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ABSTRACT - Analysis of abundant, diverse and well-preserved Albian nannofloral assemblages from onshore English sections has enabled a high-resolution nannofloral zonation to be developed with the construction of sixteen zones. The results are correlated with the ammonite zonation.

Five new species, Acenolithus viriosus sp. nov., Stauroolithites rotatus sp. nov., Stauroolithites canthus sp. nov., Bownia glabra sp. nov. and Calculites percornis sp. nov. are described. J. Micropalaeontol. 15(2): 97–129, October 1996.

INTRODUCTION
Extensive sampling of Albian, ammonite-dated field localities from England (Fig. 1) together with additional localities in Germany, France and the southern North Sea Shell/Essco well, 49/25a-9, has provided an opportunity for a refined Albian nannofossil biozonation scheme to be developed.

Prior to 1987, calcareous nannofossil zonations of the Albian generally had low resolution, e.g. Thierstein (1976), Sissingh (1977) and Perch-Nielsen (1979). Many of the marker species used in these zonations (see Fig. 18) are based on localities in Tethyan areas. These species are often rare, entirely absent or have different age ranges in the Boreal Realm.

Jakubowski (1987) highlighted the immense potential of using calcareous nannofossils to date the Lower Cretaceous using released well sections mainly from the Moray Firth Basin. He erected six zones for the Albian using a combination of last appearance datums (LAD), first appearance datums (FAD) and semi-quantitative events. However, he did not have the benefit of macrofossil-dated material and hence his correlations with the ammonite zonation were speculative.

This study attempts to establish a scheme useful both for academic workers and for industrial purposes, in which LADs and acme datums are regularly used. A total of sixteen zones are defined for the Albian. This study establishes a link between macrofossil (MF) and nannofossil (NF) biostratigraphies, thus extending interdisciplinary correlations both geographically and biostratigraphically. The zonation was developed in conjunction with studies of North Sea wells and its applicability in this area has been proven, although detailed primary data (except for well 49/25a-9) cannot be documented here for commercial reasons.

METHODS
1. Sample preparation
For light microscope examination, the samples were prepared by placing a small amount of sediment directly onto a microscope slide. A pipette was used to place a drop of distilled water onto the sample and smeared out into a thin layer by using a clean picking brush (size 101). The smeared sample was dried on a hot plate and a coverslip was attached using a permanent mounting medium. The picking brush is placed in 10% HCl to remove any remaining residue.

2. Counting technique
Samples were examined with a light microscope at a magnification of 1000X. A transect of thirty fields of view is taken with all specimens counted. Some species, e.g. Watznaueria barnesae, are so profuse that only ten or, in some instances, five fields of view are counted. Its abundance is subsequently multiplied out to thirty fields of view.

The following relative abundance categories which are used extensively in industry are also utilized in the present study:

- rare : less than 1 specimen per 30 fields of view.
- occasional : 1–2 specimens per 30 fields of view.
- common : 3–10 specimens per 30 fields of view.
- abundant : 11–29 specimens per 30 fields of view.
- influx : individuals are a major component of assemblage – greater than 29 specimens per 30 fields of view.

MATERIAL STUDIED
The stratigraphic results presented here are based on data from several localities in England and northwest Europe together with knowledge gained from numerous exploration wells drilled throughout the North Sea. The localities studied are discussed briefly in the following sections. Nannofossils recovered in these sections are presented in range charts (Figs 2–16).

1. Folkestone area and Eastbourne
2. Cambridgeshire, Bedfordshire and Buckinghamshire
3. Yorkshire
4. Mt. Risou, southeast France
5. Vöhrum, Germany
6. Shell/Essco 49/25a-9

The locations of field samples studied from mainland UK
are indicated on Fig. 1. Precise locations are cited below relative to the UK national grid (e.g. TV 955 596). A chronostratigraphic synopsis of the studied localities is given in Fig. 17.

1. FOLKESTONE AREA AND EASTBOURNE
   (a) Copt Point [TR 2414 3645]
   The classic Gault Clay succession at Copt Point near Folkestone was used to establish a correlation between the ammonite-dated clays and the nannofloral assemblages (Fig. 2). The sediments are lithologically subdivided into Beds I–XIII, Price (1874), Jukes-Browne & Hill (1900). The bulk of Bed XIII, however, together with Bed XII and the upper part of Bed XI were not exposed due to slumping. This part of the sequence was sampled from the Folkestone Warren borehole.

   (b) Folkestone Warren borehole [TR 24473 77813]
   The Folkestone Warren borehole (Fig. 3) can be viewed at BGS, Keyworth (Reg. No. TR23NW No. 10). The nannofloral assemblages indicate a marked hiatus at the Bed X1/Bed X11 boundary. NF Zone NAL 12 rests directly upon NAL 9.

   (c) English Channel borehole 16754
   A more complete Albian/Cenomanian boundary succession, than that preserved at Folkestone, is documented from English Channel boreholes (Carter & Hart, 1977; Amédro, 1994). Four samples were analysed (Fig. 4) from this borehole (Zone 6a of Carter & Hart, 1977). Lithofacies data and foraminiferal assemblages suggest a Lower Cenomanian age for Zone 6a, although macrofossil information is sparse.

   (d) Cow Gap near Eastbourne [TV 955 596]
   This section (Fig. 5) was described by Price (1879). Additional macrofossil and lithological data were provided by A.S. Gale (pers. comm., 1994).

2. CAMBRIDGESHIRE, BEDFORDSHIRE AND BUCKINGHAMSHIRE
   The Albian Gault Clay in East Anglia, Bedfordshire and Buckinghamshire consists of calcareous mudstones with rich nannofloras. The assemblages exhibit localized asmes of species that are rare elsewhere in England and in the central North Sea.

   The Gault Clay is exposed in numerous quarries in the Leighton Buzzard area. The key outcrops studied are listed below.

   (a) Chamberlain’s Barn [SP 926 264]
   This section (Fig. 9) was described by Lamplugh (1922) and Casey (1961). The most recent descriptions of the section are by Owen (1972) and Eyers (1992).

   (b) Monday’s Hill [SP 939 282]
   Monday’s Hill was described in detail by Owen (1972) and Eyers (1992). The nannofossil biostratigraphy of this section was documented by Crux (1991). A nannofloral chart is therefore not figured in this study although samples examined are documented in Appendix 2 together with NF zones and relevant discussion.

   (c) Nine Acres Quarry [SP 939 278]
   Nine Acres Quarry (Fig. 7) lies approximately 150 m southeast of the Monday’s Hill section. A reduced sequence of ?spathi to intermedius MF Subzonal mudstones are exposed (Eyers, pers. comm., 1992).

   (d) Arlesey [TL 186 354]
   This section (Fig. 8) is described by Eyers (1992). Additional macrofossil data were supplied by H. G. Owen, pers. comm., 1994.

   Chalk sedimentation was initiated earlier at Arlesey than at Folkestone. The NC1 marker, *Calcities anfractus* has a FAD approximately 3 m above the base Chalk at Arlesey whilst at Folkestone the FAD of *C. anfractus* is 2 m (pers. obs.) above the top of Bed X111 within glauconitic mudstones.

   Two sections were studied in Cambridgeshire – (e) and (f).
(e) Burwell [TL 577 687]
The ammonite fauna and lithological subdivisions of the Burwell section (Fig. 10) are documented by Gallois & Morter (1982). Additional macrofossil information was supplied by J. Eyers (pers. comm., 1993).

The top of the auritus MF Subzone in East Anglia is often missing or highly condensed (J. Eyers, pers. comm., 1993). There is evidence of this hiatus at Burwell where Eiffellithus monechia appears 10 cm below a phosphatic horizon. In Bedfordshire, however, the upper part of the auritus MF Subzone is locally more complete. At Munday’s Hill at least 4 m of the latest auritus MF Subzone is present (top not seen) and here Eiffellithus monechiai eventually becomes common.

At Burwell, sediments of rostratum MF Subzone age lie unconformably upon the upper part of the auritus MF Subzone. The very pale grey mudstones of Bed 17 are intensely bioturbated throughout. This bed is, in parts, poorly exposed due to slumping. No younger Albian sediments are preserved at Burwell.

The presence of NF Zone NAL 11 indicates that Bed 17 has no lithological equivalent at Folkstone due to an erosional phase which is expressed in phosphatic nodules at the base of the ‘Greensand Seam’, Bed XII.

(f) Soham borehole [TL 593 745]
The Soham borehole (Fig. 6) can be viewed at BGS, Keyworth. Macrofossil determinations are based on Eyers (1992).

3. YORKSHIRE
(a) Speeton [TA 155 755]
The upper part of the Speeton Clay at Speeton (Fig. 12) and the overlying Red Chalk are almost devoid of ammonites. Lamplugh (1924) divided the clays into five subdivisions lettered A to E in descending sequence using the more abundant and better preserved belemnites. The A Beds are of Albian age and were subdivided A1 to A5 by Wright (1935).

The dark clays representing Bed A5 contain the belemnite Neohibolites ewaldi and were originally correlated with the Aptian Sutterby Marl of Lincolnshire by Spath (1924). The upper part of these beds, however, contain a Lower Albian ostracod assemblage (Kaye, 1964). This age assignment is supported by the palynological flora which contains Kleithriasphaeridium simplicispinum and lacks any Aptian markers (R. Davey, pers. comm., 1993).

The ‘Greensand Streak’, Bed A4, and the basal part of Bed A3 are non-calcareous and barren of calcareous nanofossils. Kaye (1964) postulated a Middle Albian age for these beds. The overlying sediments, however, yield Lower Albian nannoflora assemblages (NF Zone NAL 3) similar to those found in the mammillatum MF Zone at Chamberlain’s Barn, Bedfordshire. Brown clays were also found yielding the Middle Albian markers, Ceratolithina cruxii and Crucicirribum anglicum (NF Zone NAL 4) associated with Hamites and Hoplites ammonites (A.S. Gale, pers. comm., 1996), but their exact level from within Bed A3 was not established. It should be noted that extensive slumping occurs at this level (P. Rawson, pers. comm., 1994). Due to slumping, Beds A2 and A1 were not sampled, although Euhoplitites and Montoniceras ammonites have previously been recovered from Bed A1 and indicate an Upper Albian age. The overlying Red Chalk (16.1 m) is also regarded as Upper Albian. Further south, at South Feribby, in proximity to the Market Weighton High the Red Chalk (= Hunstanton Formation) is only 2.5 m thick and, in part, forms a highly condensed lateral equivalent of the Red Chalk Formation at Speeton and the offshore southern UK Sector of the North Sea.

(b) Heslerton No. 2 borehole [SE 9199 7589]
This Heslerton No. 2 borehole can be viewed at BGS, Keyworth. Macrofossil data are limited from the interval studied in this borehole (P. Rawson, pers. comm., 1994). Nannofossil data (Fig. 11) suggests these sediments are equivalent to the top of Bed A5, Bed A4 and the base of Bed A3, as exposed at Speeton.

(c) South Feribby, Humberside [SE 911 204]
The Carstone Formation at South Feribby is considered to be of Lower Albian age based on the brachiopod fauna (Whitham, 1991). This formation, which consists of hard, iron- rich, pebbly sands, is non-calcareous and barren of nanofossils.

At Melton Bottoms [SE 970 270], just north of South Feribby, the basal red marls of the Hunstanton Formation are considered to be of Middle Albian age (Whitham, 1991) based on a single whorl fragment of the ammonite Dimorphoplites cf. hilli Spath. The absence of Middle Albian NF zones at South Feribby (Fig. 13) is possible evidence of a diachronous base to the Red Chalk particularly over the Market Weighton High. Sediments equivalent to the auritus MF Subzone are absent. This stratigraphic break is also present at the Heslerton No. 2 borehole (D. Rutledge, pers. comm., 1994) and possibly at Speeton (pers. obs.).

The upper part of the Hunstanton Formation at South Feribby is equivalent to the majority of the Red Chalk at Speeton.

4. MT RISOU, SOUTHEAST FRANCE
(ROANS:1:25 000, LAMBERT ZONE II, 1937: 853.2–3239)
The section at Mt. Risou (Fig. 15) exposes a thick succession of marls and minor limestones across the Albian/Cenomanian boundary which have been accurately dated with ammonites (A.S. Gale, pers. comm., 1994).

This is the only location in the present study where common/abundant Broisia novaformis have been found in Upper Albian dated sediments. A hiatus is present at this level in southern Britain.

The NF Zone NCI nominate marker, Calclutes anfractus is found at Mt. Risou. The FAD at this locality is stratigraphically higher than that seen further north in southern England, where C. anfractus is found associated with Bowenia glabra and Gartnerago chiasta. It appears that C. anfractus, although not endemic to the Boreal Realm, as
Fig. 2. Stratigraphic distribution of nannofossil species in the Copt Point section. Nannofossil samples are with reference to base Bed 1. Abundance counts from 30 fields of view. Marker species in bold. Ammonite stratigraphy after Owen (1975); bed nomenclature after Jukes-Browne & Hill (1990).
**Fig. 3.** Stratigraphic distribution of nannofossil species in the Folkstone Warren borehole. 23.55-38.00 m. Abundance counts from 30 fields of view. **Fig. 4.** Stratigraphic distribution of nannofossil species in the English Channel borehole. PM16754, 5.53-8.35 m. Abundance counts from 30 fields of view. P refers to species present outside 30 fields of view. Marker species in bold. Ammonite stratigraphy based on correlation with Folkstone cliff section (Owen, 1975); bed nomenclature after Jukes-Browne & Hill (1900).
Fig. 5. Stratigraphic distribution of nannofossil species in the Cow Gap section. Metre level of samples are with reference to base glauconitic mudstone (mantelli MF Zone). Abundance counts from 30 fields of view. P refers to species present outside 30 fields of view. Marker species in bold. Ammonite stratigraphy after Gale (pers. comm., 1994).

A proposed Albian to lower Cenomanian nannofossil biozonation

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[Diagram showing stratigraphic distribution with species names and abundance counts]
A proposed Albian to lower Cenomanian nannofossil biozonation.

### Stratigraphic Distribution of Nannofossil Species

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### Sample Details

- **Sample No.**
- **Species**
- **Reference Level**

**Marker Species:**

- Acetobolithus galloisii
- Acetobolithus viridis
- Acetobolithus dalmanni
- Bacterolithus regularis
- Barlowella boletiformis
- Buxkylithus ambiguus
- Buxkylithus grandi
- Calypolithus aff. C. dispar
- Calypolithus cruichi
- Chiasmozygus littorarius
- Corolithon achlyorum
- Corolithon exiguum
- Creolithus buiwellensis
- Cretarhabdus inaequalis
- C. inaequalis (large var.)
- Cretarhabdus inaequalis
- Crussicosium sp.
- Cylindrolepis rotata
- Cylindrolepis shirleyensis
- Diplorhabdus ignotus
- Diplorhabdus britannica

**Ammonite Stratigraphy:**

- Lower Albian
- Middle Albian
- Upper Albian

**Reference:**

- Owen (1972)
- Evers (1992)
Fig. 10. Stratigraphic distribution of nannofossil species in the Burwell section. Metre level of samples are with reference to base Bed 15. Abundance counts from 30 fields of view. P refers to species present outside 30 fields of view. Marker species in bold. Ammonite stratigraphy and bed nomenclature after Gallois & Morter (1982).
A proposed Albian to lower Cenomanian nannofossil biozonation.
Fig. 12. Stratigraphic distribution of nannofossil species in the Speeton section. Metre level of samples are with reference to base Bed A4. Abundance counts from 30 fields of view. Marker species in bold.
A proposed Albian to lower Cenomanian nannofossil biozonation

Fig. 13. Stratigraphic distribution of nannofossil species in the South Ferriby section. Metre level of samples are with reference to top Carstone. Abundance counts from 30 fields of view. P refers to species present outside 30 fields of view. Marker species in bold. Ammonite stratigraphy after Whitham (1991).
**Fig. 14. Stratigraphic distribution of nannofossil species in Shell/Esso 4972/8-a (Southern North Sea).** Abundance counts from 30 fields of view. P refers to species present outside.

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**Note:** Sample C-135 is from the base of Lower Albian. Variation in sedimentation in ammonite samples.

### Table: Lower Albian

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**Species:**
- Acarinolithus galloisii
- Assipatra aff. A. infracretacea
- A. dietzmannii
- Biaurudospheara africana
- Biscutum constans
- Bukvithus ambiguus
- Calcites dispar
- Corollithon archyorum
- Crepidolithus burlwennensis
- Crepetarhabdus inaequalis
- Crucirhombus? sp.
- Crucibiculina sp. 1
- Cyclagelosphaera margerel
- C. rotacipylea
- Discorhabdus ignotus
- Epromithus florius
- Glaukoolithus diplogrammus
- S. coronadiennis
- Hemipodorhabdus gorkae
- Lofia xenoda
- Manivilella pecten
- Manivilella permineataidea
- Mirospora obastis
- Nannoconus elongatus
- Nannoconus aff. N. fragilis
- Nannoconus aff. N. globulus
- Nannoconus truith gp.
- Octoctoculus magnus
- Oratus perspecicum
- Parhabdolithus embergeri
- Pseudoarctica spp.
- Pseudosphaera spinosa
- Repagulum panrividentatum
- R. achlyostauron
- Rhagodicoccus angustus
- Rhagodicoccus esper
- Rhagodicoccus splendidus
- Retealpius orenulaus
- Rhotha xrista
- Scopelosella spp.
- Scapholithus fossils
- Soliasites horricus
- Staurolithoites gauisothyrius
- Tetrarhabdolithus decorus
- Tranquilithus gahalus
- Vakshinaella sp.
- Watznaudia bamesae
- Zeugrhabdotes eisypus (large var.)
A proposed Albain to Lower Cenomanian nannofossil biozonation.

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<td>penillatum</td>
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**Fig. 15.** Stratigraphic distribution of nannofossil species in the Mt Risou field section. Metre level of samples are with reference to base limestone bed. Abundance counts from 30 fields of view. Marker species in bold. Ammonite stratigraphy after Gale (pers. comm., 1994).
this study has proven, certainly preferred high latitudes. The isolated occurrence of *C. anfractus* within sample R9 may indicate an earlier cold water incursion from the north. This is supported by the presence of *Seribiscutum primitivum*, a form characteristic of Boreal Realm Albian nanofloral assemblages (Crux, 1991 and pers. obs.) but extremely rare at the Mt. Risou section.

5. VÖHRUM, NORTHWEST GERMANY Vö TK 25 HÄMELERWALD No. 3626 (re: 3578 800, h: 58 00 000)

This locality (Fig. 16) exposes a succession of dark grey to black mudstones of Lowermost Albian to Uppermost Aptian age. A secondarily altered tuff is located at the Albian/Aptian boundary. The calcareous nanofossils of this section have been studied by Cepek (1982) and Mutterlose (1989). The assemblages are of low abundance and diversity.

A detailed analysis of the sequence is given by Kemper & Zimmerle (1978) and Kemper (1982).

6. SHELL/ESSO SOUTHERN NORTH SEA WELL: 49/25a-9 (latitude 53° 12' 37.760"N, longitude 02° 55' 20.328"E)

This well (Fig. 14) is located approximately 20 km west of the UK/Netherlands median line in the UK southern North Sea.

**ZONATION**

The zonation outlined below was developed as a practical tool for subdividing the Albian to Lower Cenomanian of onshore sections, mainly from England and offshore material from throughout the North Sea Basin. Work started with the aim of improving on the NF scheme of Jakubowski (1987) and constructing a scheme useful for both academic and industrial purposes. In this study, sixteen zones are defined for the Albian/Lower Cenomanian interval. They are correlated with the MF zones and compared with previous NF zonations in Fig. 18. A composite range chart of biostratigraphically useful species is presented in Fig. 19.

*Bukrylithus ambiguus* Interval Range NF Zone (NLK6, Jakubowski, 1987)

**Definition:** Interval from LAD of *Micrantholithus hoschulzi* to LAD of abundant *Rhagodiscus asper*.

**Age:** Lower Albian/Upper Aptian.

**Remarks:** In this study no change in nanofloral assemblages is identified over the Aptian/Albian boundary.

Abundant *R. asper* are found sporadically throughout the
Fig. 17. Stratigraphic sections studied.

- Chamberlain's Barn Pit
- Nine Acre Quarry
- Munday's Hill
- Folkstone-Copt Point
- Soham borehole
- Burwell
- Folkstone Warren borehole
- Arlesey
- Eastbourne
- South Ferriby
- English Channel borehole, 416754
- Mt. Risou, Vocontian Trough

*Note: NAL6 borehole, Shell/Esso 49/05a-9.
**Fig. 18.** Nannofossil zonation scheme of the present study compared with previous schemes.
Middle/Upper Albian. It is, however, only in basal Albian and older sediments that \textit{R. asper} is a major component of assemblages. At \textit{Vöhrum}, \textit{R. asper} makes up between 15\% and 30\% of the total nanoflora when \textit{Watznaueria barnesae} is discounted. This event is probably equivalent to the \textit{Bukryliithus ambiguous} Zone (NLK 6) of Jakubowski (1987) based on the LAD of common \textit{R. asper} (common occurrence was defined as 3 to 15 specimens per 30 fields of view, pers. comm., 1995).

\textit{Micrantiolithus hoschulzii}, the top Aptian marker of Jakubowski, 1987 (Zone NLK 7) is not identified from \textit{jacobi} MF dated sediments at \textit{Vöhrum} or numerous cored wells studied in the Moray Firth area (pers. obs.) and appears to have an intra Upper Aptian (\textit{natfieldiensis} MF Zone) LAD in the North Sea Basin (pers. obs.). Mutterlöse (1991) suggests an even earlier LAD for \textit{M. hoschulzii} within the \textit{drewi} MF Zone of Germany.

\textbf{Repagulin parvidentatum Interval Range NF Zone (NAL 1)}
\textbf{Definition:} Interval from LAD of abundant \textit{Rhogodiscus asper} to FAD of \textit{Acaenolithus viriosus}.
\textbf{Age:} Lower Albian, \textit{?tardefurcata} MF Zone.
\textbf{Remarks:} NF Zone NAL 1 is rarely identified in the central and northern North Sea as a result of non-calcareous lithologies. In the southern North Sea, however, calcareous mudstones are locally developed equivalent to the lower part of the A5 Beds at Speeton.

\textbf{Acaenolithus viriosus Taxon Range NF Zone (NAL 2)}
\textbf{Definition:} Total range of \textit{Acaenolithus viriosus}.
\textbf{Age:} Lower Albian, \textit{mammillatum} MF Zone.
\textbf{Remarks:} The FAD of \textit{A. viriosus} could not be correlated with the MF Zonation due to limited onshore material studied over this interval. This event, however, is biostratigraphically restricted to an intra Lower Albian age based on the absence of \textit{A. viriosus} from \textit{schrammeni} MF dated mudstones at \textit{Vöhrum} and uppermost \textit{mammillatum} MF dated mudstones at Chamberlain’s Barn.

\textbf{Crucirriburn anglicum Partial Range Zone (NAL 3)}
\textbf{Definition:} Interval from LAD of \textit{Acaenolithus viriosus} to FAD of \textit{Crucirriburn anglicum} (and \textit{Ceratolithina cruxii}).
\textbf{Age:} Lower Albian, \textit{top mammillatum} MF Zone (\textit{steinmanni} MF Subzone).
\textbf{Remarks:} The FAD of \textit{Prediscosphera columnata} was used by Thierstein (1976), Sissingh (1977), Perch-Nielsen (1979, 1983) and Jakubowski (1987) as a zonal boundary. In the present study \textit{P. columnata} was, however, found to be sporoedic towards the base of its range in the uppermost Lower Albian at Speeton and Chamberlain’s Barn. In the Tethyan Realm, however, the FAD of \textit{P. columnata}, in the absence of other markers, is a useful approximation to the base of the Middle Albian. Under the light microscope no differentiation could be made between \textit{P. spinosa} and \textit{P. cf. stoveri}.

\textbf{Braloweria boletiformis Partial Range NF Zone (NAL 4)}
\textbf{Definition:} Interval from FAD of \textit{Crucirriburn anglicum} (and \textit{Ceratolithina cruxii}) to LAD of \textit{Braloweria boletiformis}.
\textbf{Age:} Middle Albian, base of \textit{lyelli} MF Subzone to top of \textit{niobe} MF Subzone.
\textbf{Remarks:} \textit{Axopodorhabdus albianus} has its FAD at the base of the \textit{intermedius} MF Subzone both at Folkestone (Bed II) and at Mundays Hill (pers. obs.) but the occurrences are extremely rare and sporadic. These records, however, support the identification of \textit{A. albianus} by Amédro \textit{et al.} (1981) from coeval sediments at Boulonnais, France.

The FAD of \textit{A. albianus} which was used by Cepek & Hay (1969), Thierstein (1976) and Roth (1978) as a zonal marker is not taken as a reliable datum in this study due to its extreme rarity at the base of its range. Records of \textit{A. albianus} below the Middle Albian (Perch-Nielsen, 1985) are probably due to contamination or misidentification. The presence of \textit{A. albianus} and \textit{Ceratolithina humata} in the \textit{niobe} MF Subzone (Crux, 1991) is possibly due to mis-sampling over the \textit{niobe}/\textit{crustum} stratigraphic break. \textit{Hayesites albiensis} is inconsistently present and usually rare in the sections studied. The rare and intermittent occurrence limits any biostratigraphical usefulness. It however, appears to be more consistently present in localities from Kent than further north in Cambridgeshire and Bedfordshire. \textit{Hayesites albiensis} was not identified from Yorkshire field sections or the North Sea Basin.

\textbf{Braloweria boletiformis}, however, is far more widespread than previously recognized. It is consistently present in the condensed Middle Albian successions of the North Sea Basin (pers. obs.) and may be recorded outside northwest Europe in future studies. This form has only previously been recorded from onshore material (Black, 1972; Crux, 1991).

\textbf{Bownia glabra Interval Range NF Zone (NAL 5)}
\textbf{Definition:} Interval from LAD of \textit{Braloweria boletiformis} to FAD of \textit{Ceratolithina bicornuta}.
\textbf{Age:} Middle Albian, base \textit{subdelaruei} MF Subzone to top \textit{meandrinus} MF Subzone.
\textbf{Remarks:} The \textit{Bownia glabra} NF Zone yields no FADs in this study and the assemblages show only local changes in the relative abundance of some taxa. Sediments equivalent to NAL 5 are very restricted in occurrence due to the erosion of Middle Albian sediments during the \textit{crustum} MF Subzone (Owen, 1975). This NF biozone was not sampled at Folkestone due to the attenuated sequence present at this locality. Sediments equivalent to this NF zone are identified, however, within the Soham borehole. NAL 5 has not been identified in the North Sea Basin.

The LAD of a \textit{Repagulin parvidentatum} influx is an easily recognized and consistent event occurring within the North Sea Basin. The datum was used by Jakubowski (1987) in the identification of his \textit{Repagulin parvidentatum} Zone (NLK5).

This event, however, as recorded by Crux (1991) using abundance variations at Munday’s Hill is unreliable in
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Fig. 19. Composite range chart of stratigraphically important calcareous nannofossils in England and the North Sea Basin: Albian to Lower Cenomanian.
Note:
Diversity and abundance in North Sea Basin is generally lower than in offshore sections.

*Seribiscutum primitivum* in Yorkshire and North Sea Basin is abundant from NC1 to base NAL2

*tardefurcata* and *jacobi* MF dated sediments in the North Sea Basin area are generally non-calcareous and barren of nannofossils.
onshore field sections where *R. parvidentatum* is also a major component of Upper Albian assemblages. This anomaly is possibly a reflection of the normally lower diversity and poorer preservation in offshore material.

**Ceratolithina bicornuta** Taxon Range NF Zone (NAL 6)  
**Definition:** Total range of *Ceratolithina bicornuta.*  
**Age:** Middle Albian, base *nitus* MF Subzone to top *daviesi* MF Subzone.  
**Remarks:** Perch-Nielsen (1988) recorded *C. bicornuta* from Bed VI (*nitus* MF Subzone)–Bed VIII (*cristatum* MF Subzone) at Folkstone. Extensive searching at the type Gault Clay section and at other ammonite-dated sections has, as yet, failed to record this form from above the *daviesi* MF Subzone. The presence of *Ceratolithina hamata* in the *niobe* MF Subzone at Munday’s Hill, Bedfordshire, as recorded by Crux (1991), is anomalous possibly due to mis-sampling over the *niobe/cristatum* stratigraphic break. Sediments equivalent to this NF biozone appear to be very restricted due to a short but widespread period of erosion in the *cristatum* MF Subzone (Owen, 1975). *Ceratolithina bicornuta* is rare in offshore wells possibly as a result of the condensed nature or absence of NAL 6 equivalent sediments. *Ceratolithina bicornuta* has, however, been observed (pers. obs.) in the South Halibut Basin (North Sea).

**Ceratolithina hamata** Interval Range NF Zone (NAL 7)  
**Definition:** Interval from LAD of *Ceratolithina bicornuta* to FAD of *Tegulalithus tessellatus* (and *Gartnerago praeobiolum*).  
**Age:** Upper Albian, base of *cristatum* MF Subzone to top *varicosum* MF Subzone.  
**Remarks:** Due to the absence of the Middle Albian *lautus* MF Zone over much of the English Albian, the first occurrences of *Ceratolithina hamata* and *Axopodorhabdus albianus* are often found at the base of the Late Albian in the *cristatum* MF Subzone e.g. at Munday’s Hill.

Crux (1991) considered the FAD of *Owenia hilli* as a potential biostratigraphical datum for the basal Upper Albian. In the present study, the FAD of *O. hilli* is recorded earlier within the *daviesi* MF Subzone.  

*Hayestes albiensis* is confined to Albian sediments below (except for a single identification within the Folkstone borehole) the FAD of *Eiffellithus turrisieffeli* in this study (Hill 1976) and Crux (1991). Many authors including Roth & Thierstein (1972), Verbeek (1977) and Manivit et al. (1977) used *H. albiensis* as a zonal marker co-occurring with *E. turrisieffeli*. *H. albiensis* is considered an unreliable biostratigraphic marker in this study.  

*Braarudosphaera stenorhetha* appears in this NF zone in the southern North Sea where it is associated with common/abundant *Braarudosphaera primula* and *Braarudosphaera quinquecostata*. The *Braarudosphaera* assemblage is particularly well developed in East Anglia, Yorkshire and in the southern North Sea. The common/abundant occurrence of the *Braarudosphaera* group in the *orbignyi* to *varicosum* MF Subzones is considered a localized event possibly due to palaeo-environmental conditions. Hill (1976) recorded a similar event (*Braarudosphaera quinquecostata* Acme Zone) associated with *Eiffellithus turrisieffeli*.  

Lambert (1986) grouped the separate species of *Braarudosphaera* under *B. africana*, based on the discovery of entire coccoliths in Albian laminated mudstones from Cameroon. The different architectural forms have not all been grouped under *B. africana* in the present study since they appear to have distinct stratigraphic ranges.  

**Tegulalithus tessellatus** Partial Range NF Zone (NAL 8)  
**Definition:** Interval from FAD of *Tegulalithus tessellatus* (and *Gartnerago praeobiolum*) to FAD of *Staurolithites angustus*.

---

**Explanation of Plate 1**

Figs 1–4. *Owenia hilli*.  
**Fig. 1.** crossed-nicols, SMH-10-06; **Fig. 2.** bright field, same specimen, SMH-10-07. **Fig. 3.** crossed-nicols, partial side view, SMH-14-09. **Fig. 4.** crossed-nicols, side view, SMH-10-10. All specimens, *auritus* MF Subzone, Bed 6, Munday’s Hill, Bedfordshire (NAL 9).  
**Fig. 5.** *Axopodorhabdus albianus*, SMH-13-08, *varicosum* MF Subzone, Bed X, Copt Point, near Folkstone, Kent (NAL 7).  
**Fig. 6.** *Braarudosphaera primula*, crossed-nicols, SMH-11-30, *varicosum* MF Subzone, Bed 5, Munday’s Hill (NAL 7).  
**Fig. 7.** *Braarudosphaera stenorhetha*, crossed-nicols, SMH-08-05, *varicosum* MF Subzone, Bed 5, Munday’s Hill (NAL 7). **Figs 8–9.** *Criculbiscutum hayi*.  
**Fig. 8.** crossed-nicols, SMH-16-24; **fig. 9.** bright field, same specimen, SMH-16-25, *mantelli* MF Zone, Folkstone Warren borehole, 36.75 m (NAC).  
**Figs 10–11.** *Criculbiscutum* sp.1.  
**Fig. 10.** crossed-nicols, SMH-08-12; **fig. 11.** bright field, same specimen, SMH-08-13, *intermedius* MF Subzone, Bed 2, Munday’s Hill (NAL 4).  
**Figs 12–13.** *Crepodolithus burwellensis*.  
**Fig. 12.** crossed-nicols, SMH-12-20, *intermedius* MF Subzone, Nine Acres Quarry, Bedfordshire (NAL 4).  
**Fig. 13.** crossed-nicols, SMH-09-16, *orbignyi* MF Subzone, Bed IX, Copt Point (NAL 7).  
**Figs 14–15.** *Crepodolithus burwellensis* (large variety).  
**Fig. 14.** SMH-12-23 and **fig. 15.** SMH-11-35, crossed-nicols, both specimens from Block 15, UK central North Sea (NAL 8).  
**Fig. 16.** *Cyclagelosphaera rotuliphyra*, crossed-nicols, SMH-09-26, *intermedius* MF Subzone, Bed 2, Munday’s Hill (NAL 4).  
**Fig. 17.** *Cyclagelosphaera shenleyensis*, crossed-nicols, SMH-09-27, *intermedius* MF Subzone, Bed 2, Munday’s Hill (NAL 4).  
**Figs 18–19.** *Eiffellithus monoeciae*.  
**Fig. 18.** crossed-nicols, SMH-12-32, *auritus* MF Subzone, Bed 6, Munday’s Hill (NAL 10).  
**Fig. 19.** crossed-nicols, SMH-12-31, *rostratum* MF Subzone, Bed 17, Burwell, Cambridgeshire (NAL 11).  
**Fig. 20.** *Zeugrhabdotus notseiae*, crossed-nicols, SMH-06-03, *daviesi* MF Subzone, Bed VII, Copt Point (NAL 6).  
**Figs 21–22.** *Gartnerago praeobiolum*.  
**Fig. 21.** crossed-nicols, SMH-11-32; **fig. 22.** bright field, same specimen, SMH-11-31, *auritus* MF Subzone, Bed 15, Burwell (NAL 8).  
**Figs 23–24.** *Lordia xenota*.  
**Fig. 23.** crossed-nicols, SMH-11-22, *spathi* MF Subzone, Bed I, Copt Point (NAL 4).  
**Fig. 24.** crossed-nicols, SMH-11-18, *auritus* MF Subzone, Bed 16, Burwell (NAL 9).  
**Figs 25–26.** *Orastrum perspicuum*.  
**Fig. 25.** crossed-nicols, SMH-11-04; **fig. 26.** bright field, same specimen, SMH-11-05, *intermedius* MF Subzone, Bed II, Copt Point (NAL 4). Note the two perforations which were not described by Varol (1991) due to overgrowth in his material.  
**Figs 27–30.** *Braloweria boletiformis*.  
**Fig. 27.** crossed-nicols, SMH-12-17; **fig. 28.** bright field, same specimen, SMH-12-18, *intermedius* MF Subzone, Bed 2, Munday’s Hill (NAL 4).  
**Fig. 29.** crossed-nicols, SMH-10-20; **fig. 30.** bright field, same specimen, SMH-10-19, *intermedius* MF Subzone, Nine Acres Quarry (NAL 4).
A proposed Albian to lower Cenomanian nannofossil biozonation

**Age:** Upper Albian, auritus MF Subzone (lower part).

**Remarks:** *Tegulolithus tessellatus* is restricted to this NF biozone in the North Sea Basin but occurs sporadically in younger NF zones from onshore localities. The FAD of *T. tessellatus* is a reliable biostratigraphic event. This form appears at Folkstone towards the base of the *auritus* MF Subzone together with *Gartnerago praebiollacum*. This association also occurs at Munday’s Hill, Burwell and at La Hève, northern France (pers. obs.), in reliably dated *auritus* MF Subzonal sediments (J. Eyers, pers. comm., 1993) and is locally present in sequences throughout the North Sea Basin.

Staurolithites angustus Partial Range NF Zone (NAL 9)

**Definition:** Interval from FAD of *Staurolithites angustus* (and *Radiolithus hollandicus*) to FAD of *Eiffellithus monechiae*.

**Age:** Upper Albian, auritus MF Subzone.

**Remarks:** *Staurolithites angustus* appears to be a cosmopolitan form having been recorded in Tunisia and Spain (Verbeek, 1977), onshore Holland (Stradner et al., 1968) and northern France (pers. obs.), below the FAD of *Eiffellithus turriseiffeli*. *Staurolithites angustus* as described by Stover (1966), has not been found to occur outside the Upper Albian in the present study. The LAD of *Braarudosphaera stenorhetha* within this NF zone appears to represent a localized event within the southern North Sea and England. Hill (1976) recorded *B. stenorhetha* from Oklahoma and Texas in younger Albian sediments associated with *Eiffellithus turriseiffeli*.

**Eiffellithus monechiae Partial Range NF Zone (NAL 10)**

**Definition:** Interval from FAD of *Eiffellithus monechiae* to FAD of *Eiffellithus turriseiffeli*.

**Age:** Upper Albian, auritus MF Subzone (upper part).

**Remarks:** A minor hiatus at the base of the *rostratum* MF Subzone has resulted in much of the upper part of the *auritus* MF Subzone being removed in Cambridgeshire (J. Eyers, pers. comm., 1993). This hiatus also occurs in the Folkstone section, with a non-sequence represented by phosphatic nodules at the base of the ‘Greensand Seam’ (Bed XII).

**Eiffellithus turriseiffeli Partial Range NF Zone (NAL 11)**

**Definition:** Interval from FAD of *Eiffellithus turriseiffeli* to FAD of *Crucibiscutum hayi*.

**Age:** Upper Albian, rostratum MF Subzone (lower part).

**Remarks:** This NF zone contains a period of nannofloral diversification characterized by the rapid evolution of the *Eiffellithaceae*. This evolutionary lineage has previously been documented by many authors, e.g. Verbeek (1977) and Hill & Bralower (1987). A similar evolutionary trend exists between *Staurolithites angustus* and *Staurolithites rotatus* within this NF biozone, whereby the bars which were near parallel to the axes of the ellipse rotated to form large angles with the axes.

The FAD of *E. turriseiffeli* has been used as a zonal marker event by many authors, e.g. Roth (1973), Thierstein (1976), Sissingh (1977), Taylor (1982) and Jakubowski (1987).

The FAD of abundant *Eiffellithus monechiae* is an alternative marker for the base of NAL 11.

**Radiolithus hollandicus Partial Range NF Zone (NAL 12)**

**Definition:** Interval from FAD of *Crucibiscutum hayi* to LAD of *Radiolithus hollandicus*.

**Age:** Upper Albian, rostratum MF Subzone.

**Remarks:** *Radiolithus hollandicus* occurs as distinct influxes at disparate stratigraphic levels and can be missed in field samples, sidewall cores or core samples. Its LAD in ditch cuttings, however, is a recognized correlatable event in North Sea wells.

*Eiffellithus monechiae* is subordinate to *E. turriseiffeli* within this biozone.

Crux (1991) identified *Crucibiscutum hayi* throughout the Middle to Upper Albian section at Munday’s Hill, Bedfordshire. A review of these sediments, however, resulted in the identification of a variety of *Crucibiscutum* spp. from the Middle Albian which are not synonymous with

Explanation of Plate 2

**Fig. 1.** *Braloweria boletiformis*, crossed-nicols, SMH-13-29, *nobe* MF Subzone, Bed 3(iii), Munday’s Hill, Bedfordshire (NAL 4). **Figs 2–4.** *Radiolithus hollandicus* (11 rayed form). **Fig. 2.** crossed-nicols, SMH-10-27, *auritus* MF Subzone, Bed 16, Burwell, Cambridgeshire (NAL 9). **Fig. 3.** crossed-nicols, SMH-12-09; **fig. 4.** bright field, same specimen, SMH-12-10, *auritus* MF Subzone, Bed 6, Munday’s Hill (NAL 9). **Fig. 5.** *Radiolithus hollandicus* (12 rayed form), crossed-nicols, SMH-12-06, *auritus* MF Subzone, Bed 16, Burwell (NAL 9). **Fig. 6.** *Rhagodiscus splendens*, crossed-nicols, SMH-15-23, *auritus* MF Subzone, Bed 16, Burwell (NAL 9). **Fig. 7.** *Rhagodiscus asper*, crossed-nicols, SMH-04-01, *intermedius* MF Subzone, Bed 2, Munday’s Hill (NAL 4). **Figs 8–9.** *Calculites percercinis*. **Fig. 8.** crossed-nicols, SMH-12-05, holotype; **fig. 9.** crossed-nicols, SMH-12-04, same specimen, *auritus* MF Subzone, Bed 16, Burwell (NAL 9). **Figs 10–16, 27–28.** *Tegulolithus tessellatus*. **Fig. 10.** crossed-nicols, SMH-14-01; **fig. 11.** bright field, same specimen, SMH-14-02, *auritus* MF Subzone, Bed 15, Burwell (NAL 8). **Fig. 12.** crossed-nicols, SMH-14-07, *auritus* MF Subzone, Bed 6, Munday’s Hill (NAL 8). **Fig. 13.** crossed-nicols, SMH-09-09; **fig. 14.** bright field, same specimen, SMH-09-08, *auritus* MF Subzone, Bed XI, Cop Point, Kent (NAL 8). **Fig. 15.** crossed-nicols, SMH-14-05; **fig. 16.** bright field, same specimen, SMH-14-06, *auritus* MF Subzone, Soham borehole, Cambridgeshire, sample No. 3309 (NAL 8). **Fig. 17.** crossed-nicols, SMH-09-12; **fig. 18.** bright field, same specimen, SMH-09-11, *auritus* MF Subzone, Bed 6, Munday’s Hill (NAL 8). **Fig. 19.** *Staurolithaceae gausorhethium*, crossed-nicols, SMH-09-22, *auritus* MF Subzone, Bed 16, Burwell (NAL 8). **Figs 19–20.** *Staurolithaceae rotatus*. **Fig. 19.** crossed-nicols, SMH-16-30, holotype; **fig. 20.** bright field, same specimen, SMH-16-31, *dispar* MF Zone, Bed XIII, Cop Point (NAL 13). **Figs 21–24.** *Staurolithaceae angustus*. **Fig. 21.** crossed-nicols, SMH-10-31; **fig. 22.** bright field, same specimen, SMH-10-30, *auritus* MF Subzone, Bed XI, East Wear Bay, Kent (NAL 9). **Fig. 23.** crossed-nicols, SMH-12-26; **fig. 24.** bright field, same specimen, SMH-12-27, *auritus* MF Subzone, Bed 6, Munday’s Hill (NAL 9). **Figs 25–26.** *Garderella granulifera*. **Fig. 25.** crossed-nicols, SMH-11-20; **fig. 26.** bright field, same specimen, SMH-09-11, *intermedius* MF Subzone, Bed 2, Munday’s Hill (NAL 4).
**Garnerago praeobliquum Interval Range NF Zone (NAL 13)**

**Definition:** Interval from LAD of Radiolithus hollandicus to FAD of common/abundant *Broinsonia enormis*.

**Age:** Upper Albian, *rostratum-perinflatum* MF Subzones.

**Remarks:** This stratigraphic level has been correlated to a transgression within the *dispar* MF Zone (Eyers, 1992). In England, this sea-level rise is expressed by monotonous, very pale grey clays, with little evidence of breaks in sedimentation, unlike the underlying Gault Clay which is usually darker in colour and punctuated by numerous stratigraphic breaks.

The nannoflora within this NF biozone exhibit a degree of provincialism. *Crucibiscutum hayi*, *Cribroraeparella ehenbergii*, *Percivalia fenestra* and *Staurolithites rotatus* are characteristic components of this NF zone in England and the southern North Sea but are rare in the central and northern North Sea.

**Broinsonia enormis Partial Range NF Zone (NAC)**

**Definition:** Interval from FAD of *Broinsonia enormis* to FAD of *Calcilitrs anfractus*.

**Age:** Upper Albian, *perinflatum* MF Subzone - ‘Lowermost’ Cenomanian, *carnicenense* MF Subzone (lower part).

**Remarks:** In southern England NAC has only been found to correlate with macrofossil dated sediments of ‘lowermost’ Cenomanian age. A regional non-sequente is present at the Albian/Cenomanian boundary in northern France and southern Britain. An expanded ammonite dated equivalent of this NF biozone (Upper Albian to Lower Cenomanian) is preserved in the Vocontian Trough (A. S. Gale, pers. comm., 1994). A thick development of NAC dated sediments are also present in the Red Chalk of Speeton (pers. obs.). It is plausible that at Speeton, unlike in southern Britain, a complete Albian to Cenomanian boundary succession is present. Unfortunately, ammonite data are extremely sparse and the Cenomanian/Albian boundary is difficult to accurately locate (H. G. Owen, pers. comm., 1994).

The nannoflora at Mt. Risou does not exhibit any marked assemblage changes over the Albian/Cenomanian boundary. The FAD of *Garnerago chiastra* is of potential importance but further work is required to prove its value as a boundary marker. *Garnerago chiasta* is present in the Vocontian Trough, England and southern North Sea but does not appear to have migrated any further north.

**Rothia striata Partial Range NF Zone (NC 1)**

**Definition:** Interval from FAD of *Calcilitrs anfractus* to LAD of *Rothia striata*.

**Age:** ‘Lowermost’ Cenomanian, *mantelli* MF Zone (lower part).

**Remarks:** This NF zone equates in part to the *Phanulithus anfractus* (NLK 1), *Seribiscutum primitivum* (NLK 2), *Hemipodohabbus gorkae* (NLK 3) and *Garnerago praeobliquum* (NLK 4) NF Zones of Jakubowski (1987).

The NF of abundant *Biscutum consors* approximates to the top of NC 1 in the central North Sea. This event is, however, diachronous and found in younger sediments from onshore localities and in well sections from the North Viking Graben (Northern North Sea).

*Seribiscutum primitivum* is abundant at this stratigraphic level in the North Sea Basin and Yorkshire but is a minor component of macrofossil assemblages in southern Britain. At the Mt Risou section, *primitivum* is absent from the majority of samples analysed.

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**Explanation of Plate 3**

Figs 1–2. *Garnerago chiastra*. Fig. 1, crossed-nicols, SMH-16-27; fig. 2, bright field, same specimen, SMH-16-28, ‘mantelli’ MF Zone, Wilstone Reservoir, near Tring, Buckinghamshire (NC 1). Fig. 3. *Garnerago nanum*, crossed-nicols, SMH-06-11, Dutch southern North Sea, Upper Holland Marle, Well O/7-2 (NAL). Fig. 4. *Garnerago theta*, crossed-nicols, SMH-16-22, Dutch southern North Sea, Upper Holland Marle, Well O/7-2 (NAL). Fig. 5. *Percivalia fenestra*, crossed-nicols, SMH-02-01, *rostratum* MF Subzone, Arlesey, Bedfordshire (NAL 13). Fig. 6. *Cretarhabdus inaequilis*, crossed-nicols, SMH-16-12, Bed A5, *ewaldi* Marle, Speton, Yorkshire (NAL 2). Figs 7–8. *Cretarhabdus inaequilis*. Fig. 7, crossed-nicols, SMH-11-13; fig. 8, bright field, same specimen, SMH-11-14, *orbignyi* MF Subzone, Bed IX, Copit Point, Kent (NAL 7). Figs 9–10. *Calcilitrs dispar*. Fig. 9, crossed-nicols, SMH-17-08; fig. 10, bright field, same specimen, Bed A3, Speton (NAL 3). Note the four perforations in this form were not originally described by Varol (1991), due to overgrowth in his material. Figs 11–12. *Cribroraeparella ehenbergii*. Fig. 11, crossed-nicols, SMH-16-32; fig. 12, bright field, same specimen, SMH-16-33, *rostratum-perinflatum* MF Subzones. Bed XIII, Copit Point (NAL 13). Fig. 13. *Rothia striata*, crossed-nicols, SMH-13-21, Hunstanton Formation, South Ferriby, Humberside (NAL 3). Fig. 14. *?Lordia xenota* (small variety), crossed-nicols, SMH-11-17, *intermedius* MF Subzone, Bed I, Copit Point (NAL 4). Fig. 15. *Staurolithites canthus*, crossed-nicols, SMH-16-09, Bed A5, *ewaldi* Marle, Speton, holotype (NAL 2). Figs 16–17. *Cribroraeparella angulca*. Fig. 16, crossed-nicols, SMH-12-01; fig. 17, bright field, same specimen, SMH-12-02, *varicosus* Subzone, Bed 5, Munday’s Hill, Bedfordshire (NAL 7). Fig. 18. *Calcilitrs anfractus*, crossed-nicols, SMH-04-36, ‘mantelli’ MF Zone, Tring (NC 1). Fig. 19. *Hayesites albiensis*, bright field, SMH-07-19, *intermedius* MF Subzone, Nine Acres Quarry, Bedfordshire (NAL 4). Fig. 20. *Bowenia glabra*, crossed-nicols, SMH-17-36, *daviesi* MF Subzone, Bed VII, Copit Point, holotype (NAL 6). Figs 21–22. *Acantholithus varius*. Fig. 21, crossed-nicols, SMH-17-04, Bed A5, *ewaldi* Marle, Speton, holotype (NAL 2). Fig. 22, bright field, SMH-17-05, Dutch southern North Sea, Middle Holland Shale Member, Well Q/16-2 (NAL 2). Figs 23–24. *Ceratothriina bicornuta*. Fig. 23, crossed-nicols, SMH-08-08; fig. 24, bright field, same specimen, SMH-08-07, *daviesi* MF Subzone, Bed VII, Copit Point (NAL 6).
**Definition:** Interval from LAD of *Rothia striata* to LAD of *Calculites anfractus*.

**Age:** Lower Cenomanian, *mantelli* MF Zone.

**TAXONOMY**

A detailed taxonomic section is not provided, although taxa referred to in this paper are listed alphabetically in Appendix 1. Taxonomic references not included in the reference list can be found in Perch-Nielsen (1985). New species and combinations are detailed below.

**Genus ACAENOLITHUS** Black, 1973

*Calculites anfractus* Black, 1973

**Definition:** Interval from LAD of *Rothia striata* to LAD of *Calculites anfractus*.

**Age:** Lower Cenomanian, *mantelli* MF Zone.

**Diagnosis:** The coccoliths are elliptical and consist of two closely-appressed zeugoid walls. The central opening is bridged by a narrow cross parallel to the principal axes of the ellipse with flaring, arrowhead-like ends. Under crossed-nicols, the inner cycle is highly birefringent and appears brighter than the rim.

**Holotype:** SMH-17-36 (Pl. 3, fig. 20).

**Type locality and horizon:** Speeton, Yorkshire, *ewaldi* Marl, Bed A (Early Albian).

**Dimensions:** L: 6–8 µm (mean length 7.5 µm), 50 specimens measured.

**Remarks:** Stover's holotype, (Pl. 2, figs 1a–c) clearly exhibits a scalloped outer rim, similar to that of the *Arkhangelskiellaceae*, and is probably synonymous with *Brionsonia sigurta* or *Acaenolithus cenomanicus*.

Stover's paratype, (Pl. 2, figs 2a–b) has a zeugoid outer wall and is identifiable as *Bownia glabra*.

**Genus CALCULITES** Prins & Sissingh in Sissingh, 1977

*Calculites percernis* sp. nov.

(Pl. 2, figs 8–9).


1991 *Calculites* sp. 1 Crux: 214, Pl. 1, fig. 4: Pl. 2, figs 5–6.

**Derivation of name:** Latin *percernis*, meaning easily visible.

**Diagnosis:** This holococcolith is composed of a narrow rim, a broad wall consisting of a limited number of calcite blocks and a central pore. Under crossed-nicols and with the axes of the ellipse aligned with the nicsol, extinction gyres lie on the principal axes of the ellipse. With the axes rotated 45 degrees to the nicsol, the gyres do not intersect but form arches about the acute ends of the ellipse.

**Holotype:** SMH-12-05 (Pl. 2, fig. 8).

**Type locality and horizon:** Burwell, Cambridgeshire, Bed 16 (Late Albian).

**Dimensions:** L: 3–5 µm (mean length 4.4 µm), 50 specimens measured.

**Remarks:** This small holococcolith is abundant at certain horizons within the *auritus* MF Subzone in Cambridgeshire and Bedfordshire and in the *dispar* MF Zone of the Vocontian Trough, France (pers. obs.).

**Genus CRUCIBISCUOTUM** Jakubowski, 1986

*Cruicibiscutum* sp. 1

(Pl. 1, figs 10–11)

**Remarks:** A species of *Crucibiscutum* with an asymmetrical cross.

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**Explanation of Plate 4**

Figs 1–5. *Ceratolithina cruxii*. Fig. 1, crossed-nicols, SMH-11-09. Fig. 2, crossed-nicols, SMH-11-06. Fig. 3, crossed-nicols, SMH-09-17; fig. 4, bright field, same specimen, SMH-09-19. Fig. 5, crossed-nicols, SMH-11-07. All specimens, *intermedius* MF Subzone, Bed 2, Munday's Hill, Bedfordshire (NAL 4). Fig. 6. *Cyclelaepsohaera shenleyensis* (coccosphere), bright field, SMH-11-29, *intermedius* MF Subzone, Bed 2, Munday's Hill (NAL 4). Figs 7–8. *Ceratolithina hamata*. Fig. 7. crossed-nicols, SMH-09-15; fig. 8, bright field, same specimen, SMH-09-14, *orbignyi* MF Subzone, Bed 4 (ii), Munday's Hill (NAL 7). Fig. 9. *Nannococcon aquaticus*, bright field, SMH-08-15, *orbignyi* MF Subzone, Bed 4 (v), Munday's Hill (NAL 7). Fig. 10. *Nannococcon elongatus*, bright field, SMH-09-07, *auritus* MF Subzone, Soham borehole, Cambridgeshire (NAL 8). Fig. 11. *Nannococcon granis*, bright field, SMH-08-21, *auritus* MF Subzone, Bed 6, Munday's Hill (NAL 8). Fig. 12. *Nannococcon aff. N. multicus*, bright field, SMH-09-04, *auritus* MF Subzone, Bed 6, Munday's Hill (NAL 8). Fig. 13. *Nannococcon truitti*, bright field, SMH-09-05, *davius* MF Subzone, Soham borehole (NAL 6).
Genus STAUROLITHITES Caratini, 1963

Staurolithites canthus sp. nov. (Pl. 3, fig. 15)

**Derivation of name:** Latin canthus, meaning cart-wheel.

**Diagnosis:** A species of Staurolithites whose central cross is slightly offset from the principal axes of the ellipse. The two cycles forming the rim can be seen with the light microscope between crossed-nicols. The inner circle is bright and often appears segmented when rotated under crossed-nicols.

**Holotype:** SMH-16-09 (Pl. 1, fig. 15).

**Type locality and horizon:** Speeton, Yorkshire, ewaldi Marl, Bed A₃ (Early Albian).

**Dimensions:** L: 6–8 μm (mean length 7.2 μm), 50 specimens measured.

Staurolithites rotatus sp. nov. (Pl. 2, figs 19-20)

**Derivation of name:** Latin rotatus, meaning to turn around.

**Diagnosis:** This form is elliptical with a narrow, single zeugoid wall. The large central opening is bridged by a spine-bearing cross which is often missing. Each bar of the cross consists of two parallel blocks. The bars, unlike in Staurolithites angustus, form a large angle with the long axis of the ellipse. Staurolithites rotatus exhibits a slight bifurcation at the ends of the cross.

**Holotype:** SMH-16-30 (Pl. 2, fig. 19).

**Type locality and horizon:** Folkestone, Kent, Bed XIII (Late Albian – dispar MF Zone)

**Dimensions:** L: 6.5–9 μm (mean length 8.5 μm), 50 specimens measured.

**Remarks:** An evolutionary trend is considered to exist between S. angustus through intermediate forms to S. rotatus where by a gradual rotation of the bars occurs, from almost parallel to the axes of the ellipse to a position midway between the axes of the ellipse. This gradual change has also been documented by Stover (1966) and Verbeek (1977), although they did not differentiate the two end members.

**CONCLUSIONS**

Extensive sampling of Albian to Lower Cenomanian, ammonite dated localities, mainly from England, has provided an opportunity to develop a high resolution nannofossil biozonation scheme. A total of sixteen zones are defined.

The Repagulum parvidentatum (NAL 1) and Acaenolithus viriosus (NAL 2) NF Zones are poorly represented in onshore English sections possibly due to unfavourable, high energy, shallow marine environments. Exceptions include Beds A₅ to A₃ at Speeton and the Chamberlain’s Barn section, Bedfordshire, which confirms NAL 2 as Lower Albian in age. The Bowenia glabra (NAL 5) and Ceratolithina bicornuta (NAL 6) NF Zones of Middle Albian age are poorly represented at English sections and in the North Sea Basin as a result of the regional Upper Albian cristatum MF erosive event.

A major unconformity is present at the Albian/Cenomanian boundary in southern England with the dispar MF Zone truncated to varying levels. A complete sequence across the boundary is present at Mt. Risou, southern France and possibly in the Red Chalk facies of Yorkshire and the southern North Sea Basin.

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**REFERENCES**


A proposed Albian to lower Cenomanian nannofossil biozonation


APPENDIX 1: Alphabetical list of species considered in this study

Acaenolithus cernomanicus Black, 1973
Acaenolithus gallosoii Black, 1973
Acaenolithus virosus n. sp.
Axopodorhabdus dietzmannii (Reinhardt, 1965) Wind & Wise, 1983
Biscutum constans (Górka, 1957) Black in Black & Barnes, 1959
Biscutum dissimilis Wind & Wise in Wise & Wind, 1977
Bownia glabra n. sp
Braarudosphaera africana Stradner, 1961
Braarudosphaera primula Black, 1973
Braarudosphaera quinquecostata Hill, 1976
Braarudosphaera regularis Black, 1973
Braarudosphaera stenorhetha Hill, 1976
Braloweria boletiformis (Black, 1972) Crux, 1991
Broinsonia enormis (Shumenko, 1968) Manivit, 1971
Bukrylithus ambiguus Black, 1971
Calcicalathina alta Perch-Nielsen, 1979
Calcilithes anfractus (Jakubowski, 1986) Varol & Jakubowski, 1989
Calcilithes dispar Varol in Al-Rifaiy et al., 1990
Calcites percermis n. sp.
Ceratolithina bicornuta Perch-Nielsen, 1988
Ceratolithina cruxii Perch-Nielsen, 1988
Ceratolithina hamata Martini, 1967
Chiastozygia literaria (Górka, 1957) Manivit, 1971
Corollithion achlyosum (Stover, 1966) Thierstein, 1971
Corollithion exiguum Stradner, 1961
Corollithion kennedyi Crux, 1981
Corollithion rhombicum (Stradner & Adamiker, 1966) Bukry, 1969
Creterhabdus inaequalis Crux, 1987
Creterhabdus loriei Gartner, 1968
Crepidolithus burwellensis Black, 1972
Cribrusphaerella ehenbergii (Arkhangelsky, 1912) Deflandre in Piveteau, 1952
Cruicibiscutum hayi (Black, 1971) Jakubowski, 1986
Cruicibiscutum salebrosum (Black, 1971) Jakubowski, 1986
Cruicibiscutum sp.1 n. sp.
Crucicribrum anglicum Black, 1973
Cyclagosphaera rotaclypeata Bukry, 1969
Cyclagosphaera shenleyensis Black, 1973
Discorhabdus ignotus (Górka, 1957) Perch-Nielsen, 1968
Eiffellithus monochiae Crux, 1991
Eiffellithus turrissefelli (Deflandre in Deflandre & Fert, 1954) Reinhardt, 1965
Ellipsagelosphaera britannica (Stradner, 1963) Perch-Nielsen, 1968
Epolithus florisalis (Stradner, 1962) Stover, 1966
Epolithus varolii Jakubowski, 1986
Farhania sp. Varol, 1992
Flabellites biforaminis Thierstein, 1973
Gaarderella grandifera Black, 1973
Garnerago chiastus Varol, 1991
Garnerago nanum Thierstein, 1974
Garnerago praebiforaminis Jakubowski, 1986
Garnerago theta (Black, 1959), Jakubowski, 1986
Glaukolithus diplogrammus (Deflandre in Deflandre & Fert, 1954) Reinhardt, 1964
Goniolithus fluctigeri Deflandre, 1957
Gorkaeae operio Varol & Girgis, 1994
Grantarhabdus coronadventis (Reinhardt, 1966) Grün in Grün & Allemann, 1975
Haquis circumradiatus (Stover, 1966) Roth, 1978
Hayesites albiensis Manivit, 1971
Helicolithus cf. compactus (Bukry, 1969) Varol & Girgis, 1994
Hemipodorhabdus gorkae (Reinhardt, 1969) Grün in Grün & Allemann, 1975
Laguncula dorothae Black, 1971
Lithraphidites carniolensis Deflandre, 1963
Lordia senex (Stover, 1966) Varol & Girgis, 1994
Manivitella pecten Black, 1973
Manivitella pemmatoidea (Deflandre in Manivit, 1965) Thierstein, 1971
Micranton lithus hoschulzii (Reinhardt, 1966) Thierstein, 1971
Microstaurus chiastus (Worsley, 1971) Grün in Grün & Allemann, 1975
Nannoconus aquitanicus Deres & Achéritéguy, 1980
Nannoconus elongatus Brönnimann, 1955
Nannoconus grandis Deres & Achéritéguy, 1980
Nannoconus multicadis Deflandre & Deflandre, 1959
Nannoconus truitti Brönnimann, 1955
Octocyclus magnus Black, 1972
Orastrum perspicuum Varol in Al-Rifaiy et al., 1990
Owenia hilli Crux, 1991
Parhabdolithus embergeri (Noël, 1965) Stradner, 1963
Pervinolithus varius Crux, 1981
Prediscosphaera columnata (Stover, 1966) Perch-Nielsen, 1984
Prediscosphaera spinosa (Bramlette & Martini, 1964) Gartner, 1968
Prediscosphaera cf. stoveri Barrier, 1977
Radiolithus hollandicus Varol, 1992
Repagulum parvidentatum (Deflandre in Deflandre & Fert, 1954) Forchheimer, 1972

A proposed Albion to lower Cenomanian nannofossil biozonation

**APPENDIX 2: Stratigraphic details of samples collected at Munday's Hill**

<table>
<thead>
<tr>
<th>Stage</th>
<th>MF Subzone (Owen, 1972)</th>
<th>No. of samples viewed</th>
<th>NF Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Albian</td>
<td>*auritus</td>
<td>4</td>
<td>NAL 10</td>
</tr>
<tr>
<td></td>
<td>*auritus</td>
<td>4</td>
<td>NAL 9</td>
</tr>
<tr>
<td></td>
<td>*auritus</td>
<td>4</td>
<td>NAL 8</td>
</tr>
<tr>
<td></td>
<td>varicosum</td>
<td>1</td>
<td>NAL 7</td>
</tr>
<tr>
<td></td>
<td>orbignyi</td>
<td>1</td>
<td>NAL 7</td>
</tr>
<tr>
<td></td>
<td>cristatum</td>
<td>1</td>
<td>NAL 7</td>
</tr>
</tbody>
</table>


The nannofossil assemblages from this locality are discussed by Crux, 1991.

Crux notes both Ceratolithina hamata and Axopodorhabdus albianus together with the absence of Braloweria boletiformis from the *niobe* MF Subzone (samples 21 and 22). This is in conflict with my results which indicate the FAD of *C. hamata* and consistent *A. albianus* within the *cristatum* MF Subzone at Munday's Hill. *Braloweria boletiformis* is present within the *niobe* MF Subzone at this locality.

*auritus* MF Subzonal assignment (H. G. Owen, pers. comm., 1994)

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