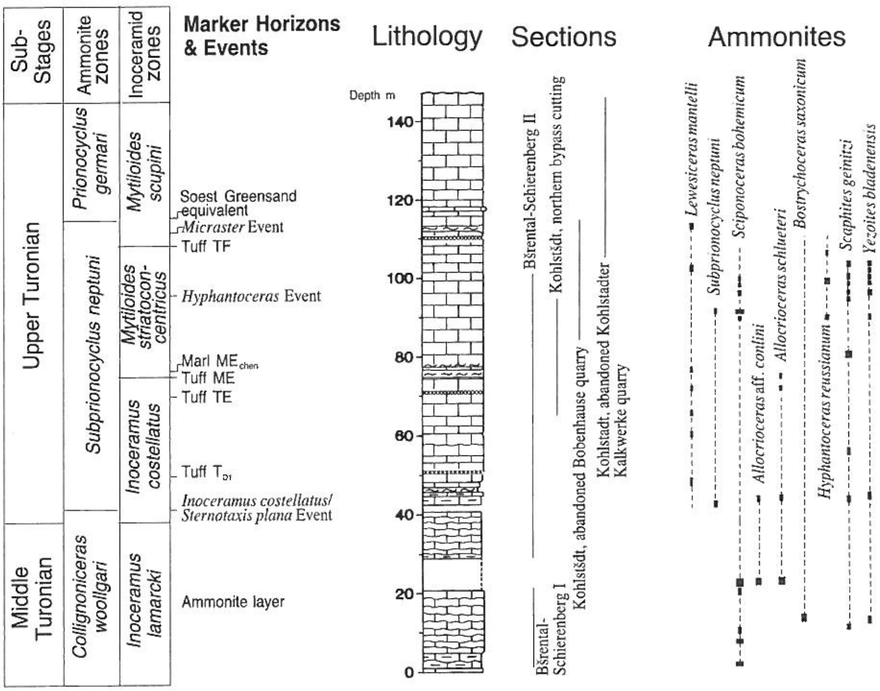


Fig. 6. Middle and Upper Turonian of Kohlstädt – Bärental and ammonite occurrences, composite section of Horn-Bad Meinberg – Bärental, Schierenberg, Kohlstädt, northern abandoned quarry, Kohlstädt, abandoned Böger-Ever quarry, Kohlstädt, eastern and northern B 1 bypass

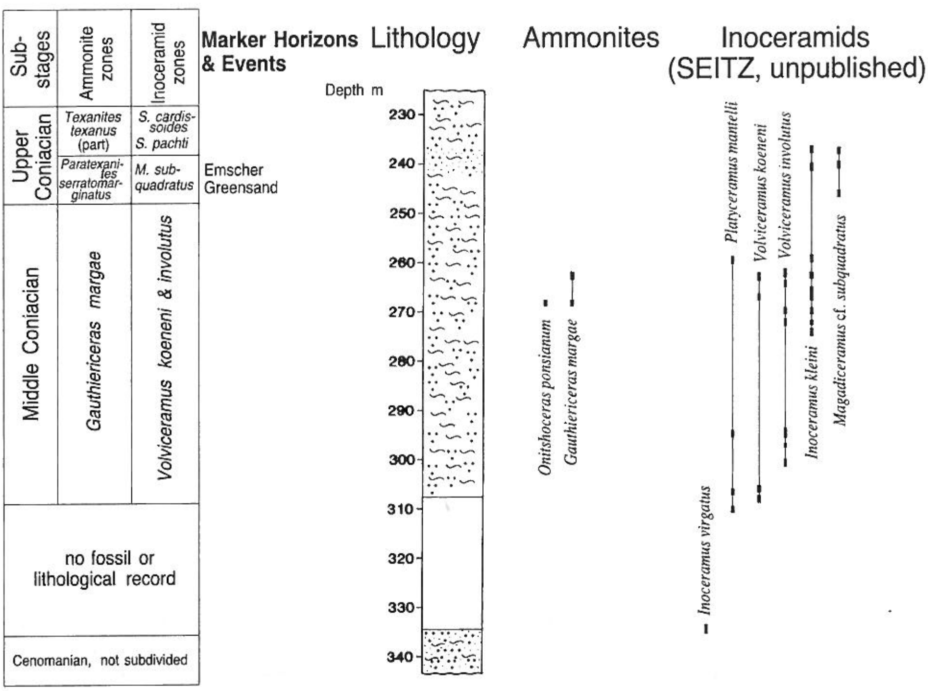


Fig. 7. Duisburg-Walsum, Walsum coal mine, Walsum I shaft = Wilhelm Roelen shaft

Duisburg-Walsum, coal mine Walsum, Walsum II shaft = Franz Lenze shaft (Text-fig. 8), TK 25 Blatt 4406 Dinslaken, R = 25 49 765, H = 57 10 790; *G. margae* Zone to *P. serratomarginatus* Zone, *V. koeneni & involutus* Zone to *M. subquadratus* Zone without *Volviceramus* (KAPLAN & KENNEDY 1994).

Erwitte, quarries of the Seibel & Söhne, Wittekind and Spenner cement-works. These contiguous quarries are combined in our account; there are no significant differences in litho- and biostratigraphy (Text-fig. 9), TK 25 Blatt 4316 Lippstadt, R = 34 55 500, H = 57 16 900 (central value of the quarry realm); *P. tridorsatum* Zone, *C. deformis* Zone (KAPLAN & SKUPIN 1992, KAPLAN & KENNEDY 1994).

Essen-Bergeborbeck, Amalie coal mine, Barbara air shaft (Text-fig. 10). TK 25 Blatt 4507 Mülheim, R = 25 69 190, H = 57 05 330; basal Coniacian to *G. margae* Zone, *V. koeneni & involutus* Zone (RIEDEL 1933, KAPLAN & KENNEDY 1994).

Essen-Bergeborbeck, Christian Levin coal mine, shaft 2, TK 25 Blatt 4507 Mühlheim, R = 25 65 550, H = 57 07 200; Upper Turonian to Coniacian, *G. margae* Zone, *V. koeneni & involutus* Zone (RIEDEL 1933, KAPLAN & KENNEDY 1994).

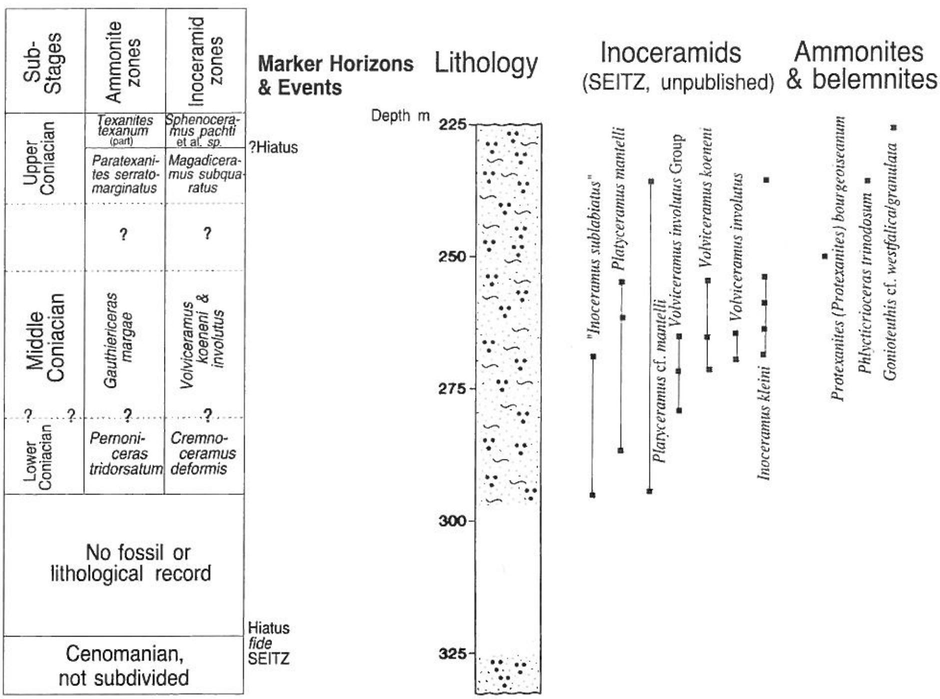


Fig. 8. Duisburg-Walsum, Walsum coal mine, Walsum II shaft = Franz Lenze shaft

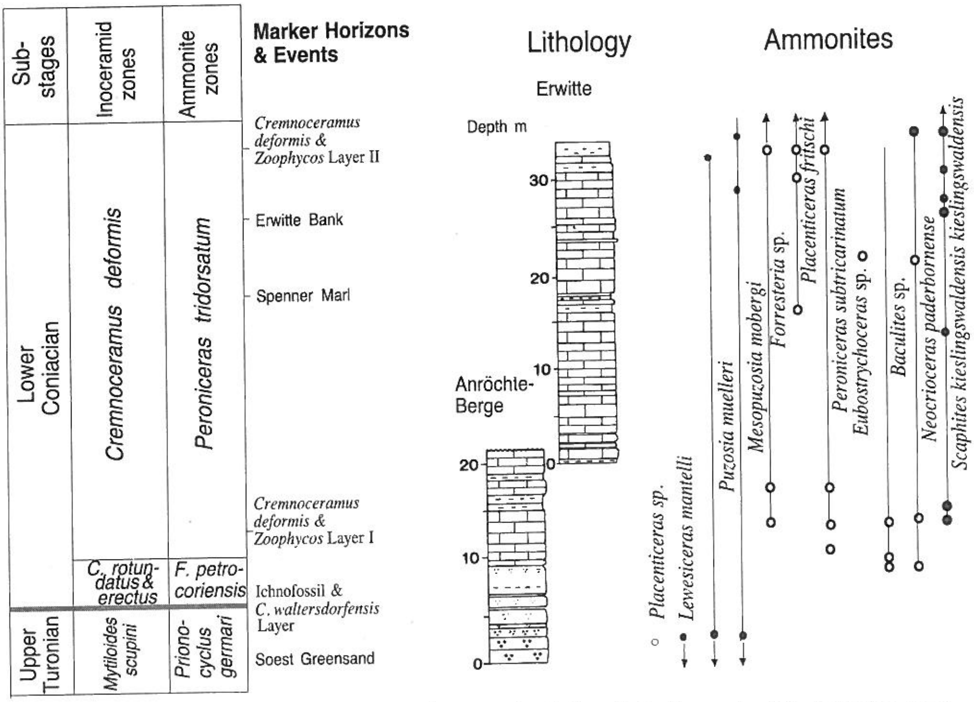


Fig. 9. Upper Turonian and Coniacian of Berge-Anröchte, Schotterwerke Westereiden quarry, also known as "Steinbruch in der Michaelishecke" and the Coniacian of Erwitte, composite section of the quarries of the Wittekind and Seibel & Söhne cementworks

Essen-Frillendoft, abandoned clay pit of the Königin Elisabeth coal mine near shafts Hubert I and II, TK 25 Blatt 4508 Essen, R = 25 73 200, H =200, H = 57 04 010, Lower Coniacian (Kaplan & Kennedy 1994)

Essen-Schonnebeck, abandoned clay pit of the Altstadt-Baugesellschaft, Huestrasse. TK 25 Blatt 4508 Essen, R = 25 73 900, H = 57 06 200, *P. serratomarginatus* Zone, *M. subquadratus* Zone with and ?without *Volviceramus* (Kaplan & Kennedy 1994).

Essen-Schonnebeck, abandoned clay pit Boonekampstrasse TK 25 Blatt Essen, R = 25 74 400, H = 57 06 650; *G. margae* Zone *P. serratomarginatus* Zone, *V. koeneni & involutus* Zone ?*M. subquadratus* Zone without *Volviceramus* (Kaplan & Kennedy 1994).

Essen-Stoppenberg, excavations for the coke works of the Ernestine coal mine at the Salkenberg in 1928, TK 25 Blatt 4508 Essen, R = 25 72 750, H = 57 04 700; Lower Emscherian according to Riedel (1933), probably *G. margae* Zone, *V. koeneni & involutus* Zone (Riedel 1928).

Gelsenkirchen-Bismarck, Graf Bismarck coal mine, central air shaft 10 (Text-fig. 13), TK 25 Blatt 4408 Gelsenkirchen, R = 25 77 232, H = 57 13 910; Turonian to Lower Santonian (Arnold 1957, Schmid & Seitz 1957).

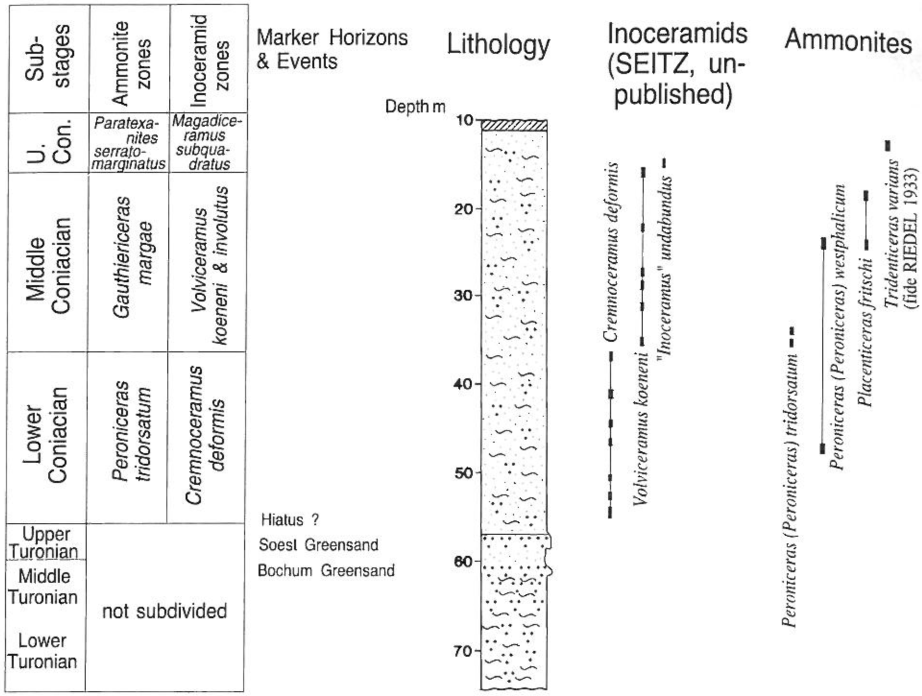


Fig. 10. Essen-Bergeborbeck, Amalie coal mine, Barbara air shaft, redrawn and annotated after RIEDEL (1933)

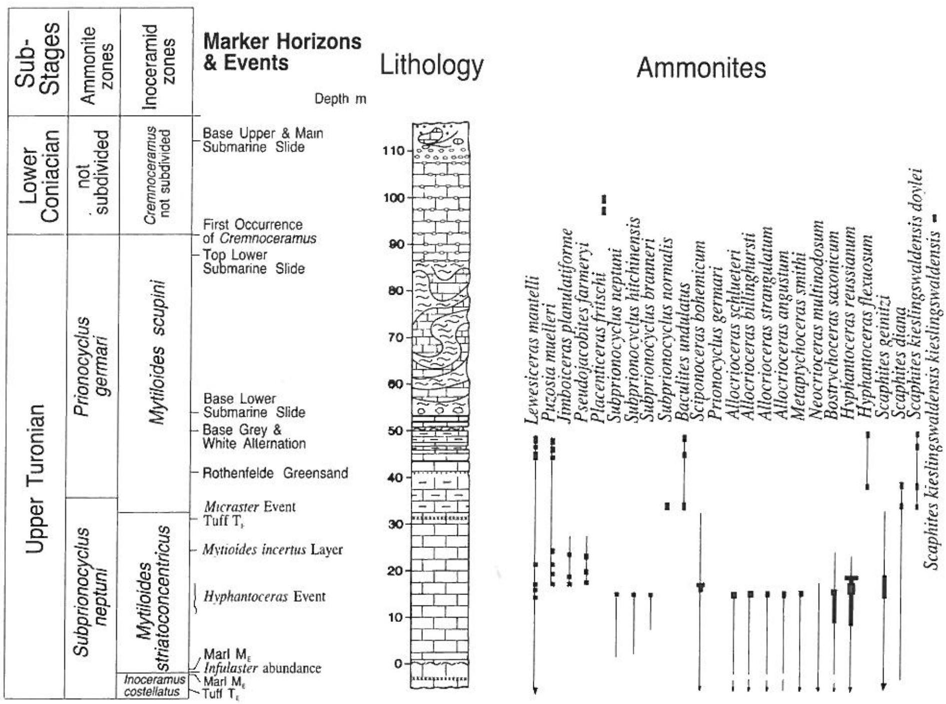


Fig. 11. Upper Upper Turonian and Coniacian of Halle (Westphalia), F. Foerth quarry

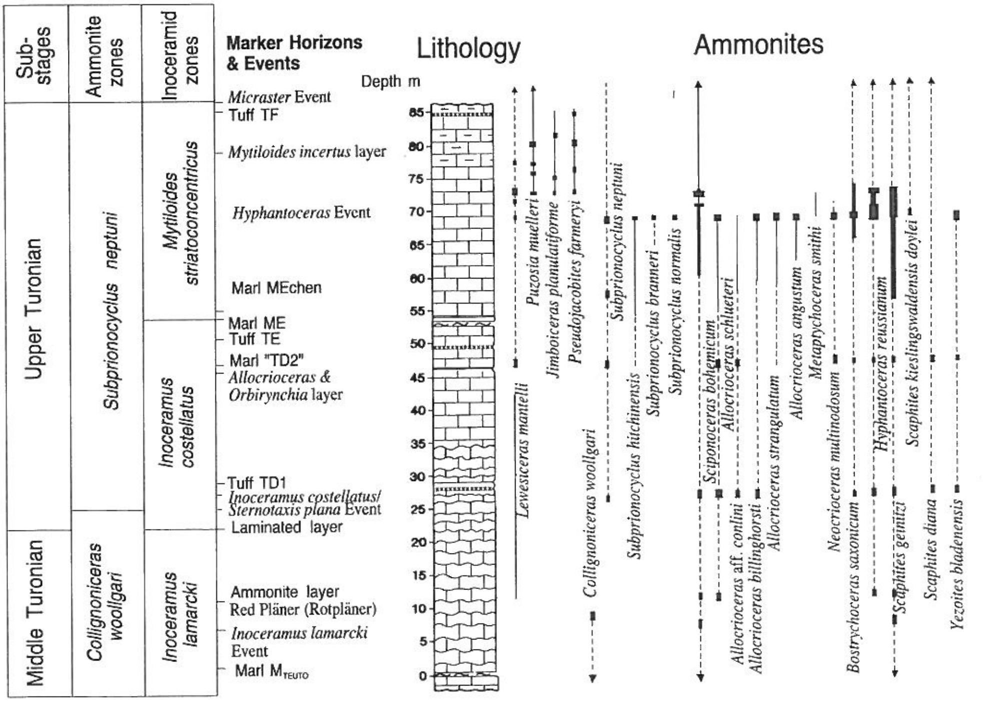


Fig. 12. Middle and Upper Turonian of Halle (Westphalia), F. Foerth quarry

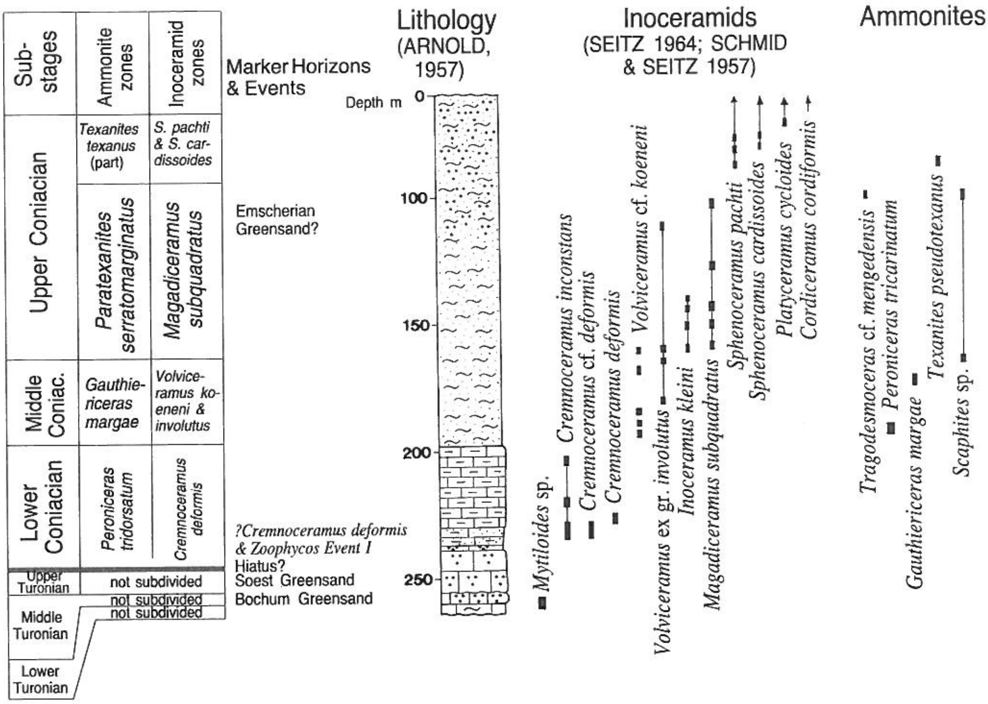


Fig. 13. Gelsenkirchen-Bismarck, Graf Bismarck coal mine, Graf Bismarck 10 central air shaft, redrawn and annotated *from* ARNOLD (1957) (lithology) and SCHMID & SEITZ (1957) (inoceramids)

Halle (Westphalia), F. Foerth quarry (Text-figs 11-12, 19), TK 25 Blatt 3916 Halle/Westfalen, R = 34 55 200, H = 57 31 300 (central value); Upper Cenomanian to Lower Coniacian, *C. deformis* Zone, overlain by Coniacian olistostromes (KAPLAN 1986, 1988, 1989, 1991; WRAY & *al.* 1995).

Hamm-Bockum-Hövel, Radbod coal mine, shaft 2, TK 25 Blatt 4312 Hamm, R = 26 21 950, H = 57 29 590; Upper Turonian to Coniacian (KAPLAN & KENNEDY 1994).

Hamm-Herringen, de Wendel coal mine, Humbert shaft, TK 25 Blatt 4312 Hamm, R = 26 21 483, H = 57 26 327; complete Upper Turonian and Coniacian (KAPLAN & KENNEDY 1994).

Hilter, abandoned Schulte Rosskotten quarry (renamed Wicking quarry) (Text-fig. 14), TK 25 Blatt 3815 Dissen, R = 34 43 000, H = 57 78 900 (central value); Upper Turonian, *S. neptuni* Zone and *P. germari* Zone (ELBERT 1902; KAPLAN & BEST 1984; KAPLAN 1986, 1989).

Kohlstädt, eastern and northern B1 bypass (Text-fig. 6), TK 25 Blatt 4119 Horn-Bad Meinberg, R = 34 92 000, H = 57 44 050; Upper Turonian, middle *S. neptuni* Zone (WRAY & *al.* 1995).

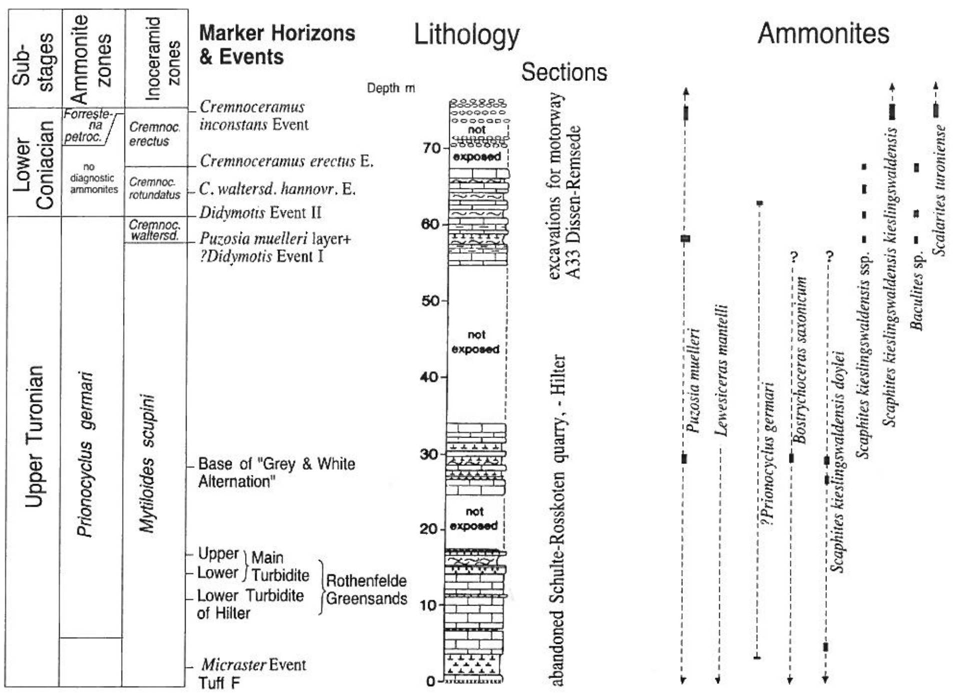


Fig. 14. Upper Turonian and Coniacian of Hilter, abandoned Schulte-Rosskotten quarry, and Dissen, A 33 motorway-cutting, composite section

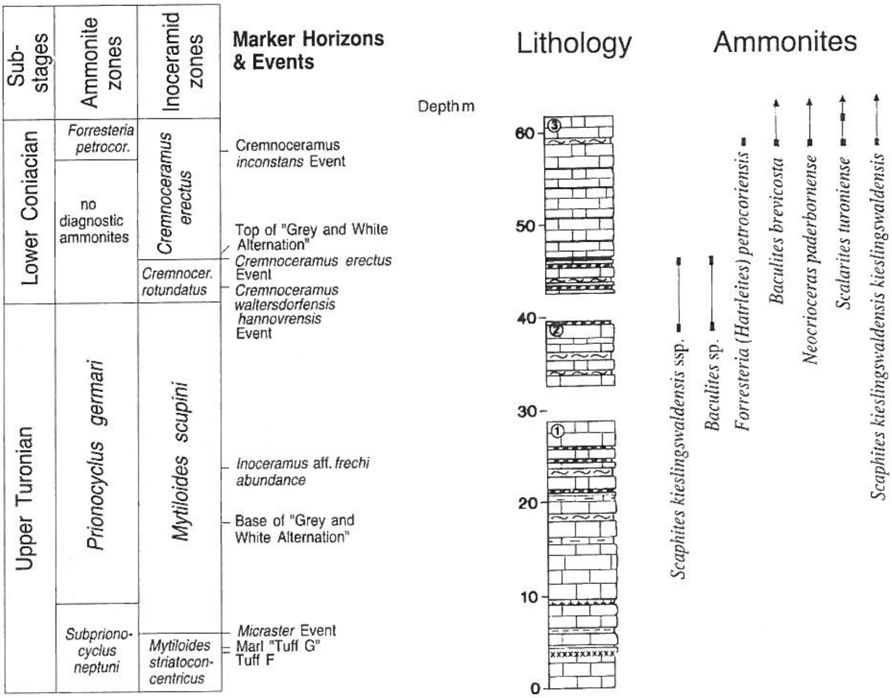


Fig. 15. Late Upper Turonian and early Coniacian of (1) Kohlstädt, B 1 bypass section, abandoned Giese quarry, (2) Bad Lippspringe, abandoned quaries and track cuttings, and (3) Schlangen, abundant Hühnerberg quarry

Kohlstädt, abandoned Bobenhausen quarry (Text-fig. 6), TK 25 Blatt 4119 Horn-Bad Meinberg, R = 34 91 610, H = 57 43 890; Upper Turonian, *S. neptuni* Zone above *Hyphantoceras* Event to *Micraster* Event (KAPLAN 1994, WRAY & *al*. 1995).

Kohlstädt, abandoned Kohlstädter Kalkwerke quarry (Text-fig. 6), TK 25 Blatt 4119 Horn-Bad Meinberg, R = 34 91 220, H = 37 43 580; Upper Turonian, high *S. neptuni* Zone to *P. germari* Zone (KAPLAN 1994, WRAY & *al*. 1995).

Kohlstädt, abandoned Giese quarry (Text-fig. 15), TK 25 Blatt 4119 Horn Meinberg, R = 34 90 680, H = 57 43 460; upper Turonian, upper *S. neptuni* Zone to *P. germari* Zone (WRAY & *al*. 1995).

Lengerich, southern railway cutting (Text-fig. 16), TK 25 Blatt 3813 Lengerich, R = 34 22 850, H = 57 84 200; upper Middle to Upper Turonian, *S. neptuni* Zone (KAPLAN 1991).

Lengerich, abandoned Wicking II quarry (Text-fig. 16), TK 25 Blatt 3813 Lengerich, R = 34 23 100, H = 57 84 100; upper Middle to Upper Turonian, *S. neptuni* Zone, *Hyphantoceras* Event (KAPLAN 1989, 1991; WRAY & *al*. 1995).

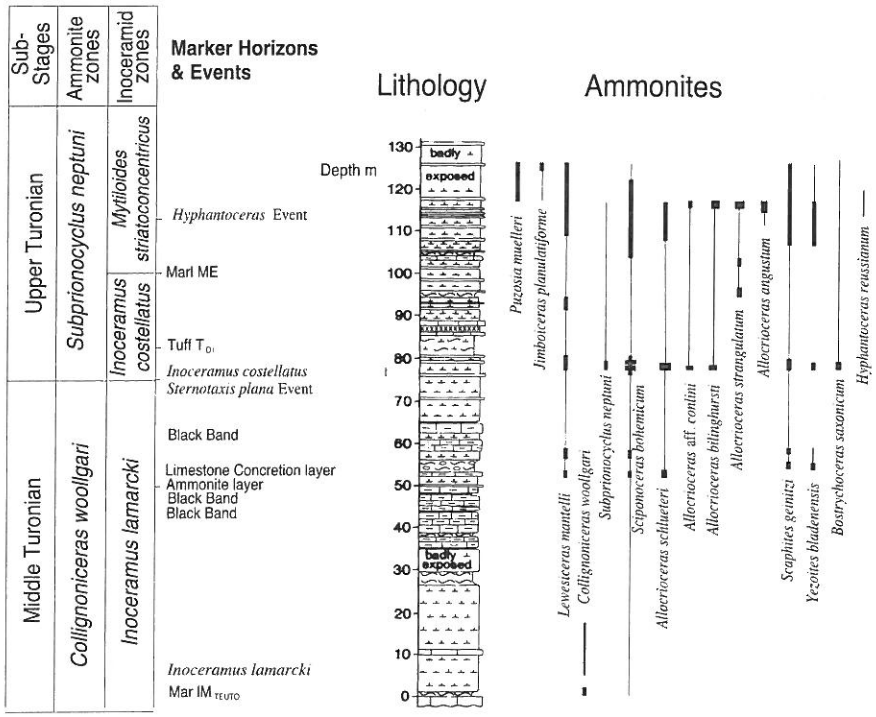


Fig. 16. Middle and Upper Turonian of Lengrich, composite section from the southern railway cutting, abandoned Wicking II quarry and Dyckerhoff AG quarry

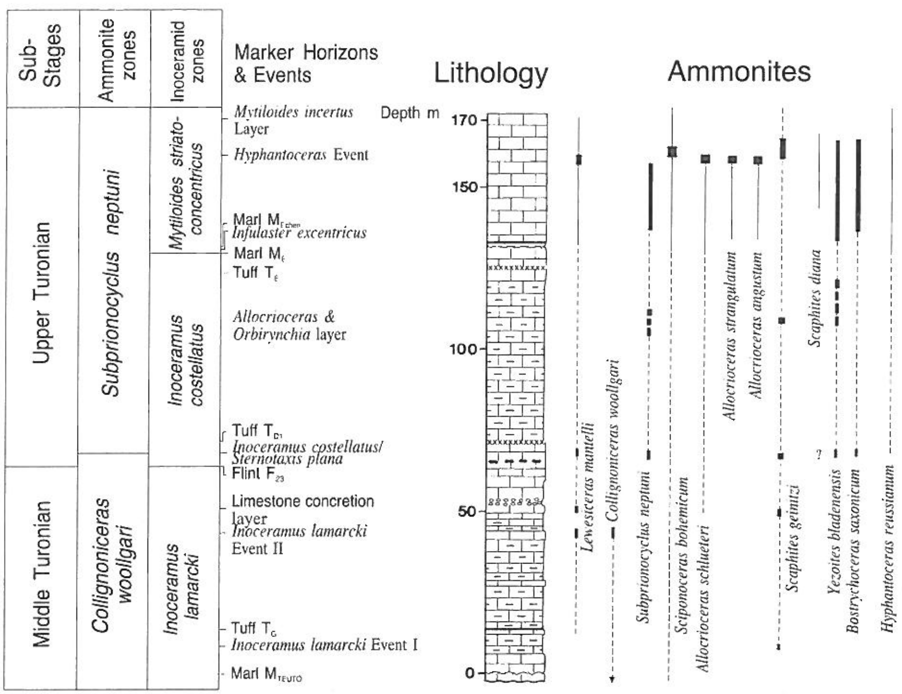


Fig. 17. Middle and Upper Turonian of Oerlinghausen, O. Foerth quarry

Lengerich, quarry of the Dyckerhoff AG (Text-fig. 16), central quarry road, TK 25 Blatt 3813 Lengerich, R = 34 24 600, H = 57 83 400; upper Middle Turonian to lower Upper Turonian, *S. neptuni* Zone (KAPLAN 1989, 1991).

Oberhausen-Alstaden, Alstaden coal mine, probably shaft 2, a SCHLÜTER locality. SCHLÜTER (1867, 1871-76) gives no precise locality for his material, but shaft 2 seems to be possible on the basis of the date of excavation. TK 25 Blatt 4506 Duisburg, R = 25 57 400, H = 57 02 796; Coniacian, exact horizons unknown (SCHLÜTER 1872-76; KAPLAN & KENNEDY 1994).

Oerlinghauen, O. Foerth quarry (Text-fig. 17), TK 25 Blatt 4017 Brackwede, R = 34 76 700, H = 57 57 050 (central value); Lower to Upper Turonian, *S. neptuni* Zone (KAPLAN 1989, 1992; WRAY & *al.* 1995).

Paderborn-Elsen, Rottberg, temporary outcrop, TK 25 Blatt 4218 Paderborn R = 34 78 100 H = 57 31 770; *P. serratomarginatus* Zone, boundary with *M. subquadratus* Zone with and without *Volviceramus* (SKUPIN 1982).

Paderborn-Tallewiesen, temporary outcrop, TK 25 Blatt 4218 Paderborn R = 34 80 300, H = 57 31 910; *P. serratomarginatus* Zone, *M. subquadratus* Zone (SKUPIN 1982).

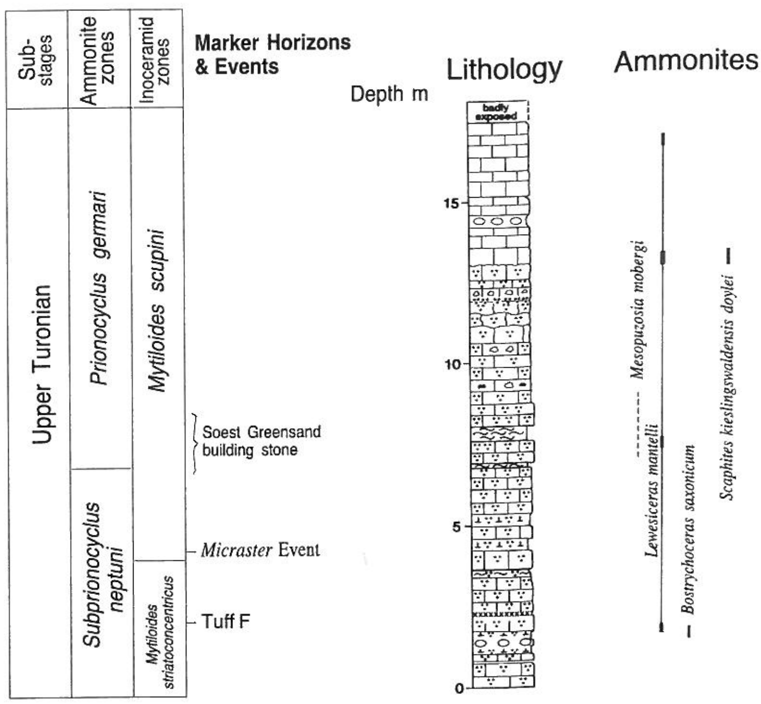


Fig. 18. Salzkotten–Niederntudorf, Stelbrink quarry, upper Upper Turonian

Salzkotten-Niederntudorf, Stelbrink quarry (Text-fig. 18), TK 25 Blatt 4318 Borchen, R = 34 78 600, H = 57 21 250; Upper Turonian, upper *S. neptuni* Zone to *P. germari* Zone (KAPLAN 1994, WRAY & *al.* 1995).

Schlangen, abandoned Hühnerberg quarry, currently (1995) being refilled as a building rubbish dump (Text-fig. 15), TK 25 Blatt 4119 Horn - Bad Meinberg, R = 34 90 420, H = 57 41 120; *F. petrocoriensis* Zone, *C. rotundatus* and *C. erectus* Zone, *C. inconstans* Event (KAPLAN 1986, KAPLAN & KENNEDY 1994).

STAGE AND SUBSTAGE DEFINITIONS

The stage and substage definitions used here are those provisionally adopted at the Subcommission on Cretaceous Stratigraphy Symposium on Cretaceous Stage Boundaries held in Brussels, September 1995.

The base of the Middle Turonian was defined at the first occurrence of *Collignoniceras woollgari* in Bed *120* of the Greenhorn Limestone at Rock Canyon, Pueblo, Colorado.

The base of the Upper Turonian was not formally agreed in Brussels, but there was agreement that it should be an inoceramid datum, corresponding to the base of the *Inoceramus costellatus* Zone of German workers.

The base of the Coniacian was defined as the entry point of *Cremnoceramus rotundatus* (*sensu* TRÖGER *non* FIEGE) at Salzgitter-Salder, Lower Saxony, Germany (*see* KAUFFMAN & *al.* 1996).

The base of the Middle Coniacian was defined as the entry point of *Volviceramus koeneni*, at a locality to be agreed subsequently.

The base of the Upper Coniacian was defined as the entry point of *Magadiceramus subquadratus* at a locality to be agreed subsequently.

The base of the Santonian was defined as the first occurrence of *Cladoceramus undulatoplicatus* at a locality to be agreed subsequently.

LITHOSTRATIGRAPHY

The Upper Turonian and Coniacian sediments of the Münster Basin can be divided into two contiguous depositional areas. The larger one is occupied by pelagic sediments, which extend over central, northern and southeastern Westphalia. The Upper Turonian and Coniacian centre of the Münster Basin lay immediately northwest of Münster (ARNOLD 1964). Pelagic sediments pass laterally with an increase in glauconite content and intercalation of sandy marlstones into nearshore sandy sediments with a high content of glauconite in southwest Westphalia. Thickness generally decreases from northeast to southwest in all lithological units.

The Turonian of the northern and northwestern Münster Basin is developed in a condensed chalk facies. Coniacian deposits were influenced by synsedimentary events and are incompletely developed, in a chalk and limestone facies. There are no outcrops at present. The only Coniacian ammonite from this area is a limestone mould of *Tongoboryceras hancocki* KENNEDY, 1984, from Ahaus-Wessum (*see* KENNEDY 1984a).

The Upper Turonian and Coniacian of the southeastern and central Münster Basin is divided into the following lithological units (from top downward) with the rank of formations (FRIEG & *al.* 1989):

5. Emscherian-Marl Group (*Emscher-Mergel*),
4. Limestone-Marl Transition Beds (*Kalkig-mergelige Übergangsschichten*),
3. Upper Pläner-Limestone Unit (*Obere Plänerkalkstein-Einheit*),
2. Grey and White Alternation (*Grauweiße Wechselfolge*),
1. Lower Pläner-Limestone Unit (*Untere Plänerkalkstein-Einheit*).

Nearshore Upper Turonian deposits of southwestern Westphalia are strongly condensed, and represented by the glauconitic Soest Greensand. This grades imperceptibly into the glauconitic Emscherian Marl and the highly glauconitic Emscherian Greensand at the top of the Coniacian in southwestern Westphalia.

EVENT STRATIGRAPHY AND MARKER HORIZONS

The event-stratigraphic scheme developed by ERNST & *al.* (1983) for the Plänerkalk-Group (Cenomanian to Coniacian) and emended for Lower Saxony Turonian/Coniacian boundary sections by WOOD & *al.* (1984) can be recognized (with some faunal differences) in the pelagic Turonian of the Teutoburger Wald and Egge in the eastern part of the study area (KAPLAN 1986, 1991, 1992; KAPLAN & KENNEDY 1994). Geochemical evidence for the occurrence of four Turonian tuff layers was presented by WRAY & *al.* (1995). In the Lower Coniacian *Peroniceras tridorsatum* Zone, *Cremnoceramus deformis* Zone (the Upper Limestone Unit = *schloenbachi* Schichten) between Paderborn and Erwitte additional marker horizons occur (Text-figs 2 and 9).

It has not yet proved possible to establish an elaborate scheme based on stratigraphic events and marker horizons for the Coniacian and Lower Santonian part of the Emscherian Marl, although there are indications of several inoceramid floods. Single traceable major events are: the Emscherian Greensand in the uppermost Coniacian of southwestern Westphalia, and an abundance of *Texanites* in the uppermost Coniacian. It is probable that, as in underlying units, inoceramid abundances are potential marker horizons.

White Boundary Bed and Marl M Teuto

In the area of the Teutoburger Wald and southwestern Westphalia, the lower *Inoceramus lamarcki* Zone White Boundary Bed yields *Inoceramus apicalis*, *I. cuvieri*, rare *I. lamarcki*, and *Collignoniceras woollgari*. The genus *Sciponoceras* occurs occasionally. The immediately overlying Marl M Teuto correlates with the Lower Saxonian marl T 0. Localities are: Lengerich, Dyckerhoff AG quarry (Text-fig. 16), Halle, F. Foerth quarry (Text-fig. 12) and Oerlinghausen, O. Foerth quarry (Text-fig. 17).

***Inoceramus lamarcki* events**

There up to four abundance levels of *Inoceramus lamarcki* and allied species between Marl M Teuto and the Middle/Upper Turonian boundary. Ammonites occur rarely and are generally badly preserved, but include *Lewesiceras mantelli*, *Collignoniceras woollgari*, *Sciponoceras bohemicum* and *Scaphites geinitzi*. Localities are: Lengerich, Dyckerhoff AG quarry (Text-fig. 3), Halle, F. Foerth quarry (Text-fig. 12), Oerlinghausen, O. Foerth quarry (Text-fig. 17), and Berental, Schierenberg forest tracks (Text-fig. 6).

Tuff TC

Only exposed at Oerlinghausen, approximately 20m below the limestone nodule layer, and at Lengerich, approximately 8m below the limestone nodule layer.

Limestone nodule layer with basal ammonite abundance

Between the third and fourth *I. lamarcki* abundance levels an approximately 3m thick horizon with limestone nodules occurs in the expanded sections of Lengerich and Oerlinghausen. It is more or less condensed at Halle and only poorly exposed at Bärental-Schierenberg. Ammonites are: *Lewesiceras mantelli*, *Sciponoceras bohemicum*, *Scaphites geinitzi*, *Yezoites bladenensis*, *Hyphantoceras reussianum* and *Allocrioceras schlueteri*. It thus already yields elements of the ammonite fauna that becomes abundant in the Upper Turonian. Localities: Lengerich, railway cutting, Wicking II quarry, Dyckerhoff AG quarry (Text-fig. 16), Halle, F. Foerth quarry (Text-fig. 12), Oerlinghausen, O. Foerth quarry (Text-fig. 17), Horn-Bad Meinberg, Schierenberg (Text-fig. 6).

Flint-layer F 23

This layer (ERNST & *al.* 1983) is sometimes represented by thinly laminated limestones. Geographically widespread flints are generally rare in the Westphalian Turonian with the exception of flint-layer F 23, where as many as four layers of grey flints up to 10cm thick occur in laminated limestones. The laminated limestones occur at localities such as the F. Foerth quarry at Halle (Text-fig. 12) and Schierenberg, Bärental, Horn-Bad Meinberg (Text-fig. 6), where the flints are missing. Flint F 23 occurs at Lengerich, in the eastern part of the Dyckerhoff AG quarry (Text-fig. 16), Hilter, A 33 motorway cutting, and F. Foerth quarry, Oerlinghausen (Text-fig. 17). The Upper Turonian inoceramid index species *Inoceramus costellatus* first occurs in flint F 23 and marks the Middle/Upper Turonian boundary.

***Inoceramus costellatus/Sternotaxis plana* Event**

Approximately 5m above Flint layer F23, there are significant faunal changes in inoceramids and ammonites. In Westphalia this is characterized by *Inoceramus costellatus*, *I. apicalis*, *I. cuvieri*, *Infulaster exentricus* and by a rich and diverse ammonite fauna especially in the northwestern Teutoburger Wald: *Lewesiceras mantelli*, *Subprionocyclus neptuni*, *Sciponoceras bohemicum*, *Scaphites geinitzi*, *Yezoites bladenensis*, *Allocrioceras schlueteri*, *A. billinghursti*, *A.* aff. *conlini*, *Eubostrychoceras saxonicum*, *Hyphantoceras reussianum*. Localities are: Lengerich, Dyckerhoff AG quarry and abandoned Wicking II quarry (Text-fig. 16), Halle, F. Foerth quarry (Text-fig. 12); Oerlinghausen, O. Foerth quarry (Text-fig. 17), Bärental, Schierenberg (Text-fig. 6).

Event pair Tuff T D1 and unnamed marl

Localities are: Tuff T D1 only, Lengerich (Text-fig. 16), Halle, F. Foerth quarry (Text-fig. 12), Oerlinghausen, O. Foerth quarry (Text-fig. 17), Bärental, Schierenberg forest tracks (Text-fig. 6).

***Allocrioceras/Orbirhynchia* layer**

This is marked by distinctive occurrences of the index species. Ammonites are: *Lewesiceras mantelli*, *Subprionocyclus neptuni*, *S. hitchinensis*, *Sciponoceras bohemicum*, *Allocrioceras schlueteri*, *A.* aff. *conlini*, *A. strangulatum*, *Neocrioceras* cf. *multinodosum*, *Scaphites geinitzi*, *S. diana*, *Yezoites bladenensis* and *Eubostrychoceras saxonicum*. Localities are: ?Lengerich, Dyckerhoff AG quarry, abandoned quarry Wicking II (Text-fig. 16), Halle, F. Foerth quarry (Text-fig. 12), Oerlinghausen, O. Foerth quarry (Text-fig. 17).

Tuff T E

This lithostratigraphic marker lies 3m approximately below Marl ME, but becomes indistinct in the basinal facies of Lengerich. Localities are: Halle, F. Foerth quarry (Text-fig. 12), Oerlinghausen, O. Foerth quarry (Text-fig. 17), Kohlstädt, B 1 northern bypass (Text-fig. 6).

Marl M E

This prominent marl is the most significant lithological marker horizon in the Turonian of northwest Germany. Localities are: Lengerich (Text-fig. 16), Halle, F. Foerth quarry (Text-fig. 12), Oerlinghausen, O. Foerth quarry (Text-fig. 17), Kohlstädt, B 1 bypass (Text-fig. 6).

Marl M Echen

This is a thin marl *ca*. 1m above M E. Localities are: Halle, F. Foerth quarry (Text-fig. 12), Oerlinghausen, O. Foerth quarry (Textx-fig. 17). Kohlstädt, Finkenberg quarry and northern B 1 bypass (Text-fig. 6).

***Hyphantoceras* Event**

The maximum expression of this event lies *ca*. 13 - 25m above Marl M E, and is the level at which the index species is most abundant. It corresponds to the *Scaphiten Schichten* sensu stricto of previous German authors. There is a succession of ammonite faunas (Text-fig. 19) with:

i) a lower allocrioceratid and collignoniceratid fauna with *Lewesiceras mantelli*, *Subprionocyclus neptuni*, *S. hitchinensis*, *S. branneri*, *Sciponoceras bohemicum*, *Allocrioceras schlueteri*, *A. strangulatum*, *A. billinghursti*, *A. angustum*, *Scaphites geinitzi*, *S. kieslingswaldensis doylei*, *S. diana*, *Yezoites bladenensis*, *Eubostrychoceras saxonicum*, and *Hyphantoceras reussianum*;

ii) a middle nostoceratid fauna, with *Lewesiceras mantelli*, *Sciponoceras bohemicum*, *Scaphites geinitzi*, *Eubostrychoceras saxonicum*, *Hyphantoceras reussianum*, and *Metaptychoceras smithi*;

iii) an upper desmoceratid fauna, with *Puzosia muelleri*, *Jimboiceras planulatiforme*, *Pseudojacobites farmeryi*, *Lewesiceras mantelli*, *Sciponoceras bohemicum*, *Scaphites geinitzi*, *Eubostrychoceras saxonicum*, and *Hyphantoceras reussianum*.

Localities are: Lengerich, southern railway cutting and Dyckerhoff AG quarry (Text-fig. 16), Dissen, abandoned Schulte-Rosskotten quarry (Text-fig. 14), Bad Laer, Kleiner Berg, abandoned Anneliese quarry (Text-fig. 4), Halle, F. Foerth quarry (Text-fig. 12), Oerlinghausen, O. Foerth quarry (Text-fig. 17), Kohlstädt, (Text-fig. 6). The Ahaus-Wüllen occurrence (Text-fig. 3) yields only a restricted ammonite fauna (ERNST & WOOD 1992).

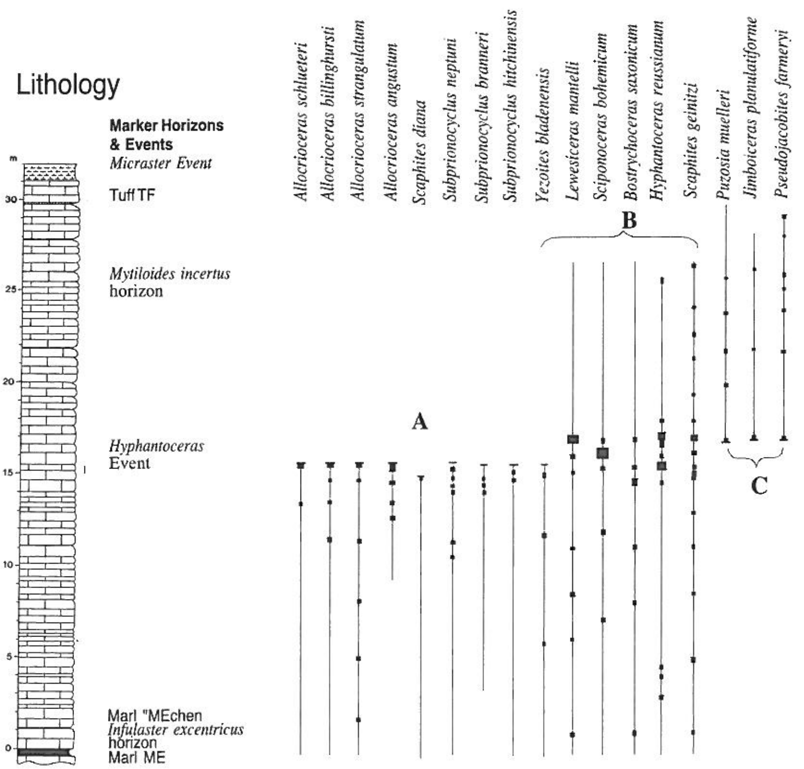


Fig. 19. Ammonite faunas around the *Hyphantoceras* Event, *Subprionocyclus neptuni* Zone, Upper Turonian, Foerth quarry, Halle (Westphalia)

***Mytiloides incertus* layer**

This is characterized by the index species, together with rare ammonites of the desmoceratid fauna of the upper *Hyphantoceras* Event: *Lewesiceras mantelli*, *Puzosia muelleri*, *Jimboiceras planulatiforme*, *Pseudojacobites farmeryi*, *Scaphites geinitzi*. Localities are: Dissen, abandoned Schulte Rosskotten quarry (Text-fig. 14), Bad Laer, Kleiner Berg, abandoned Anneliese quarry (Text-fig. 4), Halle, F. Foerth quarry (Text-fig. 12), Oerlinghausen, O. Foerth quarry (Text-fig. 17).

Tuff TF and Marl TG

These are two close-spaced lithostratigraphic marker horizons. Ammonite occurrences immediately above Marl TG are *Subprionocyclus normalis*, *Puzosia muelleri*, *Lewesiceras mantelli*, *Baculites undulatus*, *Scaphites geinitzi*, *S. kieslingswaldensis doylei* and *Hyphantoceras* sp. cf. *flexuosum*. Localities are: Dissen, abandoned Schulte Rosskotten quarry

(Text-fig. 14), Bad Laer, Kleiner Berg, abandoned Annelies quarry (Text-fig. 4), Halle, F. Foerth quarry (Text-fig. 12), Kohlstädt, B 1 bypass and Giese quarry (Text-figs 6 and 15).

Micraster Event

This is an important faunal and lithostratigraphic event *ca.* 0.3m above Marl TG, at the base of the *Mytiloides scupini* Zone. In Westphalia the index echinoid *Micraster* seems to be rarer than oysters at least in the middle and northwestern part of the Teutoburger Wald. Only a single *Subprionocyclus normalis* has been found at this horizon up to now in Westphalia; it is from Halle. Localities are: Dissen, abandoned Schulte-Rosskotten quarry (Text-fig. 14), Kleiner Berg, abandoned Anneliese quarry (Text-fig. 4), Halle, F. Foerth quarry (Text-figs 12 and 19), Kohlstädt, B1 bypass cutting (Text-fig. 15).

Soest Greensand building stone

This consists of two glauconitic, calcarenitic transgressive limestone horizons that occur on the southern margin of the Münster Basin, with a typical desmoceratid ammonite fauna as at the top of the *Hyphantoceras* Event, with *Puzosia muelleri*, *Mesopuzosia mobergi*, *Lewesiceras mantelli*, and *Placenticeras memoriaschloenbachi*. The equivalent of the lower horizon in the Pläner limestone facies is a prominent, *Micraster*-rich limestone bed, which is the first occurrence level of *Prionocyclus germari* and marks the base of its zone (KAPLAN 1994). Localities are: Salzkotten-Oberntudorf, Stelbrink quarry (Text-fig. 18), Anröchte-Berge, Schotterwerke Westereiden (Text-fig. 9), Bergkamen-Weddinghofen, shaft Grimberg IV (Text-fig. 5), Gelsenkirchen, shaft Graf Bismarck X (Text-fig. 13), and Essen, shaft Barbara (Text-fig. 10). Equivalents of the lower Soest Greensand bed occur in quarries around Borchen, Kohlstädt, Kohlstädter Kalkwerke quarry (Text-fig. 6), Halle, Foerth quarry (Text-fig. 11), Bad Laer, abandoned Anneliese quarry (Text-fig. 4).

Rothenfelde Greensand

Glauconitic limestone mass flow and turbidites *ca.* 7-9m above the *Micraster* Event. Occurrences are limited to the middle part of the Teutoburger Wald area (KAPLAN & BEST 1984). These are probably contemporaneous with the upper bed of the Soest Greensand building stone (KAPLAN 1994). Localities are: Bad Laer, Kleiner Berg, abandoned Anneliese quarry (Text-fig. 4), Hilter, abandoned Schulte Rosskotten quarry (Text-fig. 14), Halle, F. Foerth quarry (Text-fig. 11).

Lower Submarine Slide at the base of the grey and white alternation

This has the same distribution as the Rothenfelde Greensand. The marls and limestones yield *Puzosia muelleri*, *Lewesiceras mantelli*, *Prionocyclus germari*, *Hyphantoceras flexuosum*, *Scaphites* aff. *diana*, and *Scaphites kieslingswaldensis doylei*. Localities are: Bad Laer, abandoned Anneliese quarry (Text-fig. 4) and Halle, F. Foerth quarry (Text-fig. 11).

***Puzosia muelleri* abundance**

This horizon corresponds to the uppermost Turonian, ?*Didymotis* Event I of KAPLAN & KENNEDY (1994). This is known from a single Westphalian outcrop, near Dissen-Remsede, in the A 33 motorway excavation (Text-fig. 14), *ca*. 8m below the top of the Grey and White Alternation. The characteristic *Puzosia muelleri* is accompanied by *Mytiloides scupini* and other mytiliform inoceramids. Lithostratigraphic position in the Grey and White Alternation and the inoceramid fauna indicate a correlation with the *Didymotis* Event I of ERNST & *al*. (1983). As *Didymotis* has not been found to date, it is preferred to use *Puzosia muelleri* as provisional marker species.

***Didymotis* Event II**

This is present at a single Westphalian locality, the A 33 motorway cutting near Dissen-Remsede (Text-fig. 14), which yielded the typical fauna of the type locality near Salzgitter-Salder, Lower Saxony. At Dissen-Remsede it was not possible to separate the *Didymotis* Event II, the *C*.? *waltersdorfensis waltersdorfensis* Event and the *C. rotundatus* Event, as at Salzgitter-Salder (WOOD & *al*. 1984), where these three events occur in a *ca*. 1m thick interval, in spite of the fact that the marker species of these three events all occur at Dissen-Remsede. *Cremnoceramus rotundatus* marks the base of the Coniacian. Beside a questionable fragment of *Prionocyclus germari* and the nautiloid *Eutrephoceras* sp. indeterminable fragments of baculitid and scaphitid ammonites occur.

***Cremnoceramus waltersdorfensis hannovrensis* Event**

This event was proved at Dissen-Remsede (Text-fig. 14) and Schlangen (Text-fig. 15); the index-species is abundant, accompanied by fragmentary baculitid and scaphitid ammonites.

Ichnofossil and *Cremnoceramus waltersdorfensis* layer

This marker horizon is limited geographically to the condensed Turonian/Coniacian boundary sections of southern Westphalia. It lies *ca*.

3m above the Soest Greensand. The inoceramid fauna, with *C.? waltersdorfensis* ssp. and *C. rotundatus* agrees well with that of the *Didymotis* Event II and the *C.? waltersdorfensis hannovrensis* Event of the pelagic limestone facies of north-west Germany. It marks the Turonian/Coniacian boundary in the southern Münster Basin. Localities are: Anröchte-Berge, Schotterwerke Westereiden quarry (Text-fig. 9).

Cremnoceramus erectus Event

This is known from a single Westphalian locality in Schlangen (Text-fig. 15), the corresponding level at Dissen-Remsede has not been worked. Beside the index species only a fragmentary and indeterminate ammonite fauna with scaphitid and baculitid heteromorphs occurs, as in the two underlying events.

Cremnoceramus inconstans Event

This is marked by an inoceramid fauna with the index species, *C. rotundatus*, *C. erectus* and *C.? waltersdorfensis*. The first diagnostic Coniacian ammonite fauna occurs at this level, with *Forresteria (Harleites) petrocoriensis* at Schlangen only, *Scaphites (Scaphites) kieslingswaldensis kieslingswaldensis*, *Scalarites turoniense*, *Neocrioceras paderbornense*, *Baculites brevicosta* and *Puzosia muelleri*, the last only at Dissen-Remsede. This marker horizon probably correlates with an ammonite occurrence in the abandoned claypit of the Königin Elisabeth coal mine, near shafts Hubert I and II, Essen-Frillendorf, southwestern Westphalia, with *Menabonites beantalyense*, *Forresteria (Harleites) petrocoriensis*, *Scalarites turoniense*, *Scaphites (Scaphites) kieslingswaldensis kieslingswaldensis* and *Yezoites* sp. Localities are: Dissen-Remsede, A 33 motorway excavations (Text-fig. 14), Schlangen, abandoned Hühnerberg quarry (Text-fig. 15) and ?Essen-Frillendorf, abandoned claypit of Königin Elisabeth coal mine near shafts Hubert I and II.

Cremnoceramus deformis and *Zoophycos* layer I

In the condensed sections of southern Westphalia this marker horizon lies *ca.* 10m above the Soest Greensand; *Peroniceras subtricarinatum* and *Cremnoceramus deformis* are important index species at this level. Additional ammonites are *Forresteria* sp., *Baculites brevicosta*, *Neocrioceras paderbornensis* and *Scaphites (Scaphites) kieslingswaldensis kieslingswaldensis*. This event marks the base of the *Peroniceras tridorsatum* Zone in Westphalia. Localities are: Erwitte, quarries of the Wittekind, Spenner and Seibel & Söhne cementworks (Text-fig. 9).

Spenner Marl

This is a conspicuous marl in the middle part of the Upper Pläner–Limestone Unit in the Erwitte Paderborn region. Localities are: Erwitte, quarries of the Wittekind, Spenner and Seibel & Söhne cementworks (Text-fig. 9).

Erwitte Bank

This is a marked limestone and ichnofossil horizon in the upper third of the Upper Pläner–Limestone Unit in the Erwitte Paderborn region. Ammonites increase in abundance above the top of the Erwitte Bank. Localities are: Erwitte, quarries of the Wittekind, Spenner and Seibel & Söhne cementworks (Text-fig. 9).

***Cremnoceramus deformis* and *Zoophycos* Event II**

This occurs in the transition between the Upper Pläner–Limestone Unit and the Limestone–Marl Transition Beds. Large *Cremnoceramus deformis* and *Zoophycos* are abundant, a sparse but a diverse ammonite fauna is present, with *Puzosia muelleri*, *Mesopuzosia mobergi*, *Lewesiceras* sp., *Peroniceras subtricarinatum*, *Forresteria* sp., *Placenticeras fritschi*, *Baculites* sp., *Neocrioceras paderbornensis* and *Scaphites* (*Scaphites*) *kieslingswaldensis kieslingswaldensis*. Localities are: Erwitte, quarries of the Wittekind, Spenner and Seibel & Söhne cementworks (Text-fig. 9).

***Magadiceramus subquadratus* and *Placenticeras semiornatum* abundance**

This was recognized in temporary excavations in the poorly fossiliferous Emscherian Marl of Paderborn–Elsen, central and eastern Westphalia (SKUPIN 1982). It is marked by the co-occurrence of the three Upper Coniacian guide fossils, *Magadiceramus subquadratus*, *Placenticeras semiornatum*, and *Gonioteuthis westfalica praewestfalica*.

Emscherian Greensand Event

This is a lithostratigraphic marker horizon at the top of the Coniacian, a highly glauconitic and coarse-grained greensand, mainly present in the Western Ruhr district. Localities are: Gelsenkirchen-Bismarck, Graf Bismarck X shaft (Text-fig. 13), Duisburg–Walsum, Walsum I shaft = Wilhelm Roelen shaft (Text-fig. 7).

INOCERAMID STRATIGRAPHY

The Upper Turonian inoceramid stratigraphy used here (Text-figs 2, 20, 23) is based on that of KELLER (1982), ERNST & *al.* (1983), TRÖGER (1989), and WALASZCZYK & TRÖGER (1996) and applied to the pelagic limestone facies of Westphalia by KAPLAN (1986, 1992). A threefold subdivision of the Upper Turonian seems to be possible (from top bottomward):

3. *Mytiloides scupini* Zone (= *Inoceramus* aff. *frechi* Zone); base marked by the *Micraster* Event
2. *Mytiloides striatoconcentricus* Zone; base marked by the Marl ME
1. *Inoceramus costellatus* Zone; base marked by the Flint layer F23 *ca.* 5m below the *costellatus/S. plana* Event.

WOOD & *al.* (1984) established an inoceramid stratigraphy for the Grey and White Alternation and the Upper Pläner-Limestone Unit in the context of their proposal of Salzgitter-Salder as a standard section for the Turonian/Coniacian boundary. Their sequence is (from top to base):

6. *Cremnoceramus deformis* Zone; base marked by the *C. deformis* and *Zoophycos* Event I
5. *Cremnoceramus erectus* Zone
4. *Cremnoceramus rotundatus* Zone; base marked by *Didymotis* Event II.

Localities for the *C. rotundatus* Zone and the *C. erectus* Zone are excavations for the motorway section near Dissen-Remsede (Text-fig. 14) and the abandoned Hühnerberg quarry near Schlangen (Text-fig. 15). In southern Westphalia this interval is condensed, and the zones cannot be separated (Text-fig. 9). There are no new observations on inoceramid stratigraphy around the Turonian Coniacian transition in southwestern Westphalia. In contrast, the succeeding *Cremnoceramus deformis* Zone is well represented in outcrops of the Upper Pläner-Limestone Unit, between Paderborn and Erwitte (Text-fig. 9). It is well documented in shaft sections of southwestern Westphalia (Text-figs 5, 10, 13). Separation of a *C. schloenbachi* Zone at the top of the *C. deformis* Zone has not been established in Westphalia.

Inoceramid stratigraphy of the Emscherian-Marl has a long history (SCHLÜTER 1877; HEINE 1929; RIEDEL 1933; SEITZ 1962, 1970; TRÖGER 1974, 1989). SEITZ (1962) was the first to study accurately located material from shaft sections, but as he pointed out, material collected from shafts can be of limited stratigraphic use, because of technical difficulties associated with collection. The inoceramid subdivision for the Emscherian proposed by SEITZ (1962, 1970) is based on pure faunal zones, which are limited to the abundant occurrences of the zonal species, in spite of the fact that he gave very precise stratigraphic records. The Authors therefore prefer to use the subdivision proposed by TRÖGER (1989) for the Coniacian part of the Emscherian, as he defines zones on the basis of the first occurrence of index species, although his upper *Magadiceramus subquadratus* Zone without *Volviceramus* is an assemblage zone. The succession of zones is (from top to bottom):

1. *Sphenoceramus pachti* and *S. cardissoides* Zone *Magadiceramus subquadratus* Zone without *Volviceramus*; base marked by the extinction point of *Volviceramus*
2. *Magadiceramus subquadratus* Zone with *Volviceramus*
3. *Volviceramus koeneni* and *involutus* zones.

The base of the Santonian was defined by SEITZ (1970) and TRÖGER (1989) at the first occurrence of *Sphenoceramus pachti* and *S. cardissoides*, but following the 1995 Brussels Meeting, it is here drawn at the base of the succeeding *Cladoceramus undulatoplicatus* Zone.

AMMONITE STRATIGRAPHY

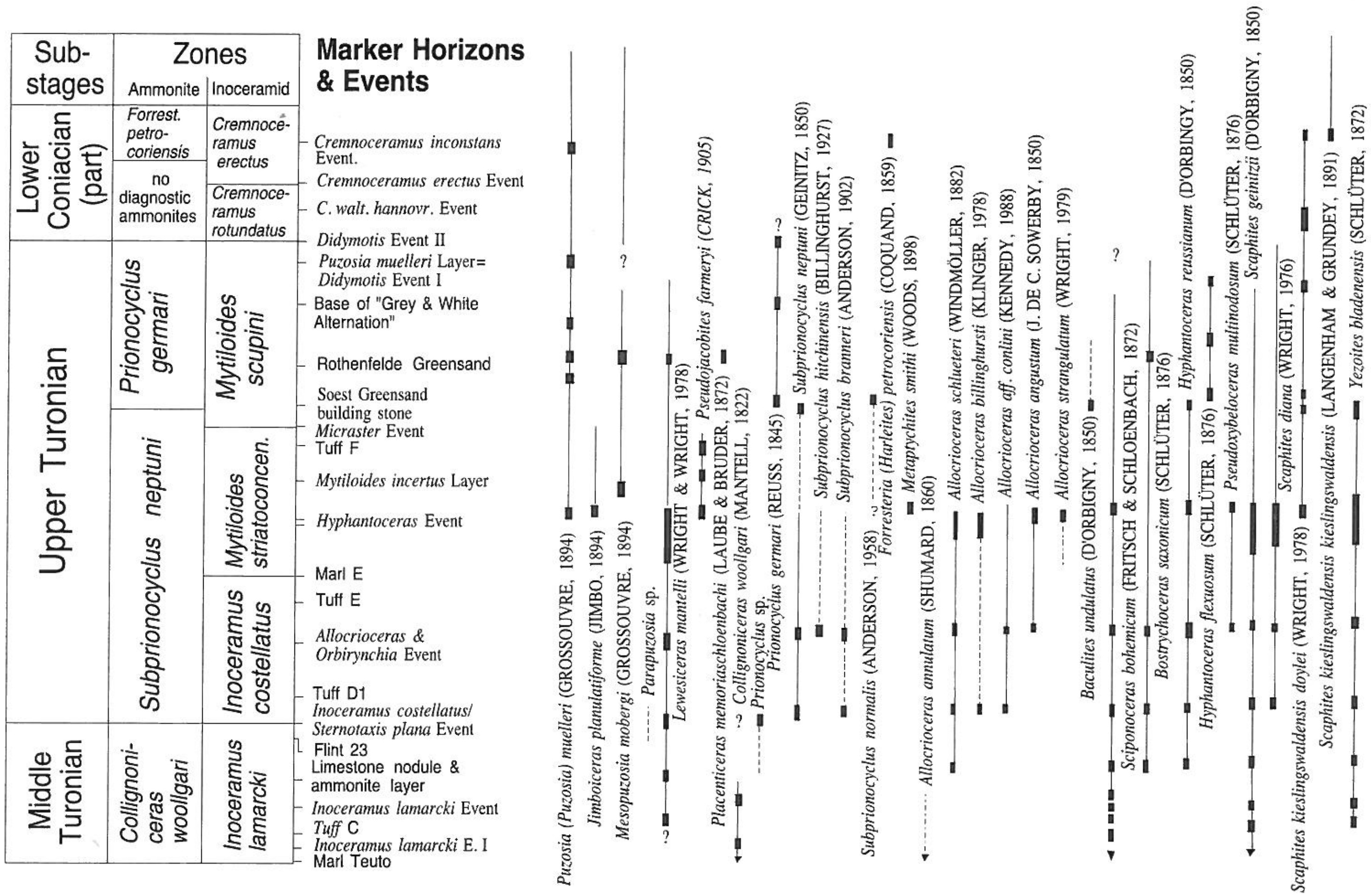
Rich ammonite fauna recorded from the numerous localities in Westphalia allows the subdivision of the Upper Turonian and Coniacian deposits and their good correlation with the inoceramid zonation (Text-figs 20-21).

Base of the Upper Turonian and the *Subprionocyclus neptuni* Zone

The upper Middle Turonian *Inoceramus lamarcki* Zone yields a rather poor ammonite fauna. In the expanded sections of the Teutoburger Wald *Collignoniceras woollgari* does not extend to the base of the Upper Turonian. In the condensed sequences of southern Westphalia, *Collignoniceras woollgari* and *Subprionocyclus neptuni* co-occur (Kaplan 1988). An ammonite horizon associated with a limestone nodule layer *ca*. 15-18m below the base of Upper Turonian (Text-figs 3-6) yields an ammonite fauna of *Lewesiceras mantelli*, *Sciponoceras bohemicum*, *Scaphites geinitzi* and *Yezoites bladenensis*, which range up from below, together with the first occurrences in Westphalia of *Allocrioceras schlueteri* and rare *Hyphantoceras reussianum* and *Eubostrychoceras saxonicum*.

Ammonite faunas from this level up to the middle *Subprionocyclus neptuni* Zone (base of the *Hyphantoceras* Event) are dominated by these genera and species.

Thge species *Subprionocyclus neptuni* first appears *ca*. 4m above the first occurrence of *Inoceramus costellatus*, the latter marking the base of the Upper Turonian. Occurrences of *S. neptuni*, have been proved at



Upper Turonian ammonite distribution Upper Turonian in the Münster Basin

Lengerich (Text-fig. 16), Halle (Text-fig. 12), Oerlinghausen (Text-fig. 17) and Horn-Bärental, Schierenberg (Text-fig. 6). There is a marked

Sub-stages	Zones: Ammonite	Zones: Inoceramid
Lower Coniacian (part)	*Forrest. petrocoriensis*	*Cremnoceramus erectus*
	no diagnostic ammonites	*Cremnoceramus rotundatus*
Upper Turonian	*Prionocyclus germari*	*Mytiloides scupini*
	Subprionocyclus neptuni	*Mytiloides striatoconcen.*
		Inoceramus costellatus
Middle Turonian	*Collignoniceras woollgari*	*Inoceramus lamarcki*

Prionocyclus germari Zone

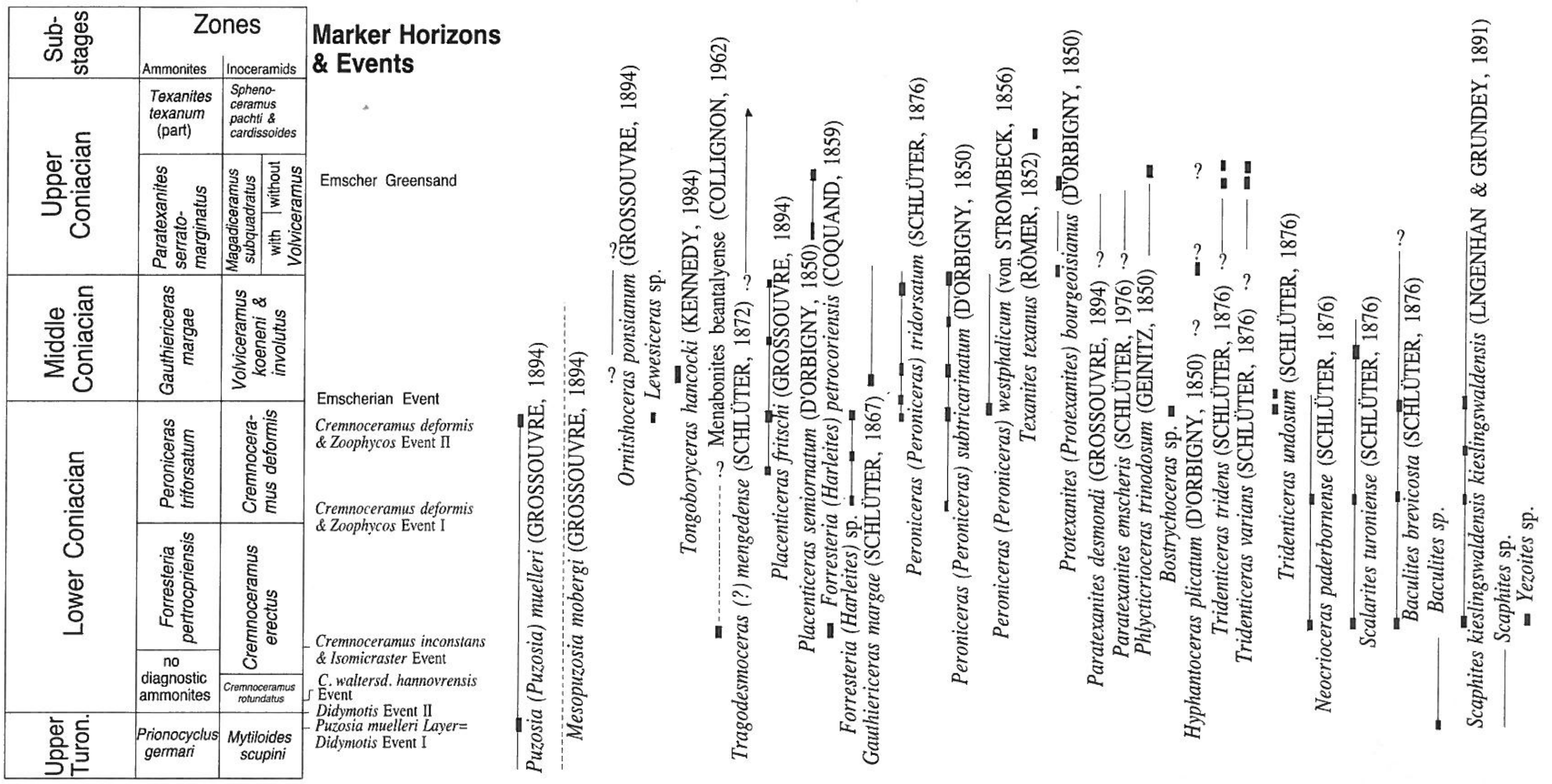
The *Prionocyclus germari* Zone as introduced here replaces the *Subprionocyclus normalis* Zone of KAPLAN (1986). As demonstrated below *P. germari* has wider geographical distribution and seems to be more abundant than *S. normalis* the Münster Basin and elsewhere.

Ammonites are infrequent in the *P. germari* Zone, as in the beds above the *Hyphantoceras* Event. The base of the zone is drawn at the first occurrence level of the index species, 3m above the *Micraster* Event, at the F. Foerth quarry Halle (Text-fig. 11) and the abandoned Anneliese quarry, Bad Laer, Kleiner Berg (Text-fig. 4). Further well localized specimens are from the middle part of the Grey and White Alternation of Bad Laer (Text-fig. 4). At Hollekamp quarry, Ahaus-Wüllen, northern Westphalia, *P. germari* occurs at the top of the Turonian (ERNST & WOOD 1992; herein Text-fig. 3). According to an unverifiable note in SCHLÜTER (1872-1876) *P. germari* occurs in the *Cuvieri* Pläner of Lower Saxony. The species *Hyphantoceras flexuosum* first appears at the same horizon as *P. germari* and could be used as a further index ammonite. In the middle and upper part of the zone there occur *Scaphites* aff. *diana* that are smaller than the typical form. Further ammonites are: *Puzosia muelleri*, *Mesopuzosia mobergi*, *Lewesiceras mantelli*, *Baculites undulatus*, *Scaphites kieslingswaldensis doylei*, S. *geinitzi*, and *Bostrychoceras saxonicum*. In and around the Soest Greensand, *P. muelleri*, *M. mobergi* and *L. mantelli* are typical (Text-figs 9, 18). A single specimen of *Placenticeras memoriaschloenbachi* is recorded from the Soest Greenland of Unna.

Turonian/Coniacian boundary

Up to now only *Scaphites* (*Scaphites*) *kieslingswaldensis doylei* WRIGHT, 1976, and fragmentary and usually indeterminate fragments of scaphitid and baculitid heteromorphs have been found in sections immediately above the Turonian/Coniacian boundary (the base of the *Cremnoceramus rotundatus* Zone) in Westphalia (KAPLAN 1986, KAPLAN & KENNEDY 1994) and Lower Saxony (WOOD & *al*. 1984).

The first typical Coniacian ammonite fauna occurs in the expanded sections of Dissen-Remsede (Text-fig. 14) and Schlangen (Text-fig. 15) *ca*. 10-15m above the entry of *Cremnoceramus rotundatus*, in the lower part of the *Cremnoceramus erectus* Zone, around the *Cremnoceramus inconstans* Event. This occurrence highlights the discrepancy between the Turonian/Coniacian boundary as used by ammonite and inoceramid workers; absence of both *P. germari* and *F*. (*H*.) *petrocoriensis* mean that the



Coniacian ammonite distribution in the Münster Basin

rotundatus Zone remains undated in ammonite terms in the Münster and Lower Saxonian Basins.

The species *Forresteria* (*Harleites*) *petrocoriensis*, *Baculites brevicosta* and *Neocrioceras paderbornense* were collected only at Schlangen, *Scalarites turoniense* at both localities, and *Scaphites* (*Scaphites*) *kieslingswaldensis kieslingswaldensis* and *Puzosia muelleri* only at Dissen-Remsede. There is a significant change in the ammonite fauna in addition to the entry of *Forresteria* (*Harleites*) *petrocoriensis*; *P. muelleri* and *M. mobergi* are the only species that occur in both *germari* and *petrocoriensis* Zones. Ammonites are rare at both localities and usually not very well preserved. In the proposed standard section for the Turonian/Coniacian boundary at Salzgitter-Salder (WOOD & *al.* 1984), *Scalarites turoniense* and *Scaphites* (*Scaphites*) *kieslingswaldensis kieslingswaldensis* occur in the near contemporaneous *Isomicraster* and *C. inconstans* events.

Records of the *F.* (*H.*) *petrocoriensis* Zone in southwestern Westphalia come from Essen-Frillendorf, where the index species is accompanied by *Menabonites beantalyense*, *S. turoniense*, *S.* (*S.*) *kieslingswaldensis kieslingswaldensis*, *Yezoites* sp. and *B. brevicosta* (KAPLAN & KENNEDY 1994), and Oberhausen-Alstaden coal mine Alstaden, shaft 2, a SCHLÜTER locality. The exact stratigraphic position of his *Ammonites alstadenensis* [= *F.* (*H.*) *peterocoriensis*] could not be ascertained.

In the Anröchte and Anröchte-Berge area of Southern Westphalia (Text-fig. 9), the Turonian/Coniacian boundary interval is condensed, and only the basal Coniacian inoceramid fauna has been recognized.

Peroniceras tridorsatum Zone

The base of the zone is exposed only in the Anröchte and Anröchte-Berge area (Text-fig. 9), where it is marked by the co-entry of *Peroniceras subtricarinatum* and *Cremnoceramus deformis* in the *Cremnoceramus deformis*/*Zoophycos* Event I. The species *Neocrioceras paderbornense*, *Baculites* sp., *Scaphites* (*Scaphites*) *kieslingswaldensis kieslingswaldensis*, and *Forresteria* sp. make up the ammonite fauna of the lower *Peroniceras tridorsatum* Zone. Above the Erwitte Bank in the upper *P. tridorsatum* Zone, ammonite diversity increases. The species *Puzosia muelleri*, *Mesopuzosia mobergi* and *Placenticeras fritschi* occur in the overlying *Cremnoceramus deformis* and *Zoophycos* II Events and the lower part of the following *kalkig-mergelige Übergangsschichten*.

SCHLÜTER (1866) demonstrated the occurrence of *P. subtricarinatum* in this unit, with records from the *Cuvieri* Schichten near Paderborn. The species *Peroniceras westphalicum* was collected from the same unit in Essen (Amalie coal mine, shaft Barbara, depth 48m), and *Peroniceras tridorsatum* in Hamm-Bockum-Hövel, shaft Radbod, from the *schloenbachi* Beds, without exact depth (KAPLAN & KENNEDY. 1994).

Gauthiericeras margae Zone

Apart from occasional outcrops, evidence for this and the succeeding *Paratexanites serratomarginatus* Zone depends on museum material, mostly collected from mine shafts that cut the Emscherian Marl (*cf.* Text-figs 5, 7, 8, 10, 13). Emscherian ammonites have their highest abundance in the nearshore sandy and glauconitic marls of southwestern Westphalia, where they are also better preserved. Elsewhere in the Münster Basin ammonites are rare and poorly preserved.

The species *Volviceramus koeneni* and *Gauthiericeras margae* appear at the same level in mine shaft sections (RIEDEL 1933) and the now infilled Dortmund-Eving marl pits, according to old records (BÄRTLING 1913, FRANKE 1914).

Other ammonites present in the *G. margae* zone are: *Peroniceras tridorstatum*, *P.* (*Z.*) *bajuvaricum*, *P. subtricarinatum*, *Placenticeras fritschi*, *Mesopuzosia mobergi*, *Scalarites turoniense* and *Scaphites* (*Scaphites*) *kieslingswaldensis kieslingswaldensis*, which occur already in the underlying *P. tridorsatum* Zone; *Onitshoceras ponsianum* and *Hyphantoceras plicatum* are seemingly restricted to the upper part of the zone. The single record of *Tongoboryceras hancocki* is from the *G. margae* Zone, *V. koeneni* and *involutus* Zone of Ahaus-Wessum, northern Westphalia, *Tridenticeras tridens* and *T. varians* have their first occurrence in the upper part of the *G. margae* Zone, but the stratigraphic occurrence of *Tridenticeras undosus* is uncertain.

The species *Paratexanites desmondi*, which is restricted to the *Paratexanites serratomarginatus* Zone in France, was collected from an imprecise level at the Kokerei Ernestine, Essen-Stoppenberg, together with *Gauthiericeras margae*, and with *Phycticrioceras trinodosum* at Essen-Schonnebeck. It cannot therefore be excluded the possibility that these two species first appear at the top of the *Gauthiericeras margae* Zone, although restricted to the *serratomarginatus* Zone elsewhere.

Paratexanites serratomarginatus Zone

The few ammonites collected in shaft sections and from pits do not permit accurate location of the boundary between the *Gauthiericeras mar-*

gae and *Paratexanites serratomarginatus* Zones. The only specimen of *Paratexanites serratomarginatus* noted from Westphalia was collected from the Grimberg coal mine, shaft IV, Bergkamen-Weddinghofen, at a depth of 150m, in the *M. subquadratus* Zone without *Volviceramus* (TRÖGER 1974). We have not seen the specimen. The same shaft and zone yielded *Placenticeras semiornatum* at a depth of 140m. The abandoned claypit of the Altstadt-Baugesellschaft in Essen-Schonnebeck yielded a typical *P. serratomarginatus* Zone fauna, with *Paratexanites desmondi*, *Phlycticrioceras trinodosum*, *Onitshoceras ponsianum* and *Scaphites* (*Scaphites*) *kieslingswaldensis kieslingswaldensis*, of which *O. ponsianum* and *S.* (*S.*) *kieslingswaldensis kieslingswaldensis* occur in the preceding zone. Single well-located ammonites typical of the *P. serratomarginatus* Zone come from a trial pit at Paderborn-Elsen, where *Placenticeras semiornatum* occurs together with *Magadiceramus subquadratus* and *Gonioteuthis westfalica praewestfalica*. In Duisburg-Walsum, shaft Walsum II (Text-fig. 19) *Protexanites* (*Protexanites*) *bourgeoisianus* was collected at a depth of 255.02m, significantly above the last occurrence of *Volviceramus involutus* and so in the *P. serratomarginatus* Zone/*Magadiceramus subquadratus* Zone.

The Coniacian/Santonian boundary

The base of the Santonian in ammonite terms has been defined by the first occurrence of *Texanites texanus* auctorum, which agrees well with the entry of sphenoceramid inoceramids, as HEINZ (1934a) stated, and confirmed by our recent work on specimens from Gelsenkirchen, shaft Graf Bismarck 10. This seemingly straightforward linking of ammonite and inocermaid zonations is complicated by taxonomic problems. In Germany, records of *Texanites* (*Texanites*) *texanus* are mostly based on *Texanites* (*Texanites*) *pseudotexanus* (DE GROSSOUVRE 1894), including that from the shaft Graf Bismark 10, noted above.

With the adoption of the first occurrence of *Cladoceramus undulatoplicatus* as the marker for the base of the Santonian, the classic *Texanites* (*Texanites*) *texanus* Zone straddles the Coniacian-Santonian boundary.

BELEMNITE OCCURRENCES

CHRISTENSEN (1982) gave an overview of the very few Middle European Turonian and Coniacian belemnite occurrences. Their stratigraphic distribution is emended, supplemented and their occurrences are

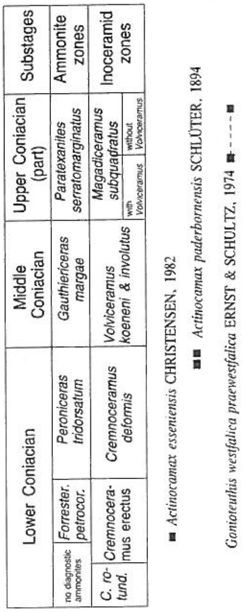


Fig. 22. Belemnite occurrences in the Coniacian of the Münster Basin

here placed in the context of the revised ammonite, inoceramid- and event-stratigraphy outlined above (Text-fig. 22).

Only a single specimen of *Actinocamax essenensis* CHRISTENSEN, 1982, has been described to date. It came from the abandoned claypit of Königin Elisabeth coal mine near the Hubert I and II shafts, Essen-Frillendorf. According to the collector, H. BASCHIN (Essen), it was found with *Forresteria (Harleites) petrocoriensis* and other ammonites typical of the Westphalian lower Lower Coniacian fauna.

The species *Actinocamax paderbornensis* SCHLÜTER, 1894, occurs in the Turonian Coniacian transition of Paderborn according to CHRISTENSEN (1982). SCHLÜTER`s stratigraphical description (obere *Cuvieri* Pläner) and the locality (*Wasserwerke östlich Paderborn*, SCHLÜTER 1894) suggest a stratigraphical position in the upper part of the upper Lower Coniacian *Peroniceras tridorsatum* Zone, upper *Cremnoceramus deformis* Zone.

The subspecies *Gonioteuthis westfalica praewestfalica* ERNST & SCHULTZ, 1974, is represented by few specimens. Its occurrence in a submarine slide near Augustdorf, in the eastern Münster Basin, cannot be dated with any precision (SKUPIN 1990). The only precisely dated specimen was collected at Paderborn-Elsen, Rottberg, associated with *Placenticeras semiornatum*, *Magadiceramus subquadratus*, *Volviceramus koeneni* and *Volviceramus involutus* (*see* SKUPIN 1982) and can be placed in the Upper Coniacian *Paratexanites serratomarginatus* Zone, *Magadiceramus subquadratus* Zone with *Volviceramus*.

STRATIGRAPHIC CORRELATION WITH OTHER AREAS

Upper Turonian

The correlation with the selected European sections as well as with the Upper Turonian of Western Kazakhstan and Tunisia is presented (Text-fig. 23).

FRENCH TYPE AREA

There are only poor ammonite records from the Upper Turonian in the type area, the Saumurois in Touraine (ROBASZYNSKI & *al.* 1982, KENNEDY & *al.* 1984). Only the lower parts of the *S. neptuni* Zone are represented, and the upper Upper Turonian *P. germari* Zone is missing. This is indicated by the presence of *Subprionocyclus neptuni* only 40-60cm below the top of the Tuffeau Jaune between Tréhet and Villedieu-le-Château (Loir-et-Cher).

NORTHERN FRANCE

Upper Turonian ammonites appear to be restricted to a limited interval, which is the correlative of the north-west German *Hyphantoceras* Event and the English Chalk Rock. Both underlying and overlying Upper Turonian ammonite faunas are absent, presumably due to non-preservation of originally aragonitic shells (AMEDRO & *al.* 1978, RAGOT 1989).

ENGLAND

The lowest well-documented occurrence of Upper Turonian ammonites is in the upper part of the traditional *Terebratulina lata* Zone is Sussex, where

Sub-stages	Inoceramid zones Westfalia	Major Events ERNST & *al.* 1983 KAPLAN 1991	Ammonite Zones: Westphalia this paper	France type area ROBASZYNSKI 1982	England	N. Spain KUCHLER & ERNST 1989	Czech Republic ČECH 1989	Poland Opole Trough TARKOWSKI 1991	Tunisia ROBASZYNSKI & *al.* 1990
Lower Coniacian	*Cremnoceramus erectus*	*C. inconstans* E. *Isomicraster* E. *C. erectus* E.	*Forresteria petrocoriensis*	*Forresteria petrocoriensis*	*Forresteria petrocoriensis*	*Forresteria petrocoriensis*	*Forresteria petrocoriensis*	*Forresteria petrocoriensis*	*Forresteria petrocoriensis*
	C. rotundatus	*Didymotis* E.II	?	Hiatus	Hiatus	*Subprionocyclus normalis*	? *Didymotis* Event II	?	*Prionocyclus interval*
Upper Turonian	*Mytiloides scupini* (*Inoceramus* aff. *frechi*)	Rothenfelde & Soest Greensand	*Prionocyclus germari*				*Prionocyclus germari*		
	Mytiloides striatoconcentricus	*Micraster* E. Tuff F *Hyphantoceras* E.	*Subprionocyclus neptuni*		Ulceby Marl Chalk Rock *Subprionocyclus neptuni*	*Subprionocyclus neptuni*	*Subprionocyclus neptuni*	*Subprionocyclus neptuni*	*Romaniceras deverianum*
	Inoceramus costellatus	Marl E Tuff E Tuff D1		*Subprionocyclus neptuni*		*Romaniceras deverianum*			
Middle Turonian	*Inoceramus lamarcki*	*I. costellatus* & *plana* E. Flint 23 *Limestone nodule and ammonite layer* Tuff C *I. lamarcki* E. Marl Teuto	*Collignoniceras woollgari* (pars)	*Collignoniceras woollgari* (pars)	*Collignoniceras woollgari* (pars)	*Romaniceras ornatissimum* (pars)		*Collignoniceras woollgari* (pars)	*Coilopoceras interval* (pars)

Fig. 23. Correlation of the Upper Turonian of the Münster Basin with that of other regions

Subprionocyclus first occurs just above the lower of the two Southerham Marls. The species *Romaniceras* (*R.*) *deverianum* occurs several meters higher in the section, just below the level of the Caburn (= Reed) Marl (LAKE & *al.* 1987). The main occurrence of Upper Turonian ammonites is higher still, at the level of the Chalk Rock (WRIGHT 1979), which is in a broad sense a correlative of the *Hyphantoceras* Event, and marks the top of the *S. neptuni* Zone in England. GALE (1996) introduced a *Subprionocyclus normalis* Subzone in England, which corresponds to the NW-German *S. normalis* Zone of KAPLAN (1986). As demonstrated above, the NW-Germany *S. normalis* Zone has its base at Tuff F and is coincident with the entry of *Mytiloides scupini*, the inoceramid marker of the upper Upper Turonian. But *S. normalis* occurs already below this level in NW-Germany. In England *S. normalis* occurs in the Hitch Wood Hardground. Here it is associated with *Mytiloides incertus* and *Inoceramus costellatus*; *Mytiloides scupini* is missing (C.J. WOOD, *pers. comm.*). Consequently the base of the *S. normalis* Zone sensu GALE (1996) lies below the base of the *S. normalis* Zone sensu KAPLAN (1986). The inoceramid-fauna of the Hitch Wood Hardground indicates the base of the *S. normalis* Zone sensu GALE (1996) and an upper *S. neptuni* Zone age, between the base of the *Hyphantoceras* Event and the *M. incertus* layer in a NW-German sense. There is no evidence for the *P. germari* Zone in England; ammonites are absent due to preservational factors.

In Lincolnshire, *Pseudojacobites farmeryi* occurs between the Chalk Rock and the Ulceby Oyster Bed. This occurrence agrees very well with that in Westphalia, where the species occurs between the correlatives of the *Hyphantoceras* Event and the *Micraster* Event (KENNEDY & KAPLAN 1995).

NORTHERN SPAIN

KÜCHLER & ERNST (1989) demonstrated for the Santander area and WIESE (1996) for the Liencres area, Cantabria, a close corrrelation between sequences in northern Spain and North-West Germany. The basal Upper Turonian in both areas is characterized by *Romaniceras deverianum*, which also occurs in their succeeding *S. neptuni* Zone. In the Santander area *P. germari* enters at a horizon where the last *Romaniceras deverianum* occurs, just above the last *Subprionocyclus*. In the Liencres area, Cantabria, *P. germari* and *Mytiloides scupini* enter *ca.* 5 meters above the last *S. neptuni*. The succession of *Subprionocyclus* and *Prionocyclus germari* agrees well with that in Westphalia.

CZECH REPUBLIC, BOHEMIA

ČECH (1989) demonstrated that, as in Westphalia, *S. neptuni* is succeeded by *P. germari*, which extends up into the *Didymotis* Event II (*sensu*

ERNST & *al.* 1984). The *P. germari* Zone correlates well with that of Westphalia. In Bohemia, *Placenticeras orbignyanum* occurs in the *P. germari* Zone, rather than *P. memoriaschloenbachi* as in Westphalia; the difference between these two species is slight.

POLAND, OPOLE TROUGH

WALASZCZYK (1988, 1992) and TARKOWSKI (1991) demonstrated a close correspondence between the Upper Turonian of the Opole Trough and that of northwest Germany. The *I. costellatus* Event marks the base of the Upper Turonian, a fauna with frequent *Hyphantoceras* represents the ammonite succession around the *Hyphantoceras* Event; the *C. waltersdorfensis* Event has been taken to mark the base of the Coniacian in inoceramid terms (WALASZCZYK 1992). As in Westphalia, *Allocrioceras* is common in the lower part of the Upper Turonian, and *Scaphites* (*Scaphites*) *kieslingswaldensis doylei* occurs in the upper part (TARKOWSKI 1991). Correlation is very close up to the level of the *Hyphantoceras* Event. For the upper Upper Turonian a close event- and ammonite correlation is not at present possible, as the *Micraster* Event and base of the *P. germari* Zone are not recognized. The species *Mytiloides incertus*, the index inoceramid of the upper Upper Turonian in Poland (*see* Walaszczyk 1992), occurs in Lengerich at the base of the Upper Turonian, together with *I. costellatus*.

WESTERN KAZAKHSTAN, MANGYSHLAK

The Upper Turonian is subdivided in a *Inoceramus costellatus* Zone below and a *Mytiloides skupini* Zone above. Ammonites are relatively common, but confined to a basal phosphatic bed (MARCINOWSKI & *al.* 1996). In the Besakty section the phosphatic bed *Va* yields an ammonite fauna with *Subprionocyclus neptuni, Allocrioceras strangulatum, Hyphantoceras flexuosum*, and *Baculites undulatus*, which indicate both *Subprionocyclus neptuni* and *Prionocyclus germari* Zone.

TUNISIA

As in Spain, the lower part of the Upper Turonian is characterized by *Romaniceras deverianum*, which is followed by a *Prionocyclus* interval with *Prionocyclus novimexicanus* (MARCOU 1858); but the first *Prionocyclus* sp. are found below the base of the *R. deverianum* Zone. There is a gap in the ammonite record between the last *Prionocyclus* and the first *Forresteria* (ROBASZYNSKI & *al.* 1990).

DISCUSSION

The *Collignoniceras woollgari* Zone is traceable throughout the northern hemisphere. The *Subprionocyclus neptuni* Zone (at least the lower part) is traceable over many parts of Europe: i.e. north-west Germany, northern Spain, the Turonian type area in Touraine, northern France, Vaucluse in SE France, England, Poland, the Czech Republic, Austria, Japan and the Gulf Coast, Western Interior and west coast of the United States, despite the fact that its boundaries still have to be clarified in some areas. In western Europe it is locally replaced by a *Romaniceras deverianum* Zone, the index species being in part coeval. The first occurrence of *R.* (*R.*) *deverianum* is difficult to place in relation to the first occurrence of *S. neptuni*, but *Subprionocyclus* appears below *R.* (*R.*) *deverianum* in Sussex, England. In Spain, there is a flood of occurrence of *R.* (*R.*) *deverianum* at what WIESE & KÜCHLER (1995) believe to be the correlative of the *costellatus/plana* Event in Germany, in which case the base of the *neptuni* and *deverianum* Zones would correspond (Text-figs 3-4).

Within the *S. neptuni* Zone, several marker horizons and events are traceable in north-west Germany and in some cases beyond. The *Inoceramus costellatus/Sternotaxis plana* Event, which marks the base of the Upper Turonian, *neptuni* Zone, can also be traced into the Opole Trough in Poland (WALASZCZYK 1992). The *Hyphantoceras* Event with its remarkable fauna can be identified in northern France (AMÉDRO & *al.* 1979), correlates with the Chalk Rock in England (WRIGHT 1979) and is present in the Opole Trough, Poland (WALASZCZYK 1988, 1992; TARKOWSKI 1991). The event may also be represented in Algeria; supposed Lower Cenomanian ammonites from Berrouaghia collected by PERON and THOMAS and described by PERVINQUIÈRE (1910) include typically Upper Turonian *Romaniceras* (*R.*) *deverianum* and *Coilopoceras* (KENNEDY & *al*. 1980, KENNEDY & WRIGHT 1984) and the type material of *Bostrychoceras thomasi* PERVINQUIÈRE, 1910, which are both *Eubostrychoceras saxonicum* and *Hyphantoceras reussianum* (e.g. the holotype of *Hyphantoceras cenomanense* WIEDMANN, 1962).

In Westphalia (Text-figs 12 and 4), northern Spain (KÜCHLER & ERNST 1989) and the Bohemian Basin in the Czech Republic (ČECH 1989) only a narrow interval separates the last occurrence of *Subprionocylus neptuni* and the first occurrence of *Prionocyclus germari*.

Beside these well documented occurrences of *P. germari*, it and allied species are known from the upper Upper Turonian of Japan, where *Subprionocylus normalis* and *Reesidites minimus* are followed by *Prionocyclus wyomingensis* MEEK, *P. cobbani* and *P. aberrans*

Traditional Subdivision	Inoceramid Zones							Ammonite Zones					
Westphalia SEITZ 1952	Westphalia SEITZ 1956, 1962, 1970		Middle & East Europe TRÖGER 1981, 1989		Lower Saxony ERNST & SCHMID 1979 ERNST, WOOD & RASEMAN 1984		Western Interior, USA KENNEDY & COBBAN 1991	Western Interior, USA KENNEDY & COBBAN 1991		Westphalia KAPLAN & KENNEDY, *herein*		France KENNEDY 1984a, b	
Middle Emscherian	*I. cardissoides* *I. pachti*	Lower Santonian	Zone 25 *I. (S.) cardissoides* *I. (S.) pachti* et al. sp.	Lower Santonian	*undulatoplicatus* ERNST & SCHMID 1979	Lower Santonian			Lower Santonian	*Texanites texanus*	Lower Santonian	*Texanites texanus*	Lower Santonian
Lower Emscherian	Beds without *I. involutus*, with *I. subquadratus*	Upper Coniacian	Zone 24 *I. (M.) subquadr.* without *I. (V.) involutus*	Upper Coniacian	*Gonioteuthis praewestfalica* ERNST & SCHMID 1979	Upper Coniacian	*I. (Magadiceramus) subquadratus crenulatus*	*Scaphites depressus*	Upper Coniacian	*Paratexanites serratomarginatus*	Upper Coniacian	*Paratexanites serratomarginatus*	Upper Coniacian
	Beds with *I. involutus* and without *I. koeneni*	Middle Coniacian	Zone 23 *I. (M.) subquadratus* *I. (Volviceramus)* *I. (S?) subcardiss.*		*koeneni-involutus* Zone ERNST & SCHMID 1979	Middle Coniacian	*I. (Volviceramus) involutus*	*Scaphites ventricosus*		*Gauthiericeras margae*	Middle Coniacian	*Gauthiericeras margae*	
	Beds with *I. koeneni*	Lower Coniacian	Zone 22 *I. (V.) involutus* *I. (V.) koeneni* *I. (P.) mantelli* et al. sp.	Middle Coniacian									
Upper Turonian	*Schloenbachi* Beds	Upper Turonian	Zone 21 *I. (C.) schloenbachi* *I. (C.) ernsti*	Lower Coniacian	*Cremnoceramus deformis* WOOD & *al.* 1984	Lower Coniacian	*I. (Cremnoceramus) deformis*	*Scaphites preventricosus*	Middle Coniacian	*Peroniceras tridorsatum*	Lower Coniacian	*Peroniceras tridorsatum*	Middle Coniacian
Late Middle Turonian	*Striatoconcentricus* Beds (pars)	Late Middle Turonian	Zone 20 *I. rotundatus* *M. incertus* *I. waltersdorfensis* *I. (C.) schloenbachi*		*Cremnoceramus erectus* WOOD & *al.* 1984 *Cremnoceramus rotundatus* WOOD & *al.* 1984		*I. (Cremnoceramus) erectus*		Lower Coniacian	*Forresteria petrocoriensis* no index ammonites		*Forresteria petrocoriensis*	Lower Coniacian
			Zone 19 *I. (S.) striatocon.* *I. costel. costel.* *I. (M.) incertus* *I. dresdensis*	Upper Turonian	*I. waltersdorfensis waltersdorfensis* *I.* aff. *frechi* (pars)	Upper Turonian	*Inoceramus frechi* (pars)	*Scaphites corvensis* (pars)	Upper Turonian	*Prionocyclus germari*	Upper Turonian	Hiatus	

Correlation of the Coniacian of the Münster Basin with that of other regions

(MATSUMOTO 1971). In Tunisia ROBASZYNSKI & *al.* (1990) established a *Prionocyclus* interval with *P. novimexicanus* above a *Romaniceras deverianum* total range Zone, which agrees very well with the situation in northern Spain (KÜCHLER & ERNST 1989), and with that in other areas. Further occurrences of *P. germari* are in the upper Upper Turonian of southern France (MIDDLEMISS & MOULLADE 1968) and the Western Interior of the United States (COBBAN 1990, KENNEDY & COBBAN 1991).

In Westphalia, the Bohemian Basin, northern Spain and Tunisia, where *Prionocyclus* is precisely localised, there is a gap between the highest *Prionocyclus* and first *Forresteria* (*Harleites*) *petrocoriensis*.

Coniacian

Correlation with the type area of the Coniacian and the selected areas in Europe and adjacent areas is shown in Text-fig. 24.

TYPE AREA

For the type-area in western France, KENNEDY (1984a) established the following sequence (from top to bottom):

4. *Paratexanites serratomarginatus* Zone, with *Protexanites bourgeoisianus*, *P. bontani*, *Proplacenticeras semiornatum*, *Phlycticrioceras trinodosum*, and *Baculites incurvatus*,
3. *Gauthiericeras margae* Zone, with *G. nouelianum*, *G.? boreaui*, *Tridenticeras* sp., and *B. incurvatus*,
2. *Peroniceras* (*Peroniceras*) *tridorsatum* Zone with several species of *Peroniceras*, *Onitshoceras ponsianum*, *Forresteria* (*Harleites*) *nicklesi*, and *Placenticeras fritschi*,
1. *Forresteria* (*Harleites*) *petrocoriensis* Zone, with the zonal index ammonite and rare *Metatissotia* species.

The succession of the zonal index species in the type area and Westphalia agrees very well. The basal *Forresteria* (*Harleites*) *petrocoriensis* Zone is only poorly documented, as in many cases outside the type area. In contrast to the virtually monospecific *petrocoriensis* Zone fauna in Aquitaine, the Westphalian assemblage includes *Scalarites turoniense*, *Neocrioceras paderbornense* and *Scaphites* (*Scaphites*) *kieslingswaldensis kieslingswaldensis*, the last of which first appears with *F.* (*Harleites*) *petrocoriensis*. Within the *Peroniceras tridorsatum* Zone, *Placenticeras fritschi* and *Forresteria* sp. occur in both the type area and Westphalia, where *Metatissotia* is missing. In Westfalia *Onitshoceras ponsianum* occurs later, in the succeeding *G. margae* Zone. Peroniceratids, which are common in the *P. tridorsatum* Zone of the type area, are rare in the *P. tridorsatum* Zone in Westphalia but widespread in the succeeding *G. margae* Zone. They do not occur in the French *Gauthiericeras margae* Zone. In both areas *Protexanites bourgeoisianus* enters high in the *G. margae* Zone, and extends into the *Paratexanites serratomarginatus* Zone.

There are no significant differences between the ammonite faunas of the type area and Westphalia. In both areas there are occurrences of *Paratexanites serratomarginatus*, *P. desmondi* and *Protexanites bourgeoisianus*, *Placenticeras semiornatum*, *Phlycticrioceras trinodosum* and *Tridenticeras*, the last of which first occurs in the *margae* Zone in Westphalia. In Westfalia, *P. desmondi*, *P. trinodosum* and *Tridenticeras* probably occur in the top of the *G. margae* Zone.

NORTHERN FRANCE

The Turonian Coniacian transition (AMEDRO & ROBASZYNSKI 1978, AMEDRO & *al.* 1979) is interrupted by several hardgrounds. As mentioned above, the Upper Turonian ammonite fauna with *Subprionocyclus neptuni*, *Lewesiceras mantelli* and *Scaphites geinitzi* is restricted to a limited horion, which correlates with the northwest German *Hyphantoceras* Event and the contemporanous English Chalk-Rock. There is no ammonite evidence for the upper *S. neptuni* Zone, the *Prionocyclus germari* Zone, or the *Forresteria* (*Harleites*) *petrocoriensis* Zone (*cf.* AMEDRO & *al.* 1982). In the higher parts of their sections, rare *Peroniceras tridorsatum* occurs with *Cremnoceramus schloenbachi*, *C. waltersdorfensis hannovrensis* and abundant *Inoceramus* ex gr. *mantelli*. A co-occurrence of *Cremnoceramus deformis/schloenbachi*, *I. mantelli* and *Peroniceras tridorsatum* is known in the Spremberg-Weisswasser area in Brandenburg-Sachsen, eastern Germany, in the upper part of the *I. schloenbachi* Zone (TRÖGER & HALLER 1966), as well in the Badabag Basin, Romania (SZASZ & ION 1988). In both areas *G. margae* and involute inoceramids are absent from this fauna. *Inoceramus mantelli* first appears high in the *C. deformis* Zone, and this faunal association seems to belong to the upper *P. tridorsatum* Zone/*Cremnoceramus deformis* Zone.

ENGLAND

GALE & WOODROOF (1981) described the occurrence of *Forresteria* (*Harleites*) *petrocoriensis* from the Top Rock of the Kent coast.

CHALK FACIES OF NORTHERN GERMANY

ERNST & SCHULTZ (1974) based the biostratigraphy of their Lägerdorf (Holstein) Richtprofil on inoceramids, echinoids and belemnites, as ammonites and some key Coniacian inoceramids are absent. While the *Cremnoceramus deformis* Zone and the base of the *Volviceramus koeneni* Zone are readily correlated with Westphalia, the correlation of the *Micraster bucaillei/Gonioteuthis westfalica praewestfalica* Zone with sequences from Westphalian shaft sections is uncertain, as *Magadiceramus subquadratus* is absent from the chalk facies and only one precisely dated specimen of *Gonioteuthis westfalica praewestfalica* has been found to date in the Emscherian-Marl of Westphalia. The base of their zone correlates approximately with the level of abundant *Volviceramus involutus*, at which *Magadiceramus subquadratus* first appears in Westphalia, and where *Gonioteuthis westfalica praewestfalica* and *Placenticeras semiornatum* were found in Paderborn-Tallewiesen (SKUPIN 1982).

LOWER SAXONY

WOOD & *al.* (1984) proposed Salzgitter-Salder as the standard section for the Turonian/Coniacian boundary and this was adopted by the 1995 Brussels Symposium (KAUFFMAN & *al.* 1996). Only scaphitid and baculitid heteromorph ammonites occur around the boundary, with *Scaphites* (*Scaphites*) *kieslingswaldensis doylei* (KAPLAN & *al.* 1987). *Scaphites* (*Scaphites*) *kieslingswaldensis kieslingswaldensis* and *Scalarites turoniense* first appearing slightly below. There are no ammonites above this level in Lower Saxony.

SAXONY

In the Spremberg 101 borehole (HALLER 1963) *Inoceramus inconstans* and *Toxoceras turoniense* (= *Scalarites turoniense*) co-occur at a depth of 1107 m, below *Inoceramus schloenbachi*. In the same area *Inoceramus ernsti*, *I. deformis*, and *I. waltersdorfensis hannovrensis* cooccur (HALLER 1963) with *Peroniceras tridorsatum*, *Placenticeras orbignianum* (= *P. fritschi*) and *Scaphites kieslingswaldensis*. This fauna correlates with the *Cremnoceramus deformis* and *Zoophycos* events in Westphalia. As mentioned above, *Platyceramus mantelli* and *Inoceramus kleini* occur already in the upper part of the *Cremnoceramus deformis* Zone. In the following units diagnostic ammonites are lacking, but inoceramid occurrences can be correlated with the Westphalian sequence (HALLER & TRÖGER 1963).

POLAND

In the Nysa Graben (German: *Neissegraben*) and in the Inner Sudetic Trough, *Placenticeras orbignyanum* occurs 8m above the first occurrence of *Inoceramus inconstans*. The ammonite species *Peroniceras subtricarinatum* and *P. westphalicum* first occur in the upper range of *Inoceramus schloenbachi*, and *P. tricarinatum* overlaps with *Inoceramus koeneni* (RADWAŃSKA 1963). These occurrences of inoceramids and ammonites correlate well with those in Westphalia. In the Central Polish Uplands, the Turonian/Coniacian boundary in inoceramid terms is associated with an ammonite fauna with *Sciponoceras* and *Scaphites* (WALASZCZYK 1992), which agrees well with occurrences in Westphalia and Lower Saxony. In the Opole Trough, *Volviceramus involutus* and *Peroniceras subtricarinatum* co-occur, as in the *Gauthiericeras margae* Zone of Westphalia.

CZECH REPUBLIC, BOHEMIAN BASIN

The species *Forresteria* (*Harleites*) *petrocoriensis* first appears in the *Cremnoceramus inconstans* Zone, and ranges up to the basal *Volviceramus koeneni and Platyceramus mantelli* Zone. *Peroniceras tridorsatum* enters above *F.* (*H.*) *petrocoriensis* in the upper part at the *Cremnoceramus inconstans* Zone, below the entry of *Cremnoceramus deformis*, but its main occurrence is in the upper part of the *Cremnoceramus deformis* Zone. The species *Gauthiericeras margae* first occurs just above the first occurrences of *Volviceramus koeneni* and *Platyceramus mantelli*. VAŠIČEK (1992) described a fauna of the *Gauthiericeras margae* Zone, *Volviceramus koeneni* and *involutus* Zone of Moravia, with *Mesopuzosia indopacifica*, *Eupachydiscus* cf. *isculensis* (probably a *Tongoboryceras*), *Gauthiericeras margae*, *Peroniceras tridorsatum*, *Placenticeras* cf. *semiornatum*, *Tridenticeras*, *Phlycticrioceras trinodosum*, *Baculites* cf. *undulatus*, and *Scaphites* (*S.*) *kieslingswaldensis kieslingswaldensis*. This succession agrees well with that in Westphalia. In both areas the upper Upper Turonian is characterized by *Prionocyclus germari*, while *Forresteria* (*Harleites*) *petrocoriensis* first appears in an interval with *Cremnoceramus inconstans*. The genus *Peroniceras* first occurs at a slightly lower level than in Westphalia, as in northern Spain, but *Gauthiericeras margae* and *Volviceramus koeneni* first appear at the same level. Involute inoceramids and *Peroniceras* co-occur in the *margae* Zone in both Westphalia, whereas *Phlycticrioceras tridorsatum* and *Placenticeras semiornatum* are typical of the succeeding *P. serratomarginatus* Zone in Westphalia.

ROMANIA, BABADAG BASIN

According to the sections in SZÁSZ & ION (1988) the Turonian and the Coniacian are highly condensed by comparison with sequences in middle and western Europe; *Didymotis* sp., *Forresteria* (*Harleites*) *petrocorien-*

sis and *Cremnoceramus rotundatus* occur, and are typical for the basal Coniacian. Also recorded is *Barroisiceras haberfellneri* (HAUER); the figured specimen (SZÁSZ & ION 1988, Pl. 6, Fig. 3) may, however, be a *Tissotioides haplophyllus* (REDTENBACHER). The succeeding fauna also includes *Forresteria* (*Harleites*) *petrocoriensis*, *Peroniceras* sp., and *Yabeiceras* aff. *orientale*. The inoceramid fauna is *Cremnoceramus deformis*, *C. inconstans* and *C. erectus*, with *Didymotis* still present. The succeeding *Peroniceras tridorsatum* Zone yields *Platyceramus mantelli*, and there is a poor representation of the *Gauthicriceras margae* Zone above. The faunal succession of the Babadag Basin is thus closely similar to that in Westphalia and the other areas discussed above.

AUSTRIA, GOSAU BEDS

SUMMERBERGER (1985) describes a succession of ammonite faunas that can be correlated with the Coniacian of the French type area and Westphalia. SUMMESBERGER & KENNEDY (1996) suggest that true *Barroisiceras haberfellneri* is Upper Turonian.

NORTH SPAIN

KÜCHLER & ERNST (1989) placed the Turonian/Coniacian boundary at the level of first occurrence of *Cremnoceramus rotundatus* in the *Didymotis* Event II; *Forresteria* (*Harleites*) is rare, and occurs well above the *Didymotis* Event II; *Peroniceras* (*Zuluiceras*) *bajuvaricum* appears slightly below the base of the *Cremnoceramus deformis* Zone. KÜCHLER & ERNST (1989) gave no faunal evidence for the *Gauthiericeras margae* and *Platyceramus mantelli* Zones, but according to their diagram, their lower boundaries coincide. The ammonite succession agrees well with those of the type area and Westphalia, although *Peroniceras* occurs as *Peroniceras* (*Zuluiceras*) *bajuvaricum* slightly earlier than in Westphalia, which agrees well with records from the Bohemian basin.

US WESTERN INTERIOR

The inoceramid zones proposed by KENNEDY & COBBAN (1991) correspond well with those recognized in Westphalia. The exact correlation of the Westphalian *Magadiceramus subquadratus* Zone and the *Magadiceramus subquadratus crenelatus* Zone of the Western Interior has still to be clarified, as SEITZ (1962) gave no exact details of the first occurrence of *M. subquadratus crenelatus* in Germany. On the basis of the correlation of inoceramid zones, the lower part of the *Scaphites corvensis* Zone corresponds to the German *Prionocyclus germari* Zone, which is confirmed by occurrences of *P. germari* in the Western Interior. The upper part of the *corvensis* Zone and the lower part of the *Scaphites preventricosus* Zone are equivalent to the *Forresteria* (*Harleites*) *petrocoriensis* Zone and the lower part of the *Peroniceras tridorsatum* Zone. The upper part of the *tridorsatum* Zone and *Gauthiericeras margae* Zone are equivalent to the *Scaphites ventricosus* Zone; the *Paratexanites serratomarginatus* Zone is equivalent to the *Scaphites depressus* Zone.

CONCLUSIONS

In Westphalia, Lower Saxony, Saxony, Poland and northern Spain diagnostic ammonites are generally missing from the lower Lower Coniacian *Cremnoceramus rotundatus* Zone. The only exception is the occurrence of *Prionocyclus germari* in Bohemia in the *Didymotis* II Event, and *S.* (*S.*) *kieslingswaldensis doylei* in Lower Saxony. The other ammonite occurrences usually consist poorly preserved scaphitid and baculitid heteromorphs only.

In the more-or-less uncondensed sections across the Turonian/Coniacian boundary interval in Westphalia (KAPLAN 1986), northern Spain (KÜCHLER & ERNST 1989) and Bohemia (ČECH 1989), *Forresteria petrocoriensis* always first appears later than *Cremnoceramus rotundatus*, in Westphalia at the level of the *C. inconstans* Event in the *C. erectus* Zone, and in Bohemia in the *C. inconstans* Zone. In northern Spain, where *Cremnoceramus erectus* and *C. inconstans* do not occur, it first occurs in the *Cremnoceramus rotundatus* Zone, but above its base. The Turonian/Coniacian boundary in ammonite terms as proposed by KENNEDY (1984b) may thus be drawn at a higher level than the boundary proposed at the 1995 Symposium, the first occurrence of *C. rotundatus*.

The ammonite boundary is also the entry level of other typical Coniacian ammonites, such as *Scaphites* (*Scaphites*) *kieslingswaldensis kieslingswaldensis*, *Neocrioceras paderbornense* and *Scalarites turoniense*, at the level of closely related *Isomicraster* and *Cremnoceramus inconstans* Events.

The species *Peroniceras* (*Zuluiceras*) first appears in northern Spain (KÜCHLER & ERNST 1989) and Bohemia (ČECH 1989) just below the base of the *Cremnoceramus deformis* Zone. In the only accessible Westphalian sections (Anröchte and Berge), this interval is condensed, and *Peroniceras* (*P.*) *subtricarinatum* and *Cremnoceramus deformis* first appear at the same level. These minor differences apart, the base of the *Peroniceras tridorsatum* Zone correlates with the *Cremnoceramus deformis* Zone in Westphalia, France, Poland, Romania and the Western Interior of the United States.

Previous problems with the correlation of these zones were based on two facts: *Peroniceras* (*Peroniceras*) is rare in or even absent from the *Cremnoceramus deformis* Zone in Westphalia, Saxony and Poland; in these areas *Peroniceras* reaches its greatest diversity in the succeeding *Gauthiericeras margae*/*Volviceramus koeneni* and *involutus* Zones. Secondly, *Gauthiericeras margae* may be rare or is even absent in this zone, as in Saxony and Poland. Consequently but erroneously, a *Peroniceras tridorsatum* Zone instead of a *Gauthiericeras margae* Zone was correlated with the *Volviceramus koeneni* and *involutus* Zone (TRÖGER 1989).

A co-occurrence of *P.* (*P.*) *tridorsatum* and *Platyceramus mantelli* is documented in the *Cremnoceramus deformis* Zone in northern France, Saxony, and Romania.

The base of the *Gauthiericeras margae* Zone and of the *Volviceramus koeneni* and *involutus* Zone correlate in Westfalia and Bohemia (ČECH 1989). In the Western Interior, the base of the *Gauthiericeras margae* Zone seems to be drawn at a higher level. In the type area, *Peroniceras* has not yet been recorded in the *Gauthiericeras margae* Zone, in contrast to Westphalia, Poland, Bohemia, and Romania.

There are few precise records of the *Paratexanites serratomarginatus* ammonite Zone, which appears to be contemporaneous with the *Magadiceramus subquadratus* inoceramid Zone. The ammonite faunas of the type area, Westphalia, Moravia and the U.S Western Interior are very similar. The zone is characterized by species of *Paratexanites*, *Placenticeras semiornatum*, *Tridenticeras*, and *Phlycticrioceras trinodosum*. The belemnite *Gonioteuthis westfalica praewestfalica* occurs together with *Magadiceramus subquadratus*, *Volviceramus involutus* and *Placenticeras semiornatum*; the *Magadiceramus subquadratus* Zone, the *Paratexanites serratomarginatus* Zone and the *Gonioteuthis westfalica praewestfalica* Zone of the North German chalk facies are coeval.

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