BRACHIOPODS AND THE STRATIGRAPHY OF THE UPPER CAMPANIAN AND LOWER MAASTRICHTIAN CHALK OF NORFOLK, ENGLAND

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ABSTRACT. Thirty-four species of brachiopods are described from the Upper Campanian and Lower Maastrichtian Chalk of Norfolk. The Campanian–Maastrichtian boundary sequence in Norfolk is very poorly exposed and is condensed. However, the existence of a highly diverse micromorphic brachiopod fauna allows correlation with more complete and well-exposed sections elsewhere in northwest Europe, especially northwest Germany and Denmark. Most of the brachiopod zones established in continental northwest Europe can be recognized in Norfolk. These are from below: the *tenuicostata-longicollis* Zone (corresponding to the bulk of the Upper Campanian of Norfolk), the *longicollis-jasmundi* Zone (uppermost Campanian), the *acutirostris-spinosa* Zone (basal Maastrichtian), the *spinosa-pulchellus* Zone (middle part of the Lower Maastrichtian) and the *pulchellus-pulchellus* Zone (upper Lower Maastrichtian). The stratigraphical scheme of previous workers was essentially based on faunal and subordinate lithological criteria. This is revised within a strictly lithostratigraphical framework to avoid ambiguities. Eight members are recognized comprising, from below: Eaton Chalk, Weybourne Chalk (including Catton Sponge Bed at its top), Beeston Chalk, Paramoudra Chalk, Sidestrand Chalk, Trimingham Sponge Beds, Little Marl Point Chalk, and Beacon Hill Grey Chalk Members.

HIGH diversity faunas of micromorphic brachiopods are well known from the Upper Cretaceous chalks of Denmark, Sweden, Germany and Poland (Steinich 1965, 1967, 1968*a*, *b*; Surlyk 1970*a*, *b*, 1972, 1973, 1974, 1975, 1982, 1984; Surlyk and Birkelund 1977; Surlyk and Johansen 1984; Bitner and Pisera 1979; Ernst 1984; Johansen 1986, 1987*a*, *b*, 1988), and a detailed brachiopod biozonation has been established for the Maastrichtian Stage. Washing of a large number of bulk samples collected in the Upper Campanian – Maastrichtian Chalk of Norfolk has yielded about 2200 specimens of brachiopods representing approximately thirty-five species. The occurrence of this fauna in the English Chalk makes it possible to correlate parts of the often poorly exposed Maastrichtian outcrops in Norfolk with the more completely exposed sections of continental northwest Europe, and to support previous correlations based on other faunal groups. Palaeoecological conclusions obtained by the study of the micromorphic fauna (Surlyk 1972) can also be extended to these parts of the English Chalk.

METHODS

Thirty-seven bulk samples were washed after boiling in a supersaturated Glauber-Salt solution following the method described by Surlyk (1972). Sample dry weight varied between 1 and 5 kg. The washed residues were sieved into 0·25–0·5 mm, 0·5–1·0 mm, and > 1·0 mm fractions, and the brachiopods were picked from the two latter fractions under a binocular microscope. The 0·25–0·5 mm fraction was in some instances checked for the earliest juvenile stages.

All specimens including the smallest juveniles were determined to species, and the minimum number of individuals was computed for each sample by adding to the number of complete shells the highest number of either dorsal or ventral valves. Ultrasonic cleaning was necessary when the details of shell ornamentation were hidden by adherent chalk. This was particularly the case with

[Palaeontology, Vol. 33, Part 4, 1990, pp. 823–872, 11 pls.]

material from the more indurated lithologies. SEM photographs were used for illustrative purposes, as normal photography is inadequate for illustrating finer details of rib sculpture and the pedicle foramen of the very small species. Preparation was done under a binocular microscope with a fine needle and brush, after attaching the specimen to a glass plate with 'Lakeside' cement.

The catalogued material is housed at the Geological Museum, University of Copenhagen. Material not catalogued belongs to a private collection of the second author of this paper (F.S.).

STRATIGRAPHY

The Campanian–Maastrichtian part of the Chalk in Norfolk is not very well known because of its incomplete exposure (Text-fig. 1). For much of the succession the sections are limited to widely scattered, often abandoned, chalk pits, and larger, glacially transported masses in coastal cliffs. This chalk was subdivided into a number of units by Brydone (1906, 1908, 1909, 1930, 1938). These units form the basis for the detailed geological map of Peake and Hancock (1970, pl. 2).

The nature of Brydone's stratigraphic units is somewhat unclear. Most of the subdivisions are named after a locality, although the fossil content is normally the main defining element. According to Wood (1988) the scheme is essentially palaeontological and the units of Brydone, as revised and updated by Peake and Hancock (1961, 1970), can be mapped out as faunal belts. The units are, however, in most cases characterized by a distinct lithology, or topped by a thin horizon of different lithology such as a hardground. They are redefined as lithostratigraphic units in the present paper, but it should be noted that the units recognized here are essentially equivalent to those of earlier authors even if they are conceptually different. Our aim in this revision is thus to introduce some consistency to the stratigraphical terminology.

The rank of the units is difficult to establish since the Upper Cretaceous Chalk of the North Sea and surrounding land areas has received little study from a lithostratigraphic point of view. Several formations have been recognized for the subsurface chalks of the North Sea (e.g. Deegan and Scull 1977; Svendsen 1979). These units are, however, of a very broad nature, and they are defined on the basis of petrophysical logs and relatively sparse core material from boreholes. They are difficult to correlate with exposed onshore chalk sequences.

The lithological differences between the individual units of the Chalk of Norfolk are relatively small and the thickness of the individual units usually amounts to a few metres only. The units can thus conveniently be treated as having member rank. The Chalk of Norfolk is generally of a more shallow-water nature than the North Sea Chalk, as witnessed by the common occurrence of single or compound hardgrounds and richer benthic faunas.

Lithostratigraphy

All localities described in the present paper expose Chalk of Late Campanian and Maastrichtian age; older sediments, including the 'Basal *mucronata* chalk' of Norfolk (Peake and Hancock 1970), are thus not dealt with in the following account. Since the lithostratigraphic units are given member rank (Text-figs 1 and 3) they should logically be grouped in one or more formations. This we leave, however, to students of the regional geology of eastern England. The description of the individual members is mainly based on Peake and Hancock (1970), Wood (1967, 1988), and our own observations.

Eaton Chalk Member

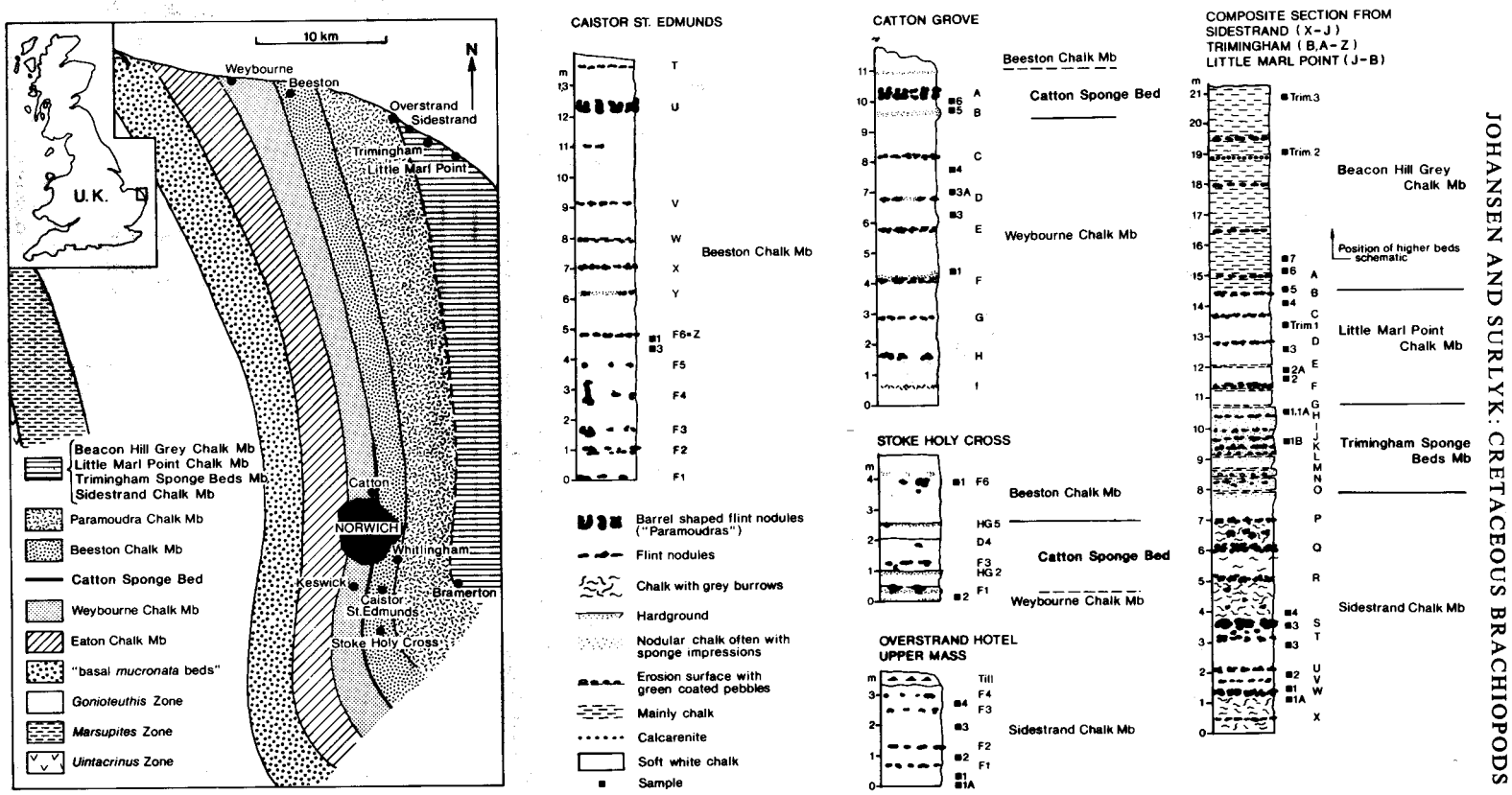
Name. After underground workings at the village of Eaton (National Grid Reference TG 208063).

Type section. The great part of the member is unexposed, so a satisfactory type section cannot be designated.

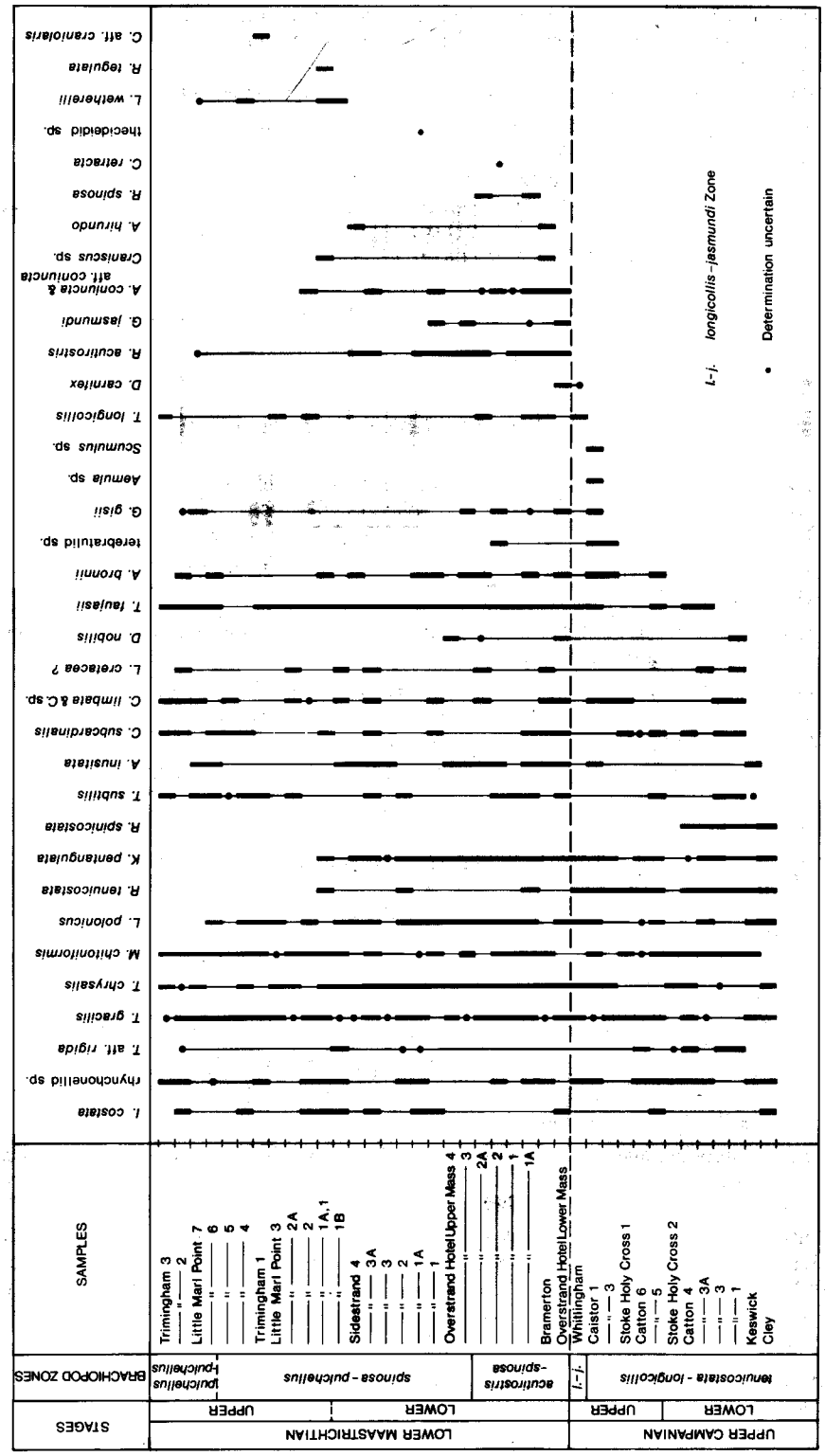
Reference sections. Small exposures may be found in the vicinity of Cley (TG 054440) and Drayton (TG 175132). Coastal sections at Weybourne Hope show the upper boundary, which is taken at Flint Z of Peake and Hancock (1970, fig. 5, p. 339D–E; Text-fig. 1 herein).

Thickness. Approximately 15 m (Peake and Hancock 1970, fig. 3).

Lithology. Soft chalk with irregularly scattered flints, sometimes forming 'open' bands.



TEXT-FIG. 1. Geological sketch showing the Upper Campanian–Lower Maastrichtian localities and sections of Norfolk described in this paper. The map and the letter key to individual beds are modified from Peake and Hancock (1970).



TEXT-FIG. 2. Range chart of brachiopod species in the Upper Campanian–Lower Maastrichtian Chalk sequence of Norfolk.

Boundaries. The member overlies the 'Basal *mucronata* chalk', but the boundary to this unit is ill-defined and possibly mainly based on palaeontological criteria. The latter unit may thus in the future be included in the Eaton Chalk Member. The member is overlain by the Weybourne Chalk Member, the base of which is taken at the top of the sponge-bed hardground above Flint Z of Peake and Hancock (1970, fig. 5).

Distribution. The member is presently only recognized in Norfolk (Peake and Hancock 1970, pl. 2), although probably present at Studland and the Isle of Wight (J. M. Hancock, written communication, June 1986).

Geological age. The member is probably contemporaneous with the lower part of the Ballintoy Chalk Member of Northern Ireland which corresponds to the lower Upper Campanian *basiplana – spiniger* Zone of northwest Germany (Fletcher and Wood 1978; Schulz 1985). This level was chosen as stratotype for the neotype of *Belemnitella mucronata mucronata*, and falls within the *Hoplitoplacenticeras 'vari'* Zone of the international ammonite zonal scheme (Christensen *et al.* 1975).

Samples. One sample was collected from an excavation for a house foundation in Cley.

Weybourne Chalk Member

Name. After the village of Weybourne (TG 110430), situated 700 m south of the coastal outcrops of the member.

Type section. The member is exposed in an interrupted line of low chalk bluffs on the north coast of Norfolk at Weybourne Hope. A composite section is shown in Peake and Hancock (1970, fig. 5; Text-fig. 1 herein).

Reference sections. The lower part of the section at Catton Grove (TG 229109) (Peake and Hancock 1970, fig. 6), Keswick (TG 212048), and a former section at Stoke Holy Cross (TG 235016; Text-fig. 1).

Thickness. Approximately 25 m (Peake and Hancock 1970, fig. 3).

Lithology. Chalk with bands of nodular flint, strong and more or less continuous in the lower part. Fossils have a pinkish tinge in the middle 15 m of this unit.

Boundaries. This member overlies Eaton Chalk, the base taken at the top of the sponge-bed hardground above Flint Z of Peake and Hancock (1970, fig. 5) in the section at Weybourne Hope. The upper boundary is drawn at the top of hardground forming the top of the Catton Sponge Bed.

Distribution. The member has only been recognized in Norfolk (Peake and Hancock 1970, pl. 2).

Geological age. Highest part of the lower Upper Campanian, approximately corresponding to the German *roemeri* Zone (Schulz 1985).

Samples. Four samples from Catton Grove, one from Keswick, and one from Stoke Holy Cross (Text-figs 1 and 3).

Catton Sponge Bed

Name. After Catton Grove (TG 229109) in the northern outskirts of Norwich.

Type section. Catton Grove (Peake and Hancock 1970, fig. 6; Text-fig. 1 herein).

Reference sections. Stoke Holy Cross. Foreshore at Sheringham, north coast of Norfolk (see Peake and Hancock 1970, p. 317).

Thickness. From about 0·3 m to a few metres.

Lithology. The member comprises one to three yellow-stained hardgrounds and the intervening soft chalk with bands of often huge flint nodules. The member contains a characteristic 'hardground preservation fauna' comprising casts of originally aragonite shelled bivalves, gastropods and ammonites.

Boundaries. The Catton Sponge Bed forms the top unit of the Weybourne Chalk Member. The lower boundary is placed at the base of the sponge-bed (B in Peake and Hancock 1970, fig. 6) overlying the unlithified Weybourne Chalk Member, while the upper boundary is placed at the top of the hardground which is overlain by the unlithified Beeston Chalk Member. This definition conforms with that of Wood (1988).

Distribution. The member is only known from Norfolk.

Geological age. Boundary between lower and upper Upper Campanian, corresponding to the boundary between the German *roemeri* and *polyplocum* Zones (Schulz 1985). A contemporaneous hardground sequence has been described from the Glenarm Chalk Member of Northern Ireland as the North Antrim Hardground

(Fletcher and Wood 1978). Many of the Norfolk specimens of *B. polyplocum* probably come from this member (J. M. Hancock, written communication, June 1986).

Samples. Two samples from Catton Grove (Text-figs 1 and 3).

Beeston Chalk Member

Name. After Beeston Hill, east of Sheringham on the north coast of Norfolk.

Type section. Caistor St Edmunds (TG 238046) (Peake and Hancock 1970, fig. 6; Text-fig. 1 herein).

Reference section. Stoke Holy Cross (TG 235016).

Thickness. Approximately 25 m (Peake and Hancock 1970, fig. 3).

Lithology. White chalk characterized by irregular bands of large flints many of which appear as flint circles 0·5–3 m or more in diameter when seen on bedding planes. Sometimes two or more circles are concentric, and there may be a hollow core of the trace fossil *Bathichnus paramoudrae* at the centre (Peake and Hancock 1970, pp. 318, 339F; Bromley *et al.* 1975).

Boundaries. The member overlies the highest hardground of the Catton Sponge Bed (Weybourne Chalk Member) and is overlain by the poorly exposed Paramoudra Chalk Member. The upper boundary of the member is defined at the top of a hardground which appears on the shore about 200 metres east of West Runton (Peake and Hancock 1970, p. 339F).

Distribution. The Beeston Chalk Member has only been recorded from Norfolk (Peake and Hancock 1970, pl. 2).

Geological age. Lower part of the upper Upper Campanian roughly equivalent to the German *polyplocum* and *langei* Zones (Schulz 1985). It correlates well with the Portrush Chalk Member of Northern Ireland (Fletcher and Wood 1978).

Samples. Two samples from Caistor St Edmunds and one from Stoke Holy Cross (Text-figs 1 and 3).

Paramoudra Chalk Member

Name. After the name applied to the barrel-shaped flints which are characteristic of the unit (Peake and Hancock 1970, p. 318; Bromley *et al.* 1975). The name thus does not meet the strict demands of a lithostratigraphic term, but since it refers to the lithology and as it has no biostratigraphic connotations there is no strong reason to abandon it.

Reference sections. The member is very poorly exposed and a type section cannot be proposed. Whitlingham (TG 267078), Frettenam (TG 246173) and Postwick (TG 270080) may serve as reference sections. The reference section at Bramerton is no longer exposed (J. M. Hancock, written communication, June 1986).

Thickness. Approximately 25 m (Peake and Hancock 1970, fig. 3).

Lithology. White chalk with repeated hardgrounds and characterized by the occurrence of 'paramoudras'. A 'paramoudra' is a vertically orientated barrel-shaped or cylindrical flint with a semi-lithified core of chalk through which passes a vertical dark tube like burrow which may extend upwards and downwards for many metres. The burrow and the associated 'paramoudra' were described in detail by Bromley *et al.* (1975) who named the trace fossil *Bathichnus paramoudrae*.

Boundaries. The base of the member is defined at the top of a hardground, which crops out on the shore about 200 m east of West Runton (Peake and Hancock 1970, p. 339F).

The upper boundary cannot be precisely defined, as younger beds are only exposed in glacially disturbed masses. The overlying 'pre-*Porosphaera* Beds' of Wood (1967) comprise relatively hard, sometimes yellowish chalk largely without 'paramoudras'. According to J. M. Hancock (pers. comm. 1988) there is a marker bed – the Overstrand Pyramidata hardground – below the Overstrand Hotel Lower Mass and above undoubted chalk with paramoudras. The top of this hardground may serve as the upper boundary of the member.

Distribution. The member is not known outside Norfolk (Peake and Hancock 1970, pl. 2).

Geological age. The member represents the highest Campanian of Norfolk. It is equivalent to the Ballymagarry Chalk Member of Northern Ireland (Fletcher and Wood 1978), and corresponds to the German *grimmensis-granulosus* Zone and perhaps the basal *lanceolata* Zone of Schulz (1978, 1979, 1985).

Samples. One from Whitlingham at the level of the top flint, probably of uppermost Campanian age.

Sidestrand Chalk Member

History. The member encompasses the 'pre-*Porosphaera* Beds' of Wood (1967) and the '*Porosphaera Beds*' of Brydone (1906, 1908, 1938) (see also Peake and Hancock 1970).

Name. After the village of Sidestrand on the northeast coast of Norfolk.

Type section. The sequence exposed in the glacially induced anticlines at Sidestrand (TG 255404) (Text-fig. 1; see also Peake and Hancock 1970, figs 7 and 8). The eastern (left) anticline especially shows a good section through the main part of the member, which comprises the chalk containing flints X to P in the composite section of Peake and Hancock (1970, fig. 7).

Reference sections. Overstrand Hotel Upper Mass (TG 255406).

Thickness. Probably about 10–12 m.

Lithology. White, in places nodular chalk with grey lenticular streaks representing burrows, and about 15 bands of nodular flint. Flint band S is particularly characteristic as it comprises huge cylindrical, black nodules (up to 30 cm thick and 1 m in diameter) with chalk filled holes.

Boundaries. The lower boundary with the Paramoudra Chalk Member is conventionally placed at the top of the Overstrand Pyramidata hardground. The upper boundary is defined at the top of the hardground labelled O in Peake and Hancock (1970, fig. 7).

Distribution. The member has only been recognized along the northeast coast of Norfolk (Peake and Hancock 1970).

Geological age. Lowermost Maastrichtian (Wood 1967). Schulz (1978) referred the Overstrand Hotel Upper Mass to the *lanceolata* Zone, and the part of the member exposed at Sidestrand to the *pseudobtusa* and *obtusa* Zones.

Samples. One sample from Overstrand Hotel Lower Mass, one sample from Bramerton, six samples from Overstrand Hotel Upper Mass and six samples from Sidestrand (Text-figs 1 and 3).

Trimingham Sponge Beds Member

History. The member corresponds to the 'Sponge Beds' of Brydone (1908).

Name. After the village of Trimingham on the northeast coast of Norfolk.

Type section. Trimingham, where the top is occasionally exposed (Peake and Hancock 1970, fig. 7, beds D to G). The lower beds can also be seen at Sidestrand.

Thickness. 2·9 m.

Lithology. Lithified chalk with several erosion surfaces with green-coated pebbles. The chalk is yellow in outcrop, but grey on fresh surfaces. Impressions of large masses of lithistid and hexactinellid sponges are characteristic. Masses of pyrite are not infrequent (Peake and Hancock 1970). Four bands of nodular flint with thick white cortices (K, J, I, H) occur in the upper part of the member.

Boundaries. The lower boundary of the Trimingham Sponge Beds Member is placed at the top of the sponge-bed labelled O in Peake and Hancock (1970, fig. 7). The upper boundary is defined by the top of the thick 'greasy' marl band labelled G in Peake and Hancock (1970, fig. 7).

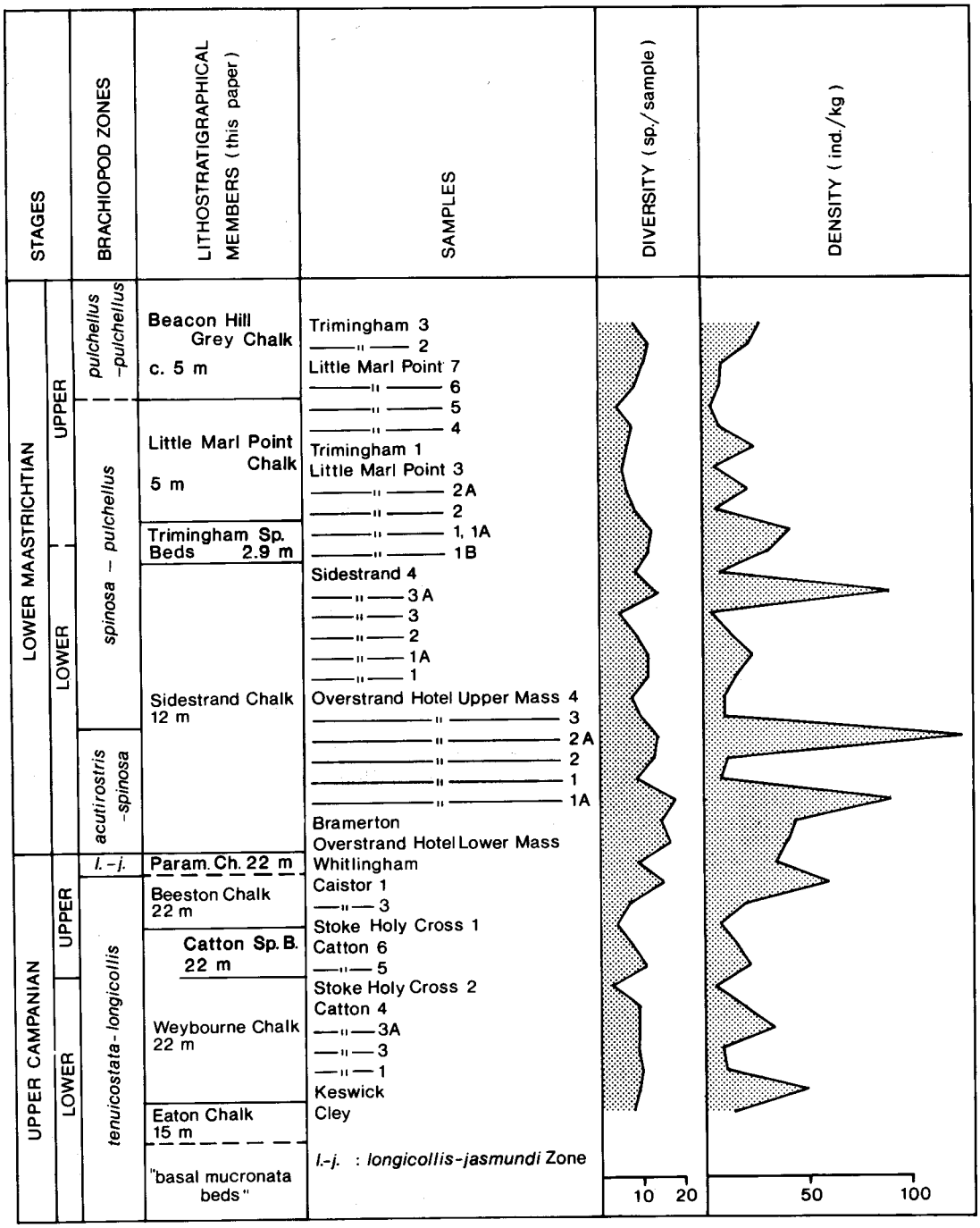
Distribution. Only recorded in the coastal sections of the northeast Norfolk (Peake and Hancock 1970).

Geological age. Top of the lower Lower Maastrichtian. The member probably mainly belongs to the *obtusa* Zone of Schulz (1978, 1985).

Samples. Three samples from the top of the member at Little Marl Point.

Little Marl Point Chalk Member

History. The member comprises the so-called 'White Chalk without *Ostrea lunata*' and the overlying 'White Chalk with *Ostrea lunata*' (Brydone 1906; Peake and Hancock 1970). *Ostrea lunata* was originally proposed as zonal index fossil for the whole of the Maastrichtian exposed at Trimingham. Brydone (1906) demonstrated that *O. lunata* did not occur throughout the sequence and suggested that *Terebratulina gracilis* should take its place as index fossil. Brydone (1906, 1938) suspected that several horizons with *O. lunata* were present, but Peake and Hancock (1970) demonstrated that there is only one horizon with *O. lunata*.



TEXT-FIG. 3. Lithostratigraphy, biostratigraphy, and brachiopod diversity and density of the Norfolk sections.

Name. After the bluff Little Marl Point (TG 298380) on the coast east of Trimingham (Peake and Hancock 1970, fig. 9) where the member is well exposed.

Type section. Little Marl Point (Text-fig. 1; Peake and Hancock 1970, fig. 7, sequence with beds F to B).

Thickness. About 5–5·6 m (Peake and Hancock 1970).

Lithology. Soft white chalk with four horizons (F, D, C, B) of nodular flint and two thin marl bands (below F, E). The top contains a horizon densely packed with the dark blue grey shells of the small oyster *Ostrea lunata*.

Boundaries. The base of the member is placed at the top of the 'greasy' marl band labelled G in Peake and Hancock (1970, fig. 7). The upper boundary is placed at the base of the first soft grey chalk beds of the Beacon Hill Grey Chalk Member labelled A by Peake and Hancock (1970, fig. 7).

Distribution. The member is only known from northeast Norfolk.

Geological age. Lower part of the upper Lower Maastrichtian. Schulz (1979, 1985) correlated it with the *sumensis* Zone of Germany.

Samples. Five samples from Little Marl Point and one from Trimingham mass C of Brydone (1908) (Text-figs 1 and 3).

Beacon Hill Grey Chalk Member

History. The member corresponds to the 'Grey Beds' of Brydone (1906, 1908) and Peake and Hancock (1970).

Name. After Beacon Hill (TG 289383) on top of the cliff overlooking the type locality.

Type section. Trimingham Mass C (Peake and Hancock 1970, figs 7 and 9). The sequence is only occasionally exposed and the fragmentary section figured by Peake and Hancock (1961, fig. 7) was based on a fortuitous exposure opposite Beacon Hill (Peake and Hancock 1970, p. 339H) (approximately TG 292386). Their data have been integrated in the synthetic section shown in Text-figures 1 and 3.

Thickness. About 5 m, but the upper limit is not known (Peake and Hancock 1970, p. 339H).

Lithology. Grey chalk with five flint bands. A fawn-coloured calcarenite 0·1 m thick occurs below the second flint band from the top (Peake and Hancock 1970, p. 339H).

Boundaries. The lower boundary of the member is defined by the base of the first soft grey chalk bed labelled A by Peake and Hancock (1970, fig. 7). The upper boundary is not known since the member comprises the youngest Cretaceous rocks exposed in England.

Distribution. Only known from northeast Norfolk.

Geological age. Lower part of the upper Lower Maastrichtian. The unit belongs to the upper part of the German *sumensis* Zone (Schulz 1978, 1985). A highly characteristic form of *Echinocorys* occurs above the calcarenite band and can be matched exactly in a section near 'die Zeven Wegen' in southern Limburg (Netherlands), where it accompanies *B. sumensis* (N. B. Peake, written communication, June 1986).

Samples. Two samples from Trimingham Mass C, and one sample from Little Marl Point (Text-figs 1 and 3).

BRACHIOPOD STRATIGRAPHY

The Upper Campanian and Maastrichtian Chalk of Norfolk is exposed in small quarries, road cuts, and strongly disturbed coastal cliff sections. The majority of the sections are only a few metres thick. The succession is furthermore characterized by hardgrounds reflecting periods of non-deposition and perhaps erosion. It is thus clear that a chart showing the full range of brachiopod species through the time interval represented by the investigated sequence cannot be constructed. Exposure of the Campanian–Maastrichtian boundary strata are particularly fragmentary.

The Chalk of Norfolk is thus here dated within the framework of the brachiopod zonation worked out for the thick continuous Campanian–Maastrichtian boundary section at Kronsmoor, northwest Germany (Surlyk 1982, 1984). Schulz (1978, 1979, 1985) presented a detailed belemnite zonation for the Kronsmoor sequence and this zonation is well integrated with the brachiopod zonation. It is thus possible to use the combined evidence from brachiopods and belemnites in the correlation of the Norfolk sequence.

The localities of Text-figure 1 were first arranged in ascending stratigraphic order on the basis of evidence from macrofossils, notably belemnites and to some extent echinoids (Schulz 1978, 1979, 1985; Peake and Hancock 1970; Wood 1967) and field mapping (Peake and Hancock 1970) supplemented by scattered information in the literature on the Cretaceous of the British Isles (Fletcher and Wood 1978).

The brachiopod species were then plotted on this scheme and their vertical distributions compared with ranges in the Kronsmoor section (Surlyk 1982, 1984) and to more limited successions in Denmark (Surlyk 1984) and Poland (Bitner and Pisera 1979).

Seven brachiopod zones were recognized in the Kronsmoor section within the interval represented by the *langei* through *sumensis* belemnite zones (Text-fig. 3). The Maastrichtian portion of the Norfolk and Kronsmoor sequences can be roughly correlated, while the Norfolk Campanian investigated here reaches lower than the part exposed in Kronsmoor.

It is important to stress that both the brachiopod and belemnite zones are defined by first or last occurrences of species with Kronsmoor as the key locality. This means, for example, that a slightly later appearance of a brachiopod index species in Norfolk relative to a belemnite index species is reflected by an upwards shift of a brachiopod zone boundary in respect to the belemnite zone boundary. Schemes showing the correlation of the same brachiopod and belemnite zones in northwest Germany and Norfolk respectively are thus somewhat different. This is shown in Text-figure 4.

The brachiopod zones are defined and named following the system proposed by Murphy (1977). The lower boundary of each zone is defined in a stratotype by a biostratigraphic event such as the first appearance or last occurrence of a species. The upper boundary is defined by the base of the next, higher zone to avoid gaps or overlap of zones. A binomial nomenclature is used to name the zone. The name of the species which defines the lower boundary is followed by the name of the species which defines the lower boundary of the following zone. Thus the *longicollis-jasmundi* Zone is from the first occurrence of *Terebratulina longicollis* to immediately below the first occurrence of *Gisilina jasmundi*. The following *jasmundi-acutirostris* Zone is defined by the first occurrences of *Gisilina jasmundi* and *Rugia acutirostris* respectively.

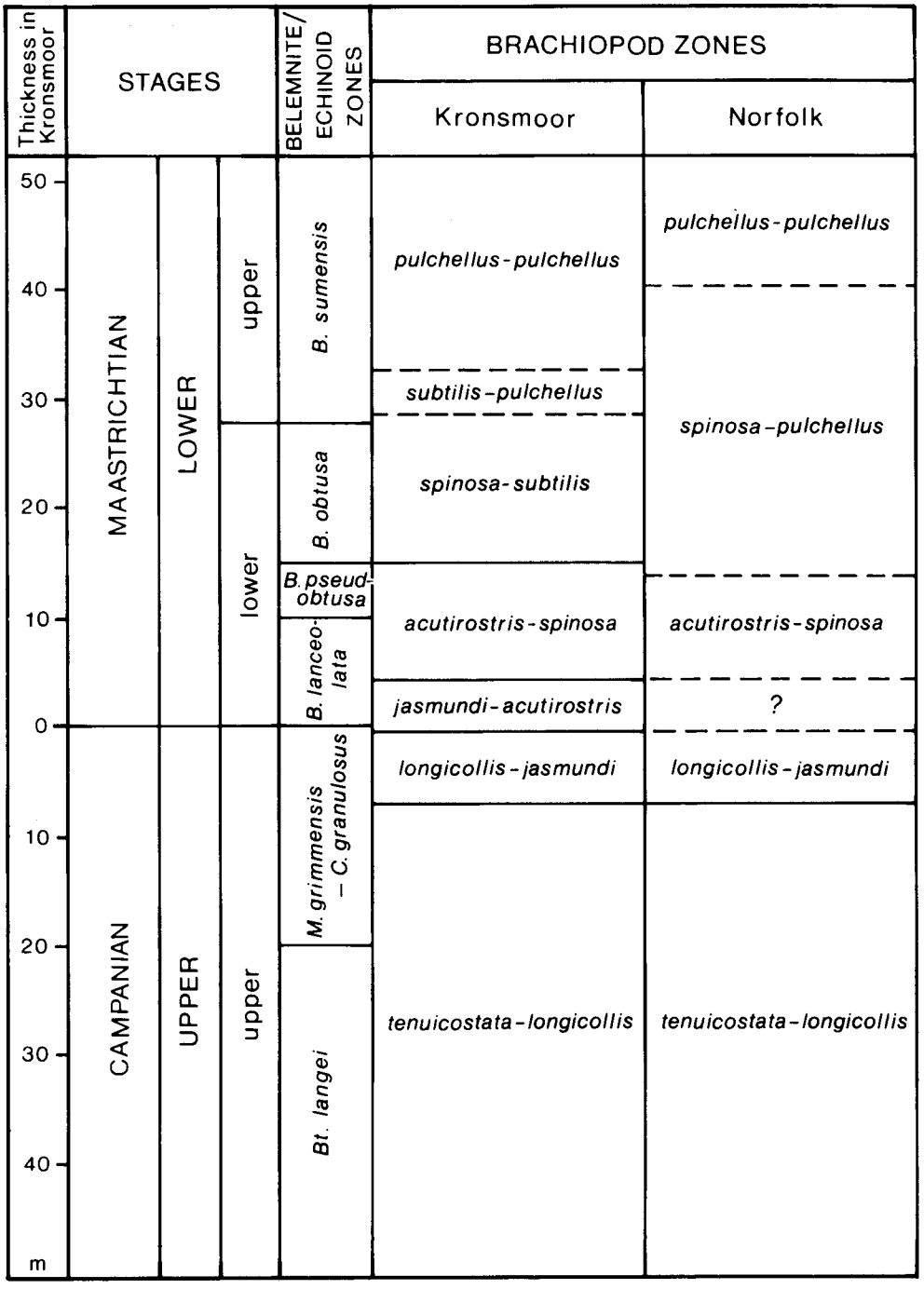
Most of the brachiopod zones recognized in Kronsmoor are also represented in Norfolk. The *tenuicostata-longicollis* Zone includes the localities Cley, Stoke Holy Cross, Catton and Caistor (Text-fig. 2). This zone can undoubtedly be subdivided, when the brachiopod faunas from continuous sections through the lower Upper Campanian are investigated.

The *longicollis-jasmundi* Zone corresponds to the highest Campanian in Kronsmoor and seems to be represented by the Whitlingham locality.

The basal Maastrichtian *jasmundi-acutirostris* Zone in Kronsmoor is defined by the first occurrence of *Gisilina jasmundi* and *Rugia acutirostris*. *G. jasmundi* has its first occurrence in Kronsmoor sample F10 which was sampled 20 cm below flint band F600. The lowest *Belemnella lanceolata*, which defines the base of the Maastrichtian (e.g. Schulz 1978, 1979), was found at the level of F600. This means that the bases of the *lanceolata* Zone and the *jasmundi-acutirostris* Zone essentially coincide. For convenience, Schulz (1978), however, placed the Campanian–Maastrichtian boundary precisely at the midpoint of F600. The *jasmundi-acutirostris* Zone thus seems to have its base immediately below the Campanian–Maastrichtian boundary (Surlyk 1982, fig. 1), but this only reflects the greater precision of sample localization in respect to the lithological marker beds. *G. jasmundi* and *R. acutirostris* occur for the first time in the Norfolk material in Overstrand Hotel Lower Mass which is the next locality stratigraphically above Whitlingham (Text-fig. 2). It is thus highly probable that the *jasmundi-acutirostris* Zone is represented by unexposed strata stratigraphically between Whitlingham and Overstrand Hotel Lower Mass.

The *acutirostris-spinosa* Zone is defined by the first occurrence of *Rugia acutirostris* and the last occurrence of *Rugia spinosa*. In Norfolk it is represented by the localities Overstrand Hotel Lower Mass, Bramerton, and Overstrand Hotel Upper Mass samples 1–2A (Text-fig. 2).

The *spinosa-subtilis* Zone is defined by the last occurrence of *Rugia spinosa* and the first occurrence of *Terebratulina subtilis*. The latter species has a much longer vertical range in Norfolk



TEXT-FIG. 4. Scheme showing the correlation of the belemnite and brachiopod zones of Kronsmoor (northwest Germany) and Norfolk based on Schulz (1978, 1979, 1985), Surlyk (1982, 1984) and this paper.

than in northwest Europe generally (Text-fig. 2) and its first appearance is thus of no value in regional correlation. The next higher stratigraphic event used in the northwest European brachiopod zonation is the incoming of *Trigonosemus pulchellus*. This species has not been found in our material but is reported from the Grey Beds (the Beacon Hill Grey Chalk Member of this paper) by Wood (1967). This is confirmed by the study of the museum collections of the British Geological Survey by one of us (F.S.). The Beacon Hill Grey Chalk Member includes the samples Little Marl Point 6 and Trimingham 2 and 3.

The lowest occurrence of *T. pulchellus* is not known, but is provisionally taken to correspond to the base of the Beacon Hill Grey Chalk Member. A *spinosa-pulchellus* Zone can thus be recognized as including the localities Overstrand Hotel Upper Mass 3 and 4, Sidestrand, Little Marl Point 1–5, and Trimingham 1.

It is followed by the *pulchellus-pulchellus* Zone defined by the first and last appearance of *Trigonosemus pulchellus*. The top of the zone may not be exposed in Norfolk.

SYSTEMATIC PALAEONTOLOGY

Repositories. Specimens from Norfolk have MGUH as prefix to their registration numbers. MGUH refers to the formal numbering system of Geological Museum, the University of Copenhagen, Denmark. Specimens from Lägerdorf and Kronsmoor are prefixed SPGIH, referring to the formal numbering system of the Institute of Geology and Palaeontology, the University and Museum of Hamburg, Germany. The abbreviation in the plate captions WKC refers to specimens collected by Walter Kegel Christensen, Geological Museum, the University of Copenhagen.

Family LINGULIDAE Menke, 1828
Genus LINGULA Bruguiere, 1797

Type species. *Lingula anatina* Lamarck, 1801, p. 141.

Lingula cretacea? Lundgren, 1885

Plate 1, figs 1 and 2

1885 *Lingula cretacea* Lundgren, p. 20, pl. 1, fig. 1.
1894 *Lingula cretacea* Lundgren; Posselt, p. 14.
1909 *Lingula cretacea* Lundgren; Nielsen, p. 17.
1972 *Lingula cretacea* Lundgren; Surlyk, p. 27, figs 5 and 12.
1982 *Lingula cretacea* Lundgren; Surlyk, fig. 1.

Material. The shell of this species is very fragile, and when found in the washed residues is highly fragmented. The Norfolk material consists of one dorsal and one ventral valve, and twenty-five fragments. Significant measurements have not been obtained. Catalogue numbers MGUH 16841, 16842.

EXPLANATION OF PLATE 1

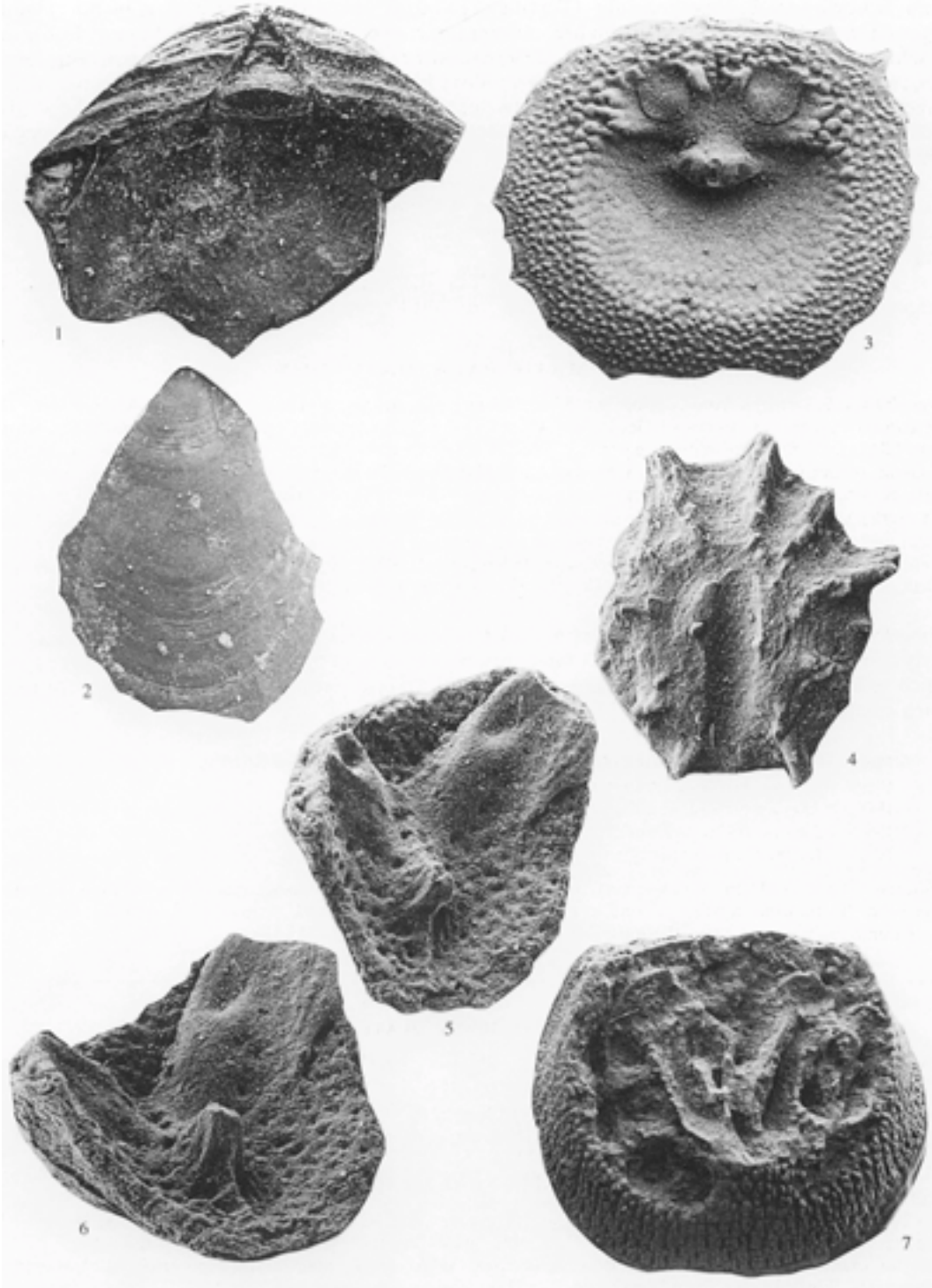
Figs 1 and 2. *Lingula cretacea*? Lundgren, 1885. 1, MGUH 16841, lower Lower Maastrichtian, Overstrand Hotel Upper Mass 2A, Norfolk; interior-posterior view of ventral valve, ×35. 2, MGUH 16842, lower Lower Maastrichtian, Little Marl Point 1B, Norfolk; exterior of broken valve, ×30.

Figs 3 and 4. *Isocrania costata* (J. de C. Sowerby, 1823). 3, MGUH 16843, upper Lower Maastrichtian, Trimingham (coll. WKC, 1971), Norfolk; interior of adult ventral valve, ×12. 4, MGUH 16844, lower Lower Maastrichtian, Sidestrand 1, Norfolk; exterior of juvenile ventral valve showing stem-shaped attachment surface, ×27.

Figs 5 and 6. *Craniscus* sp. MGUH 16845, lower Lower Maastrichtian, Little Marl Point 1A, Norfolk. 5, interior of fragmented dorsal valve, ×50. 6, oblique lateral view showing median septum, ×50.

Fig. 7. *Lacazella* (*Bifolium*) *wetherelli* Morris, 1851, MGUH 16846, lower Lower Maastrichtian, Little Marl Point 1B, Norfolk; interior of adult ventral valve, ×10.

PLATE 1



JOHANSEN and SURLYK, *Lingula, Isocrania, Craniscus, Lacazella*

Description. Shell small and thin. Outline irregular elongate, oval, almost parallel-sided, gently biconvex. Beak of ventral valve contains broad triangular groove for passage of pedicle. Posterior margins of shell are broadly pointed, anterior margins broadly rounded. Shell surface smooth apart from numerous growth lines. Shell composed of a brown to whitish material. Interior details not seen.

Remarks. The material is too sparse and fragmented to give a more precise statement of the species than *Lingula cretacea*?

Occurrence. Catton 1 and 3A, Bramerton, Overstrand Hotel Upper Mass 2A, Sidestrand 3A, Little Marl Point 1B and 2A and Trimingham 2?

Family CRANIIDAE Menke, 1828
Genus CRANIA Retzius, 1781

Type species. Anomia craniolaris Linnaeus, 1758, p. 700.

Crania aff. *craniolaris* (Linnaeus, 1758)

1972 *Crania* aff. *craniolaris* (Linnaeus); Surlyk, p. 27, fig. 5.

Material. Only one fragmented ventral valve, estimated length 4·4 mm.

Description. Outline rounded; valve attached to substrate by entire outer surface. Margin thickened and pustulose forming rather wide limbus. Anterior and posterior adductor scars close together in posterior part of valve. Surface of attachment area shows prominent growth lines and very fine radial striation, which may reflect nature of substrate.

Remarks. The specimen is too fragmentary for a reliable species determination, but it belongs to a fairly common group of rather small craniaceans, which occur in the chalk of northwest Europe and which resemble *Crania craniolaris* (Linnaeus 1758, p. 700) in virtually all features except for their much smaller size.

Occurrences. Trimingham 1 and elsewhere in the Upper Campanian and Maastrichtian of northwest Europe.

Genus ISOCRANIA Jaekel, 1902

Type species. Crania egnabergensis Retzius, 1781, p. 52.

Isocrania costata (J. de C. Sowerby, 1823)

Plate 1, figs 3 and 4

1823 *Crania costata* J. de C. Sowerby, pl. 35, fig. 6.
1973 *Isocrania costata* (J. de C. Sowerby); Surlyk, figs 1, 2, 5–10, 12; pl. 1, figs 1–11, 16–19; pls 3, 4, 6; fig. 12.
1975 *Isocrania costata* (J. de C. Sowerby); Nestler, p. 42, text-fig. 52.
1979 *Isocrania costata* (J. de C. Sowerby); Bitner and Pisera, p. 70, fig. 2.
1982 *Isocrania costata* (J. de C. Sowerby); Surlyk, fig. 1.
1984 *Isocrania costata* (J. de C. Sowerby); Ernst, p. 65–67, pl. 6, figs 3 and 4; pl. 7, figs 1–6; pl. 8, figs 1, 2, 9–11.
1984 *Isocrania costata* (J. de C. Sowerby); Surlyk and Johansen, fig. 1.
1987*a* *Isocrania costata* (J. de C. Sowerby); Johansen, fig. 7.
1988 *Isocrania costata* (J. de C. Sowerby); Johansen, fig. 2, pl. 4, fig. 4.

Material. Three dorsal, thirteen ventral valves and seven fragments; largest specimens all somewhat fragmentary. Dorsal valve from Sidestrand 1 is 5·8 mm wide. Catalogue numbers MGUH 16843, 16844.

Description. Outline rectangular to circular. Dorsal valve low conical with sculpture of 10–30 primary ribs. A few additional ribs form by intercalation increasing to a total of about 35. Ribs are strong, prominent, protruding somewhat beyond the valve margin. Anterior and posterior ribs straight; lateral ribs curve slightly in posterior direction. Surface of valve between ribs covered with coarse, radially directed spines. Interior surface has two closely situated anterior adductor scars. Posterior adductors separated by septum-like extension of limbus and also limited anterio-laterally by such extensions. Limbus wide and finely pustulose. Ventral valve similar to dorsal valve in outline and sculpture except for flat protegulal node in some cases showing imprints of tiny attachment substrates. Anterior adductor scars drop-shaped, converging anteriorly towards midline of valve. Posterior adductor scars oval, of same size and in same position as in dorsal valve. A pointed septum is situated between anterior adductors.

Remarks. I. costata can be distinguished from earlier forms known from the English Chalk by the low number of ribs which only protrude slightly beyond the valve margin, and by the subcentral position of the umbo.

Occurrence. Cley, Catton 5, Overstrand Hotel Lower Mass, Sidestrand 1, 1A and 3A, Little Marl Point 1B, 1, 1A, 2 and 4, and Trimingham 2. In addition the species is recorded from the Upper Campanian and Maastrichtian of northern Germany and eastern Poland, and from the Maastrichtian and Lower Danian of Denmark.

Genus CRANISCUS Dall, 1871

Type species. Crania tripartita Münster, 1837, p. 297.

Craniscus sp.

Plate 1, figs 5 and 6

Material. Three fragmentary dorsal valves. Largest valve 3·6 mm in diameter, and from Bramerton sample. Catalogue number MGUH 16845.

Description. Outline irregular subrectangular to subrounded. Dorsal valve conical, surface smooth. Anterior adductor scars in dorsal valve situated on two strong ridges extending posterio-laterally from apex, united with the median septum or ridge. The three ridges divide the valve into three chambers. Margins of valve not thickened. Inner surface with densely spaced minute cavities.

Remarks. The material is too poorly preserved to warrant any specific determination; generic assignment is based on the three characteristic ridges dividing the dorsal valve into three compartments.

Occurrence. Bramerton and Little Marl Point 1A.

Order RHYNCHONELLIDA Kuhn, 1949
Family RHYNCHONELLIDAE Gray, 1848
Unidentified rhynchonellids

Material. Twenty-two dorsal, forty-nine ventral valves and more than two hundred and fifty fragments. The material is too fragmentary for any further description but belongs to the family Rhynchonellidae, showing the characteristic glossy, fibrous structure of the thick and impunctate shell. Some fragments probably belong to *Cretirhynchia* sp. described below.

Occurrence. Cley, Keswick, Catton 3A and 4, Stoke Holy Cross 2, Catton 5 and 6, Caistor 1, Whitlingham, Bramerton, Overstrand Hotel Upper Mass 1A and 2, Sidestrand 1A and 2, Little Marl Point 1B, 1, 1A and 2, Trimingham 1, Little Marl Point 6 and 7, and Trimingham 2 and 3.

Subfamily CYCLOTHYRIDINAE Makridin, 1955
Genus CRETIRHYNCHIA Pettitt, 1950

Type species. Terebratula plicatilis J. Sowerby, 1816, p. 37.

Cretirhynchia sp.

Plate 2, figs 1 and 2

Material. Eight complete shells, nine dorsal and twelve ventral valves and a large number of fragments. All specimens represent early juvenile stages and no measurements have been obtained. Catalogue numbers MGUH 16847, 16848.

Description. Shell smooth, pointed oval in juvenile stages. Beak suberect to erect; deltidial plates have a characteristic growth pattern which results in two laterally directed wing-like doublings of the plates. This pattern is a result of changes in growth direction of deltidial plates during ontogeny as described by Steinich (1965). Material does not allow adequate description of brachidium or hinge, although inner socket ridges are strong, low, short and converge strongly anteriorly. Posteriorly they almost meet. Crura strongly built, long, converging ventrally.

Remarks. A large number of species of *Cretirhynchia* are recorded from the Upper Campanian and Lower Maastrichtian of Norfolk (e.g. Peake and Hancock 1961, 1970; Pettitt 1950, 1953). From the Upper Campanian *C. lentiformis* (Woodward) of the '*limbata* series' is present below the Weybourne Chalk Member, and *C. arcuata* Pettitt of the '*plicatilis* series' above this member. *C. norvicensis* Pettitt and *C. woodwardi* (Davidson) appear at the base of the Weybourne Chalk Member. In the Lower Maastrichtian *C. magna* Pettitt occurs in the Sidestrand Chalk Member along with *C.* aff. *arcuata* Pettitt and *C. retracta* (Roemer). *C. limbata* s.s. (Schlotheim) appears in the upper Lower Maastrichtian Beacon Hill Grey Chalk Member. Note that Pettitt's (1950, 1953) species are in need of revision.

It is not at present possible to recognize juveniles of these species and thus not possible to assign the present material to any known species.

Occurrence. Catton 1 and 3, Caistor 1 and 3, Overstrand Hotel Lower Mass, Bramerton, Overstrand Hotel Upper Mass 2A, Sidestrand 1 and 3A, Little Marl Point 1B, 2A, 5 and 7, and Trimingham 2 and 3.

Cretirhynchia limbata (Schlotheim, 1813)

Plate 2, figs 3–5

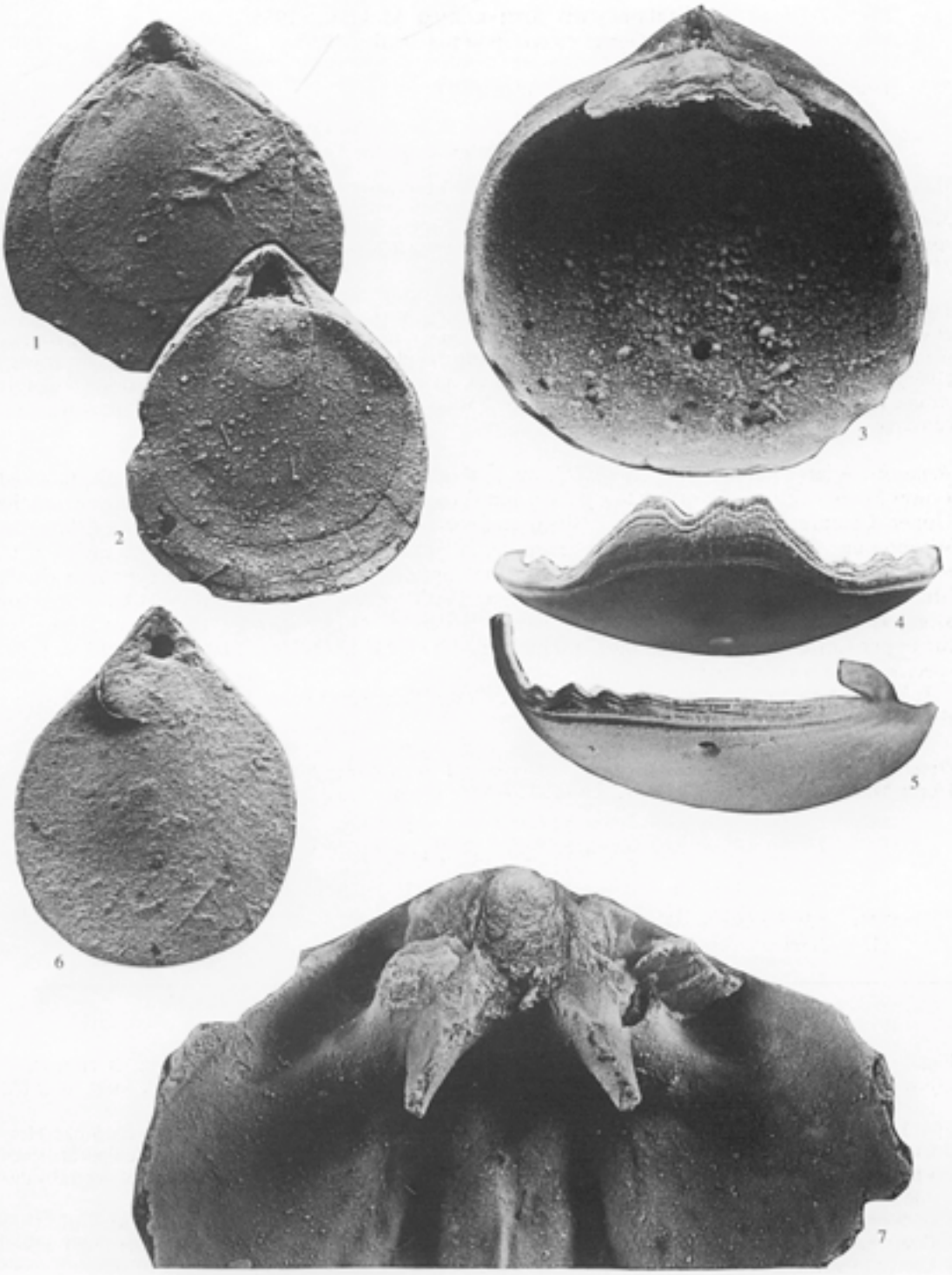
(1798) *Térébratulus fossiles* Faujas, pl. 26, fig. 4.
1813 *Terebratulites limbatus* Schlotheim, p. 113.

EXPLANATION OF PLATE 2

Figs 1 and 2. *Cretirhynchia* sp., MGUH 16847, lower Lower Maastrichtian, Little Marl Point 1B, Norfolk. 1, juvenile specimen in dorsal view, × 20. 2, MGUH 16848, lower Lower Maastrichtian, Little Marl Point 1A, Norfolk; small juvenile specimen in dorsal view, × 35.

Figs 3–5. *Cretirhynchia limbata* (Schlotheim, 1813), MGUH 16849, upper Upper Campanian, Stoke Holy Cross 1, Norfolk. 3, interior of medium-sized ventral valve, × 10. 4, frontal view showing uniplicate sinus with low rounded costae at anterior shell margin, × 10. 5, lateral view showing convexity of ventral valve and curvature of sinus and rostrum, × 8.

Figs 6 and 7. *Carneithyris subcardinalis* (Sahni, 1925). 6, MGUH 16850, lower Lower Maastrichtian, Overstrand Hotel Upper Mass 2A, Norfolk; juvenile specimen in dorsal view, × 10. 7, MGUH 16851, upper Lower Maastrichtian, Little Marl Point 6, Norfolk; posterior part of adult dorsal valve showing fused cardinalia, × 10.



JOHANSEN and SURLYK, *Cretirhynchia, Carneithyris*

1841 *Terebratula subplicata* Mantell; Roemer, p. 38, fig. 10.
1856 *Rhynchonella limbata* (Schlotheim); Boll, p. 47.
1894 *Rhynchonella limbata* (Schlotheim); Posselt, p. 27, fig. 1; pl. 2, fig. 16.
1953 *Cretirhynchia limbata* (Schlotheim); Pettitt, p. 27, fig. 16; pl. 1, fig. 1*a–c*; pl. 2, fig. 12*a–c*; text-figs 7*a–c*, 8, 9.
1965 *Cretirhynchia limbata* (Schlotheim); Steinich, p. 24, fig. 13; pl. 2, fig. 4*a–d*.
1972 *Cretirhynchia limbata* (Schlotheim); Surlyk, p. 24, fig. 17.

Material and occurrence. One bivalved, fragmentary adult specimen found in the Upper Campanian sample Stoke Holy Cross 1. Dimensions: length, 11·4 mm; width, 10·9 mm; length of dorsal valve, 10·0 mm; width of hinge line, 2·5 mm; width of foramen, 0·5 mm. Fragments of this species are probably also present among the fragments of the *Cretirhynchia* sp. described elsewhere in this paper. Catalogue number MGUH 16849.

Description. Shell relatively pointed subtriangular in outline. Shell surface smooth except for weak rib pattern developed along anterior shell margin. Uniplicate sinus with low, rounded costae developed in anterior commissure. Shell almost plano-convex with dorsal valve strongly convex. Ventral valve fragmentary but probably only slightly convex. Beak low, pointed incurved; foramen is small, oval to subcircular and limited by collar-like deltidium. Hinge strong, consists of strongly built, blunt, triangular hinge teeth, inner sockets which continue directly into the crura. Cardinal process present but material does not allow study of brachidium.

Remarks. Both external features and nature of the hinge are consistent with descriptions of *Cretirhynchia limbata* (Schlotheim) by Steinich (1965) and others. This is the first record of *C. limbata* in the Upper Campanian of Norfolk. It is widely distributed in the Maastrichtian of England, the Netherlands, northern Germany and Denmark.

Family TEREBRATULIDAE Gray, 1840
Genus CARNEITHYRIS Sahni, 1925

Type species. Carneithyris subpentagonalis Sahni, 1925, p. 364.

Carneithyris subcardinalis (Sahni, 1925)

Plate 2, figs 6 and 7

1842 *Terebratula carnea* J. Sowerby; Hagenow, p. 539, fig. 13.
1894 *Terebratula carnea* J. Sowerby; Posselt, p. 38, fig. 29.
1909 *Terebratula carnea* J. Sowerby; Nielsen, p. 163, pl. 2, figs 68–77.
1925 *Chatwinothyris subcardinalis* Sahni, p. 369, pl. 23, fig. 9; pl. 24, fig. 4, 4*a*; pl. 26, fig. 4, 4*a*.
1929 *Chatwinothyris subcardinalis* Sahni; Sahni, p. 40, pl. 5, figs 20–22; pl. 6, figs 10–12; pl. 10, figs 1–4.
1965 *Chatwinothyris subcardinalis* Sahni; Steinich, p. 37, figs 24–34; pl. 5, figs 1*a–d*, 2*a–d*, 3, 4; pl. 7, figs 1*a*, *b*, 2; pl. 11, figs 1, 2*a–b*, 3.
1972 *Carneithyris subcardinalis* (Sahni); Surlyk, p. 24, figs 5, 11, 16–18; pl. 5, fig. c.
1975 *Carneithyris subcardinalis* (Sahni); Asgaard, p. 320, pl. 8, figs 1–4.
1982 *Carneithyris subcardinalis* (Sahni); Surlyk, fig. 1, pl. 1, fig. *a*.
1984 *Carneithyris subcardinalis* (Sahni); Surlyk and Johansen, fig. 1.
1987*a* *Carneithyris subcardinalis* (Sahni); Johansen, p. 13, pl. 2, fig. 2.
1988 *Carneithyris subcardinalis* (Sahni); Johansen, fig. 2.

Material. Five complete shells, ten dorsal, twenty-two ventral valves and about ninety fragments. No usable measurements have been obtained. Catalogue number MGUH 16851.

Description. Adult shell large, relatively thin, with large punctae. The outline changes during ontogeny from elongated pointed oval to oval – subpentangonal. Biconvex except for earliest juvenile stages which are almost plano-convex. Shell surface smooth, anterior commissure straight. Hinge line short; beak changes from acute and suberect to incurved in adult stages. Foramen very small through ontogeny, due to presence of two

characteristically large triangular deltidial plates. In large forms foramen is circular and of submesothyridid to mesothyridid pin-hole type. Hinge strong in adults with dorsal cardinalia so that socket ridges, cardinal process and crural bases are fused. Cardinal process typically lacking. Brachidium simple, consists, in juveniles, of short, rather widely separated crura. During growth descending branches develop from dorsal part of crura, ultimately to fuse and thereby form a transverse bridge.

Remarks. The material is consistent with descriptions of *Carneithyris subcardinalis* (Sahni) by Sahni (1925, 1929), Steinich (1965), Asgaard (1975) and Johansen (1987*a*). A more detailed description of the ontogenetic stages is given by these authors. The juveniles of *C. subcardinalis* are distinguished from other small smooth-shelled related species by the very small foramen limited by two triangular, deltidial plates.

Occurrence. The species was first described by Sahni (1925) from the Lower Maastrichtian *Ostrea lunata* Zone of Trimingham, Norfolk. In the present paper the species is recorded from the following samples: Catton 1, 3, 5? and 6, Stoke Holy Cross 1, Caistor 1?, Overstrand Hotel Lower Mass, Bramerton, Overstrand Hotel Upper Mass 1A, Sidestrand 1 and 3A, Little Marl Point 1A, 4, 5 and 6, and Trimingham 2 and 3. *Carneithyris subcardinalis* is in addition recorded from the Maastrichtian and Upper Campanian of Denmark, northern Germany and Poland.

Order TEREBRATULIDA Waagen, 1883
Family TEREBRATULIDAE Gray, 1840

Undetermined terebratulid

Remarks. Fragments of a punctate, smooth and thin-shelled form occur in the samples Overstrand Hotel Upper Mass 2, Caistor 3 and 1, all of Early Maastrichtian age. The state of the material does not allow any generic assignment of the fragments but it is clearly a juvenile terebratulid.

Family CANCELLOTHYRIDIDAE Thomson, 1926
Genus TEREBRATULINA d'Orbigny, 1847

Type species. Anomia craniolaris Linnaeus, 1758, p. 700.

Terebratulina chrysalis (Schlotheim, 1813)

Plate 3, figs 1–5

1813 *Terebratulites chrysalis* Schlotheim, p. 113.
1894 *Terebratulina striata* Wahlenberg; Posselt, p. 32, fig. 19; p. 5, footnote 3; p. 10.
1909 *Terebratulina striata* Wahlenberg; Nielsen, p. 159, fig. 20; pl. 1, figs 28–32; p. 134, fig. 20; p. 137, fig. 20; pp. 138–139, fig. 20; p. 141, fig. 20; p. 144.
1965 *Terebratulina chrysalis* (Schlotheim); Steinich, p. 53, figs 44–61; pl. 8, fig. 1*a–d*; pl. 9, figs 1–5, 9*a*, *b*, 10*a*, *b*.
1972 *Terebratulina chrysalis* (Schlotheim); Surlyk, p. 21, figs 12–18; pl. 4, figs 5–8.
1979 *Terebratulina chrysalis* (Schlotheim); Bitner and Pisera, p. 73, pl. 3, figs 12–15.
1982 *Terebratulina chrysalis* (Schlotheim); Surlyk, fig. 1.
1984 *Terebratulina chrysalis* (Schlotheim); Surlyk and Johansen, fig. 1.
1987*a* *Terebratulina chrysalis* (Schlotheim); Johansen, p. 14, fig. 14A–D; pl. 4, figs 1–5.
1988 *Terebratulina chrysalis* (Schlotheim); Johansen, fig. 2; pl. 2, figs 7–10.

Material. At least forty-five complete shells, one hundred and thirty-five dorsal and seventy ventral valves and a large number of fragments. The size of fully grown specimens has not been measured or estimated. Catalogue numbers MGUH 16852–16855.

Description. Shell relatively large. Outline changes during ontogeny from elongated subtriangular to elongated subpentagonal. The juveniles possess large, well-defined auricles which in adults become small and oblique. Shell surface with 8 to more than 60 straight ribs, increasing by intercalation. Ribs strong and coarsely

tuberculate in the juveniles, sculpture characteristically consists of nodes placed on top of ribs, never forming transverse half rings as is seen in *Terebratulina faujasii* and *T. longicollis*. Rib width constant through ontogeny, interspaces very wide in large specimens. Beak short, suberect; foramen changes from subtriangular hypothyridid to oval submesothyridid with growth. Hinge relatively weak. Brachidium development as in other terebratulinids (e.g. Steinich 1965) forming strong crura; short, robust descending branches terminate in closed brachial ring, rather wide in *T. chrysalis*. The spicular skeleton well-mineralized; plectolophe.

Remarks. The material is consistent with descriptions of *Terebratulina chrysalis* by a large number of authors, e.g. Steinich (1965) and Johansen (1987*a*). *T. longicollis* Steinich differs from *T. chrysalis* in the lack of intercalated ribs or branching of ribs, the coarse rib sculpture and very elongated outline. *T. faujasii* (Roemer) differs from *T. chrysalis* in possessing single undivided ribs ornamented by coarse transverse half rings.

Occurrence. Cley, Catton 3 and 4, Stoke Holy Cross 2, Caistor 1 and 3, Whitlingham, Overstrand Hotel Lower Mass, Bramerton, Overstrand Hotel Upper Mass 1A, 1, 2, 2A, 3 and 4, Sidestrand 1, 1A, 2, 3, 3A, 4 and 5, Little Marl Point 1B, 1, 1A, 2A, 3, 4 and 7, and Trimingham 2 and 3. *Terebratulina chrysalis* is widespread and very common throughout the Upper Cretaceous and Danian chalks of northwest Europe.

Terebratulina faujasii (Roemer, 1841)

Plate 4, figs 8 and 9

1841 *Terebratula faujasii* Roemer, p. 40, fig. 24; pl. 7, fig. 8.
1965 *Terebratulina faujasii* (Roemer); Steinich, p. 72, figs 76–94; pl. 9, figs 6–8; pl. 10, figs 1*a–d*, 2–5.
1972 *Terebratulina faujasii* (Roemer); Surlyk, p. 18, figs 5, 12, 14–16, 18; pl. 2, figs *c–g*.
1982 *Terebratulina faujasii* (Roemer); Surlyk, fig. 1, pl. 1, figs *c* and *d*.
1984 *Terebratulina faujasii* (Roemer); Surlyk and Johansen, fig. 1.
1987*a* *Terebratulina faujasii* (Roemer); Johansen, p. 15, pl. 7, fig. 3.
1988 *Terebratulina faujasii* (Roemer); Johansen, fig. 2.

Material. Seventy-five complete shells, 296 dorsal, 268 ventral valves, and approximately 300 fragments. Largest specimen is a fragmented dorsal valve from Sidestrand 3A: length of dorsal valve, 4·5 mm; width, 5·0 mm; 12 ribs. Catalogue numbers MGUH 16861, 16860.

Description. Outline changes during ontogeny from broad subtriangular to elongated subtriangular with maximum width at anterior shell margin. Auricles large. Shell surface with 8–12 straight, coarse, broad single ribs, with sculpture of very coarse prominent transverse half rings on rib crests. Beak low, suberect to erect; foramen large, triangular, submeso- to mesothyridid in the adults. Brachidium consists of strong crura, distinct descending arms and closed brachial ring. Spicular skeleton well-mineralized; plectolophe.

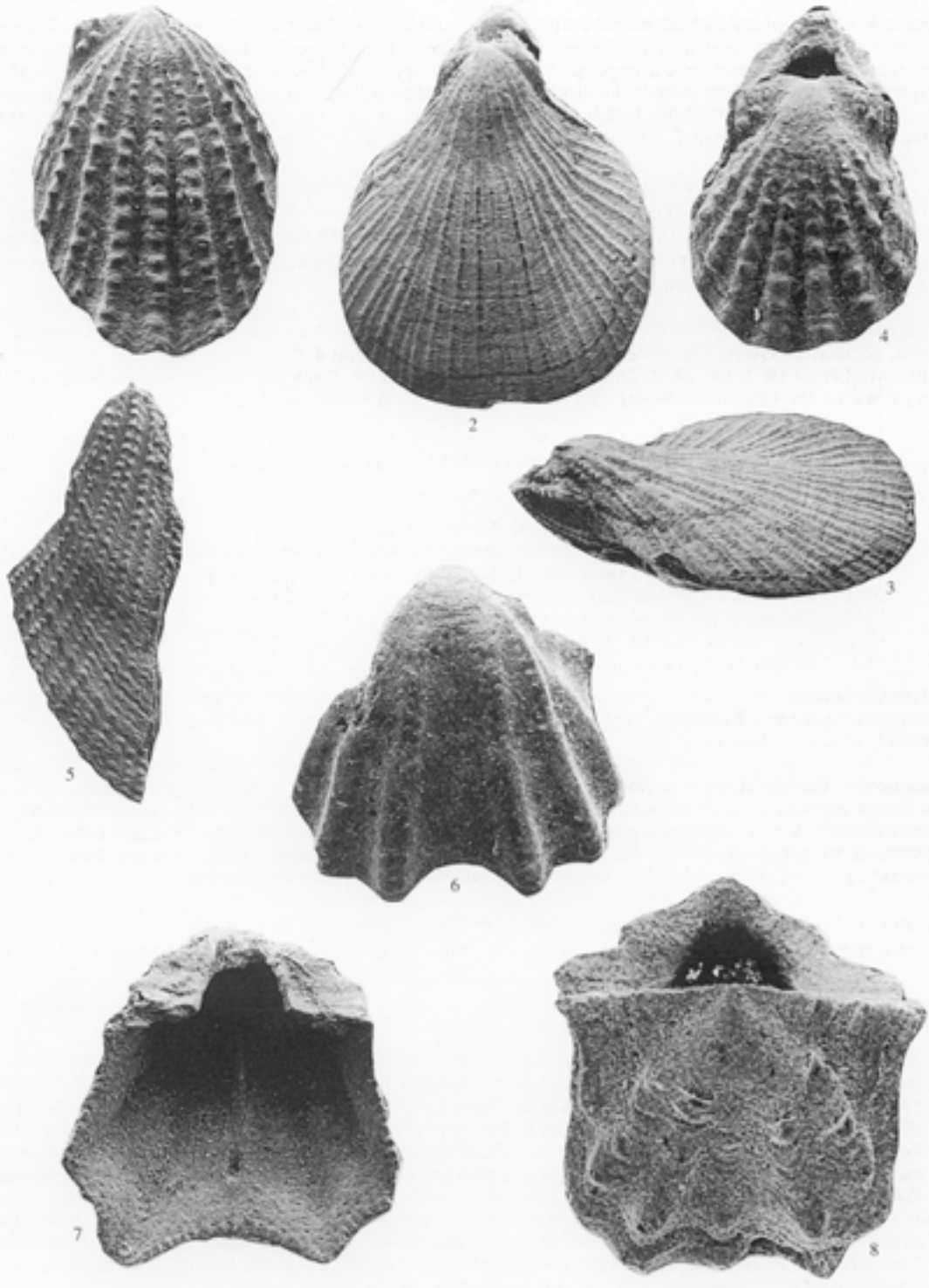
Remarks. Terebratulina faujasii differs from other *Terebratulina* species in possessing single ribs with a sculpture of coarse transverse half rings. Juveniles of *Gisilina jasmundi* Steinich differ from *T.*

EXPLANATION OF PLATE 3

Figs 1–5. *Terebratulina chrysalis* (Schlotheim, 1813). 1, MGUH 16852, lower Lower Maastrichtian, Sidestrand 1A, Norfolk; exterior of juvenile dorsal valve, × 15. 2 and 3, MGUH 16853, Lower Maastrichtian, Rørdal, Denmark (coll. MBJ, 1981); 2, adult specimen in dorsal view, × 10; 3, lateral view. 4, MGUH 16854, lower Lower Maastrichtian, Overstrand Hotel Upper Mass 2A, Norfolk; small juvenile specimen in dorsal view, × 35. 5, MGUH 16855, upper Upper Campanian, Caistor 1, Norfolk; fragment of large specimen showing characteristic rib pattern, × 10.

Figs 6–8. *Argyrotheca hirundo* (Hagenow, 1842). 6, MGUH 16856, Campanian–Maastrichtian boundary strata?, Bramerton, Norfolk; exterior of adult ventral valve, × 22. 7, MGUH 16857, lowermost Maastrichtian, Bramerton, Norfolk; interior of adult ventral valve, × 22. 8, SPGIH 3534, upper Lower Campanian, G 79, Lägerdorf; adult specimen in dorsal view, × 20.

PLATE 3



JOHANSEN and SURLYK, *Terebratulina, Argyrotheca*

faujasii in possessing a larger number of weaker sculpted ribs. Juveniles of *T. chrysalis* (Schlotheim) differ from *T. faujasii* in having intercalated ribs at a very early growth stage.

Occurrence. Catton 3A, 4 and 5, Caistor 1, Whitlingham, Bramerton, Overstrand Hotel Lower Mass, Overstrand Hotel Upper Mass 1, 1A, 2, 2A, 3 and 4, Sidestrand 1, 1A, 2, 3, 3A, 4 and 5, Little Marl Point 1, 1A, 1B, 2, 2A and 3, Trimingham 1, Little Marl Point 6 and 7, and Trimingham 2 and 3. In addition, the species is recorded from the Upper Campanian – Maastrichtian of Denmark, northern Germany and Poland.

Terebratulina gracilis (Schlotheim, 1813)

Plate 4, figs 1–7

1813 *Terebratulites gracilis* Schlotheim, p. 113, pl. 3, fig. 3*a*, *b*.
1860 *Terebratulina gracilis* (Schlotheim); Bosquet, p. 390.
1866 *Terebratulina gracilis* (Schlotheim); Schloenbach, p. 287, pl. 38, figs 18*a*, *b*, 19*a*, *b*, 20*a*, *b*.
1894 *Terebratulina gracilis* (Schlotheim); Posselt, p. 33, fig. 20; pl. 3, figs 5–7.
1908 *Terebratulina gracilis* (Schlotheim); Brydone, p. 403.
1909 *Terebratulina gracilis* (Schlotheim); Nielsen, p. 161, fig. 22; p. 134, fig. 22; p. 137, fig. 22.
1965 *Terebratulina gracilis* (Schlotheim); Steinich, p. 81, figs 95–114; pl. 11, fig. 1*a–d*; pl. 12, figs 1, 2*a*, *b*; pl. 13, figs 1–3.
1972 *Terebratulina gracilis* (Schlotheim); Surlyk, p. 24, figs 5, 9, 11, 13, 15*b*, 18–22.
1982 *Terebratulina gracilis* (Schlotheim); Surlyk, fig. 1.
1984 *Terebratulina gracilis* (Schlotheim); Surlyk and Johansen, fig. 1.
1987*a* *Terebratulina gracilis* (Schlotheim); Johansen, p. 16, pl. 7, figs 7–9.
1988 *Terebratulina gracilis* (Schlotheim); Johansen, fig. 2; pl. 1, fig. 5*a*, *b*.

Material. Fifty complete shells, 320 dorsal and 170 ventral valves, and more than 1200 fragments. Largest specimen from Sidestrand 2 (lower Lower Maastrichtian) representing ventral valve medium sized adult: length, 3·4 mm; width, 3·2 mm; dorsal valve length, 3·4 mm; width of foramen, 0·3 mm; 30 ribs. Material also contains fragments from larger specimens, but no usable measurements have been obtained from these. Catalogue numbers MGUH 16858, 16859; SPGIH 3535–3538.

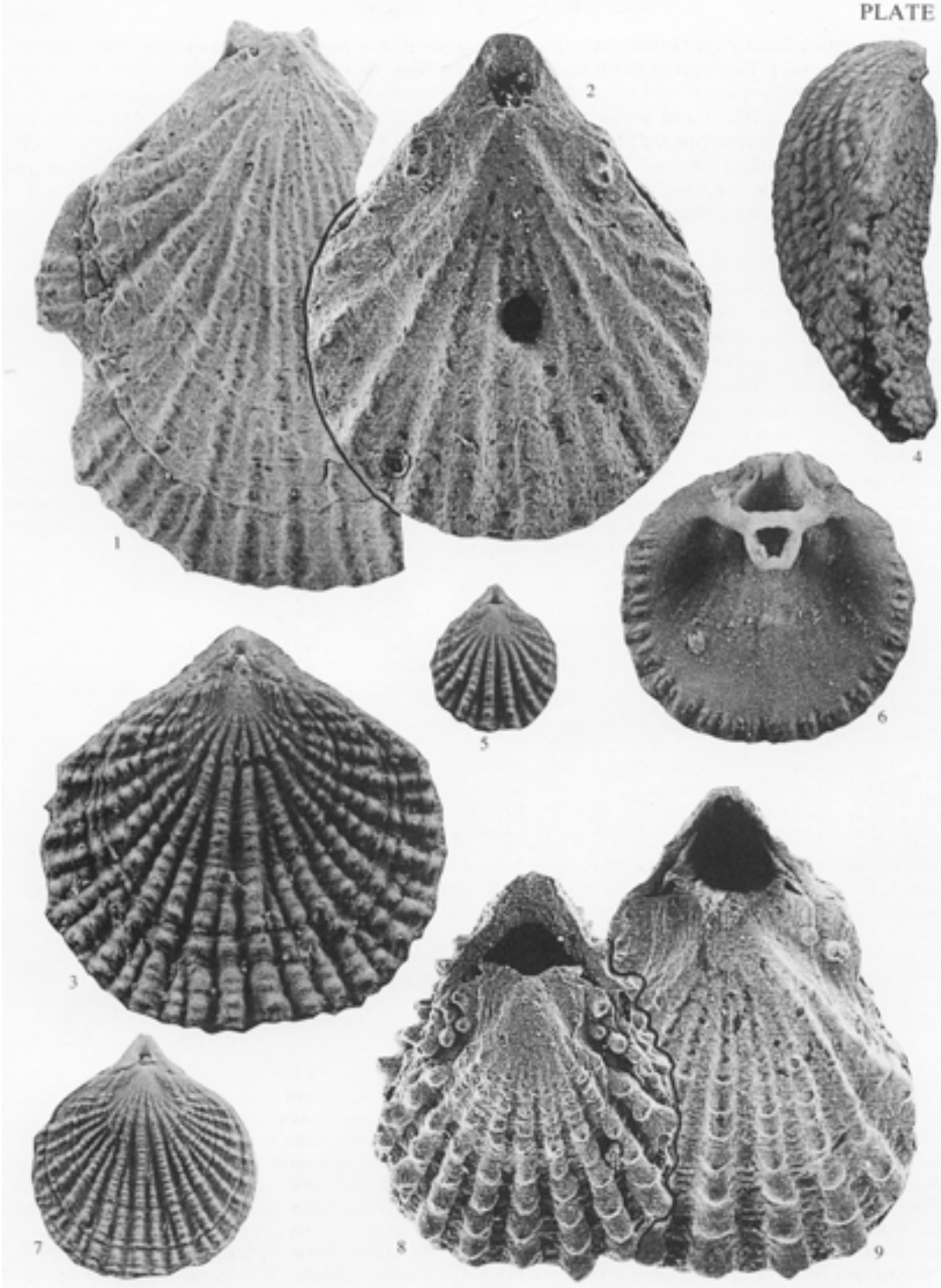
Description. Shells large, thick. Outline changes from elongated oval to subcircular during growth. Juvenile shells are biconvex, ventral valve of highest convexity; adults plano-convex. Very early growth stages possess 8–10 straight finely knobbed strong radial ribs forming characteristic fanlike pattern. At shell length of approximately 1·5 mm lateral deflection of ribs begins; at this stage new ribs form by intercalation. Large specimens may possess 50–60 ribs. Hinge line very short, oblique; auricles small. Beak short, erect to somewhat incurved; foramen oval, submesothyridid to permesothyridid and small throughout ontogeny. Hinge strong; brachidium consists of thin crura and closed brachial ring. Probably plectolophe.

EXPLANATION OF PLATE 4

Figs 1–7. *Terebratulina gracilis* (Schlotheim, 1813). 1, MGUH 16858, upper Lower Maastrichtian, Little Marl Point 7, Norfolk; broken adult dorsal valve in exterior view showing lateral bend of ribs, × 15. 2, MGUH 16859, upper Lower Maastrichtian, Little Marl Point 3, Norfolk; large juvenile in dorsal view, × 30. 3 and 4, SPGIH 3535, lower Lower Maastrichtian, G 148–150, Kronsmoor; 3, adult specimen in dorsal view, × 10; 4, lateral view showing reclining profile, × 10. 5, SPGIH 3536, lower Lower Maastrichtian, G 148–150, Kronsmoor; small juvenile specimen in dorsal view, × 5. 6, SPGIH 3537, lower Lower Maastrichtian, G 148–150, Kronsmoor; interior of adult dorsal valve showing ring-formed brachidium, × 8. 7, SPGIH 3538, lower Lower Maastrichtian, G 148–150, Kronsmoor; large juvenile in dorsal view, × 8.

Figs 8 and 9. *Terebratulina faujasii* (Roemer, 1841). 8, MGUH 16860, upper Lower Maastrichtian, Trimingham 1, Norfolk; adult specimen in dorsal view, × 22. 9, MGUH 16861, lower Lower Maastrichtian, Overstrand Hotel Upper Mass 2A, Norfolk; adult specimen in dorsal view, × 30.

PLATE 4



JOHANSEN and SURLYK, *Terebratulina*

Remarks. The species is consistent with descriptions of *Terebratulina gracilis* (Schlotheim) by, for example, Steinich (1965) and Johansen (1987*a*). *Terebratulina gracilis* differs from other species of *Terebratulina* in the plano-convex shell, short incurved beak, very small foramen and the high number of deflected ribs. Later forms of *T. gracilis* (e.g. from the Upper Maastrichtian of Denmark) possess almost concavo-convex shells and highly incurved beaks; these two features represent modifications for a free living mode of life on soft chalk substrates and presumably had not yet reached optimum development in the Upper Campanian–Lower Maastrichtian.

Gisilina gisii (Roemer) differs from juvenile *T. gracilis* in having straight, faintly nodate or almost smooth ribs.

Throughout the literature *T. gracilis* has been confused with *Terebratulina rigida* (J. Sowerby). Schloenbach (1866) described and compared *T. gracilis* and *T. rigida* and from both his descriptions and illustrations it is clear that *T. rigida* is smaller and possesses a less incurved beak and much less reflexed ribs than *T. gracilis*. *T. rigida* or a close relative is present in the Norfolk material. It is described below as *T.* cf. *rigida* and is slightly biconvex, possesses finely knobbed ribs which are only very slightly reflexed in large forms and possesses a distinct hinge line. It has, however, not in all cases been possible to separate the two species, but the material is dominated by *T. gracilis*.

Occurrence. Cley?, Keswick, Catton 3A and 4, Stoke Holy Cross 1, Catton 5 and 6, Caistor 3 and 1?, Whitlingham, Overstrand Hotel Lower Mass, Bramerton?, Overstrand Hotel Upper Mass 1A, 1, 2?, 2A, 3? and 4, Sidestrand 1A?, 2, 3?, 3A and 4?, Little Marl Point 1B, 1, 1A, 2, 2A? and 3, Trimingham 1, Little Marl Point 4, 5, 6 and 7, and Trimingham 2 and 3. *Terebratulina gracilis* is in addition known from the Upper Campanian and Maastrichtian of northern Germany, and the Maastrichtian of the Netherlands, Denmark, southern Sweden and eastern Poland.

Terebratulina longicollis Steinich, 1965

Plate 5, figs 4 and 5

1965 *Terebratulina longicollis* Steinich, p. 66, figs 62–75, pl. 8, fig. 2*a–d*.
1972 *Terebratulina longicollis* Steinich; Surlyk, p. 18, figs 5, 12–15, 17, 18.
1979 *Terebratulina longicollis* Steinich; Bitner and Pisera, p. 75, pl. 3, figs 9–11.
1982 *Terebratulina longicollis* Steinich; Surlyk, fig. 1, pl. 1, fig. *e*.
1984 *Terebratulina longicollis* Steinich; Surlyk and Johansen, fig. 1.
1987*a* *Terebratulina longicollis* Steinich; Johansen, p. 16, figs 15A–F; pl. 7, figs 4–6.
1988 *Terebratulina longicollis* Steinich; Johansen, fig. 2, pl. 2, fig. 11.

Material. Seven complete specimens, four dorsal and six ventral valves. Largest specimen is from Little Marl Point 3: length, 2·8 mm; width, 1·7 mm; length of dorsal valve, 2·2 mm; thickness, 1·0 mm; 9 ribs. Catalogue numbers MGUH 16865; SPGIH 3539.

Description. Outline elongate subpentagonal. Auricles small, but clearly defined. Biconvex, ventral valve the more convex. Commissure is straight. At 0·5 mm width there are 6–8 radial ribs; larger specimens normally have 8–10 ribs. Width and height of ribs increases during growth; new ribs occasionally form in the auricular

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EXPLANATION OF PLATE 5

Figs 1–3. *Terebratulina* cf. *rigida* (J. de C. Sowerby, 1821), lower Upper Campanian, Catton 1, Norfolk. 1, MGUH 16862, exterior of medium-sized dorsal valve, ×20. 2, MGUH 16863, medium-sized specimen in dorsal view, ×30. 3, MGUH 16864, interior of adult ventral valve showing recrystallized spicular skeleton of a plectolophe, brachidium itself is broken off, ×25.

Figs 4 and 5. *Terebratulina longicollis* Steinich, 1965. 4, SPGIH 3539, upper Upper Campanian, G 142, Kronsmoor; adult specimen in dorsal view, ×25. 5, MGUH 16865, upper Lower Maastrichtian, Little Marl Point 3, Norfolk; interior of adult ventral valve showing large foramen, ×30.

PLATE 5

JOHANSEN and SURLYK, *Terebratulina*

regions external to first formed ribs; no intercalated ribs. Ribs straight; sculpture comprises small crescentic nodes. Rib sculpture strongest on the ventral valve. Rib width is 1·5 times the width of interspaces; 1–2 growth lines. Beak suberect, short, the cardinal area very narrow, sharply delimited. Foramen initially hypothyridid, later mesothyridid. Deltidial plates converge anteriorly during growth resulting in subcircular foramen. Pedicle collar well developed. Inner socket ridges high, thin, long; outer socket ridges low. Hinge teeth relatively strong, pointed. Brachidium begins to form at 0·6 mm width. Fully developed terebratulinid brachidium attained at width about 1·5 mm (see Steinich 1965, fig. 71).

T. longicollis possesses a well-developed spicular skeleton in mantle, anterior body wall, and lophophore arms. Plectolophe at maturity.

Inner shell surface has smooth topography matching that of exterior. Shell relatively thick.

Remarks. T. longicollis can be distinguished from *T. chrysalis* (Schlotheim) by its undivided ribs. Juvenile *T. chrysalis*, in which intercalation of new ribs has not appeared, are always relatively wider, and the ribs lack the crescentic sculpture of *T. longicollis*. The ribs of *T. longicollis* are furthermore much more closely-spaced. *T. longicollis* resembles *T. faujasii* (Roemer) in that both have undivided ribs and similar rib sculpture, but they can always be distinguished by the very elongate outline of *T. longicollis*.

Occurrence. Whitlingham, Bramerton, Overstrand Hotel Upper Mass 1A and 2A, Little Marl Point 2 and 3, and Trimingham 3. The species is in addition recorded from the Upper Campanian and Maastrichtian of northern Germany and eastern Poland, and from the Maastrichtian and possibly also Lower Danian of Denmark.

Terebratulina cf. *rigida* (J. Sowerby, 1829)

Plate 5, figs 1–3

cf. 1829 *Terebratula rigida* J. Sowerby, p. 69, pl. 536, fig. 2.
cf. 1866 *Terebratulina rigida* (J. Sowerby); Schloenbach, p. 287, pl. 38, figs 10–17.

Material. Eleven complete shells, twelve dorsal, thirty-two ventral valves, and a large number of fragments. Largest complete specimen is juvenile from Catton 1: length, 3·8 mm; width, 3·1 mm; length of dorsal valve, 2·8 mm; thickness, 1·3 mm; width at hinge line, 1·0 mm; width of foramen, 0·5 mm; 21 ribs. Catalogue numbers MGUH 16862–16864.

Description. Shell relatively large, biconvex, outline subtriangular, rather thick and punctuate. Auricles small but distinct; hinge line straight. At shell width 2·0 mm, shell bears 10 ribs, at 2·5 mm, 18–20 ribs and at 3·0 mm 23–25 ribs. New ribs arise by intercalation; ribs straight to slightly reflexed in larger specimens. Rib sculpture consists of closely-spaced transverse half rings, most prominent on ventral valve. Beak erect, blunt to slightly incurved; foramen rather large, broad, triangular to elongate oval. Deltidial plates high, triangular, converging; internal morphology otherwise poorly known. Plate 5, fig. 3 shows a recrystallized spicular skeleton from a plectolophous lophophore.

Remarks. T. gracilis and *T. rigida* have been confused since their descriptions in 1813 and 1821 respectively (Schloenbach 1866; J. Sowerby 1829). Steinich (1965) and Johansen (1987*a*) both mention this problem. *T. rigida* is in general smaller, possesses a larger foramen, a less incurved beak and ribs much less reflexed than in *T. gracilis*. The Norfolk specimens correspond to *T. rigida*, but as the material does not permit detailed observations of internal morphology, we refer to the material as *T.* cf. *rigida*.

T. chrysalis differs from *T.* cf. *rigida* in possessing a more elongated outline, and more ribs, which retain their width during growth.

Occurrence. Catton 1, 3, 4 and 6, Sidestrand 1A? and 2?, Little Marl Point 1B?, and Trimingham 2.

Terebratulina subtilis Steinich, 1965

Plate 6, figs 1 and 2

1965 *Terebratulina subtilis* Steinich, p. 93, figs 115–129; pl. 9, fig. 2*a–d*.
1970*b* *Terebratulina subtilis* Steinich; Surlyk, p. 13, fig. 3.
1972 *Terebratulina subtilis* Steinich; Surlyk, p. 18, fig. 2.
1982 *Terebratulina subtilis* Steinich; Surlyk, fig. 1.
1988 *Terebratulina subtilis* Steinich; Johansen, fig. 2.

Material. Eleven complete shells, twenty-six dorsal, twenty-five ventral valves, and thirty-five fragments. The largest specimen is from Little Marl Point 6: length, 2·5 mm; width, 2·0 mm; thickness, 0·8 mm; length of dorsal valve, 2·1 mm; 48 ribs. Catalogue numbers MGUH 16866, 16867.

Description. Shell thin with smooth interior. Outline very elongate subpentagonal to subtriangular in juvenile stages, changing into more pointed oval with growth. Biconvex to almost plano-convex; dorsal valve normally convex umbonally, otherwise flat. Auricles poorly-defined; commissure straight. Ornament consists of numerous delicate radial ribs. At a width of *c.* 0·5 mm, 3–10 relatively wide ribs appear. New ribs arise by intercalation and are always narrower than earlier formed ribs. Specimens 2 mm or more wide have 40–50 ribs of very low amplitude bearing a characteristic sculpture of small granules often somewhat coarser on ventral than on dorsal valve, where they may be very difficult to detect. Growth lines indistinct or absent. Beak short, suberect, cardinal area narrow, but well-defined. Foramen limited by two narrow triangular deltidial plates; develops from hypothyridid to submesothyridid during growth. Pedicle collar wide, well-developed. Hinge rather weakly–developed; inner socket ridges thin. Brachidium develops at a width 0·4 mm; normal, rather delicate terebratulinid brachidium present at width *c.* 1·3 mm.

Spicular skeleton well-developed, normally strongly recrystallized. Plectolophe. Mantle spicules not found.

Remarks. Terebratulina subtilis shows great resemblance to *Rugia tenuicostata* Steinich, and the juveniles of the two species are particularly difficult to separate. *T. subtilis*, however, always has a larger number of ribs, and a less pointed beak. The most important difference is in the rib morphology where *R. tenuicostata* has rather high, relatively widely-spaced serrate ribs, while *T. subtilis* has flat densely-spaced ribs with only small rather rounded tubercles.

Occurrence. Keswick?, Catton 1, 3 and 5, Overstrand Hotel Lower Mass, Overstrand Hotel Upper Mass 1A, 1 and 2, Sidestrand 2 and 3A, Little Marl Point 2A, Trimingham 1, Little Marl Point 6 and 7, and Trimingham 3. In addition, the species is known from the Lower Maastrichtian of northwest Germany, East Germany and Denmark.

Genus GISILINA Steinich, 1963

Type species. Terebratula gisii Roemer, 1841, p. 40, fig. 23.

Gisilina gisii (Roemer, 1841)

Plate 6, figs 3–5

1841 *Terebratula gisii* Roemer, p. 40, fig. 23.
1963*b* *Gisilina gisii* (Roemer); Steinich, p. 732, figs 1–8.
1965 *Gisilina gisii* (Roemer); Steinich, p. 100, figs 130–148; pl. 14, figs 2 and 3*a–d*; pl. 15, figs 1–7.
1972 *Gisilina gisii* (Roemer); Surlyk, p. 18, figs 2, 12, 20–22.
1982 *Gisilina gisii* (Roemer); Surlyk, fig. 1, pl. 2, fig. *d*.
1988 *Gisilina gisii* (Roemer); Johansen, fig. 2.

Material. Three complete shells, eleven dorsal, six ventral valves, and one fragment. Largest specimen is a dorsal valve from Caistor 1: length of dorsal valve, 3·1 mm; width, 3·2 mm; 12 ribs. Catalogue numbers MGUH 16868; SPGIH 3540.

Description. Outline rounded subtriangular; auricles small, indistinct. Shell rather thick, strongly biconvex, ventral valve having highest convexity. Shell surface with 7–12 straight, coarse, broad, smooth or faintly nodate ribs. New ribs arise by intercalation. Beak changes from acute and suberect to slightly incurved or erect during ontogeny. Foramen large, initially hypothyridid, thereafter submesothyridid and in some cases

mesothyridid in large forms, and thus partly absorbed in ventral valve. Inner socket ridges short and teeth strong. Little can be said of the brachidium in present material: crura very short. Probably a plectolophe.

Remarks. Large specimens of *G. gisii* are easily distinguished from *G. jasmundi* Steinich because they are more strongly biconvex, have smooth to faintly nodate ribs, and a mesothyridid foramen. Small specimens are very difficult to distinguish from juvenile *Terebratulina chrysalis* (Schlotheim) and *G. jasmundi*. *G. gisii* has fewer ribs than *T. chrysalis* and is more biconvex. *G. jasmundi* is less biconvex than *G. gisii* and has distinctly coarser sculpted ribs. Ribs are single in *G. jasmundi*.

Occurrence. Caistor 1, Overstrand Hotel Lower Mass, Overstrand Hotel Upper Mass 1A, 2 and 3, Little Marl Point 7, and Trimingham 2. The species is also recorded from the Upper Campanian and Maastrichtian of northwest Germany, and the Maastrichtian of East Germany, southern Sweden and Denmark.

Gisilina jasmundi Steinich, 1965

Plate 6, fig. 6

1965 *Gisilina jasmundi* Steinich, p. 110, figs 149–161; pl. 16, figs 1*a–d* and 2.
1972 *Gisilina jasmundi* Steinich; Surlyk, p. 18, figs 2, 5, 13, 15*a*, 16, 17.
1982 *Gisilina jasmundi* Steinich; Surlyk, fig. 1, pl. 2, figs *a–c*.
1984 *Gisilina jasmundi* Steinich; Surlyk and Johansen, fig. 1.
1987*a* *Gisilina jasmundi* Steinich; Johansen, p. 21, pl. 8, fig. 3.
1988 *Gisilina jasmundi* Steinich; Johansen, fig. 2.

Material. At least one complete shell, twelve dorsal, two ventral valves, and four fragments. Largest specimen represented by ventral valve from Sidestrand 1: length, 3·8 mm; width, 3·0 mm; length of dorsal valve, 3·0 mm; width of hinge line, 2·4 mm; 13 ribs. Catalogue number MGUH 16869.

Description. Norfolk specimens have subtriangular to subpentangonal outline and small but distinct auricles. Beak suberect, foramen large, submesothyridid. Hinge line short, straight. Characteristic for this species are 12–18 straight, radial, and coarsely nodate single ribs, and a relatively flat shell. Rib sculpture varies between coarse knobs on top of ribs and prominent transverse half rings arranged across the ribs. Inner socket ridges high, teeth short. Crura short, other details of brachidium not seen. Probably plectolophe.

Remarks. G. jasmundi is thoroughly described by Steinich (1965). Large specimens of *G. jasmundi* recall *Terebratulina faujasii* (Roemer), but differ in the larger number of ribs, flatter shell, and finer

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EXPLANATION OF PLATE 6

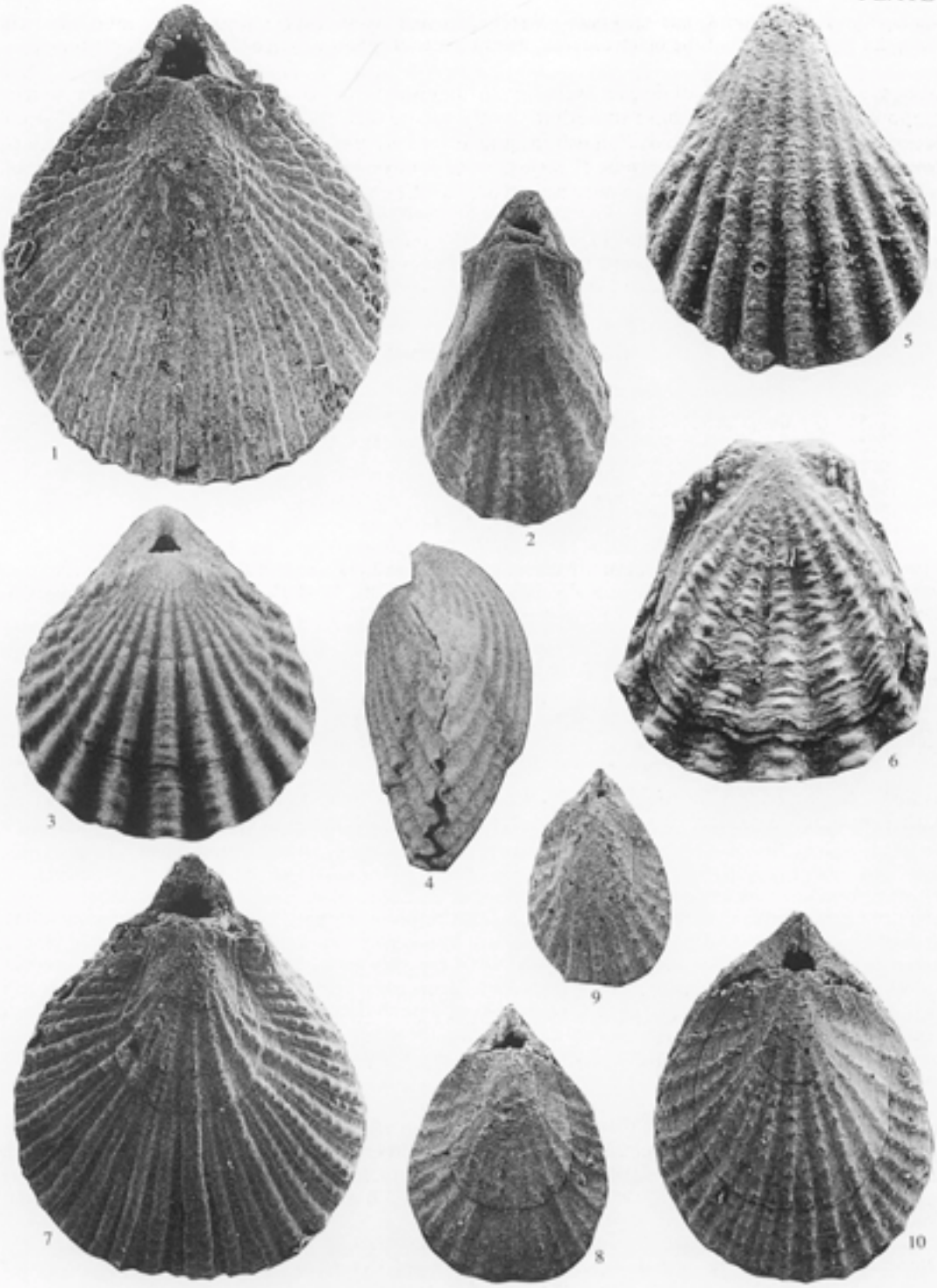
Figs 1 and 2. *Terebratulina subtilis* Steinich, 1965. 1, MGUH 16866, lower Upper Campanian, Keswick, Norfolk; dorsal view of adult specimen, ×30. 2, MGUH 16867, lowermost Maastrichtian, Overstrand Hotel Upper Mass 1A, Norfolk; dorsal view of juvenile specimen, ×30.

Figs 3–5. *Gisilina gisii* (Roemer, 1841). 3 and 4, SPGIH 3540, lower Upper Campanian, G 140, Lägerdorf; 3, adult specimen in dorsal view, ×18. 4, lateral view showing strongly biconvex shell, ×18. 5, MGUH 16868, upper Lower Maastrichtian, Trimingham 2, Norfolk; medium-sized adult ventral valve in exterior view, ×25.

Fig. 6. *Gisilina jasmundi* Steinich, 1965. MGUH 16869, uppermost Campanian, Overstrand Hotel Lower Mass, Norfolk; medium-sized adult ventral valve in exterior view, ×25.

Fig. 7. *Rugia tenuicostata* Steinich, 1963. MGUH 16870, lower Upper Campanian, Keswick, Norfolk; adult specimen in dorsal view, ×25.

Figs 8–10. *Rugia acutirostris* Steinich, 1965, lower Lower Maastrichtian, Overstrand Hotel Upper Mass 2A, Norfolk. 8, MGUH 16871, juvenile in dorsal view, ×27. 9, MGUH 18226, Norfolk; small juvenile in dorsal view, ×20. 10, MGUH 18227, adult specimen in dorsal view, ×25.



JOHANSEN and SURLYK, *Terebratulina, Gisilina, Rugia*

sculptured rib surface. Small specimens of *G. jasmundi* with more faintly sculptured ribs are extremely difficult to distinguish from juveniles of *G. gisii* (Roemer) and *T. chrysalis* (Schlotheim). Juvenile *G. jasmundi* possess coarse sculptured, single ribs; *T. chrysalis* is elongate and has intercalated ribs.

Occurrence. Overstrand Hotel Lower Mass, Overstrand Hotel Upper Mass 1A and 3?, and Sidestrand 1. In addition, the species is recorded from the Maastrichtian of northwest Germany, East Germany and Denmark.

Genus RUGIA Steinich, 1963

Type species. Rugia tenuicostata Steinich, 1963*b*, p. 735, fig. 3.

Rugia tenuicostata Steinich, 1963

Plate 6, fig. 7

1963*b* *Rugia tenuicostata* Steinich, p. 738, figs 6, 7, 8*a–d.*
1965 *Rugia tenuicostata* Steinich; Steinich, p. 116, figs 162–174; pl. 11, 3*a–d* and 4.
1970 *Rugia tenuicostata* Steinich; Surlyk, figs 2 and 3.
1972 *Rugia tenuicostata* Steinich; Surlyk, p. 8, figs 2, 5, 12, 16.
1979 *Rugia tenuicostata* Steinich; Bitner and Pisera, p. 77, pl. 4, figs 3–6; pl. 5, fig. 3.
1982 *Rugia tenuicostata* Steinich; Surlyk, fig. 1, pl. 1, figs *f–h.*
1984 *Rugia tenuicostata* Steinich; Surlyk and Johansen, fig. 1.
1987*a* *Rugia tenuicostata* Steinich; Johansen, p. 22, figs 18F, G, pl. 7, fig. 2.
1987*b* *Rugia tenuicostata* Steinich; Johansen, p. 159, figs 3, 14A–F; pl. 6, figs 1–5.
1988 *Rugia tenuicostata* Steinich; Johansen, fig. 2, pl. 2, fig. 1.

Material. Seventeen complete shells, eighty-one dorsal, sixty-nine ventral valves, and one hundred fragments. Largest specimen from Keswick: length, 2·48 mm; width, 2·04 mm; length of dorsal valve, 2·12 mm; thickness, 0·96 mm; 41 ribs. Catalogue number MGUH 16870.

Description. Outline very elongate subtriangular in early growth stages, changing through ontogeny to more pointed oval. Shell is biconvex; dorsal valve always less convex than ventral valve. Inner shell smooth. Some juvenile specimens may have completely flat dorsal valve. Auricles indistinct. Commissure straight. Shell ornamentation of straight radial ribs with serrate sculpture. Initial ribs are formed at width 0·4 mm, number increases by intercalation from about 6–7 to 28–30. In rare cases large forms have 40 ribs, but last 10 ribs are very narrow low intercalatories close to shell margin. Ribs are of uniform height and width through ontogeny. Rib density varies considerably, decreasing markedly during ontogeny. Rib sculpture highly characteristic, comprising small triangular tubercles aligned on top of ribs, giving saw-tooth appearance. New intercalated ribs often form an acute angle to adjacent older ribs but change to more parallel alignment during growth. Growth lines uncommon. beak short, suberect, pointed in juvenile stages; more rounded in adult forms. Cardinal area narrow, well-defined. Foramen delineated by two narrow deltidial plates, which grow in ventro-median direction in the earliest stages; at shell width of 0·6 mm they grow outwards in ventro-lateral direction; at width of 0·7 mm growth direction changes to median. Pedicle collar increases relative length in growth to half length of beak. Foramen triangular, hypothyridid. Hinge close to that of *Terebratulina*. Brachidium consists of long, thin crura, converging strongly anteriorly. Crural processes short, spoon-shaped, not fused during growth. Descending branches thin, fusing under acute angle. Mantle and arms heavily spiculate; lophophore plectolophe.

Remarks. R. tenuicostata can be distinguished from *R. acutirostris* Steinich by the less acute beak, lower rib density, and characteristic rib sculpture. Juveniles are difficult to separate from *Terebratulina subtilis* Steinich, other than by the rib characters; *T. subtilis* has numerous weakly sculptured very low ribs.

Occurrence. Cley, Keswick, Catton 1?, 3, 3A and 4, Stoke Holy Cross 1, Catton 5 and 6, Caistor 3 and 1, Whitlingham, Overstrand Hotel Upper Mass 1A, Little Marl Point 1?, 1A and 5?. Also known from the Upper Campanian to Maastrichtian of northwest and East Germany, Denmark and Poland.

Rugia acutirostris Steinich, 1965

Plate 6, figs 8–10

1965 *Rugia acutirostris* Steinich, p. 122, figs 175–178; pl. 14, 1*a–d*.
1970 *Rugia acutirostris* Steinich; Surlyk, figs 2 and 3.
1972 *Rugia acutirostris* Steinich; Surlyk, p. 18, figs 2, 5, 14, 18.
1979 *Rugia acutirostris* Steinich; Bitner and Pisera, p. 77, pl. 3, figs 1–3.
1982 *Rugia acutirostris* Steinich; Surlyk, fig. 1, pl. 1, figs *i* and *j*.
1984 *Rugia acutirostris* Steinich; Surlyk and Johansen, fig. 1.
1987*a* *Rugia acutirostris* Steinich; Johansen, p. 22, pl. 7, fig. 1A, B.
1987*b* *Rugia acutirostris* Steinich; Johansen, p. 163, figs 3, 15A–F; pl. 5, fig. 4.
1988 *Rugia acutirostris* Steinich; Johansen, fig. 3.

Material. Thirty-eight complete shells, sixty dorsal, thirty-seven ventral valves, and sixty fragments. Largest specimen is from Overstrand Hotel Upper Mass 1A: length, 2·0 mm; length of dorsal valve, 1·7 mm; width, 1·5 mm; thickness, 0·8 mm; 26 ribs. Catalogue numbers MGUH 16871, 18226, 18227.

Description. Outline changes from elongate subpentagonal to pointed oval during ontogeny. Auricles small, blunt. Shell biconvex, the valves of equal convexity. 6–8 radial ribs are present at shell width of 0·2–0·3 mm. Ribs increase in number by intercalation to about 40. Rib width constant during growth. Rib sculpture consists of small, scale-like tubercles; in some specimens ribs are smooth. Lateral ribs curve slightly outwards. Beak very acute, suberect. Cardinal area wide, clearly delineated, triangular, slightly concave. Foramen very small, elongate triangular, hypothyridid, limited by two narrow slightly elevated deltidial plates, often granular. Pedicle collar very long. Hinge and brachidium development as in *R. tenuicostata*. Inner surface of shell is smooth. The mantle and arms heavily spiculate. Plectolophe.

Remarks. R. acutirostris is characterized by its pointed oval outline, its very acute beak, and small foramen.

Occurrence. Overstrand Hotel Lower Mass, Bramerton, Overstrand Hotel Upper Mass 1A, 1, 2A, 3 and 4, Sidestrand 1, 1A, 3A and 4, and Little Marl point 5 and 7. Also known from both the Lower and Upper Maastrichtian of northwest and East Germany, Denmark and Poland.

Rugia tegulata Surlyk, 1970

Plate 7, figs 1 and 2

1970*a* *Rugia tegulata* Surlyk, p. 152, pl. 1, figs *a–e*, fig. 4*a–d*.
1972 *Rugia tegulata* Surlyk; Surlyk, p. 18, fig. 5.
1984 *Rugia tegulata* Surlyk; Surlyk, fig. 2.
1988 *Rugia tegulata* Surlyk; Johansen, fig. 2.

Material. Five dorsal, three ventral valves, and four fragments. Largest specimen a dorsal valve: length, 1·6 mm; width, 1·9 mm; 21 ribs. Catalogue numbers MGUH 18228–9.

Description. Outline subtriangular to pointed oval; length to width ratio decreases rapidly during growth. Auricles blunt; shell slightly biconvex, dorsal valve being a little less convex than ventral valve. Ornament very characteristic: radial ribs with imbricate, plate-like scales. Rib number increases rapidly by intercalation from about 5 at width 0·5 mm to about 20 in largest specimens. Beak suberect; cardinal area small. Foramen is triangular, hypothyridid, limited by two deltidial plates which often take the form of irregular ridges with constriction at middle of each plate. Inner socket ridges short, strong. Crurae long, thin; full brachidium is not preserved. Shell is rather thick; gentle undulations on inner surface correspond to the ribs on outer.

Remarks. Although limited the material falls well within the range of the type material from the lower Upper Maastrichtian of Denmark. The characteristic rib sculpture distinguishes it from other Chalk brachiopods.

Occurrence. All specimens are from Little Marl Point 1A. The species has previously been described only from the lower Upper Maastrichtian of Denmark.

Rugia spinosa Surlyk, 1970

1970*a* *Rugia spinosa* Surlyk, p. 157, fig. 3*d–f*; pl. 2, figs *a–d*; table 1.
1972 *Rugia spinosa* Surlyk; Surlyk, p. 18, figs 2, 5.
1982 *Rugia spinosa* Surlyk; Surlyk, p. 262, fig. 1.
1984 *Rugia spinosa* Surlyk; Surlyk, p. 219, figs 2 and 3.
1987*b* *Rugia spinosa* Surlyk; Johansen, p. 157, figs 3, 11A–F, 12A, B, 13.
1988 *Rugia spinosa* Surlyk; Johansen, fig. 2.

Material. One fragmentary valve and two fragments.

Description. Shell small and thin, outline oval to pointed oval. Auricles are blunt. Shell strongly biconvex, anterior commissure straight. Shell sculpture comprises long, pointed spines of variable form and size in many cases extending from irregular, poorly-developed radial ribs. They tend to be at right angles to the shell surface on the posterior part of the shell, while larger and directed forwards in the anterior part of shell. Spines may be arranged in rows, on a more-or-less distinctly developed rib. Ribs few in number, irregularly distributed, often best seen on inside of shell as strong, well-defined smooth ribs. Beak very short, pointed and suberect. Cardinal area and deltidial plates narrow. Foramen very small, submesothyridid. Inner socket ridges short with anterior lateral bend, close together. Teeth short, pointed. Crura thin, cylindrical, originating from position anterior to inner socket ridges. Inner surface of the shell smooth apart from a few irregularly distributed ribs.

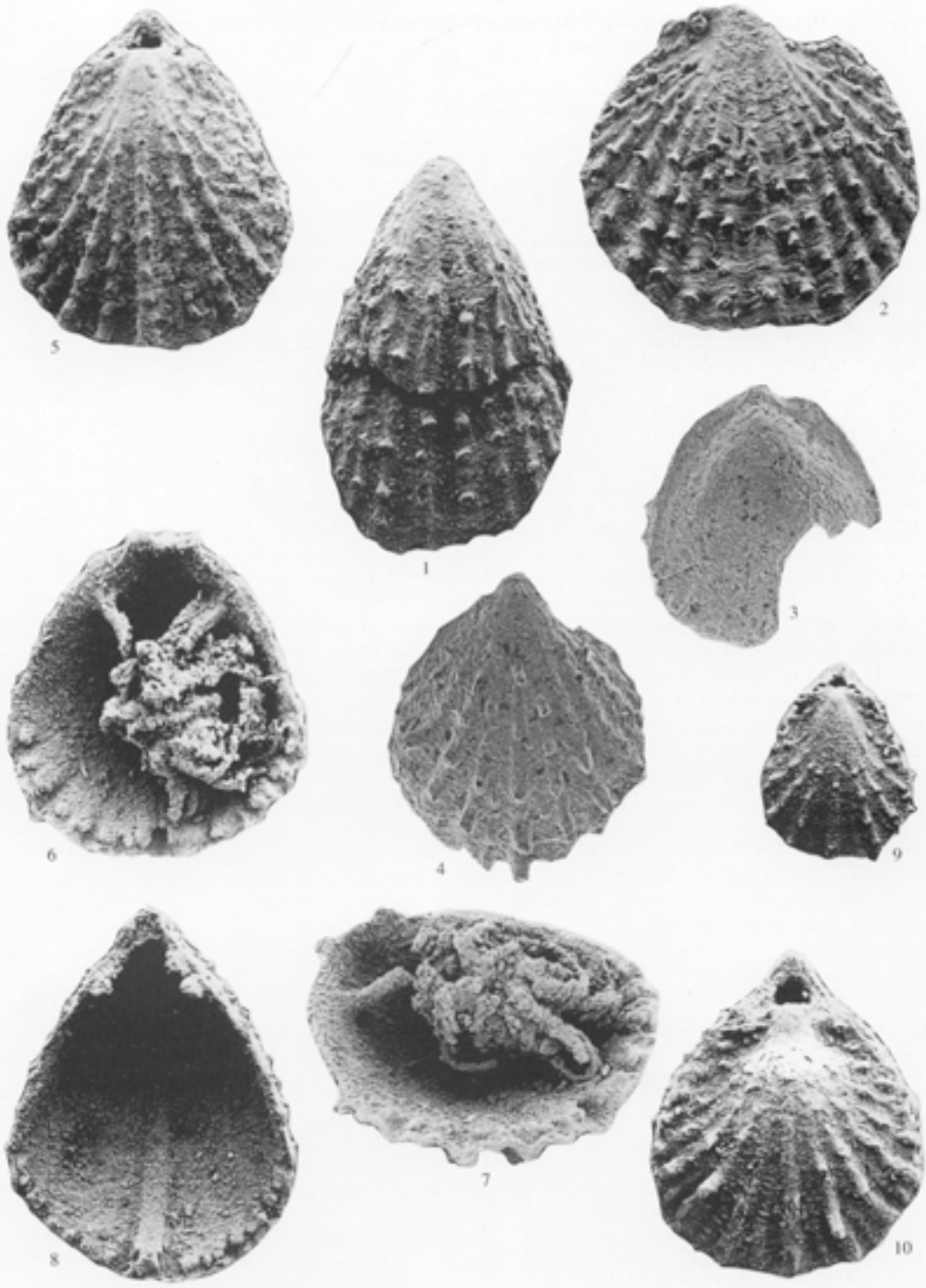
Remarks. R. spinosa is characterized by its rib sculpture; it differs from *R. spinicostata* Johansen and Surlyk in having only a few irregularly distributed ribs. Bitner and Pisera (1979) emended the original diagnosis of *R. spinosa* to include forms with regularly distributed ribs, but study of abundant stratigraphically well-dated material of this form from eastern England, northwest Germany and Denmark shows that lower Lower Maastrichtian forms are *R. spinosa*, while Upper Campanian forms belong to *R. spinicostata*, described below (Surlyk 1982; Johansen 1987*b*). Bitner and Pisera (1979) assigned the Mielnik chalk section, eastern Poland to the Lower Maastrichtian because of the presence of *R. spinosa* in the lower part of the section, but the Polish material clearly belongs to *R. spinicostata*. The lower part of the Mielnik section is thus most probably of Late Campanian age.

Occurrence. Overstrand Hotel Upper Mass 1A and 2A. Also known from the lower Lower Maastrichtian of Denmark and northwest and East Germany.

EXPLANATION OF PLATE 7

Figs 1 and 2. *Rugia tegulata* Surlyk, 1970. 1, MGUH 18228, lower Lower Maastrichtian, Little Marl Point 1A, Norfolk; exterior of broken ventral valve, ×30. 2, MGUH 18229, lower Lower Maastrichtian, Little Marl Point 1A, Norfolk; exterior of dorsal valve, ×20.

Figs 3–10. *Rugia spinicostata* Johansen and Surlyk *in* Johansen, 1987*b*. 3, MGUH 18230, upper Upper Campanian, Catton 3A, Norfolk; interior of broken adult dorsal valve, ×25. 4, MGUH 18231, upper Upper Campanian, Cley, Norfolk; ventral valve in exterior view, ×25. 5, SPGIH 3541, upper Lower Campanian, G 81, Lägerdorf; adult specimen in dorsal view, ×30. 6 and 7, SPGIH 3542A, lower Upper Campanian, G 103, Lägerdorf; 6, interior of adult dorsal valve showing almost complete spoon-shaped brachidium and recrystallized plectolophous lophophore, ×30; 7, oblique lateral view showing long recrystallized spicular skeleton of lophophore filaments, ×30. 8, SPGIH 3542B, interior of ventral valve corresponding to dorsal valve shown on figs 6 and 7, ×30. 9, SPGIH 3543, upper Lower Campanian, G 78, Lägerdorf; juvenile in dorsal view, ×20. 10, SPGIH 3544, lower Upper Campanian, G 103, Lägerdorf; dorsal view, ×30. dorsal view, ×30.



JOHANSEN and SURLYK, *Rugia*

Rugia spinicostata Johansen and Surlyk, 1987 *in* Johansen, 1987*b*

Plate 7, figs 3–10

1979 *Rugia spinosa* Surlyk; Bitner and Pisera, p. 78, pl. 3, figs 4–8.
1982 *Rugia spinosa* s.l. Surlyk; Surlyk, p. 262, fig. 1.
1984 *Rugia spinosa* s.l. Surlyk; Surlyk, p. 219, fig. 2.
1987*b* *Rugia spinicostata* Johansen and Surlyk; Johansen, p. 152, figs 3 and 11A–F; pl. 5, figs 1–3.
1988 *Rugia spinicostata* Johansen and Surlyk; Johansen, fig. 2, pl. 2, fig. 2.

Material. Five dorsal, six ventral valves, and three fragments. Largest Norfolk specimen a ventral valve from the upper Upper Campanian of Cley: length, 1·6 mm; width, 1·4 mm; length of dorsal valve, 1·3 mm; width of hinge line, 0·8 mm; foramen diameter, 0·2 mm; 22 ribs. Catalogue numbers MGUH 18230, 18231; SPGIH 3541, 3542A and B, 3543, 3544.

Description. Shell small, pointed oval to pointed subtriangular in outline. Strongly biconvex, anterior commissure straight. Auricles are blunt; stumpy. Surface sculpture of long, pointed spines extending from regularly distributed radial ribs, slightly reflexed in larger forms. Spines are cylindrical, pointed solid, variable in form and size. Spines arranged in rows on distinct ribs; in most cases spines are directed anteriorly. About 16 ribs present at shell width 1·0 mm; about 26 at 2·0 mm. Inside of the shell typically with very prominent, strong, smooth straight median rib and several straight and smooth ribs lateral to this. Beak short, suberect; cardinal area narrow. Deltidial plates narrow, triangular, foramen small, subtriangular, submesothyridid.

Structure of hinge and brachidium similar to *R. acutirostris* and *R. tenuicostata*. Inner socket ridges strong, short and close together, forming an anterio-lateral bend. Cardinal process small, bulbous, protrudes well beyond posterior shell margin together with inner socket ridges. Teeth short, pointed, triangular. Crura long, thin, developing from anterior edge of inner socket ridges. Descending branches converge rapidly and fuse in strong bridge. Ascending branches short. Shell relatively thin. Plectolophe when adult.

Remarks. R. spinicostata differ from other *Rugia* species in possessing a surface sculpture of long, pointed spines extending from regularly distributed and distinct radial ribs; it was first recognized and described as a distinct form *Rugia spinosa* s.l. by Surlyk (1982).

The surface sculpture of *Rugia spinosa* Surlyk also consists of long, pointed spines, but in this species spines often extend from poorly-developed, irregular, radial ribs, which are fewer in number than in *R. spinicostata*. Ribs of *R. spinosa* often are recognized only from the inside of the shell as strong, smooth ridges (Surlyk 1970*a*).

R. spinosa is generally smaller than *R. spinicostata* and possesses a shorter and more pointed beak, and very close-lying, anterio-laterally bent inner socket ridges (Johansen 1987*b*).

Occurrence. Cley, Keswick, and Catton 1, 3, 3A and 4. Also known from the Lower to the upper Upper Campanian of northwest Germany, and from possible Upper Campanian strata of eastern Poland (see discussion under *Rugia spinosa*).

Genus DRACIUS Steinich, 1967

Type species. Dracius carnifex Steinich, 1967, p. 1146, pl. 1, fig. 1.

Dracius carnifex Steinich, 1967

Plate 9, figs 5–8

1967 *Dracius carnifex* Steinich, p. 1145, figs 1–7; pl. 1, figs 1–4.
1972 *Dracius carnifex* Steinich; Surlyk, figs 5, 16, 18.
1982 *Dracius carnifex* Steinich; Surlyk, fig. 1, pl. 2, figs *e* and *f*.
1988 *Dracius carnifex* Steinich; Johansen, fig. 2.

Material. One ventral valve and two fragments. Catalogue numbers MGUH 18241, 18242; SPGIH 3548, 3849.

Remarks. Limited material prevents detailed description, but characteristic ribbing of the ventral valve points to *D. carnifex*. Ribs at a shell length *c.* 0·5 mm are seen as 7–8 highly irregular rows of small spines. Ribs become stronger during growth and separation increases markedly. Ribs ornamented by small often spiny tubercles. Interspaces bear a dense cover of identical tubercles.

Occurrence. Whitlingham (?) and Overstrand Hotel Lower Mass. Also known from the Maastrictian of East and northwest Germany and Denmark.

Family MEGATHYRIDIDAE Dall, 1870
Genus ARGYROTHECA Dall, 1900

Type species. Terebratula cuneata Risso, 1826, p. 388.

Argyrotheca bronnii (Roemer, 1841)

Plate 8, figs 1–4, 7

1841 *Terebratula bronnii* v. Hagenow; Roemer, p. 41, fig. 31.
1965 *Argyrotheca bronnii* (Roemer); Steinich, p. 124, figs 179–196; pl. 17, figs 1*a–d* and 2*a–d*.
1972 *Argyrotheca bronnii* (Roemer); Surlyk, p. 20, figs 5, 14–16; pl. 4*g*.
1979 *Argyrotheca bronnii* (Roemer); Bitner and Pisera, p. 78, pl. 4, figs 1 and 2.
1982 *Argyrotheca bronnii* (Roemer); Surlyk, fig. 1, pl. 3, figs *i* and *j*.
1984 *Argyrotheca bronnii* (Roemer); Surlyk and Johansen, fig. 1.
1987*a* *Argyrotheca bronnii* (Roemer); Johansen, p. 27.
1988 *Argyrotheca bronnii* (Roemer); Johansen, fig. 2.

Material. Three complete shells, seventeen dorsal and twenty ventral valves, and twenty-seven fragments. Largest specimen is from Sidestrand 1: length, 2·52 mm; width, 3·32 mm; length of dorsal valve, 2·08 mm; thickness, 1·56 mm; eight ribs. Catalogue numbers MGUH 18232–3; SPGIH 3543, 3546.

Description. A very variable species. Outline semicircular to subpentagonal. Hinge margin often extended into small wings. Juveniles clearly biconvex, but plano-convex shape is rapidly attained. Rib number increases during growth from four to about eight. Ribs divided into two wide bundles, separated by shallow median sinus. Single ribs can develop in sinus at all stages of growth. Ribs rather flat, extending only slightly beyond shell margin; there are up to eight strong growth lines. Beak pointed; nearly straight to suberect. Cardinal area plane to slightly concave. Deltidial plates are narrow, foramen large, triangular. Pedicle collar well-developed with concave anterior margin. Inner socket ridges diverge strongly anteriorly. Cardinal process developed as low knob between posterior edges of inner socket ridges. Two concave circular separated hinge plates are situated anterior to the cardinal process. Brachidium is not preserved in present material. Dorsal median septum high, extended in ventral direction by attached distal ends of descending branches giving septum a characteristic split appearance. Ventral septum very thin, short. Inner surface of the shell is ornamented by a weak negative of external sculpture. Margin slightly elevated, finely tuberculated.

Remarks. The great variability of *A. bronnii* results in morphological overlap with several other species. It can normally be separated from these on the basis of its rib number, split median septum, disjunct hinge plates and low median sinus.

Occurrence. Catton 5, Caistor 3 and 1, Overstrand Hotel Lower Mass, Overstrand Hotel Upper Mass 1A, 2A and 3, Sidestrand 1, 1A, 4 and 5, Little Marl Point 1, 5 and 6?, and Trimingham 2. The species is also recorded from the Upper Campanian and Maastrichtian of England, the Netherlands, northwest and East Germany, eastern Poland and Denmark. In Denmark it also occurs in the Lower Danian.

Argyrotheca coniuncta Steinich, 1965

Plate 8, figs 5, 6, 8 and 9

1965 *Argyrotheca coniuncta* Steinich, p. 138, figs 200–206; pl. 18, fig. 2*a–d*.
1972 *Argyrotheca coniuncta* Steinich; Surlyk, p. 20, figs 5–12.
1979 *Argyrotheca coniuncta* Steinich; Bitner and Pisera, p. 79, pl. 5, figs 5–7.
1982 *Argyrotheca coniuncta* Steinich; Surlyk, fig. 1, pl. 4, figs *a–d*.
1984 *Argyrotheca coniuncta* Steinich; Surlyk and Johansen, fig. 1.
1987*a* *Argyrotheca coniuncta* Steinich; Johansen, p. 28, pl. 12, fig. 5A, B.
1988 *Argyrotheca coniuncta* Steinich; Johansen, fig. 2.

Material. One complete shell, nine dorsal, eight ventral valves, and six fragments. Largest specimen a dorsal valve from Overstrand Hotel Upper Mass 2: length of dorsal valve, 3·4 mm; width (which corresponds to the width of the hinge line), 7·0 mm; 12 ribs. Catalogue numbers MGUH 18234–18236; SPGIH 3547.

Description. Outline characteristically semicircular very often with wing-like extensions of the hinge line. Anterior commissure straight, shell flat biconvex, shell surface bears 6–12 low, straight ribs. Beak erect and characteristically strongly withdrawn. Foramen very large, hypothyridid, triangular; hinge strong; cardinal process small, anterior margins of inner socket ridges much longer than posterior. Hinge plates fused mid-dorsally into closed platform, sometimes seen as individual plates separated by median furrow. Dorsal median septum high, strong, not split. Shell surface with large punctae; rather thick.

Remarks. The specimens investigated correspond in many details to the originals of *A. coniuncta* described by Steinich (1965). Minor differences in the development of the hinge plates are, however, observed as the hinge plates in specimens from Rügen always fuse to form a closed platform (Steinich 1965), while the hinge plates in the specimens from Norfolk form both closed platforms and separate plate-like hinge plates.

Large forms of *A. bronnii* (Roemer) differ from *A. coniuncta* in always possessing two distinctly separate concave disc-like hinge plates and a split dorsal median septum.

Occurrence. Overstrand Hotel Lower Mass, Bramerton, Overstrand Hotel Upper Mass 1A, 1, 2 and 2A, Sidestrand 1 and 3A, and Little Marl Point 2. Also known from the Upper Campanian and Maastrichtian of northwest Germany and from the Maastrichtian of East Germany, Denmark and eastern Poland.

Argyrotheca hirundo (Hagenow, 1842)

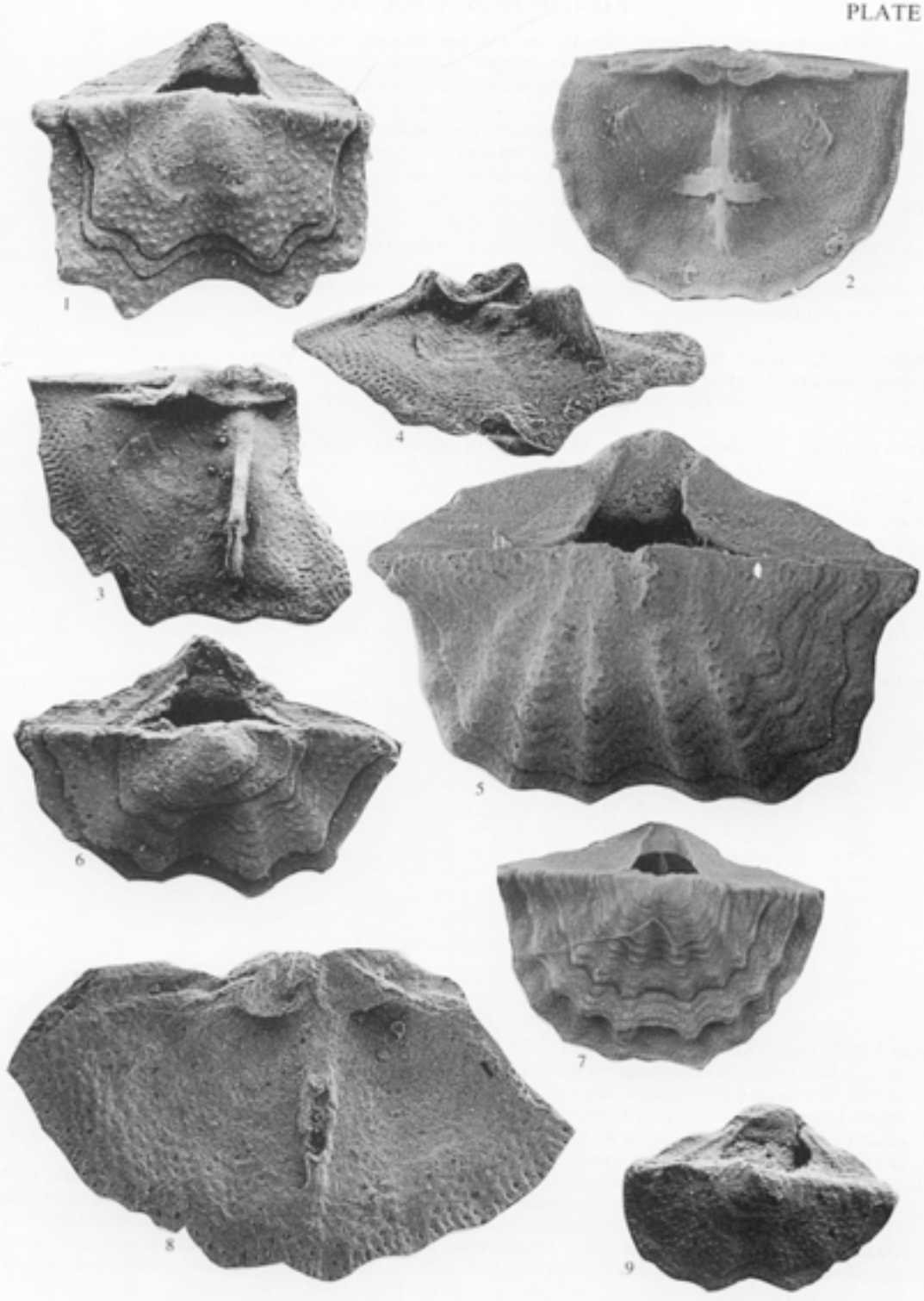
Plate 3, figs 6–8

1842 *Orthis hirundo* Hagenow, p. 545, pl. 9, fig. 9*a–d*.
1965 *Argyrotheca hirundo* (Hagenow); Steinich, p. 152, figs 232–249; pl. 16, fig. 3; pl. 17, fig. 3*a–d*.
1972 *Argyrotheca hirundo* (Hagenow); Surlyk, p. 20, figs 5, 17, 18.
1979 *Argyrotheca hirundo* (Hagenow); Bitner and Pisera, p. 79, pl. 4, fig. 7.
1982 *Argyrotheca hirundo* (Hagenow); Surlyk, fig. 1, pl. 3, figs *f–h*.
1984 *Argyrotheca hirundo* (Hagenow); Surlyk and Johansen, fig. 1.
1987*a* *Argyrotheca hirundo* (Hagenow); Johansen, p. 34, fig. 23A–H; pl. 14, figs 1–8.
1988 *Argyrotheca hirundo* (Hagenow); Johansen, fig. 2, pl. 3, fig. 2.

EXPLANATION OF PLATE 8

Figs 1–4, 7. *Argyrotheca bronnii* (Roemer, 1841). 1, MGUH 18232, upper Lower Maastrichtian, Trimingham (coll. WKC, 1971), Norfolk; large juvenile in dorsal view, ×30. 2, SPGIH 3543, lower Lower Maastrichtian, G 147, Kronsmoor; interior of large adult dorsal valve, ×15. 3 and 4, MGUH 18233, upper Lower Maastrichtian, Trimingham (coll. WKC, 1971), Norfolk; 3, interior of broken adult dorsal valve, ×15. 4, oblique lateral view showing profile of median septum, ×50. 7, SPGIH 3546, lower Lower Maastrichtian, G 147, Kronsmoor; large adult specimen in dorsal view, ×10.

Figs 5, 6, 8, 9. *Argyrotheca coniuncta* Steinich, 1965. 5, SPGIH 3547, upper Lower Campanian, G 79, Lägerdorf; large adult specimen in dorsal view, ×30. 6, MGUH 18234, upper Lower Maastrichtian, Trimingham (coll. WKC, 1971), Norfolk; juvenile specimen in dorsal view, ×25. 8, MGUH 18235, lowermost Maastrichtian?, Overstrand Hotel Lower Mass, Norfolk; broken adult dorsal valve showing separated hinge plates and high median septum, ×25. 9, MGUH 18236, lower Lower Maastrichtian, Overstrand Hotel Upper Mass 2A, Norfolk; small juvenile in dorsal view, ×20.



JOHANSEN and SURLYK, *Argyrotheca*

Material. Two dorsal valves, one ventral valve, and one fragment. Largest specimen a ventral valve from Bramerton: length, 1·92 mm; width, 1·84 mm; length of dorsal valve (measured from hinge line to anterior margin), 1·28 mm. Catalogue numbers MGUH 16856, 16857; SPGIH 3534.

Description. Outline subtriangular. Shell biconvex with rather flat dorsal valve. Hinge margin enlarged in some specimens as lateral pointed extensions. Surface has very strong growth lines and 4–6 radial ribs in two anterio-laterally directed bundles divided by wide median furrow. Beak pointed, suberect, cardinal area plane to slightly concave. Foramen large, triangular, hypothyridid, limited by two narrow deltidial plates. Pedicle collar strongly developed with concave anterior margin. Inner socket ridges strong, anteriorly divergent. Cardinal process knob-shaped. Hinge plates small, converging anteriorly, delimiting a triangular chamber together with socket ridges and cardinal process. Dorsal median septum is high. Its anterior margin forms right angle with inner surface of the shell, posterior margin forms gentle, concave-upward slope. Ventral septum thin, low. Relatively thin shelled.

Remarks. A. hirundo is an extremely variable species, but can normally be distinguished by its triangular outline, and the bundled arrangement of the ribs.

Occurrence. Bramerton and Sidestrand 4. Also known from the Upper Campanian and Maastrichtian of northwest Germany and from the Maastrichtian of East Germany, Poland, the Netherlands and Denmark. In Denmark it also occurs in the Lower Danian.

Family TEREBRATELLIDAE King, 1850
Subfamily MAGASINAE Dall, 1870
Genus MAGAS J. Sowerby, 1816

Type species. Magas pumilus J. Sowerby, 1816, p. 30.

Magas chitoniformis (Schlotheim, 1813)

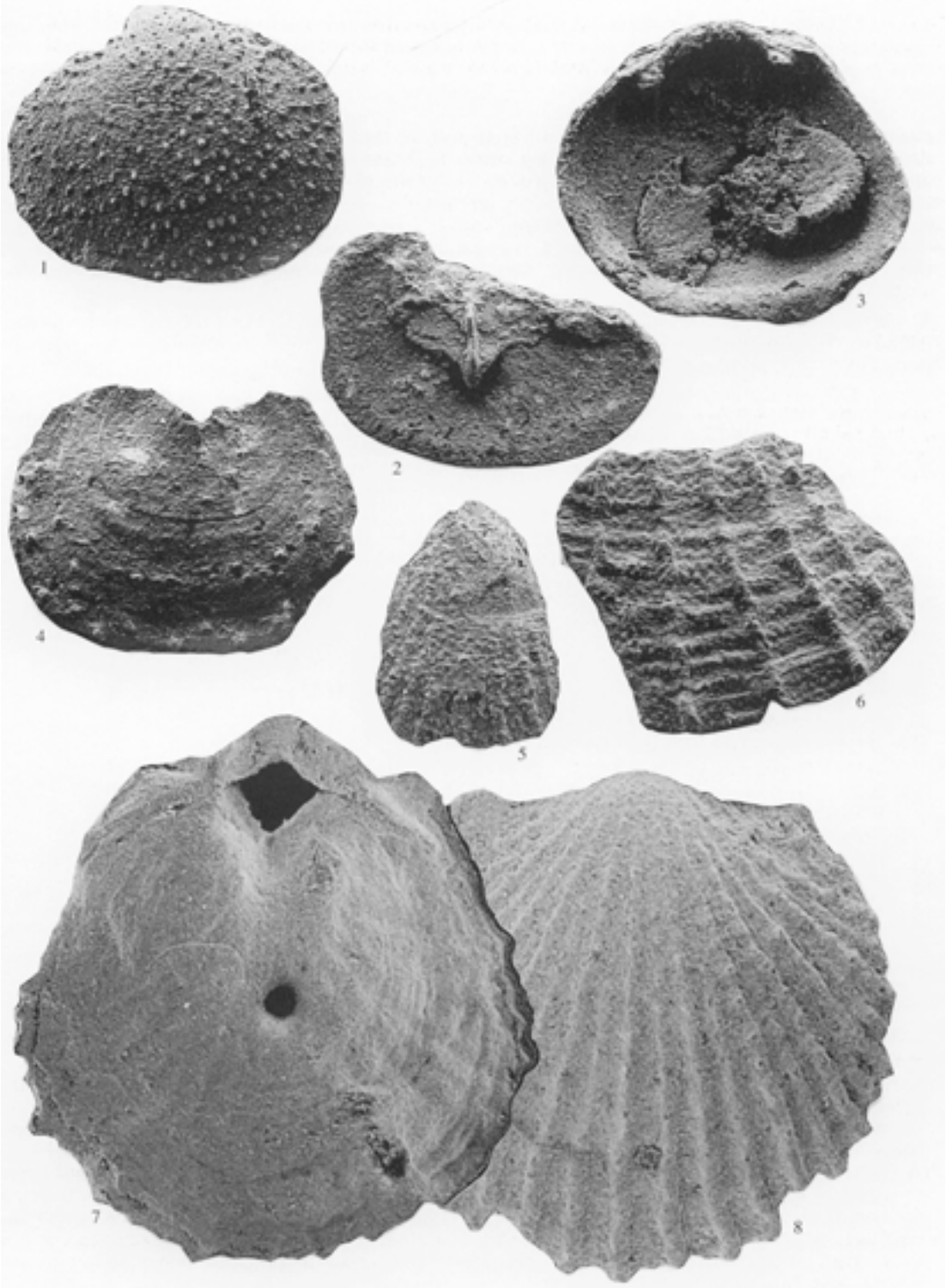
Plate 10, figs 1–6

(1798) *Térébratulus fossiles* Faujas, pl. 26, fig. 6.
1813 *Terebratula chitoniformis* Schlotheim, p. 133.
1818 *Magas pumilus* J. Sowerby, p. 40, pl. 119, figs 3–5.
1965 *Magas chitoniformis* (Schlotheim); Steinich, p. 183, figs 280–294; pl. 19, fig. 2; pl. 20, fig. 1*a–d.*
1972 *Magas chitoniformis* (Schlotheim); Surlyk, p. 26, figs 5, 11, 12; pl. 5, fig. c.
1982 *Magas chitoniformis* (Schlotheim); Surlyk, fig. 1, pl. 4, figs *e–i.*
1984 *Magas chitoniformis* (Schlotheim); Surlyk and Johansen, fig. 1.
1987*a* *Magas chitoniformis* (Schlotheim); Johansen, p. 43.
1988 *Magas chitoniformis* (Schlotheim); Johansen, fig. 2.

EXPLANATION OF PLATE 9

Figs 1–4. *Aemula inusitata* Steinich, 1968. 1, MGUH 18237, upper Lower Maastrichtian, Trimingham (coll. WKC, 1971), Norfolk; exterior view of ventral valve, ×25. 2, MGUH 18238, lower Lower Maastrichtian, Overstrand Hotel Upper Mass 3, Norfolk; interior of slightly broken dorsal valve, ×20. 3, MGUH 18239, upper Lower Maastrichtian, Trimingham (coll. WKC, 1971), Norfolk; interior of ventral valve showing recrystallized schizolophe, ×30. 4, MGUH 18240, lower Lower Maastrichtian, Overstrand Hotel Upper Mass 3, Norfolk; juvenile dorsal valve in exterior, ×30.

Figs 5–8. *Dracius carnifex* Steinich, 1967. 5, MGUH 18241, lowermost Maastrichtian, Overstrand Hotel Lower Mass, Norfolk; exterior of juvenile ventral valve, ×30. 6, MGUH 18242, lowermost Maastrichtian, Overstrand Hotel Lower Mass, Norfolk; fragment of large ventral valve showing characteristic surface sculpture, ×25. 7, SPGIH 3548, lower Lower Maastrichtian, G 148–150, Kronsmoor; adult specimen in dorsal view, ×25. 8, SPGIH 3549, lower Lower Maastrichtian, G 148–150, Kronsmoor; exterior of large ventral valve, ×25.



JOHANSEN and SURLYK, *Aemula, Dracius*

Material. Twenty-one complete shells, the majority juvenile specimens, ninety-six dorsal, twenty-seven ventral valves, and one hundred and sixty fragments. Largest specimen a slightly damaged complete adult from Little Marl Point 7: length, 9·0 mm; length of dorsal valve, 7·0 mm; width, 9·0 mm; width of hinge line, 6·4 mm; width of foramen, 1·0 mm and thickness, 4·0 mm. Catalogue numbers MGUH 18243–18246.

Description. Shell relatively large, smooth, with large punctae. Outline changes during growth from elongated oval to subcircular. Shell flattened biconvex in juveniles, becoming plano-convex with very high convex ventral valve as size increases. Hinge line straight, relatively long, giving posterior margin of dorsal valves of juveniles a pair of characteristic shoulders. Beak low, blunt, erect; changes to distinctly incurved during growth. Foramen subtriangular, large, hypothyridid in juveniles; later triangular, submesothyridid. Hinge strongly built; brachidium characteristically complex as shown in the illustrations of Steinich (1965, figs 287–292). Dorsal median septum high, strong, ventral valve contains low median ridge in anterior part of valve floor.

Remarks. Juvenile *M. chitoniformis* characteristically possess shoulders on the posterior margin of the dorsal valve but otherwise resemble *Dalligas nobilis* Steinich and *Scumulus inopinatus* Steinich. *D. nobilis* is distinugished from *M. chitoniformis* in possessing a much simpler brachidium. Larger forms of *D. nobilis* bear weak radial ribs; their shells are flat biconvex. *S. inopinatus* differs from juvenile *M. chitoniformis* in often possessing an amphithyridid foramen and an irregular outline. *Leptothyrellopsis polonicus* Bitner and Pisera is distinguished from juvenile *M. chitoniformis* by its high hypothyridid foramen and long, high, plate-like median septum.

Occurrence. Keswick, Catton 1, 3 and 3A, Stoke Holy Cross 2?, Catton 4?, 5? and 6?, Caistor 1, Bramerton, Overstrand Hotel Upper Mass 1A, 1, 2, 3 and 4?, Sidestrand 1, 1A?, 3A and 5, Little Marl Point 1A, 1B, 1?, 2, 2A, 3?, 4, 5, 6 and 7, and Trimingham 1, 2 and 3. Also widely distributed in the Upper Campanian and Maastrichtian of northwest Germany and the Maastrichtian of East Germany, Poland, France, the Netherlands and Denmark.

Subfamily KINGENINAE Elliott, 1948
Genus KINGENA Davidson, 1852

Type species. Terebratula lima DeFrance, 1828, p. 156.

Kingena pentangulata (Woodward, 1833)

Plate 11, figs 5–8

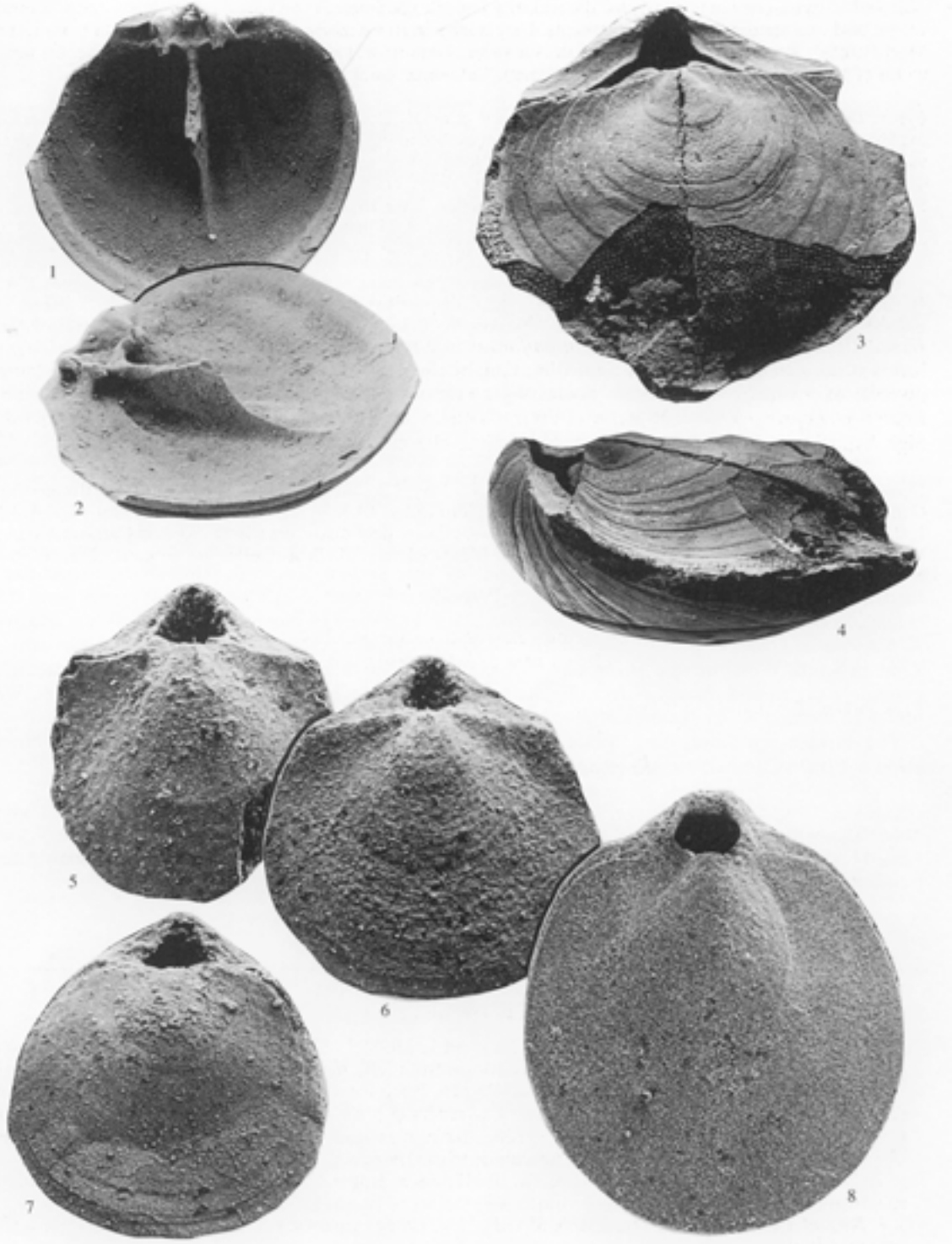
1833 *Terebratula pentangulata* Woodward, p. 49, pl. 6, fig. 10.
1970 *Kingena pentangulata* (Woodward); Owen, p. 64, pl. 7, figs 6 and 7; pl. 8, figs 2–6; text-fig. 13.
1970 *Kingena blackmorei* Owen, p. 63, pl. 7, figs 1–3; pl. 8, fig. 1.
1968*b* *Kingena* sp.; Steinich, p. 342, figs 4 and 5.
1972 *Kingena pentangulata* (Woodward); Surlyk, p. 17.

EXPLANATION OF PLATE 10

Figs 1–6. *Magas chitoniformis* (Schlotheim, 1813). 1 and 2, MGUH 18243, lower Upper Campanian, Catton 1, Norfolk; 1, interior of large slightly broken dorsal valve, × 7. 2, oblique lateral view, × 7. 3 and 4, MGUH 18244, upper Lower Maastrichtian, Little Marl Point 7, Norfolk; 3, slightly broken large adult specimen in dorsal view, × 10; 4, oblique lateral view showing reclining profile, × 13. 5, MGUH 18245, lower Upper Campanian, Catton 3A, Norfolk; small juvenile specimen in dorsal view, × 40. 6, MGUH 18246, lower Upper Campanian, Catton 1, Norfolk; juvenile specimen in dorsal view, × 25.

Fig. 7. *Dalligas nobilis* Steinich, 1968*b*, MGUH 18247, lower Upper Campanian, Catton 1, Norfolk; adult specimen in dorsal view, × 25.

Fig. 8. *Scumulus inopinatus* Steinich, 1968*b*, SPGIH 3550, lower Upper Campanian, G 109, Lägerdorf; adult specimen in dorsal view, × 30.



JOHANSEN and SURLYK, *Magas, Dalligas, Scumulus*

1979 *Kingena* sp.; Bitner and Pisera, p. 81, pl. 5, figs 1 and 2.
1984 *Kingena pentangulata* (Woodward); Surlyk and Johansen, fig. 1.
1987*a* *Kingena pentangulata* (Woodward); Johansen, p. 42, pl. 20, figs 5 and 6.
1988 *Kingena pentangulata* (Woodward); Johansen, fig. 2.

Material. Seven shells, thirty-seven dorsal, thirty-four ventral valves, and two hundred and fifty-six fragments. Largest valves have following dimensions: fragment of ventral valve from Overstrand Hotel Upper Mass 2A: length at least 4·4 mm; dorsal valve from Cley: length, 2·9 mm; width, 3·4 mm; shell from Overstrand Hotel Upper Mass 3: length, 2·6 mm; width, 3·0 mm; length of dorsal valve, 2·2 mm; thickness at least 0·6 mm. Catalogue numbers MGUH 18252–18255.

Description. Adults not seen; medium-sized specimens are highly fragmented. Juvenile stages less than 5 mm in length. The outline changes during growth from subtriangular to circular to subpentagonal. Small forms plano-convex to weakly biconvex; larger forms more uniformly biconvex. Commissure straight in early stages. Shell surface characteristically bears densely-spaced small regular tubercles. Beak almost straight to suberect in earliest stages, changing to suberect and finally erect. Cardinal area wide, sharply delimited. Foramen large, trapezoidal; submesothyridid in forms less than 5 mm long. It becomes permesothyridid as beak becomes more incurved in larger forms. Foramen limited laterally by rather large triangular deltidial plates. Teeth strong, pointed, supported by well-developed dental plates which converge posteriorly. Larger specimens have well-defined hinge plate. A low median septum is formed at *c.* 0·8 mm length. At *c.* 1·4 mm length two pointed anterio-laterally directed ascending branches form at top of anterior margin of the septum. At the same time two short crurae are formed as extensions of inner socket ridges. Strongly divergent descending branches extend from end of crurae. Latest stages of brachidium development not seen in present material. Shell is thin and almost always rather deformed. Inner surface is smooth.

Remarks. The present material is referred to *K. pentangulata* with slight reservation. It corresponds, however, in all details to abundant material of this species from the Danish Maastrichtian. Furthermore the neotype of *K. pentangulata* (Woodward) selected by Owen (1970) comes from the transition between the Eaton and Weybourne Chalk Members in Norfolk, while its closest relative *K. blackmorei* Owen is said to characterize the somewhat older chalk of the *Goniotheuthis quadrata* Zone in South Wiltshire and Hampshire (Owen 1970). The differences between the two species are extremely slight, and mainly reflect one main feature, the less incurved umbo of *K. blackmorei*. We prefer to include *K. blackmorei* in *K. pentangulata*.

The surface sculpture, hinge plate and brachidium distinguish *K. pentagulata* from all other known Upper Campanian–Maastrichtian species.

Occurrence. Cley, Keswick, Catton 1, 3, 3A, 4, 5 and 6, Caistor 3 and 1, Whitlingham, Overstrand Hotel Lower Mass, Bramerton, Overstrand Hotel Upper Mass 1A, 1, 2, 2A, 3 and 4, Sidestrand 1, 1A, 2, 3, 3A and 4, and Little Marl Point 1A. The species is known from the Upper Campanian–Maastrichtian and possibly older Chalk strata of northwest Europe.

Family PLATIDIINAE Thomson, 1927
Genus AEMULA Steinich, 1968

Type species. Aemula inusitata Steinich, 1968*a*, p. 193.

Aemula inusitata Steinich, 1968

Plate 9, figs 1–4

1968*a* *Aemula inusitata* Steinich, p. 192, figs 1–5; pl. 1, fig. 1.
1972 *Aemula inusitata* Steinich; Surlyk, fig. 5, pl. 3, figs *e*, *f*, *h*.
1974 *Aemula inusitata* Steinich; Surlyk, figs 1 and 3, pl. 2.
1979 *Aemula inusitata* Steinich; Bitner and Pisera, p. 79, pl. 5, fig. 4.
1982 *Aemula inusitata* Steinich; Surlyk, fig. 1, pl. 2, figs *g* and *h*.
1984 *Aemula inusitata* Steinich; Surlyk and Johansen, fig. 1.

1987*a* *Aemula inusitata* Steinich; Johansen, p. 39, pl. 18, figs 1–5.
1988 *Aemula inusitata* Steinich; Johansen, fig. 2, pl. 3, figs 4*a*, *b*, 5, 6.

Material. Five complete shells, ten dorsal, sixty-three ventral valves and ten fragments. Largest specimen is a dorsal valve from Overstrand Hotel Upper Mass 3: length, 2·32 mm; width, 2·64 mm. Catalogue numbers MGUH 18237–18240.

Description. Outline oval to circular, commonly very irregular. Shell plano-convex to slightly concavo-convex. Commissure straight in regular specimens. Surface of dorsal valve smooth, surface of the ventral valve bears short pointed tubercles. Shells with width of less than 1·0 mm rarely have tubercles, but larger specimens show no correlation between shell size and size and density of tubercles. There are several growth lines, clearly developed on the dorsal valve. Beak very short, suberect. Cardinal area small, clearly delineated. Hinge line almost straight. Foramen relatively large, amphithyridid; laterally delineated by two narrow deltidial plates. Short, slightly elevated pedicle collar is delineated from deltidial plates by furrow. Teeth are very short, obtuse. Inner socket ridges well-developed, extending somewhat outside posterior shell margin. Dorsal valve has low triangular median septum, with two ventrally directed short triangular ascending branches. *A. inusitata* has a strongly developed spicular skeleton; schizolophe. Inner side of the rather thin shell is smooth.

Remarks. A. inusitata is easily distinguished from all other Chalk brachiopods. Very regular and smooth forms may, however, show considerable overlap with a new species of *Aemula* illustrated from the Maastrichtian chalk of Hemmoor, northwest Germany by Surlyk (1974, pl. 2*b*). The present material does not help in the separation of the two forms.

Occurrence. Keswick, Caistor 1, Overstrand Hotel Lower Mass, Bramerton, Overstrand Hotel Upper Mass 1A, 2, 2A, 3 and 4, Sidestrand 3, 3A, 4 and 5, and Little Marl Point 1B, 6 and 7. Also known from the Santonian to the Maastrichtian of northwest Germany and from the Maastrichtian of East Germany, Denmark and eastern Poland.

Aemula sp.

Material. One complete shell and one ventral valve. Both specimens are juveniles with shell widths around 1·5 mm.

Description. Shell smooth, thin, plano-convex pointed, oval, slightly irregular outline. Beak very short, acute, suberect; foramen large, amphithyridid. Teeth small, blunt, inner socket ridges protrude beyond posterior shell margin. Internal morphology not known.

Remarks. A. inusitata Steinich differs from this species in possessing a shell sculpture of low, densely-spaced tubercles concentrated on the ventral valve. This smooth *Aemula* sp. may be conspecific with the *Aemula* n. sp. illustrated from the Maastrichtian chalk of Hemmoor, northwest Germany (Surlyk, 1974, pl. 2*b*). The material from Norfolk is, however, too small to allow this problem to be resolved.

Occurrence. Caistor 1.

Genus SCUMULUS Steinich, 1968

Type species. Scumulus inopinatus Steinich, 1968*a*, p. 199, pl. 1, fig. 2.

Scumulus sp.

Material. One fragmented ventral valve is present, but this is not illustrated here due to its poor state of preservation. For comparison a specimen of *S. inopinatus* from the lower Upper Campanian of Lägerdorf is shown (Pl. 10, fig. 8). Catalogue number SPGIH 3550.

Description. Valve small, smooth, elongated oval in outline. Beak short, erect, blunt; area characteristically broad and triangular with lateral edges formed by shallow ridges. Deltidial plates very narrow, hinge teeth are strong, acute.

Remarks. The species can be assigned to the genus *Scumulus* Steinich, but the material does not allow specific determination.

Juveniles of *Magas chitoniformis* (Schlotheim) show great resemblance to this species, but *M. chitoniformis* differs in possessing a small, distinctly limited cardinal area and large punctae. *Leptothyrellopsis polonicus* Bitner and Pisera and *Dalligas nobilis* Steinich both differ from the Norfolk species in their very narrow cardinal areas.

Occurrence. Caistor 1.

Family DALLINIDAE Beecher, 1893
Genus DALLIGAS Steinich, 1968

Type species. Dalligas nobilis Steinich, 1968*b*, p. 336, pl. 1, fig. 1.

Dalligas nobilis Steinich, 1968

Plate 10, fig. 7

1968*b* *Dalligas nobilis* Steinich, p. 336, figs 1–3; pl. 1, figs 1 and 2.
1972 *Dalligas nobilis* Steinich; Surlyk, p. 20, figs 5, 13–15, 17, 18.
1987*a* *Dalligas nobilis* Steinich; Johansen, p. 43, pl. 18, figs 6 and 7.

Material. Two bivalved specimens, three ventral and one dorsal valve. All specimens fragmentary, largest specimen, from Overstrand Hotel Upper Mass 4, is 2·8 mm long. Catalogue number MGUH 18247.

Description. Outline circular, shell flatly biconvex. Auricles not delimited. Commissure straight. Numerous very fine radial ribs appear at 0·5–1·0 mm width. Rib number about 30. Cardinal area is narrow, triangular. Deltidial plates narrow, well-separated posteriorly. Foramen triangular to trapezoidal. Pedicle collar wide, well-defined. Inner socket ridges subparallel, forming characteristic triangular area together with well-defined hinge plates, and posterior margin of the median septum. Septum high, bearing two short ascending branches. Remaining elements of the brachidium not developed. Shell relatively thin.

Remarks. The specimen closely resembles *D. nobilis* as described by Steinich (1968*b*) from Rügen, although the ribbing seems to appear somewhat earlier in ontogeny. Juvenile specimens, where ribbing has not yet developed, cannot be distinguished form the smooth *D. mielnicensis* Bitner and Pisera. Young specimens differ from *Leptothyrellopsis polonicus* Bitner and Pisera in their more circular outline, larger foramen, triangular area and wider, less pointed beak.

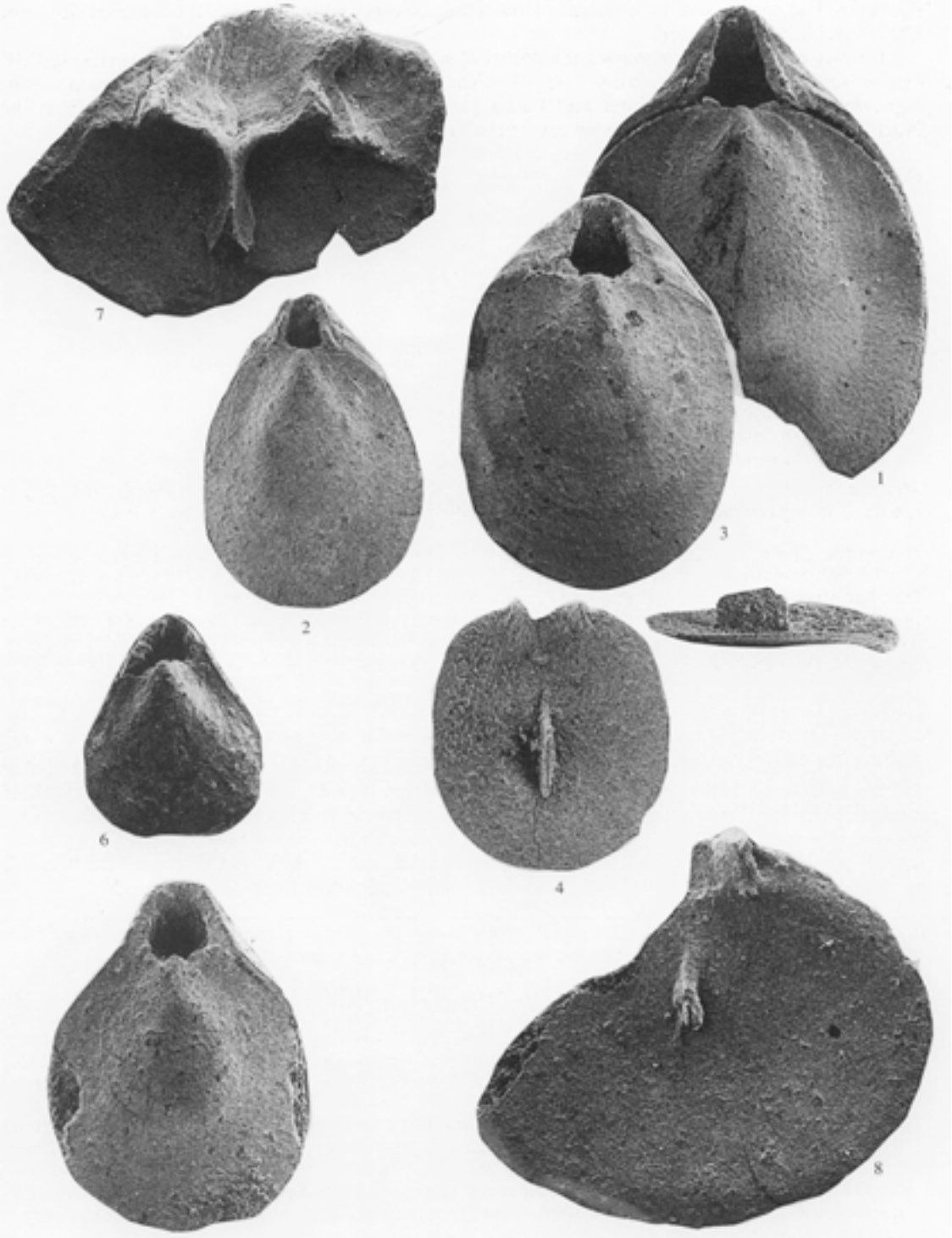
Occurrence. Keswick, Catton 1, Overstrand Hotel Lower Mass, and Overstrand Hotel Upper Mass 2A and 4. The stratigraphic and geographic distributions of this almost featureless species are not yet well known.

EXPLANATION OF PLATE 11

Figs 1–5. *Leptothyrellopsis polonicus* Bitner and Pisera, 1979. 1, MGUH 18248, lower Lower Maastrichtian, Sidestrand 3A, Norfolk; broken adult specimen in dorsal view, ×30. 2, MGUH 18249, uppermost Campanian?, Whitlingham, Norfolk; juvenile in dorsal view, ×25. 3, MGUH 18250, uppermost Campanian?, Whitlingham, Norfolk; large juvenile specimen in dorsal view, ×30. 4 and 5, MGUH 18251, lower Lower Maastrichtian, Sidestrand 2, Norfolk; 4, interior of juvenile dorsal valve, ×25; 5, 4 in lateral view showing profile of median septum, ×50.

Figs 6–9. *Kingena pentangulata* (Woodward, 1833). 6, MGUH 18252, lower Lower Maastrichtian, Overstrand Hotel Upper Mass 2A, Norfolk; cardinal area of medium-sized dorsal valve, ×25. 7, MGUH 18253, lower Lower Maastrichtian, Overstrand Hotel Upper Mass 2A, Norfolk; small juvenile specimen in dorsal view, ×25. 8, MGUH 18254, upper Upper Campanian, Caistor 3, Norfolk; interior of broken medium-sized dorsal valve, ×25. 9, MGUH 18255, upper Upper Campanian, Catton 3A, Norfolk; juvenile specimen in dorsal view, ×30.

PLATE 11



JOHANSEN and SURLYK, *Leptothyrellopsis, Kingena*

Family THECIDEIDAE Gray, 1840
Subfamily LACAZELLINAE Backhaus, 1959
Genus LACAZELLA Munier-Chalmas, 1880

Type species. Thecidea mediterranea Risso, 1826, p. 393.

Subgenus BIFOLIUM Elliott, 1948

Lacazella (Bifolium) wetherelli (Morris, 1851)

Plate 1, fig. 7

1851 *Thecidea wetherelli* Morris, p. 86, pl. 4, figs 1–3.
1852 *Thecidea wetherelli* Morris; Davidson, p. 14, pl. 1, figs 15–26.
1874 *Thecidium wetherelli* Morris; Davidson, p. 22.
1908 *Thecidium wetherelli* Morris; Rowe, p. 320.
1959 *Lacazella (Bifolium) wetherelli* (Morris); Backhaus, p. 35, pl. 2, figs 1–3.
1965 *Lacazella (Bifolium) wetherelli* (Morris); Steinich, p. 15, pl. 4, figs 2 and 3*a*, *b*.
1972 *Bifolium wetherelli* (Morris); Surlyk, p. 27, fig. 5.
1974 *Praelacazella wetherelli* (Morris); Pajaud, p. 333.
1988 *Lacazella (Bifolium) wetherelli* (Morris); Johansen, fig. 2.

Material. Four dorsal valves and three fragments, all of which probably belong to ventral valves. Largest specimen a dorsal valve from Lower Maastrichtian sample Little Marl Point 1B. Length of dorsal valve, 5·5 mm; width, 6·5 mm. Catalogue number MGUH 16846.

Description. Outline of the dorsal valve subtriangular to trapezoidal. Shell margins broad, steep, levelling out towards anterior shell margin. Valves thick, stout. Shell surface smooth with several growth rings. Dorsal valve planar. Shell margin sculptured with numerous fine, minute pustules and radiating, low ridges. Posterior shell margin short, straight. Cardinal process protrudes well beyond posterior shell margin and is broad and short. Ascending part of brachial apparatus consists of two separate laminae which rise anteriorly in dorsal valve. Laminae follow depression in floor of valve and run obliquely posteriorly towards jugum, where laminae abruptly change direction of growth deflecting towards aperture. Folded laminae unite mid dorsally above jugum. A second folding of laminae may occur but characteristically only one or two folds are present. Ptycholophe.

Remarks. Backhaus (1959) mentions that the dorsal valve of this species is typically very thin, but this is not the case in the specimens from Norfolk. When present, the ventral valve of this species is characterized by being attached (cemented) to the substrate with the entire outer surface, and by possessing a distinct radial rib pattern in the inner surface of the ventral valve. *Lacazella (Bifolium) wetherelli* is distinguished from other closely-related species of *Lacazella* in the form of the brachial apparatus. In *L. (B.) wetherelli* the laminae are folded once or in some cases twice.

Occurrence. Little Marl Point 1B, 1, 4 and 7?. Also known from Upper Campanian–Maastrichtian Chalk strata of northwest Germany and from the Maastrichtian of East Germany and Denmark.

Family UNCERTAIN
Genus LEPTOTHYRELLOPSIS Bitner and Pisera, 1979

Type species. Leptothyrellopsis polonicus Bitner and Pisera, 1979, p. 82, pl. 7, fig. 2.

Leptothyrellopsis polonicus Bitner and Pisera, 1979

Plate 11, figs 1–4

1979 *Leptothyrellopsis polonicus* Bitner and Pisera, p. 82, pl. 7, figs 1–4.
1982 *Leptothyrellopsis polonicus* Bitner and Pisera; Surlyk, fig. 1, pl. 3, figs *c–e*.
1988 *Leptothyrellopsis polonicus* Bitner and Pisera; Johansen, fig. 2.

Material. Seventy complete shells, one hundred and ninety dorsal, one hundred and fifty-three ventral valves, and fifty-eight fragments. Largest specimen from Cley: length, 3·4 mm; width, 2·8 mm; length of brachial valve, 2·9 mm; thickness, 0·6 mm. Catalogue numbers MGUH 18248–18251.

Description. Outline oval to elongate oval. No clearly delimited auricles. Shell flatly biconvex; commissure straight. Surface smooth apart from a few growth lines; beak erect; shell is punctate; area small; deltidial plates narrow with subparallel sides; elevated above shell surface as low ridges. Foramen large, subtriangular. There is no pedicle collar but high inner socket ridges. Dorsal valve has prominent plate-like median septum.

Remarks. The almost total absence of diagnostic features makes it difficult to distinguish *L. polonicus* from other small smooth brachiopods. It differs from juvenile *Dalligas* Steinich and *Magas chitoniformis* (Schlotheim) in the absence of a pedicle collar and of a prominent hinge plate. *Scumulus inopinatus* Steinich can be distinguished from *L. polonicus* by its well-developed brachidium, its amphithyridid foramen and irregular outline.

Occurrence. Cley, Keswick, Catton 3A, 5 and 6, Caistor 1, Whitlingham, Overstrand Hotel Lower Mass, Overstrand Hotel Upper Mass 1A, 1, 2, 2A, 3 and 4, Sidestrand 1, 1A, 2, 3A and 4, Little Marl Point 1B, 2 and 3, Trimingham 1, and Little Marl Point 4 and 6. This species is known from Upper Campanian–Maastrichtian Chalk strata of northwest Germany, and from the Maastrichtian of eastern Poland and probably also Denmark.

SUMMARY

The Upper Cretaceous Chalk of Norfolk is not very well known due to its poor exposure in scattered, commonly abandoned chalk pits, and in glacially transported masses exposed in coastal cliffs. The sediments consist of white to yellowish chalk with scattered bands of nodular or barrel-shaped flints ('paramoudras'). Calcarenites, nodular cemented chalks with sponge impressions, and hardgrounds are also common.

The Chalk has been subdivided into a number of units, but the stratigraphic nature of these is rather vague, although they seem to be mainly palaeontologically defined (see also Peake and Hancock 1961, 1970; Wood 1988). In the present paper we have attempted to present a coherent lithostratigraphic scheme based on the older units, and eight lithostratigraphical units of member rank are proposed.

A detailed biozonation based on the micromorphic brachiopod fauna has been established for the Upper Campanian and Maastrichtian of northwest Europe (Surlyk 1984). A large number of bulk samples collected in the Upper Campanian–Lower Maastrichtian of Norfolk, England has, after Glauber-Salt treatment and freeze-thawing, yielded a brachiopod fauna of about 2200 specimens representing at least thirty-five species. All of the species present are known also from the Upper Cretaceous Chalk of Denmark, Sweden, Germany and Poland.

The existence of this fauna in the English Chalk makes it possible to correlate parts of the Campanian and Maastrichtian outcrops in Norfolk with more complete and better exposed sections of northwest continental Europe, especially the Campanian–Maastrichtian boundary section at Kronsmoor, West Germany.

In spite of the condensed and poorly exposed nature of the Norfolk section, most of the brachiopod zones established in northwest Europe can be recognized. These zones are from below:

1. The *tenuicostata-longicollis* Zone corresponding to the bulk of the Upper Campanian of Norfolk;
2. the *longicollis-jasmundi* Zone corresponding to the uppermost Upper Campanian;
3. the *acutirostris-spinosa* Zone corresponding to the basal Maastrichtian;
4. the *spinosa-pulchellus* Zone corresponding to the middle part of the Lower Maastrichtian;
5. the *pulchellus-pulchellus* Zone of the upper Lower Maastrichtian.

The *jasmundi-acutirostris* Zone which includes the lowermost Maastrichtian in Kronsmoor is undoubtedly represented in unexposed strata between the highest Campanian locality, Whitlingham and the lowest Maastrichtian exposed at Overstrand Hotel Lower Mass.

In spite of its highly fragmentary exposure, the Upper Campanian–Maastrichtian of Norfolk is now correlated in detail on the basis of the brachiopods with the standard boundary sequences at Kronsmoor and Lägerdorf in northwest Germany, and with the detailed macrofossil zonation established for these localities by German workers.

Acknowledgements. The samples which form the basis for the present study were collected in 1971 by W. Kegel Christensen and F. Surlyk under the excellent and highly inspiring guidance of J. M. Hancock and N. B. Peake. Some additional samples were collected by R. G. Bromley in 1971. This paper was read critically by J. M. Hancock, N. B. Peake, W. J. Kennedy and one anonymous referee. The typing was done by B. Larsen and A. Brantsen and drafting by B. Sikker Hansen. Stereoscan work was undertaken in the Scanning Electron Microscope Laboratory of the Geological Central Institute, University of Copenhagen, and darkroom work was done by J. Aagaard and O. B. Berthelsen. The paper was written while Surlyk was a recipient of a research professorship awarded by the Danish Natural Science Research Council.

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Typescript received 3 July 1989
Revised typescript received 5 February 1990