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With a review of the Cenomanian-Santonian lithostratigraphic formations and locality details

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KARL-ARMIN TRÖGER & WALTER KEGEL CHRISTENSEN

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Key words:
Inoceramid bivalves, Upper Cretaceous, Cenomanian,
Coniacian, Santonian, biostratigraphy, lithostratigraphy, locality details, Bornholm, Denmark.

With four plates and 33 figures

Vignette:
Inoceramus schoendorfi Heinz

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Contents

Abstract

The inoceramid bivalve faunas from the Arnager Greensand, Arnager Limestone, and Bavnodde Greensand Formations of the island of Bornholm, Denmark are described. The fauna from the basal part of the Arnager Greensand s. str. is from the Lower Middle Cenomanian and includes *Inoceramus crippsi* Mantell, *I. crippsi hoppenstedtensis* Tröger, and *I. schoendorfi* Heinz. The Arnager Limestone at its type locality immediately west of Arnager yielded a diverse fauna, including *I. waltersdorfensis* cf. *hannovrensis* Heinz, *I. lusatiae* Andert, *I.* cf. *rotundatus* Fiege, *I. striatoconcentricus* Gümbel, *I. (Heroceramus)* cf. *hercules* Heinz, *I.* cf. *wandereri* Andert, *I.* cf. *annulatus* Goldfuss, *I.* cf. *renngarteni* Bodilevski & Schulgina, and *I. (Mytiloides) incertus* Jimbo. This fauna is Lower Coniacian. *I.* cf. *lusatiae* and *I.* cf. *guerichi* Heinz are recorded from the top part of the formation east of Horsemyre Odde, which is Lower Coniacian. *I. (Cremnoceramus) schloenbachi* Böhm from the upper Lower Coniacian is reported from the Arnager Limestone Formation at Muleby. *I. (Volviceramus) koeneni* Müller and *I. (V.) alievimussensis* Ivannikov occur in the top part of the Arnager Limestone Formation at Stampe Å; this fauna is probably Lower Middle Coniacian. The fauna of the Bavnodde Greensand Formation at the type locality consists of *I. (Sphenoceramus) pachti* cf. *pachti* Arkhangelsky and *I. (S.) cardissoides* Goldfuss which are Lower, but not lowest, Santonian. At Risenholm, the formation yielded *I. (S.) subcardissoides* Schlüter, *I. (S.) cardissoides, I. (S.?) bornholmensis* n. sp., *I. (S.)* sp. ex gr. *pachti/cardissoides,* and incomplete, poorly preserved inoceramids possibly belonging to the *I. (Magadiceramus) subquadratus* group; this fauna is basal Santonian. The fauna of the formation at Jydegård comprises *I. (S.?) bornholmensis* n. sp. and *I. (S.)* sp. ex gr. *pachti/cardissoides,* and the formation here is lowest Santonian and possibly highest Coniacian.

The Cenomanian-Santonian lithostratigraphic formations of Bornholm are reviewed and their ages are discussed with regard to various fossil groups, including inoceramid bivalves, ammonites, belemnites, and foraminifera. Locality details are given.

Introduction (WKC)

Ravn (1916a, 1916b, 1918, 1921, 1925, 1930, 1946) described the Cenomanian-Santonian lithostratigraphic formations on Bornholm and their fossil contents in a series of papers. In addition to these papers the macrofauna was dealt with by Schlüter (1874a, 1874b), Stolley (1897, 1930), Rosenkrantz (1945), and Birkelund (1957). Later Christensen (1971, 1973, 1990) revised or commented upon the belemnites, Kennedy, Hancock & Christensen (1981) revised the ammonites from the Arnager Greensand Formation, and Kennedy & Christensen (in press) described the ammonites from the Arnager Limestone and Bavnodde Greensand Formations. Work is in progress on the belemnites from the Arnager Limestone and Bavnodde Greensand by Dr. M.-G. Schulz, Kiel and W.K. Christensen. Foraminifera were described, discussed or commented upon by Douglas & Rankin (1969), Stenestad (1972), Hart (1979, 1980), Bailey & Hart (1979), Solakius & Larsson (1985), and Solakius (1988, 1989). Forchheimer (1970) described coccoliths from the Arnager Greensand. Sorgenfrei (1957) surveyed the Upper Cretaceous lithostratigraphic formations of Bornholm, and Christensen (1985) reviewed the Albian to Maastrichtian of Bornholm and southern Sweden.

The aim of the present paper is to describe the inoceramid bivalve faunas from the Upper Cretaceous of Bornholm and to discuss their stratigraphical significance. Since the papers by J.P.J. Ravn were published in Danish, it is considered appropriate to review the lithostratigraphical formations and provide locality details.

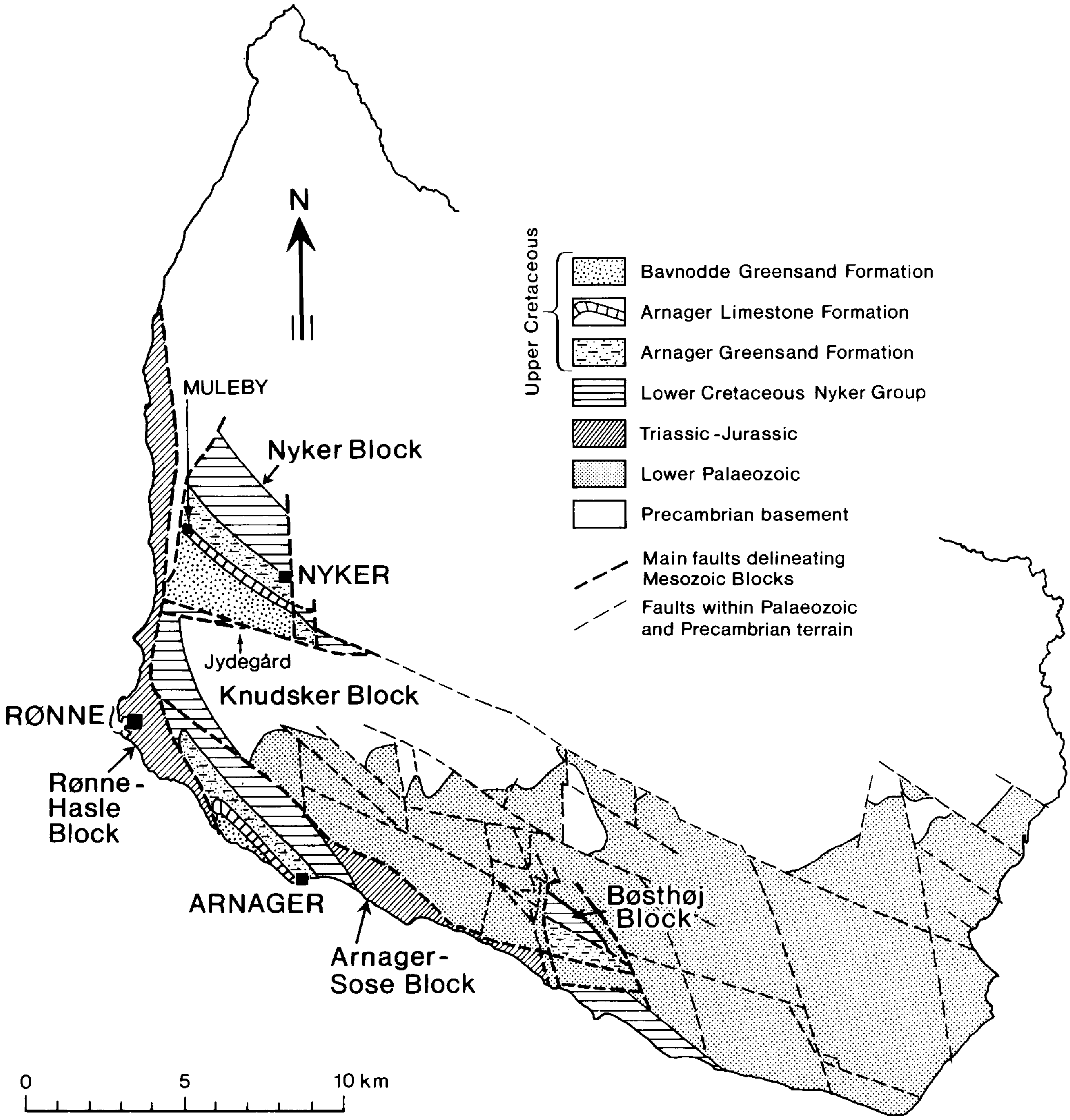


Fig. 1. Geological map of Bornholm. Modified from Gry (1960, 1969) and Gravesen et al. (1982).

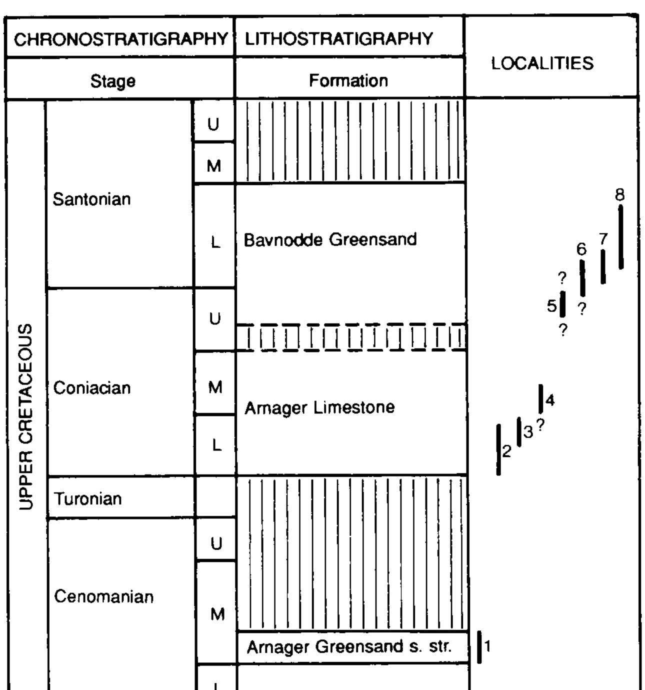
Geological setting (WKC)

The island of Bornholm in the Baltic Sea is a horst within the Fennoscandian Border Zone: that is the marginal area between the stable Precambrian Baltic Shield and the subsiding Late Palaeozoic-Mesozoic Danish Subbasin. The northern part of the island consists of Precambrian basement, whereas Palaeozoic and Mesozoic sediments occur in down-faulted blocks to the south and west (Fig. 1).

The lithostratigraphy and sedimentary environments of the Triassic, Jurassic, and Lower Cretaceous were fully described by Gravesen, Rolle & Surlyk (1982). From the Landinian to Valanginian, Bornholm occupied a position in the transition zone between land and sea. After an important hiatus, including the Hauterivian, Barremian, and Aptian, the sedimentary environment changed to open marine in the Albian.

The open marine Cretaceous sediments, ranging in age from the Albian to Santonian, include the following lithostratigraphic units, from bottom to top, the Arnager Greensand, the Arnager Limestone, and the Bavnodde Greensand Formations (Figs 2–3). The formations occur in three fault blocks: (1) the Nyker block to the west, (2) the Arnager-Sose block to the southwest, and (3) the Bøsthøj block to the south (Fig. 1) (Gry 1956, 1960, 1969). The names of the fault blocks are from Gravesen *et al.* (1982). The Albian-Santonian deposits of Bornholm are known from low coastal cliffs, small sections along stream-cuttings, small pits, and shallow bore-holes. The Mesozoic deposits offshore SW Bornholm were dealt with by Hamann (1987) and Jensen & Hamann (1989).

Very little attention has been paid to the study of sedimentary facies and environments of the formations, except for recent studies on the Arnager Limestone (Noe-Nygaard & Surlyk 1985) and the Bavnodde Greensand (Brüsch 1984).



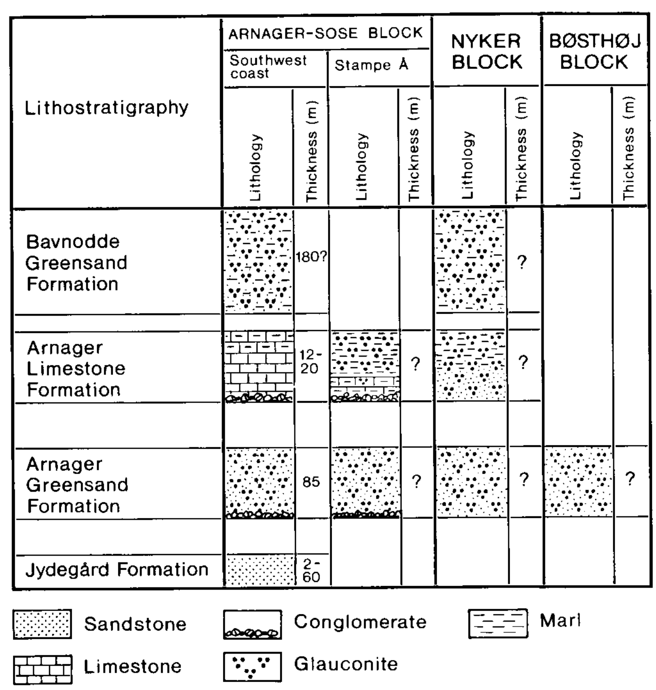


Fig. 2. Scheme of the Cenomanian-Santonian lithostratigraphic formations of Bornholm and biostratigraphical age of exposures based on inoceramid bivalve, ammonite, and belemnite evidence. 1 is the Arnager Greensand at the type locality; 2 is the Arnager Limestone at the type locality; 3 is the Arnager Limestone Formation at Muleby; 4 is the top part of the Arnager Limestone Formation at Stampe Å; 5 is the Bavnodde Greensand Formation in the bay east of Forchhammers Odde and west of Horsemyre Odde; 6 is the Bavnodde Greensand Formation at Jydegård; 7 is the Bavnodde Greensand Formation at Risenholm; and 8 is the Bavnodde Greensand Formation west and east of Bavnodde and at Horsemyre Odde.
Fig. 3. Scheme showing the Cenomanian-Santonian sedimentary sequences on three blocks on Bornholm.

Lithostratigraphy (WKC)

Arnager Greensand Formation

Ravn (1916a)

Name

From the small village of Arnager on the southwest coast of Bornholm (Fig. 4).

Type locality

The coast at Arnager Bugt (bay) between Madsegrav in the east to immediately west of Arnager (Fig. 4).

Thickness

Gry (1960) estimated the thickness of the formation to be about 70–130 m. In a shallow borehole (DGU No. 246.615), placed about 280 m northeast of Horsemyre Odde (Fig. 4), the thickness is about 85 m.

Lithology

Poorly sorted, glauconitic quartz sand. The greensand is unconsolidated except for a few cemented beds in the basal part and is heavily bioturbated. A 18–55 cm thick conglomerate with complexly built phosphatized pebbles and cobbles is also present in the basal part of the

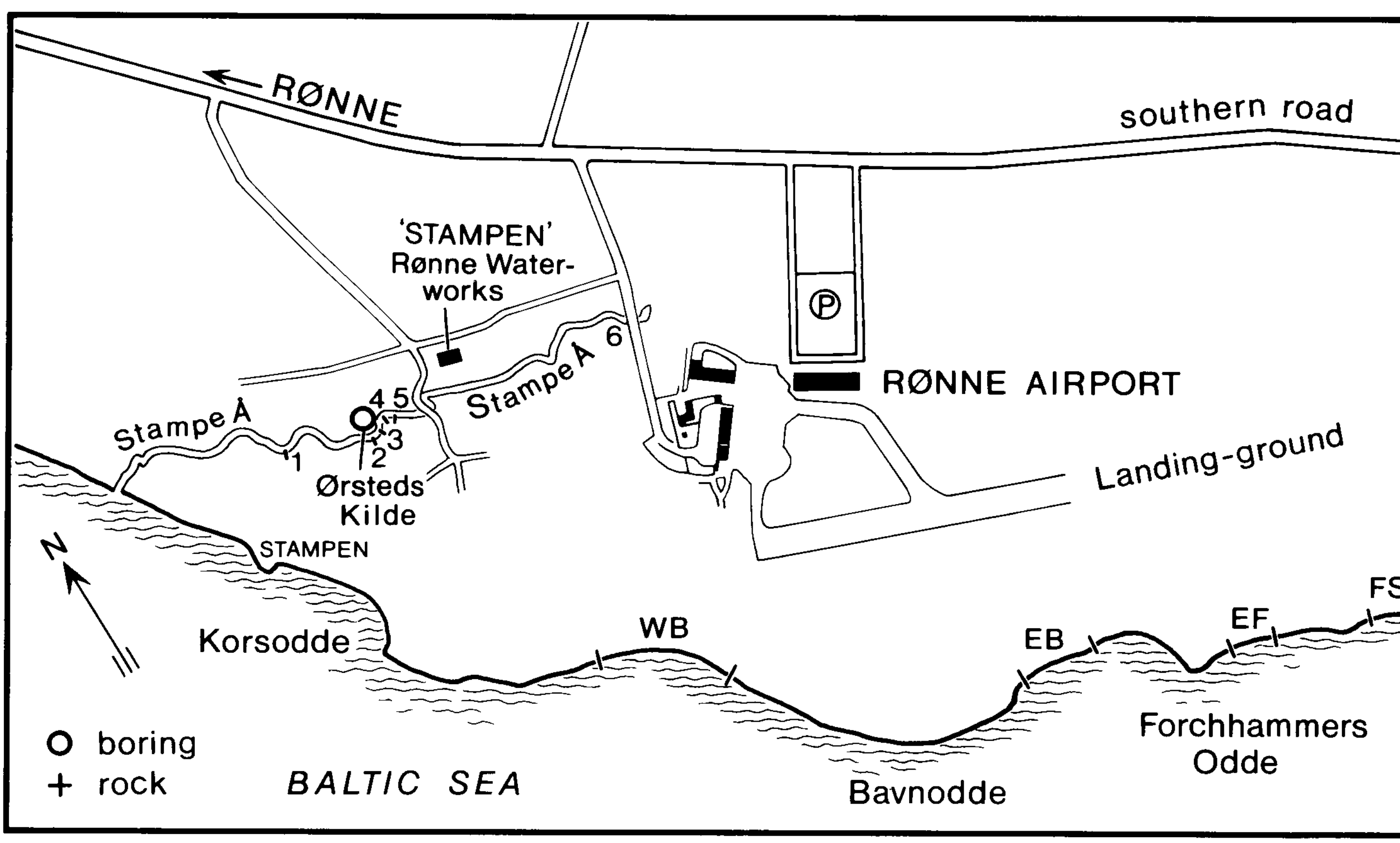


Fig. 4. Map of the Arnager-Sose fault block showing exposures on the southwest coast on Bornholm from Madsegrav in the east to west of Bavnodde, and along Stampe Å. The Arnager Greensand Formation is exposed in the Arnager Bugt (bay) between Madsegrav to immediately west of Arnager. The Arnager Limestone Formation is exposed from west of Arnager to east of Horsemyre Odde. The Bavnodde Greensand Formation is exposed from east of Horsemyre Odde to west of Bavnodde. The outcrops showing Bavnodde Greensand on the southwest coast have the following abbreviations: WB = west of Bavnodde, EB = east of Bavnodde, EF = east of Forchhammers Odde, FS = between Forchhammers Odde and Skidteper, WS = west of

greensand (Ravn 1916a, 1925; Kennedy *et al.* 1981, Fig. 3; and Figs 5–6 herein). The conglomerate has not been observed in the Nyker fault block (Gravesen *et al.* 1982).

Boundaries

In the Arnager-Sose block at Madsegrav the formation rests with a slight angular unconformity on the Lower Cretaceous Jydegård Formation (Gry 1960) (Figs 3 and 5). At the brook Stampe Å the base of the greensand occurs in inverted position (Grönwall & Milthers 1916; Ravn 1921; Gry 1960). The Arnager Greensand Formation is conformably overlain by the Coniacian Arnager Limestone Formation. The boundary between the greensand and the overlying Arnager Limestone is discussed below.

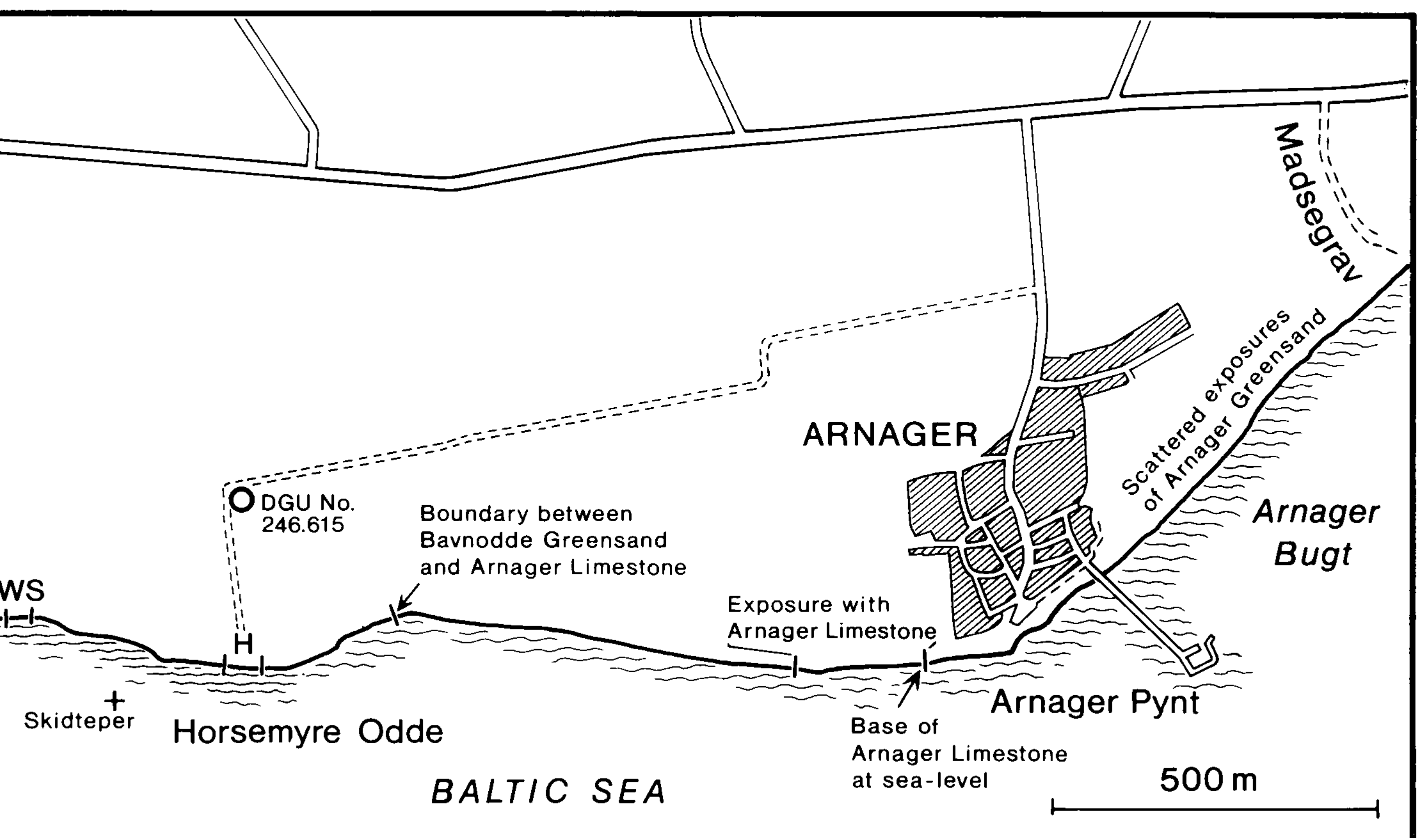
Distribution

The formation occurs in the Nyker, Arnager-Sose, and Bøsthøj blocks (Ravn 1916a, 1916b, 1921, 1925, 1946; Andersen 1944; Gry 1956, 1960), but is poorly known from the Nyker and Bøsthøj blocks.

Geological age

The basal 30 cm of glauconitic quartz sand of the formation at Madsegrav has yielded shark teeth, foraminifers, *"Rhynchonella" sigma,* and *Avellana incrassata;* all of little stratigraphic value (Bromley 1979).

A 40 cm thick conglomerate with complexly built phosphatized pebbles and cobbles follows upon the glauconitic quartz sand at Madsegrav. The ammonites from the Arnager Greensand Formation were revised by Kennedy *et al.* (1981). The specimens from the primary nodules of the conglomerate represent two time intervals in the Albian (*Leymeriella tardefurcata* and *Douvilleiceras mammillatum* Zones). The specimens from the secondary nodules of the conglomerate (various species of *Schloenbachia*) are from the Lower Cenomanian, *Mantelliceras saxbii* and/or *M. dixoni* Zones. The ammonites from the Arnager Greensand *sensu stricto* originated by and large from the hard beds near the base of the greensand and include *Turrilites*



Skidteper, and H = Horsemyre Odde. In the Stampe A area, the boundary betweeen the Lower Cretaceous Jydegård Formation and the Cenomanian Arnager Greensand Formation is exposed at loc. 1. Loc. 2 is Jespersens Hule (Jespersen's Cave), where the Arnager Greensand is exposed. Loc. 3 at Ørsteds Kilde (Ørsted's spring) also shows Arnager Greensand. Ørsteds Kilde is a bore-hole made in 1819. A sandy limestone of the Arnager Limestone Formation is exposed at loc. 4, and a glauconitic marl of the Arnager Limestone Formation crops out at loc. 5, which has yielded inoceramid bivalves and belemnites. Loc. 6 is the abandoned building "Stampen" (the former sea-side hotel). After Kennedy & Christensen (in press).

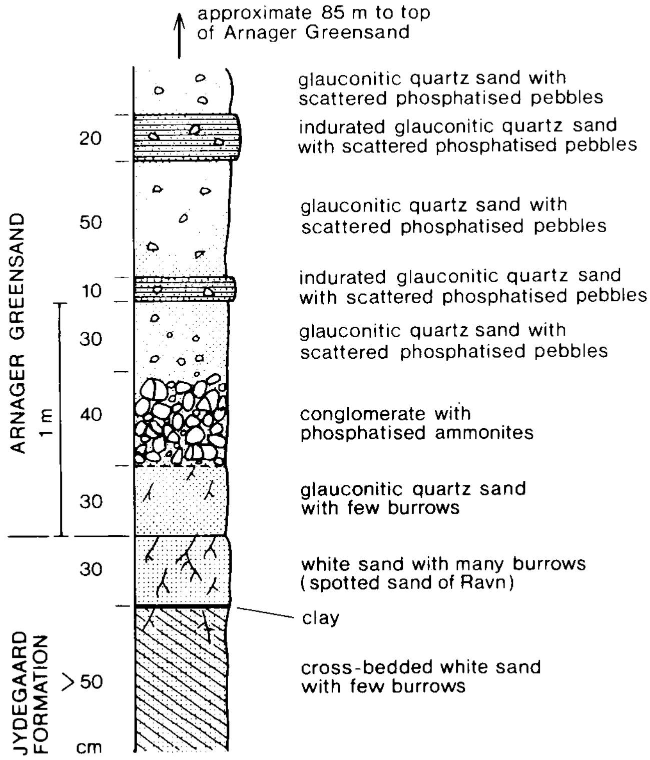


Fig. 5. Section of the boundary beds between the Lower Cretaceous Jydegård Formation and the overlying Arnager Greensand Formation at Madsegrav. After Kennedy et al. (1981).

scheuchzerianus Bosc, *Acanthoceras rhotomagense sussexiense* (Mantell), and species of *Schloenbachia* suggesting the lower Middle Cenomanian *Turrilites costatus* Zone (Figs 2, 7). The greensand has also yielded the belemnite *Actinocamax primus* Arkhangelsky which occurs in the Lower to Middle Middle Cenomanian (cf. Birkelund 1957; Christensen 1990).

The inoceramid bivalve fauna from the basal part of the greensand includes *Inoceramus crippsi* Mantell, *I. crippsi hoppenstedtensis* Tröger, and *I. schoendorfi* Heinz (this paper) which occur in the Lower and Middle Cenomanian (Fig. 8). It is worthy of note that Kaplan, Keller & Wiedmann (1984) correlated the *I. schoendorfi* Zone with the *T. costatus* Zone (see Fig. 7). The biostratigraphic age based on inoceramid bivalves is therefore in accordance with the ammonite dating.

The foraminifera of the Arnager Greensand *sensu stricto* were studied by Hart (1979). According to Hart the benthic foraminifera of the basal 5 m of the greensand are of Early Cenomanian age, while the main thickness of the greensand is of early Middle Cenomanian age. Of particular interest is the report by Hart of *Rotalipora reicheli* Mornod from the top of the greensand; this species spans the boundary between the Zones of *M. dixoni* and *T. costatus* of Early and Middle Cenomanian age, respectively.

To summarize, the Arnager Greensand *s. str.* can be referred to the lower Middle Cenomanian on ammo-

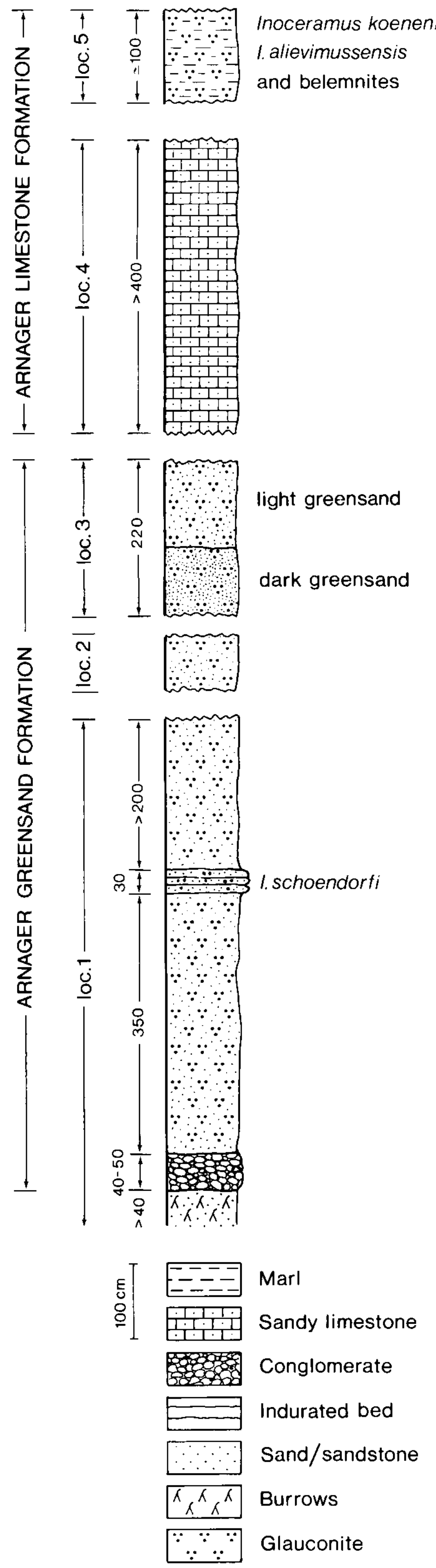


Fig. 6. Section of the Arnager Greensand and Arnager Limestone Formations in the Stampe Å area; for explanation of outcrops, see Fig. 4.

nite and inoceramid bivalve evidences. On foraminiferal evidence, the basal 5 m of the greensand is from the Lower Cenomanian, while the remaining greensand is from the lower Middle Cenomanian.

		AMMONITE ZONES	AMMONITE SUBZONES	*INOCERAMUS* ZONES	FORAMINIFERA ZONES	BELEMNITE ZONES NW EUROPE	BELEMNITE ZONES RUSSIAN PLATFORM
TURON.	LOWER	*Mammites nodosoides*					
TURON.	LOWER	*Watinoceras coloradoense*					
CENOMANIAN	UPPER	*Neocardioceras juddii*		*Inoceramus pictus bohemicus*			
CENOMANIAN	UPPER	*Metoicoceras geslinianum*		*Inoceramus pictus bohemicus*		*Actinocamax plenus*	*Actinocamax plenus*
CENOMANIAN	UPPER	*Calycoceras guerangeri*		*Inoceramus p.pictus*			
CENOMANIAN	MIDDLE	*Acanthoceras jukesbrownei*		*Inoceramus atlanticus*	*Rotalipora cushmani*		
CENOMANIAN	MIDDLE	*Acanthoceras rhotomagense*	*Turrilites acutus*				
CENOMANIAN	MIDDLE	*Acanthoceras rhotomagense*	*Turrilites costatus*	*Inoceramus schoendorfi*	*Rotalipora reicheli*	*Actinocamax primus*	
CENOMANIAN	LOWER	*Mantelliceras dixoni*			*Rotalipora appenninica*	*Actinocamax primus*	
CENOMANIAN	LOWER	*Mantelliceras mantelli*	*Mantelliceras saxbii*	*Inoceramus virgatus*	*Rotalipora appenninica*	*Actinocamax primus*	
CENOMANIAN	LOWER	*Mantelliceras mantelli*	*Neostlingoceras carcitanense*	*Inoceramus crippsi*		*Actinocamax primus*	

Fig. 7. Stratigraphic correlation diagram of the Cenomanian and Lower Turonian. The diagram is based on Ernst et al. (1983), Kaplan et al. (1984), and Kaplan & Best (1985). According to K.-A. Tröger, the Inoceramus zones are acme zones. After Christensen (1990).

Arnager Limestone Formation

Jespersen (1865)

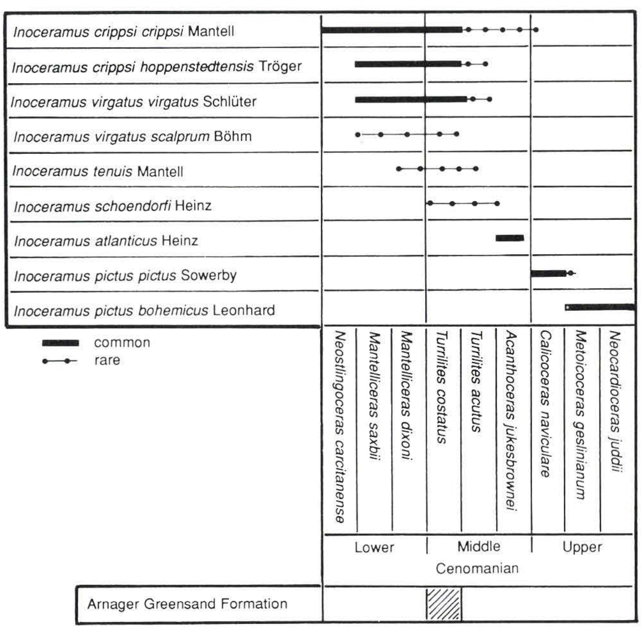


Fig. 8. Diagram showing the stratigraphical range of Cenomanian inoceramid bivalves in the Subhercynian Cretaceous Basin and the Elbe Valley at Dresden, and the age of the Arnager Greensand.

Name

From the small village of Arnager on the southwest coast (Fig. 4).

Type locality

The low cliffs on the southwest coast immediately west of Arnager (Figs 4, 9).

Thickness

Gry (1960) estimated the thickness of the formation to be about 12–20 m.

Lithology

At the type locality the formation consists of a marly chalk (hard splintery limestone) with a 20 cm thick basal bed of phosphatized and glauconitized pebbles (see sketch by Bromley 1979). The lower 7 m of the strongly bioturbated formation is light grey and has a carbonate content varying from 45–70%. The top part of the formation, exposed east of Horsemyre Odde, is

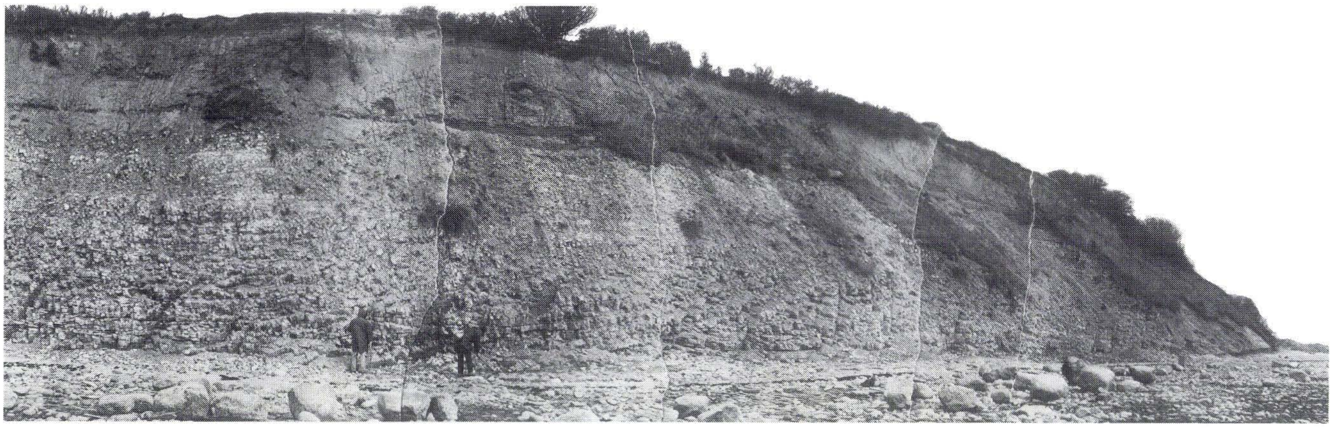


Fig. 9. Photomozaic showing the type locality of the Arnager Limestone west of Arnager, looking southeast. Note the mound bedding of the limestone. April 1984.

bluish-grey and the carbonate content is only about 30% (Christensen 1985). The non-carbonates include clay, fine-grained quartz sand and silica in the form of abundant cristobalite lepispheres (Noe-Nygaard & Surlyk 1985).

Noe-Nygaard & Surlyk (1985) showed that deposition of the formation at Arnager took place in a complex of low mud mounds, and they suggested that the mounds were caused by the baffling effect of dense growth of siliceous sponges and sponge spicule mats.

At the brook Stampe Å the formation is developed as glauconitic marl and sandy limestone (Fig. 6). In the Nyker block the formation consists of sandy, glauconitic marl, the so-called "Glass-marl" of Ravn (1946).

Distribution

The Arnager Limestone Formation occurs in the Arnager-Sose and Nyker blocks (Fig. 3) (Ravn 1918, 1921, 1946; Gry 1960).

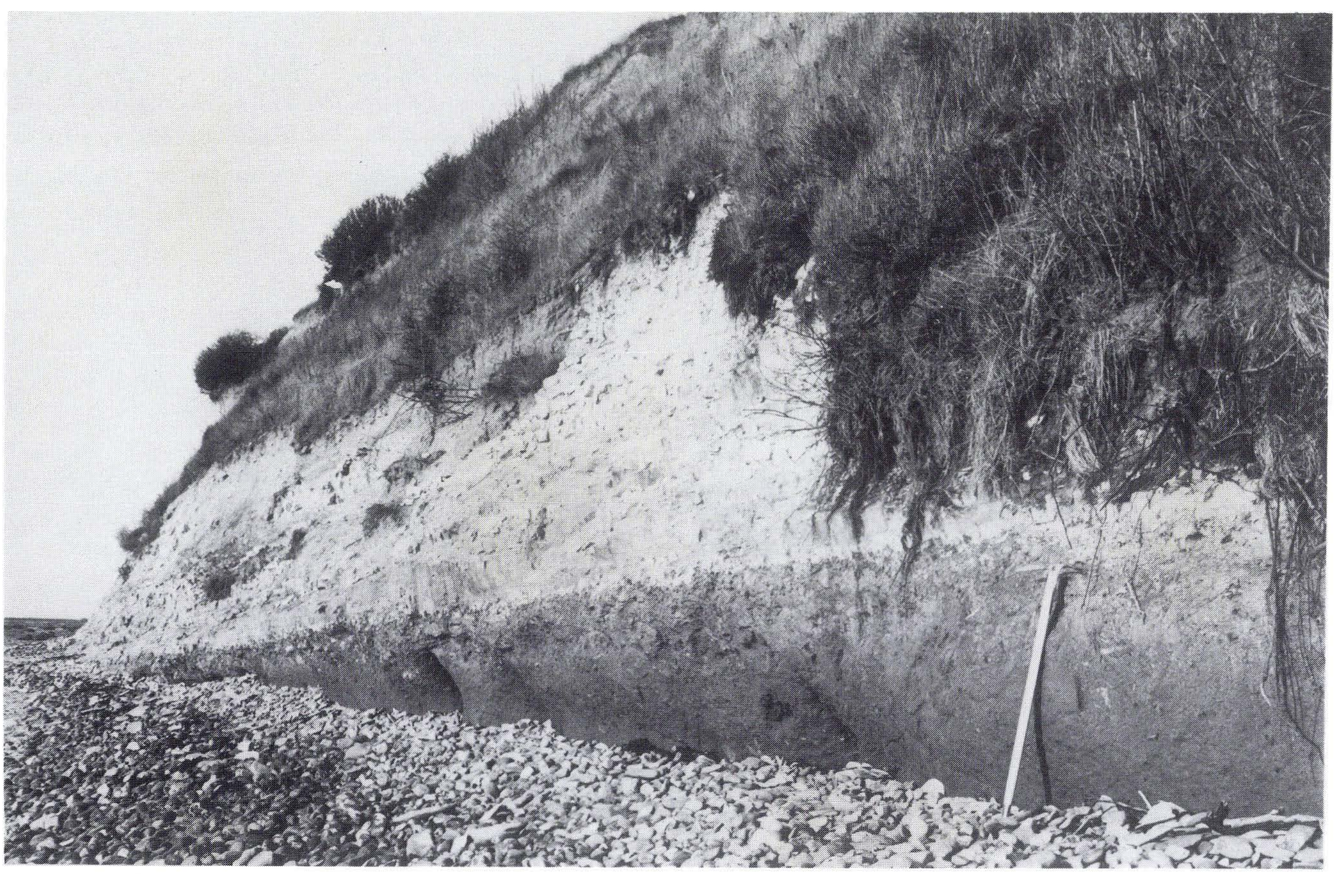


Fig. 10. The boundary beds between the Arnager Greensand below and Arnager Limestone above immediately west of Arnager, looking southwest. The head of the ice-pick points towards the base of the conglomerate, consisting of phosphatized and glauconitized pebbles, at the base of the limestone. The length of the ice-pick is 90 cm. April 1984.

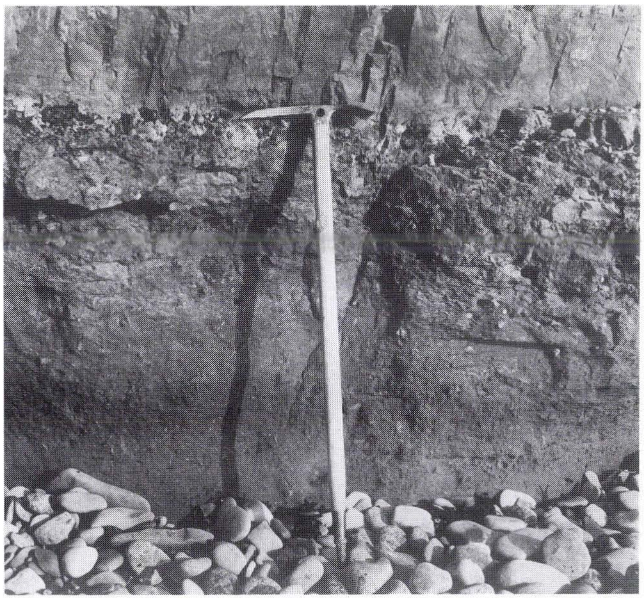


Fig. 11. The boundary beds between the Arnager Greensand below and the Arnager Limestone above immediately west of Arnager. The head of the ice-pick points towards the top of the conglomerate, consisting of phosphatized and glauconitized pebbles, at the base of the limestone. The length of the ice-pick is 90 cm. April 1984.

Boundaries

The formation rests on the lower Middle Cenomanian Arnager Greensand with an erosional unconformity (Figs 10–11) and is overlain conformably by the Bavnodde Greensand.

Geological age

The biostratigraphical age of the Arnager Limestone has formerly been the subject of much discussion, which is summarized by Christensen (1973, pp. 132–133) (see also Christensen 1985; Kennedy & Christensen in press). It was placed in the Upper Turonian on the basis of ammonites, inoceramid bivalves, and belemnites by Ravn (1918, 1930, 1946) and Birkelund (1957). Stolley (1930) referred the formation to the "Mittlerer Emscher" (= Middle to Upper Coniacian) on inoceramid evidence, and Jeletzky (1958) suggested that it was late Coniacian on belemnite evidence. On the basis of foraminifera, the Arnager Limestone at its type locality was assigned to the upper Coniacian by Douglas & Rankin (1969), Stenestad (1972), and Hart (1980). On the other hand, Solakius & Larsson (1985), on foraminiferal evidence, suggested that the formation spans most of the Coniacian, and they recognized a lower *Reussella kelleri* Zone of early Coniacian age and an upper *Stensioeina exsculpta* Zone of late Coniacian age.

The ammonites of the Arnager Limestone at the type locality west of Arnager and east of Horsemyre Odde were described by Kennedy & Christensen (in press). They recorded five species, including the age diagnostic *Scaphites (S.) kieslingswaldensis kieslingswaldensis* Langenhan & Grundey and *Peroniceras tridorsatum* (Schlüter). *P. tridorsatum* is the index species of the Middle Coniacian in ammonite terms, and *S. (S.) k. kieslingswaldensis* first appears in the middle part of the Lower Coniacian and ranges into the Upper Coniacian (Fig. 12). Kennedy & Christensen concluded that the formation at the type locality is in part at least Middle Coniacian on ammonite evidence (Fig. 2).

According to Tröger (this paper) the relatively diverse inoceramid fauna occurring in the formation at the type locality west of Arnager comprises taxa that elsewhere are recorded from the top of the Turonian and the base of the Coniacian. The fauna includes *I. waltersdorfensis* cf. *hannovrensis* Heinz, *I. lusatiae* Andert, *I.* cf. *rotundatus* Fiege, *I.* cf. *wandereri* Andert, *I. striatoconcentricus* Gümbel, *I.* cf. *annulatus* Goldfuss, *I. (Mytiloides)* cf. *incertus* Jimbo, and *I. (Heroceramus) hercules* Heinz. The sum of evidence, however, suggest that the formation here is from the Lower Coniacian on inoceramid evidence (Figs 2, 13). The top part of the formation east of Horsemyre Odde has yielded *I.* cf. *lusatiae* Andert and *I.* cf. *guerichi* Heinz, and it is considered to be Lower Coniacian. *I. (Cremnoceramus) schloenbachi* Böhm of late Early Coniacian age is recorded from the sandy, glauconitic marl (loc. 1) of the Arnager Limestone Formation at Muleby (see below). *I. (Volviceramus) koeneni* Müller and *I. (V.) alievimussensis* Ivannikov occur in the glauconitic marl at the top of the Arnager Limestone Formation in the Stampe Å area; this fauna is probably Lower Middle Coniacian (Figs 2, 13).

Solakius (1989) discussed the age of the boundary beds of the Arnager Limestone and Bavnodde Greensand exposed east of Horsemyre Odde with respect to foraminifera. He postulated that there is a non-sequence, corresponding to the *Loxostomum eleyi* Assemblage Biozone *sensu* Bailey *et al.* (1983), between the two formations, because he did not recognize the eponomous species in the top part of the Arnager Limestone. According to Bailey *et al.* (1983) this zone ranges in southern England from the Hope Point Marl, which is low in the Middle Coniacian to immediately above the Whitaker's 3-inch Flint Band, which is lower to middle Middle Santonian. This is at variance with the dating of the formations based on ammonites, inoceramid bivalves, and belemnites. It is also at variance with the dating of the Arnager Limestone based on foraminifera by Solakius & Larsson (1985). We do not think that negative evidence, the lack of *L. eleyi* in the top part of the Arnager Limestone, should be used in biostratigraphical analysis, because this species may be facies controlled (Bailey & Hart 1979).

In summary, it can be concluded that the Arnager Limestone Formation at its type locality is Coniacian.

STAGES	STANDARD AMMONITE ZONES (1)	STAGES	AMMONITE ZONES NW GERMANY (2)	STAGES	*INOCERAMUS* ZONES (3)	BELEMNITE ZONES (4) NW EUROPE	BELEMNITE ZONES (4) BALTO-SCANDIA
SANTONIAN UPPER	*Placenticeras polyopsis*	SANTONIAN		SANTONIAN UPPER	*I. patootensiformis / I. angustus* (pars)	*Gonioteuthis granulata*	*Gonioteuthis granulata*
					I. pinniformis		
SANTONIAN MIDDLE				SANTONIAN MIDDLE		*Gonioteuthis westfalicagranulata*	*G. westfalica-granulata / B. propinqua*
					I. cordiformis	*Gonioteuthis w. westfalica*	*G. w. westfalica / Belemnitella propinqua*
SANTONIAN LOWER				SANTONIAN LOWER	*I. pachti / I. cardissoides*		*G. w. westfalica / B. propinqua / 'A.' lundgreni*
CONIACIAN UPPER	*Paratexanites serratomarginatus*	CONIACIAN UPPER		CONIACIAN UPPER	*I. subquadratus*	*Gonioteuthis westfalica praewestfalica*	*'Actinocamax' lundgreni*
	Gauthiericeras margae	CONIACIAN MIDDLE	*Gauthiericeras margae*	CONIACIAN MIDDLE	*I. involutus*		
					I. koeneni		
CONIACIAN M.	*Peroniceras tridorsatum*	CONIACIAN LOWER	*Peroniceras subtricarinatum*	CONIACIAN LOWER	*I. deformis*		
CONIACIAN LOWER	*Forresteria petrocoriense*		*Forresteria petrocoriense*		*I. erectus*		
					I. rotundatus		
TURONIAN UPPER	*Subprionocyclus neptuni*	TURONIAN UPPER	*Subprionocyclus normalis*	TURONIAN UPPER	*I.* aff. *frechi*		
			Subprionocyclus neptuni		*I. striatoconcentricus*		
					I. costellatus		

Fig. 12. Stratigraphical correlation diagram of the Upper Turonian to Santonian, based on ammonites, inoceramid bivalves, and belemnites. Sources: Column 1 is based on Kennedy (1984) and Hancock (in press); column 2 on Küchler & Ernst (1989); column 3 on Ernst et al. (1983), Kaplan (1986), and Tröger (1989); and column 4 on Christensen (1986, 1988). The correlation of the ammonite and inoceramid bivalve zones is very tentative. After Christensen (1990).

There are, however, discrepancies with respect to which part of the Coniacian Stage the formation should be placed. It is in part at least Middle Coniacian on ammonite evidence, Lower Coniacian on the basis of inoceramid bivalves, while the foraminifera suggest that the formation spans most of the Coniacian. This discrepancy is not related to the definition of the Coniacian substages, because the inoceramid bivalves appears earlier in the fossil record than the ammonites. The formation is upper Lower Coniacian at loc. 1 at Muleby, and the top part of the formation at Stampe Å is lower Middle Coniacian on inoceramid bivalve evidence.

Bavnodde Greensand Formation

Ravn (1916a)

Name

From the point Bavnodde on the southwest coast of Bornholm (Fig. 4).

Type locality

The low coastal cliffs on the southwest coast of Bornholm from west of Bavnodde to east of Horsemyre Odde (Figs 4, 14–16).

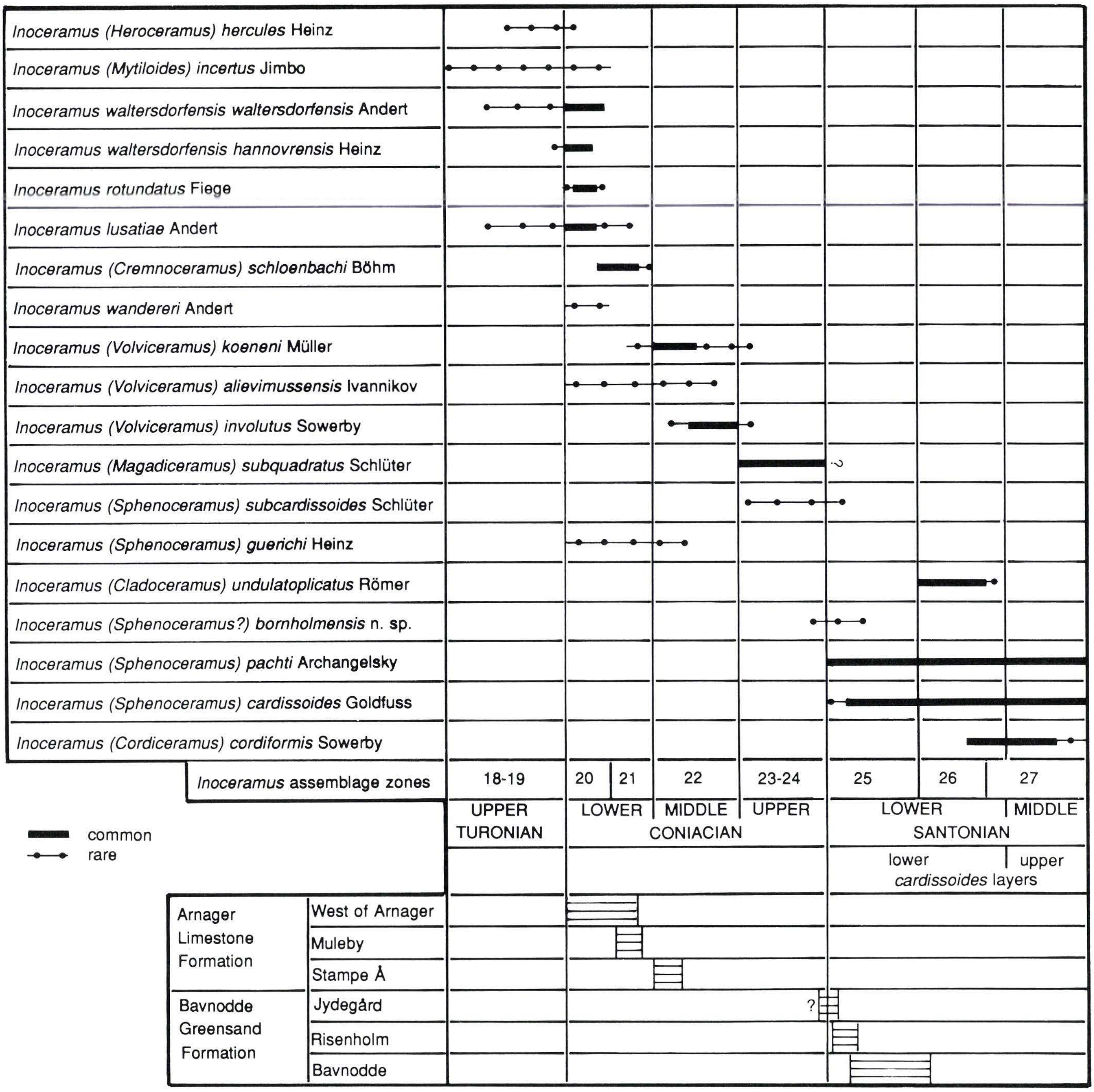


Fig. 13. Diagram showing the stratigraphical range of Upper Turonian to Middle Santonian inoceramid bivalves and the age of Arnager Limestone and Bavnodde Greensand Formations based on inoceramid evidence. Sources: Seitz (1965), Tröger (1981, 1989), and Keller (1982). The Inoceramus assemblage zones are after Tröger (1989).

Thickness

Gry (1960) estimated the thickness to be 180 m. Brüsch (1984) estimated the formation to be maximum 120 m. Offshore Bornholm, the formation may be as thick as 800 m (Jensen & Hamann 1989).

Lithology

At the type locality the formation consists of poorly sorted, calcareous, glauconitic, fine-grained, silty quartz sand. Several layers of nodular greeensand, quartzitic beds, and marly beds are included in the greensand, which is strongly bioturbated. In the Nyker fault block the formation consists of greensands and marls.

Boundaries

At the type locality the greensand rests with a disconformity on the Arnager Limestone Formation and follows directly upon the top bed of the limestone without any development of conglomerate or phosphatized

Fig. 14. Photomozaic showing the exposure of the Bavnodde Greensand west of Bavnodde, looking southeast. Bavnodde is to the right. Bed 2 is a quartzose sandstone and beds 4 and 5 are nodular sandstone (cf. Fig. 15). April 1984.

nodules at the base of the greensand (Ravn 1921; Christensen 1985; Solakius 1989) (Fig. 17). At the Jydegård clay pit in the Nyker block (Figs 18–19) the Bavnodde Greensand Formation is separated from the Lower Cretaceous Jydegård Formation by a reverse fault (see Gry 1956, 1960; Gravesen *et al.* 1982).

The formation is unconformably overlain by Quaternary glacio-fluvial deposits. The Bavnodde Greensand is the youngest pre-Quaternary formation known from Bornholm.

Distribution

The formation is reported from the Arnager-Sose and Nyker blocks (Ravn 1921, 1946; Gry 1960).

Geological age

Ravn (1921) assigned the Bavnodde Greensand on the southwest coast of Bornholm to the Lower Senonian (= Emscher, by and large equivalent to the Lower and lower Middle Santonian) on the basis of *Gonioteuthis westfalica* (Schlüter), *Texanites pseudotexanus* (de Grossouvre), and the presumed occurrence of *Scaphites inflatus* Roemer. According to Ravn all outcrops on the southwest coast were of the same age, and this view was followed by Stolley (1930). Birkelund (1957: table 4) placed the Bavnodde Greensand on the southwest coast in the Lower Middle Santonian *I. cordiformis* Zone on the basis of *G. westfalica, Belemnitella propinqua ravni* (Birkelund), and the presumed occurrence of *I. cordiformis* Sowerby (Fig. 12). She suggested that the oldest part of the Bavnodde Greensand was exposed to the east, and that the formation is getting younger westwards. Due to small-scale faulting, the strike and dip of the sediments, and the course of the coastline, the suggestion has been shown to be incorrect. The oldest Bavnodde Greensand on the southwest coast is exposed in the bay between Forchhammers Odde and Horsemyre Odde (Christensen & Schulz, personal observation).

Christensen (1971) showed that *B. propinqua ravni* is a junior synonym of *B. p. propinqua* (Moberg), and he referred, on the basis of a biometric analysis of a sample of *G. westfalica* from the Bavnodde Greensand west of Bavnodde, the formation to the Lower and lower Middle Santonian. The Bavnodde Greensand at Jydegård was considered by Birkelund (1957) to be slightly older than that on the southwest coast. It was placed in the basal Santonian on the basis of the co-occurrence of *G. westfalica, G.* aff. *westfalica,* and *"A". lundgreni excavata* (Sinzow). Christensen (in press) placed *G.* aff. *westfalica sensu* Birkelund and *"A." lundgreni excavata* (Sinzow) in synonymy of *"A." l. lundgreni.*

Ravn (1921) recorded *I. cordiformis* from the type locality and Christensen (1985) reported *I. patootensiformis* Seitz and *I. angustus* Beyenburg (determined by Dr. E.G. Kauffman, Boulder) from the formation. The two last-mentioned species are elsewhere known from the Upper Santonian-Lower Campanian. Following the revision by Tröger (this paper) it is now known that none of these taxa occur in the formation. According to Tröger the greensand exposed at the type locality has yielded *I. (Sphenoceramus) pachti* cf. *pachti* Arkhangelsky, *I. (S.) pachti* subsp. indet., and *I. (S.) cardissoides* Goldfuss subsp. indet., and it is Lower Santonian (Figs 2, 13). Tröger records *I. (S.) subcardissoides* Schlüter, *I. (S.) cardissoides* subsp. indet., *I. (S.?) bornholmensis* n. sp., and *I. (S.)* sp. ex gr. *pachti/cardissoides* from the Bavnodde Greensand Formation exposed at Risenholm, and the formation is here basal Santonian. He reports *I. (S.)* sp. ex gr. *pachti/cardis-*

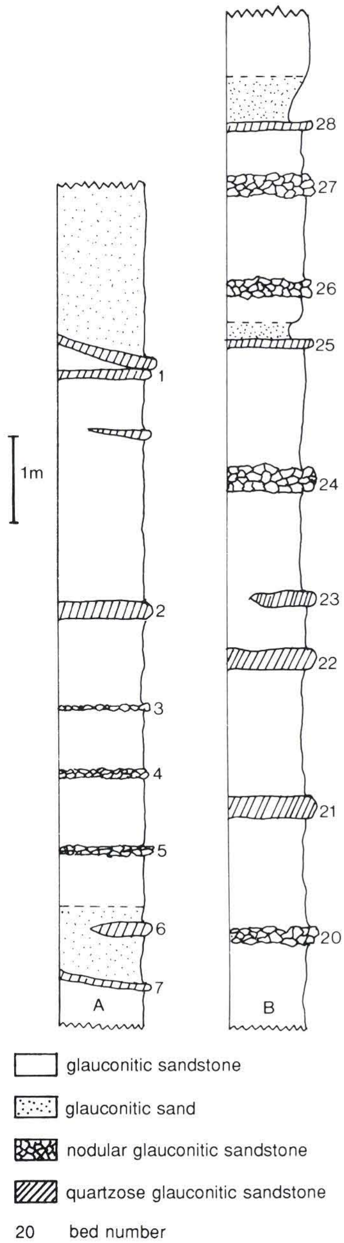


Fig. 15. Two sections of the Bavnodde Greensand. A is the exposure west of Bavnodde and B is the exposure east of Bavnodde.

soides and *I. (S.?) bornholmensis* n. sp. from the greensand at Jydegård, and this greensand is lowest Santonian and possibly highest Coniacian (Figs 2, 13).

According to Kennedy & Christensen (in press) the ammonites from east and west of Bavnodde, Forchhammers Odde, Horsemyre Odde, Risenholm, and Jydegård either indicate a Santonian age, are longer ranging, or are imprecisely dated. It is worthy of note, however, that *Scaphites (S.) kieslingswaldensis fischeri* Riedel, which occurs at Bavnodde, Forchhammers Odde, and Risenholm, first appears in the Lower Santonian elsewhere.

Dr. M.-G. Schulz, Kiel and W.K. Christensen have recently made new collections of belemnites from the Bavnodde Greensand Formation at the type locality and at Jydegård. These are under study now, but preliminary results indicate that the formation probably embraces the Upper Coniacian-Lower Santonian in belemnite terms. The oldest part of the formation crops out in the bay between Forchhammers Odde and Horsemyre Odde. These outcrops have only yielded *"A." lundgreni*, and the greensand here is considered to be from the upper Coniacian (Figs 2, 12). The Bavnodde Greensand east and west of Bavnodde, at Forchhammers Odde, and at Horsemyre Odde has yielded the age diagnostic *Gonioteuthis westfalica westfalica* (Schlüter) and *Belemnitella propinqua propinqua* (Moberg). and the greensand at these outcrops is Lower Santonian on belemnite evidence (Figs 2, 12). The age of the boundary beds of Arnager Limestone and Bavnodde Greensand Formations were discussed by Solakius (1989) (see above).

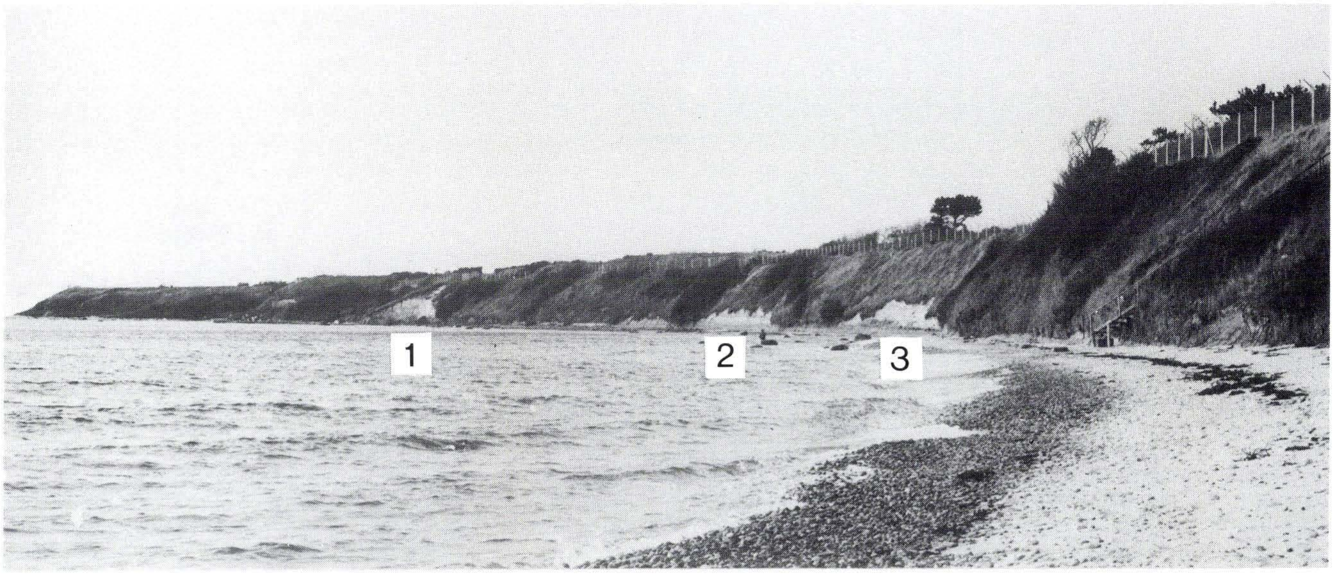


Fig. 16. Exposures of the Bavnodde Greensand Formation in the bay east of Forchhammers Odde and west of Horsemyre Odde, looking northwest. 1 is the exposure east of Forchhammers Odde (EF), 2 is the outcrop referred to as Forchhammers Odde-Skidteper (FS), and 3 is the exposure west of Skidteper (WS) (see also Fig. 4).

Concluding remarks

The Upper Cretaceous sedimentary succession of Bornholm is about 220 m thick and consists mainly of detrital clastic sediments: calcareous, glauconitic, clayey, quartz sand/sandstones and siltstones.

Fig. 17. The boundary beds between the Arnager Limestone Formation below and the Bavnodde Greensand Formation above east of Horesmyre Odde. Lens cap is 5 cm. August 1986.

The Arnager Greensand Formation of Early Middle Cenomanian age is about 85 m thick, and the Bavnodde Greensand Formation of late Coniacian-Early

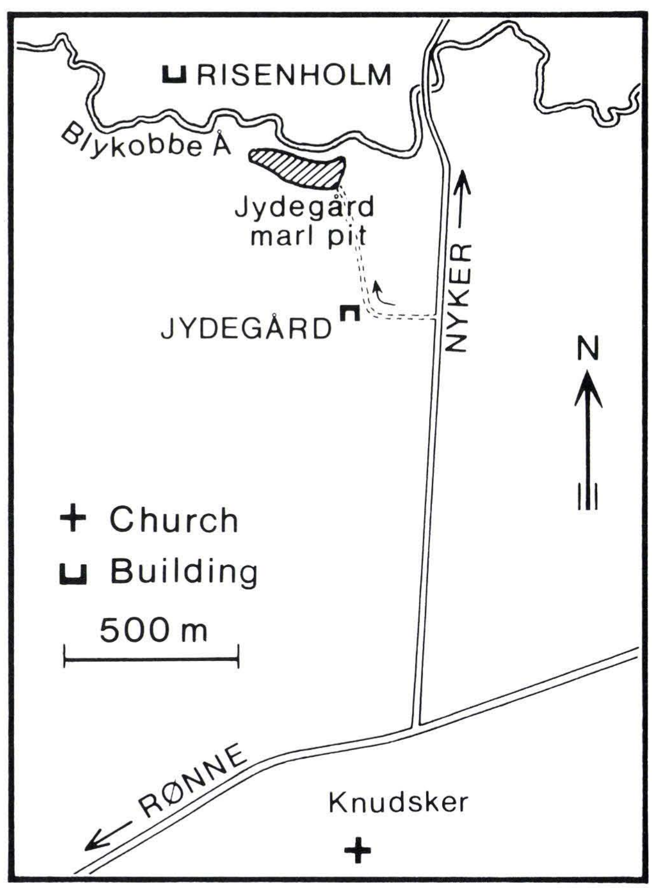


Fig. 18. Map showing the Jydegård marl pit and Blykobbe Å at Risenholm. The Bavnodde Greensand Formation is recorded from the marl pit and stream cuttings of the Blykobbe Å close to Risenholm. After Kennedy & Christensen (in press).

Santonian age is about 120 m thick. The Coniacian Arnager Limestone Formation, which is sandwiched between the two greensands, is only 12–20 m thick.

The Arnager Greensand and Bavnodde Greensand Formations seem to be developed in the same way on the fault blocks, although it should be stressed that the degree of exposure is generally poor, especially in the Nyker and Bøsthøj blocks.

The Arnager Limestone Formation has generally a higher content of carbonate than the subjacent and superjacent formations, but it is only on the southwest coast immediately west of Arnager that the formation consists of marly chalk. The top of the formation, exposed east of Horsemyre Odde, is developed as a marl/calcareous siltstone and has a low carbonate content (*c.* 30%). The Arnager Limestone Formation at the brook Stampe Å, situated only 3–4 km northwest of Arnager on the same block, consists of glauconitic marl and sandy limestone. At Muleby on the Nyker block, the formation consists of sandy, glauconitic marl. At the type locality deposition of the Arnager Limestone took place in a complex of low mud-mounds most likely caused by the baffling effect of siliceous sponges working in concert with sponge spicule mats. It may be suggested that the small amount of terrigeneous clastics here was caused by the filter effect of siliceous sponges close to the shore-line.

Fig. 19. Photomozaic of the northern and part of the eastern faces of the Jydegård marl pit. The northern face shows marls below and glauconitic sand above of the Bavnodde Greensand Formation. The Lower Cretaceous Jydegård Formation is exposed at the eastern face. The strata of the Bavnodde Greensand Formation are steeply dipping and separated from the vertical strata of the Jydegård Formation by a reverse fault. April 1975.


Jydegård Formation

Locality details (WKC)

Arnager-Sose block

In this block the Albian-Santonian sedimentary rocks crop out in low coastal cliffs on the southwest coast and along stream-cuttings of the brook Stampe Å (also referred to as Vellens Å) (Fig. 4). In addition, sediments are known from shallow bore-holes (see below).

The general strike of the Cretaceous strata of the block is about 120–140° and they dip about 6–8° towards southwest (Gry 1969; Christensen & Schulz, personal observations). In the Stampe Å area the Cretaceous of the Arnager-Sose block is separated from the Middle Jurassic Bagå Formation on the Rønne-Hasle block by a prominent fault (see Fig. 1). The Cretaceous strata are inclined and they are inverted adjacent to the fault (Ravn 1921; Gry 1960: Fig. 5, Gry 1969: Fig. 5).

Southwest coast of Bornholm

The Arnager Greensand Formation is known from Madsegrav in the east to about 130 m west of Arnager Pynt (point) (Fig. 4). The basal part of the formation is exposed at Madsegrav (Fig. 5), the top part of the greensand and the boundary between the greensand and the overlying Arnager Limestone Formation is exposed east of Arnager (see sketch of the boundary strata by Bromley 1979) (Figs 10–11). Between Madsegrav and Arnager Pynt the formation is only known from small scattered exposures.

The lower 7 metres of the Arnager Limestone Formation is exposed immediately west of Arnager, and the very top of the formation has been recorded from the bay east of Horsemyre Odde (Figs 9, 17).

The Bavnodde Greensand Formation is recorded from scattered exposures from east of Horsemyre Odde to west of Bavnodde (Fig. 4). Larger exposures are present west and east of Bavnodde, at Forchhammers Odde, in the bay between Forchhammers Odde and Horsemyre Odde, and at Horsemyre Odde (Figs 14, 16).

Stampe Å

The Albian-Coniacian sedimentary sequence in the Stampe Å area (also referred to as Stampen by earlier authors) is poorly known due to the small number of stream cuttings along the brook.

First a few comments on the place names "Stampe" and "Stampen". A stamp mill was built in 1750 at the brook, hence the name Stampen and Stampe Å. The noun Stampen, however, has been used in different ways earlier. The abandoned hotel, situated at loc. 6 on Fig. 4, was called Stampen. The noun Stampegården has also been used for this building. Rønne Water Works from 1937 is also called Stampen (the name is not indicated on the topographical map). Lastly, a small point northwest of the point Korsodde is called Stampen on the newest topographical map from 1978, 1812 III NV Rønne (1: 25.000).

The outcrops along Stampe Å were discussed by Grönwall & Milthers (1916), Ravn (1921), and Hansen (1939). Gry (1960) gave a schematized section of the sedimentary sequence along Stampe Å from its mouth to Robbedale; the section seems to be based partly on the papers by Grönwall & Milthers (1916) and Hansen (1939).

The following description is based on observations made by earlier authors in addition to observations made by W.K. Christensen in 1986 and 1987. It should

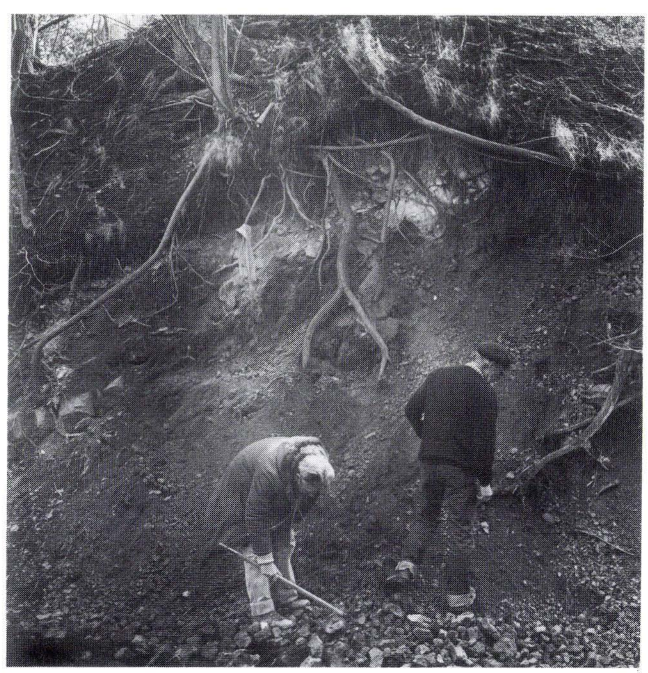


Fig. 20. Exposure showing glauconitic marl (calcareous greensand of Ravn 1921) of the upper part of the Arnager Limestone Formation at locality 5 at Stampe Å. This exposure has yielded inoceramid bivalves of early Middle Coniacian age and belemnites. Dr M.-G. Schulz to the left and Prof. F. Schmid to the right are looking for fossils in fallen material.

be mentioned that J.P.J. Ravn collected samples of the sediments when he did field-work in the area in the beginning of this century. These samples are housed in the Geological Museum, Copenhagen, and they have been examined by W.K. Christensen.

Towards the west the Arnager Greensand is inverted and overlies the Lower Cretaceous Jydegård Formation (loc. 1 in Figs 4, 6). The basal beds of the Arnager Greensand Formation strike 135° and dip 100° towards northeast. A 50 cm thick conglomerate occurs at the base of the greensand (Fig. 6). An indurated bed, which has yielded *Inoceramus schoendorfi* and *I. crippsi* subsp. indet., occurs about 4 m above the base. Further upstream, the Arnager Greensand crops out at Jespersens Hule (cave) (loc. 2) and east of Ørsteds Kilde (spring) (loc. 3). Ørsteds Kilde is a bore-hole made in 1819 (Grönwall & Milthers 1916). The beds at loc. 2 and 3 seem to be vertical and they strike about 140°.

According to Ravn (1921) a bed with phosphatized pebbles was present at the base of the Arnager Limestone Formation. This pebble bed was not exposed in 1986 and 1987, but samples collected by Ravn confirm this observation. A little further upstream, at loc. 4, the Arnager Limestone Formation is developed as sandy limestone. At loc. 5 (Fig. 20) the formation is developed as glauconitic marl (calcareous greensand of Ravn), which has yielded *Inoceramus (Volviceramus) koeneni* and *I. (V.) alievimussensis,* in addition to *"Actinocamax" lundgreni* and *A. verus.* At this locality the strata are less inclined than the basal part of the formation.

Ravn (1921) reported greensand from the abandoned building Stampen (loc. 6) to the east. The greensand did not yield any fossils, but on the basis of its similarity to the Bavnodde Greensand exposed between Forchhammers Odde and Horsemyre Odde (Fig. 4), Ravn tentatively assigned it to the Bavnodde Greensand Formation. On the other hand, Gry (1960: Fig. 5) did not indicate this formation on his schematized drawing of the section along Stampe å, and the greensand to the east was assigned to the Arnager Greensand Formation. According to Hansen (1939), it is uncertain if the Bavnodde Greensand was penetrated by bore-holes in the Stampe Å area. It may thus be concluded that the Bavnodde Greensand Formation is not exposed along the Stampe Å.

Birkelund (1957) recorded *"A." lundgreni?* from the glauconitic marl at Stampe Å and *"A." lundgreni excavata?* from the greensand at Stampen. Stolley (1897) recorded a specimen of *A. propinquus* mut. (var.) nov. (= *"A." lundgreni*) from Stampen. In the opinion of W.K. Christensen the locality names "Stampen" and "Stampe Å" were used synonymously by earlier authors, and the belemnite specimens mentioned above came most likely from the glauconitic marl at loc. 5. Christensen (in press) placed *"A." lundgreni excavata*? sensu Birkelund and *A. propinquus* mut. (var.) nov. in synonymy of *"A." lundgreni*.

Nyker Block

The Upper Cretaceous sedimentary strata of the Nyker fault block are poorly known because only very few exposures have been recorded and most of these are not accessible today.

Ravn (1946) described the outcrops which were found in stream cuttings along the brooks Blykobbe Å to the south (Fig. 18) and Muleby Å to the north (Figs 21–22). The exposures along the stream cuttings only showed very small sections. Upper Cretaceous deposits were also recorded from two marl pits.

Ravn (1946) recorded a sandy, yellow, grey, or green marl from an exposure at Blykobbe Å, southwest of the farm-house Risenholm (Fig. 8). This marl was included in the Bavnodde Greensand Formation by Ravn on the basis of belemnites, ammonites and inoceramid bivalves. This marl has yielded basal Santonian inoceramid bivalves (this paper) and Santonian ammonites (Kennedy & Christensen in press).

An alternating sequence of glauconitic, medium to fine-grained sand and marl belonging to the Bavnodde Greensand Formation is known from the Jydegård marl pit, situated close to Blykobbe Å (Fig. 18) (Ravn 1946; Gry 1956; Birkelund 1957; Gravesen *et al.* 1982). The formation is separated from the Lower Cretaceous Jydegård Formation by a reverse fault and the greensand and marl are steeply dipping. Birkelund (1957) re-

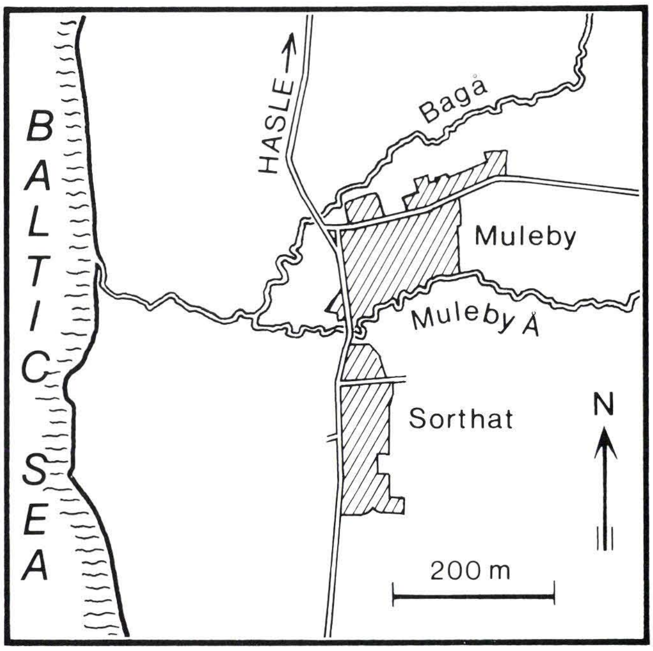


Fig. 21. Map showing the brooks Bagå and Muleby Å close to the west coast of Bornholm. Cenomanian-Coniacian sedimentary rocks were recorded from stream cuttings of the Muleby Å and at the abandoned Muleby marl pit immediately west of Sorthat-Muleby (for details, see Fig. 22).

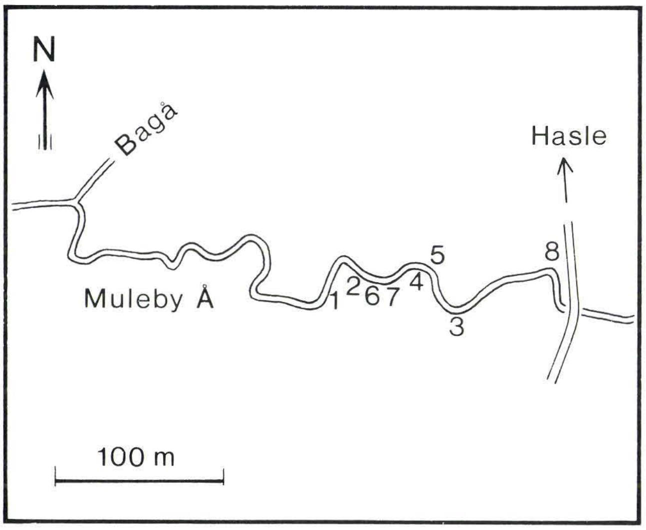


Fig. 22. Map showing exposures at the brook Muleby Å. After Ravn (1946).

garded the greensand and marl to be slightly older than the Bavnodde Greensand on the southwest coast on the basis of *G. westfalica, G.* aff. *westfalica,* and *"A". lundgreni excavata* (see above). The greensand and marl of the Jydegård marl pit was well-exposed in 1975 and 1976 and new collections of belemnites and inoceramid bivalves were made by Dr. M.-G. Schulz and W.K. Christensen. Today the strata are covered by scree. This locality has yielded Santonian ammonites (Kennedy & Christensen in press) and the inoceramid bivalves are from the lowest Santonian and possibly the highest Coniacian (this paper).

Ravn (1946: Fig. 1) indicated eight exposures along Muleby Å (Figs 21–22). Calcareous glauconitic sand was recorded from outcrops to the west (loc. 1, 2, 6, and 7), and Ravn suggested that this greensand might belong to the Arnager Greensand Formation although it did not yield any diagnostic fossils. The strata at loc. 1 dip at least 60° towards southeast. The strata to the east at loc. 2, 6, and 7 were less inclined. It is now known that *Inoceramus (Cremnoceramus) schloenbachi* (this paper) occurs at loc. 1. The age of the calcareous glauconitic sand here is thus Coniacian.

The so-called "Glass-marl" of Ravn (1946), a sandy, glauconitic marl, was reported from exposures to the east (loc. 3–5), in addition to the abandoned marl pit at Muleby (loc. 8), situated immediately west of the road leading from Sorthat to Hasle. This marl was formerly exploited for manufacturing of bottle glass, hence the name "Glass-marl". Ravn (1946) and Birkelund (1957) regarded the "Glass-marl" to be a contemporaneous, lateral equivalent to the Arnager Limestone on the southwest coast on belemnite evidence.

Bøsthøj block

The Arnager Greensand Formation was recorded in the Bøsthøj fault block by Andersen (1944) and Gry (1956). The greensand crops out in stream cuttings along Læså and was met with also in shallow boreholes. Fossils have not been recorded from the greensand of the block. The fault block with Arnager Greensand is separated by faults to the west, south and east from Lower Palaeozoic deposits; to the north the greensand is separated from the Lower Cretaceous Jydegård Formation by a fault (Fig. 1).

Systematic palaeontology (KAT)

Specimens figured by earlier authors are housed in the Type Collection of the Geological Museum of the University of Copenhagen, prefix MMH. The specimens figured in the present paper that have not been figured before are filed as MGUH. Specimens that have not been figured carry the accession numbers of the museum with prefix GM.

The inoceramid bivalves from Bornholm are usually incomplete, badly preserved, and deformed by sediment compaction. The critical characters of the specimens (Fig. 23) were measured and compared, if possible, to specimens of the same species and subspecies from Central Europe.

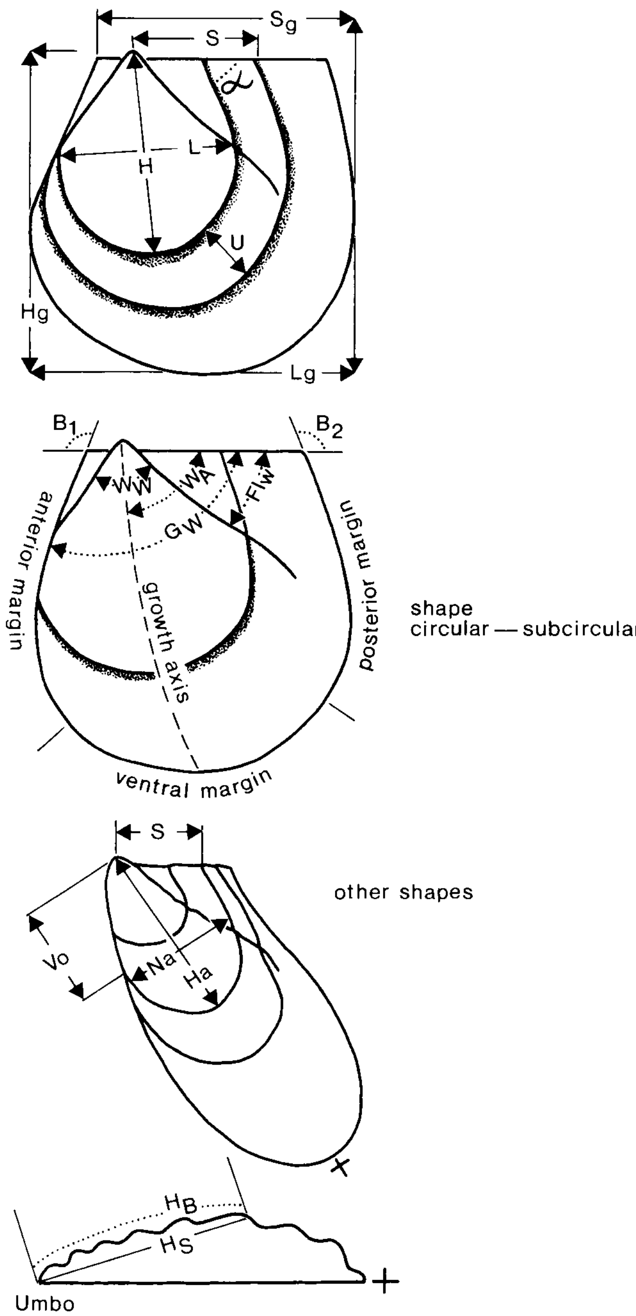


Fig. 23. Morphological characters of the inoceramid shell; see Seitz (1961) and Tröger (1967). Hg = heigth of shell; Lg = length of shell; Sg = hinge line; H = heigth of one rib; L = length of one rib; S = part of the hinge line, from the umbo to the rib; Vo = part of the anterior margin, from the umbo to the beginning of an undulation; Ha = length of long axis of one rib, in specimens with an oval to elliptical shape; Na = length of short axis of one rib; U = distance between two ribs; GW = angle between hine line and anterior margin; Fl_w = angle between the beak and the hinge line; W_w = umbonal angle; WA = angle of the growth axis; and α = angle between one rib and the hinge line.

Mollusca Linné, 1758

Bivalvia Linné, 1758

Inoceramidae Zittel, 1881

Remarks. – Heinz (1932) proposed a new classification of the inoceramid bivalves and distinguished two families: Inoceramidae and Sphenoceramidae. He also established many new genera and species. The classification of Heinz was critized by Jaworski (1934), Stolley (1937), and Seitz (1965) because he ignored the variability and new genera and species were inadequately described. The new genera and species are considered nomina nuda following O.H. Schindewolf (see Seitz 1965).

In many inoceramid bivalve species important characters, such as the hinge line with the ligamental pits, are poorly known or not known at all. Following Seitz (1965) only one genus, *Inoceramus,* is recognized within Inoceramidae. Moreover, only subgenera used in the Treatise on Invertebrate Palaeontology, Part N, Vol. 1 (of 3), Mollusca 6, Bivalvia, or subgenera established by R. Heinz and later redescribed are used in the present paper.

Genus *Inoceramus* J. Sowerby, 1814

Type species. – *Inoceramus cuvierii* Sowerby, 1814.

Nomina nuda: *Oxyceramus* Heinz, type species *I. schoendorfi* Heinz; *Callistoceramus* Heinz, type species *I. annulatus* Goldfuss pars; *Striatoceramus* Heinz, type species *I. striatoconcentricus* Gümbel; *Gonioceramus*

Heinz, type species *I. lusatiae* Andert; and *Astatoceramus* Heinz, type species *I. hannovrensis* Heinz.

Inoceramus crippsi group

Remarks. – In Europe the most important representatives of this group are the Lower and Middle Cenomanian *I. crippsi crippsi* Mantell and *I. crippsi hoppenstedtensis* Tröger. Transitional forms between the two subspecies have been recognized. Most of the specimens from Bornholm belonging to the *I. crippsi* group are badly preserved, and it is not possible to assign them safely to subspecies.

Inoceramus crippsi Mantell, 1822 subsp. indet.
Pl. 1, Figs 1, 2, 4; Pl. 3, Fig. 1

Synonymy. – See Tröger (1967) and Keller (1882).

Material. – MGUH 20548, GM 1915.104.3, and GM 1923.404 from the Arnager Greensand at Madsegrav; MGUH 20545–20547 and GM 1984.1774–1775, from the Arnager Greensand east of Arnager; and MGUH 20549 from the indurated bed in the basal part of the Arnager Greensand in the Stampe Å area (see Fig. 6.).

Discussion. – Parts of the anterior and posterior margins are damaged, and the umbonal regions are poorly preserved. On the basis of the nearly circular shape of the internal moulds (only GM 1915.104.3 and MGUH 20547 are elongated), the shape of the ribs, and the cross-section of the ribs which are rounded, the specimens are referred to *I. crippsi* subsp. indet. Specimen MGUH 20548 has an endocostean scar (Pl. 3, Fig. 1).

Distribution. – Mainly Lower and Middle Cenomanian.

Inoceramus crippsi hoppenstedtensis Tröger, 1967
Pl. 1, Figs 5–6; Fig. 24

Synonymy. – See Tröger (1967) and Keller (1982).

Material. – MGUH 20551 and GM 1984.1787 from the Arnager Greensand at Madsegrav; MGUH 20550 from the Arnager Greensand east of Arnager. GM 1984.1787 may be redeposited.

Discussion. – The three specimens are identical in all critical characters, such as the shape, the ontogenetic change of the Na/Ha ratio, and the shape of the concentric ribs, to *I. crippsi hoppenstedtensis* from the Subhercynian Cretaceous Basin in Germany as described by Tröger (1967) (cf. Fig. 24).

Distribution. – This subspecies is common in the upper Lower Cenomanian *Mantelliceras saxbii* and *M. dixoni*

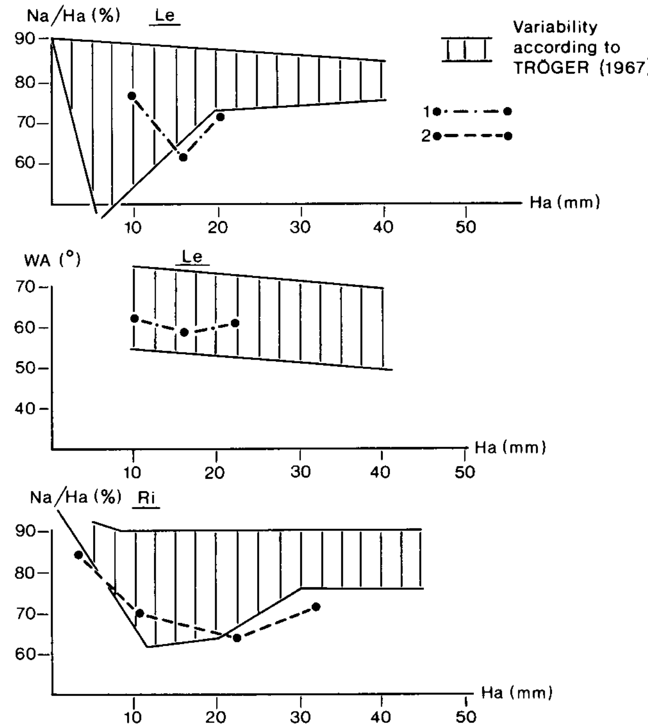


Fig. 24. Comparison of the ontogenetic change of Na/Ha and WA of specimens of Inoceramus crippsi hoppenstedtensis *Tröger from the Subhercynian Cretaceous Basin (vertical hatching; Tröger 1967) and the Arnager Greensand on the southwest coast of Bornholm. Le = left valve; Ri = right valve. 1 is MGUH 20551, 2 is MGUH 20550.*

Zones and the Lower Middle Cenomanian *Turrilites costatus* Zone. It is rare in the Middle Middle Cenomanian *T. acutus* Zone.

Inoceramus schoendorfi Heinz, 1928
Pl. 1, Figs 7–11; Figs 25–26

Synonymy. – See Sornay (1980) and Keller (1982).

Remarks. – Heinz (1928a) established the species, but it was first described and figured adequately by Sornay (1980). *I. orbicularis* Münster of Ravn (1916, Pl. 5, Fig. 1, MMH 1537) is here assigned to *I. schoendorfi*.

Material. – MMH 1537 from the Arnager Greensand at Madsegrav; MGUH 20554–20556, GM 1917.151.1, GM 1917.151.3–4, GM 1917.151.6–8, GM 1917.151. 10–11, and GM 1917.151.13 from the indurated bed in the basal part of the Arnager Greensand in the Stampe Å area (see Fig. 6); GM 1915.104.4–5, 1984.1770, and GM 1984.1781 from the Arnager Greensand at Madsegrav; and MGUH 20552–20553 and GM 1984.1783 from the Arnager Greensand east of Arnager.

Discussion. – The shape of internal moulds of *I. schoendorfi* is similar to internal moulds of *I. crippsi hoppenstedtensis*. In *I. schoendorfi*, however, the small umbo is placed above the hinge line. The wings are

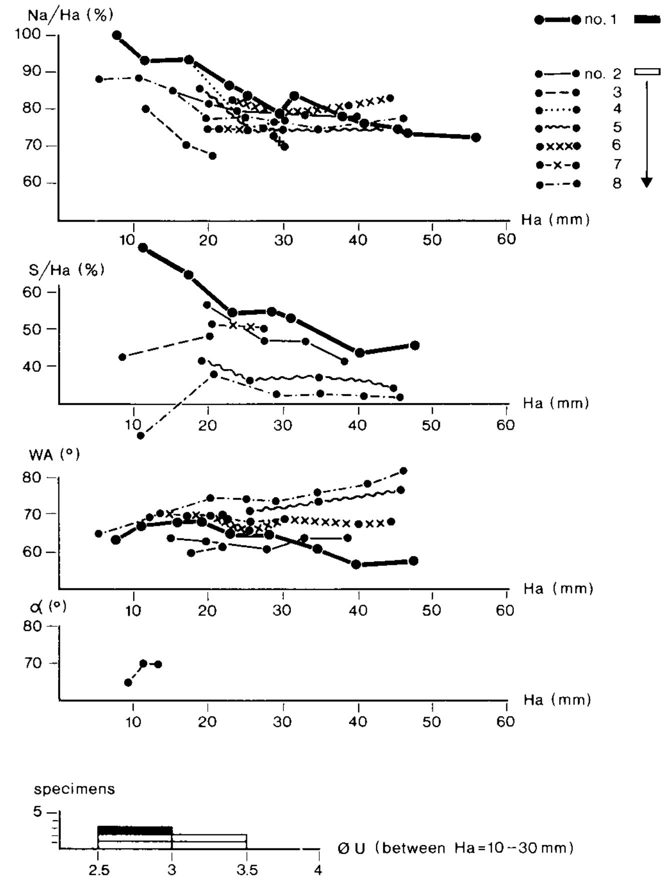


Fig. 25. Comparison of the ontogenetic change of Na/Ha, S/Ha, WA, the angle α, and the average distance between the ribs (ØU) at Ha = 10–30 mm of the holotype of Inoceramus schoendorfi *Heinz (no. 1) and specimens from the basal part of the Arnager Greensand at Stampe Å (nos 2–8). 2 is MGUH 20556, 3–4 are GM 1917.151.3–4, 5 is MGUH 20554, and 6–8 are GM 1917.151.6–8.*

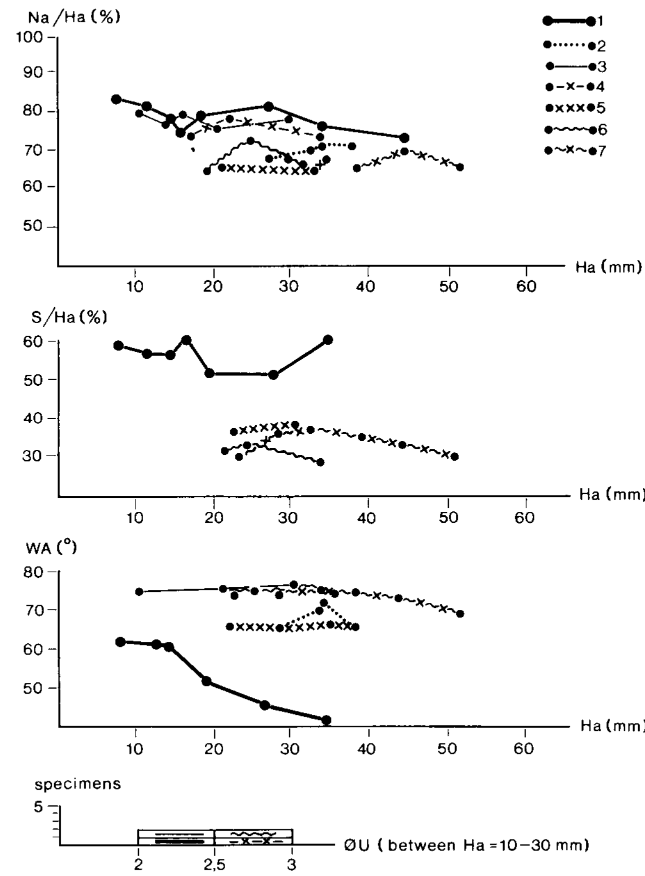


Fig. 26. Comparison of the ontogenetic change of Na/Ha, S/Ha, WA, and the average distance between the ribs (ØU) at Ha = 10–30 mm of specimens of Inoceramus schoendorfi *Heinz from the Arnager Greensand at Madsegrav (nos. 1–3) and Stampe Å (nos 4–7). 1 is MMH 1537, 2 is GM 1984.1770, 3 is MGUH 20552, 4 is GM 1917.151.21, 5 is GM 1917.151.22, 6 is GM 1917.151.13, and 7 is MGUH 20555.*

small but clearly differentiated from the umbonal area. The short anterior margins are straight. In contrast to *I. crippsi hoppenstedtensis, I. schoendorfi* has concentric ribs, the cross-section of which is sharp, like in *I. costellatus* Woods. The ontogenetic change of the Na/Ha ratio, S/Ha ratio, and WA in the specimens from Bornholm is similar to that known from the holotype (see Figs 25–26). The average distance measured between the ribs at 10–30 mm from the umbo in the Bornholm specimens is also similar to the holotype.

Distribution. – The species occurs in the Middle Cenomanian *Turrilites* costatus and *T. acutus* Zones. *I. schoendorfi* is the most common inoceramid bivalve species on Bornholm.

Inoceramus striatoconcentricus Gümbel, 1868 subsp. indet.

Pl. 3, Fig. 2; Fig. 27

Synonymy. See Tröger (1967) and Keller (1982).

Material. – MGUH 20557 from the Arnager Limestone at Arnager.

Discussion. – MGUH 20557 is slightly deformed by compaction. The shape of the specimen is elongated as in specimens from western Europe. The ontogenetic change of the Na/Ha ratio and Wa and the nearly subquadrate shape of the ribs are closely comparable to *I. s. striatoconcentricus* from Central Europe (cf. Fig. 27). Since the wing in MGUH 20557 is not preserved, it is referred to *I. striatoconcentricus* subsp. indet.

Distribution. – This species occurs in the Upper Turonian-basal Coniacian. It is most common in the Upper Turonian.

Inoceramus sp. ex gr. *striatoconcentricus* Gümbel, 1868

Material. – GM 1919.176, GM 1922.276, and GM 1922.126 from the Arnager Limestone at Arnager.

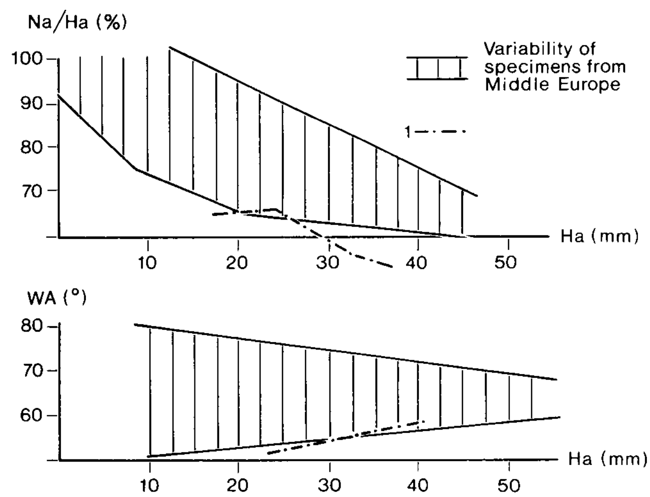


Fig. 27. Comparison of the ontogenetic change of Na/Ha and WA of specimens of Inoceramus striatoconcentricus *Gümbel from Central Europe (vertical hatching) and the Arnager Limestone at Arnager. 1 is MGUH 20557.*

Discussion. – The three specimens are incomplete internal moulds. Due to their state of preservation they are referred to *I.* sp. ex gr. *striatoconcentricus.*

Inoceramus waltersdorfensis group

Remarks. – This species group comprises several subspecies, including *I. w. waltersdorfensis* Andert and *I. waltersdorfensis hannovrenis* Heinz, both of which are circular to subcircular. The sculpture consists of growth lines in *I. w. waltersdorfensis* and ribs in *I. waltersdorfensis hannovrensis.*

Inoceramus waltersdorfensis cf. *hannovrensis* Heinz, 1932
Pl. 3, Fig. 5

Synonymy. – See Tröger (1967) and Keller (1982).

Material. – MGUH 20560 from the Arnager Limestone at Arnager.

Discussion. – The specimen is an incomplete deformed internal mould of a left valve. It is not possible to measure Na, Ha, S, WA, and GW because the umbonal region is not complete. The specimen is referred to *I. waltersdorfensis* cf. *hannovrensis* on the basis of the circular shape of the internal mould, in addition to the subquadrate shape of the ribs and growth lines.

Distribution. – *I. waltersdorfensis hannovrensis* occurs together with *I. rotundatus* in the basal part of the Lower Coniacian. It is rare in the uppermost Turonian.

Inoceramus sp. ex gr. *waltersdorfensis* Andert, 1911
Pl. 1, Figs 14–15

Synonymy. – Detailed synonymies of *I. w. waltersdorfensis* were given by Tröger (1967).

Material. – MGUH 20558–20559 and GM 1984.1820–1821 from the Arnager Limestone at Arnager.

Discussion. – The four specimens are poorly preserved and deformed by compaction. Due to the state of preservation the following characters cannot be measured: Na, Ha, S, and WA. The specimens are referred to *I.* sp. ex gr. *waltersdorfensis* on the basis of the shape of the internal moulds, the circular to subquadrate shape of the growth lines, and the distance between the growth lines, which varies from 0.5–0.7 mm.

Distribution. – *I. w. waltersdorfensis* occurs in the Upper Turonian (very rare) and basal Coniacian (common).

Inoceramus cf. *annulatus* Goldfuss, 1836
Pl. 4, Fig. 1

Remarks. – The species was erected by Goldfuss (1836), who figured two specimens as *I. annulatus* nobis. The tall specimen, figured as Fig. 7b on Table 110 by Goldfuss, was referred to *I. latus* var. *stuemckei* n. var. by Heinz (1928b). According to Keller (1982) this specimen is the holotype of *I. lamarcki stuemckei* Heinz. The specimen figured as Fig. 7a on Table 110 by Goldfuss is therefore the lectotype of *I. annulatus.*

Material. – MGUH 20561 from the Arnager Limestone at Arnager.

Discussion. – The specimen is deformed by compaction, and it is incomplete as parts of the wing and posterior margin are missing. On the basis of the elongated shape of the shell, the distance between the ribs, and cross-section of the ribs (Anwachsreifen sensu Heinz 1928c) the specimen is referred to *I.* cf. *annulatus.*

Distribution. – The species occurs in the Upper Turonian-basal Coniacian.

Inoceramus cf. *renngarteni* Bodilevski & Schulgina, 1958
Pl. 1, Fig. 16

Remarks. – The species was established by Bodilevski & Schulgina (1958), who gave synonymies and discussed its affinity to *I. cuvierii* sensu Mantell (1822, Pl. 28, Fig. 4) and *I. lamarcki* sensu Woods (1912, Fig. 69).

Material. – MGUH 20562 and GM 1984.1610 from the Arnager Limestone at Arnager.

Discussion. – According to Bodilevski & Schulgina (1958) *I. renngarteni* belongs to the *I. lamarcki* group and has ribs the cross-section of which is like a stair-case. The distance between the ribs varies from 10–20 mm in the umbonal region, and the umbo does not rise above the hinge line. The two poorly preserved internal moulds of left valves from Bornholm are crushed by compaction, and parts of the umbonal region and the anterior and posterior margins are missing. The ribs are shaped like a stair-case, and the distance between the ribs varies from 5.5–11.5 mm. The ribs are covered by growth lines and the distance between the growth lines varies from 1–2.3 mm. Since the umbonal region is not complete in the two specimens a definite specific determination is not possible, and they are tentatively referred to *I.* cf. *renngarteni.*

Distribution. – According to Bodilevski & Schulgina (1958) this species occurs in the Coniacian and possibly the Lower Santonian.

Inoceramus lusatiae Andert, 1911
Pl. 3, Fig. 6

Synonymy. – See Tröger (1967) and Keller (1982).

Material. – MGUH 20563, GM 1976.644, GM 1976.652, GM 1976.657, GM 1984.1822, and GM 1984.2015 from the Arnager Limestone at Arnager, with precisely located specimens 2–3 m from the base (GM 1984.2015) and from the top of the formation, exposed east of Horsemyre Odde (GM 1976.644, GM 1976.652, and GM 1976.657).

Discussion. – This species is a medium tall representative of the *I. lamarcki* group. The specimens from Bornholm are more or less incomplete and crushed by sediment compaction. Many of the important characters are only present in MGUH 20563. This specimen has a well-developed wing with curved ribs, a sharp umbo clearly differentiated from the wing, and the cross-section of the ribs are rounded. It is assigned to *I. lusatiae.* The other specimens are incomplete and are therefore referred to *I.* cf. *lusatiae.*

Distribution. – *I. lusatiae* occurs in the Upper Turonian (very rare) and Lower Coniacian. Specimens closely comparable to *I. lusatiae* have been recorded from the uppermost part of Middle Turonian (Keller, 1982).

Inoceramus sp. aff. *cuvierii* Sowerby, 1911
Fig. 28

Material. – MGUH 20564 from the Arnager Limestone at Arnager, 1–2 m above the base.

Discussion. – The specimen is incomplete and deformed by compaction. The umbo, parts of the wing, and the ventral and anterior margin are missing. This large fragment has ribs shaped like a stair-case, and the distance between the ribs varies in the following way: 16.3 mm, 10.8 mm, 9.5 mm, 13.2 mm, 19.0 mm, and 23.5 mm. The distance between the growth lines varies from 1.0–4.5 mm. At the wing the growth lines bend outwards. The fragment from Bornholm is closely comparable to *I. cuvierii* sensu Woods (1911, Fig. 78). Woods (1911) referred various tall inoceramid bivalve species to *I. lamarcki* var. *cuvierii.* Heinz (1932) assigned the specimen, figured as Fig. 78 by Woods, to *Inoceramus (Orthoceramus) securiformis* n. sp. without description. This name is therefore a nomen nudum.

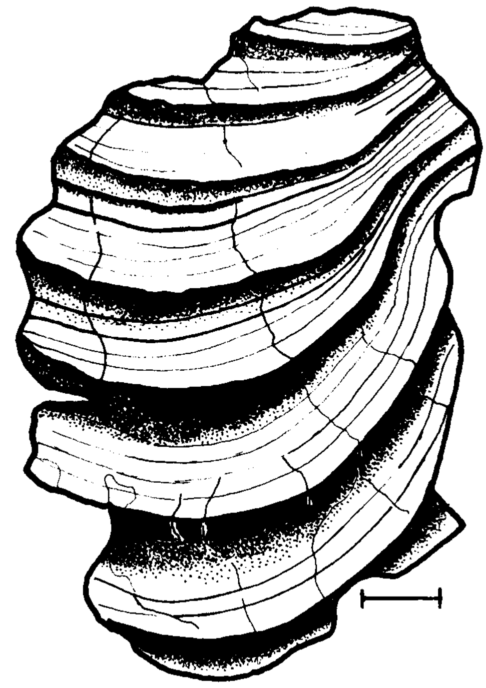


Fig. 28. Inoceramus *sp. aff.* cuvierii *Sowerby from the Arnager Limestone at Arnager, 1–2 m above the base. MGUH 20564. Scale bar is 10 mm.*

Distribution. – The specimen of Woods (1911, Fig. 78) came from the Upper Turonian, Zone of *Sternotaxis planus.*

Inoceramus cf. *rotundatus* Fiege, 1930
Pl. 3, Fig. 3

Synonymy. See Tröger (1967) and Keller (1982).

Material. – MGUH 20565 from the Arnager Limestone at Arnager.

Discussion. – The specimen is a small, poorly preserved, internal mould, which has a subcircular shape. The major part of the anterior and posterior margins are missing, and the umbo is badly preserved. The shape of the ribs reflects the subquadrate shell outline. The cross-section of the ribs are rounded. The quadrate to subquadrate shape of the shell is typical of *I. rotundatus*.

Distribution. – *I. rotundatus* is the index inoceramid bivalve of the basal Coniacian, inoceramid assemblage zone 20 (see Tröger, 1989, Fig. 2).

Inoceramus cf. *wandereri* Andert, 1911
Pl. 1, Fig. 12

Synonymy. – See Andert (1911, 1934).

Material. – MGUH 20566 from the Arnager Limestone at Arnager, 2–3 m above the base.

Discussion. – The specimen is a poorly preserved internal mould. It has a nearly lanceolate shape and a small wing, which is clearly differentiated from the umbonal region. The rounded umbo is placed above the hinge line and is slightly coiled. The cross-section of the ribs is rounded. The ribs start at 34 mm from the umbo, and they are well-developed 75 mm from the umbo. In these characters the specimen from Bornholm is similar to the holotype. Due to the poor preservation, Na, Ha, Vo, and the ontogenetic change of WA cannot be measured. A definite specific determination is therefore not possible, and the specimen is referred to *I.* cf. *wandereri.*

Distribution. – The species is the index inoceramid bivalve of the basal Coniacian *I. schloenbachi Zone.*

Subgenus *Mytiloides* Brongniart, 1822
Type species. – *Inoceramus (Mytiloides) labiatus* Schlotheim.

Inoceramus (Mytiloides) cf. *incertus* Jimbo, 1894
Pl. 1, Fig. 13

Synonymy. – See Noda (1984).

Remarks. – According to Noda (1984) *I. (M.) fiegei* Tröger, 1967 is a junior synonym of *I. (M.) incertus.* Keller (1982) gave synonymies of *I. (M.) fiegei.*

Material. – MGUH 20567 and GM 1984.1824 from the Arnager Limestone at Arnager.

Discussion. – The two specimens are deformed by compaction and they are poorly preserved. Parts of the anterior and posterior margins and the small umbo are missing. The shape of the preserved part of the umbonal region is nearly circular. The posterior part of the valve is elongated. The internal moulds have growth lines, and the distance between the growth lines varies from 1.0–1.5 mm. The Na/Ha ratio of the internal moulds varies from 100–66%. This is in accordance with the Na/Ha ratio of *I. (M.) incertus* from the Upper Turonian Strehlen Limestone in the Dresden-Strehlen area in Saxony. In MGUH 20567 (Pl. 1, Fig. 13) a bend of the growth direction was deformed by compaction. The specimens from Bornholm are very similar to specimen No. D260 from Dresden-Strehlen housed in the collection of H.B. Geinitz in the Staatliches Museum für Mineralogie und Geologie, Dresden.

Distribution. – *I. (M.) incertus* occurs in Europe in the Upper Turonian and the basal part of the Coniacian.

Subgenus *Heroceramus* Heinz, 1932
Type species. – *Inoceramus (Heroceramus) hercules* Heinz.

Inoceramus (Heroceramus) cf. *hercules* Heinz, 1932
Pl. 1, Fig. 17; Pl. 3, Fig. 4

Synonymy. – See Tröger (1984).

Remarks. – This large species was established, but inadequately described, by Heinz (1932).

Material. – MGUH 20568, MGUH 20584, GM 1976.656, GM 1984.2012–2013, and GM 1984.2016 from the Arnager Limestone west of Arnager, with precisely located specimens 2–3 m from the base (MGUH 20584, GM 1984.2016 and GM 1984.2013) and from the top of the formation east of Horsemyre Odde (GM 1976.656).

Discusssion. – The material from Bornholm consists of large, incomplete, internal moulds, and the umbo, wing, and major parts of the anterior and posterior margins are missing. The most complete specimen, MGUH 20568 (Pl. 3, Fig. 4), which is highly deformed by compaction, has ribs which are rounded (Anwachsreifen sensu Heinz 1928c). The distance between the ribs varies from 27.5–49.5 mm like in specimens of *I.(H.) hercules* from Central Europe.

Distribution. – *I. (H.) hercules* occurs in the Upper Turonian-basal Coniacian (basal part of the *I. schloenbachi* Zone).

Subgenus *Cremnoceramus* Cox, 1969
Type species. – *Inoceramus (Cremnoceramus) inconstans* Woods.

Inoceramus (Cremnoceramus) schloenbachi Böhm, 1911
Pl. 2, Fig. 1; Fig. 29

Synonymy. – See Tröger (1967) and Keller (1982).

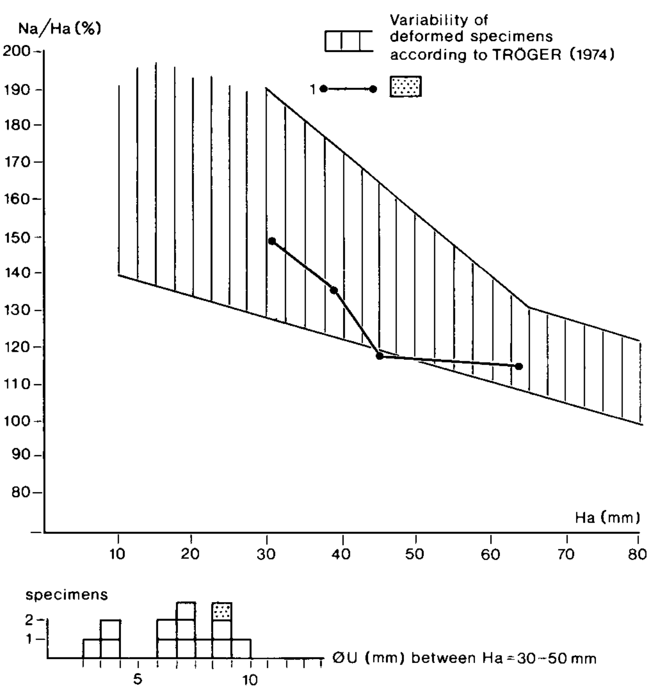


Fig. 29. Comparison of the ontogenetic change of Na/Ha and the average distance between the ribs (ØU) at Ha = 30–50 mm of deformed specimens of Inoceramus (Cremnoceramus) schloenbachi *Böhm from Central Europe (vertical hatching; Tröger 1974) and the Arnager Limestone at Muleby, locality 1 of Ravn (1946). 1 is MGUH 20569.*

Material. – MGUH 20569 from the Arnager Limestone Formation at the brook Muleby Å, loc. 1 of Ravn (1946). GM 1924.738 from the Arnager Limestone at Arnager, determined as *Inoceramus* sp., may be belong to the *I. (C.) schloenbachi* group.

Discusssion. – The internal mould of the right valve of MGUH 20569 is incomplete as parts of the wing, and the anterior and posterior margins are missing. Moreover, the umbonal region of the valve is extremely damaged by compaction due to its strongly convex and nearly involute shape. The ontogenetic change of the Na/Ha ratio of the Bornholm specimen is similar to specimens of *I. (C.) schloenbachi* from Central Europe (Tröger 1967; and Fig. 29 herein). The average distance between the ribs of the Bornholm specimen is similar to specimens from the eastern part of the Subhercynian Cretaceous Basin.

Distribution. – *I. (C.) schloenbachi* is the key inoceramid bivalve of the upper part of the Lower Coniacian *I. schloenbachi* or *I. deformis* Zones.

Subgenus *Volviceramus* Stoliczka, 1871

Type species. – *Inoceramus (Volviceramus) involutus* Sowerby.

(Nomen nudum: *Cymatoceramus,* type species *I. koeneni*).

Inoceramus (Volviceramus) koeneni Müller, 1887
Pl. 2, Figs 2–3; Pl. 3, Fig. 7; Fig. 30

Synonymy. – Detailed synonymies were given by Tröger (1969), who also described the species in detail on the basis of material from the type locality.

Material. – MGUH 20570–20572 from the glauconitic marl of the Arnager Limestone Formation in the Stampe Å area. MGUH 20570 and MGUH 20572 are labelled "greensand at Stampen", and MGUH 20571 came from loc. 5 in the Stampe Å area (see Fig. 6).

Discussion. – The three incomplete internal moulds (two left valves and one right valve) with parts of the shell preserved are large. The two left valves are highly deformed by compaction due to their convex and involute shape. The right valve is less deformed. The umbonal region is clearly differentiated from the wing. The ontogenetic change of the Na/Ha ratio, and the average distance between the ribs 30–50 mm from the umbo in MGUH 20571–20572 are similar to specimens of *I. (V.). koeneni* from the type locality near Quedlinburg in Germany (see Fig. 30). The hinge line in GM 20571 (Pl. 2, Fig. 3a) is also similar to specimens from the type locality.

Distribution. – *Inoceramus (Volviceramus) koeneni* is the key inoceramid bivalve of the lower Middle Coniacian in inoceramid terms. It occurs rarely in the up-

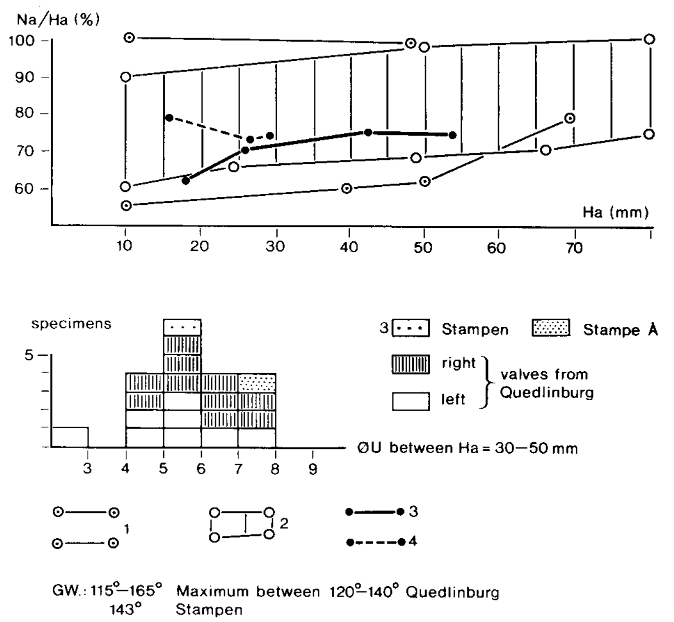


Fig. 30. Comparison of the ontogenetic change of Na/Ha and the average distance (ØU) of the ribs at Ha = 30–50 mm of specimens of Inoceramus (Volviceramus) koeneni *Müller from Quedlinburg (GDR) and the Arnager Limestone Formation at Stampe Å. 1: ontogenetic change of left valves from Quedlinburg; 2: ontogenetic change of right valves from Quedlinburg; 3 is MGUH 20571; 4 i MGUH 20572. GW = angle between hinge line and anterior margin.*

permost Lower Coniacian and upper Middle and basal Upper Coniacian.

Inoceramus (Volviceramus) alievimussensis Ivannikov, 1979
Pl. 4, Fig. 2

Synonymy. – See Ivannikov (1979).

Material. – MGUH 20573 and GM 1935.62 from the glauconitic marl of the Arnager Limestone Formation in the Stampe Å area. The specimens are labelled "greensand at Stampen".

Discussion. – The material consists of one shell fragment of the umbo and some fragments of the tall ligamental area partly fixed on shell fragments. The specimens belong to a tall, convex, inoceramid bivalve species. The size and the shape of the ligamental pits of the specimens from Bornholm are similar to the holotype of *I. (V.) alievimussensis.*

Distribution. – According to Ivannikov (1979) *I. (V.) alievimussensis* occurs together with *I. (C.) crassus* Petrascheck, *I. (C.) deformis* Meek, *I. (C.) schloenbachi, I. guerichi* Heinz, and *I. frechi* Flegel in the Donets Basin. *I. (V.) alievimussensis* is thus Lower and Middle Coniacian.

Subgenus *Sphenoceramus* Böhm, 1915
Type species. – *I. (S.) cardissoides* Goldfuss, 1836.
(Nomen nudum: *Dictyoceramus,* type species *I. subcardissoides* Schlüter).

Inoceramus (Sphenoceramus) subcardissoides Schlüter, 1877
Pl. 2, Fig. 4

1877 *Inoceramus subcardissoides* Schlüter, p. 271, Pl. 37

Material. – MMH 5440 from the sandy marl of the Bavnodde Greensand Formation at Risenholm. The specimen was figured by Ravn (1946, Pl. 1, Fig. 10).

Discussion. – The specimen is an incomplete internal mould, and the umbonal region, the wing, the radial depression, and great parts of the anterior and posterior margins are missing. Moreover, the specimen is deformed by compaction. It has sharp radial ribs and three concentric ribs. The species was described and figured by Schlüter (1877, Pl. 37). The shape of the specimen is elongated trigonal (*Sphenoceramus*-like). In contrast to the type specimen, the anterior margin of the Bornholm specimen does not dip steeply. The hinge line is short and the umbo is rounded and sharply differentiated from the wing. The shell has radial running ribs with distances between 5–8 mm crossing the concentric undulations. A radial depression is present.

Distribution. – According to Schlüter (1877) the species occurs in the so-called Emscher marls of Westphalia. Wegner (1905, p. 169) recorded the species from the "Untere Granulatenkreide", Zone of *I. cardissoides,* that is Lower Santonian. Stolley (1930), in the stratigraphic diagram on p. 189, reported the species from the upper part of the "Mittlere Emscher" together with *I. involutus,* that is Upper Coniacian. According to Tröger (1974) the species occurs together with *I. (Magadiceramus) subquadratus* Schlüter in the Upper Coniacian. It may thus be concluded that the taxon under discussion occurs in the Upper Coniacian-Lower Santonian.

Inoceramus (Sphenoceramus) pachti/cardissoides group

Remarks. – This species group comprises various subspecies of *I. (S.) pachti* Arkhangelsky and *I. (S.) cardissoides* Goldfuss, which were described in detail by Seitz (1965). The specimens from Bornholm belonging to this group were earlier referred to either *I. (Cordiceramus) cordiformis* Sowerby by Ravn (1921, Pl. 2, Fig. 2), *I. lobatus* Münster by Ravn (1946, Pl. 1, Fig. 5), or *I. (Sphenoceramus) patootensiformis* Seitz and *I. (S.) angustus* Beyenburg by Christensen (1985).

Inoceramus (Sphenoceramus) pachti Arkhangelsky, 1912
Pl. 2, Figs 5–6; Fig. 31

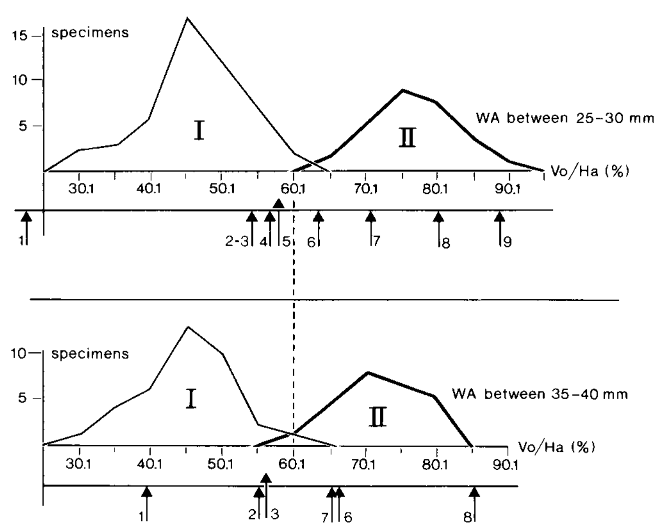


Fig. 31. Diagram showing the range of variation of the Vo/Ha (= WA) ratio of Inoceramus (Sphenoceramus) *pachti Arkhangelsky (I) and I. (S.) cardissoides Goldfuss (II) following Seitz (1965). The Vo/Ha ratio of specimens from the Bavnodde Greensand Formation are shown by arrows. 1 is GM 1984.1767, 2 is MGUH 20580, 3 is MGUH 20576, 4 is GM 1984.1831, 5 is GM 1984.1796, 6 is MGUH 20577, 7 is MMH 5435, 8 is MMH 1801, and 9 is GM 1984.1782.*

Synonymy.- See Seitz (1965).

Material. – MGUH 20575 and GM 1984.1767 from the Bavnodde Greensand west of Bavnodde, between beds 5–6; MGUH 20576 from the Bavnodde Greensand at Forchhammers Klint; and GM 1913.59, GM 1984.1831, and GM 1984.1814 from the Bavnodde Greensand at Bavnodde. MGUH 20575 is referred to *I. (S.) pachti* cf. *pachti* and the remaining material to *I. (S.) pachti* subsp. indet. (see below).

Discussion. – The material consists of internal moulds. The umbo is preserved in four specimens (MGUH 20576, GM 1913.59, GM 1984.1831, and GM 1984.1967). These specimens have a trigonal valve shape with a short hinge line and a narrow, sharply rounded umbo. Radial furrows (Radialdepression *sensu* Seitz 1965) are developed, especially in the posterior to ventral part of the shell. Specimen GM 1984.1831 is extremely deformed by compaction. The concentric ribs, the cross-section of which are rounded, follow the shape of the shell and the radial depression. Ribs splitting the growth lines (Anwachsschnittreifen *sensu* Heinz 1928c and Seitz 1965), which are typical for *I. (S.) patootensiformis,* are not present in the sphenoceramid species from Bornholm. The poorly preserved internal mould of MGUH 20575 has very weak radial ribs and is referred to *I. (S.) pachti* cf. *pachti.* The other specimens have separated weak ribs and are referred to *I. (S.) pachti* subsp. indet. following the method used by Seitz (1965). The ontogenetic change of the Vo/Ha ratio in the Bornholm specimens of *I. (S.) pachti* cf. *pachti* and *I. (S.) pachti* subsp. indet. at Ha (= Wa) = 15–30 mm and Wa = 35–40 mm (Fig. 31) is similar to the variation of specimens from Central Europe as shown by Seitz (1965). *I. (S.) patootensiformis* of Christensen (1985) is here assigned to *I. (S.) pachti.*

Distribution. – *I. (S.) pachti* and its subspecies are common in the Lower and Middle Santonian and very rare in the Upper Santonian.

Inoceramus (Sphenoceramus) cardissoides Goldfuss, 1836 subsp. indet.
Pl. 2, Fig. 8; Fig. 31

Synonymy. – See Seitz (1965).

Material. – MMH 1801 from the Bavnodde Greensand Formation at Horsemyre Odde; MMH 5435 and MGUH 20577 from the Bavnodde Greensand Formation at Risenholm; GM 1984.1782 from the Bavnodde Greensand west of Bavnodde, 40 cm below bed 5; and GM 1984.2006 from the Bavnodde Greensand at Bavnodde.

Discussion. – The material consists of internal moulds. The shape of *I. (S.) cardissoides* and its subspecies is very similar to *I. (S.) pachti* and its subspecies. According to Seitz (1965) the most critical character for determining the species is the variation of the Vo/Ha ratio at Ha (= Wa) = 25–60 mm and the size of the angle β. There are transitional forms between the two species (see Seitz 1965, Fig. 4). The Vo/Ha ratio in the intervals Ha = 25–30 mm and Ha = 35–40 mm of the Bornholm specimens (Fig. 31) is similar to the variation shown by Seitz (1965). MGUH 20577 is closely comparable to the transition form between the two species as described by Seitz (1965). Ribs are missing or weakly developed in all specimens. The specimens from Bornholm, therefore, cannot be referred to subspecies. *I. (C.) cordiformis* of Ravn (1921, Pl. 2, Fig. 2; MMH 1801) and *I. lobatus* of Ravn (1946, Pl. 1, Fig. 5; MMH 5435) are here assigned to *I. (S.) cardissoides* subsp. indet.

Distribution. – *I. (S.) cardissoides* subsp. indet. is common in the Lower and Middle Santonian and rare in the Upper Santonian.

Inoceramus (Sphenoceramus) sp. ex gr. *pachti/cardissoides*
Pl. 2, Fig. 7; Pl. 4, Figs 6–7

Material. – MGUH 20580 from the marl of the Bavnodde Greensand Formation at Jydegård; and MGUH 20578–20579, GM 1984.1796, and GM 1984.1834 from the marl of the Bavnodde Greensand Formation at Risenholm.

Discussion. – These specimens are poorly preserved or forms transitional between *pachti* and *cardissoides.* They are therefore referred to *I. (S.)* sp ex gr. *pachti/cardissoides. I. (S.) angustus* Beyenburg of Christensen (1985) (Pl. 4, Fig. 7) is here assigned to *I.* (S.) sp. ex gr. *pachti/cardissoides.*

Inoceramus (Sphenoceramus) cf. *guerichi* Heinz, 1928
Fig. 32

compare:
1928b *Inoceramus gürichi* Heinz, p. 75, Pl. 2: 1

Material. – MGUH 20574 from the uppermost Arnager Limestone exposed east of Horsemyre Odde.

Discussion. – The specimen is incomplete as the wing, great parts of the umbo, and parts of the anterior, posterior and ventral margins are missing. Moreover, it is deformed by compaction. The shape is rounded, elongated trigonal. The anterior margin is almost straight. Parts of the umbo are placed above the ante-

Fig. 32. Inoceramus (Sphenoceramus) *cf.* guerichi *Heinz from the uppermost Arnager Limestone east of Horsemyre Odde. MGUH 20574. The arrow points towards the two radial ribs. Scale bar is 10 mm.*

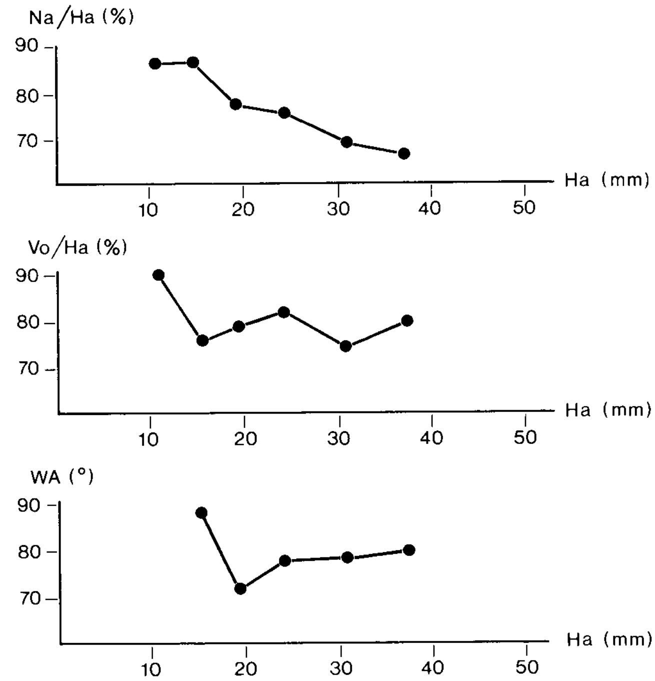


Fig. 33. Ontogeny of Na/Ha, Vo/Ha, and WA of the holotype of Inoceramus (Sphenoceramus?) bornholmensis *n. sp. from the Bavnodde Greensand Formation at Jydegård. MGUH 20581.*

rior margin. A radial depression is present. The sculpture consists mainly of concentric ribs, and the distance between the ribs is as follows: 7.5 mm, 15.2 mm, 31.8 mm, 16.5 mm, 18.2 mm. Hg (incomplete) is 93 mm, Lg (incomplete) is 58.2 mm, and Ww is greater than 108°. According to Heinz (1928b) this species belongs to the *I. (S.) pachti* group, and it differs from *I. pachti* by a special kind of growth lines (Anwachsmarken *sensu* Heinz 1928c) and by having short radial ribs which do not cross the concentric ribs. The shape of the Bornholm specimen is similar to the holotype, which came from Lüneburg. According to Heinz (1928b) the short radial ribs start 50 mm from the beak in the holotype. The Bornholm specimen has only two weakly developed radial ribs. The distances between the growth lines (1.2–5 mm) are smaller in the Bornholm specimen than in the holotype.

Distribution. – The stratigraphical range of *I. (S.) guerichi* is poorly known, because it is very rare. The holotype came from the Middle Coniacian, Zone of *I. involutus,* of Lüneburg (Heinz 1928b), and Ivannikov (1979) reported the species from the same level of the Donets Basin. On Bornholm it occurs together with *I.* cf. *lusatiae* in the top part of the Arnager Limestone Formation east of Horsemyre Odde, which is considered to be Lower Coniacian.

Inoceramus (Sphenoceramus?) bornholmensis n. sp.
Pl. 4, Figs 3–4; Fig. 33.

Etymology. – The species is named after the island of Bornholm in the Baltic Sea.

Holotype. – The specimen figured on Pl. 4, Fig. 3 is the holotype. It came from the basal marly part of the Bavnodde Greensand Formation at Jydegård. It is housed in the Collections of the Geological Museum, Copenhagen, filed as MGUH 20581.

Material. – MGUH 20582 and GM 1984.1833–1934 from the Bavnodde Greensand Formation at Risenholm; and MGUH 20581, GM 1984.1784 and GM 1990.76.1–2 from the Bavnodde Greensand Formation at Jydegård. Moreover, one specimen from the vicinity of Gardelegen, situated *c.* 50 km NNW of Magdeburg in Germany, has also been studied. This specimen is housed in the Collections of the Mining Academy of Freiberg,

Description of the holotype. – The internal mould of the right valve is slightly deformed by compaction. It is medium-sized and elongated trigonal (*Sphenoceramus*-like). The narrow, sharply rounded umbo is slightly bent towards the anterior margin. The wing and hinge line are imcomplete. The wing is separated from the umbonal region. The anterior margin in the umbonal region dips steeply. A radial depression is only slightly developed. Concentric ribs and radial ribs are missing. The specimens are therefore tentatively referred to the subgenus *Sphenoceramus.* The sculpture consists only of growth lines following the shape of the internal mould. The distance between the growth lines varies from 0.5–1.4 mm. Since the internal mould is incomplete the length and height cannot be measured. The ontogenetic change of the Vo/Ha ratio, Na/Ha ratio, and WA is shown in Fig. 33. The ontogenetic change of the Vo/Ha ratio in *I. (S.?) bornholmensis* and *I. (S.). cardissoides* is similar.

Affinity. – The holotype is closely comparable to *I. (S.) lingua* Goldfuss and *I. (S.)* cf. *lingua* as figured by Seitz (1965, Plate 18, Figs 3–4). Species of the *I. lingua* group from the Upper Santonian and Lower Campanian, however, differ from *I. (S.?) bornholmensis* by having greater distance between the growth lines.

Distribution. – *I. (S.?) bornholmensis* n. sp. occurs in the Bavnodde Greensand Formation at Risenholm and Jydegård on the island of Bornholm. Moreover, it occurs also in the marls close to Gardelegen in Germany, where it is found together with *Inoceramus (Magadiceramus) subquadratus* Schlüter from the uppermost Upper Coniacian. At Risenholm the species occurs together with *I. (S.) subcardissoides, I. (S.) cardissoides, I. (S.)* sp. ex gr. *pachti/cardissoides* and incomplete, poorly preserved inoceramids possibly belonging to the *I. (M.) subquadratus* group (see Plate 4, Fig. 5). At Jydegård it occurs together with *I. (S.)* sp. ex gr. *pachti/cardissoides. I. (S.?) bornholmensis* n. sp. is thus from the uppermost Coniacian and basal Santonian.

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References

Andersen, S.A. 1944. Det danske landskabs historie. Bind 1. Undergrunden, 480 pp. Populær-videnskabeligt forlag. København.

Andert, H. 1911. Die Inoceramen des Kreibitz-Zittauer Sandsteingebirges. Festschr. Humboldt-Vereins in Ebersbach zur Feier seines 50-jährigen Bestehens, 33–63.

Andert, H. 1934. Die Kreideablagerungen zwischen Elbe und Jeschken. Teil III. Die Fauna der obersten Kreide in Sachsen, Böhmen und Schlesien. Abh. Preuss. geol. Landesanst. N.F. 159, 477 pp.

Bailey, H.W., Gale, A.S., Mortimore, R.N., Swiecicki, A. & Wood, C.J. 1983. The Coniacian-Maastrichtian Stages of the United Kingdom, with particular reference to southern England. Newsl. Stratigr. 12, 29–42.

Bailey, H.W. & Hart, M.B. 1979. The correlation of the Early Senonian of western Europe using Foraminiferida. Aspekte der Kreide Europas. IUGS A6, 159–169.

Birkelund, T., 1957. Upper Cretaceous belemnites of Denmark. Biol. Skr. Dan. Vid. Selsk. 9, 57 pp.

Bodilevski V.I. & Schulgina, N.I. 1958. Jurskie i melovie fauni nisoviev Eniseja. Trudi nautschnoissledovadedelskogo instituta geologii Arktiki. Ministerstvo geologii i ochrani nedr SSR 93, 99 pp. [In Russian].

Bromley, R.G. 1979. Field meeting in southern Scandinavia 18–28 September 1975. Proc. Geol. Ass. 90, 181–191.

Brüsch, W. 1984. Bavnodde Grønsandets palæomiljø og -geografi. Unpublished M.Sc.Thesis, 181 pp. Copenhagen University.

Christensen, W.K. 1971. *Belemnitella propinqua propinqua* (Moberg, 1885) from Scandinavia. Bull. Geol. Soc. Denm. 20, 369–384.

Christensen, W.K. 1973. The belemnites and their stratigraphical significance. *In* Bergstöm, J., Christensen, W.K., Johansson, C. & Norling, E.: An extension of Upper Cretaceous rocks to the Swedish west coast at Särdal. Bull. Geol. Soc. Denm. 22, 113–140.

Christensen, W.K. 1985. The Albian to Maastrichtian of southern Sweden and Bornholm, Denmark: a review. Cretaceous Research 5, 313–327. (Misdated 1984).

Christensen, W.K. 1986. Upper Cretaceous belemnites from the Vomb Trough in Scania, Sweden. Sver. Geol. Unders. Ca 57, 57 pp.

Christensen, W.K. 1988: Upper Cretaceous belemnites of Europe: State of the art. *In* Streel, M. & Bless, M.J.M. (Eds.): The Chalk District of the Euregio Meuse-Rhine, 5–16. Natuurhistorisch Museum, Maastricht and Laboratoires de Paléontologie de l'Université d'Etat, Liège.

Christensen, W.K. 1990. *Actinocamax primus* Arkhangelsky (Belemnitellidae; Upper Cretaceous): Biometry, comparison and biostratigraphy. Paläont. Z. 64, 75–90.

Christensen, W.K. 1990. Upper Cretaceous belemnite stratigraphy of Europe. Cretaceous Res. 11, 371–386.

Christensen, W.K. (in press). Belemnites from the Coniacian to Lower Campanian chalks of Norfolk and southern England. Palaeontology.

Douglas, R.G. & Rankin, C. 1969. Cretaceous planktonic foraminifera from Bornholm. Lethaia 2, 185–219.

Ernst, G., Schmid, F. & Seibertz, E. 1983. Event-Stratigraphie im Cenoman und Turon von NW-Deutschland. Zitteliana 10, 531–554.

Forchheimer, S. 1970. Scanning electron microscope studies of some Cenomanian coccospheres and coccoliths from Bornholm (Denmark) and Köpingsberg (Sweden). Sver. Geol. Unders. C647, 43 pp.

Goldfuss, A. 1834–1840. Petrefacta Germaniae tam ea, quae in museo Universitatis Regiae Borussicae Fridericiae Wilhelmiae Rhenanae servantur quam alia quaecunque in Museis Hoeninghusiano Muensteriano aliisque extant, iconibus et descriptionihus illustrata. Division Quarta, 65–140. Düsseldorf.

Gravesen, P., Rolle, F. & Surlyk, F. 1982. Lithostratigraphy and sedimentary evolution of the Triassic, Jurassic and Lower Cretaceous of Bornholm. Danm. Geol. Unders. B7, 51 pp.

Grönwall, K.A. & Milthers, V. 1916. Kortbladet Bornholm. Danm. Geol. Unders. I Rk., 13, 281 pp.

Gry, H. 1956. Wealdenaflejringerne på Bornholm. Medd. Dansk Geol. Foren. 13, 134–141.

Gry, H. 1960. Geology of Bornholm. – Guide to Excursions Nos. A 45 and C 40. Intern. Geol. Congr. 21 Session, Norden, 16 pp.

Gry, H. 1969. Megaspores from the Jurassic of the island of Bornholm, Denmark. Medd. Dansk Geol. Foren. 19, 69–89.

Hamann, N.E. 1987. Bornholm, Geological Map (Mesozoic formations). The National Forest and Nature Agency.

Hancock, J.M. (in press). An ammonite-scale for the Cretaceous System. Cretaceous Res.

Hansen, K. 1939. Et geologisk profil langs Vellensaa paa Bornholm. Medd. Dansk Geol. Foren. 9, 482–488.

Hart, M.B. 1979. Biostratigraphy and palaeozoogeography of planktonic Foraminiferida from the Cenomanian of Bornholm, Denmark. Newsl. Stratigr. 8, 83–96.

Hart, M.B. 1980. The recognition of Mid-Cretaceous sea-level changes by means of foraminifera. Cretaceous Res. 1, 289–297.

Heinz, R. 1928a. Ueber Cenoman und Turon bei Wunstorf westlich von Hannover. Beiträge zur Kenntnis der oberkretazischen Inoceramen. II. 21. Jb. Nieders. geol. Ver. 19–43.

Heinz, R. 1928b. Das Inoceramen-Profil der Oberen Kreide Lüneburgs. Mit Anführung der neuen Formen und deren Kennzeichnung. Beiträge zur Kenntnis der oberkretazischen Inoceramen. I. 21. Jb. Nieders. geol. Ver. 65–81.

Heinz, R. 1928c. Über die bisher wenig beachtete Skulptur der Inoceramen-Schale und ihre stratigraphische Bedeutung. Beiträge zur Kenntnis der Oberkretazischen Inoceramen IV. Mitt. Miner.-Geol. Staatsinst. Hamb. 10, 1–39.

Heinz, R. 1932. Aus der neuen Systematik der Inoceramen. Beiträge zur Kenntnis der Inoceramen. XIV. Mitt. Miner.-Geol. Staatsinst. Hamb. 13, 1–26.

Ivannikov, A.V. 1979. Inocerami verchnemelovich otloschenii jugosapada vostotschno-Evropeiskoi platformi. Akad. nauk Ukr. SSR. Inst. Geol. Nauk, 101 pp. [In Ukrainian].

Jaworski, E. 1934. Referat über R. Heinz: Aus dem neuen Systematik der Inoceramen (Inoceramen XII). Paläont. Zblt. 4, 92–95.

Jeletzky, J.A. 1958. Die jüngere Oberkreide (Oberconiac bis Maastricht) Südwestrusslands, und ihr Vergleich mit der Nordwest- und Westeuropas. Beih. Geol. Jb. 33, 157 pp.

Jensen, J.B. & Hamann, N.E. 1989. Geological mapping of Mesozoic deposits along the eastern margin of the Rønne Graben, offshore Bornholm, Denmark. Bull. Geol. Soc. Denmark 37, 237–260.

Jespersen, M. 1865. Liden Geognostisk Veiviser paa Bornholm. 67 pp. Rønne.

Kaplan, U. 1986. Ammonite stratigraphy of the Turonian of NW-Germany. Newsl. Stratigr. 17, 9–20.

Kaplan, U. & Best, M. 1985. Zur Stratigraphie der Tieferen Oberkreide im Teutoburger Wald (NW-Deutschland). I. Cenoman. 27. Bericht Naturw. Ver. Bielefeld, 81–103.

Kaplan, U., Keller, S. & Wiedmann, J. 1984. Ammoniten- und Inoceramen-Gliederung des norddeutschen Cenomans. Österreichische Akademie der Wissenschaften. Schriftenreihe der Erdwissenschaftlichen Kommission 7, 307–347.

Keller, S. 1982. Die Oberkreide der Sack-Mulde bei Alfeld (Cenoman – Unter-Coniac), Lithologie, Biostratigraphie und Inoceramen. Geol. Jb. A64, 3–171.

Kennedy, W.J. 1984. Ammonite faunas and the "standard zones" of the Cenomanian to Maastrichtian Stages in their type areas, with some proposals for the definition of the stage boundaries by ammonites. Bull. Geol. Soc. Denmark 33, 147–161.

Kennedy, W.J. & Christensen, W.K. (in press). Coniacian and Santonian ammonites from Bornholm, Denmark. Bull. Geol. Soc. Denmark.

Kennedy, W.J., Hancock, J.M. & Christensen, W.K. 1981. Albian and Cenomanian ammonites from the island of Bornholm (Denmark). Bull. Geol. Soc. Denmark 29, 203–244.

Küchler, T. & Ernst, G. 1989. Integrated biostratigraphy of the Turonian-Coniacian transition interval in northern Spain, with comparison to NW Germany. *In* Wiedmann, J. (Ed.): Cretaceous of the Western Tethys, 161–190. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

Mantell, G. 1822. The fossils of the South Downs, or illustrations of the Geology of Sussex, 327 pp. London.

Noe-Nygaard, N. & Surlyk, F. 1985. Mound bedding in a sponge-rich Coniacian chalk, Bornholm, Denmark. Bull. Geol. Soc. Denmark 34, 237–249.

Noda, M. 1984. Notes on *Mytiloides incertus* (Cretaceous Bivalvia) from the Upper Turonian of the Pombets area, central Hokkaido. Trans. Proc. Paleont. Soc. Japan, N.S. 136, 455–473.

Ravn, J.P.J. 1916a. Om Kridtaflejringerne paa Bornholms Sydvestkyst. Medd. Dansk Geol. Foren. 5, 3–14.

Ravn, J.P.J. 1916b. Kridtaflejringerne paa Bornholms Sydvestkyst og deres fauna. I. Cenomanet. Danm. Geol. Unders. II Rk., 30, 40 pp.

Ravn, J.P.J. 1918. Kridtaflejringerne paa Bornholms Sydvestkyst og deres fauna. II. Turonet. Danm. Geol. Unders. II Rk., 31, 39 pp.

Ravn, J.P.J. 1921. Kridtaflejringerne paa Bornholms Sydvestkyst og deres fauna. III. Senonet. IV. Kridtaflejringerne ved Stampe aa. Danm. Geol. Unders. II Rk., 32, 52 pp.

Ravn, J.P.J. 1925. Det cenomane bundkonglomerat paa Bornholm. Danm. Geol. Unders. II Rk., 42, 64 pp.

Ravn, J.P.J. 1930. Nogle bemærkninger om Bornholms kridtaflejringer. Geol. Fören. Stockh. Förh. 52, 279–283.

Ravn, J.P.J. 1946. Om Nyker-omraadets kridtaflejringer. Biol. Skr. Dan. Vid. Selsk. 4, 36 pp.

Rosenkrantz, A. 1945. Smaabidrag til Danmarks Geologi. 2. Nye ammonitfund i Kridtformationen paa Bornholm. Medd. Dansk Geol. Foren. 10, 439–442.

Schlüter, C. 1874a. Die Belemniten der Insel Bornholm. Z. dt. geol. Ges. 26, 827–855.

Schlüter, C. 1874b. Über die Scaphiten der Insel Bornholm. Sitzungsberichte der niederrheinischen Gesellschaft für Natur und Heilkunde in Bonn 31, 23–27.

Schlüter, C. 1877. Kreide-Bivalven. Zur Gattung *Inoceramus*. Palaeontographica 24, 249–288.

Seitz, O. 1961. Die Inoceramen des Santons von Nordwestdeutschlands. I. Die Untergattungen *Platyceramus*, *Cladyceramus*, *Cordiceramus*. Beih. Geol. Jb. 46, 186 pp.

Seitz, O. 1965. Die Inoceramen des Santon und Unter-Campan von Nordwestdeutschland. II. Biometrie, Dimorphismus und Stratigraphie der Untergattung *Sphenoceramus* J. Böhm. Beih. Geol. Jb. 69, 194 pp.

Solakius, N. 1988. The type material of the Upper Cretaceous benthic foraminifer *Pseudovalvulineria vombensis* Brotzen, 1945. Geol. Fören. Stockh. Förh. 110, 197–201.

Solakius, N. 1989. Foraminifera from the Arnager Limestone-Bavnodde Greensand boundary on Bornholm, Denmark. Geol. Fören. Stockh. Förh. 111, 101–104.

Solakius, N. & Larsson, K. 1985. Foraminifera and biostratigraphy of the Arnager Limestone, Bornholm, Denmark. Danm. Geol. Unders. C5, 41 pp.

Sorgenfrei, T. 1957. Danemark. In Lexique Stratigraphique International. 1: Europe, fascicule 2d, Danemark, 44 pp.

Sornay, J. 1980. *Inoceramus schöndorfi* Heinz, une espèce mal connue du Cénomanien. Anns Palaéont. (Invertébrés) 66, 43–49.

Stenestad, E. 1972. Traek af det danske bassins udvikling i Øvre Kridt. Dansk geol. Foren. Årsskr. 1971, 63–69.

Stolley, E. 1897. Ueber die Gliederung des norddeutschen und baltischen Senon sowie die dasselbe characterisirenden Belemniten. Arch. Antropol. Geol. Schlesw.-Holst. 2, 216–302.

Stolley, E. 1930. Einige Bemerkungen über die Kreide Südskandinaviens. Geol. Fören. Stockh. Förh. 52, 157–190.

Stolley, E. 1937. Grundsätzliches zur paläontologischen Systematik. I. Inoceramen-Systematik von R. Heinz. Jber. nieders. Geol. Ver. 28, 1–12.

Tröger, K.-A. 1967. Zur Paläontologie, Biostratigraphie und fazielle Ausbildung der unteren Oberkreide (Cenoman bis Turon). I. Paläontologie und Biostratigraphie der Inoceramen des Cenomans und Turons. Abh. Staatl. Mus. Miner. Geol. 12, 13–207.

Tröger, K.-A. 1969. Bemerkungen zur Variabilität von *Inoceramus koeneni* G. Müller aus der subherzynen Kreide. Freiberger Forschungsh. C245, 68–81.

Tröger, K.-A. 1974. Zur Biostratigraphie des Ober-Turon bis Unter-Santon aus dem Schachtaufschluss der Zeche Grimberg IV bei Bergkamen. Freiberger Forschungsh. C298, 110–130.

Tröger, K.-A. 1981. Zu Problem der Biostratigraphie der Inoceramen und der Untergliederung des Cenomans und Turons in Mittel- und Osteuropas. Newsl. Stratigr. 9, 139–156.

Tröger, K.-A. 1984. Über zwei aussergewöhnlich grosse Inoceramen-Arten aus dem Ober-Turon von Europa. Freiberger Forschungsh. C395, 47–53.

Tröger, K.-A. 1989. Problems of Upper Cretaceous inoceramid biostratigraphy and paleobiogeography in Europe and western Asia. *In* Wiedmann, J. (Ed.): Cretaceous of the Western Tethys, 911–930. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

Wegner, T. 1905. Die Granulatenkreide des westlichen Münsterlandes. Z. dt. Geol. Ges. 57, 112–232.

Woods, H. 1911. A Monograph of the Cretaceous Lamellibranchiata of England. Monogr. Palaeon. Soc. Lond., 261–284.

Woods, H. 1912. The evolution of *Inoceramus* in the Cretaceous Period. Q. Jl. geol. Soc. Lond. 48, 1–20.

PLATE 1–4

Plate 1

Fig. 1. Inoceramus crippsi Mantell subsp. indet. from the Arnager Greensand east of Arnager. MGUH 20545.

Fig. 2. *Inoceramus crippsi* Mantell subsp. indet. from the Arnager Greensand east of Arnager. MGUH 20546.

Fig. 3. *Inoceramus crippsi* Mantell subsp. indet. from the Arnager Greensand at Stampe Å. MGUH 20549. a: redeposited phosphatized internal mould, b: umbonal region.

Fig. 4. *Inoceramus crippsi* Mantell subsp. indet. from the Arnager Greensand east of Arnager. MGUH 20547. This specimen has an elongated shape and is transitional to *I. crippsi hoppenstedtensis* Tröger.

Fig. 5. *Inoceramus crippsi hoppenstedtensis* Tröger from the Arnager Greensand at Arnager. MGUH 20550.

Fig. 6. *Inoceramus crippsi hoppenstedtensis* Tröger from the Arnager Greensand at Madsegrav. MGUH 20551.

Fig. 7. Inoceramus schoendorfi Heinz from the Arnager Greensand east of Arnager. MGUH 20552.

Fig. 8. *Inoceramus schoendorfi* Heinz from the Arnager Greensand east of Arnager. MGUH 20553. a: internal mould, b: diameter of the hinge line below the umbo; c: cross-section of the rib.

Fig. 9. *Inoceramus schoendorfi* Heinz from the Arnager Greensand at Stampe Å. MGUH 20554. a: internal mould, b: hinge line with ligamental pits.

Fig. 10. *Inoceramus schoendorfi* Heinz from the Arnager Greensand at Stampe Å. MGUH 20555.

Fig. 11. *Inoceramus schoendorfi* Heinz from the Arnager Greensand at Stampe Å. MGUH 20556. a: internal mould, b: shape of the ribs.

Fig. 12. *Inoceramus* cf. *wandereri* Andert from the Arnager Limestone at Arnager, 2–3 m above the base. MGUH 20566.

Fig. 13. *Inoceramus (Mytiloides)* cf. *incertus* Jimbo from the Arnager Limestone at Arnager. MGUH 20567.

Fig. 14. *Inoceramus* sp. ex gr. *waltersdorfensis* Andert from the Arnager Limestone at Arnager. MGUH 20558. a: specimen deformed by sediment compaction, b: cross-section of a growth line.

Fig. 15. *Inoceramus* sp. ex gr. *waltersdorfensis* Andert from the Arnager Limestone at Arnager. MGUH 20559. The specimen is highly deformed due to sediment compaction.

Fig. 16. *Inoceramus* cf. *renngarteni* Bodilevsky & Schulgina from the Arnager Limestone at Arnager. MGUH 20562.

Fig. 17. *Inoceramus (Heroceramus)* cf. *hercules* Heinz from the Arnager Limestone at Arnager, 2–3 m above the base. MGUH 20584.

Scale bars are 10 mm.

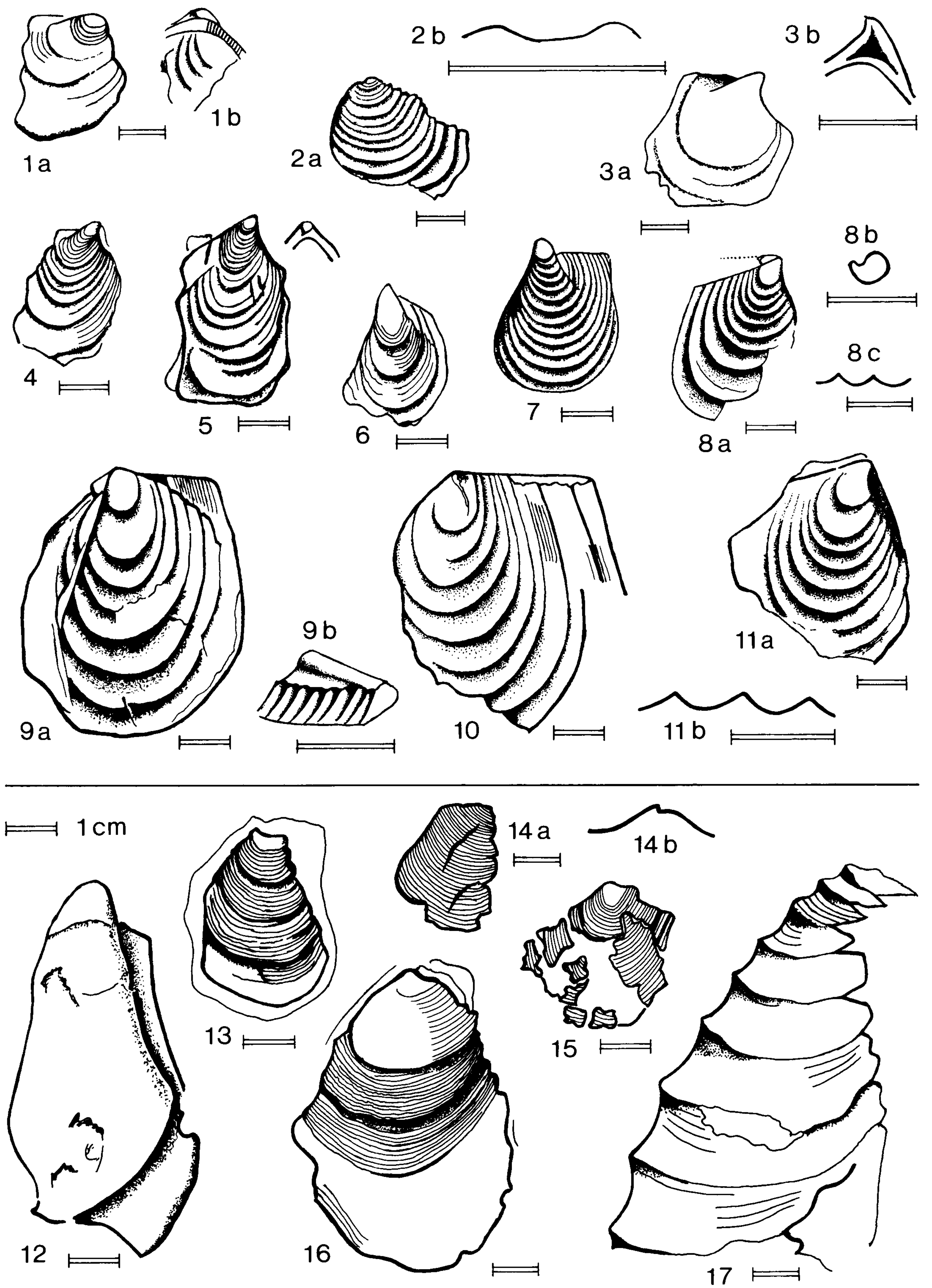

1a
1b
2a
2b
3a
3b
4
5
6
7
8a
8b
8c
9a
9b
10
11a
11b
1 cm
12
13
14a
14b
15
16
17

Plate 2

Fig. 1. Inoceramus (Cremnoceramus) schloenbachi Böhm from the Arnager Limestone Formation at Muleby, loc. 1 of Ravn (1946). MGUH 20569. The specimen is deformed by compaction.

Fig. 2. *Inoceramus (Volviceramus) koeneni* Müller from the Arnager Limestone Formation at Stampe Å. MGUH 20570. a: fragment of right valve, b: cross-section of growth line. This specimen is labelled "greensand at Stampen".

Fig. 3. *Inoceramus (Volviceramus) koeneni* Müller from the Arnager Limestone Formation at Stampe Å, loc. 5 in Fig. 6. MGUH 20571. a: hinge line with ligamental pits, b: internal mould of a left valve deformed by compaction.

Fig. 4. *Inoceramus (Sphenoceramus) subcardissoides* Schlüter from the Bavnodde Greensand Formation at Risenholm. MMH 5440. This specimen was figured by Ravn (1946, Pl. 1, Fig. 10).

Fig. 5. *Inoceramus (Sphenoceramus) pachti* cf. *pachti* Arkhangelsky from the Bavnodde Greensand west of Bavnodde, between beds 5 and 6. MGUH 20575. This specimen has weak radial ribs.

Fig. 6. *Inoceramus (Sphenoceramus) pachti* Arkhangelsky subsp. indet. from the Bavnodde Greensand at Forchhammers Cliff. MGUH 20576. a: anterior margin, b: incomplete internal mould.

Fig. 7. *Inoceramus (Sphenoceramus)* sp. ex gr. *pachti/cardissoides* from the Bavnodde Greensand Formation at Risenholm. MGUH 20578.

Fig. 8. *Inoceramus (Sphenoceramus) cardissoides* Goldfuss from the Bavnodde Greensand Formation at Risenholm. MGUH 20577.

Scale bars are 10 mm.

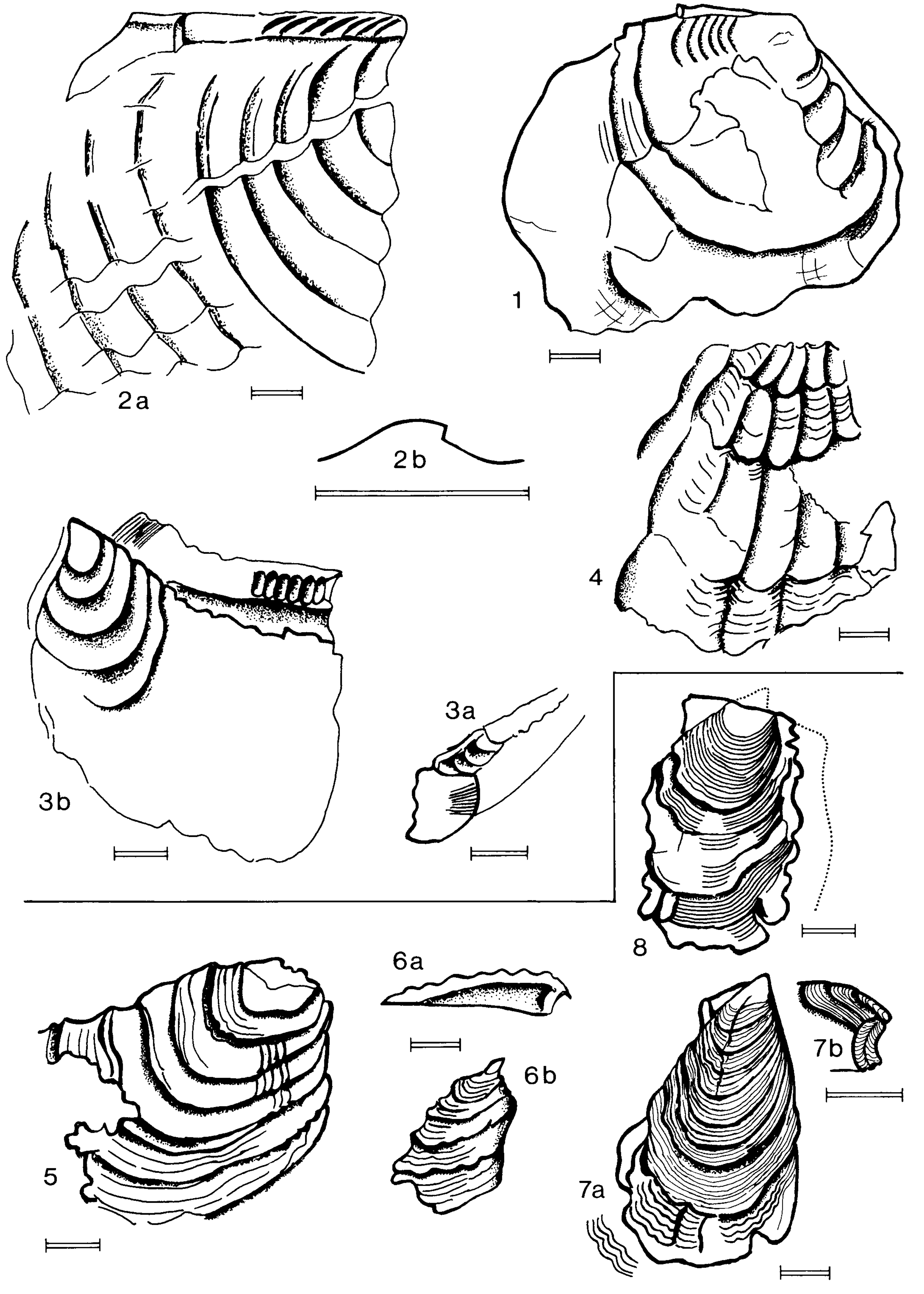

1
2a
2b
3a
3b
4
5
6a
6b
7a
7b
8

Plate 3

Fig. 1. Inoceramus crippsi Mantell subsp. indet. from the Arnager Greensand at Madsegrav. MGUH 20548. Specimen with an endocostean scar.

Fig. 2. *Inoceramus striatoconcentricus* Gümbel subsp. indet. from the Arnager Limestone at Arnager. MGUH 20557. Height of specimen is 41.1 mm.

Fig. 3. *Inoceramus* cf. *rotundatus* Fiege from the Arnager Limestone at Arnager. MGUH 20565.

Fig. 4. *Inoceramus* (*Heroceramus*) cf. *hercules* Heinz from the Arnager Limestone at Arnager. MGUH 20568.

Fig. 5. *Inoceramus waltersdorfensis* cf. *hannovrensis* Heinz from the Arnager Limestone at Arnager. MGUH 20560.

Fig. 6. *Inoceramus lusatiae* Andert from the Arnager Limestone at Arnager. MGUH 20563.

Fig. 7. *Inoceramus* (*Volviceramus*) *koeneni* Müller from the Arnager Limestone Formation at Stampe Å. MGUH 20572. This specimen is labelled "greensand at Stampen."

Scale bars are 10 mm.

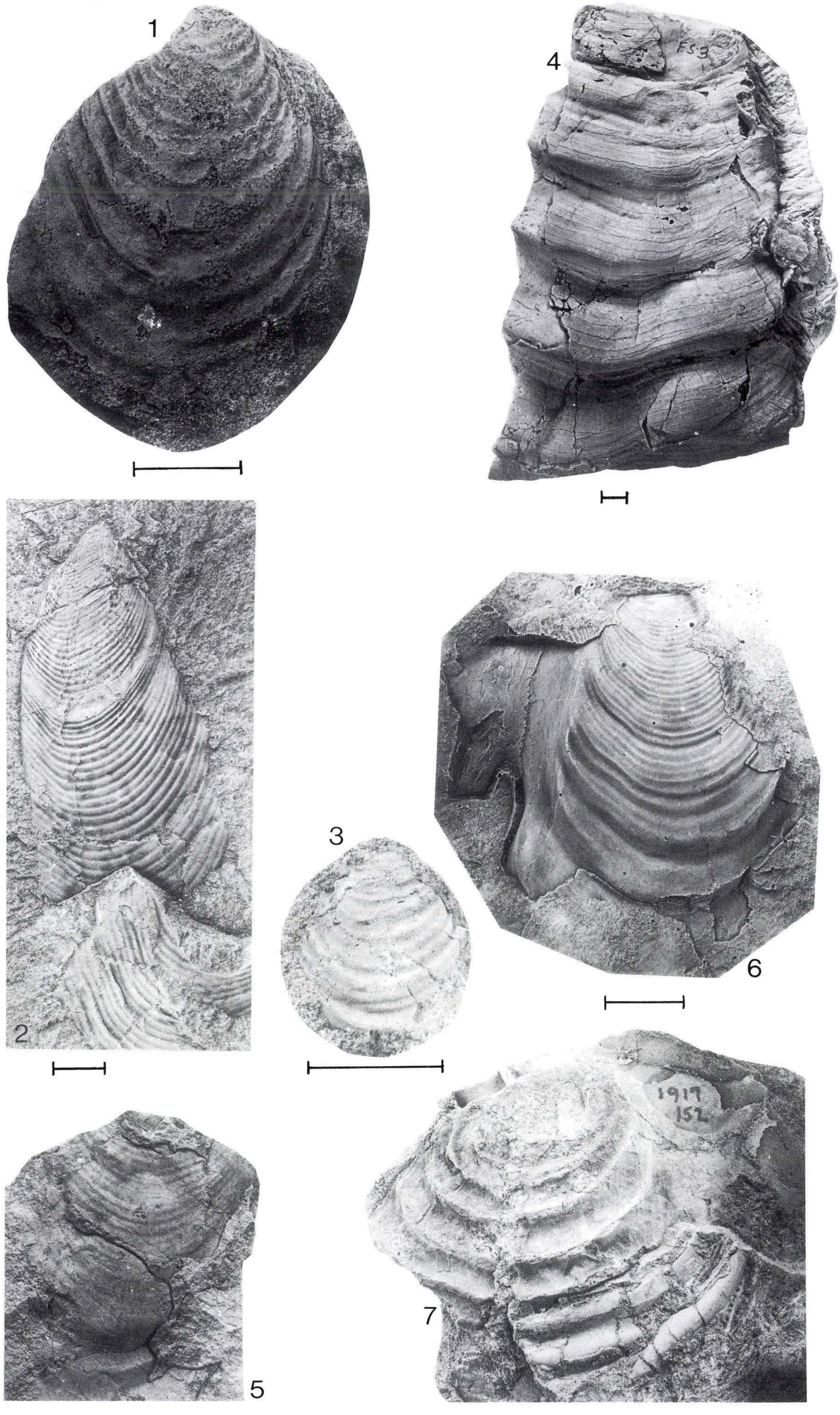

1
4
FS3
2
3
6
1917
152
7
5

Plate 4

Fig. 1. Inoceramus cf. *annulatus* Goldfuss from the Arnager Limestone at Arnager. MGUH 20561.

Fig. 2. *Inoceramus* (*Volviceramus*) *alievimussensis* Ivannikov from the Arnager Limestone Formation at Stampe Å. MGUH 20573. The specimen is labelled "greensand at Stampen".

Fig. 3. *Inoceramus* (*Sphenoceramus*?) *bornholmensis* n. sp. from the Bavnodde Greensand Formation at Jydegård. MGUH 20581. Holotype. Height of specimen is 50 mm.

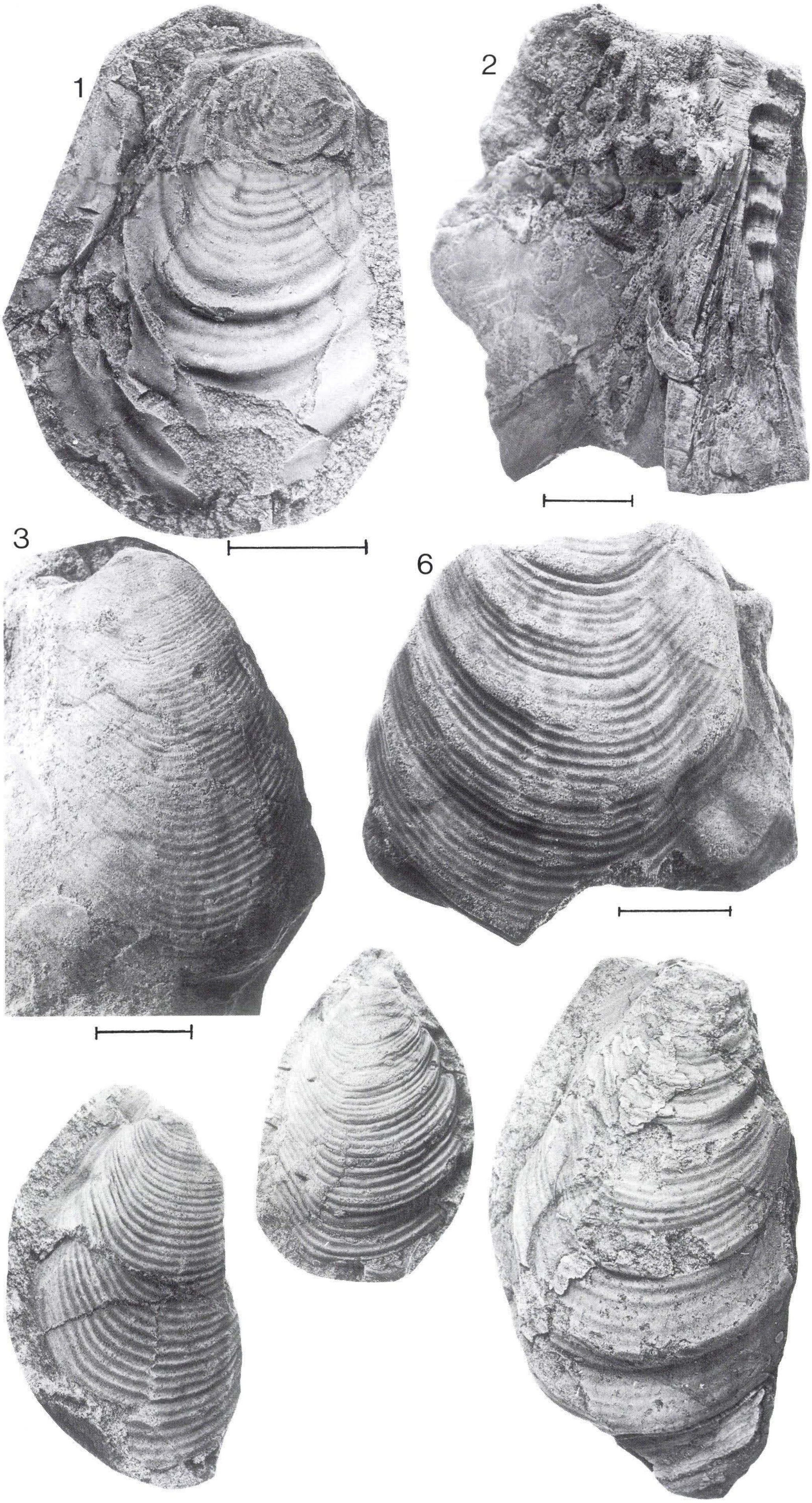
Fig. 4. *Inoceramus* (*Sphenoceramus*?) *bornholmensis* n. sp. from the Bavnodde Greensand Formation at Risenholm. MGUH 20582.

Fig. 5. *Inoceramus* sp. from the Bavnodde Greensand Formation at Risenholm. MGUH 20583. The shape of the ribs is similar to *Inoceramus* (*Magadiceramus*).

Fig. 6. *Inoceramus* (*Sphenoceramus*) sp. ex gr. *pachti/cardissoides* from the Bavnodde Greensand Formation at Risenholm. MGUH 20579. This specimen has indications of radial ribs.

Fig. 7. *Inoceramus* (*Sphenoceramus*) sp. ex gr. *pachti/cardissoides* from the Bavnodde Greensand Formation at Jydegård. MGUH 20580.

Scale bars are 10 mm.


1
2
3
6

This paper presents a taxonomic study of the Upper Cretaceous inoceramid bivalve faunas from the island of Bornholm, Denmark, and includes a description of the Upper Cretaceous lithostratigraphic formations together with a discussion on their age, based on various fossil groups, such as inoceramid bivalves, ammonites, belemnites, and foraminifera.

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