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Ammonites and associated macrofauna from the early Late Albian of the Zippelsförde 1/64 core, NE-Germany

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ABSTRACT:

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The macrofaunal content of an exceptionally fossiliferous Late Albian core section is described from Zippelsförde in the Brandenburg district in eastern Germany. The main faunal horizon includes among others *Euhoplites vulgaris*, *Mortoniceras* (*Deiradoceras*) *albense*, *Neohibolites minimus*, *Inoceramus* cf. *anglicus* and *Actinoceramus sulcatus*. This assemblage indicates a *Hysteroceras varicosum* Zone, *Hysteroceras orbignyi* Subzone age. That interval is known from the Anglo-Paris as well as from the Lower Saxony Basin in western Germany, but not was previously recorded from the North East German Basin. Therefore, the record fills a palaeogeographical gap between the Albian in the Carpathians and that of Central Europe. The superjacent interval contains *Aucellina gryphaeoides*, dating it as latest Albian (*Mortoniceras* (*M.*) *inflatum* Zone, late *C. auritus* Subzone or younger), and thus indicating a significant condensation within the Late Albian.

Key words: Early Cretaceous, Albian, Biostratigraphy, E-Germany, Borehole, Correlation, Macrofauna, Ammonites.

INTRODUCTION

In Brandenburg, northeastern Germany, no outcrops of Albian (Early Cretaceous) age sediments exist. However, during the German Democratic Republic regime many borings were drilled through the Early Cretaceous succession. The results were kept secret until the political turnaround and this is why only a few data on ammonites and other macrofossils have been published for the Late Albian of Brandenburg so far. Thus, there is a lack of published data for the area between the ammonite faunas recorded in the northwestern part of Germany, the Lower Saxony Basin (e.g, LEHMANN & *al.* 2007, WIEDMANN & OWEN 2001, OWEN 2007), and the Albian of Poland (e.g. MARCINOWSKI & WIEDMANN 1990).

In recent years, Late Albian macrofossil samples from a couple of cores in Brandenburg were reexamined in the Sternberg repository and in the Bergakademie Freiberg. This produced a few, but remarkably well-preserved ammonites from the Zippelsförde 1/64 boring located some 50 km NW of Berlin. The results from this borehole can now be compared to recent work on boreholes elsewhere in northwestern Germany. This shows some indications in parts of the succession, of condensation of sediments, but in other parts significant expansion (WIEDMANN & OWEN 2001, LEHMANN & *al.* 2007, OWEN 2007). Furthermore, the new data can be compared with that of the classical outcrops in the Anglo-Paris Basin, where the Late Albian succession was originally established, based on quite a few locations (e.g. OWEN 1971, 1972; AMÉDRO 1992). However, in the Zippelsförde 1/64 boring, parts of the Late Albian succession are significantly reduced in thickness and therefore, recent modifications incorporate data from other parts of Europe (OWEN 2007).

In the framework of the palaeogeographical development of western and central Europe the Late Albian is characterized by a mixing of geographically rather restricted and more cosmopolitan ammonites (OWEN 1996a). A tendency of Tethyan mortoniceratids to inhabite northern temperate European shelf areas during the *Dipoloceras cristatum* Zone, is accompanied by a simultaneous invasion of a few Arctic gastroplitid ammonites (OWEN 1996a, 2007) of the generalized *Gastroplites* Zone of JELETZKY (1980). This indicates a migration of faunas due to the opening of gateways, rather than climatic factors. In the succeeding *Hysteroceras orbignyi* Subzone (*Hysteroceras varicosum* Zone) mortoniceratids are still an important part of the fauna in western and central Europe, but Arctic elements are missing. In East Greenland in the *H. orbignyi* Subzone, there is an interfingering of European province ammonites into this border region with the Arctic faunal province reflecting the marked extension of deposits of this Subzone seen throughout Europe. This places the Zippelsförde fauna into a time

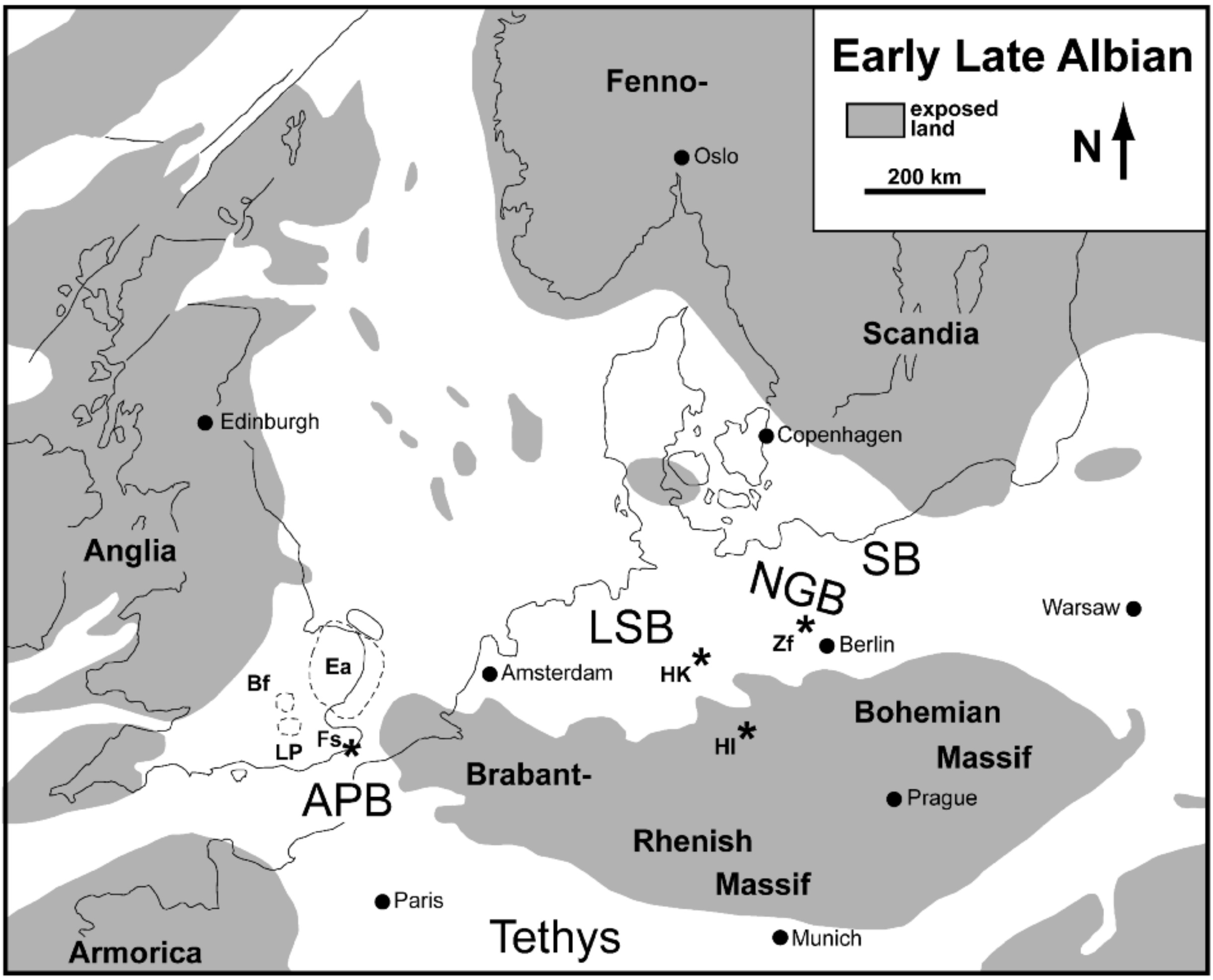

Fig. 1. Palaeogeography of the early Late Albian in northern Europe with localities and areas mentioned in the text. Areas in stippled lines: Bf – Arlesey & Leighton Buzzard in Bedfordshire, EA – East Anglia, LP – London Platform. Localities: Fs – Folkestone, Kent; Zf – Zippelsfoerde, Brandenburg district; Hl – Later in the Albian downfaulted graben deposits occur within the Harz mountains, an example is Holungen, Zippelsförde, see TRÖGER & SCHUBERT 1993. HK – Hannover-Kirchrode. APB – Anglo-Paris Basin, LSB – Lower Saxony Basin, NGB – Northeast German Basin, SB – Szczecin Basin. Map modified after ZIEGLER 1982, 1990

of minor change of faunal associations and the ongoing invasion of Tethyan mortoniceratids into the European shelf sea and their distribution also to the East.

GEOLOGICAL SETTING AND CORE DETAILS

The Zippelsförde 1/64 boring was drilled in 1964 near the village of Zippelsförde in Brandenburg, about 10km NE of Neuruppin and about 45 km NW of Berlin (Text-fig. 1). It had been part of a project set up by the former German Democratic Republic government to explore for oil and gas resources in eastern Germany ("VEB Erdöl und Erdgas", "VEB Geologische Erkundung Nord"). The cores, except for macrofossil samples taken out in 1964, were subject to water damage some 30 years ago and are lost as well as the log data.

All macrofossils investigated come from five different levels of the very short interval between 812.5 and 806.3 m depth within the Zippelsförde core (Text-fig. 2). This interval includes the following taxa, with the number in brackets indicating the total number of specimens present:

806.3 m: *Aucellina gryphaeoides* (J. DE C. SOWERBY, 1836) (3), Text-fig. 3.3; bivalve, non det. (1)

808.2 m: *Aucellina gryphaeoides* (J. DE C. SOWERBY, 1836) (3)

810.5 m: *Platythyris* cf. *diversa* COX & MIDDLEMISS, 1978 (1), Text-fig. 3.4; juvenile brachiopod, indet. (1); *Actinoceramus sulcatus* (PARKINSON, 1819), forma A, juvenile (1), Text-fig. 4.1; *Euhoplites* sp. 1 (1), Text-fig. 4.4a-b; *Neohibolites* sp. (3); *Mortoniceras* (*Deiradoceras*) *albense* SPATH, 1933 (1), Text-fig. 3.2a-c; Disarticulated fish remains, indet., Text-fig. 4.2

811.5 m: *Euhoplites vulgaris* SPATH, 1928 (1), Text-fig. 4.6a-c; *Neohibolites* sp. (2); Disarticulated fish remains, indet.

812.5 m: *Inoceramus* cf. *anglicus* WOODS, 1911 (1), Text-fig. 4.5; *Beudanticeras* sp. (1), Text-fig. 4.3; *Neohibolites minimus minimus* MILLER, 1823 (1), Text-fig. 3.1; *Neohibolites* sp. (2)

All horizons listed consist of light olive grey calcareous silt- and claystones (colour 5Y 6/1, following THE ROCK-COLOR CHART COMMITTEE 1991), except for the sample 806.3 m that is a yellowish grey marlstone

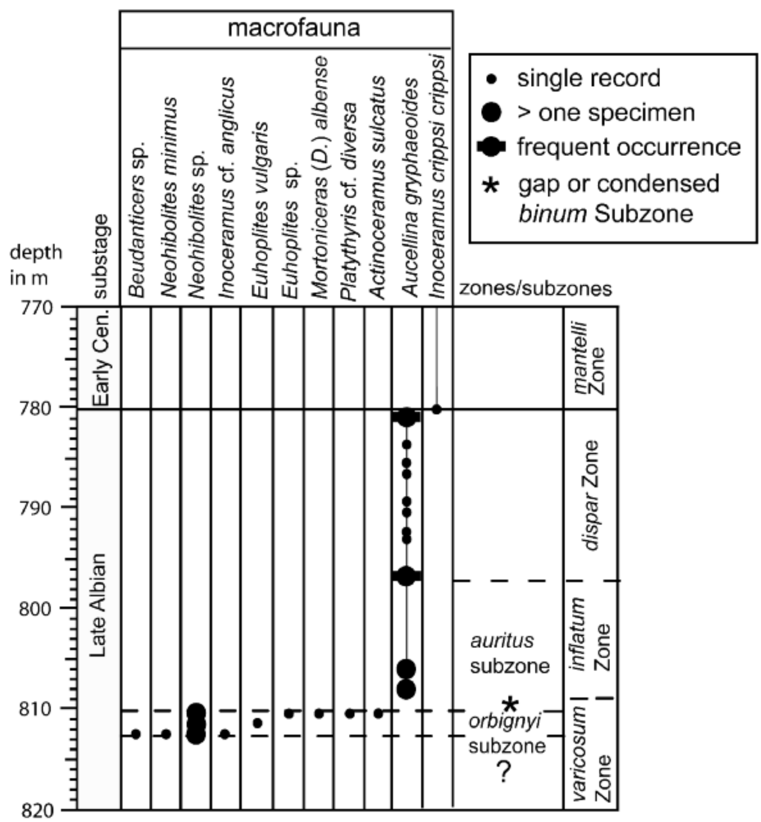

Fig. 2. Ranges of Late Albian and Early Cenomanian macrofossils in the Zippelsförde core. Ranges of fossils above the *H. orbignyi* Subzone fauna according to unpublished data by K.-A. TRÖGER obtained in 1966

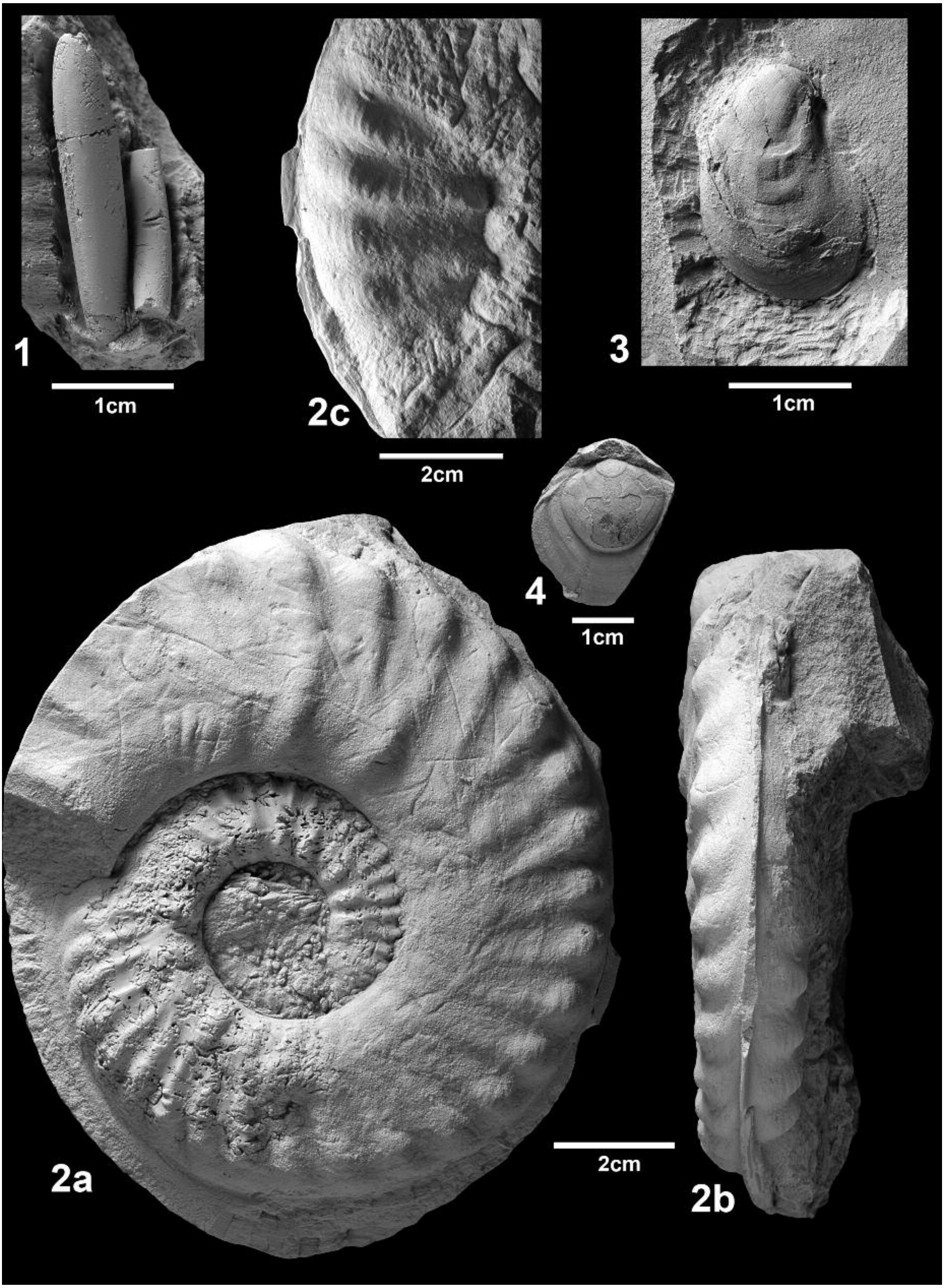

Fig. 3. Macrofauna of the Zippelsförde core. 1 – *Neohibolites minimus minimus* Miller; GSUB C5535; 2 – *Mortoniceras* (*D.*) *albense* Spath; GSUB C5533; 3 – *Aucellina gryphaeoides* (J. de C. Sowerby); GIBF 806.3 m; 4 – *Platythyris* cf. *diversa* Cox & Middlemiss; GSUB B2604

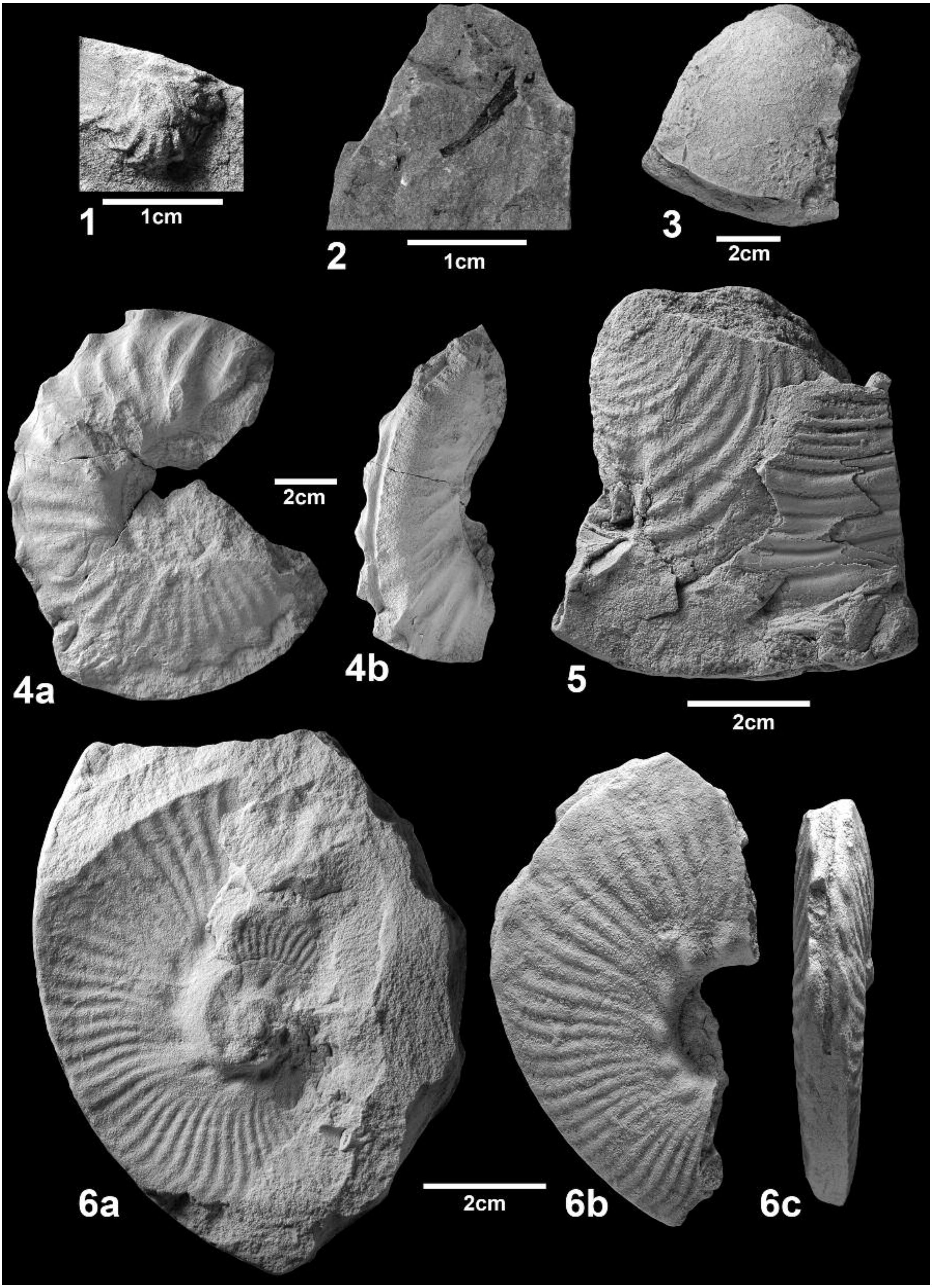

Fig. 4. Macrofauna of the Zippelsförde core. 1 – *Actinoceramus sulcatus* (Parkinson); GSUB L8895; 2 – Fish remains; GSUB V2483; 3 – *Beudanticeras* sp.; GSUB 5534; 4 – *Euhoplites* sp. 1; GSUB C5532; 5 – *Inoceramus* cf. *anglicus* Woods; GSUB L8894. 6 – *Euhoplites vulgaris* Spath; a – GIBF 377/99, b-c – GSUB C5531

Substage	Zone	Subzone
Upper Albian	*Stoliczkaia dispar*	
	Mortoniceras (Mortoniceras) inflatum	*Mortoniceras (Cantabrigites) minor*
		Callihoplites auritus
	Hysteroceras varicosum	*Hysteroceras choffati*
		Hysteroceras binum
		Hysteroceras orbignyi *
	Dipoloceras cristatum	
Middle Albian (pars)	*Euhoplites lautus*	*Anahoplites daviesi*
		Euhoplites nitidus

Fig. 5. Ammonite biostratigraphy around the Middle–Late Albian boundary of the European hoplitid faunal province, following the subdivision by OWEN 2007, and the age of the fauna described herein (asterisk)

and 808.2 m that is a light olive grey marlstone. At 810.5 m depth phosphatic concretions occur within the calcareous siltstones that are intensively bioturbated. The phragmocone of *M.* (*D.*) *albense* described below and a possible reworked ammonite fragment are examples of phosphatic internal moulds from this level. However, the body chamber of the *M.* (*D.*) *albense* specimen is filled with the surrounding matrix. At 811.5 m the calcareous siltstones are also intensively bioturbated. The lowermost sample from 812.5 m depth is a bioturbated claystone characterized by abundant glauconite grains.

In all samples of *H. orbignyi* Subzone age (810.5, 811.5 and 812.5 m), specimens of the belemnite *Neohibolites* are common (Text-fig. 2). In England a larger number of *Neohibolites* specimens were encountered in the *H. varicosum*/*M.* (*M.*) *inflatum* Zone (sensu present zonation, Text-fig. 5; MILBOURNE 1963, MORTER & WOOD 1983 and WOODS & *al.* 1995). This corresponds to our core data, and according to unpublished data independently obtained by two of us (JL, KAT), in the Lower Saxony Basin *Neohibolites* is already common in the Late Albian *D. cristatum* Zone (fig. 3 in LEHMANN & *al.* 2007, around section meters 70-75 and 96, there erroneously dated as Middle Albian).

Text-fig. 3.1 is a fairly complete rostrum enabling the determination as *Neohibolites minimus minimus*. This fits to the correlation of the belemnite succession with the ammonite biostratigraphy in southern England (SPAETH 1973), where *N. ernsti* and *N. oxycaudatus* are co-occurring with *N. minimus minimus* in the *H. orbignyi* Subzone.

In the Zippelsförde 1/64 core all other *Neohibolites* are too fragmentary for a determination at species level (Text-fig. 2; compare SPAETH 1971). At 810.5 m additionally, numerous remains of fish bones are evenly distributed in the rock (Text-fig. 4.2), more than 50 disarticulated bones up to a length of a few mm have been encountered during preparation of the ammonite samples. A distorted brachiopod specimen resembling *Platythyris diversa* in general shape is also present (text-fig. 3.4, compare COX & MIDDLEMISS 1978, pl. 42, figs 3-6).

SYSTEMATIC PALAEONTOLOGY

The macrofossil samples are housed in the collection of the Geologische Hauptsammlung, Bergakademie Freiberg in Freiberg (GIBF) and in the Geowissenschaftliche Sammlung der Universität Bremen in Sternberg (GSUB). The latter specimens were earlier located in the Geologisches Sammlungsarchiv Mecklenburg-Vorpommern in Sternberg, before a decision was made to transfer them to the GSUB.

Order Ammonoidea ZITTEL, 1884
Suborder Ammonitina HYATT, 1889
Superfamily Hoplitoidea DOUVILLÉ, 1890
Family Hoplitidae DOUVILLÉ, 1890
Genus *Euhoplites* SPATH, 1925

TYPE SPECIES: *Euhoplites truncatus* SPATH, 1928, by original designation of SPATH 1925.

Euhoplites vulgaris SPATH, 1928
(Text-figs 4.6a-c)

1928. *Euhoplites vulgaris* Spath, p. 266.
1930. *Euhoplites vulgaris* Spath; Spath, p. 294, pl. 26, figs 4a-c.
2001. *Euhoplites vulgaris* Spath; Wiedmann & Owen; pl. 4, fig. c.

MATERIAL: GSUB C5531, GIBF 377/99 (811.5 m).

DESCRIPTION: There are about 30 fine ribs per half a whorl (GIBF 377/99; corresponds to 15 per quarter whorl in GSUB C5531), arising from prominent umbilical bullae, either branching from these bullae or intercalated. In cross section the ribs are well-rounded. The ribs unite on the ventro-lateral shoulders to form clavi which are moderately large and distinct, there being about half the number in comparison to the umbilical bullae (GSUB C5531). There is a distinct ventral furrow.

DISCUSSION: *E. alphalautus* of *auritus* Subzone age is clearly distinguished from the present species by possessing more finer and less prominent umbilical bullae and ventro-lateral clavi. *E. boloniensis* has more distant umbilical tubercles and outer clavi and it shows more widely spaced ribs which are sharper, rather than being well-rounded in cross section as in the present species.

OCCURRENCE: In the Zippelsförde 1/64 boring the species occurs at 811.5 m depth. *E. vulgaris* was originally described from southern England (Spath 1930) and is also known from northwestern Germany (Wiedmann & Owen 2001). It ranges from the Late Albian *H. orbignyi* Subzone to the *C. auritus* Subzone (Spath 1930, compare Amédro 1992, fig. 10).

Euhoplites sp. 1
(Text-figs 4.4a-b)

MATERIAL: GSUB C5532 (810.5 m).

DESCRIPTION: The present specimen represents a late growth stage, showing a peculiar transition from a fine ornament of low ribs at the initial part of the fragment to a coarser ornament of high ribs on the middle to apertural part. The initial part shows distinct ventrolateral clavi and very regular, slightly prorsiradiate ribs, outnumbering the clavi about twice.

At middle and late growth stage the ventrolateral clavi remain distinct, the primary ribs arise at strong, prorsiradiate elongated umbilical bullae and cross the flank with a pronounced prorsiradiate projection. In contrast to the initial part, the ribbing is high and coarse. There are usually two secondary ribs between each primary rib, one of which is usually intercalated and the other branching from the primary rib at mid flank. The length of secondary ribs apparently shortens towards the aperture.

Since the specimen is obliquely distorted it is unclear if the ventral sulcus is channel-like or if the venter is rather folded. It has to be pointed out that the sharp accentuated edge right of the sulcus in Text-fig. 4.4b is caused by a fracture line and does not represent a primary feature.

DISCUSSION: The change in ornament is a particular feature and despite the fact that the specimen consists of fragments that are glued together, this unequivocally represents an ontogenetic change in a single specimen.

The distal part of the ammonite resembles *Euhoplites subcrenatus* (Spath 1930, pl. 27, fig. 4 and text-fig. 96), but the ventrolateral clavi are more closely spaced and are distinctly less pointed – not significantly projecting above the outline of the shell. In this aspect the features rather indicate similarities to *Euhoplites serotinus* (Spath 1930, pl. 26, fig. 6), showing distant ventrolateral clavi that outnumber the low and regular ribs twice, and that are slightly projecting above the shell. The initial part is also similar to *Euhoplites sublautus* (Spath 1930, pl. 29, fig. 1c; pl. 30, figs 1, 5), but the ventrolateral clavi and the ribbing appear less accentuated at this growth stage with clearly differentiated primary ribs in contrast to GSUB C5532. Finally, the fairly broad intercostal areas, distant clavi with four to five ribs in between, strong umbilical bullae and the moderately evolute coiling is comparable to *Euhoplites boloniensis*. The comparison with specimens in the literature is hindered by the fact that actually no complete large shells of *E. boloniensis* are figured (e.g. Spath 1930, text-fig. 98c), which is also true for most other species mentioned above.

Referring to the characteristic coarse adult ornament, the holotype of *Euhoplites trapezoidalis* is similar (Spath 1930, pl. 28, fig. 1), but the ribbing on middle growth stage is not loop-like around the tubercles, but simple and regular in GSUB C5532.

OCCURRENCE: In the Zippelsförde 1/64 core the species is known from 811.5 m depth and its association with *Mortoniceras* (*D.*) *albense* described below which indicates a *H. orbignyi*/*H. binum* Subzone age of the Late Albian.

Superfamily Acanthoceratoidea DE GROSSOUVRE, 1894
Family Mojsisovicziidae HYATT, 1903
Genus *Mortoniceras* MEEK, 1876
Subgenus *Deiradoceras* VAN HOEPEN, 1931

TYPE SPECIES: *Inflaticeras prerostratum* SPATH, 1921, by original designation.

Mortoniceras (*Deiradoceras*) *albense* SPATH, 1933
(Text-figs 3.2a-c)

1933. *Mortoniceras (Deiradoceras) albense* SPATH, p. 424; pl. 43, fig. 2; pl. 44, fig. 4; text-figs 145b, 147, 149.
1975. *Mortoniceras (Mortoniceras) albense* SPATH; FÖRSTER, p. 237, pl. 15, fig. 2 (and synonymy).

MATERIAL: GSUB C5533 (810.5 m).

DESCRIPTION: Strong umbilical bullae arise somewhat above the umbilical seam. They give rise to low primary ribs that are straight on the inner whorls (up to whorl height 30 mm), but later, ribs and bullae are backwardly inclined. Secondary ribs are also low, intercalated or mostly indistinctly branching from umbilical bullae slightly below mid flank. There are a total of 32 strong ribs per whorl outnumbering the umbilical bullae by 1.3 to 2 at a diameter of about 120mm, each rib terminating in a ventrolateral tubercle. On the right side of the shell the ventrolateral tubercles show fine spiral striae (Text-fig. 3.2c); on the left side this ornament is partially present on ribs and intercostal areas too, which implies that this feature strongly depends on the preservation. A high, pronounced siphonal keel is present. The specimen shows a slightly distorted body chamber, but the phragmocone (ends at a diameter of about 75 mm) is preserved three-dimensionally as a phosphatic concretion. The whorl section (Text-fig. 6) is compressed with the greatest whorl breadth at the umbilical bullae that are sometimes strongly projected. There is a second maximum at the outer third of the flanks (Text-fig. 6). The coiling is very evolute and the umbilicus is broad (35% of diameter), with a well-rounded umbilical wall that is vertical very close to the umbilical seam only. The partially preserved suture line (Text-fig. 7) shows asymmetric, fairly low and broad saddles with irregularly shaped elements and slender lobes with basically bifid terminations.

diameter in mm	whorl height in mm (% of diameter)	umbilical width in mm (% of diameter)
115.3	40.95 (35.5)	40.35 (35.0)

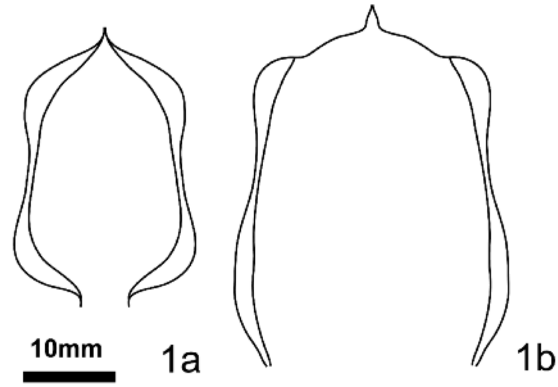

Fig. 6. Cross sections of *Mortoniceras* (*Deiradoceras*) *albense* (GSUB C5533). 1a at a whorl height of 31 mm, 1b at a whorl height of 43 mm. Late Albian, *H. orbignyi* subzone fauna. Zippelsförde core, 810.5 m depth

DISCUSSION: Our material shows a typical adult whorl section, with the largest breadth at the umbilical shoulder that is distinctly less broad than the breadth at the ventrolateral shoulder, and possesses a pronounced keel. Since our material is a single specimen, we follow KENNEDY (in KENNEDY & *al.* 1999, p. 1109) in using a narrow species interpretation for this group of ammonites. However, already SPATH (1933, 1934) noted the strong similarities between different species and even genera and subgenera and AMÉDRO 1992 suggested to unify the present species with *Goodhallites goodhalli* (J. SOWERBY, 1820), *Goodhallites delabechei* SPATH 1934, *Mortoniceras* (*Mortoniceras*) *pricei* (SPATH, 1922), *M.* (*D.*) *cunningtoni* SPATH 1933, *M.* (*D.*) *devonense* SPATH, 1933 and *M.* (*D.*) *bipunctatum* SPATH, 1933. However, there are arguments for continuing the distinction as different species as the following discussion of our material demonstrates.

The present material is very similar to *Goodhallites goodhalli*, but at mid-size, the latter is even more compressed and slender in whorl section, there is no bulge between the ventrolateral shoulder and the keel and in most specimens, the ventrolateral tubercles are bullate rather than tuberculate in comparison to *Mortoniceras* (*D.*) *albense*. This is true for the material described by SPATH (1934) including the holotype of *G. goodhalli* as well as the material figured from Australia (HENDERSON & KENNEDY 2002). However, already SPATH (1934) noted that some varieties might be difficult to distinguish like his *G. goodhalli tuberculata*.

Compared to *Mortoniceras* (*M.*) *pricei*, *M.* (*D.*) *albense* shows a similar strength of ribbing, but additionally to the ribbing, the ornament is accentuated by more coarser umbilical bullae, giving it a specific appearance. This can be observed when comparing the holotype of *M.* (*D.*) *albense* with that of *M.* (*M.*) *pricei* figured in SPATH (1932, 1933). Material referred to as *M.* (*M.*) *pricei* from Texas (KENNEDY in KENNEDY & *al.* 1999) might not be conspecific, its coarser ornament rather reminds us of *M.* (*D.*) *albense* as discussed above. More significant, however, are differences in whorl section. *M.* (*D.*) *albense* differs from *M.* (*M.*) *pricei* in possessing a broader whorl section with a distinct maximum of breadth at the umbilical bullae and the presence of a bulge between the ventrolateral shoulder and the keel. This becomes clear by comparing the whorl section of *M.* (*D.*) *albense* in SPATH (1933, text-fig. 145) and of Text-fig. 6 herein with that of *M.* (*M.*) *pricei* in WIEDMANN & DÜRR (1995, fig. 4a) and SPATH (1933, fext-fig. 145d), referred to as *M.* (*M.*) sp., transitional to *pricei*. South African material described by VAN HOEPEN 1946 as *Mimeloceras latiumbilicatum* differs from *M.* (*D.*) *albense* only by a broader section, a lower keel, less accentuated and blunt umbilical bullae and a slightly more accentuated bulge at mid flank. Another South African specimen referred to as *M.* (*D.*) *albense* (VENZO 1936, pl. 8, fig. 5a) is of the same size as the type and also has a slightly more accentuated bulge at mid flank, as well as a more compressed section with a fairly low keel. Therefore, the material of VENZO (1936) links be-

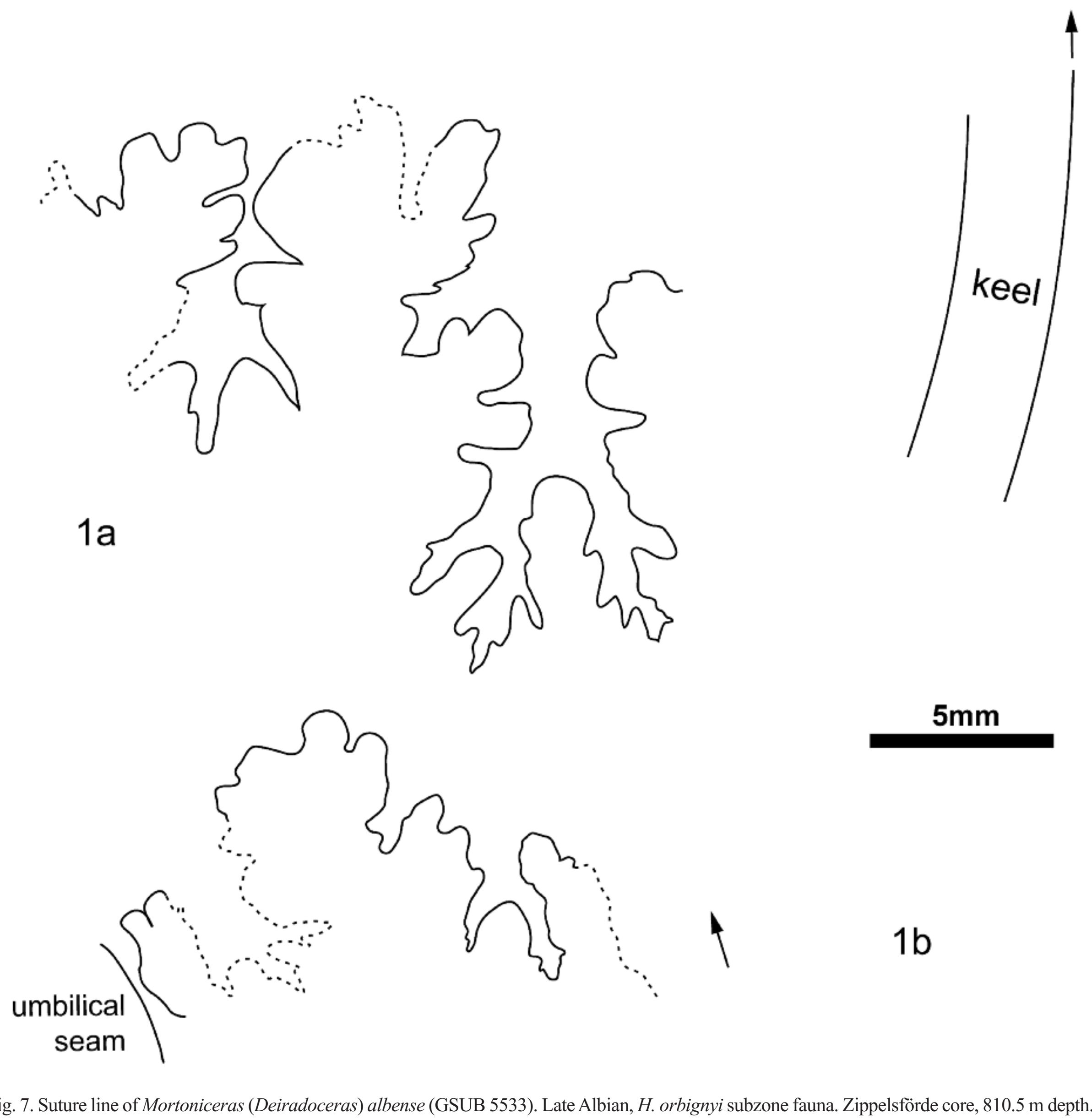

Fig. 7. Suture line of *Mortoniceras* (*Deiradoceras*) *albense* (GSUB 5533). Late Albian, *H. orbignyi* subzone fauna. Zippelsförde core, 810.5 m depth. 1a suture at 30 mm whorl height, 1b suture at an estimated whorl height of around 26 mm

tween the comparatively depressed specimens of VAN HOEPEN (1946) and the holotype of *M.* (*D.*) *albense*.

The suture of GSUB C5533 (Text-fig. 7) differs from that of the holotype of *M.* (*D.*) *albense* in having less evenly fringed lobes and saddles (see SPATH 1933). There are similarities in the lobes of GSUB C5533 to that of *M.* (*M.*) *pricei* SPATH 1932 (text-fig. 130c) that is also showing basically bifid terminations.

OCCURRENCE: This species is known from England, South Africa, Madagascar and Mozambique (FÖRSTER 1975). SPATH (1933, p. 429) records this species in England from the *H. orbignyi* to *H. varicosum* subzones of the Late Albian (*H. orbignyi* to *H. binum* subzones of the modern view). This corresponds to CASEY (1966) who reports it from beds IX to X at Folkestone. In north and east Kent, the species is known also to occur in sediments of *H. choffati* Subzone age. The stratigraphic occurrence is narrow even using a wider taxonomic concept (AMÉDRO 1992, see above), since the allied species *G. goodhalli*, *G. delabechei*, *M.* (*M.*) *pricei*, *M.* (*D.*) *cunningtoni, M.* (*D.*) *devonense* and *M.* (*D.*) *bipunctatum* (compare above) all have a similar stratigraphic occurrence (e.g. CASEY 1966, KENNEDY in KENNEDY & *al.* 1999, AMÉDRO & *al.* 2004).

SPATH (1942) records the stratigraphical range of *G. goodhalli* from beds IX to the base of XI at Folkestone. However, the specimens from Bed IX which superficially resemble *G. goodhalli* belong elsewhere. Moreover, the common occurrence in the Boulonnais in France (e.g. AMÉDRO 1992) is in the equivalent of beds IX and X of Folkestone as well as bed 5 of the Upper Gault at Mundays Hill, in the Leighton Buzzard area of Bedfordshire (OWEN 1972). For correlation of beds and zones see SPATH (1941), and CASEY (1966) and compare summary by HENDERSON & KENNEDY (2002, p. 244) and AMÉDRO (1992).

Superfamily Desmoceratoidea ZITTEL, 1895
Family Desmoceratidae ZITTEL, 1895
Genus *Beudanticeras* HITZEL, 1905

TYPE SPECIES: *Ammonites beudanti* BRONGNIART in CUVIER & BRONGNIART 1822, by original designation.

Beudanticeras sp.
(Text-figs 4.3)

MATERIAL: GSUB C5534 (812.5 m).

DESCRIPTION: This is a completely smooth fragment with a maximum whorl height of about 55 mm. The large whorl height in proportion to the umbilical rim, that is poorly preserved, infers an involute coiling. The specimen is distorted but not flattened and therefore the arched shape of the venter is discernible.

DISCUSSION: The specimen is most likely a representative of the widely distributed and common *Beudanticeras beudanti* (BRONGNIART) (e.g. WIEDMANN & DIENI 1968, p. 128), but is too poorly preserved to give a definite determination at species level.

OCCURRENCE: *Beudanticeras* is a genus ranging throughout the Albian (WRIGHT 1996, p. 81) and occurs in Europe, Near East, Australia, Japan, Alaska, British Columbia, Texas, Argentina and Greenland (WRIGHT 1996, p. 81). The exact range of *Beudanticeras beudanti* is not known but WIEDMANN & DIENI (1968, p. 128) report that it is most common in the upper part of the Albian. Following CASEY (1966, p. 107) it ranges at Folkestone (Kent) from the earliest Late Albian bed VIII (*Dipoloceras cristatum* Zone (Text-fig. 5), to bed X *(H. binum* Subzone) that is the level with *Mortoniceras* (*M.*) *pricei*, referred to as *Mortoniceras* (*M.*) *pricei* Zone by AMÉDRO & *al.* (2004).

BIVALVE SUCCESSION

Until the end of the *Hysteroceras varicosum* Zone, species of *Actinoceramus* were the characteristic and very abundant bivalve of the late Early, Middle and early Late Albian in the European province (e.g. CRAMPTON 1996). At the end of the *H. varicosum* Zone, they virtually disappeared from the stratigraphical record and were replaced by the large, relatively thick-shelled *Inoceramus* (*Inoceramus*) *lissa* SEELEY of geographically widespread occurrence. Within the Kirchrode Mergel Member traversed in the Kirchrode I and II boreholes, *Inoceramus* (*I.*) *lissa* has been shown to be the characteristic bivalve of the early part of the *Callihoplites auritus* Subzone and its range associated with ammonites has been determined (TRÖGER in FENNER & *al.* 1996; WIEDMANN & OWEN 2001; OWEN 2007).

Among these important markers we are able to report *Actinoceramus sulcatus* a form ranging from the early *Dipoloceras cristatum* Zone to the end of the *Hysteroceras orbignyi* Subzone in the Zippelsförde 1/64 borehole (Text-figs 2, 4.1). Additionally there are several yet unpublished records of this species from borings in NE-Germany (Gransee 1/63, Schwerin 2, Tarnow 1/65, Waddekath 22c/E1 60, Waddekath 30/61, Waddekath 31/66), which provide important dating and correlation evidence. The other common *Inoceramus*, *I.* (*I.*) *anglicus* WOODS does not permit a similar high-resolution, but its first occurrence is reported in the literature from the base of the Late Albian (LEHMANN & *al.* 2007), which is consistent with our find of *I.* (*I.*) cf. *anglicus* at 810.5 m (Text-figs 2, 4.5).

Aucellina is a third stratigraphically important bivalve genus recorded in the present core section. Studies in England, formerly placed the appearance of *Aucellina* at the base of the *C. auritus* Subzone (e. g. GALLOIS & MORTER 1982, East Anglia; MORTER & WOOD 1983, East Anglia; OWEN 1996b, base of Bed XI at Folkestone), but this is an artefact produced by the differential erosion which occurred within the early part of the *C. auritus* Subzone in England. Thus WOODS & *al.* (1995) showed that in a borehole succession at Arlesey (Bedfordshire), where a good succession of early *C. auritus* Subzone sediments was present, *I.* (*I.*) *lissa* was the characteristic bivalve and *Aucellina* of *gryphaeoides* type was absent and appeared later in the *C. auritus* Subzone succession. OWEN (1972) concluded that there was no evidence of the presence of *C. auritus* Subzone sediments in the Leighton Buzzard area further south in Bedfordshire. However, it became clear from the Kirchrode I core that Owen's Bed 6 of the Gault in that area of Bedfordshire, which contains fragments of *I.* (*I.*) *lissa* throughout, should be classified with the early part of the *C. auritus* Subzone. Recently it has become apparent that the *Aucellina* biostratigraphy in England is significantly different from that in northern Germany (C.J. WOOD, pers. comm.). WOOD states that *Aucellina* spp. do not occur before the late *C. auritus* Subzone in the Lower Saxony Basin, correcting the records of WIEDMANN & OWEN (2001) and PROKOPH & THUROW (2001); the records being based on misidentified specimens. Either way the Late Albian reappearance of the genus takes place in the early or late *C. auritus* Subzone of the *M.* (*M.*) *inflatum* Zone. Since the first appearance of *Aucellina* at Zippelsförde is at 808.2 m depth, there is most probably a hiatus indicated in this part of the core. The thin interval of 2.3 m in thickness between the upper limit of the *H. orbignyi* Subzone fauna (810.5 m depth) and the oldest record of *Aucellina* at 808.2, lacks any fossils. Because of the lack of *Aucellina,* probably it can be dated as early *C. auritus* Subzone (*M.* (*M.*) *inflatum* Zone) to *H. varicosum* Zone (*H. binum* Subzone*,* possibly including latest *H. orbignyi* Subzone).

The striate ornament close to the umbo on the left valve of the stratigraphically lowermost specimen recorded from the present succession, is similar to that of the neotype of *Aucellina gryphaeoides* (see MORTER & WOOD 1983, pl. 2, fig. 1). According to MORTER & WOOD (1983) this feature is not observable before the earliest Cenomanian in eastern England. However, it might set in earlier further east, in Daghestan, where BARABOSHKIN & *al.* (1997) have recorded *A. gryphaeoides* from an interval most probably correlating with the *C. auritus* Subzone of the European zonation, accompanied by *Mortoniceras* (*M.*) *inflatum*, *M.* (*M.*) cf. *kiliani*, *M.* (*M.*) *nanum*, *M.* (*M.*) *potternense, M.* (C.) *subsimplex*, *M.* (*Deiradoceras*) cf. *cunningtoni* and heteromorph ammonites.

Within the Late Albian range of *Aucellina*, abundant occurrence events have also been used as stratigraphical criteria. An abundant occurrence of *Aucellina* spp. is recorded from the base of the "Oberalb 2" in the Hannover area (BERTRAM & KEMPER 1971) and presumably correlates with the same observation in eastern England (MORTER & WOOD 1983). An abundant occurrence in the present succession is not recorded below 796.80 m, this might indicate condensation within the late *M. inflatum* Zone, since the occurrence of abundant *Aucellina* in eastern England and in the Lower Saxony Basin is dated as probably earliest *S. dispar* Zone of the Late Albian (MORTER & WOOD 1983).

AMMONITE ZONES AND CORRELATION

The *Hysteroceras orbignyi* Subzone is an interval originally established in the Anglo-Paris Basin. *H. orbignyi* is a species first used as a zonal index by SPATH (1923) and finally a subzone within his *Mortoniceras inflatum* Zone in the later part of his monograph on Gault Ammonoidea (SPATH 1941, p. 668). Subsequently, it has been used in this region in a series of papers mainly by OWEN (e.g. 1999). AMÉDRO & *al.* 2004 and others incorporated this sequence within a *Mortoniceras* (*M.*) *pricei* interval zone that is an alternative Late Albian subzone, incorporating the *H. orbignyi* and *H. binum* subzones as used herein (Text-fig. 5; CRAMPTON & GALE 2005).

In the *H. orbignyi* Subzone a strongly ornamented *Actinoceramus sulcatus* (forma A sensu e.g. CRAMPTON in KENNEDY & *al.* 1999, LEHMANN & *al.* 2007) is present, a morphology that first appears in the preceding *D. cristatum* Zone (*D. cristatum* Subzone in OWEN 1984a, 1984b, 1996b, 1999). The *H. orbignyi* Subzone is furthermore characterized by a phylogenetic transition from completely ribbed *Actinoceramus* (forma A, e.g. of CRAMPTON in KENNEDY & *al.* 1999 and *A. sulcatus* sensu OWEN 1984a, 1984b, 1996b, 1999) to smooth forms (summary of different concepts see LEHMANN & *al.* 2007). Different ranges for *Actinoceramus* have been suggested for the Lower Saxony Basin (LEHMANN & *al.* 2007), but after a subsequent revision of data the traditional phylogenetic view prevails. The record of *A. sulcatus* forma A in the present core thus unequivocally indicates a *D. cristatum* Zone/*H. varicosum* Zone, *H. orbignyi* Subzone age (Text-fig. 2, compare Text-fig. 5).

H. orbignyi is recorded from a large number of different areas (LEHMANN & *al.* 2007). The base of the *H. orbignyi* Subzone is marked by the common appearance of *H. orbignyi* and the first occurrence of *Euhoplites inornatus* (OWEN 1972; 1976, p. 493). However, the *Hysteroceras orbignyi* Subzone can only be defined as an assemblage zone containing *H. orbignyi* and *A. sulcatus* (e.g. OWEN 1972, 1976), since the index more rarely occurs in the succeeding *H. binum* Subzone. This makes a correlation based on the index species alone impossible. The top is more precisely drawn at a level immediately after the appearance of smooth forms of *A. sulcatus* forma D (*A. concentricus* sensu OWEN 1984a), tracing a very rapid morphological transition originating from strongly radial-ribbed *Actinoceramus* (OWEN 1984a, p. 340). *H. binum,* the index ammonite of the succeeding Subzone, occurs throughout that subzone and does not occur earlier.

In the area of the "London Platform" current scours were active and condensation is indicated by thin horizons of phosphatic nodules (OWEN 1976, p. 495). Likewise, in the adjacent Lower Saxony Basin, ammonite faunas indicating the *H. orbignyi* subzone are recognized in cores as a comparatively thin interval (WIEDMANN & OWEN 2001, LEHMANN & *al.* 2007). The total thickness is around 5 m in the Hannover-Lahe borehole (LEHMANN & *al.* 2007) and about 10 m in the Hannover-Kirchrode I core (WIEDMANN & OWEN 2001), and there are indications of condensation by abundant inoceramid debris and common phosphatic concretions (LEHMANN & *al.* 2007).

In the extra-Carpathian Albian of Poland the successions are much more condensed than in Western and Central Europe; almost the whole Albian is included in a few meters of section (MARCINOWSKI & RADWANSKI 1983, MARCINOWSKI & WIEDMANN 1990). Ammonite assemblages described by MARCINOWSKI & WIEDMANN 1990 are similar to those of the *H. orbignyi* Subzone in western and central Europe as defined above, but *Actinoceramus sulcatus* is only known from the Carpathians of Poland (MAREK & *al.* 1989, p. 68). In the Czech Carpathians and the Ukraine, however, *H. orbignyi* is accompanied by *A. sulcatus* (VAŠÍCEK & RAKÚS 1993, LESCHUKH 1987).

In many areas of the former Soviet Union both faunal elements occur, in Dagestan the subzonal index species is present only (BARABOSHKIN & *al.* 1997) and in Far-east Russia, where ammonites of the Pacific faunal province replace brancoceratids, *A. sulcatus* is also present (ZONOVA 2004).

In conclusion, a correlation of the *H. orbignyi* Subzone is possible almost throughout the western to eastern hemisphere, with the Zippelsförde record connecting both areas. A combined occurrence of *A. sulcatus* and *H. orbignyi* is furthermore reported in southern Germany (GEBHARD 1984) and southern France (BRÉHÉRET 1997, CRAMPTON & GALE 2005). Nevertheless, a correlation of the *H. orbignyi* Subzone with the remaining Tethys is limited, since in the Mediterranean, the *H. orbignyi* Subzone can only be separated where the inoceramid *Actinoceramus sulcatus* is present (following OWEN in LÓPEZ-HORGUE & *al.* 1999). A connection of European with North American outcrops is still difficult at subzone level (KENNEDY & *al.* 1999).

PALAEOBIOGEOGRAPHY

During the Early Cretaceous, swells dominated the palaeogeography in north-eastern Germany. The Wealden facies represents terrestrial deposits of Berriasian age and the succeeding marine Early Cretaceous represents all stages in the distal parts of the Mecklenburg-Prignitz-Altmark-Brandenburg syncline (Text-fig. 5; e.g. DIENER 1968, MUSSTOW 1968, DIENER 2000, DIENER & *al.* 2004). This situation changed with the globally recognized second order sea level rise at the Early-Late Cretaceous transition (HAQ & *al.* 1987) that also inundated the more elevated areas. The initial transgression took place in the early Late Albian and is well recorded globally by marine faunas (COOPER 1977, YOUNG 1998).

The area of investigation in the present paper belongs to the European Boreal province, characterized by endemic hoplitid ammonites (e.g. OWEN 1996a). In the Zippelsförde 1/64 core, the *H. orbignyi* Subzone fauna of the early Late Albian is characterized by a mixture of faunal elements of Tethyan (*M.* (*M.*) *albense*, *Beudanticeras* sp.) and the European Boreal origin (*Euhoplites* spp., *Neohibolites minimus*), following e.g. WIEDMANN & OWEN (2001) and SPAETH (1971). This composition is accompanied by the bivalve *Actinoceramus sulcatus* of almost cosmopolitan distribution (e.g. CRAMPTON & GALE 2005). This agrees with the Lower Saxony Basin, where the early Late Albian is characterized by an increasing occurrence of Tethyan faunas in the European

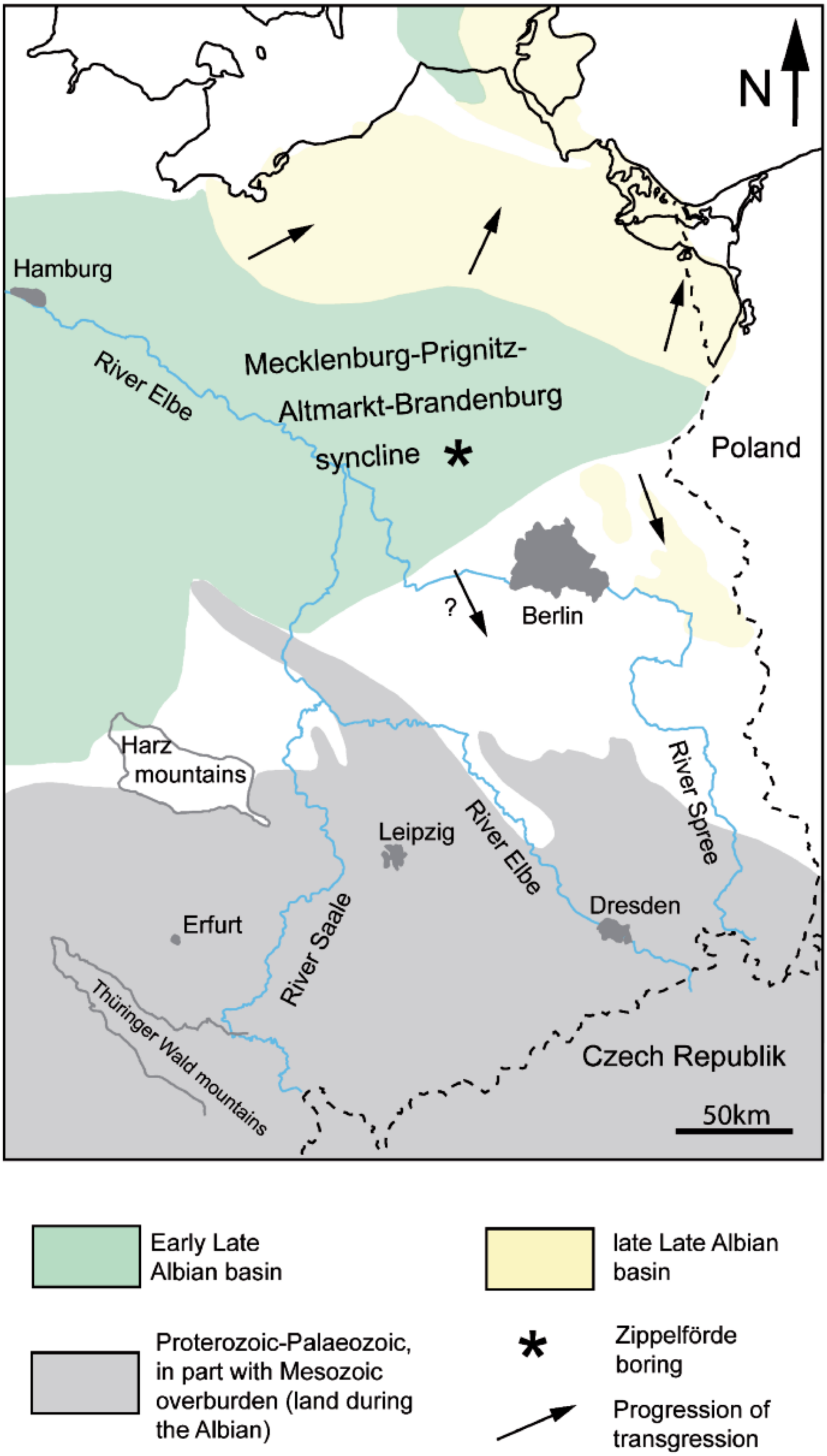

Fig. 8. Palaeogeographic development of the Middle–Late Albian in the North East German Basin (modified after Diener 1967, 1968; Musstopf 1966; Musstow 1968; Tröger & Schubert 1993; Diener & *al.* 2004 and previously unpublished data). The base of the late Late Albian is indicated by the first occurrence of *Aucellina gryphaeoides*, that probably does not take place before the late *C. auritus* Subzone (C.J. Wood, pers. comm.)

Boreal province (e.g. WIEDMANN & OWEN 2001, LEHMANN & *al.* 2007). A connection to the Tethys was possible over the Albian forerunner of the North Sea Basin and the Anglo-Paris Basin as well as along the Polish trough (OWEN 1996a). The early Late Albian sea level rise (HAQ & *al.* 1987) not only triggered faunal exchange between provinces in general, but also led to the widespread distribution of *H. orbignyi* Subzone sediments in the North East German Basin (Text-figs 1, 8) and after a period of erosion in the *H. binum* Subzone, thick sedimentary successions representing the remainder of the Late Albian.

In the cores from the Northeast German Basin, the continuous third-order sea level rise can be traced higher upwards by the onset of beds with common *Aucellina gryphaeoides*. These beds probably correlate with the base of the late *C. auritus* Subzone (Text-fig. 5), in the present area as well as in the Lower Saxony Basin (KEMPER 1978). WOOD (pers. comm.) suggested a corresponding change from rather Tethyan dominated ammonite faunas, accompanied by inoceramid bivalves, to those characterized by North European province ammonites associated with *Aucellina*. However, on the data from the present core section, we cannot add to the discussion, since the succession is reduced and lacks ammonites in the higher part.

It needs to be noted that *Aucellina* is still common in the earliest Cenomanian, for example in the Bemerode beds of the Lower Saxony Basin and equivalents previously referred to as "Vraconian", Late Albian *S. dispar* Zone, (e.g. COOPER 1977, KEMPER 1978). These beds are in fact at least partly earliest Cenomanian (e.g. NIEBUHR & *al.* 1999, OWEN 2007). Despite difficulties with dating of the latest Albian sediments in western Germany (e.g. KEMPER 1978), the base of the interval with common *Aucellina* is transgressive (Text-figs 3.3 and 5) and indicates continuous northeastwards prograding of the transgression into parts of Brandenburg in the Northeast German Basin and even further to the east into the Szczecin Basin in Poland (MUSSTOPF 1966, MUSSTOW 1968). This is more recently supported by PROKOPH & THUROW (2000), despite the fact that some of their *Aucellina gryphaeoides* might represent similar but different small bivalves (C.J. WOOD, pers. comm.). In the south a transgressive horizon in the northwestern part of Thuringia might be related to this sea level rise (TRÖGER & SCHUBERT 1993).

Historically, this ongoing enlarging of the Northeastern German Basin to the east during the Late Albian was already recognized by LINSTOW (1921), although his dating of the transgression is difficult to compare with the higher resolution data present today. Nevertheless, the results are the same and it is not clear yet how they are connected with a sequence boundary in Lower Saxony (NIEBUHR & *al.* 2001) as well as the global trend to regressive deposition in the latest Albian close to the Albian–Cenomanian transition (COOPER 1977, HAQ & *al.* 1988). It might have been masked in northeastern Germany due to the complicated local tectonic background including an increase of halokinetic activity during the Cretaceous (KEMPER 1978, JARITZ 1973, PROKOPH & THUROW 2000).

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