Biostratigraphical criteria for the recognition of the Coniacian to Maastrichtian stage boundaries in the Chalk of north-west Europe, with particular reference to southern England.

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The biostratigraphical criteria for the recognition of Coniacian to Maastrichtian stage boundaries in the English Chalk, published in the Abstracts to the Copenhagen Symposium on Cretaceous Stage Boundaries 1983, are reviewed in the light of the discussion at the Symposium and the final recommendations. Particular attention is given to problems relating to the base of the Coniacian and Santonian Stages. A critical assessment is made of criteria used by French workers for recognising the base of the Senonian Stage in the Anglo-Paris Basin. Benthonic Foraminifera used to identify the base of the Senonian are shown to have discrepant ranges in Kent compared with Sussex and Senonian stratotype. The nannofossil *Marthasterites furcatus* first appears below the level of acme-occurrence of ammonites of the Late Turonian *Subprionocyclus neptuni* Zone in southern England, and cannot therefore be used as a marker to identify the base of the Coniacian in the Anglo-Paris Basin. Extended comment is made on the biostratigraphy of the successions in southern England and northern Germany across the Coniacian – Santonian boundary, and it is suggested that the Upper Coniacian *Micraster bucaillei/Gonioteuthis praewestfalica* Zone of the German Lägerdorf standard section should be re-assigned to the basal part of the Santonian. The base of the Campanian Stage in southern England is arbitrarily taken at the evolutionary first appearance of *Bolivinoides culverensis*, a level coincident with the top of the local *Uintacrinus anglicus* Zone, rather than at the extinction-level of *Marsupites* and/or entry of *Gonioteuthis granulata-quadrata* lower in the succession. The entry of the nannofossil *Broinsonia parca*, widely taken as a criterion for recognising the base of the Campanian Stage, is shown to occur at an horizon well above the entry-level of *B. culverensis*.

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Introduction

Detailed stratigraphical investigation of Late Cretaceous sections throughout Europe is currently being carried out in order to establish criteria for the recognition of the Coniacian to Maastrichtian stage boundaries that can also be correlated with the stratotypes in France and Holland. This paper reviews these criteria with particular reference to current research in southern England, and updates the information published by us previously (Bailey et al. 1983a, 1983b). It is a supplementary contribution to the U.K. regional subgroup of the Working Group on the Coniacian-Maastrichtian Stages.

The Turonian – Coniacian boundary

The base of the Coniacian Stage is conventionally recognised using one or a combination of the following criteria:

1. The entry of the ammonite *Forresteria (Harleites) petrocoriense* (Coquand)

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2. The entry of the inoceramid bivalve *Cremnoceramus? waltersdorfensis hannovrensis* (Heinz)
3. The entry of *C. deformis* (Meek) and/or *C. schloenbachi* (Böhm) [note that there is still controversy as to whether these two taxa should be regarded as distinct – for discussion and references see Tröger 1981]
4. The entry of the nannofossil *Marthasterites furcatus* (Deflandre)
5. The entry of the foraminifera *Lingulogavelinella* cf. *vombensis* (Brotzen) [see Jenkins & Murray 1981, Plate 7.19, figs. 1–3 for an illustration of this distinctive species] and *Reussella kelleri* Vasilenko [Jenkins & Murray, ibid., Plate 7.22, figs. 5, 6]. This is approximately coincident with the first apperance of the genus *Stensioeina* in the Anglo-Paris Basin, represented by *S. granulata levis* Koch.
6. The entry of the echinoids *Micraster normanniae* Bucaille and *M. decipiens* (Bayle)

There is a general consensus amongst macropalaeontologists, reflected in the final conclusions of the Copenhagen Symposium,that a combination of criterion 1 [using *F. (H.) petrocoriense* in Europe, and other species of *Forresteria* elswhere] and criterion 2 best serves to recognise the base of the Coniacian Stage worldwide (see discussion by Kauffman *in* Herm, Kauffman & Wiedmann 1979).

In the most complete successions, *C ? waltersdorfensis hannovrensis* enters below and overlaps with the range of the lowest members of the *C ? rotundatus* (Fiege) sensu Tröger – *C. erectus* (Meek) – *C. deformis* – *C. schloenbachi* lineage (Kauffman *in* Herm et al. 1979). Inoceramids of this lineage are well represented in north-west Europe, and occur in a wide variety of facies. In chalk facies successions these characteristic early Coniacian inoceramids normally appear abruptly, above a hardground, nodular chalk, or similar indication of condensed sedimentation, suggesting that the base of the Coniacian as recognised by inoceramids is situated immediately above a non-sequence in most cases. In the Pläner limestone succession of Salder, Lower Saxony (GFR), however, there is no obvious evidence of a non-sequence in the Turonian – Coniacian boundary succession. At this locality, *C ? waltersdorfensis hannovrensis* enters in flood abundance a short distance below the entry of *C? rotundatus*, coincident with the higher of two *Didymotis* acme-occurrences (Ernst & Wood 1983).

Criterion 3 is favoured by Seibertz (1983) and by Tröger (1981), using the entry of *C. deformis* and *C. schloenbachi* respectively. In either case, this would imply a stratigraphical level higher than the first occurrences of ammonites such as *Forresteria* and *Peroniceras*, genera which are usually held to be early Coniacian and are known to co-occur with the earlier members of the *Cremnoceramus* lineage.

Criterion 4 is much favoured by nannoplankton workers, on the basis that the taxon concerned and its first appearance, are easily recognisable. As shown in Fig. 1, however, the appearance of *M. furcatus* in southern England (Dover) lies well within the range, and below the level of acme-occurrence, of *Subprionocyclus neptuni* (Geinitz), a late Turonian index (Crux 1980; 1982). It is therefore clear that the appearance of *M. furcatus* cannot be used to recognise the base of the Coniacian in our area.

The suggestion of Pomerol (1983) and Pomerol, Damotte, Fouray & Monciardini (1983) that the base of the Senonian (and presumably the base of the Coniacian, its lowest constituent stage) in the Yonne and northern coastal areas of France, and at Shoreham Cement works in Sussex, can be drawn at the appearance of

1. *Lingulogavelinella* cf. *vombensis* and *Reussella kelleri*
2. *Micraster* of the *normanniae* – *decipiens* group

presents certain problems. The first and probably the most important of these is the significantly discrepant entry of the foraminiferal markers in the North Downs area of southern England, as compared with the South Downs (including the Shoreham Cement-works succession) and the type area of the Senonian. According to our data from Dover, both species enter at *different* levels *lower* in the succession (see Fig. 1), and in each case co-occur with ammonites of the *Subprionocyclus neptuni* Zone such as *S. neptuni* (Geinitz), *Didymoceras saxonicum* (Schlüter) and *Scaphites geinitzii* d'Orbigny. This co-occurrence is also reported from the Boulonnais by Robaszynski, Amedro, Foucher,

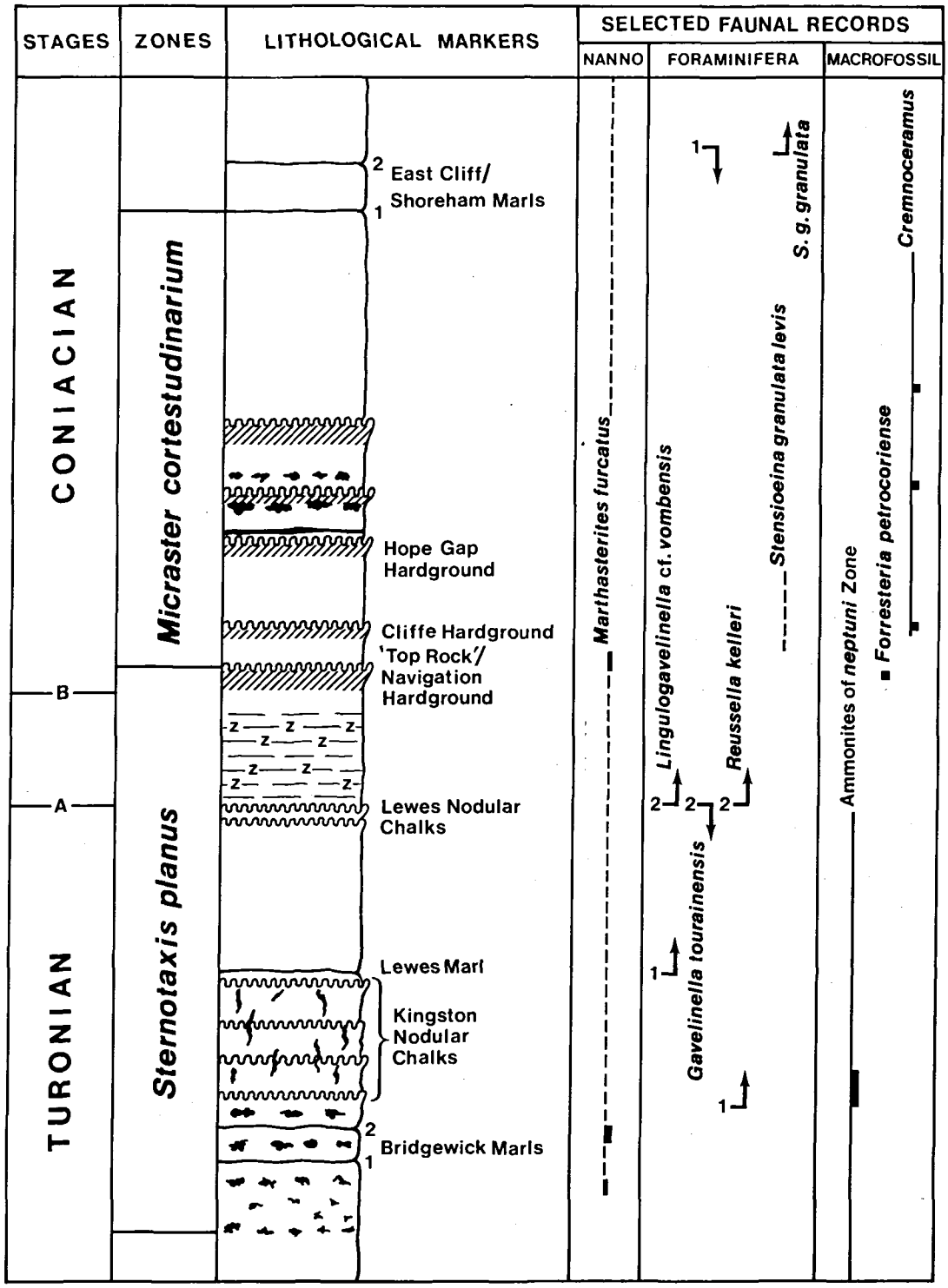

Fig. 1. Schematic lithological succession (not to scale) showing the beds across the Turonian-Coniacian boundary as developed in Kent and Sussex, with ranges and levels of acme-occurrence of selected critical taxa. Lithological markers shown conventionally, with only the most conspicuous flints indicated; hardgrounds are distinguished from nodular chalks by cross-hatching in the ornament. Note that the Lewes Marl is not recognisable as a discrete marl seam in the Dover (Kent) section. In the left-hand column, 'A' indicates the level of the supposed Coniacian base taken previously by Bailey et al. (1983b) and by Pomerol (1983); 'B' indicates the level taken in this paper. Discrepant ranges of key foraminiferal taxa between Kent (denoted by '1') and Sussex ('2') are shown. 'Z' indicates *Zoophycos*. Nannofossil data interpreted from Crux (1980; 1982).

Gaspard, Magniez-Jannin & Sornay (1980, p. 284). Secondly, serious difficulties attend the use of many of the available names for species of *Micraster,* particularly in the Turonian and Coniacian. These problems are currently under review (see discussion by Drummond, in press), but until they are satisfactorily resolved, we feel that it is advisable to be circumspect.

In the Symposium Abstract (Bailey et al. 1983b), we provisionally took the base of the Coniacian in southern England at or about the same level as that proposed by Pomerol (1983) i.e. at the base of the *Micraster cortestudinarium* Zone sensu Rowe (1900) at Dover (see Fig. 1, level A). We noted that there was a significant change in the *Micraster* lineage at this level, generally understood as the appearance of *M. normanniae,* and that there was also a significant change in the inoceramids, with the replacement of *Mytiloides*-dominated assemblages of late Turonian aspect by early members of the characteristically early Coniacian *Cremnoceramus* lineage. The base of the Coniacian, thus recognised, was also marked by the appearance of the ichnogenus *Zoophycos* in the White Chalk succession.

In view of the consensus at the end of the Symposium that the base of the Coniacian should be recognised by the first appearance of *Forresteria* and *Cremnoceramus? waltersdorfensis hannovrensis,* and in the light of subsequent research, we now feel that the suggestion we put forward earlier was ill-advised. We therefore provisionally place the base of the Coniacian in southern England immediately beneath the 'Top Rock'/Navigation Hardground (Fig. 1, level B), for the following reasons:

1. The first indubitable Coniacian ammonite is a single *Forresteria petrocoriense* collected within the indurated sediment of the 'Top Rock'/ Navigation Hardground, and 2. basal Coniacian inoceramids including *Cremnoceramus ? waltersdorfensis waltersdorfensis* and *C ?* cf. *rotundatus* occur 0.5 m above the top of this hardground at Dover.

No identifiable inoceramids or ammonites have been collected so far from the circa 5 m of chalks with *Zoophycos* underlying the Navigation Hardground. The record (Bailey et al. 1983b) of inoceramids of the *Cremnoceramus ? waltersdorfensis* (Andert) – *C ? rotundatus* complex from these beds was based on tentatively identified incomplete material collected from the succession below the highly condensed Top Rock in the Bury St. Edmunds area of East Anglia, and should not have been extrapolated to the very different successions in Kent and Sussex. (It should be noted that the Top Rock of East Anglia is not the equivalent of the 'Top Rock'/ Navigation Hardground of southern England, but represents a condensation of the greater part of the *Micraster cortestudinarium* Zone). In East Anglia, *C ? waltersdorfensis hannovrensis* and *C ? rotundatus* are preserved as phosphatised steinkerns within the Top Rock hardground. The inoceramids of Coniacian aspect from the underlying succession require further investigation, and for the moment judgment should be reserved on their affinities.

Our record of *Stensioeina granulata levis* from the beds beneath the Navigation Hardground (Bailey et al. 1983b) referred to a single specimen from beneath the Top Rock in an equivalent succession to the East Anglian succession at the Redbournbury Quarry, Hertfordshire. The lowest horizon from which we record this subspecies at Dover is from above the 'Top Rock'/ Navigation Hardground, in a part of the succession that is definitely Coniacian. Similar sparse records of *S. granulata levis* were noted by Robaszynski et al. (1980) in the Boulonnais.

In the English Northern Province (Kiplingcotes, Yorkshire), there is a significant increase in faunal diversity below the second of the three Kiplingcotes Marls (see Wood & Smith 1978 for lithostratigraphical details). This increase is marked by the abrupt entry of abundant *Cremnoceramus ? rotundatus* associated with *Didymotis sp.* The underlying beds are incipiently nodular and rich in *Zoophycos,* but otherwise poorly fossiliferous and almost devoid of inoceramids. There is thus a broad correspondence with the *Zoophycos* -rich chalks and the overlying 'Top Rock'/Navigation Hardground of the southern England succession, and the two successions are almost certainly correlative.

The Coniacian – Santonian boundary

At the conclusion of the Symposium it was decided that the base of the Santonian Stage could be

recognised using one or a combination of the following criteria:

1. The entry of the inoceramid *Platyceramus siccensis* (Pervinquière), using the Djebel Fguira Salah section in Tunisia as reference section.
2. The entry of the inoceramid *Cladoceramus undulatoplicatus* (Roemer), using as reference section either the White Chalk section exposed in the coastal cliffs of the Isle of Thanet, Kent, southern England; or the marl succession exposed in the Olazagutia quarry, Navarra, northern Spain.
3. The entry of the ammonite *Texanites oliveti* (Blanckenhorn), using Djebel Fguira Salah as reference section.

There is general consensus that the first appearances of *Cladoceramus* and *Texanites* s.s. are approximately coincident in many areas, although only in two areas in Europe, viz. the Craie de Villedieu Formation in the southern part of the Paris Basin (Jarvis, Gale & Clayton 1983; Jarvis & Gale, in press) and in the area around Olazagutia (CJW and Berlin University research group, unpublished) is this directly demonstrable. Elsewhere, the reported co-occurrence, e.g. the Ruhr area mineshafts in the southern part of the Münster Basin, GFR, (Seitz 1961) is based on poorly preserved texanitids which are not definitely referable to *Texanites* s.s.

Two further criteria have been used to recognise the base of the Santonian Stage in northern European chalk facies successions:

1. The entry of *Sphenoceramus* ex gr. *cardissoides* (Goldfuss)/*pachti* (Arkhangelsky) – see discussion by Seitz (1965, pp. 133–135).

2. The entry of the foraminiferan *Stensioeina granulata polonica* Witwicka e.g. in Poland (Poszaryska & Witwicka 1983), and in the area of the Pompeckj Block, GFR (Koch 1977).

In southern England, we previously (Bailey et al. 1983a,b) took the base of the Santonian at the entry-point of *S. granulata polonica,* which is coincident with a level of major faunal change including the entry of *Spinaptychus* [i.e. aptychi of texanitid ammonites] (see Bailey et al. 1983a, fig. 2, and this paper, fig. 2). This level falls between two laterally continuous narrow bands of *Cladoceramus* that are traceable throughout southern England and northern France in basinal chalk facies. We previously referred the inoceramid characterising the lower of these bands to *Inoceramus digitatus* J. de C. Sowerby *non* Schlüter, but it has now been re-identified on the basis of better material as a *Cladoceramus,* near to *C. undulatoplicatus michaeli* (Heinz). *I. digitatus* J. de C. Sowerby is an unrelated inoceramid which is probably restricted to the English Northern Province. Following the recommendations of the Symposium, the base of the Santonian in the Anglo-Paris Basin is now better identified by the lower of the two main *Cladoceramus* bands. Selected biostratigraphical data relevant to this revised interpretation of the boundary, including nannofossil data not previously available, is given in fig. 2.

In the Lägerdorf standard section of northern Germany, the lower of the two *Cladoceramus* floods recognised in the Anglo-Paris Basin does not appear to be represented. *S. granulata polonica,* although reported (Koch *in* Ernst & Schulz 1974) to enter coincident with the first *Cladoceramus,* is now known (HWB) to enter approximately 4 m lower, at a level of major faunal change. The unit between the entry of *S. g. polonica* and the first recorded occurrence of *Cladoceramus* was referred by Ernst & Schulz (1974) to the local Zone of *Micraster bucaillei* and *Gonioteuthis praewestfalica,* and assigned to the Upper Coniacian (Oberconiac), but the evidence presented here clearly indicates that it should be attributed to a low level in the Santonian. The faunal change at this level corresponds closely to that documented by us (Bailey et al 1983a, fig. 2) at the level of the Chartham Flint (see fig. 2).

In northern Spain, two *Cladoceramus* floods comparable to those of the Anglo-Paris Basin successions are present in the *Micraster* marl facies of the Olazagutia quarry, and *Texanites* s.s. has been identified in proximity to one of these floods in a nearby section (CJW and Berlin University research group, unpublished).

The Santonian – Campanian boundary

Following a somewhat unsatisfactory and inconclusive discussion, and in the absence of valid data on ammonites and inoceramids in the boundary succession, the Symposium tentatively

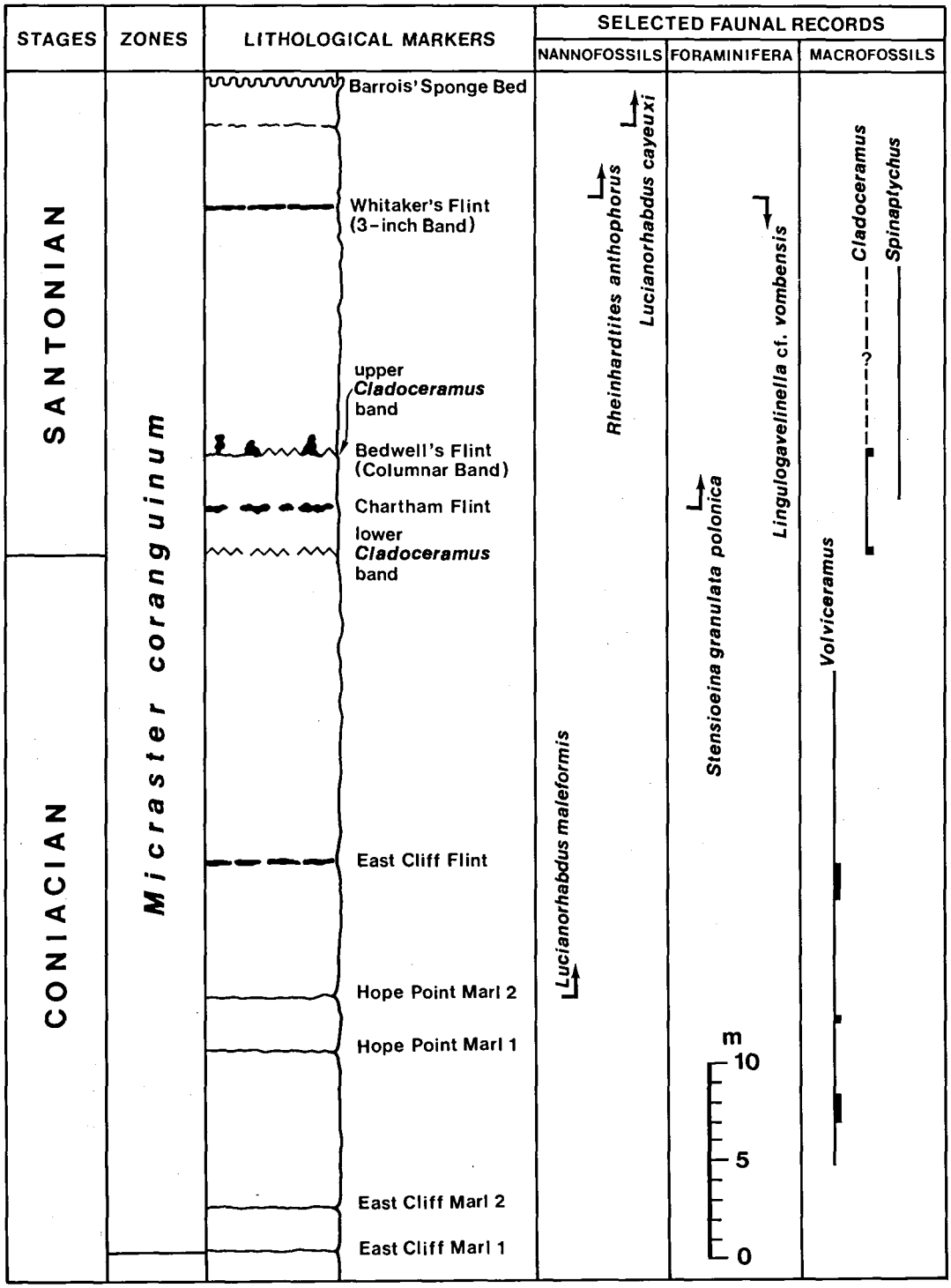

Fig. 2. Schematic lithological succession (to scale) showing the beds across the Coniacian – Santonian boundary in the Kent coast section (Dover–Thanet), with ranges and levels of acme-occurrence of selected critical taxa. Nannofossil data interpreted from Crux (1980; 1982).

adopted the following two criteria for recognising the base of the Campanian:

1. The entry of the nannofossil *Aspidolithus parcus* = *Broinsonia parca* (Stradner), and 2. The entry of the belemnite *Gonioteuthis granulataquadrata* (Stolley).

Although there is general consensus amongst nannofossil workers that the entry of *Broinsonia parca* marks the base of the Campanian, the entry-point in southern England in the Seaford Head standard section (Crux 1980; 1982) is at a level well above the base of the Campanian as defined in chalk facies in the Anglo-Paris Basin by de Grossouvre (1901) and followed by Rawson, Curry, Dilley, Hancock, Kennedy, Neale, Wood & Worssam (1978). *B. parca* first appears at about the level of the Old Nore Marl (Bailey et al. 1983a, fig. 3), i.e. just below the base of Brydone's (1914) Subzone of abundant *Offaster pilula* of the *Offaster pilula* Zone.

The proposal that the base of the Stage should be taken at the evolutionary boundary between *Gonioteuthis granulata* (Blainville) and *G. granulataquadrata* is open to criticism in that it is dependent on the detailed biometric analysis of large populations of *Gonioteuthis*, such as are found preserved only in marginal sediments. In southern England, belemnites are insufficiently common to provide valid data at this level. *Gonioteuthis granulata* is, however, not uncommon in the *Marsupites testudinarius* Zone, and exhibits an acme-occurrence coincident with the acme of *Marsupites* in the Thanet coast section (see Bailey et al. 1983a, fig. 2). In northern England, preliminary studies by Ernst (1966, fig. 5 and p. 138) on the belemnites of the Yorkshire coast section suggested that they were 'phylogenetically retrograde' compared with supposedly contemporaneous populations from northern German successions. Such a discrepancy would tend to invalidate the use of the *Gonioteuthis* lineage as a criterion for recognising the base of the Santonian Stage in sediments containing belemnites.

In northern European chalk facies, the Santonian – Campanian boundary has been conventionally drawn (following de Grossouvre, 1895–1901) at the extinction-level of the pelagic crinoid *Marsupites*. This criterion can be readily applied in the English Northern Province, Northern Ireland and Germany. In southern England, however, a further crinoid zone, that of *Uintacrinus anglicus* Rasmussen, is found succeeding the *M. testudinarius* Zone. Contrary to the position adopted by Rawson et al. (1978) we now arbitrarily take the base of the Campanian in the southern England successions at the *top* rather than at the base of the *U. anglicus* Zone, i.e. at the top of the ranges of the pelagic crinoid genera *Uintacrinus* and *Marsupites* which appear to characterise the late Santonian worldwide. This horizon can be best defined in the Seaford Head section (Sussex) at the Friars Bay Marl 3 (see Mortimore, in press, Table 1). As so drawn, this boundary is situated within the lower part of a succession of oyster-rich chalks characterised by *Pseudoperna boucheroni* (Woods *non* Coquand), approximately equivalent to and contemporaneous with the 'Grobkreide' facies of north German chalk successions.

With reference to the foraminiferid data, the base of the Campanian as used here is:

1. Coincident with the first evolutionary occurrence of *Bolivinoides culverensis* Barr,
2. Slightly below the top of the range of *Globigerinelloides rowei* (Barr),
3. Marked by a significant influx of planktonic foraminifera, mainly comprising *Archaeoglobigerina* with some *Globotruncana.*

This level is significantly below the entry point of *Broinsonia parca* which, in the Seaford Head section, is situated approximately 15 m above the top of the *anglicus* Zone.

The Campanian – Maastrichtian boundary

This boundary cannot be precisely located in the English Chalk. The critical successions comprise a complex of glacially-emplaced thrust and overfolded chalk masses in Pleistocene drift which are difficult to interpret stratigraphically, and do not provide a continuous succession (Peake & Hancock 1961; 1970; Wood 1967). By convention, and following the decision of the Symposium, the base of the Maastrichtian in chalk facies is taken at the entry of the belemnite genus *Belemnella.* It must be noted, however, that *Belemnella* is at first extremely rare, and its lowest occurrence is

therefore of limited use except in continuous and well-investigated successions such as the Kronsmoor standard section.

The base of the Maastrichtian in the UK is conveniently recognised by micropalaeontological criteria, using the level of flood abundance of the foraminiferan *Reussella szajnochae* (Grzybowski) occurring below and immediately above the base of the Maastrichtian in Kronsmoor. This flood occurrence has been identified in one of the glacial-tectonic slices in eastern England (Swiecicki 1980) and is recognised throughout the North Sea Basin. The local disappearance of *Micraster* appears to coincide with this microfaunal change.

The Maastrichtian – Danian boundary

In the UK sector of the North Sea Basin, this boundary is recognised by the extinction of the foraminifera *Abathomphalus mayaroensis* (Bolli), *Globotruncana contusa* (Cushman) and *Pseudotextularia elegans* (Rzehak).

Dansk sammendrag

Kriterier for definition af etage grænserne for coniacian-maastrichtien i England diskuteres, og der fremsættes følgende forslag: (1) turonien-coniacien grænsen defineres ved første forekomst af *Forresteria* og *Cremnoceramus*? *waltersdorfensis hannovrensis;* (2) coniacien-santonien grænsen defineres ved den nedre *Cladoceramus* horisont; (3) santonien-campanien grænsen defineres ved toppen af *Uintacrinus anglicus* zonen. Denne grænse svarer til første forekomst af *Bolivinoides culverensis;* (4) campanien-maastrichtien grænsen er ikke veldefineret i England. Som en praktisk grænse anvendes en 'flood abundance' af *Reussella szajnochae.*

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