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The holostratigraphy of the Albian Stage (Lower Cretaceous) of the United Kingdom and its continental shelf

Holostrat

Research Report RR/06/01

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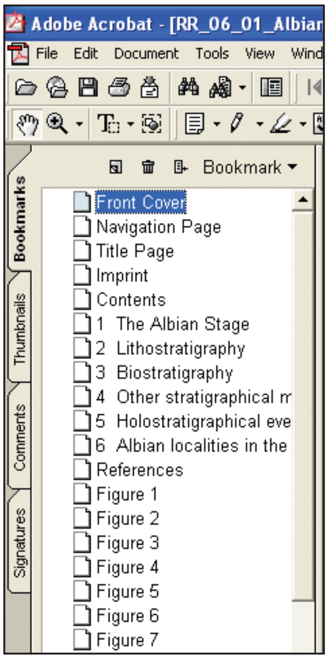

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- from each figure, plate or table caption to the first place that figure, plate or table is mentioned in the text and
- from each page number back to the contents page.

RETURN TO CONTENTS PAGE

BRITISH GEOLOGICAL SURVEY

RESEARCH REPORT RR/06/01

The holostratigraphy of the Albian Stage (Lower Cretaceous) of the United Kingdom and its continental shelf

I P Wilkinson

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Key words

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Front cover

Folkestone Warren, Kent. Slipped and fallen masses of Chalk and Gault overlying the Gault outcrop.

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Contents

TABLES

FIGURES

1 The Albian Stage

The Albian succession of the United Kingdom crops out in a narrow belt from eastern Devon and Dorset to The Wash and northward through Lincolnshire into Yorkshire, with a further area bordering The Weald (Figure 1). The stage has a widespread geographical distribution offshore in the Southern North Sea and the English Channel and has been penetrated by numerous boreholes. The Albian has been successfully subdivided employing a number of methods (lithostratigraphy, biostratigraphy, chemostratigraphy, seismostratigraphy, sequence stratigraphy, etc) which, when combined into a holostratigraphical scheme, provides the basis of a high resolution stratigraphical tool (Figure 2)[1].

1.1 DEFINITION

The Albian is the highest stage of the Lower Cretaceous, lying between the Aptian and Cenomanian.

A definition of the base is problematical. It is defined by the appearance of *Leymeriella schrammeni* in Germany, but this species is rarely found elsewhere. The appearance of the common and widespread ammonite genus *Douvilleiceras* may prove better, although in Britain it is unknown below the *regularis* Zone. Casey (1961) defined the base of the Albian in Britain on the first appearance of *Farnhamia farnhamensis*. This taxon is not widely distributed and appears to be stratigraphically younger than the *L. schrammeni* Zone of Germany (Owen, 1988a).

Subdivision of the Lower and Middle Albian is based on leymeriellids and hoplitids. The base of the Middle Albian is at the base of the *Hoplites* (*Hoplites*) *dentatus* Zone (base *Lyelliceras lyelli* Subzone). The base of the Upper Albian is taken at the base of the *Mortoniceras* (*Mortoniceras*) *inflatum* Zone (base *Dipoloceras cristatum* Subzone) which can be recognised directly or indirectly over a wide geographical area.

The top of the Albian (i.e. the base of the Cenomanian) in north-west Europe can be defined by the appearance of the acanthoceratid ammonite, *Mantelliceras*. This is summarised by Hancock (1991).

1.2 AUTHOR

The stage was proposed by d'Orbigny (1842).

1.3 DERIVATION OF NAME

After *Alba* the Roman name for the Aube, northern France.

1.4 ORIGINAL REFERENCE LOCALITIES

Wissant (Pas-de-Calais); Noires (Hautes Marne); Gaty, Marepaire, Dienville and Ervy (Aube); Saint-Florentin and Perte-du-Rhône (Ain); Mâcheromenil (Ardennes); Varennes Meuse); and Folkestone, Kent.

1 This diagram has been included at the end of the report due to its large size.

1.5 SYNONYMS

The Vraconian equates with the English Upper Gault and Upper Greensand (*S. dispar* Zone) but it is little used and there is little justification for its retention. Selbornian (Jukes-Browne and Hill, 1900) was proposed for the English Gault and Upper Greensand, but was and is not in widespread use. This term should also be suppressed.

1.6 SUBSTAGES

In Britain the Albian is divided into three substages (Lower Middle and Upper) and equivalent time intervals (Early, Mid and Late).

1.7 BRITISH LITHOSTRATIGRAPHICAL UNITS

1.7.1 Principal units

Folkestone Beds, 'Lower Greensand' (pars), Carstone, Gault, Hunstanton Formation (= Red Chalk), Upper Greensand, Cambridge Greensand (pars) and upper part of the 'A' Beds of Speeton Clay formations. Offshore: Rødby, Carrack (pars) and Wick Sandstone (pars) formations

1.7.2 Local and/or obsolete units

The Langton 'Series' of Swinnerton (1935) equates with the Carstone Sands and Clay (?uppermost Aptian) and Carstone Grit (Lower Albian), but is not widely used.

The Hunstanton Formation of Lincolnshire has been divided into the Goulceby (lower) and Brinkhill (upper) members by Jeans (1980, fig. 3), although these have not been formally defined. Mitchell (1995) divided the expanded Hunstanton Formation of the Yorkshire Coast (which he regarded as a formation) into five members, from the base up, Queen's Rocks Member, Speeton Beck Member, Dulcey Dock Member, Weather Castle Member and Red Cliff Hole Member. The Albian/Cenomanian boundary was placed within the top of the Weather Castle Member on the basis of the Stable isotope ($\delta^{13}C$) signature.

The Carstone Grit equates with the Thoresway Sand of Dikes and Lee (1837).

The Cirripede Bed equates with 'Red Clay' and the basal bed of the Gault in the Leighton Buzzard area after the occurrence of *Cretiscalpellum unguis* and *Pycnolepas rigida* (Toombs 1935; Hancock, 1958).

The Horton Wood Clay (Casey, 1961a,b) is restricted to the upper part of the Folkestone Formation, *Leymeriella regularis* Zone, a little below the boundary between the Folkestone Formation and the Gault, in a few isolated boreholes in Sussex.

The Shaftesbury Sandstone Member replaces 'Ragstone Beds' (sensu White, 1923, p.46), 'Ragstone and Freestone Beds' (sensu White, 1923, p.51) and 'Ragstone' (of Drummond, 1970). It is equivalent to the Exogyra Sandstone and Exogyra Rock of south-west and southern Dorset (Drummond, 1970).

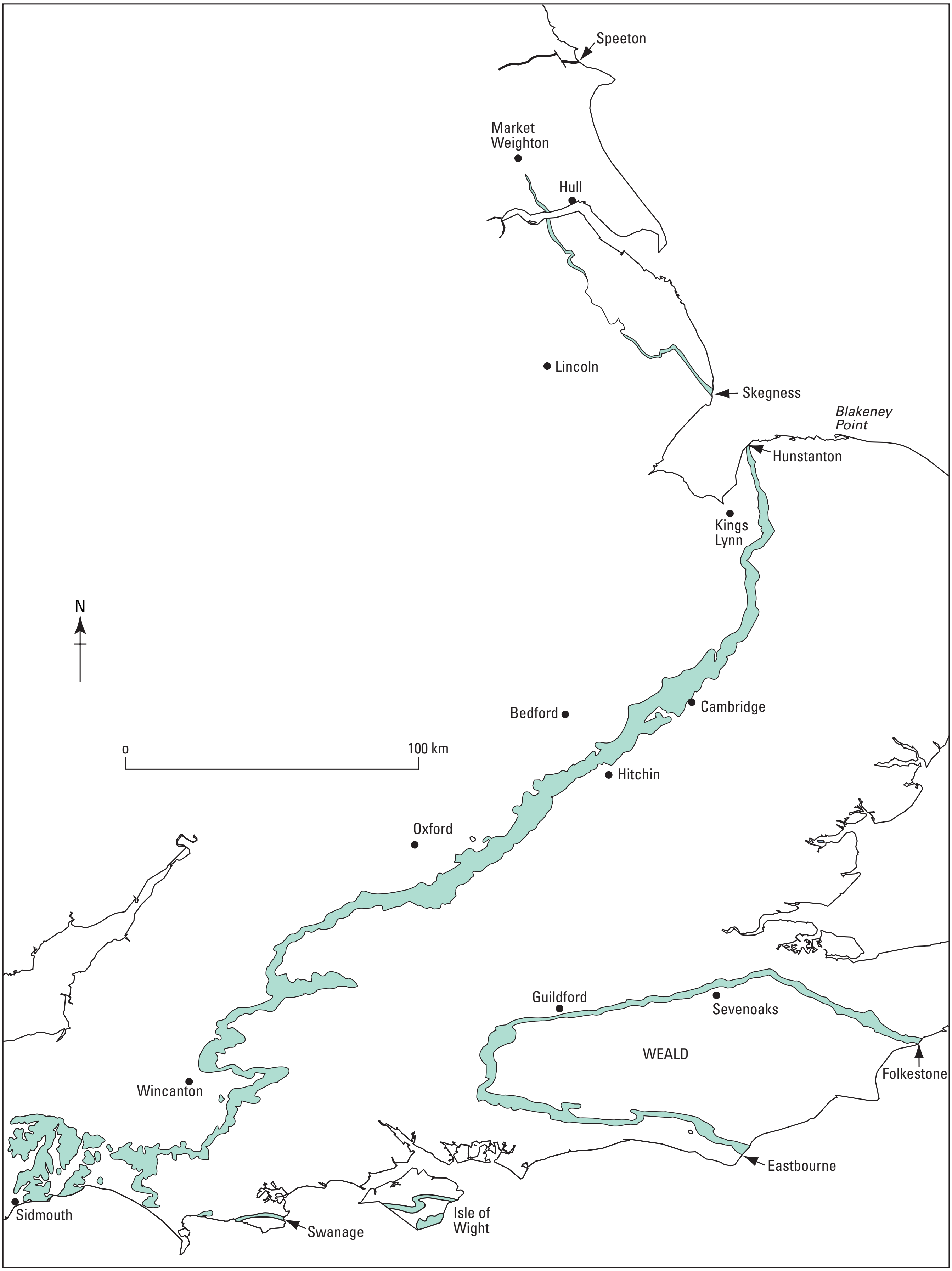


Figure 1 Distribution of Albian sediments at outcrop.

The Upper Greensand Formation has been given a number of local names including the Foxmould Sands and the Haldon Sands in south eastern Devon. The Haldon Sands, being decalcified, fall within the Blackdown Facies sensu Tresise (1960). They are considered to be of formational status and have been divided into members (Hamblin and Wood, 1976):

The Telegraph Hill Sands Member is equivalent to at least part of the Foxmould Sands (Hamblin and Wood, 1976).

The Woodlands Sands Member is equivalent to part of the Chert Beds on the south-east Devon Coast according to Hamblin and Wood (1976).

The Ashcombe Gravels Member appears to correlate with the 'Top Sandstones' and the Chert Beds (Jukes-Browne and Hill, 1900; Smith, 1961; Hamblin and Wood, 1976).

The Cullum Sands are Cenomanian in age and not considered further herein.

Several local names have been used in Wiltshire. The 'malmstone' equates with the Cann Sand; the Devizes Sand is coeval with the Cann Sand and Shaftesbury Sandstone; and Potterne Rock equates with the Ragstone at the top of the Shaftesbury Sandstone.

The base of the Upper Greensand is transitional with the Gault in some areas. The term 'Passage Beds' has been used by some, e.g. Jukes-Browne and Hill (1900) in the Isle of Wight.

Milton Brachiopod Bed, is a local shelly band in the Upper Gault.

Dentatus Nodule Bed comprises phosphatic pebbles (with fragments of *Hoplites* cf. *dentatus* and *H.* cf. *spathi*) in a silty mudstone in the Lower Gault.

Some beds in the Gault, notably G14, G16 and G17 (sensu Gallois and Morter, 1982), at Gayton, Pentney and Bilney, respectively, form thin chalky limestones before passing laterally into the Hunstanton Chalk. These have been referred to as the 'Pentney Limestone' and 'Bilney Limestone' by Seeley, (1861), but these terms are not in general use.

2 Lithostratigraphy

Lithostratigraphical details of the Albian succession have been described from many localities across England during the last 150 years, although offshore data have been collected for a relatively short period, commencing with the exploration for hydrocarbons in the 1960s. It has been mapped geologically and the various facies and lithostratigraphic units are well known. A summary is given in Figure 2 and details are given below.

2.1 NORTH SEA BASIN

The correlation of the main stratigraphical units making up the Albian of the North Sea Basin is summarised in Figure 3.

2.1.1 Carrack Formation

Derivation of name

Named after a type of merchant ship, the Carrack Formation was originally defined by Johnson and Lott (1993), the type section being in borehole 14/20–8 (in the Witch Ground Graben, Figure 4) between the depths 2670.5 and 2771.5 m. Deegan and Scull (1977) included it in the Valhall Formation.

Lithological characteristics

In the Southern North Sea the formation is a poorly calcareous, occasionally sandy, pale grey to red brown or variegated mudstone. Thin sandy beds and phosphatic pebbles occur sporadically. The top of the unit is defined by a downward change from the chalky mudstones of the Rødby Formation into the dark, poorly calcareous mudstones of the Carrack Formation. This change is reflected in the wireline log signature where there is a rapid down-section increase in gamma-ray values and a decrease in velocity. The low average velocity is characteristic throughout the North Sea Basin. The basal boundary is marked by a downward change to the more indurated chalky mudstones of the Valhall Formation and in this case there is a corresponding down-section decrease in gamma-ray values and a marked increase in velocity.

In the Central and Northern North Sea the formation is dark grey or black in colour, although locally it is a red-brown. Occasional, thin, white to buff, interbedded limestones and chalky mudstones occur, causing high velocity spikes on the wire line logs. At the base, sandstones occur (e.g. the Skiff Sandstone Member), but as they are Aptian in age, they are not considered further here.

Stratigraphical relationships

The Albian part of the Carrack Formation is coeval with the A-Beds of the Speeton Clay Formation, the Carstone and Sutterby Marls onshore. It is coeval with the Middle Holland Claystone Member (Holland Formation) in the Dutch Sector of the North Sea (Crittenden, 1982; van Adrichem, Boogaert and Kouwe, 1993). It is also coeval with the Sola Formation of the Norwegian Sector of the Central North Sea (in the sense of Hesjedal and Hamar, 1983), but there have been several interpretations of that formation since its original designation, such that its usage can cause confusion. The Carrack Formation passes laterally into the Skiff Sandstone (Aptian), Britannia Sandstone (Aptian) or Wick Sandstone formations (Aptian to Lower Albian).

Regional variation

The Carrack Formation is usually quite thin in the Southern North Sea Basin. It is absent on intrabasinal highs and up to 25 m thick in the midbasinal areas. In the Central North Sea Basin the formation is generally between 40 and 100 m thick, although it is very thin or absent over the highs. It forms only 2.6 m of variegated and grey-brown mudstones off Northumberland, in Borehole 81/40 (Lott, Ball and Wilkinson, 1985).

Chronostratigraphical position

The Carrack Formation straddles the Aptian/Albian stage boundary. The upper part of the formation is dominated by a calcareous foraminiferal assemblage that is associated with the *Globigerinelloides gyroidinaeformis* biomarker and an Early Albian age is inferred. The middle part of the formation

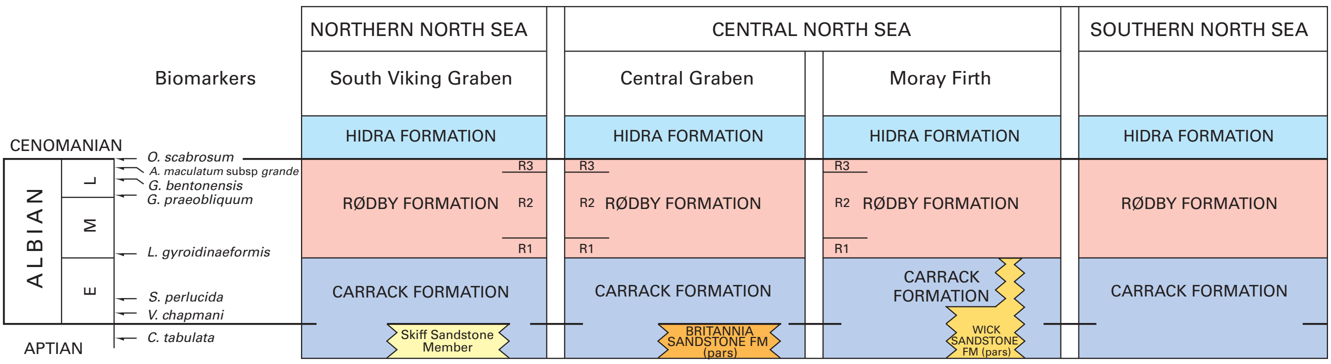
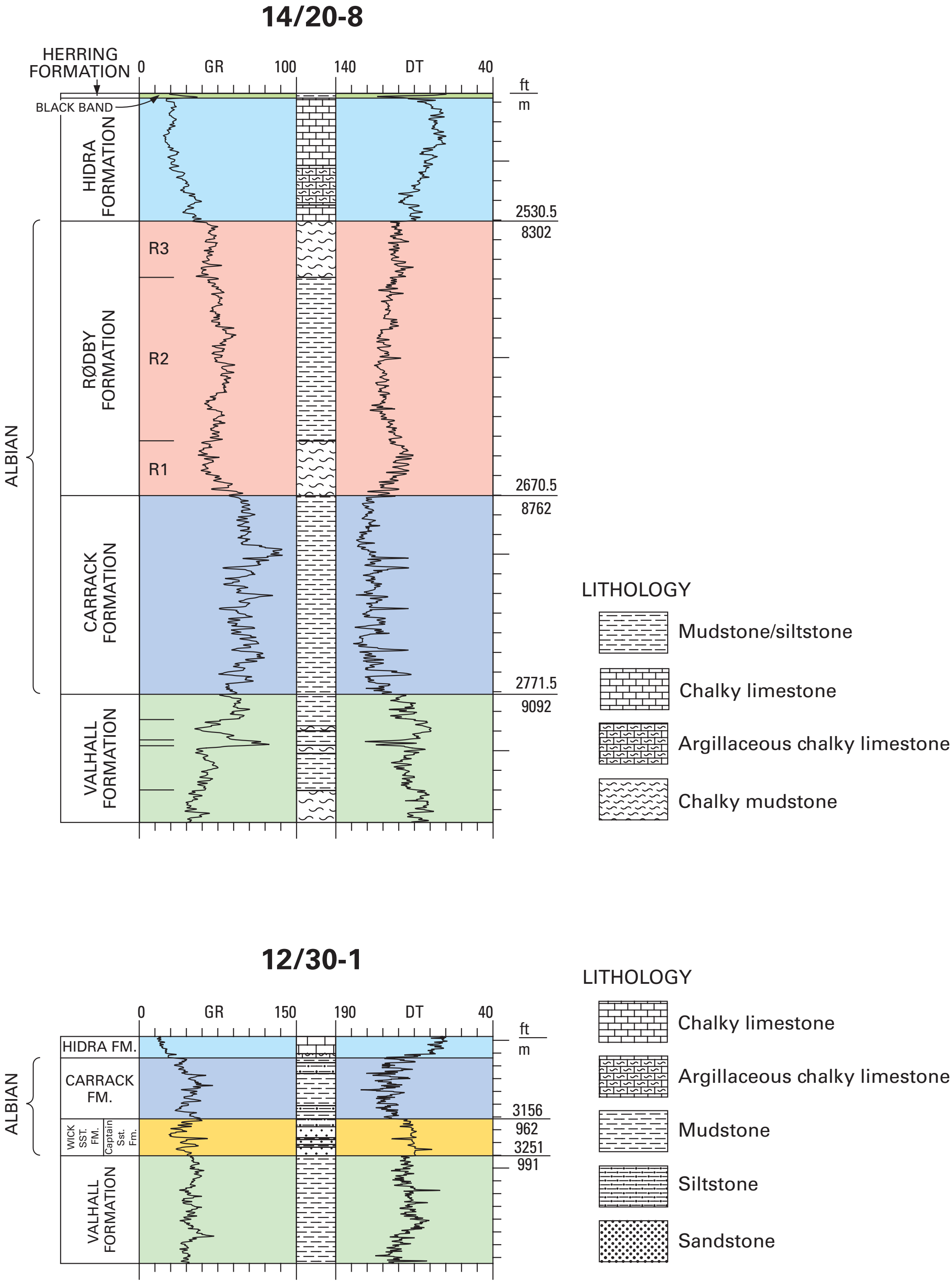


Figure 3 Correlation of the Albian formations in the North Sea Basin (after Johnson and Lott, 1993).

Figure 4 The Albian sequence of the North Sea: Wick Sandstone. Carrack and Rødby formations (after Johnson and Lott, 1993).



yields an agglutinated foraminiferal assemblage characterised by the first downhole occurrence (FDO) of *Verneuilinoides chapmani*, which is interpreted as indicating the earliest Albian (*tardefurcata* Zone). The FDO of the dinoflagellate cyst *Subtilisphaera perlucida* in the lower part of the formation also indicates an Early Albian (*tardefurcata* Zone) age. Near the base of the formation, the FDO of the nannofossils *Micranolithus hoschulzii* and *M. obtusus*, the foraminifer *Gaudryina dividens*, the ostacod *Saxocythere tricostata tricostata* and the dinoflagellate cyst *Cerbia tabulata* indicate the Late Aptian (*nutfieldiensis* Zone).

Selected references

Crittenden (1982), Deegan and Scull (1977), Johnson and Lott (1993), Lott, Ball and Wilkinson (1985), van Adrichem Boogaert and Kouwe (1993).

2.1.2 Wick Sandstone Formation (part)

Derivation of name

This formation was named after the town on the north-eastern coast of Scotland by Johnson and Lott (1993) and represents a thick unit of mass-flow sandstone with interbedded siltstones and mudstones. The type section is in borehole 12/30-1 (Inner Moray Firth Basin, Figure 4) at depth ranges of 962–991, 1366–1405 and 1457–1556 m below KB.

Lithological characteristics

The Wick Sandstone Formation comprises pale grey to grey-brown, very fine-grained to coarse-grained and pebbly, poorly sorted, and locally argillaceous quartz sandstones with interbedded siltstones and pale to dark grey, grey brown, red-brown and grey green, calcareous mudstones. The formation is glauconitic in part and lignite is widespread. Sporadic, thin argillaceous and microcrystalline limestones have been recorded.

Stratigraphical relationships

The Albian part of the Wick Sandstone Formation interdigitates with the Valhall and Carrack formations. It has been subdivided into a number of members, of which the Captain Sandstone Member is in part Albian.

The upper boundary is normally taken at the downhole change from mudstones and siltstones (of the Carrack Formation) to sandstones with interbedded siltstones and mudstones. This is represented on the wireline log as a marked decrease in gamma-ray values and an increase in velocity downhole. The base of the formation may rest on the V1 unit of the Valhall Formation or the Kimmeridge Clay Formation, but is not considered further as the boundary is well below the base of the Albian. There is no obvious lithostratigraphical break at the base of the Albian.

Regional variation

The formation is confined to the north, central and eastern parts of the Inner Moray Firth, and extends onto the north-western margins of the Halibut Shelf and Halibut Horst. It reaches 1400 m thick at 13/11–1, but thins to the south.

Chronostratigraphical position

The Wick Sandstone Formation spans the Late Ryazanian to Early Albian and only the Albian part is considered here. The first downhole occurrences (FDOs) of *Lingulogavelinella gyroidinaeformis* (foraminifera) is indicative of the Early Albian (*auritiformis* Zone); *Subtilisphaera perlucida* (dinoflagellate) proves the Early Albian (*tardefurcata* Zone) and *Verneuilinoides chapmani* (foraminifer) indicates the earliest Albian (earliest *tardefurcata* Zone). Below these biomarkers, a number of other indices, down to the Late Ryazanian, have been recorded in the formation.

Selected references

Johnson and Lott, 1993; Linsley, Potter, McNab and Racher, 1980.

2.1.2.1 Captain Sandstone Member

Derivation of name

From the Captain Oil Field in which the member is the oil reservoir. In some company reports this member has been assigned to the Valhall Formation and has been informally termed 'Wick Member C'. The type section is in borehole 13/17–1 (Figure 5) between the depths 992.5 and 1183.5 m below KB where it is Aptian in age.

Lithological characteristics

Fine to coarse grained, poorly sorted, occasionally pebbly, grey to grey-brown quartz sandstone, glauconitic or carbonaceous in part, with interbedded siltsones and mudstones. Calcareous concretions are present locally and reflected in the high velocity spikes on the wireline logs. The pale to dark grey, occasionally red-brown and variagated, mudstones and siltstones are calcareous and may be glauconitic.

Stratigraphical relationships

The Albian part of the Captain Sandstone Member forms the upper part of the Wick Formation in parts of the Moray Firth. The upper boundary is at a down-section change from dark grey, carbonaceous, non-calcareous low velocity mudstone (Carrack Formation) to sandstones with interbedded mudstones. The pre-Albian part may be overlain by high velocity mudstones (the Valhall Formation). The lower boundary is at a down-section change to mudstones of Aptian age (the Valhall Formation). It passes laterally into undifferentiated Wick Sandstone Formation, or into the Carrack or Valhall formations.

Regional variation

The member is restricted to the Inner Moray Firth. Its thickness is very variable, but usually less than 100 m (an exception being in the expanded section in borehole 13/17–1 where it reaches a thickness of 200 m, see Figure 5).

Chronostratigraphical position

The first downhole occurrence (FDO) of the foraminifera *Verneuilinoides chapmani* at or near the top of the member suggests an earliest Albian age (early part of the *tardefurcata* Zone). All biostratigraphical markers below this are of Aptian age (Wilkinson et al., in Johnson and Lott, 1993) and outside the scope of the study.

Selected references

Johnson and Lott, 1993

2.1.3 Rødby Formation

Derivation of name

The name is derived from the Town of Rødby in southern Denmark. Although the upper boundary of the formation is widely agreed, the lower boundary has been placed at various levels (e.g. Burnhill and Ramsey, 1981; Rawson and Riley, 1982; Harker et al 1987; King et al., 1989; Crittenden et al, 1991). The definition of the Rødby Formation followed herein is that of Larsen (1966) as applied by Johnson and Lott (1993) (Figures 4 and 5).

Lithological characteristics

The formation comprises grey or brick-red to brown, calcareous mudstone and chalky mudstones (with occasional thin beds of argillaceous limestones). They are variable in detail from hard to soft, blocky to fissile, and may be glauconitic or silty. In the Southern North Sea they may have a variegated, colour-mottled appearance.

The upper boundary is placed at the upward change to pale to dark grey and pink interbedded argillaceous chalks and calcareous mudstones (Hidra Formation). In a number of boreholes the boundary is placed at a thin limestone bed. On wireline logs the boundary is at an upward decrease in gamma-ray values and upward increase in velocity (Johnson and Lott, 1993). The log characteristics are often very subtle and it is difficult to identify the boundary.

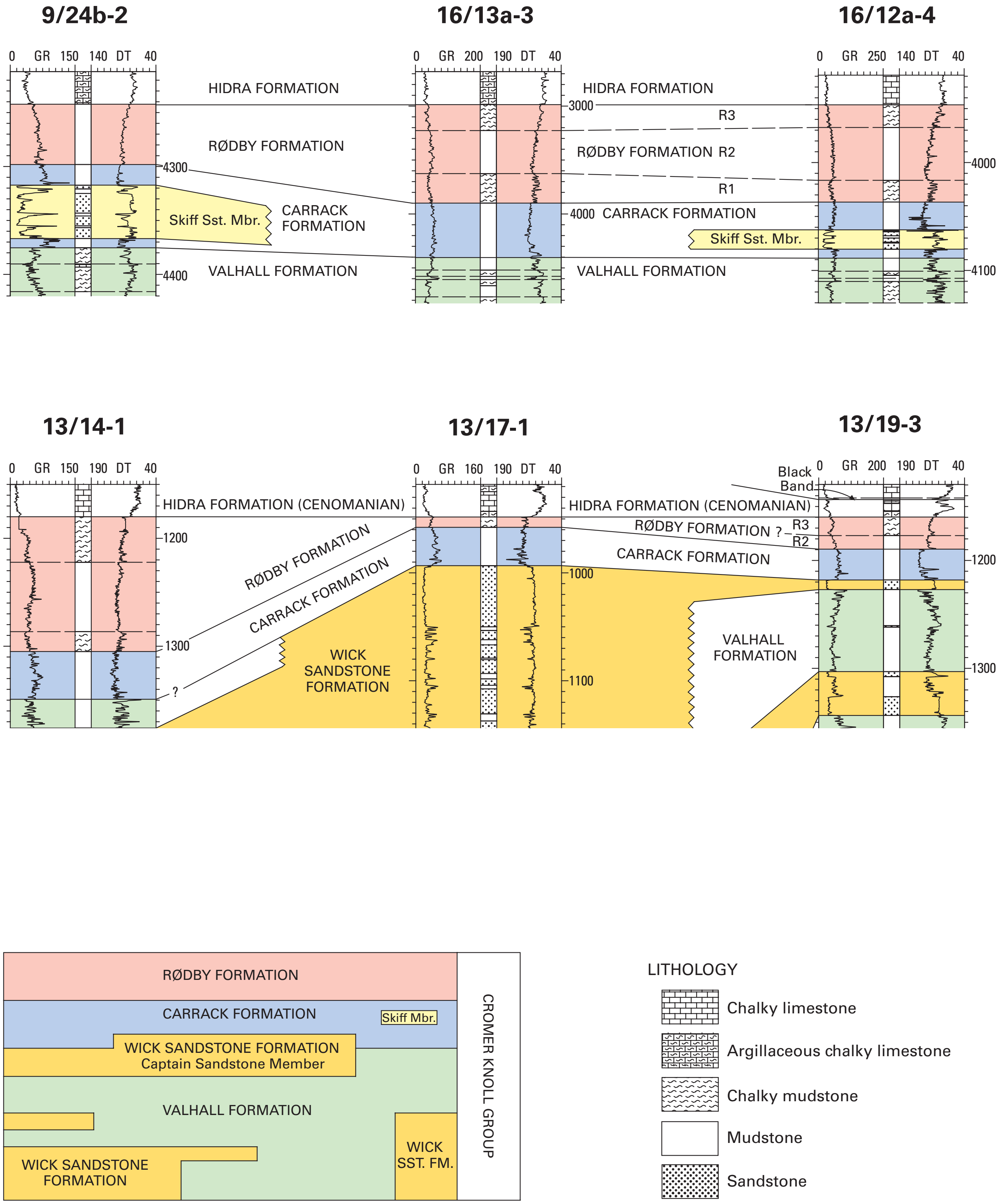


Figure 5 Correlation of the Rødby, Carrack and Wick sandstone formations in the North Sea Basin (after Johnson and Lott, 1993).

In the Central and Northern North Sea, the formational base it taken at a downward change to dark grey, non-calcareous, low velocity mudstones (Carrack Formation). This causes a downward increase in gamma values and a decrease in velocity. However, in the Inner Moray Firth, where the Rødby Formation rests directly on the Wick Sandstone Formation, the wire line log characteristics lack the clarity to separate the two. In the Southern North Sea, the Rødby Formation is underlaid by darker, grey, calcareous mudstones of the Valhall Formation. As a result there is a down-section increase in gamma-ray values and a sharp decrease in the sonic signature across the boundary. In some areas over structural highs, the formation may disconformably overlie Jurassic sediments (e.g. 49/9–1).

In the Central and Northern North Sea, the formation has been subdivided into three informal members (Crittenden et al., 1991; Johnson and Lott, 1993) (Figure 4):

R3: Red-brown, brick-red and pale grey chalky mudstones and calcareous mudstones with thin interbedded limestones. The base is marked by a downward increase in average gamma-ray values and a decrease in average velocity into the less calcareous R2.

R2: Pale to dark grey mudstones, chalky locally, with sporadic thin interbeds of pale grey argillaceous limestone. The base is marked by a downward decrease in average gamma-ray values and increase in velocity due to the more calcareous R-NSB1. The gamma-ray and sonic log interval transit time values increase and then decrease through R2 giving rise to what Crittenden et al. (1991) describe as a 'waist' pattern

R1: Red-brown and pale to dark grey, chalky mudstones and calcareous mudstones with occasional, thin argillaceous limestone (e.g.15/16–9). The base is usually marked by a downwards increase in gamma-ray values and a decrease in velocity (into the non-calcareous, low-velocity mudstones of the Carrack Formation)

This subdivision can also be traced into the Southern North Sea (e.g. 53/4–6), but the deposits here are frequently condensed rendering subdivision difficult and only part of R1 is recognisable (e.g. in 49/24–1).

Stratigraphical relationships

The Rødby Formation is approximately equivalent with the Upper Holland Marl Member (Holland Formation) in the Dutch Sector of the Southern North Sea Basin. It is represented onshore in eastern England by the Hunstanton Formation. A case can be made infavour of uniting the two under the name of Hunstanton Formation, but at the moment the status quo is maintained. No ammonites have been recorded from the formation and calibration demands the use of microfaunas and floras.

Regional variation

The formation is widespread over Central North Sea and South Viking Graben, however it may disappear onto the basin margin highs and intrabasinal highs (e.g. 14/10–1). Locally, R1 may be missing so that R2 rests disconformably on the Carrack Formation (e.g. 13/19–3, Figure 5). Thickness varies considerably from 80 to 180 m in the Outer Morray Firth to about 90 m over the Halibut Shelf (e.g. 13/14–1, Figure 5) and about 100 m in the South Viking Graben (e.g. 16/12b–6). Further south in the Central Graben, the formation varies from about 30 m, on the graben margins and intrabasinal highs, to about 100 m in the more basinal areas. In the Southern North Sea, sequences are more condensed, but it may reach 20–30 m in thickness (e.g. 53/2–5), but in basinal areas it may reach 50 m thick.

Chronostratigraphical position

Within R3, the FDO of the dinoflagellate cysts *Ovoidinium scabrosum* and *Apteodinium maculatum grande* and the FDO of the foraminifer *Osangularia schloenbachi* indicate the *dispar* macrofaunal Zone.

The first downhole occurrence (FDO) of calcareous nannoplankton *Hemipodorhabdus gorkae* and *Gartnerago praeobliquum*; the dinoflagellate cyst *Protoellipsoidinium spinosum*; and the foraminifera, *Globigerinelloides bentonensis*, in R2, indicate the *inflatum* macrofaunal Zone. Also within R2 the dinoflagellate cyst *Systematophora cretacea* suggests the *lautus* Zone and the FDO of the foraminifer *Falsogaudryinella* sp.1 is interpreted as indicating the basal *inflatum* or highest *lautus*. In the Outer Moray Firth region, the *Recurvoides* sp. biomarker has local biostratigraphical importance in R2 and is believed to be indicative of the *lautus* Zone.

In the basal part of the formation (within R1), the FDO of the foraminifer *L. gyroidinaeformis* is biostratigraphically useful as it is regarded as being indicative of the basal *dentatus* Zone (see Figure 3).

Selected references

Burnhill and Ramsey, 1981; Crittenden et al., 1991; Harker et al., 1987; Johnson and Lott, 1993; King et al., 1989; Larsen, 1966; and Rawson and Riley, 1982.

2.2 ONSHORE ENGLAND

2.2.1 Speeton Clay Formation ('A' Beds)

Derivation of name

The formation was named after the village of Speeton, Yorkshire. Lamplugh (1889) established a notation used by all later authors, in which the sequence was divided into 'A' Beds (at the top) through to 'E' Beds (at the base). The Albian part of the formation is located immediately north and north-east of Speeton between Speeton Beck and Speeton Cliffs (see Figure 6). The 'A' Beds are mainly Albian in age, although the lower part, which is excluded from the present discussion, is Aptian. The beds can be considered to be members, although they have never been formally named.

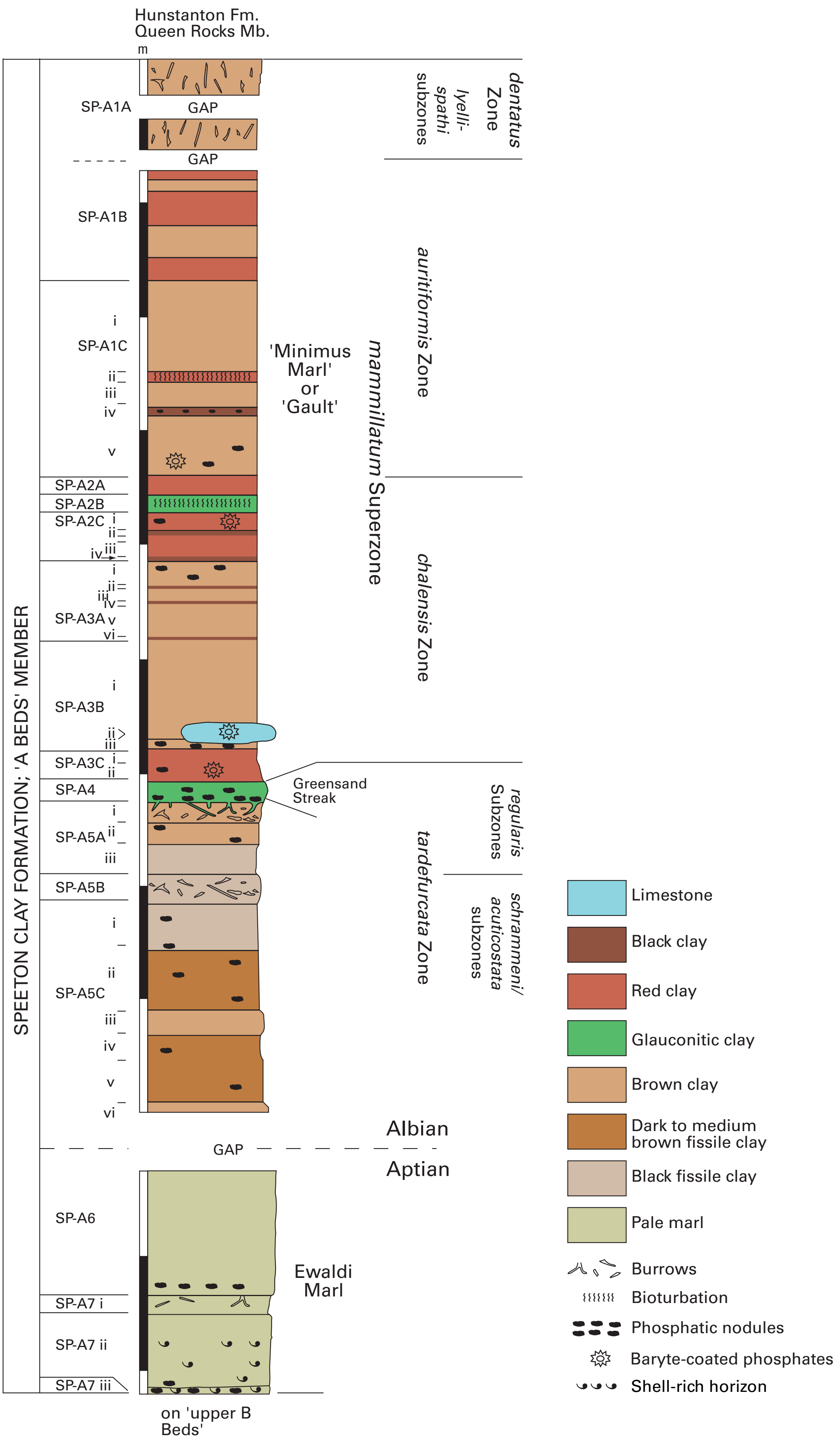
Lithological characteristics

The Speeton Clay Formation comprises principally mudstones and siltstones with occasional nodule horizons and seams of bentonite, but only the uppermost part (the 'A' Beds) falls within the Albian.

Although rarely exposed, 8.58 to 10.87 m of brown to grey-green, silty mudstones, glauconitic in part, with bands of nodules, overlie the black pyritic mudstone at the top of the Upper 'B' Beds. Lamplugh divided these, the 'A' Beds, into the lower *ewaldi* Zone (Ewaldi Marls or Beds) and upper *minimus* Zone (Minimus Marls or 'Gault') on the basis of their belemnite fauna, separated by the 'Greensand Streak'. The 'A' Beds have been subdivided into five lithological units, numbered A1 to A5 from the top down (Ennis, 1937; Wright, in Swinnerton, 1955; Kaye, 1964a; Neale, 1974). The most recent attempt to subdivide the Albian part of the 'A' Beds was made by Mitchell and Underwood (1999) who recognised a total of 34 units (see Figure 6).

The 'A' Beds straddle the Aptian/Albian boundary, which has always been difficult to recognise; the critical part of the succession (the lowest part of SP-A5 beds) is devoid of diagnostic fossils and poorly exposed. Kaye (1962) showed that the upper part of the 'A' Beds contains Early Albian ostracods, an observation confirmed by Mitchell and Underwood (1999) who also recovered foraminifera and

Figure 6
'A Beds' Member of the Speeton Clay Formation at Reighton, Yorkshire (after Mitchell and Underwood, 1999, with minor modifications).



macrofossils. However, the base of the Albian was not recognised by the latter authors, who placed the boundary at a gap in the succession between their beds LA3(vi) and LA5A (i.e. beds SP-A5C(vi) and SP-A6, herein).

Stratigraphical relationships

The 'A' Beds of the Speeton Clay are essentially coeval with the Carstone of eastern England and the southern North Sea, although there is some uncertainty as to their exact relationship. The lower part of the 'A' Beds (Bed SP-A6 and below) is Aptian in age, thus pre-dating the Carstone. Mitchell (1995) considered the erosion surface at the base of the 'Greensand Streak' (Bed SP-A4) to represent the sub-Carstone unconformity and as the bed grades up into SP-A3C, considered it of *chalensis* Biozone age. The Hunstanton Formation (sometimes called 'Red Chalk') overlies the 'A' Beds in Yorkshire.

The upper boundary of the 'A' Beds in Yorkshire approximates to the Carstone/Gault and Carstone/Hunstanton Formation boundary elsewhere. This is traditionally placed at the base of the *dentatus* Zone, but may be a little higher as Owen (1995) found early *dentatus* zone ammonites in the top of the Carstone at Hunstanton and Mitchell (1995) found ammonites and other fossils indicative of the early *dentatus* Zone in the highest part of Bed SP-A1.

Regional variation

The Speeton Clay has been mapped inland as far west as West Heslerton, and is known from a number of boreholes. However, the 'A' Beds are generally unexposed, and little detailed work has been carried out on the borehole material so that they remain poorly understood away from the coastal exposure. For this reason, it is not possible to record regional variations in the 'A' Beds. However, in the West Hestlerton Borehole, the 'A' Beds appear to be only about 4.95 m thick (Kaye, 1962).

Chronostratigraphical position

The SP-A5 Beds have traditionally been considered to be of Aptian age on the basis of the occurrence of *Neohibolites ewaldi*. However, although the lower part of the bed is barren of ostracods according to Kaye (1962), the upper part has yielded *Pseudocythere goerlichi*, *Protocythere nodigera*, *Protocythere mertensi* in a low diversity fauna. The *nodigera* ostracod Zone is therefore indicated and, by implication, the *regularis* to *tardefurcata* ammonite Zone (Early Albian). Calcareous nannofossils have been recovered from SP-A3 and SP-A5 by Black (1973, p.iii) and assigned to the Lower Albian, but unfortunately no further stratigraphical information was published. Ammonites of *grandis* subzonal age (*deshayesi* Zone), and thus Aptian, occur in the upper part of SP-A6 (Mitchell and Underwood, 1999). The Aptian/Albian boundary can be placed between between SP-A5C and SP-A6.

Mitchell (1995) indicated that the assemblage comprising *Neohibolites* cf. *pinguis* and *Inoceramus* cf. *anglicus* and a morph of *Neohibolites minimus* is identical to that of HC-SF1 (at South Ferriby) and from the *lyelli* to early *spathi* subzones (*dentatus* Zone) at Folkestone and Leighton Buzzard. He also recorded crushed ammonites that were tentatively assigned to *Hoplites dentatus.* The upper boundary of the Bed SP-A1 may therefore be placed within the early *dentatus* Zone.

The following biostratigraphical correlation was suggested by Mitchell and Underwood (1999):

Table 1 Biostratigraphical correlation of the Speeton 'A' beds (Mitchell and Underwood, 1999).

Mitchell and Underwood	Herein	Biostratigraphical position
UA1A	SP-A1A	*dentatus* Zone
UA1B-A1C	SP-A1B-A1C	*mammilatum* Superzone; *auritiformis* Zone
UA2-A4	SP-A2-A4	*mammillatum* Superzone; ?*chalensis* Zone
LA1	SP-A5A	*regularis* Zone
LA2 and LA3	SP-A5B-A5C	*tardefurcata* Zone

Selected references

Judd, 1868; Kaye 1962, 1964a; Lamplugh 1889, 1924; Mitchell, 1995; Mitchell and Underwood, 1999; Neale, 1974.

Locality details

Speeton, Yorkshire (Section 6.1.1, Figure 6)

2.2.2 Carstone Formation

Derivation of name

Rose (1862) referred to the ferruginous sands below the Gault by the term 'Carstone'. It apparently comes from the local quarrymen's name 'Carr Stone' (also called Fen Stone).

Lithological characteristics

The Carstone is best exposed along the coast north of Hunstanton (Gallois, 1994), (see Figure 7). The typical lithology of the Carstone is a greenish-brown (rusty when weathered), massive, cross-bedded, oolitic ferruginous sandstone. It is burrowed in places with common *Arenicolites* and *Skolithus*.

Stratigraphical relationships

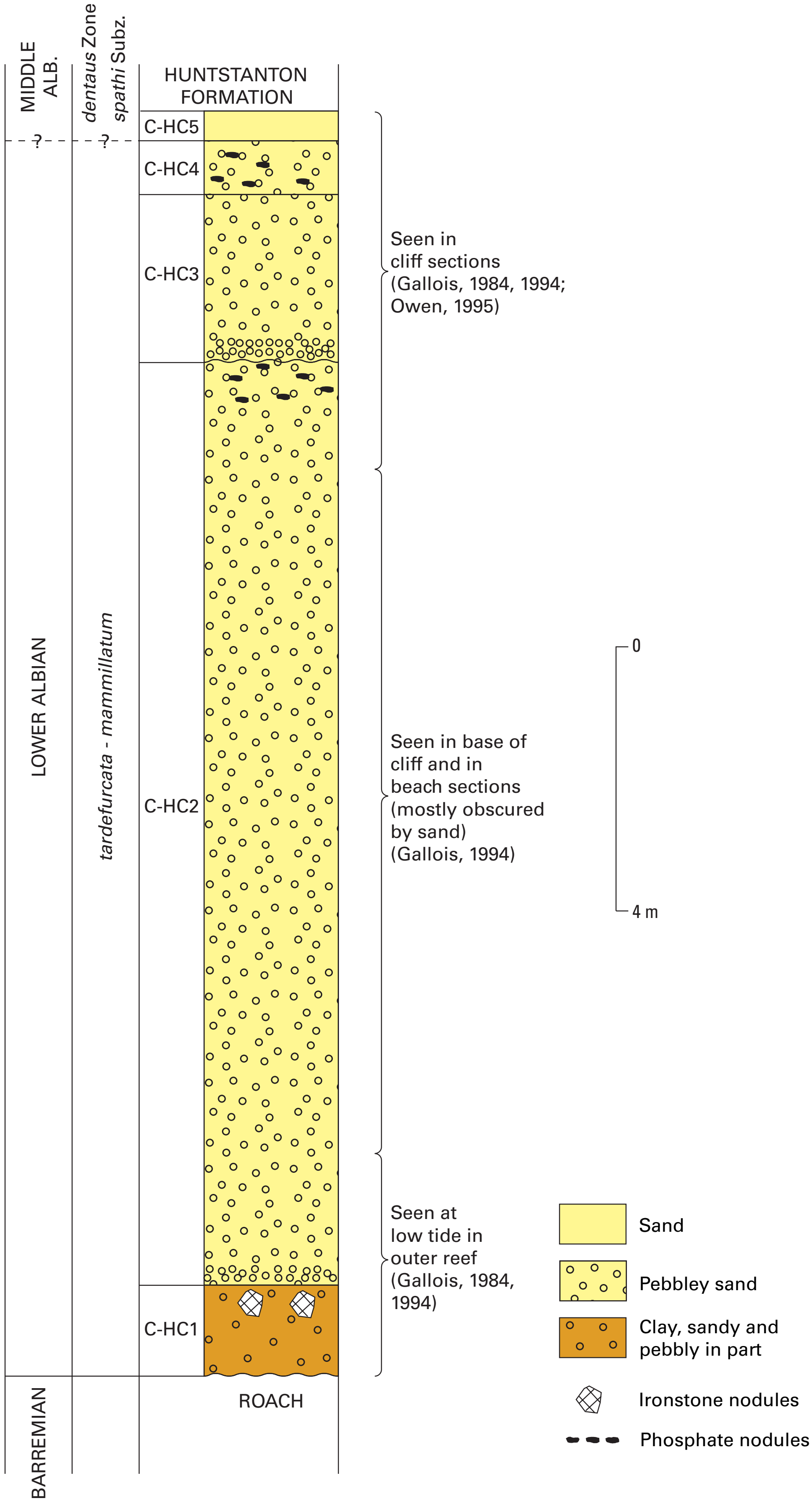
The lower boundary is disconformable so that it overlies Neocomian deposits in southern Lincolnshire and Kimmeridgian deposits at South Ferriby, South Humberside (Lincolnshire) and Ampthill Clay at Melton, North Humberside (Yorkshire). In East Anglia, the Carstone oversteps the truncated Neocomian and uppermost Jurassic deposits (Dersingham Formation and Sandringham Sands Formation between Leziate and West Dereham) and finally thins and disappears on the flanks of the London Massif.

Its upper boundary with the Gault or Hunstanton formations is transitional as shown by Casey (1961a, 1967). The latter author also showed the relationship between the Carstone and Shenley Limestone of Leighton Buzzard, using the brachiopod fauna.

Regional variation

The Carstone extends from Norfolk, through Lincolnshire and as far north as southern Yorkshire.

Figure 7 The Carstone at Hunstanton (after Gallois, 1984, 1994; Owen, 1995).



The most southerly outcrop recorded is that near West Dereham, between Roxham Farm and Wissington railway bridge [TL639 995 to 662 996] as described by Casey and Gallois (1973) and Gallois (1994). The formation becomes a thin pebbly sand south of the River Little Ouse (Gallois, 1988) before disappearing. It varies in thickness from about 17.5 m at North Creake Borehole (Kent, 1947) to 8.5 m in the Gayton Borehole, 5.5 m in the Marham Borehole, 2.6 m in the Mundford 'C' Borehole and 0.4 m in the Four Ashes Borehole. It reaches its maximum thickness, of 18.9 m, in the Hunstanton Borehole. At Hunstanton (Figure 7) the Carstone is exposed in the base of the Cliff and on the foreshore.

Although the formation cannot be seen in its entirity due to the accumulation of beach sands, excavations on the foreshore at Hunstanton have exposed the basal part of the formation (Gallois, 1973, 1975). Gallois (1984) and Owen (1995) described the c.18.9 m sequence and showed that lateral variations occur when studied at a small scale.

In Lincolnshire, Swinnerton divided the Carstone into two, 3–4.5 m of 'Sand and Clay' and an overlying 2–3 m of 'Carstone Grit' (which were placed in the 'Langton Series'). At Goulceby, about 10.7 m of 'Carstone Grit' were recorded by Penney and Rawson (1969) but the formation thins rapidly to only 0.8 m thick at South Ferriby, South Humberside and between 0.45 and 0.9 m at Melton, North Humberside.

At Melton, Bissat (1922) recorded 4 feet [1.2 m] of 'greenish brown sand with polished pebbles, analogous with the Lincolnshire Carstone' and Kaye (1964) recorded 3 feet [0.96 m] of 'yellow and red sandy clay with abundant iron ooliths' overlain by up to 2 inches [0.05 m] of 'gritty clay with harder green and cream eroded nodules' which were assigned to the Carstone. Owen et al. (1968) reported about 0.45–0.60 m of Carstone at Melton, mentioning that the greater thickness recorded earlier may have been due to the irregularity of the surface on which the unit rests.

Further north on the Market Weighton Block, a coarse gritty sand about 0.15 m thick has been recorded, e.g. Rifle Butts Quarry, Goodmanham, where it rests on Lower Lias (Owen et al., 1968). It would appear that the Carstone thins on to the Market Weighton Block, however, 'immediately east of Kirby Underdale, up to 20 feet [6.1 m] of coarse ferruginous sands with laminae of limonite occur beneath the Red Chalk and grade up into it (Blake, 1878; Hill, 1888; Wilson, 1932)' (Owen et al, 1968). This has been assumed to be Carstone by authors, although it has a much greater thickness than any other known record in Yorkshire.

Carstone is not found on the northern side of the Market Weighton Block.

In southern England and the Isle of Wight, arenaceous deposits have been called 'Carstone', although the true stratigraphical relationships are unclear and it is not possible to trace the units across into eastern England. To the east and north-east of Calne, Wiltshire, for example, coarse red sandstones disconformably overlie the Aptian Calne Sandstone. Hesselbo et al. (1990) refer to this as 'Carstone', and although there is no evidence of the age of the deposit, based on the lithostratigraphical position and the facies, an Early Albian age was suggested. So-called 'Carstone', situated between the Sandrock and Gault on the Isle of Wight (e.g. at Blackgang and St Cathrine's Point), is of Early Albian age and contains ammonites and other macrofossils characteristic of the *mammilatum* Superzone (Casey, 1961). Here the 'division forms the top of the Lower Greensand, consisting of 12 feet of gritty reddish-brown sands with pebbles and phosphatic nodules, and rests with sharp junction on the sands below.' It superficially resembles the Carstone of eastern England and requires a new formational name which will be addressed by Hopson et al. (in prep).

Chronostratigraphical position

The formation is generally regarded as being of Early Albian (*L. tardefurcata* Zone and D. *mammilatum* Superzone.) age, but Owen (1991, 1995) referred to two ammonite specimens from 'towards the top of Bed 2' at Hunstanton, which indicate the lower part of the *spathi* Subzone (*dentatus* Zone). If the two museum specimens, one collected by Le Strange and the other by Rose (1835) are correctly located stratigraphically, the upper part of the formation must be of earliest Mid Albian. It should also be noted that the Folkestone Formation (= Lower Greensand) of south-east England is of *L. lyelli* subzonal age at some localities (Owen, 1992) and the top of the Speeton Clay 'A' Beds was placed at a similar level by Mitchell (1995). In Yorkshire, faunas from Melton Bottoms [SE973 273] macrofossils are similar to those in the Shenley Limestone (*tardefurcata* Zone) (Owen et al., 1968) and microfaunas are similar to the A3 beds of the Speeton Clay and a *tardefurcata* zonal age has been postulated (Dilley, 1969).

Selected references

Bissat, 1922; Blake, 1878; Casey 1967; Dilley, 1969; Gallois, 1973, 1975, 1984, 1994; Hesselbo, Coe, Batten and Wach, 1990; Hill, 1888; Kent, 1947; Mitchell, 1995; Owen et al., 1968; Owen, 1991, 1992, 1995; Penney and Rawson, 1969; Rose, 1835, 1862; Swinnerton, 1935; Taylor, 1823; Teall, 1875; Wilson, 1932.

Locality details

East Anglia
- West Dereham (Section 6.2.1)
- Marham Borehole (Section 6.2.2)
- Gayton Borehole (Section 6.2.3)
- Mundford 'C' Borehole (Section 6.2.4)
- Hunstanton Cliff (Section 6.2.5, Figure 7)
- Hunstanton Borehole (Section 6.2.6)
- The Wash (Borehole 72/78) (Section 6.2.7)

Lincolnshire and South Humberside
- Skegness Borehole (Section 6.2.8)
- Nettleton Bottom Quarry (Section 6.2.9)
- South Ferriby Quarry (Section 6.2.10)
- Elsham Interchange (Melton Gallows) (Section 6.2.11)

Yorkshire and North Humberside
- Melton Bottoms (Section 6.2.12)

2.2.3 Folkestone Formation

Derivation of name

Named after the town near which the stratotype section (East Cliff, Folkestone, Kent) is located (see Figures 8 and 9).

Lithological characteristics

Fitton (1836) described the Folkestone Beds as consisting 'principally of sand, white, yellowish, or ferruginous, with concretions of limestone and of chert, frequently in false stratification'.

In outcrops along the northern margin of the Weald (see Figure 10) (e.g. Coxbridge, Wrecclesham, Figures 11 and 12; Squerryes, Figure 13; Sandling, Figure 13; and Folkestone, Figures 8, 9 and 12), the formation comprises cross-bedded quartz sands, with thin pebble beds and seams of clay, becoming siltier in the upper part. Beds rich in phosphatic nodules occur particularly toward the top. The formation varies in colour from white to grey and yellow to orange, and in some parts is glauconitic, giving it a green hue. Chert is developed locally.

Owen (1992) treated the formation in two parts. The lower part was referred to as the 'Folkestone Beds' and the upper part as the 'Lower Greensand Junction Beds'. The

Figure 8 Lower unit of the Folkestone Formation, East Cliff, Folkestone (after Casey, 1961).

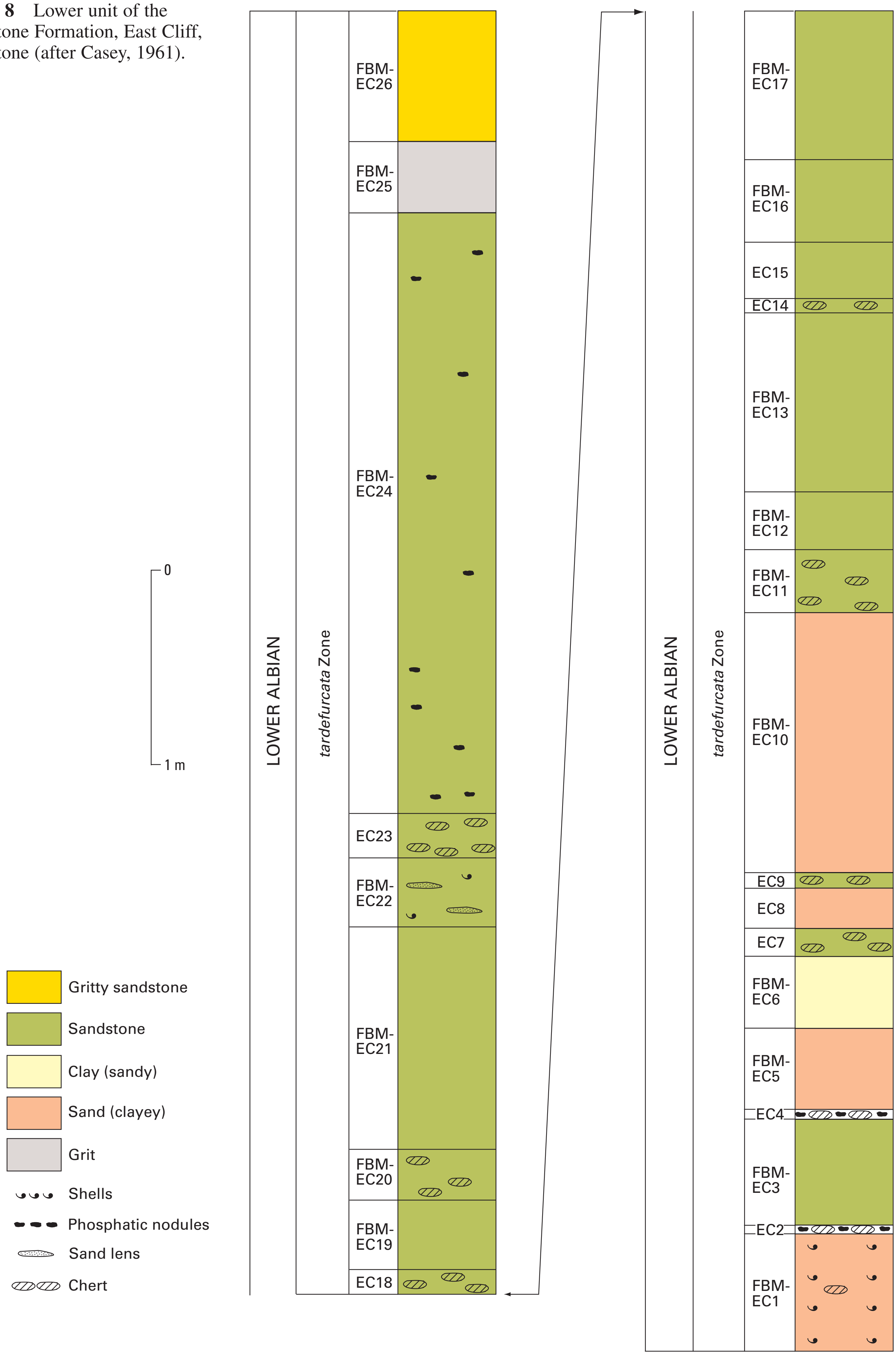
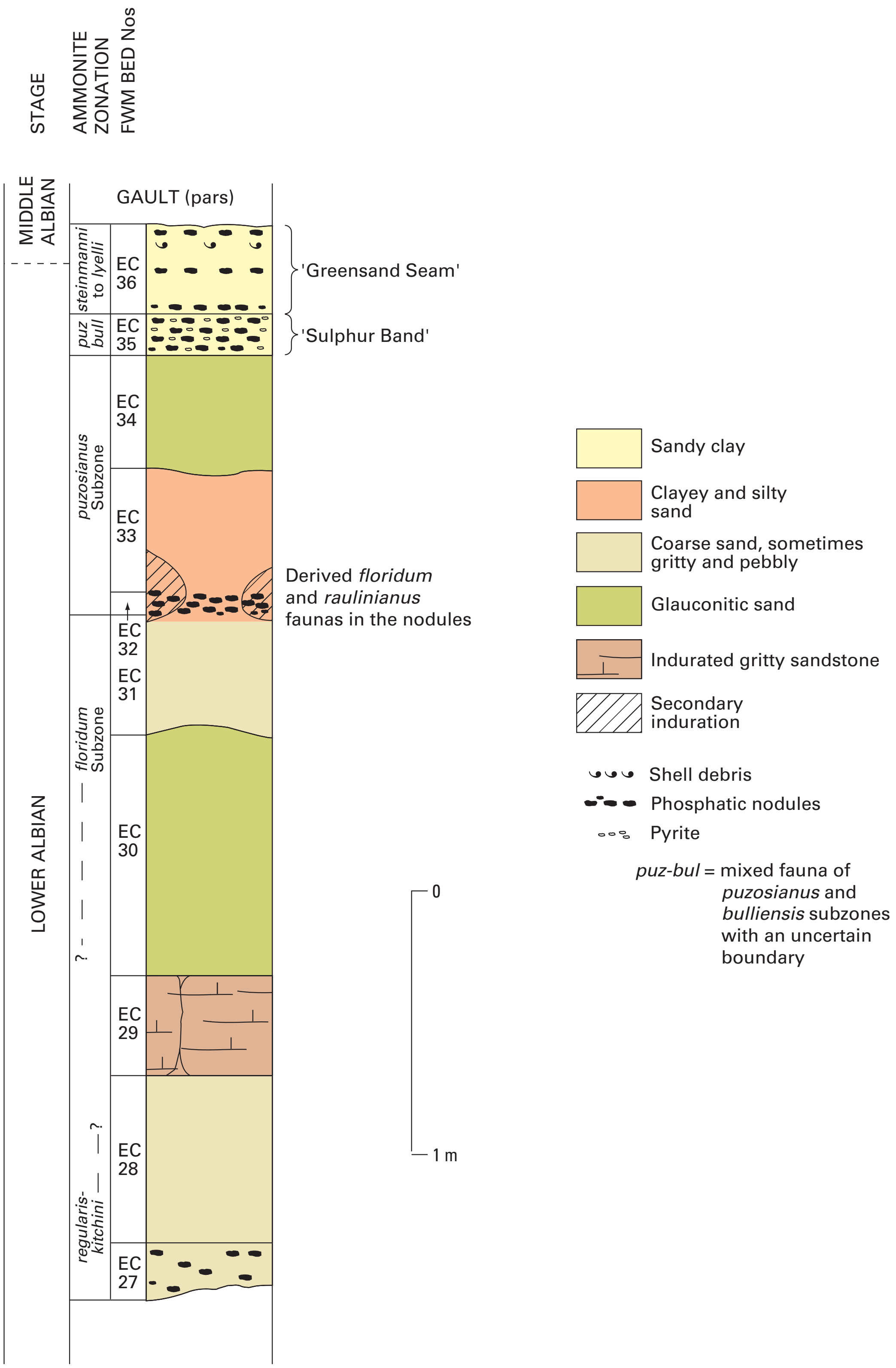


Figure 9 Upper part of the Folkestone Formation at Baker's Gap, East Cliff, Folkestone (after Owen, 1992).



lower part of the formation comprises cross-bedded sands with occasional white gritty phosphatic nodules. The upper part comprises silty sands and sandy clays with numerous beds of phosphatic nodules and occasional boxstones. The use of 'Junction Beds' is considered inadvisable due to the possibility of confusion with other strata given that name.

An intraformational erosion surface has been related to eustatic movements and is sometimes referred to as the 'Mid-*tardefurcata* Break' (Casey, 1961a). This surface has been interpreted as a sequence boundary that can be recognised over a very wide area (Haq et al., 1988). The boundary forms the base of the *Leymeriella* Zone.

Allen and Narayan (1964), Narayan (1971) and Allen (1982) discussed deposition of the formation, and Anderson (1986) gave further sedimentological details.

Stratigraphical relationships

The upper (Albian) part of the formation is contemporaneous with the Carstone of southern and eastern England, the

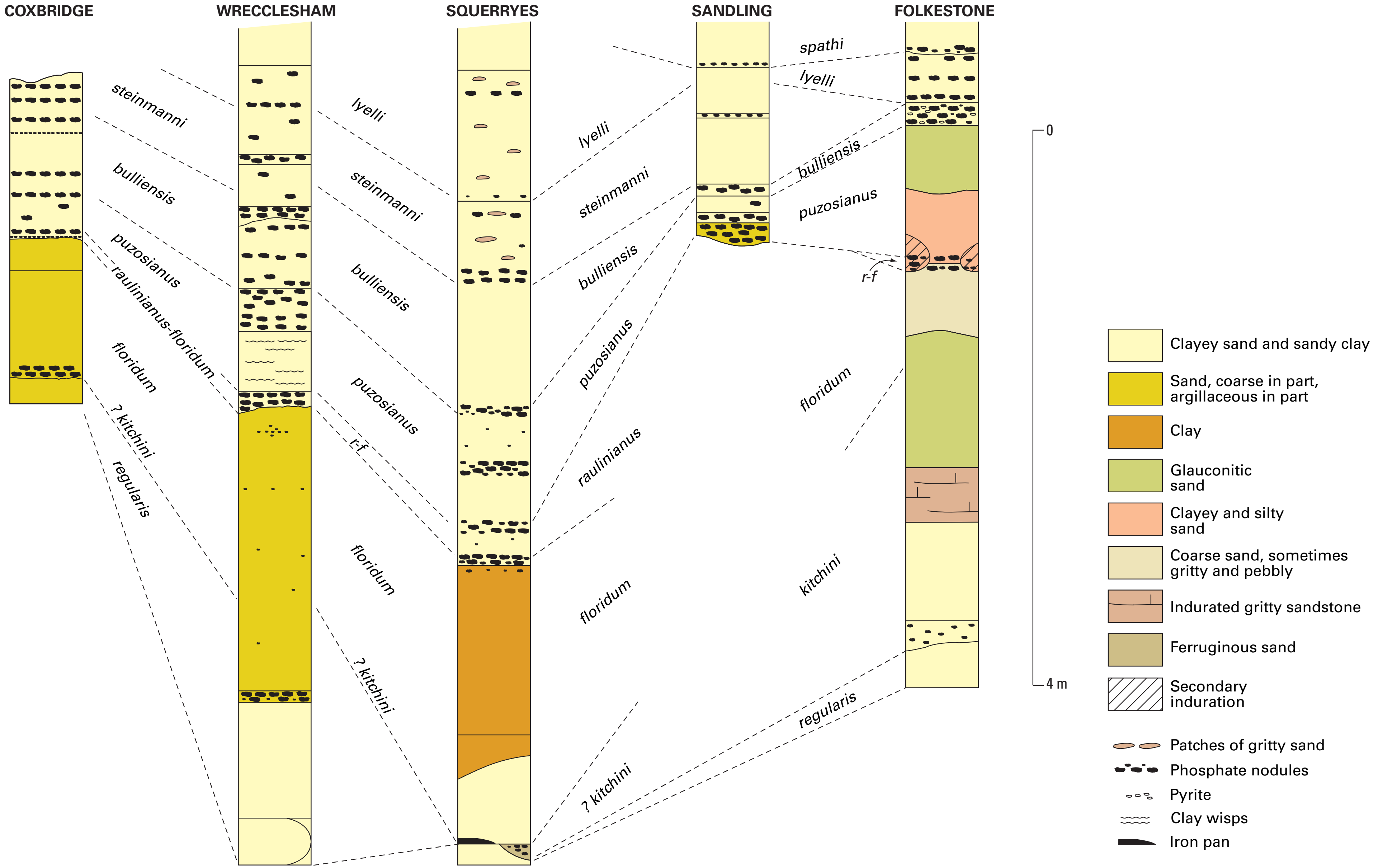


Figure 10 Correlation of the upper unit of the Folkestone Formation in south-east England, (modified from Owen, 1992).

Figure 11 Upper part of the Folkestone Formation at Parrat's Pit, Wrecclesham (after Owen, 1992).

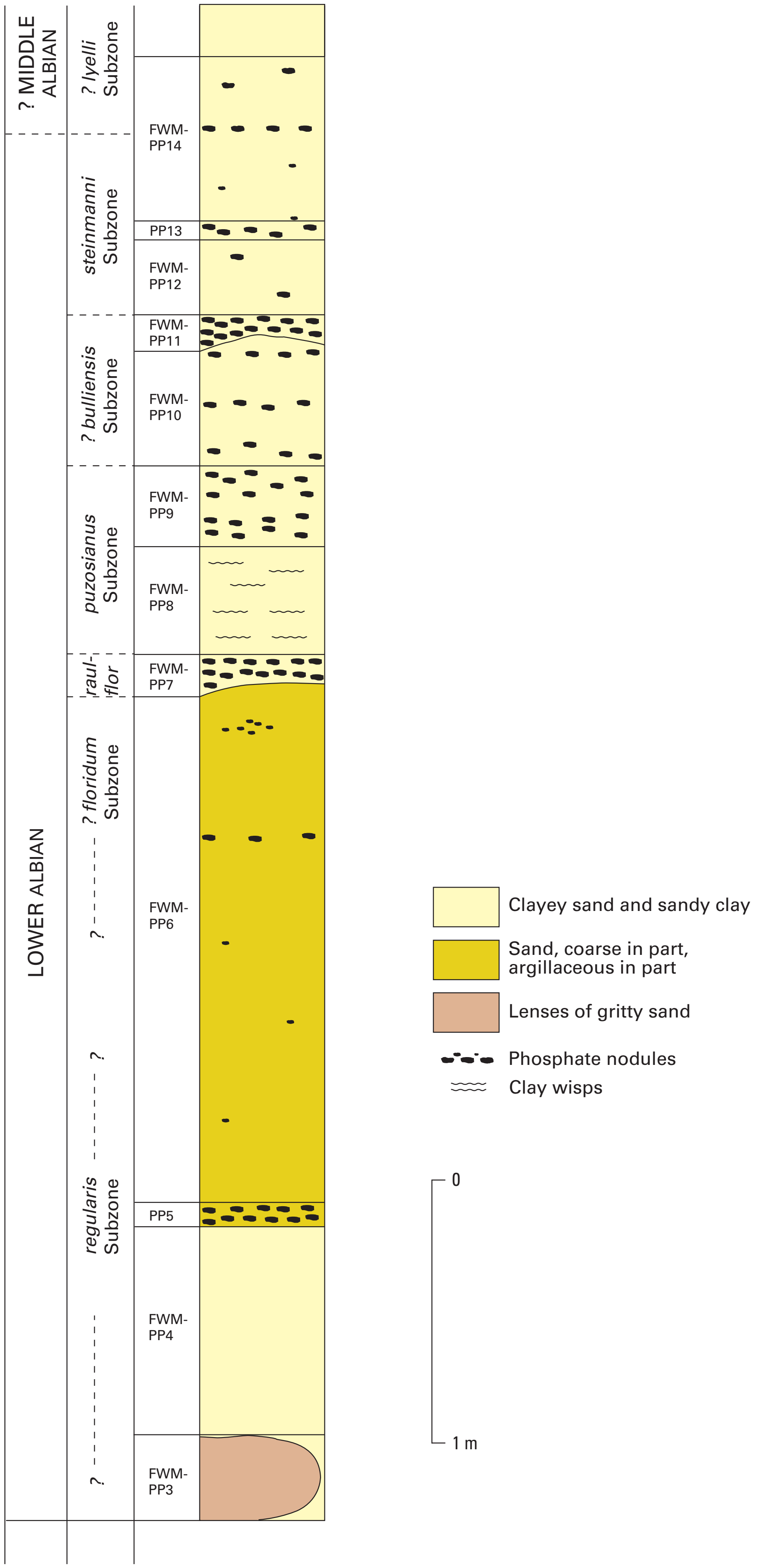
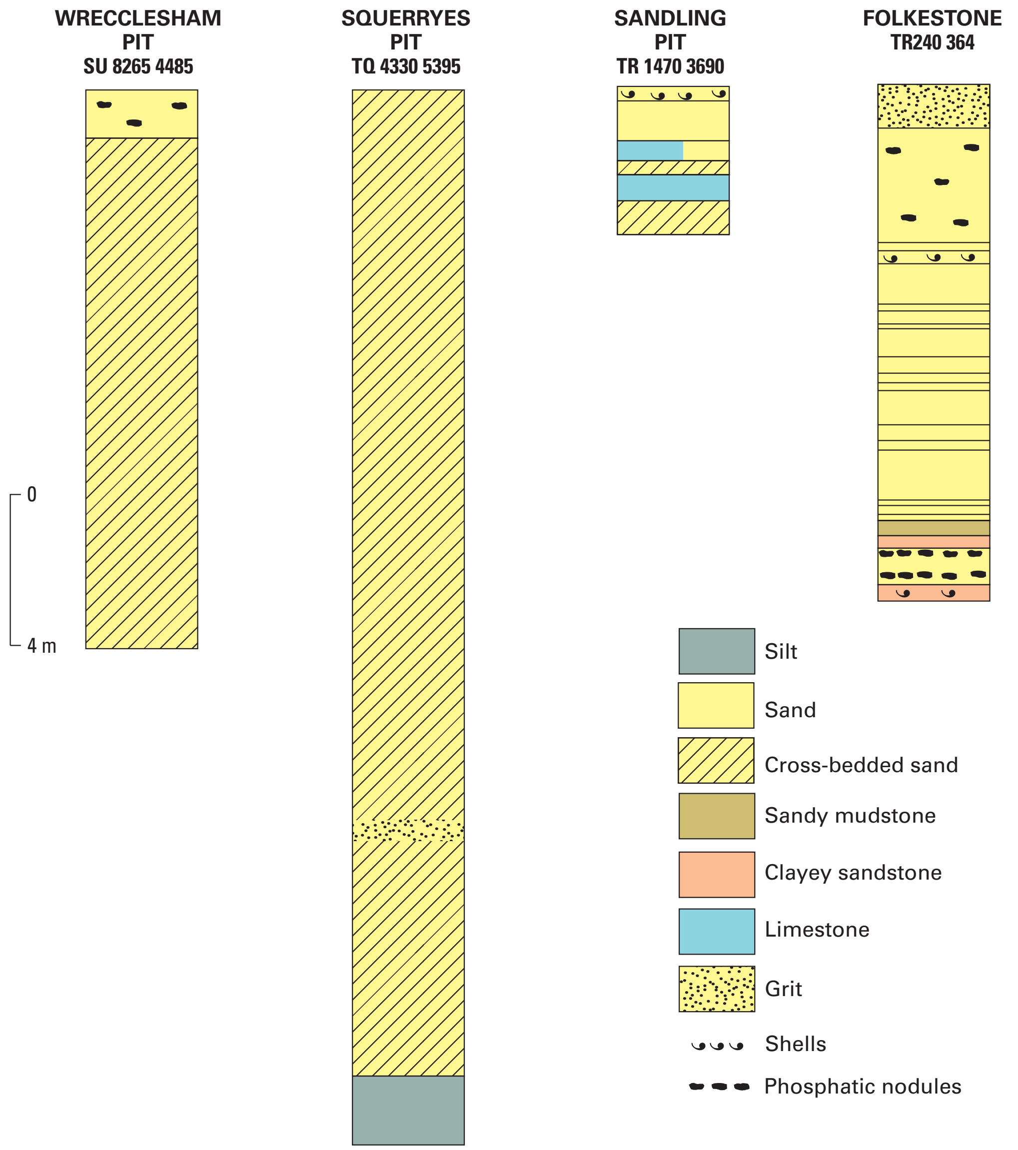


Figure 12 Lower part of the Folkestone Formation in south-east England.



Junction Beds of Leighton Buzzard and Speeton Clay Bed A5 (Ewaldi Marl), Yorkshire. According to Knox (1999) the Basal Sands of the Folkestone Formation in the Redhill–Nutfield area correlate with the Calne Sands.

Regional variation

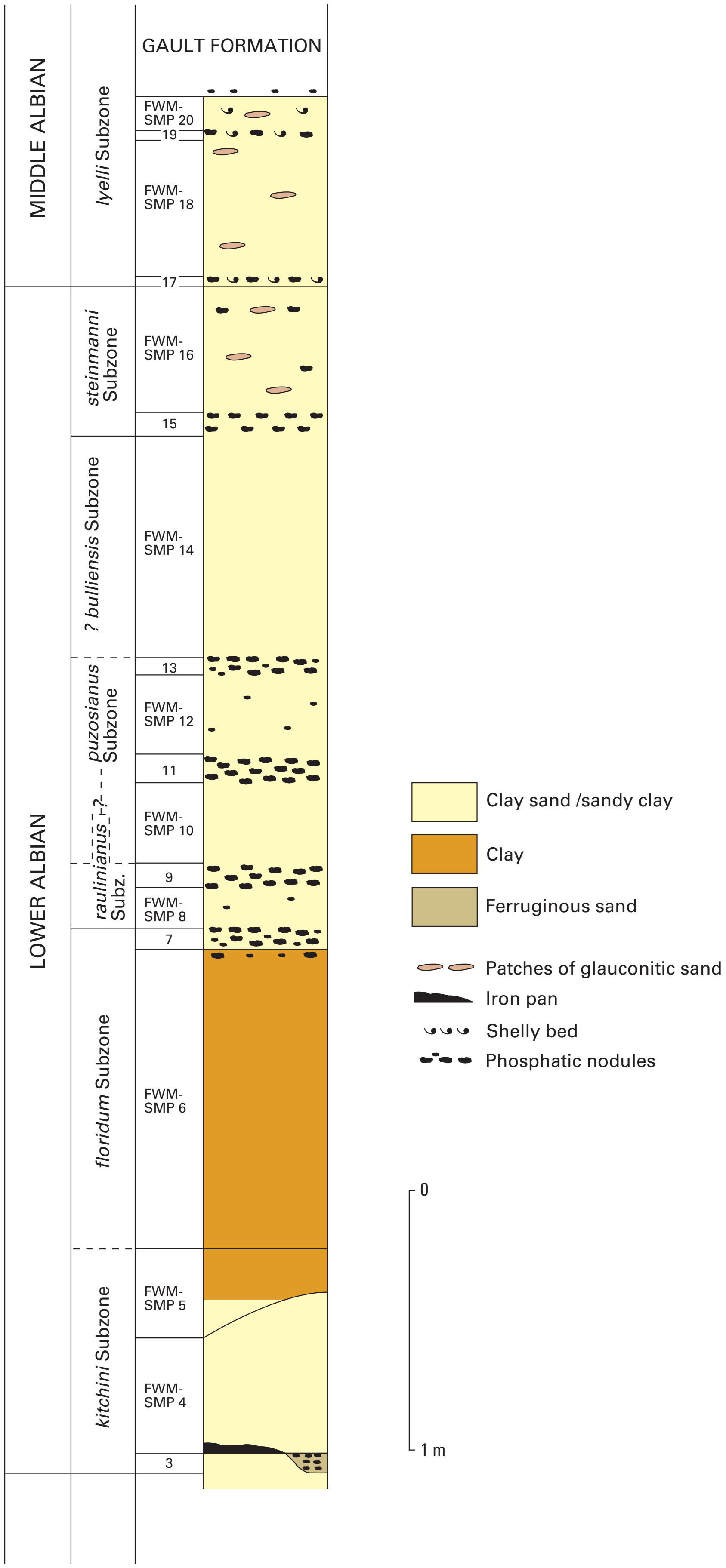
The outcrop of the Folkestone Formation encircles the Weald. In detail, there are variations in the presence and thickness of nodule horizons, secondary concretions, the proportion of the argillaceous component of sandy clay and clayey sand, and the degree of erosion and condensation. It is rarely seen in its entirety.

The sands are generally fine to medium grained, but in the eastern part of the Weald, around Folkestone, the formation comprises coarse-grained, yellowish sand with occasional bands of glauconitic greensand (Smart et al., 1966). In the Brighton area, Young and Lake (1988) describe the formation as medium- to coarse-grained sands and weakly cemented sandstones known as 'sandrock'. In some parts of western parts of Sussex, west of Washington, the formation becomes more argillaceous and the glauconite content increases (Gallois and Edmunds, 1965; Young and Lake, 1988).

In the Petersfield district of Hampshire, the Folkestone Formaton is a medium- to coarse-grained, cross-bedded, yellow and orange, weakly cemented sandstone with thin mudstone seams (Bristow, 1991), the argillaceous content increasing between Petersfield and Washington. In this district the thickness varies from about 10 m at Stroud [SU 7225 2360] and Flexcombe [SU 7684 2692] to 34 m at Ryefield [SU 7761 2230] and 54 m at Elsted [SU 8422 2093]. The formation is 25 m thick in the West Heath Pit [SU 785 228], west of Rogate (Bristow, 1991). Sedimentological details were discussed by Allen and Narayan (1964). The most westerly record of the formation in the Weald is around Stroud, where it is overlain by the Gault (Bristow, 1991).

In general terms, the formation thins towards the north and east of the Weald. Around Washington 40–70 m have been recorded (Young and Lake, 1988), around Sompting it is 35.1 m thick (Young and Monkhouse, 1980), but in the neighbourhood of Henfield and Poynings, it is 20–25 m (and locally 10 m) thick. At Streat, the formation is 15 m thick, but it is absent from Horton Clay Pit [SU 2100 1245] near Small Dole. Thickness varies from 18 m near Folkestone to 46 m near Maidenhead, 55 m near Red Hill and 79 m at Farnham (Owen, 1992). At the western end of the Weald, in the Petersfield area, its thickness increases from about 10 m to 54 m in the Elsted Borehole [SU 8422 2092] (Bristow 1991). Young and Lake suggest that the sandwave model of Allen and

Figure 13 Upper part of the Folkestone Formation at Squerryes Main Pit, Westerham, Kent [TQ 4330 5395] (after Owen, 1992).



Narayan (1964) and Narayan (1971) may in part account for this variation, but suggested that scouring may have also played a role.

More indurated beds occur towards the top of the formation in the Maidstone (Worssam, 1963) and Sevenoaks areas (Dines et al., 1969). These include 4.6 m of 'pink and white sandrock', 1.22 m of hard, grey-white, siliceous sandstone ('Oldbury Stone') and 1.22 m of chert ('Ightham Stone'), which are particularly well formed around Sevenoaks (Dines et al., 1969).

At the top of the Folkestone Formation, immediately underlying Gault, near Small Dole, Upper Beeding, are about 5 m of arenaceous deposits. They include the 'basement beds of the Gault', part of which is placed in the Folkestone Formation (Casey, 1961a, Owen, 1971).

Chronostratigraphical position

The formation straddles the Aptian/Albian stage boundary.

For the most part, the formation ranges from the Aptian *Hypacanthoplites jacobi* Zone, *H. rubricosus* Subzone, at the base, to the Albian *Douvilleiceras mammillatum* Superzone, *Otohoplites auritiformis* Zone; *Pseudosonneratia* (*Isohoplites*) *steinmanni* Subzone at the top. However in some localities it extends up into the basal Middle Albian, where the top of the formation can be placed in the lower part of the *Hoplites dentatus* Zone (*Lyelliceras lyelli* Subzone).

The lower unit of the Folkestone Formation ('Folkestone Beds' sensu Owen, 1992) extends up to the eroded top of the *acuticostata* Subzone and the upper unit ('Lower Greensand Junction Beds' sensu Owen, 1992) ranges from the *regularis* Zone to the earliest *lyelli* Subzone.

Selected references

Allen, 1982; Allen and Narayan, 1964; Anderson, 1986; Bristow, 1991; Casey, 1961a; Dines, Buchan, Holmes and Bristow, 1969; Fitton, 1836; Gallois and Edmunds, 1965; Haq et al, 1988; Knox, 1999; Morter, 1982; Narayan, 1971; Owen, 1971, 1988b, 1992; Smart, Bisson and Worssam, 1966; Worssam, 1963; Young and Lake, 1988.

2.2.3.1 Horton Wood Clay Bed

Derivation of name

Named after the locality of the British Portland Cement Manufacturers' Horton Wood Borehole No. 9a, Small Dole, where it occurs at a depth of 57–69 feet (17.38–21.04 m). Originally called Hopton Wood Clay (Casey, 1961a), this misspelling was corrected by Casey (1961b).

Locality details

Parrat's Pit, Wrecclesham, Surrey (Section 6.3.1, Figures 10, 11 and 12)
Coxbridge Pit, Farnham, Surrey (Section 6.3.2, Figure 10)
Squerryes Main Pit, Westerham, Kent (Section 6.3.3, Figures 10 and 13)
Sandling Pit, Saltwood, Kent (Section 6.3.4, Figures 10 and 12
East Cliff, Folkestone, Kent (Section 6.3.5, Figures 8, 9, 10 and 12
Horton Wood Borehole No. 9, Small Dole, near Upper Beeding, W. Sussex (Section 6.3.6)
Horton Hall clay pit, Upper Beeding, Sussex (Section 6.3.7)

Lithological characteristics

'Dark grey, non-calcareous clay with hard, flat, whitish nodules, especially at the top, a few pyritic nodules and numerous algal filaments; some threads of glauconitic sand; washed residues full of glauconite and mica, a few forams. *Aconeceras* and *Leymeriella* with iridescent test; crustacean limbs fairly common.' (Casey, 1961, p.558).

Stratigraphical relationships

The Horton Wood Clay Bed is situated in the upper part of the Folkestone Formation. It is apparently coeval with the Junction Beds and Shenley Limestone of Leighton Buzzard.

Regional variation

Unknown. The only place that the bed is described is at the stratotype locality. It may occur in the Warren Farm Industrial School borehole, near Rottingdean, where Edmunds (1928, p.194) recorded, at 1275 feet (388.72 m) depth, 'brown clay, not effervescing with acid as the rest of the Gault does, with hard white nodules (?phosphatic)'.

Chronostratigraphical position

Leymeriella regularis Zone

Selected references

Casey, 1961a, b

2.2.4 Sandrock Formation (part)

Derivation of name

Fitton (1845, 1847) used the term 'Upper Clays and Sand Rock' for his group XV. The Geological Survey of 1887 used the term 'Sandrock Series' and this lithological name has since entered the literature.

Lithological characteristics

The Sandrock Formation comprises upward coarsening sedimentary cycles. When complete, the cycle consists of dark grey mudstone and finely laminated, fine-grained sands and silts, overlain by well-sorted fine to coarse, frequently cross-bedded sand with a pebble bed resting on the scoured top (Wach and Ruffell, 1990; Insole, Daley and Gale, 1998; Ruffell and Wach, 1998a,b).

Stratigraphical relationships

The Sandrock Formation is situated between the Ferruginous Sands Formation and Carstone Formation of the Isle of Wight. It forms the upper part of Fitton's (1847) Group XV ('Upper Clays and Sandrock') and probably the lower part of his Group XVI (which was ill-defined due to problems of accessibility and exposure). In terms of the Weald, Casey (1961a) considered the Sandrock Formation to be coeval (at least in part) with the Folkestone Formation. The muds at the base of the formation on the Isle of Wight, placed in the Ferruginous Sands Formation by Casey (1961a), were considered by him to be coeval with the Marehill Clay of Sussex.

The top of the formation was eroded prior to the accumulation of the overstepping Carstone Formation. This depositional break is the 'Mid-*tardefurcata* Break' of Casey (1961a).

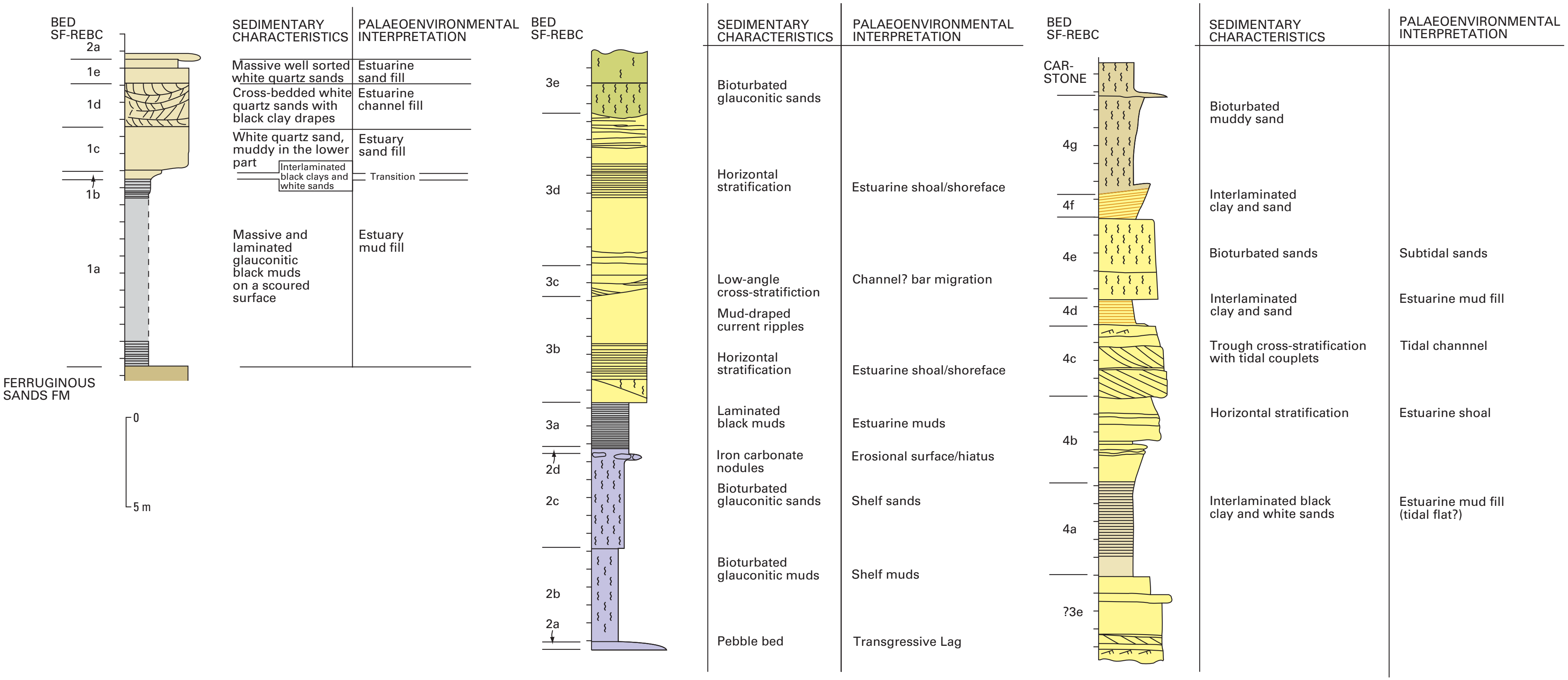
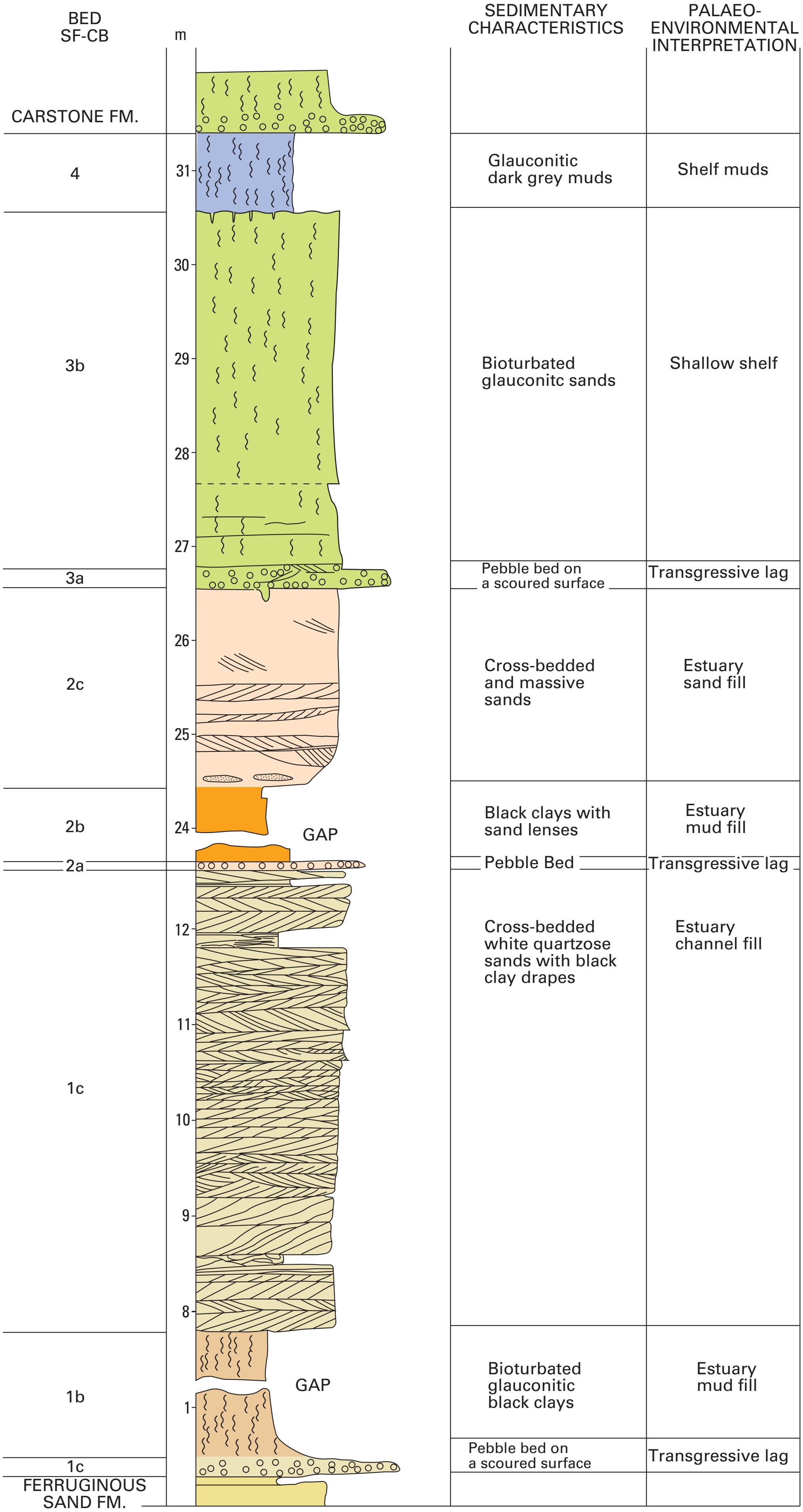


Figure 14 Lithostratigraphy of the Sandrock Formation at Rocken End to Blackgang Chine, Chale Bay, Isle of Wight (modified from Wach and Ruffell, 1990 and Ruffell and Wach, 1998a, b).

Figure 15 The Sandrock Formation at Compton Bay (after Watch and Ruffell, 1990).



The formation straddles the Aptian-Albian boundary on the Isle of Wight.

Regional variation

The Albian part of the formation is restricted to the Isle of White, but is not well exposed so that variation in lithologies is not known. The most complete sequence is that in the Rocken End–Blackgang area of Chale Bay (see Figure 14) where about 90 m occur (approximately 60 m fall within the Albian — it is difficult to be accurate as part of the sequence is obscured). At Compton Bay (Figure 15), the formation is 31.5 m thick and it is not clear how much of this, if any, is Albian. The lower part of the Compton Bay sequence can be correlated with Chale Bay, but correlation of the upper part is more difficult due to variations in facies, intraformational erosion and the absence of biostratigraphical markers. It is not possible to say whether any part of the sequence is Albian.

Chronostratigraphical position

Casey (1961a, pp.497 and 512) considered that the formation (i.e. above Fitton's Group XV) could be placed within the *H. jacobi* Zone, *H. rubricosus* Subzone (latest Aptian) to *L. tardefurcata* Zone, *H. milletioides* Subzone (earliest Albian). This was based mainly on stratigraphical evidence. The erosive event at the top of the formation, prior to the deposition of the Carstone, was equated with the 'Mid-*tardefurcata* Break' and the 'Clay band of Bed XV' was correlated with the Marehill Clay, which is at a stratigraphical position above the *P. cunningtoni* Subzone and at a similar stratigraphical level to faunas of the *N. nolani* Subzone.

Rawson et al. (1978) reported a specimen of *Hypacanthoplites* aff. *trivialis* at Dunnose, Isle of Wight, suggesting that the top of the Sandrock Formation is within the *H. milletioides* Subzone of the *L. tardefurcata* Zone (Early Albian). Insole et al. (1998, p.63) placed the upper part of the Sandrock Formation of Chale Bay in the '?*farnhamensis*' and '?*milletioides*' subzones of the *L. tardefurcata* Zone, although the basis for this correlation was not given. Ruffell and Wach (1998) supported the *H. jacobi* to *L. tardefurcata* age.

The position of the Aptian/Albian boundary within the Sandrock Formation, cannot be recognised with certainty, but it is tentatively placed at the base of their Bed SF-REBC3a in Chale Bay. There is no evidence that any part of the sequence is Albian in age at Compton Bay.

Selected references

Fitton, 1845, 1847; Insole, Daley and Gale, 1998; Jackson, 1939; Lamplugh, 1901; Ruffell and Wach, 1998a, b; Wach and Ruffell, 1990.

2.2.5 Lower Greensand 'Formation'

Derivation of name

The Lower Greensand has generally been regarded as a group, particularly after the work of Casey (1961a). However, in south-west England, where the group becomes very thin, it has been referred to as a formation (cf. Bristow et al., 1995). Clearly an alternative formational name is required, but for the purposes of this compilation, the concept of Bristow et al. (1995) is followed.

Locality details

Chale Bay, Rocken End–Blackgang Chine (Section 6.4.1, Figure 14)
Compton Bay (Section 6.4.2, Figure 15)

Lithological characteristics

The Lower Greensand Group comprises mainly sands and sandstones with silts and clays at some intervals. Only the Albian part in Dorset is considered here.

Arenaceous deposits at the top of the Lower Greensand 'Formation' (in the sense of Bristow et al., 1995) in several parts of southern England, immediately underlying Gault (e.g. near Shaftesbury), comprise the Bedchester Sands Member (Bristow et al., 1995). At some localities (e.g. in the Winterborne Kingston Borehole), this unit may have been been regarded as 'the basal beds of the Gault' (Morter, 1982). The member comprises dark grey, glauconitic, sandy clay, becoming increasingly glauconitic down section. In the lower part, it comprises hard, dark green, glauconitic, silty and sandy clay with pockets and seams of coarse sand, nodules and small pebbles. The member may be shelly, particularly in the upper part.

Stratigraphical relationships

In Dorset, the Albian part of the Lower Greensand is situated immediately below the Gault. In the few localities described, it rests on thin, questionably Aptian, sands (Child Okeford Sands Member) or disconformably on Kimmeridge Clay.

Regional variation

At Okeford Fitzpaine, in the Shaftesbury area, the Lower Greensand is 2.7 m thick, but the Albian part (the Bedchester Member) is only 0.46 m thick (Bristow et al., 1995). In the Winterborne Kingston Borehole, Dorset, the 'basement beds of the Gault' (0.31 m thick, perhaps up to about 1 m thick taking core loss into account) are considered to be part of the Bedchester Member. Although only 0.36 m were recovered due to core loss, the Bedchester Member may be as much as 3.85 m thick at this locality (Morter, 1982).

Chronostratigraphical position

A *kitchini* Subzone fauna (basal *D. mammillatum* Superzone; *chalensis* Zone) has been recorded in the Bedchester Member.

Selected references

Bristow et al., 1995; Casey, 1961a; Morter, 1982.

2.2.5.1 Bedchester Sands Member

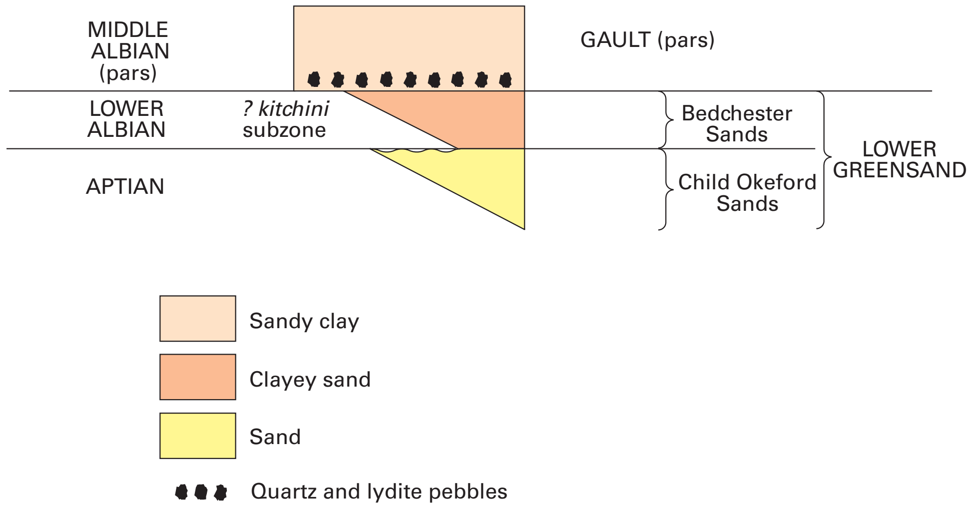
Derivation of name

After Bedchester, the type area (see Figure 16) (White, 1923, pp.42–44, and further discussed by Bristow et al., 1995).

Lithological characteristics

Bristow et al. (1995) divided the 'Lower Greensand Formation' of Dorset, into two members:

Figure 16 The position of the Bedchester Sands Member near Bedchester (after Bristow et al., 1995).



2. Bedchester Sands Member: muddy, fine-grained, poorly to very poorly sorted, glauconitic sand or very fine-grained sandy clay.
1. Child Okeford Sands Member: fine to very fine grained, poorly sorted, glauconitic sand with beds of medium grained sand, silty beds and ferruginously cemented beds.

The two members are treated here as members of the 'Lower Greensand Formation' in the sense of Bristow et al. (1995), although an alternative formational name needs to be found. The Child Okeford Sands Member is believed to be Aptian in age (Bristow et al., 1995) and outside the scope of this work.

Stratigraphical relationships

Locally the Bedchester Sands overstep the Child Okeford Sands to rest on the Kimmeridge Clay. Its lower boundary is, therefore, generally an erosion surface, but in some areas the contact between the Bedchester Sands and Child Okeford Sands is conformable. The Bedchester Member immediately underlies Gault in the Winterborne Kingston Borehole and near Shaftesbury (e.g. Casey, 1961; Owen 1971; Morter, 1982; Bristow et al., 1995).

Regional variation

The member varies in thickness from 1.6 m at Hartgrove Farm Pit, where it overlies the Kimmeridge Clay, to 6.5 m between Child Okeford and Farringdon where it rests on the Child Okeford Sands. Morter (1982) suggested that the 'basal beds of the Gault' and the grey silty mudstones and sands between 346.35 and 346.40 m in Winterborne Kingston Borehole (the base was not seen due to core loss) may represent the 'Bedchester Sands'.

Chronostratigraphical position

The age of the Lower Greensand of Dorset is not clear, but Early Albian foraminifera have been recovered from the Bedchester Sands. In the Okeford Fitzpaine Brickpit [ST 815 109], Owen (1971) recorded fossils of the *kitchini* Subzone from brown sandy ironstone immediately below the basal pebble bed of the Gault (his description implies the Bedchester Sands). At Dinton, Wiltshire [SU 010 318], 0.76 m of grey, sandy, ferruginous, fossiliferous mudstone between the Gault and the Kimmeridge Clay (Casey, 1956), assumed to be the Bedchester Sands, also yielded a *kitchini* Subzone fauna.

Selected references

Bristow et al., 1995; Casey, 1956; Jukes-Browne, 1891; Owen 1971; White, 1923.

Locality details

Child Okeford, near Shaftesbury (Section 6.5.1)
Piper's Mill, near Shaftesbury (Section 6.5.2)
Hartgrove Farm pit, near Shaftesbury (Section 6.5.3)
Winterborne Kingston Borehole (Section 6.5.4)

2.2.6 Gault Formation

Derivation of name

William Smith used the term 'Golt Brick Earth' on his geological Map of England and Wales (1815) and Norfolk (1819). The Reverend J Hailstone, however, read a paper to the Geological Society on November 18th 1814 (which was published in 1816) in which he states (p.243) that 'they [the chalk hills] appear to rest upon an extensive bed of blue clay, provincially called gault', and later (p.249) refers to 'the bluish clay or marle called gault.' These are the earliest published references to the unit known to the author. 'Golt' or 'Gault' is a local quarryman's (brick-making) term.

Lithological characteristics

The Gault comprises medium and dark grey mudstones and pale grey, calcareous mudstones. It is silty and or sandy at some horizons. The formation may be glauconitic in part and very fossiliferous (notably with bivalves, ammonites and belemnites). Bands of phosphatic nodules, pyrite and calcareous nodules also occur.

The formation can be divided into two parts, called Lower Gault and Upper Gault by De Rance (1868). The Lower Gault comprises predominantly medium and dark grey mudstones in which illite and kaolinite are the main clay minerals. The Upper Gault is more calcareous, paler grey, and smectite is the main clay mineral (Perrin, 1971).

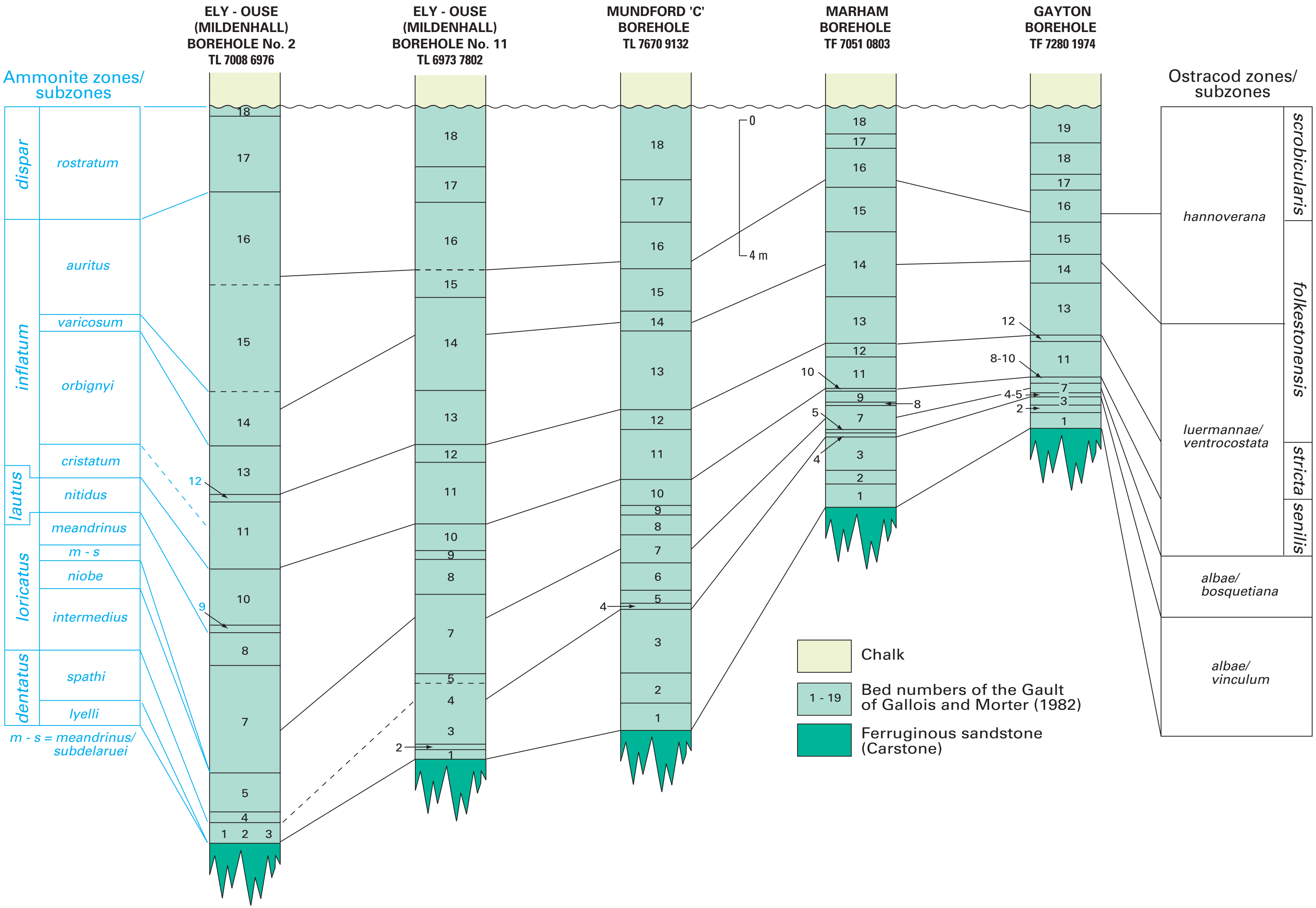


Figure 17 Correlation of the Gault of the reference section of the Mundford 'C' Borehole with other sequences of East Anglia and the relationship between macrofossil and ostracod biostratigraphy (after Wilkinson, 1990).

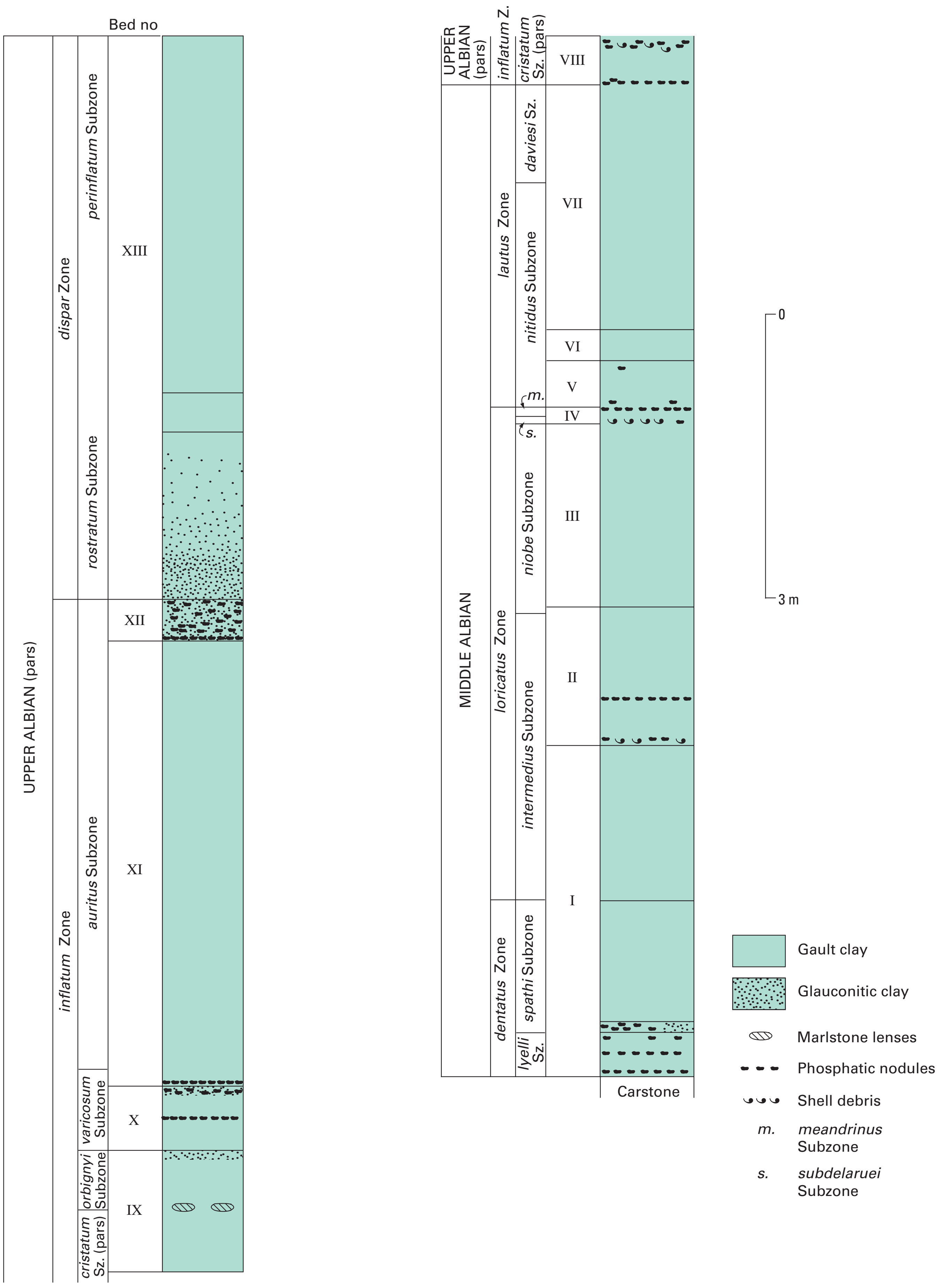


Figure 18 Stratigraphy of the Gault at Copt Point, Folkestone (after Owen, 1976).

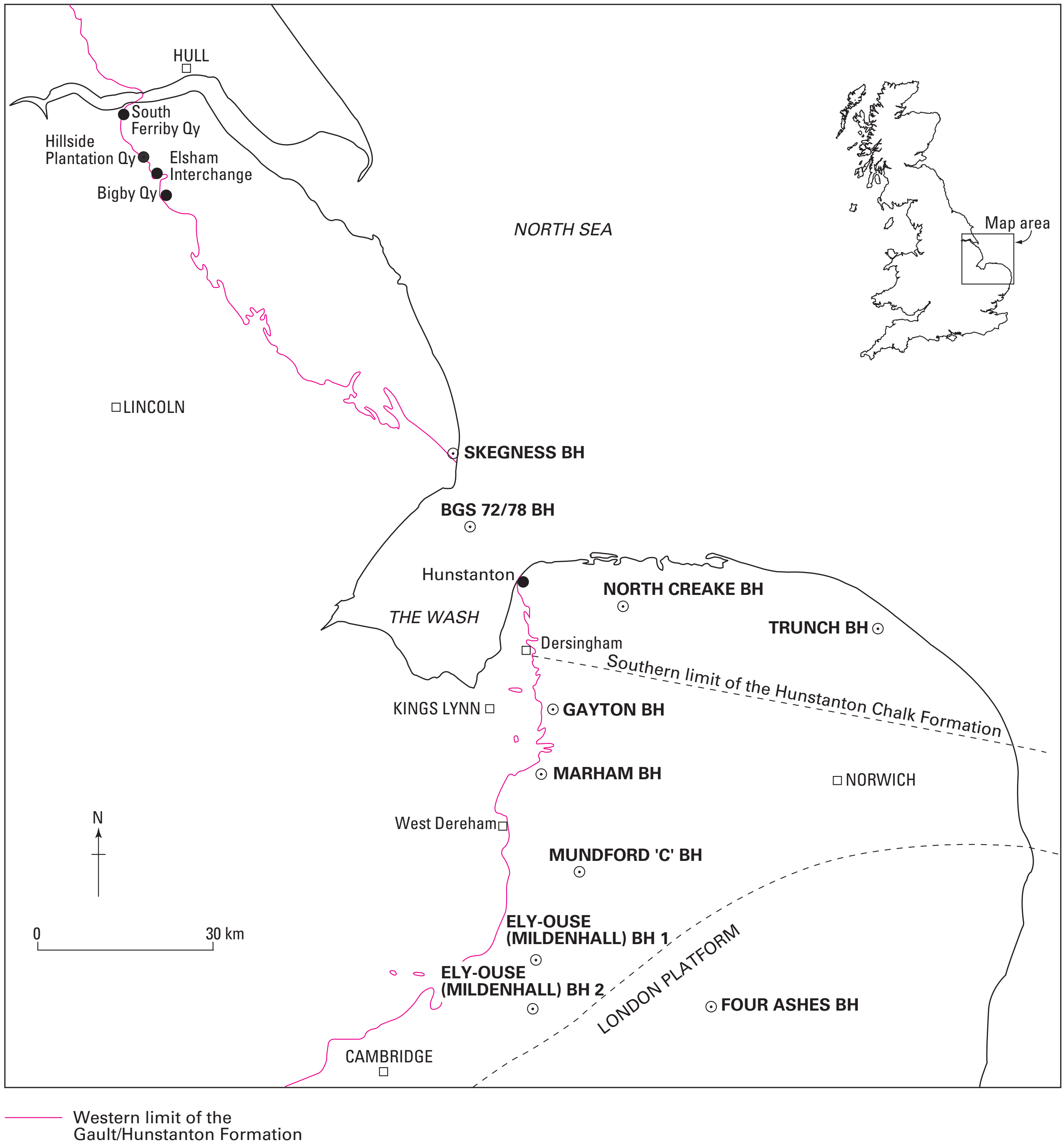


Figure 19 Locality map of East Anglia and Lincolnshire showing the limits of the Gault and Hunstanton Formation.

The Gault of East Anglia (Mudford borehole 'C' being the reference section, see Figure 17) shows rhythmic sedimentation (Gallois and Morter, 1982). Each rhythm is 1 to 2 m thick. Erosion has resulted in few of the rhythms being preserved in their entirity, but ideally each comprises, in ascending order:

1. medium or dark grey, shelly, pebbly silty mudstone or muddy siltstone rich in inoceramid prisms, oysters, belemnites, exhumed phosphatised burrow-fills and water-worn phosphatic pebbles, resting on a partially phosphatised and glauconitised burrowed surface. This passes up into
2. medium grey calcareous mudstone with a decrease in the coarser clastic (including bioclastic) content and an increase in calcium carbonate. There may be a decrease in faunal diversity and numbers. This passes up into
3. pale grey mudstone with further increase in the calcium carbonate content. The upper part is burrowed and the top boundary of the bed is a partially phosphatised and glauconitised burrowed surface forming the base of the succeeding rhythm.

De Rance (1868, 1875) and Price (1874, 1876) divided the Gault of Copt Point, Folkestone, Kent, into 11 lithological

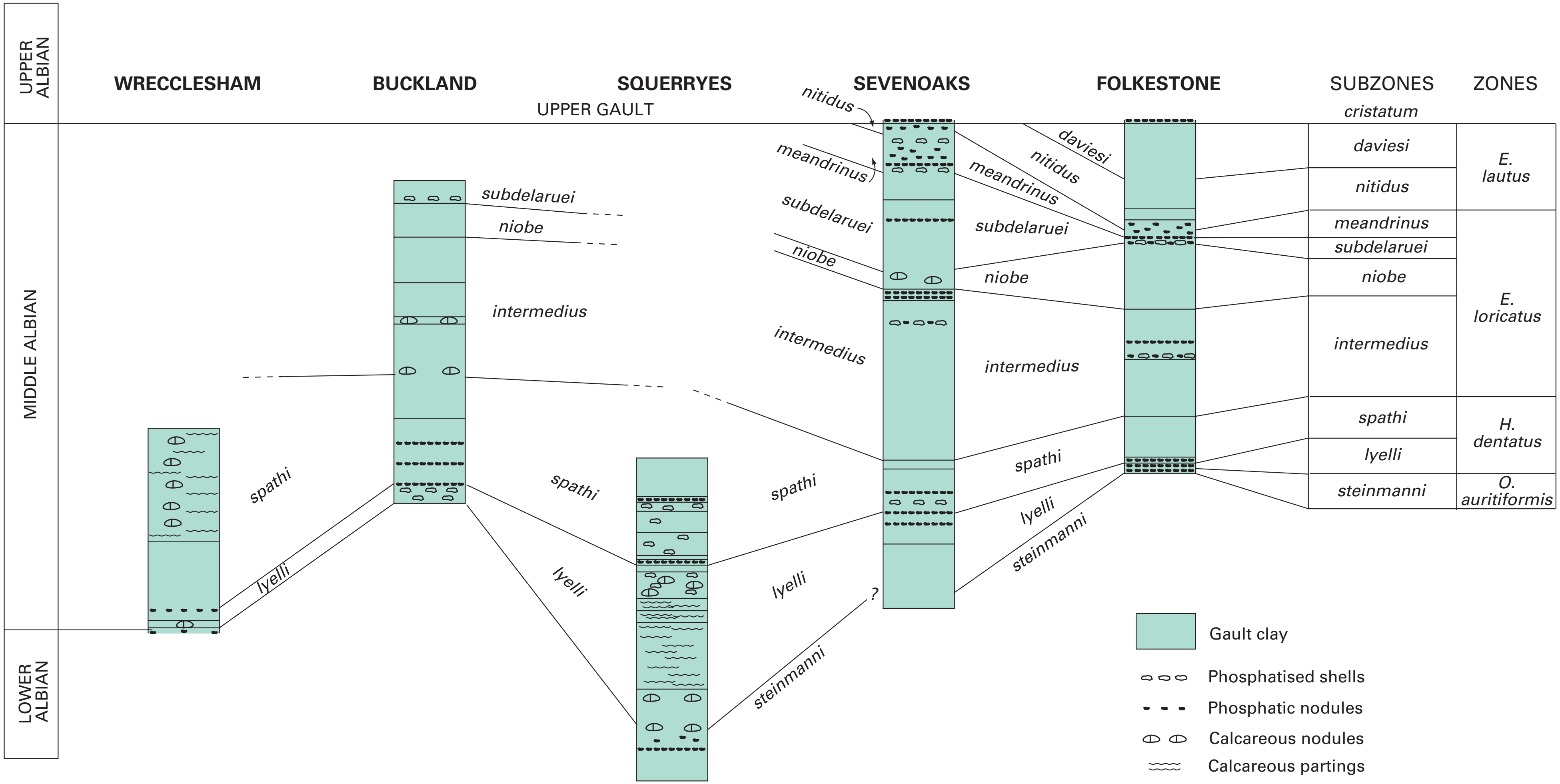


Figure 20 Correlation of the Lower Gault in the north Weald (after Owen, 1976).

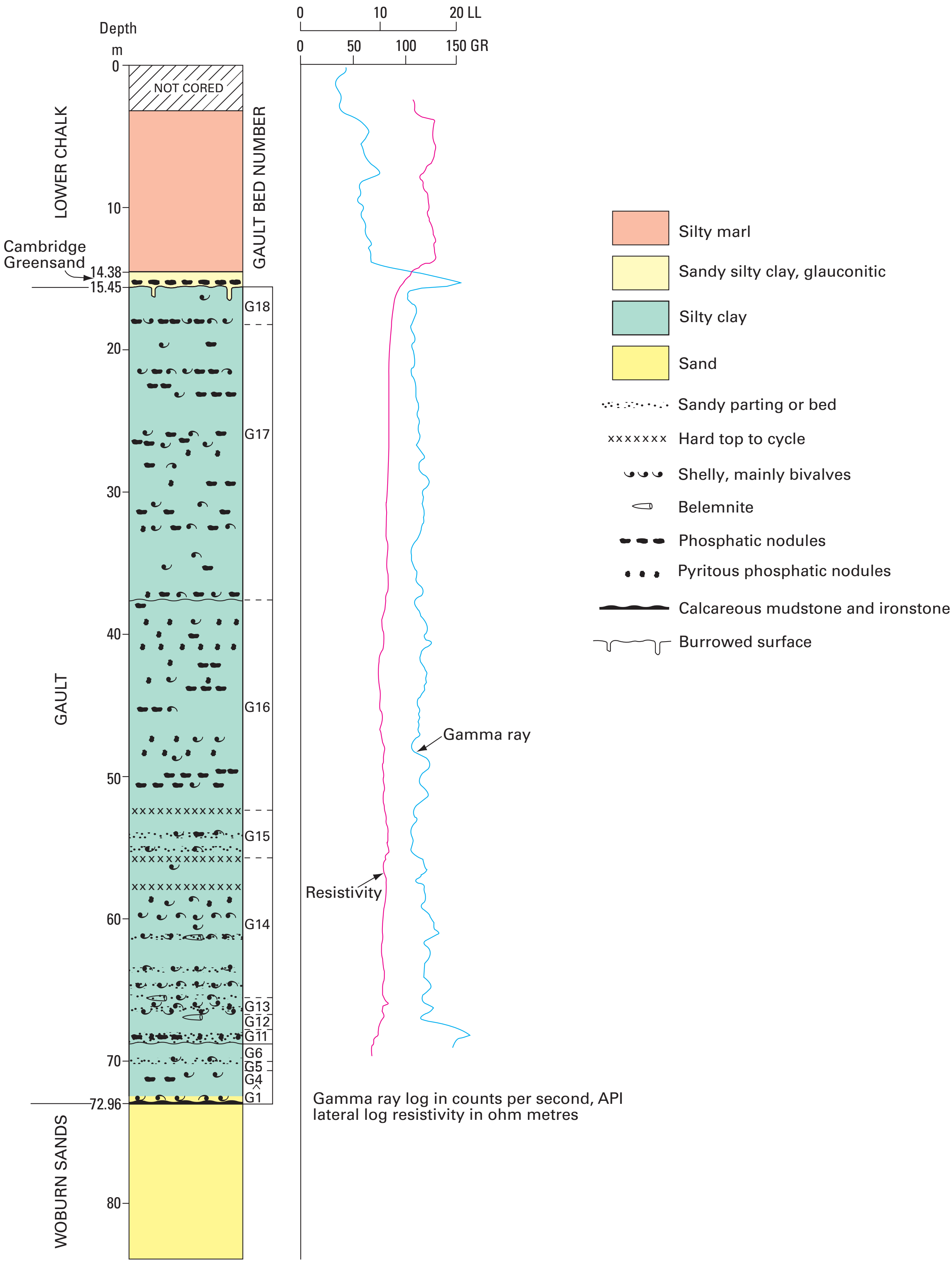


Figure 21 The Arlesey Borehole [TL 1887 3463] graphic lithology and geophysical logs and the relationship to the Gault Bed numbers of Gallois and Morter (1982) (From Hopson et al., 1996).

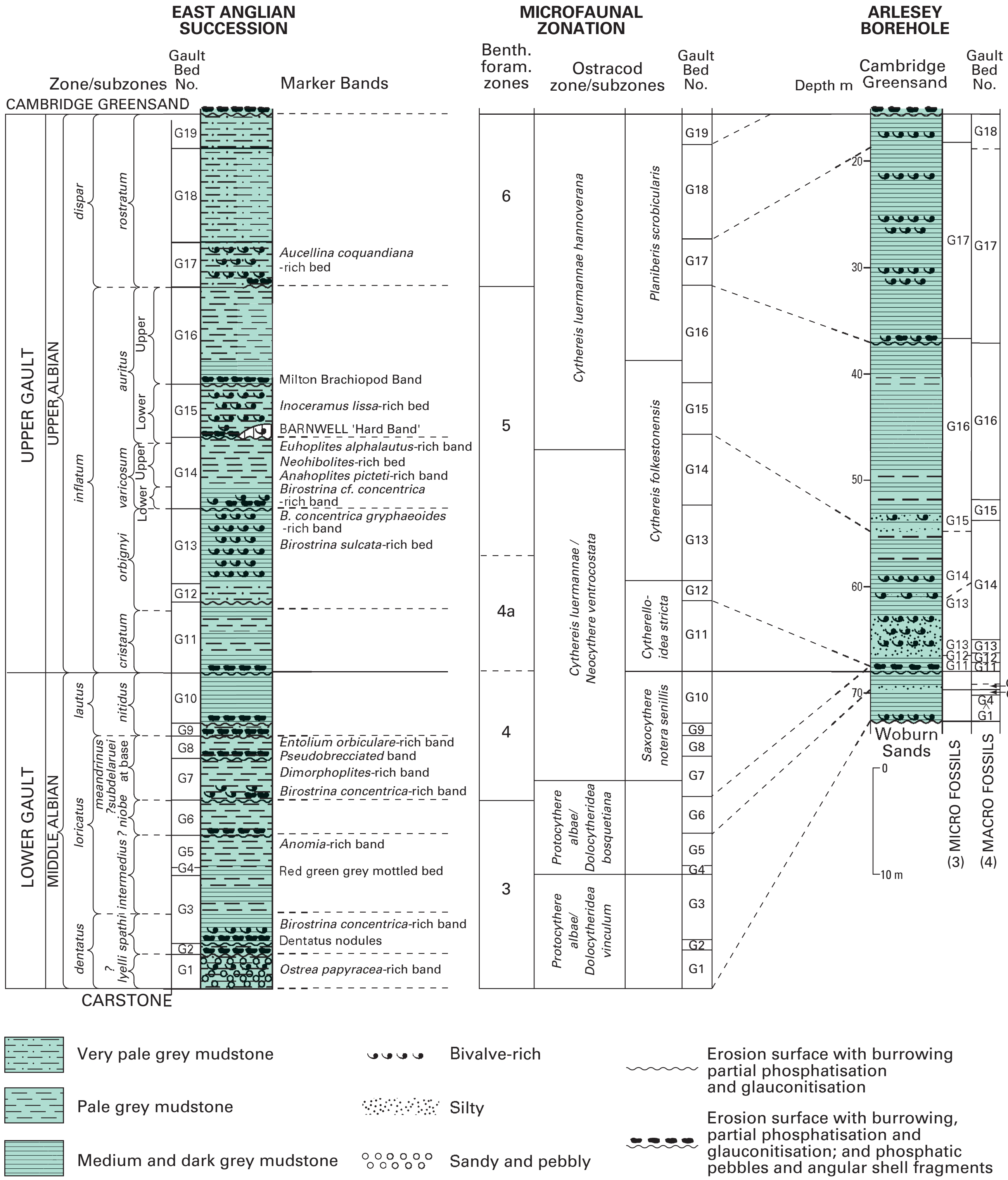


Figure 22 Relationship of the Gault sequence in the Arlesey Borehole to the standard East Anglian succession of Gallois and Morter (1982) and the microfossil zonation (Carter and Hart, 1977; Wilkinson, 1990) (after Hopson et al., 1996).

units, based on a combination of lithology and faunal content. The uppermost of these units was subdivided into three by Jukes-Browne (1900) and the resulting 13 beds were numbered I to XIII from the base up. Originally these beds were believed to coincide with the ammonite zone/subzonal scheme (Spath, 1923–1943; Casey, 1966), but Owen (1971, 1976) has shown that only one of Price's beds coincides with an ammonite subzone (see Figure 18).

The Gault of East Anglia was similarly subdivided on a combination of lithology and faunal content (Gallois and Morter, 1982) and 18 (and locally 19) beds have been recognised, the base of each bed being the erosion surface that forms the lower boundary of a sedimentary rhythm (see Figure 17). The erosion surfaces sometimes coincide with faunal changes. These beds can be recognised over large areas and it is likely that they will be applicable to southern

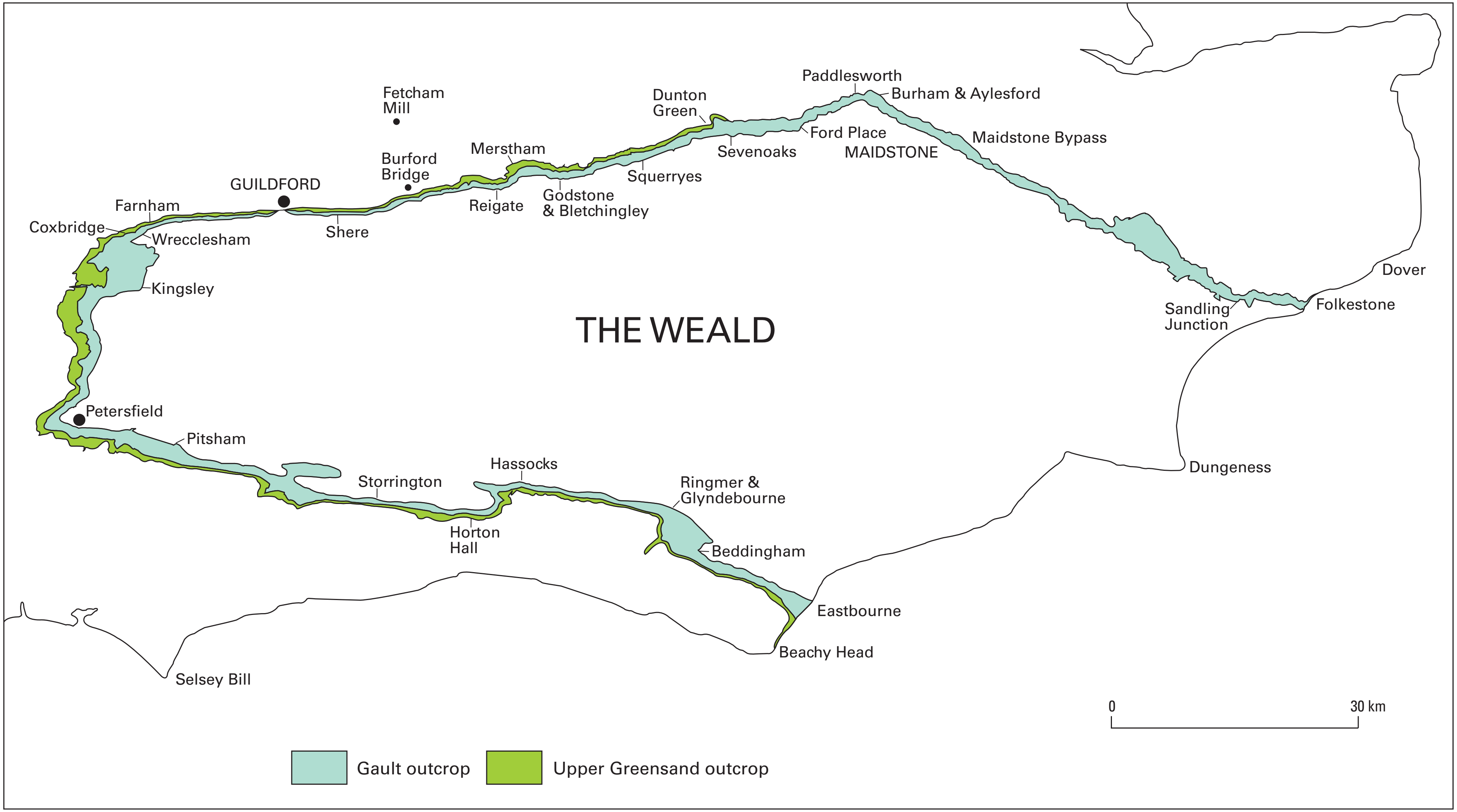


Figure 23 Distribution of the Gault and Upper Greensand outcrop of the Weald (after Owen, 1976).

England as well, although with modification as the upper part of the Upper Gault is missing in East Anglia.

In south-west England, the Gault becomes progressively more sandy before passing up into the Upper Greensand. The beds defined in East Anglia and in Kent cannot be used there.

Stratigraphical relationships

The Gault and the Hunstanton formations are essentially contemporaneous in eastern England. The Gault can be traced as far north as the Sandringham area where it passes laterally into the Hunstanton Formation. In southern England the Upper Gault passes into the Upper Greensand (see Figure 19).

The lower boundary of the Gault is generally gradational, passing rapidly down, via increasingly sandy deposits, into the Carstone. However, on the London Platform it may rest unconfomably on Lower Greensand or Palaeozoic strata. In the Leighton Buzzard area, the base of the Gault is a red mudstone (locally known as the Cirripede Bed), which overlies the Junction Beds and associated Shenley Limestone.

The upper boundary in East Anglia is an erosion surface. There the highest part of the Gault (the *M. perinflatum* Subzone and possibly the upper part of the *M. rostratum* Subzone) was removed prior to deposition of the Cambridge Greensand. In the south-west, the formation passes up into Upper Greensand facies.

Regional variation

The individual beds of the Gault are remarkably uniform and can be traced throughout East Anglia and south-east England (Gallois and Morter, 1982). In the south-east, around Folkestone, the numbered beds recognised by Price (1874, 1876) and Jukes-Browne (1900) are still widely used, but they have not been re-examined to place them into the modern context of Gallois and Morter (1982). Owen (1976, 1992, 1996a, b) provides valuable information on the Gault sequences in Kent, Surrey and Sussex (see Figure 20). Towards the south-west, the formation becomes more arenaceous and is much thinner so it is not possible to use the standard subdivisions. On the flanks of the London Platform, some parts of the formation are arenaceous.

The thickness of the deposit varies considerably from 2 m in Norfolk to about 104 m in the Glyndebourne Borehole, Sussex.

In parts of East Anglia, e.g. the Four Ashes Borehole [TM 0230 7187] (where the Gault is 14.76 m thick) and the Clare Borehole [TL 7834 4536] (where it is 11.08 m thick), part of the Lower Gault is missing as the London High was not flooded until the Late Albian (the upper part of the formation rests unconformably on Palaeozoic sediments). The Gault also thins rapidly northwards through Norfolk and passes laterally into the Hunstanton Formation (see Figure 19). Hence, from a maximum thickness of 57.35 m in the Arlesey Borehole [TL 1887 3463] (see Figures 21

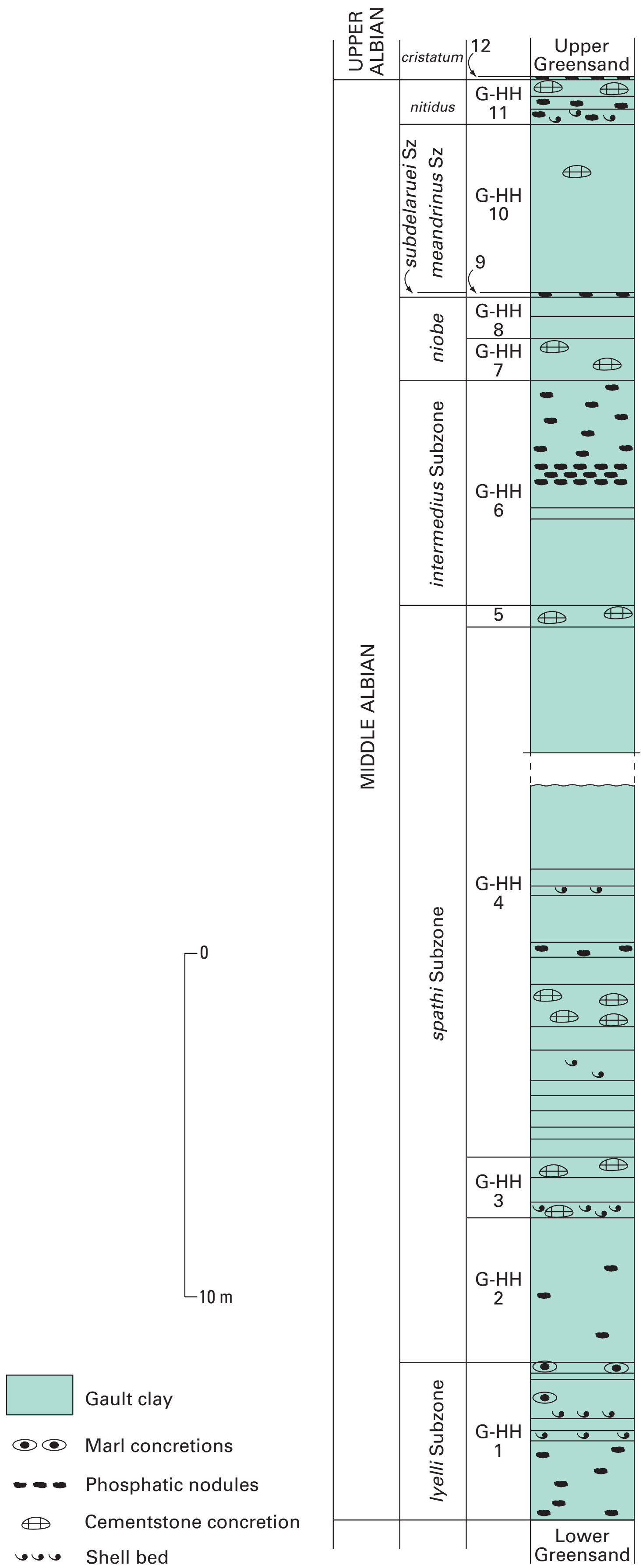
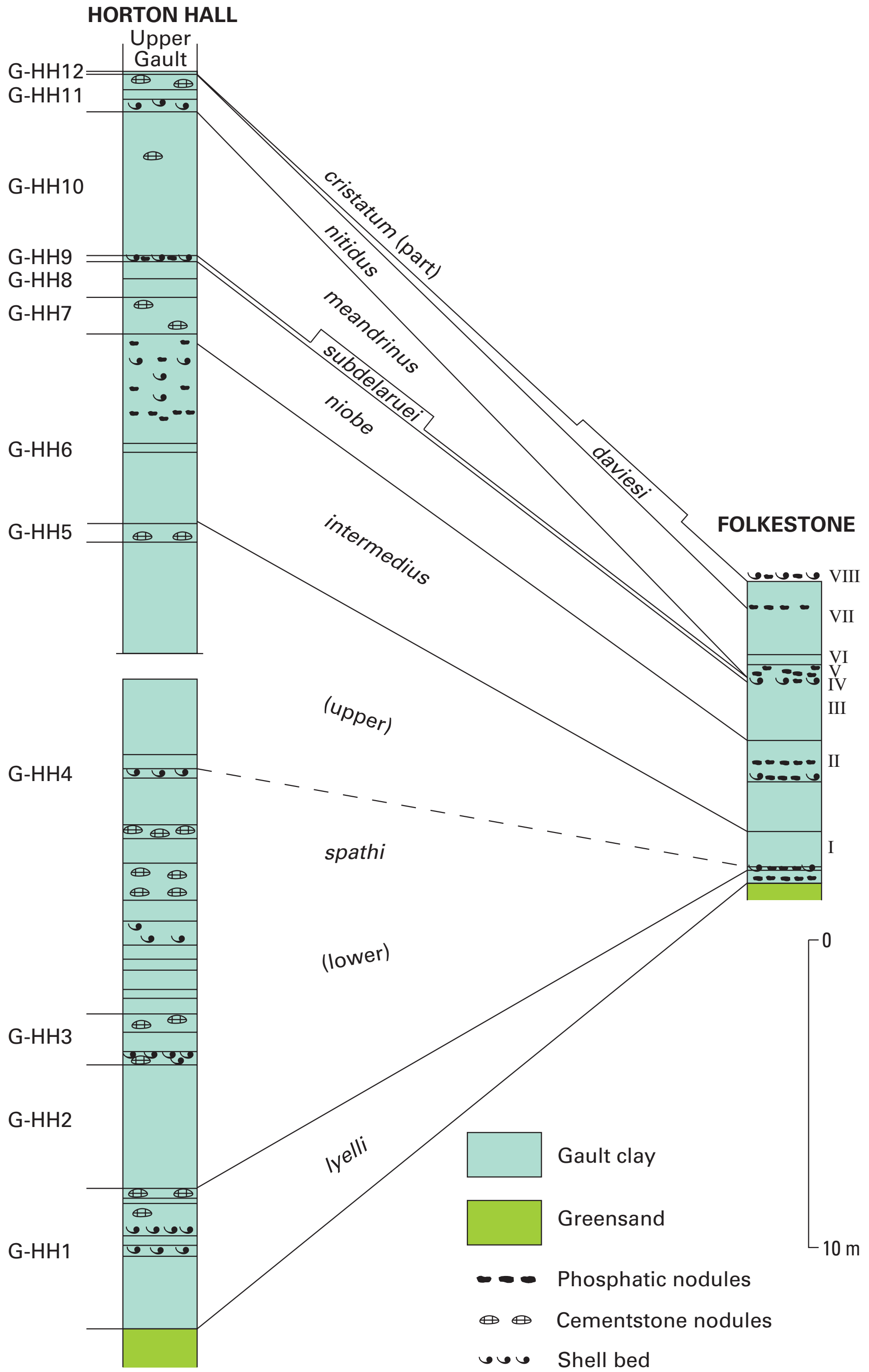


Figure 24 The Gault of Horton Hall clay pit, Upper Beeding, Sussex (after Owen, 1971).

Figure 25 Correlation of Lower Gault sections at Horton Hall and Folkestone (after Owen, 1971).



and 22), the formation thins to 18.92 m in the Ely-Ouse borehole No. 14 [TL 6962 8115], 18.08 m in the Mundford 'C' borehole [TL 7670 9132], 11.60 m in the Marham Borehole [TF 7051 0803] and 8.97 m in the Gayton Borehole [TF 7280 1974] (see Figure 17). Farther north, near Sandringham, the Gault comprises approximately 2 m of pink and cream, calcareous clay. Gallois and Morter (1982) pointed out that some beds (notably Gault Beds G14, G16 and G17 at Gayton, Pentney and Bilney, respectively) form thin chalky limestones (the 'Pentney Limestone' and 'Bilney Limestone' of Seeley, 1861), before passing laterally into the Hunstanton Formation (see Figure 19).

There is a lack of modern, detailed data in the Bedfordshire, Hertfordshire, Buckinghamshire and Berkshire area.

In the Weald (see Figure 23), the Gault thins onto the London Platform. At Copt Point, near Folkestone (Figure 18), the formation is 40.4 m thick; in Dover Harbour, the Channel Tunnel Borehole P000 [TR 3342 4137] penetrated 38.4 m of Gault; at Horton Hall clay pit (Figures 24 and 25), the Lower Gault reaches about 43 m thick (Owen, 1971); and in the Glyndebourne Borehole [TQ 442 114], near Ringmer, Sussex, the formation reaches a thickness of 104.35 m. However at Margate, the formation is only 17.4 m thick (Shephard-Thorn, 1988). Construction of the M25, M23 and M26 motorways provided temporary exposures for the Kent and Surrey areas and showed the relationship between the Gault and Upper Greensand (Owen, 1992, 1996a,b).

Farther west, the British Gas Wytch Farm boreholes and British Petroleum Shapwick No. 1 Borehole, near Bournemouth and Poole, proved 20 to 35 m of Gault across the area (Bristow, Freshney and Penn, 1991). There is little information regarding the Gault in Dorset, but the

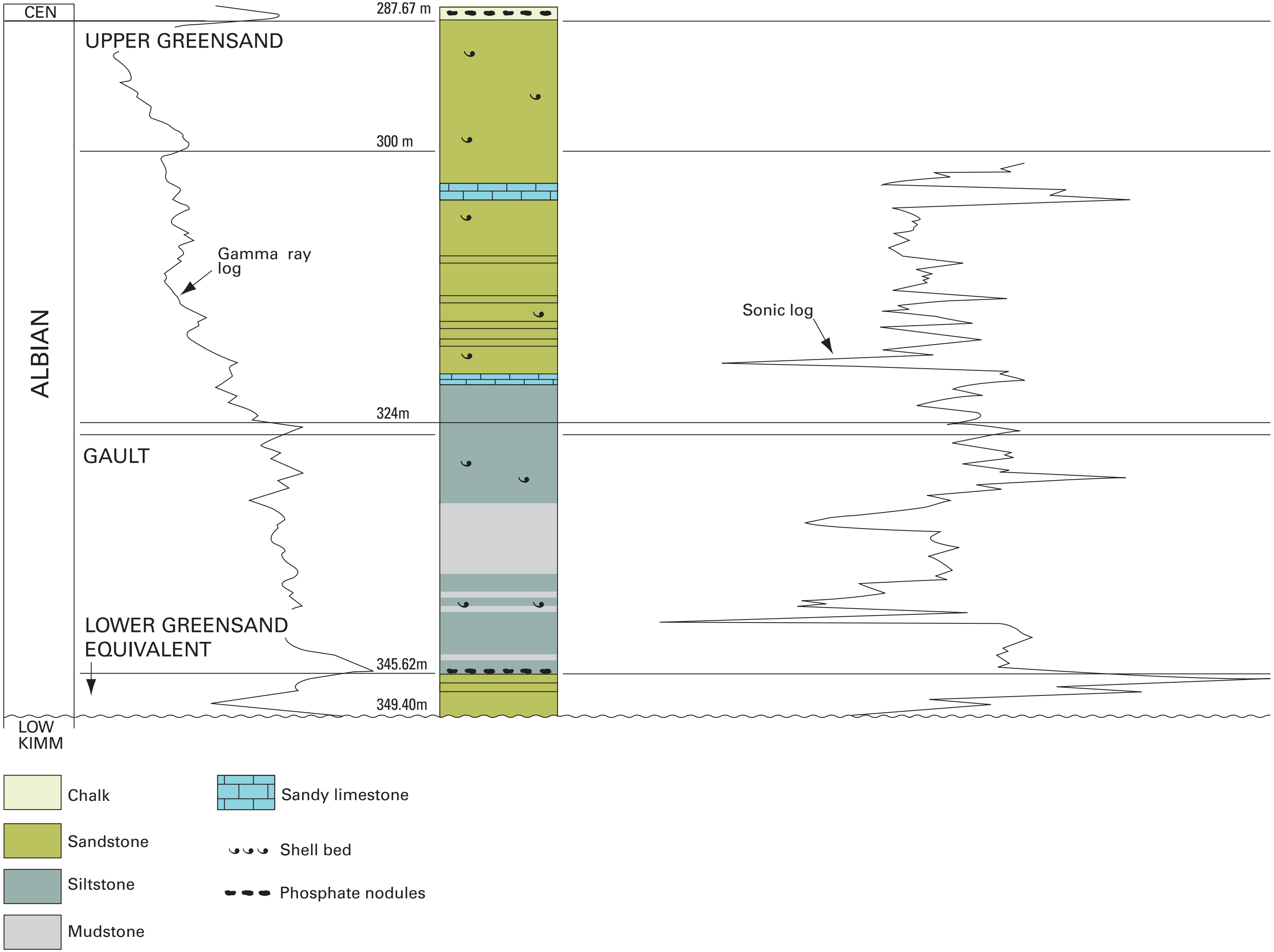
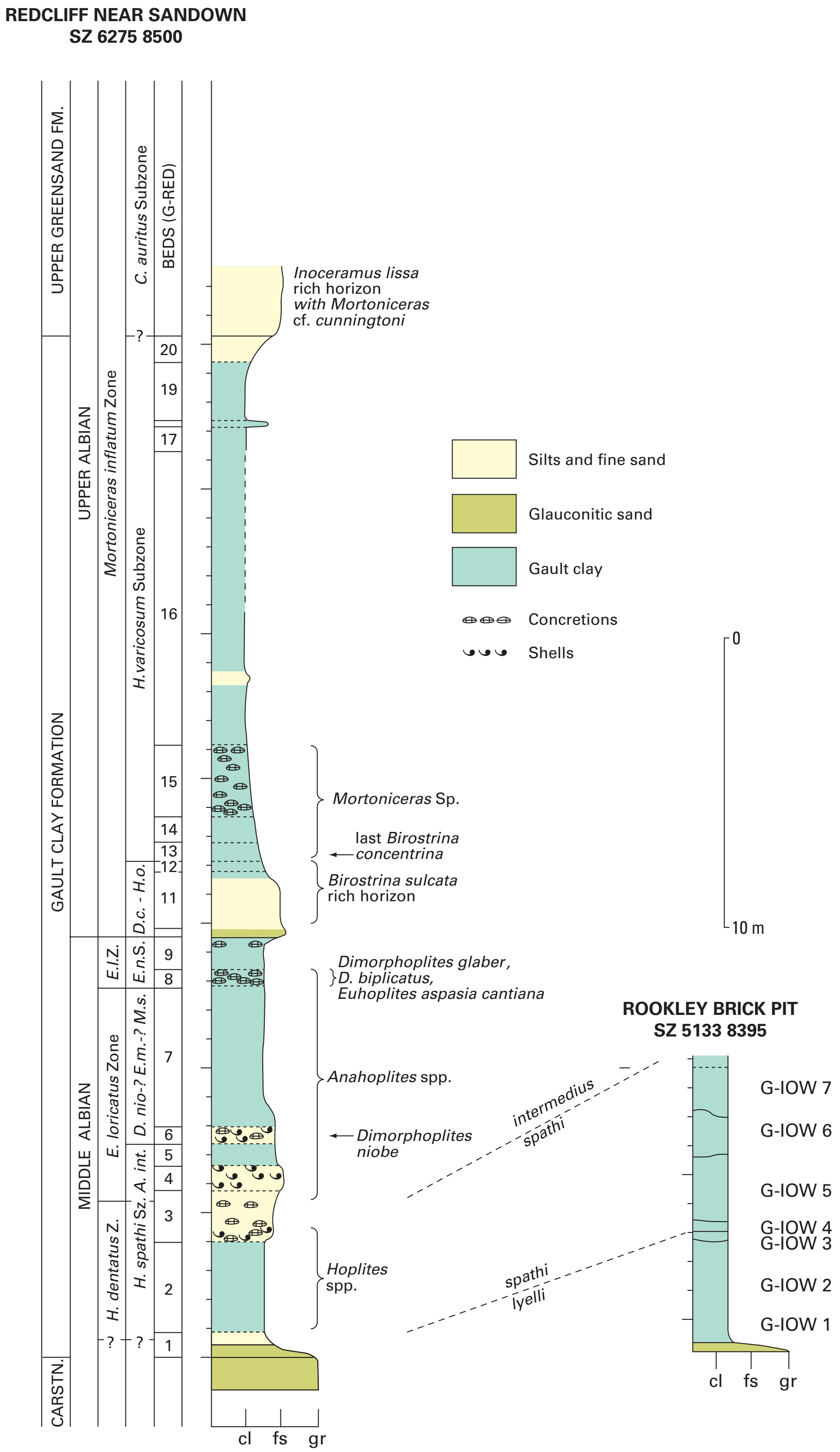


Figure 26 Geophysical logs of the Winterbourne Kingston Borehole (after Rhys, Calver and Lott, 1982).

Figure 27 The Gault Formation at Redcliff, near Sandown, and Rookley Brick Pit, Isle of Wight (after Casey, 1961; Owen, 1971, 1988; Gale et al., 1996) (D. *nio* - *D. niobe* Subzone; *E. m.* - *E. meandrinus* Subzone; *M. s.* - *M.subdelarvei* Subzone; *E. n. S.* - *E. nitidus* Subzone; *D. c.* - *D. cristatum* Subzone; *H. o.* - *H. orbignyi* Subzone; *E.l. Z.* - *E.lautus* Zone).



Winterborne Kingston Borehole [SY 8470 9796] (Figure 26) proved 21.62 m (between the depths 324.00 and 345.62 m) of argillaceous sandstone, silts and sandy mudstones. The base of the Gault here is unclear as it apparently passes down into the Lower Greensand via 'basement beds' of Early Albian age (Morter, 1982). The Gault is poorly exposed on the Isle of Wight, although Owen (1971) described the incomplete and slipped exposures including those at Compton Bay and Blackgang. The succession best described on the island is that at Redcliff (Figures 27 and 28), east of Sandown [SZ 6275 8500] where 34.9 m of Gault lies between the Carstone and Upper Greensand (Gale et al., 1996).

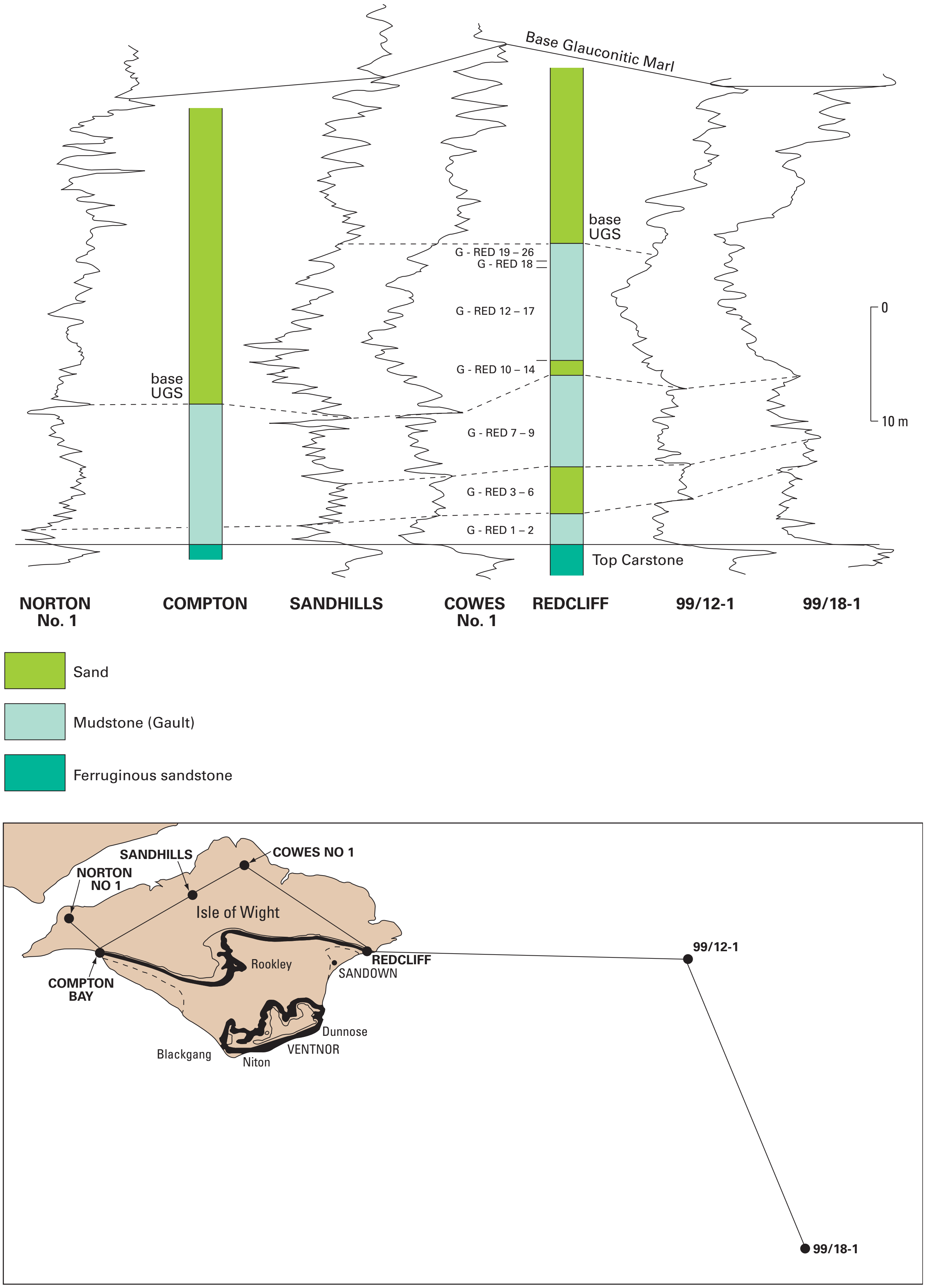
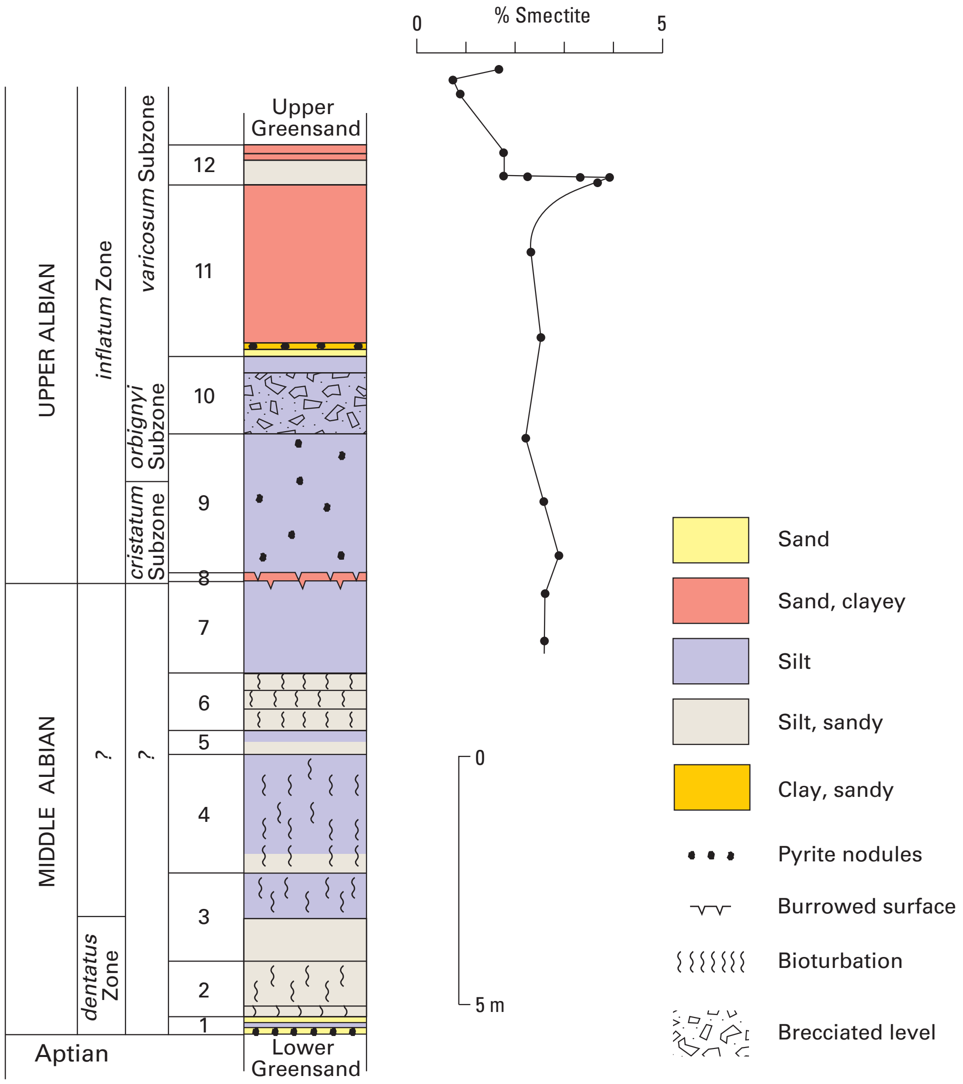


Figure 28 Correlation of the Gault and Upper Greensand (UGS) formations in the Isle of Wight and English Channel by means of density (DT) logs (after Gale et al., 1996).

Figure 29 The Gault of Church Farm Borehole, Shaftesbury (after Bristow et al., 1995).



The Gault in the area around Shaftesbury in part comprises a sandstone, the 'Fontmell Magna Sand' (Bristow and Owen, 1991). In this region the Gault is predominantly silt and silty sand and varies in thickness from 23 m at Fontmell Magna, 17 m in the Church Farm Borehole [ST 8555 2223] (Figure 29) and about 15 m between Stoke Wake and Okeford Fitzpaine, thinning to 12–14 m between Lyon's Gate and Buckland Newton (Bristow et al., 1995). Some 4.5 to 15.0 m of Gault is present between Winsham and Abbotsbury, although it is rarely exposed. The section best known is that at Golden Cap [SY 406 922], between Charmouth and Bridport, where 15.05 m have been recorded (Lang, 1914; Wilson et al., 1958).

Chronostratigraphical position

The Mid to Late Albian standard ammonite zones, from the *dentatus* Zone (*lyelli* Subzone) to the *dispar* Zone (*perinflatum* Subzone), are found in the Gault of southern and eastern England. Where Upper Greensand overlies the Gault (e.g. at Redcliff, Isle of Wight, Figure 27), the top of the latter is of *varicosum* Subzone age (Gale et al., 1996). The *Neohibolites*-based belemnite zones can also be recognised, together with the foraminifera zones 3i to 6a of Carter and Hart (1977), Hart (1973, 1993) and 3i to 9 of Price (1977), and the ostracod zones of Wilkinson and Morter (1981) and Wilkinson (1988, 1990). Other zonations based on calcareous nannofossils (Jeremiah, 1996) and dinoflagellate cysts (Costa and Davey, 1992; Riding et al., 1993) can also be used in the Gault.

Selected references

Bristow, 1990; Bristow, Freshney and Penn, 1991; Bristow and Owen, 1991; Bristow et al., 1995; De Rance, 1868, 1875; Gale, Huggett and Gill, 1996; Gallois and Morter, 1982; Hailstone, 1816; Jukes Browne and Hill, 1900; Lang, 1914; Morter, 1982; Owen, 1958, 1960, 1971, 1976, 1992, 1996a, b; Perrin, 1971; Price, 1874, 1876; Seeley, 1861; Shephard-Thorn, 1988; Spath, 1923–1943; Wilson et al., 1958.

2.2.6.1 'Junction Beds' Member

Derivation of name

An informal name refering to the beds between the Woburn Sands (Lower Greensand Group, Aptian) and Gault in the Leighton Buzzard area (Figure 31) and incorporating the Shenley Limestone (see Casey, 1961a; Owen, 1972; Shephard Thorne et al., 1994; Smart, 1997). Owen (1992) used this term in a different sense in southern England, to include the 'Lower Greensand Junction Beds' at the top of the Folkestone Formation. Hopson et al. (in prep) addresses this unit further.

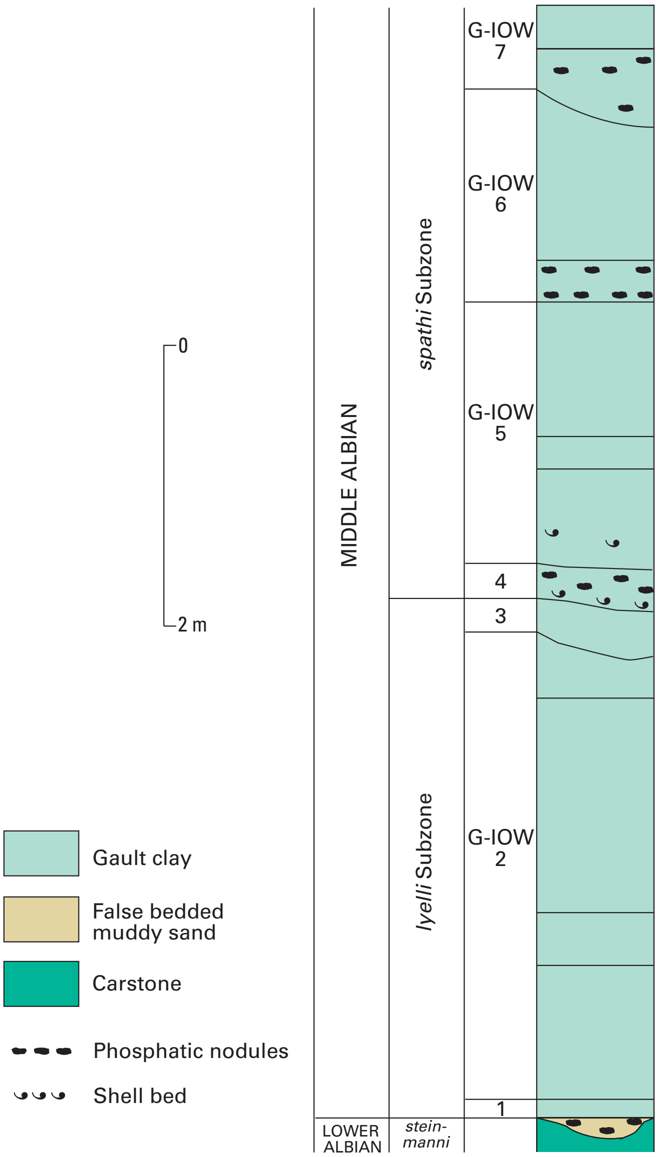


Figure 30 The Gault of Rookley Brick Pit, Isle of Wight (after Owen, 1971).

Lithological characteristics

Overlying silty beds at the top of the Woburn Sands is a gritty ironstone ('carstone'), which passes up into a sandy mudstone, associated with lenticular beds of a pale brown phosphatic limestone with scattered polished goethite ooliths (Shenley Limestone) (Owen 1972; Smart, 1997).

The 'Junction Beds Member' locally comprises a basal conglomeratic bed of hard, gritty ironstone ('carstone'), siderite nodules ('boxstone'), rare Shenley Limestone pebbles together with quartz and quartzite pebbles in a gritty matrix. This is overlain by brown, sandy, gritty fossiliferous mudstone and silty sands with glauconite and bands of phosphatic nodules.

Lenticles of Shenley Limestone have been recorded at the base of similar silty sands at Southcott Mill [SP 9045 2453] and Littleworth [SP 881 233] (Lamplugh, 1922; Owen, 1971) (both Figure 32) as well as Bryants Lane Quarry [SP 929 286], Reach Lane Quarry [SP 933 284] and Munday's Hill [SP 937 282] (Figure 32) (Shephard-Thorn et al., 1994, Hancock, 1958; Casey, 1961a). Chamberlain Barn Pit [SP 930 265] (Figure 32) and Billington Crossing are similar in that the conglomerate and 'carstone' is present, but this passes up into sandy mudstones, with four horizons of phosphatic nodules, and the Shenley Limestone is missing (Hancock, 1958, Casey, 1961a).

Locality details

Eastern England (Bedfordshire–Norfolk)
- Arlesey Borehole (Section 6.6.9, Figures 21 and 22
- Clare Borehole ((Section 6.6.4)
- Ely-Ouse Borehole No. 2 (Mildenhall Borehole No. 2) (Section 6.6.6, Figure 17)
- Ely-Ouse Borehole No. 11 (Mildenhall Borehole No. 11) (Section 6.6.7, Figure 17)
- Ely-Ouse Borehole No. 14 (Mildenhall Borehole No. 14) (Section 6.6.8)
- Four Ashes Borehole (Section 6.6.5)
- Gayton Borehole (Section 6.6.2, Figure 17)
- Marham Borehole (Section 6.6.3, Figure 17)
- Mundford 'C' Borehole (Section 6.6.1, Figure 17)

Southern England (Dorset–Kent)
- Church Farm Borehole No. 2 (Section 6.7.4, Figure 29)
- Copt Point, Folkestone (Section 6.7.1, Figure 18)
- Glyndebourne Borehole (Section 6.7.2)
- Horton Hall clay pit, Upper Beeding, Sussex (Section 6.7.8, Figures 24 and 25)
- Redcfiff, east of Sandown, Isle of Wight (Section 6.7.7, Figures 27 and 28)
- Rockshaw Interchange, Merstham (Section 6.7.3)
- Rookley Brick Pit, Isle of Wight (Section 6.7.6, Figure 30)
- Winterborne Kingston Borehole (Section 6.7.5, Figure 26)

Stratigraphical relationships

The controversy between Lamplugh and Kitchin and Pringle regarding the stratigraphical position of the Shenley Limestone, was resolved by Lamplugh (1922) and confirmed by Spath (1925) who recovered *Leymeriella* in the limestone and Mid Albian ammonites in the overlying Gault.

The lower boundary of the Junction Beds is an erosion surface, possibly caused by the mid-*tardefurcata* Zone regression (only the highest subzone of this zone is proved, see below). It separates the 'Carstone' (and 'Carstone conglomerate') and Shenley Limestone from the underlying Woburn Sands.

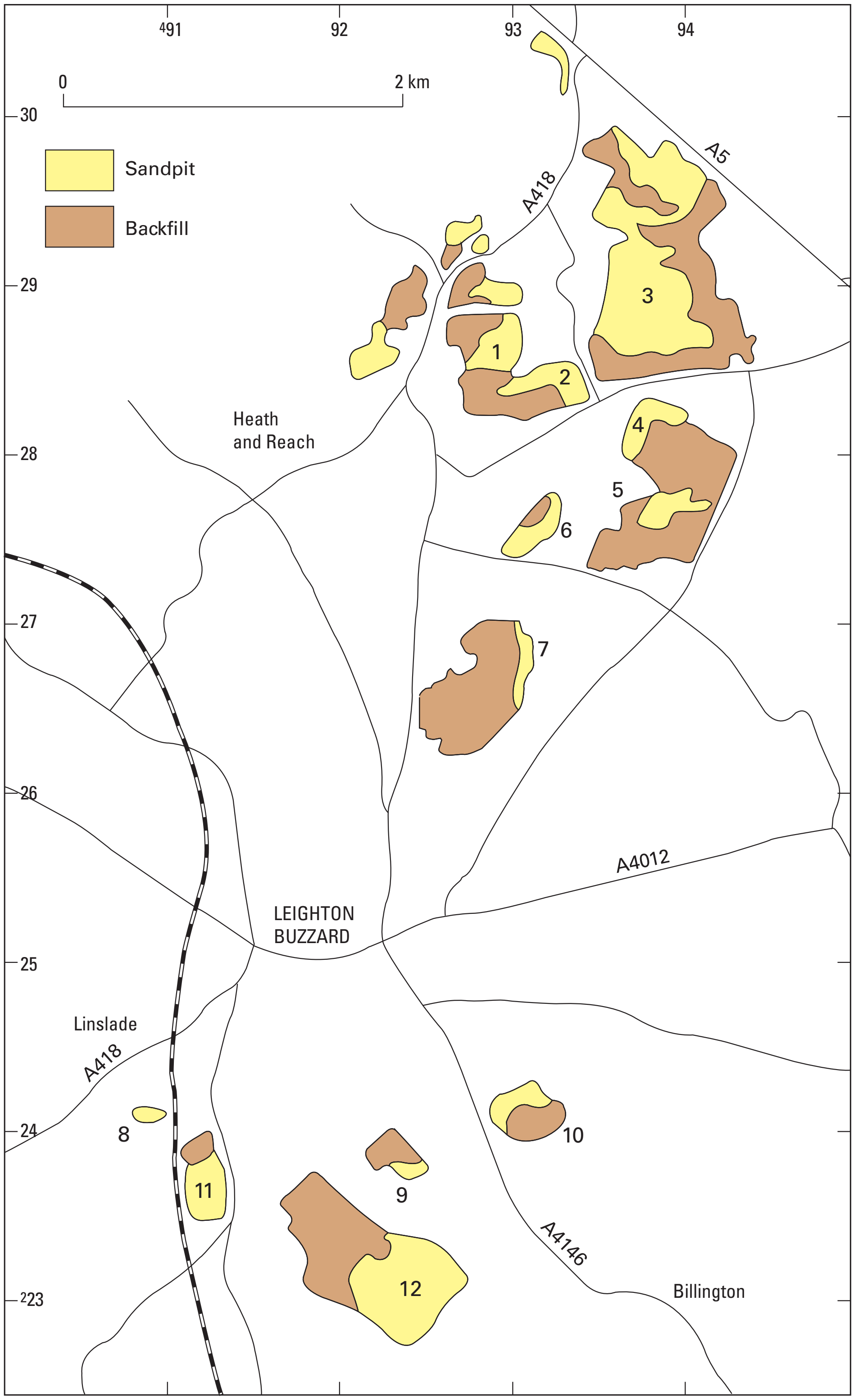
The highest part of the Lower Albian is represented in the highest phosphatic nodule horizon (Band IV of Casey, 1961a) at Billington Crossing (Figure 32), where the *Pseudosonneratia* (*Isohoplites*) *steinmanni* Subzone can be recognised. The Gault rests on the Junction Beds and in some areas its basal bed comprises red fissile mudstone, up to 1.2 m thick, which has been termed 'Red Clay' or 'Cirripede Bed' (Toombs, 1935).

Regional variation

The Junction Beds Member is restricted geographically. There is evidence of variations in thickness of the Junction Beds even over small distances, for example, in the southern part of Chamberlains Barn Pit (Figure 32), beds JB-CB1 to 3 increase from 1.15 m to 2.20 m and beds JB-CB4 and 5 increase from 0.42 to 0.80 m (Smart, 1997).

The Shenley Limestone is not found throughout the Leighton Buzzard area, being confined to lenses in some quarries only. The 'carstone' is more widespread in the Leighton Buzzard area.

Figure 31 Locality map of the Leighton Buzzard area showing the localities from which the Junction Beds and Gault have been described (after Shephard-Thorn et al., 1994).



1 Bryants Lane Pit
2 Reach Lane Pit
3 Double Arches Pit
4 Mundays Hill Pit
5 Nine Acres Pit
6 New Trees Pit
7 Chamberlains Barn Pit
8 Ascott Farm Pit
9 Brickyard Pit
10 Pratts Pit (Billington Crossing)
11 Tiddenfoot New Pit
12 Grovebury Pit

Chronostratigraphical position

Early Albian: *Leymeriella regularis* Zone, and *Douvilleiceras mammillatum* Superzone, *Sonneratia chalensis* Zone (including elements of the *Sonneratia kitchini* and *Cleoniceras* (*Cleoniceras*) *floridum* subzones) and the *Otohoplites auritiformis* Zone (including elements from the *Otohoplites raulinianus*, *Otohoplites bulliensis* and the *Pseudosonneratia* (*Isohoplites*) *steinmanni* subzones), have been proved (Casey, 1961a; Owen, 1972, 1988, 1992; Smart 1997). The highest part of the Junction Beds has yieded *lyelli* subzonal markers (Smart, 1997).

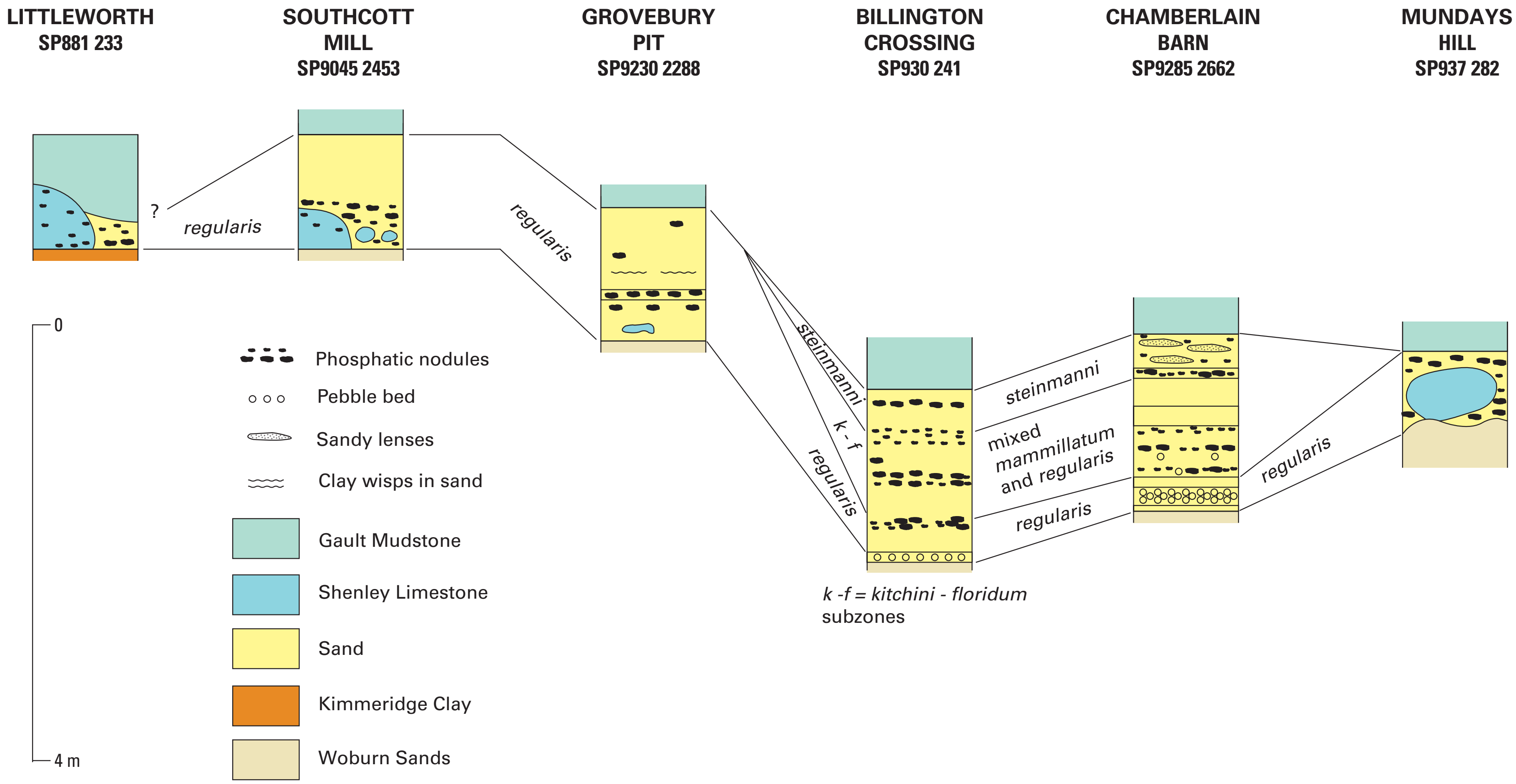


Figure 32 'Junction Beds' around Leighton Buzzard (after Owen, 1972; Shephard-Thorn et al., 1994).

Selected references

Casey, 1961a; Hancock, 1958; Lamplugh, 1922; Owen, 1971, 1972, 1988, 1992; Shephard-Thorn et al., 1994; Smart, 1997; Spath, 1925; Toombs, 1935.

Locality details

Bryants Lane Quarry (Section 6.8.1, Figure 31)
Reach Lane Quarry (Section 6.8.2, Figure 31)
Munday's Hill (Section 6.8.3, Figures 31 and 32)
Chamberlain Barn (Section 6.8.4, Figures 31 and 32)
Billington Crossing Pit (or Pratt's Pit) (Section 6.8.5, Figures 31 and 32)
Grovebury Pit (Section 6.8.6, Figures 31 and 32)

2.2.6.2 Fontmell Magna Sand Member

Derivation of name

Coined by Bristow and Owen (1991) after the type locality near Shaftesbury.

Lithological characteristics

Fine grained, clayey, micaceous, sand and sandstone.

Stratigraphical relationships

A lens of sand in the Upper Gault. See under Gault Formation for further details.

Regional variation

Known from a temporary exposure at Fontmell Magna [ST 8670 1708], along Fontmell Brook and Collyer's Brook (Bristow and Owen, 1991).

Chronostratigraphical position

The macrofauna includes *Actinoceramus sulcata*, *Birostrata sulcata/concentrica* transition, *Hysteroceras binum*, *Entolium orbiculare*, *Limnaria gaultina*, as well as other bivalves. This is indicative of the Late Albian *inflatum* Zone and the late *orbignyi* or early *varicosum* subzones.

Selected references

Bristow and Owen (1991); Bristow et al. (1995).

2.2.7 Hunstanton Formation

Derivation of name

This unit has been referred to as the Red Chalk, Hunstanton Limestone and the Red Rock. Although it is red stained in many areas, e.g. in the stratotype area of Hunstanton and in the sequence at South Ferriby, the red coloration has been removed by sulphidisation at several localities in Lincolnshire, where the deposit is white, yellow and pink as well as red (Jeans, 1973, 1980; Wood and Smith, 1978). Red marls interbedded with white or cream limestones are also present in Lincolnshire where secondary red staining has been recorded. Coloration is therefore not a useful criterion for defining this unit along its entire outcrop or appropriate in terms of nomenclature. The term Hunstanton Chalk was coined by Wood and Smith (1978) but the unit is now considered to be of formational rather than member status. This is because it can be easily mapped and even when the coloration is missing, the marls and marly limestone can be distinguished from the overlying Cenomanian Lower Chalk. The consensus at a meeting held to discuss chalk stratigraphy at BGS Keyworth in 1999 was that the unit is not part of the newly defined Chalk Group as it is older than the major hiatus at the base of the Cenomanian. This position is formalised in Hopson, 2005.

Lithological characteristics

The formation comprises a sequence of nodular and porcellaneous chalky limestones and calcareous marls, which are sandy in parts, particularly towards the base where it overlies the Carstone. Belemnites are common throughout and *Inoceramus* and *Birostrina* are common to abundant at some horizons. The lithostratigraphy, sedimentology and chemistry have been described in detail by Wood and Smith (1978), Jeans (1973, 1980), Owen, (1995) and Mitchell (1995). It has been subdivided into two, three, five and eleven units by different authors (e.g. Wiltshire, 1869; Jeans, 1973, 1980; Morter, 1980; Andrews, 1983, Morter in Gaunt, Fletcher and Wood, 1992; Gallois 1994; Owen, 1995). Jeans (1980, fig.3) divided the Hunstanton Formation of Norfolk and Lincolnshire into two members, the higher Brinkhill Member and lower Goulceby Member, although he did not describe them in detail. Mitchell (1995) divided the Hunstanton Formation of Yorkshire into five members, namely the Queen Rocks (4.95 m thick), Speeton Beck (3.86 m), Dulcey Dock (6.7 m), Weather Castle (2.81 m) and the Red Cliff Hole (5.61 m) members (see Figure 33). The last is Cenomanian in age and not considered further.

Stratigraphical relationships

In Lincolnshire and Norfolk, the lower boundary is gradational with the Carstone or else rests unconformably on Palaeozoic strata (Jeans, 1973, 1980). The upper boundary is defined by an erosion surface, separating the Hunstanton Formation from a 0.025 m bed of iron-stained, silty marl, sometimes with stromatolites, which forms the basal part of the overlying Cenomanian Paradoxica Bed (Jeans, 1973, 1980; Gaunt et al., 1992; Wood and Schmidt, in prep).

The Hunstanton Formation passes laterally into the Gault in the neighbourhood of Dersingham, the red pigmentation can be seen in some parts of the latter facies (Gallois and Morter, 1982).

The Albian/Cenomanian stage boundary is placed within the uppermost part of the Weather Castle Member (within Bed WC7), on the basis of the $\delta^{13}C$ signature. As the Yorkshire sequence is considerably expanded compared to that of Lincolnshire and Norfolk, it is difficult to relate these members to the sequence further south. However, Table 2 is a suggested correlation, modified from Mitchell (1995) and including Hunstanton sequence sensu Owen (1995).

Regional variation

The Hunstanton Chalk extends from Dersingham, in the south (where it passes laterally into the Gault) through Lincolnshire and into south Yorkshire. It thins onto the Market Weighton Block, but is also found to the north of that structure in the Speeton–West Heslerton area. It is red

Table 2 Correlation of the Hunstanton Formation at Speeton, South Ferriby and Hunstanton with the Gault of East Anglian.

Zone/Subzone	Speeton	South Ferriby	Hunstanton	East Anglia (Gault)
dispar	WCM			
	upper DDM	SF11	Av-vi	G17-18 (19)
inflatum/auritus	lower DDM	SF8-10	Aiii-iv	G15-16
inflatum/varicosum	upper SBM	SF6-7	Ai-ii	G14
inflatum/orbignyi	lower SBM	SF4-5	Biv (pars)	G11 (pars)-13
	upper QRM			
inflatum/cristatum		SF3	Biii-Biv (pars)	G11 (pars)
lautus				G9-10
loricatus/niobe–loricatus/meandrinus				G6-8
loricatus/intermedius	lower QRM	SF2 (pars)	Bi-ii	G3 (pars)-5
dentatus/spathi		upper SF1–SF2 (pars)	C and highest Carstone?	G2-G3 (pars)
dentatus/lyelli	uppermost Speeton Clay	SF1 (pars)	Carstone?	G1

QRM = Queen Rocks Mb. SB = Speeton Beck Mb. DDM = Dulcey Dock Mb. WCM = Weather Castle Mb.

stained in many areas, e.g. in the stratotype area of Hunstanton [TF 6725 4130 to 6786 4238] and in the sequence at South Ferriby [SE 9915 2045] (Figure 34). However, in several localities in Lincolnshire (e.g. Elsham Interchange and Bigby Quarry), the red coloration is lost and the deposit is white, yellow or pink (Figure 34).

At South Ferriby, eleven beds have been recognised, based on a combination of lithology and the faunal content (Morter in Gaunt et al., 1992). This subdivision can be recognised throughout much of Lincolnshire and into northern Norfolk, although lithostratigraphical variation causes some problems, particularly in the lower part of the unit. Colour changes may also cause confusion with the Cenomanian Chalk; some of the Albian 'Red Chalk' is white. The sequence has been measured at Elsham Interchange [TA 052 111] and Skegness Borehole [TF 5711 6398] (see Figure 34).

The Hunstanton Formation is remarkably consistent throughout much of eastern England, although there are variations, particularly when comparison is made with Yorkshire. At Hunstanton it is 1.25 m thick, whereas in the North Creake Borehole it is 1.8 m (Kent, 1947). It thins rapidly towards the Trunch Borehole where it is only 0.23 m thick. In much of Lincolnshire the thickness varies between about 2.0 m and 5.38 m, but the thickest succession is in central Lincolnshire, where Rawson, Curry, Dilley et al. (1978) recorded up to 7 m. Thicknesses between 15.8 m and 30.5 m given by Falcon and Kent (1960) bear no relation to observations seen in outcrop and boreholes, with the exception of the Yorkshire coast.

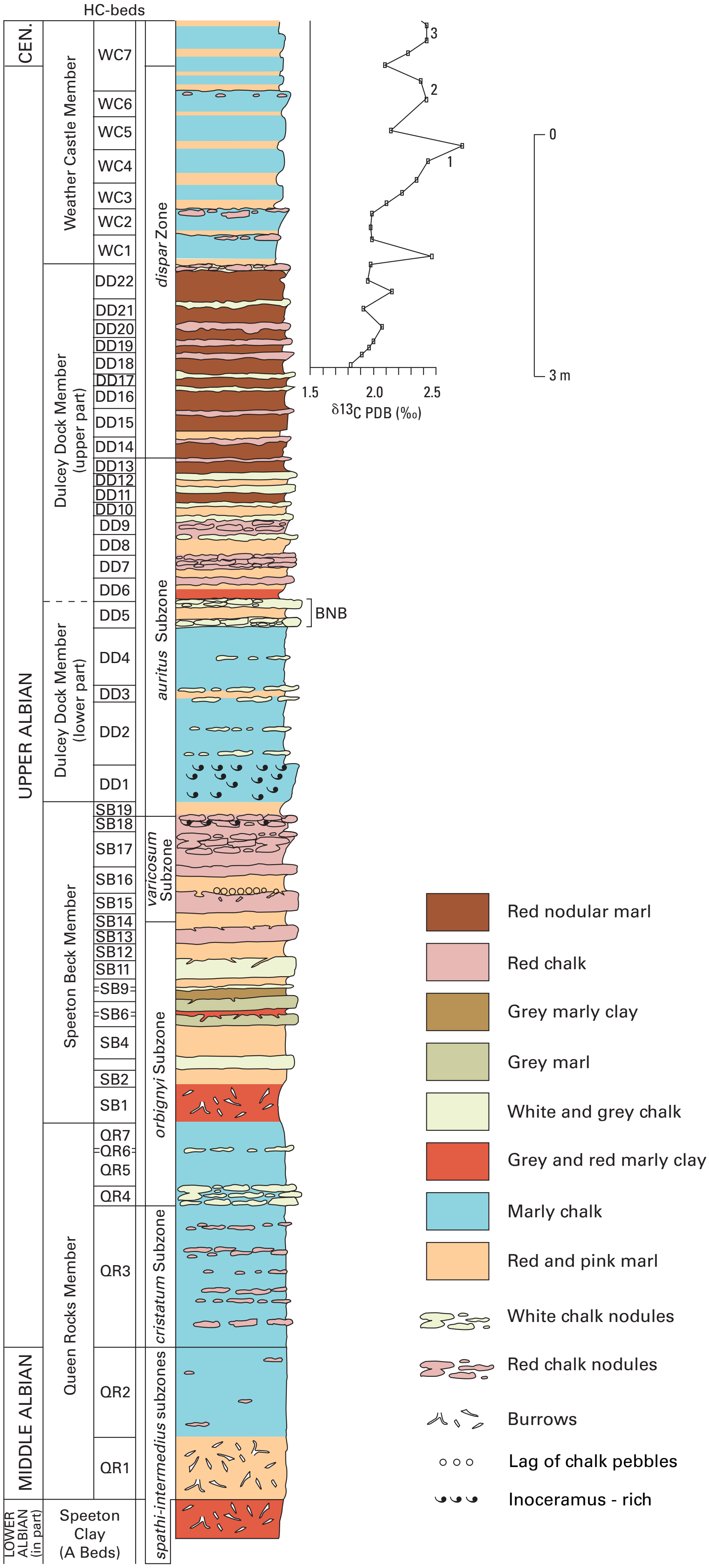
The two key sections south of the Market Weighton High are Hunstanton Cliff (beds HC-HC1-11) and South Ferriby (HC-SF1-11) (Figures 33 and 34).

Beds HC-HC1-8 and HC-SF1-8 fall within the Goulceby Member (sensu Jeans, 1980). These beds are essentially argillaceous, with detrital grains throughout. Bed HC-HC8 and HC-SF8 are characterised by abundant '*Inoceramus*' fragments, predominantly '*Inoceramus*' *lissa*, and *Biplicatoria ferruginea* (found in Beds HC-SF1-7) is replaced by *Biplicatoria hunstantonensis*. These biomarkers can be traced into the Gault facies of Britain and Germany. Other faunal characteristics are *Birostrina concentrica* in beds HC-HC1-2 and HC-SF1, 2 and basal 3; *B. sulcata* restricted to beds HC-HC3 (upper part) and HC-SF4 and 5; the absence of *Birostrina* in Bed HC-HC8. Bed HC-HC8 is coeval with Gault Bed G15 and Bed HC-HC7 correlates with the belemnite bioevent in Gault Bed G14 (Gallois, 1994). The boundary between the upper and lower members is a phosphatised hardground and represents an important non-sequence.

The Brinkhill Member (sensu Jeans, 1980) comprises beds HC-HC9-11, which have less detrital material and are predominantly calcareous. The highest known specimen of *Biplicatoria* in Bed HC-SF9 may represent the Milton Brachiopod Band at the base of Gault Bed G16. The inception of smooth shelled *Aucellina* is within the basal part of Bed HC-HC5b and HC-SF10 (and can be correlated with the *Aucellina*-rich Gault Bed G17 of eastern England and Bed XII of Folkestone) (Gallois, 1994).

The formation thins onto the Market Weighton Block in Yorkshire; it is about 0.50 to 0.96 m thick in the Melton, Goodmanham, Millington, Wharram Grange, Grimston Hill area (Dakyns and Fox-Strangeways, 1886; Kaye, 1964b; Jeans, 1973; Whitham, 1991). However, in the Speeton–West Hesleton area of Yorkshire, the formation is greatly expanded. The only sections to have been studied in detail are those where the formation is exposed on the Yorkshire coast at Filey Bay (Ennis, 1932; Wright and Wright, 1955; Kaye, 1962; Neale, 1974; Mitchell, 1995), where the formation extends up into the basal Cenomanian and is considerably expanded (c.24 m thick). Mitchell (1995) subdivided the Hunstanton Formation into five members, of which four are Albian (Queen Rocks Member, Speeton Beck Member, Dulcey Dock Member and part of Weather Castle Member). He placed much emphasis on the carbon isotope signature in order to define the Albian/Cenomanian boundary, which falls within the upper part of the Weather Castle Member (see Figure 33).

Figure 33 The Hunstanton Formation at Speeton, Yorkshire (after Mitchell, 1995) - BNB - breccia nodule band of Jeans (1973, 1980).



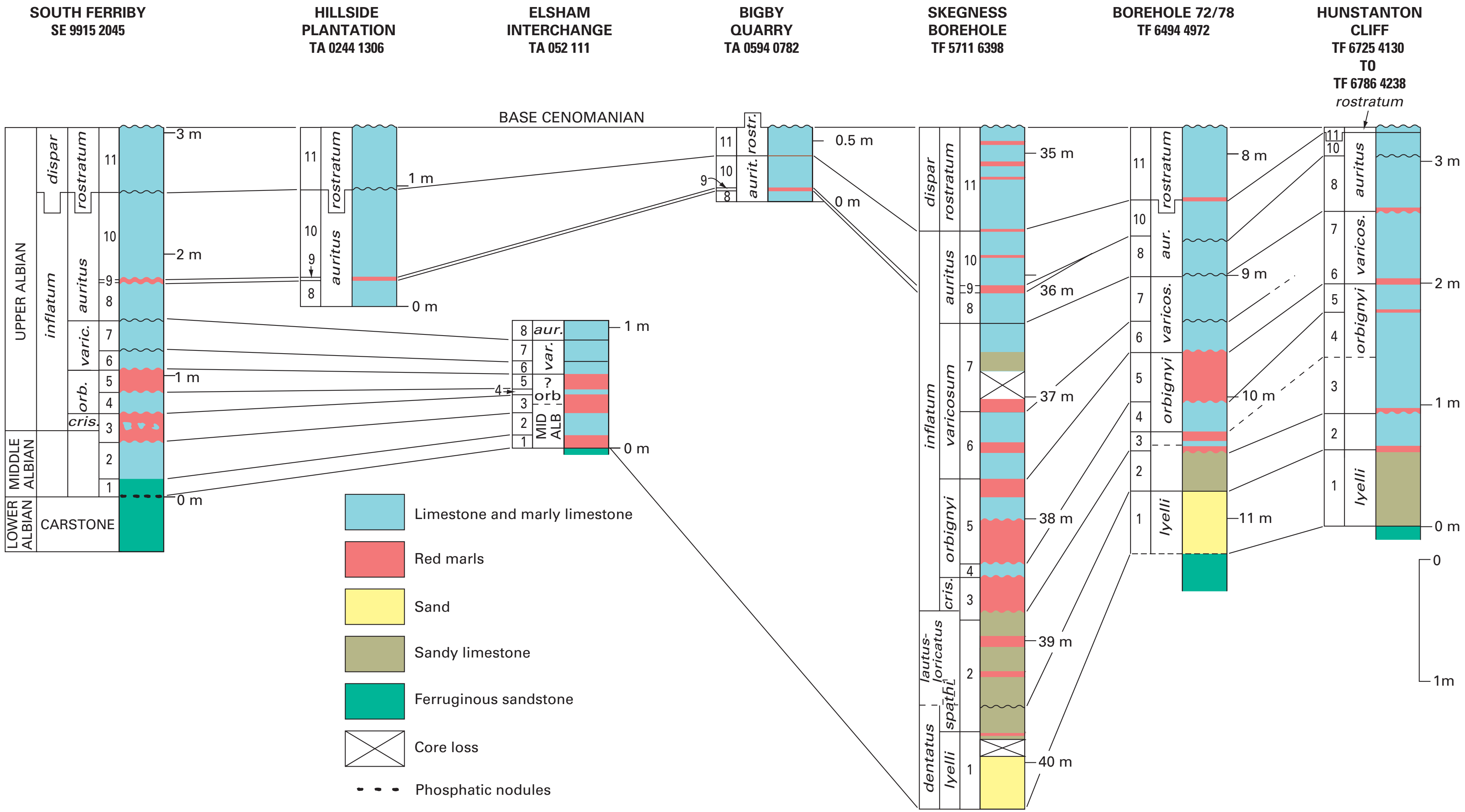


Figure 34 The Hunstanton Formation at seven localities in Norfolk and Lincolnshire. Scale shown to the right of each column. Bed numbers are all in the sense of South Ferriby (Gaunt et al., 1992) in order to indicate correlation (modified from Wilkinson, 1990).

The Hunstanton Formation extends offshore into the Southern North Sea Basin, but is given a different name. Originally called 'Red Chalk Formation' by Rhys (1974), it is now usually referred to as the Rødby Formation (see Johnson and Lott, 1993). A case can be made in favour of uniting the two under the name of Hunstanton Formation, but at the moment the status quo is maintained.

Chronostratigraphical position

Mid to Late Albian (*H. dentatus Zone*, *L. lyelli* Subzone, to *S. dispar* Zone, *M. rostratum* Subzone) in northern Norfolk and Lincolnshire. Many of the ostracod zones recognised in the Gault can also be recognised in the Hunstanton Formation (Wilkinson, 1990).

Selected references

Andrews, 1883; Clarke, 1964; Dakyns and Fox-Strangeways, 1886; Fitton, 1836; Gallois, 1973, 1975, 1984, 1994; Gaunt, Fletcher and Wood, 1992; Jackson, 1911; Jeans, 1973, 1980; Johnson and Lott, 1993; Mitchell, 1995; Jukes-Browne and Hill, 1900; Kaye, 1964b; Kitchin and Pringle, 1922, 1932; Larwood, 1961; Le Strange, 1975; Morter, 1980; Neale, 1974; Reed, 1897; Rose, 1835; Seeley, 1861, 1864a, 1864b, 1866; Taylor, 1823; Whitaker, 1883; Whitaker and Jukes-Browne, 1889; Wilkinson, 1988a, 1988b, 1990; Wiltshire,1859a, 1859b, 1869; Wood and Smith, 1980; Woodward, 1833; Wright and Wright, 1955.

Locality details

Yorkshire
- Red Cliff Hole, Filey Bay (Section 6.9.1, Figure 33)
- Weather Castle, Filey Bay (Section 6.9.2, Figure 33)
- Crab Rocks to Red Cliff Hole, Filey Bay (Section 6.9.3, Figure 33)
- Double Rocks to Red Cliff Hole, Filey Bay (Section 6.9.4, Figure 33)
- Foreshore near Crab Rocks, Filey Bay (Section 6.9.5, Figure 33)

Lincolnshire
- South Ferriby Quarry (Section 6.9.6, Figure 34)
- Elsham Interchange (Section 6.9.7, Figure 34)
- Skegness Borehole (Section 6.9.8, Figure 34)

North Norfolk
- Hunstanton Cliff (Section 6.9.9, Figure 34)

2.2.7.1 Queen Rocks Member

Derivation of name

The stratotype for the Queen Rocks Member is on the foreshore near Crab Rocks and was defined by Mitchell (1995).

Lithological characteristics

The member comprises red marly chalk with occasional bands of pale nodules, and is 4.95 m thick. Mitchell (1995) divided it into seven beds (see Figure 33).

Stratigraphical relationships

The Queen Rocks Member is divided into two parts by an erosion surface. The upper part is contemporaneous with HC3 and HC4 (to the south of the Market Weighton Block). The lower part of the member is approximately coeval with HC1 and HC2 and the *lyelli to intermedius* subzones. The member can be distinguished from the underlying 'A' Beds of the Speeton Clay Formation by its marly chalk lithology and bands of chalk nodules. The underlying 'A' Beds are clays with occasional 'potato stones'.

Regional variation

None described

Chronostratigraphical position

The upper part of the member can be placed into the *cristatum* and *orbignyi* subzones and the lower part in the *lyelli* to *intermedius* subzones.

Selected references

Mitchell, 1995

2.2.7.2 Speeton Beck Member

Derivation of name

After its stratotype at Speeton Beck (Mitchell, 1995).

Lithological characteristics

This member comprises rhythmic alternations of white to pink chalks and grey or red marls or clays and is divided into nineteen beds. The coloration of the argillaceous beds is paler in the lower part, but the reddening becomes darker up sequence. The chalks become harder up section and the clays become marly and nodular (see Figure 33).

Stratigraphical relationships

The Speeton Beck Member is distinguished from the underlying Queen Rocks Member by its strong rhythms of marl or marly clay and chalks. Beds HC5 and HC6 to the south of the Market Weighton Block are contemporaneous with the upper part of the member, the remainder having been removed by erosion.

Regional variation

None described

Chronostratigraphical position

The unit extends from the later part of the *orbignyi* Subzone through to the top of the *varicosum* Subzone.

Selected references

Mitchell, 1995

2.2.7.3 Dulcey Dock Member

Derivation of name

The stratotype section for this member is on the foreshore at Crab Rocks to Red Cliff Hole, to the east of Dulcey Docks, where the lowest bed forms a step on the beach (Mitchell, 1995).

Lithological characteristics

This member, defined by Mitchell (1995), can be divided into 22 beds. It comprises 6.7 m of red nodular chalk. The

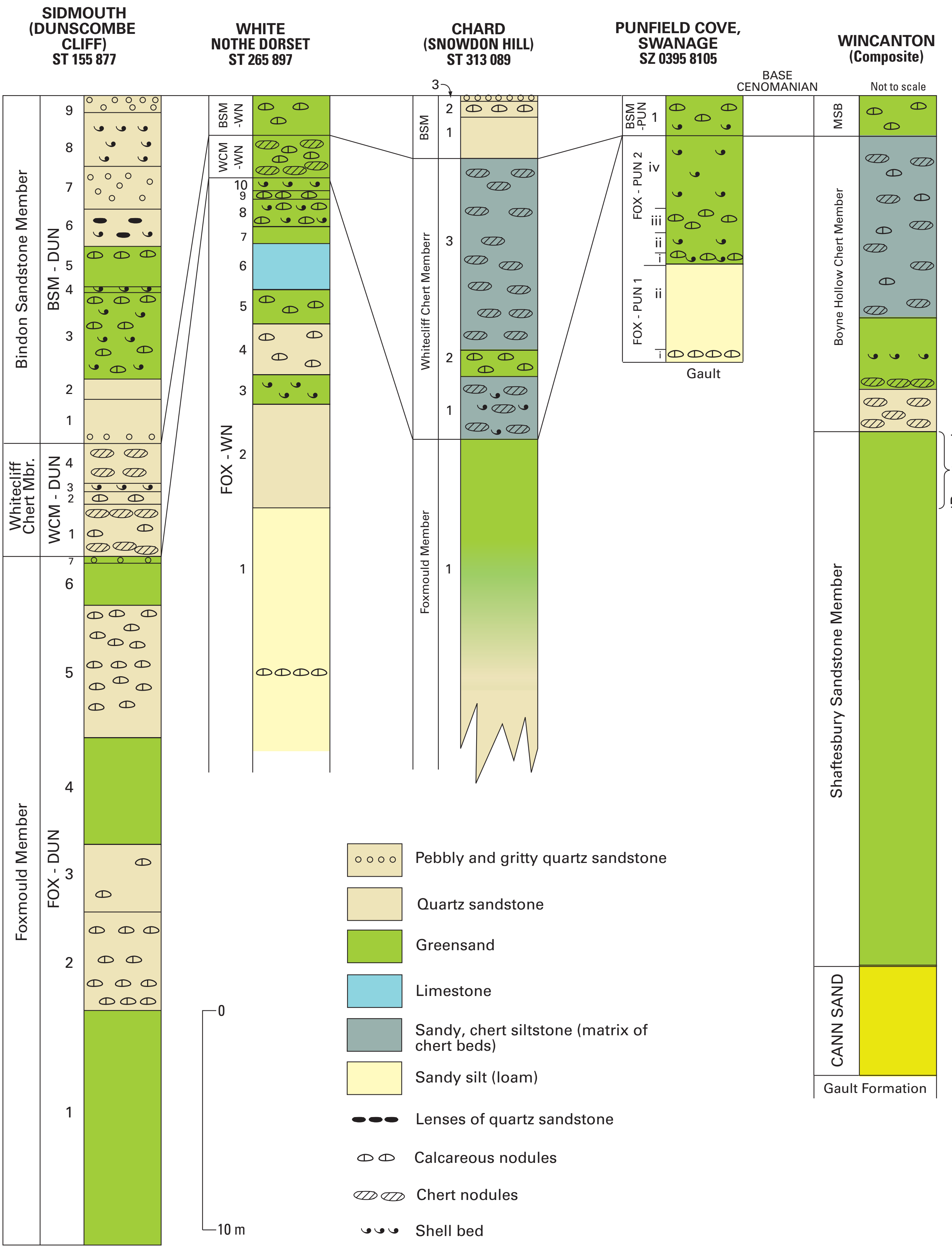


Figure 35 The Foxmould, Whitecliff Chert and Bindon Sandstone members of the Upper Greensand Formation of Devon, Dorset and Somerset.
(after Arkell, 1947; Tresise, 1960, 1961; Smith, 1961). (WCM - Whitecliffe Chert Member, BSM - Bindon Sandstone Member; MSB - Melbury Sandstone Member).

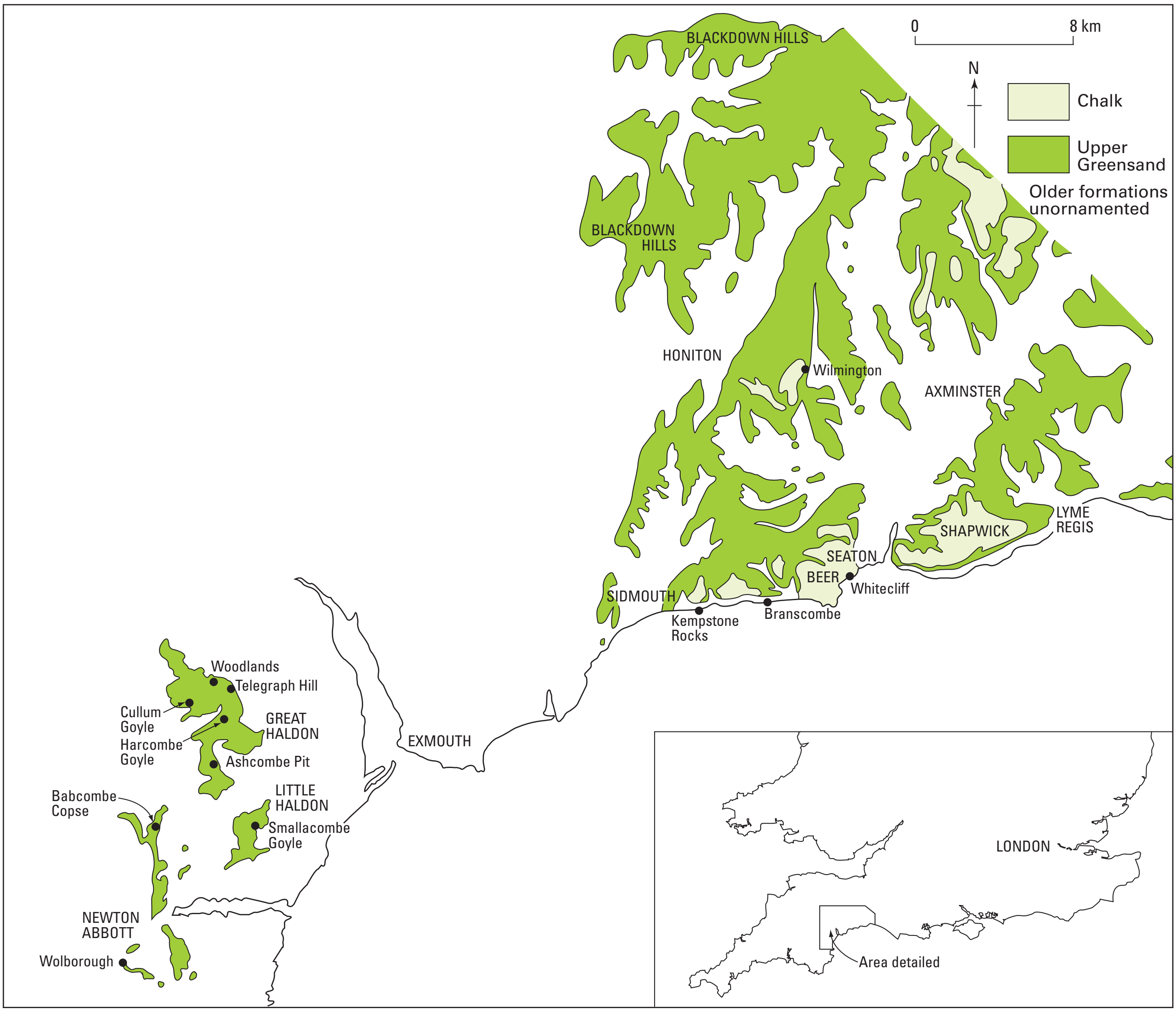


Figure 36 Distribution of the Upper Greensand Formation, eastern Devon and western Dorset (after Hamblin and Wood, 1976).

presence of an *Inoceramus lissa*-rich horizon in HC-DD1, the *Biplicatoria hunstantonensis*-rich horizon in HC-DD3, and the breccia nodule bed (sensu Jeans, 1973) in bed HC-DD5 are important marker horizons (see Figure 33).

Stratigraphical relationships

The Dulcey Dock Member is equivalent to beds HC7-HC11 of the area to the south of the Market Weighton Block. The member can be distinguished from the underlying Speeton Beck Member by its nodular nature.

Regional variation

None described

Chronostratigraphical position

The member is placed in the *auritus* and *rostratum* subzones.

Selected references

Mitchell, 1995

2.2.7.4 Weather Castle Member

Derivation of name

Defined by Mitchell (1995), the type locality for the member is the foreshore at Weather Castle, Yorkshire. It is the same unit as that described as ‘red uniform chalk’ by Phillips (1875) and ‘smooth red chalk containing belemnites’ by Hill (1888).

Lithological characteristics

Mitchell (1995) described this member as comprising 2.81 m of brick-red, marls and marly chalks, which is divided into six ill-defined rhythms of clayey marl passing up into marl (beds WC1–6) and a thicker red marl (Bed WC7) at the top which also exhibits three poorly defined rhythms. *Aucellina* occurs throughout (see Figure 33).

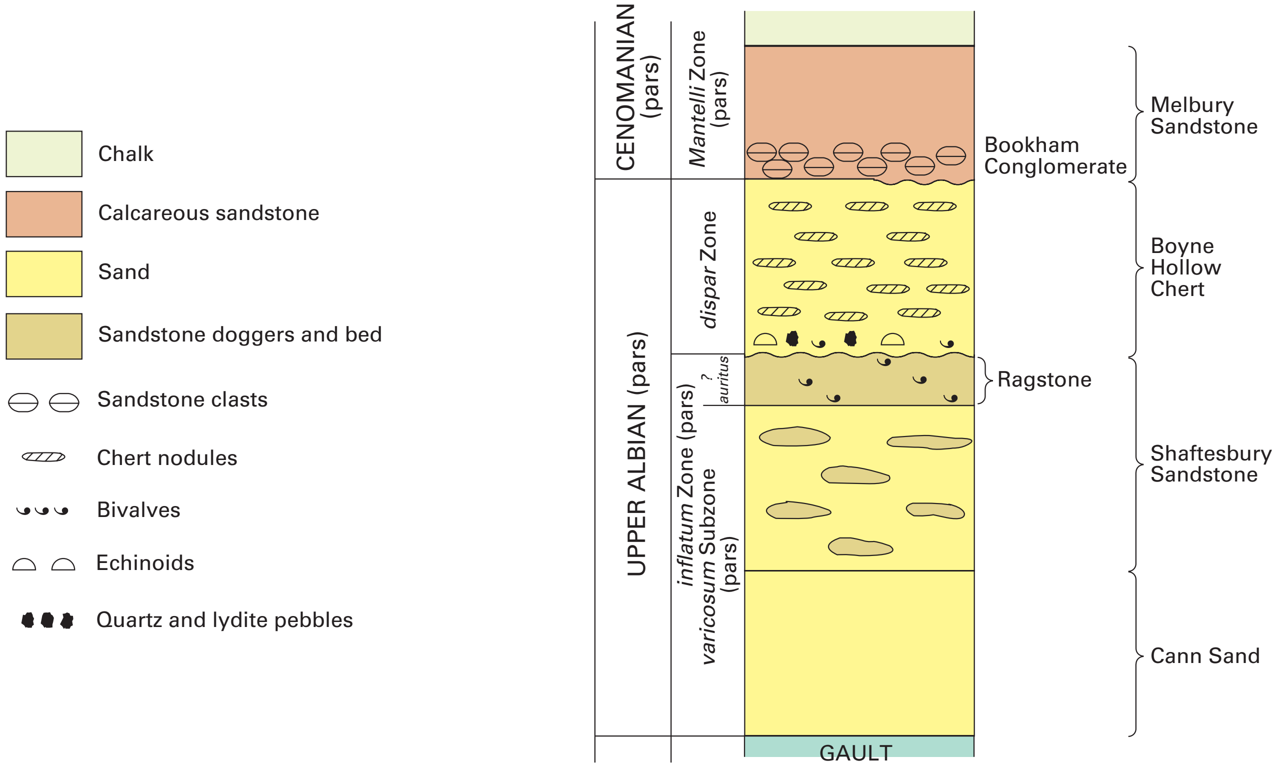


Figure 37 Overview of the Upper Greensand in Dorset (after Bristow et al., 1995.

Stratigraphical relationships

The Weather Castle Member can be separated from the underlying Dulcey Dock Member by its marly nature and absence of nodular chalks.

Regional variation

None described

Chronostratigraphical position

Bed HC-WC7 straddles the Albian/Cenomanian boundary (Mitchell, 1995) its base is in the upper part of the *rostratum* Subzone (Mitchell, 1995).

Selected references

Mitchell, 1995

2.2.7.5 Red Cliff Hole Member

Derivation of name

Defined by Mitchell (1995) from the type locality at Red Cliff Hole [TA1566 7502], on the Yorkshire Coast.

Lithological characteristics

It is composed of 5.6 m of dark red and grey, nodular chalks. *Aucellina* and brachiopods common throughout; belemnites near the base. It can be divided into five beds, which, in turn, can be further subdivided (Mitchell, 1995).

Stratigraphical relationships

The Red Cliff Hole Member is distinguished from the underlying Weather Castle Member by its markedly nodular lithology. Jeans (1973, 1980) considered the Red Cliff Hole/Weather Castle boundary to define the top of the 'Red Chalk'. This member, being Cenomanian, is not considered further herein.

Regional variation

None described

Chronostratigraphical position

carcitanense Subzone (Cenomanian)

Selected references

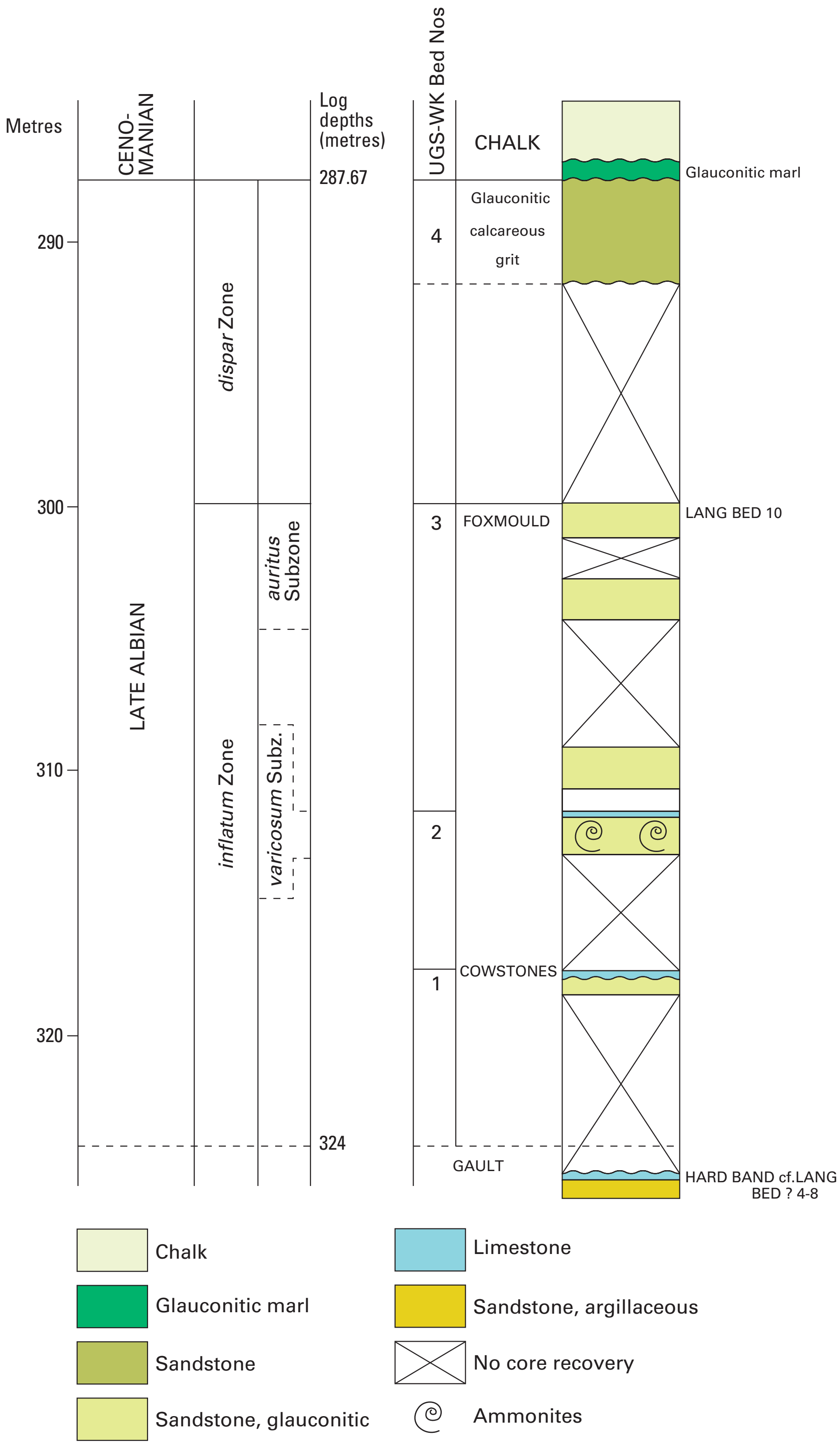
Mitchell, 1995

2.2.8 Upper Greensand Formation

Derivation of name

The term 'Greensand' was probably erected by Smith during the first decade of the 19th Century and used in the sense of the modern Upper Greensand, i.e. the sands between the Gault and Chalk in southern England. However, Phillips and Mantell confused the issue by using the same term for the sands below the Gault in about 1818–1822. Almost by accident (as Jukes-Browne and Hill, 1900, explain in detail), Webster (1824) was the first to refer to 'Lower Greensand' and 'Upper Greensand', although this terminology was not adopted universally, the Upper Greensand also being referred to as 'Firestone', 'Merstham Beds' and 'Malm' and the Lower Greensand as 'Shanklin Sand'. Despite the fact that the terms are not really appropriate, Murchison adopted 'Upper Greensand' and 'Lower Greensand', and the Geological Survey of Great Britain used these names

Figure 38 The Upper Greensand in the Winterbourne Kingston Borehole [SY 8470 9796] (after Morter, 1982).



through the 19th Century. 'Upper Greensand' is now well entrenched in the literature. In some areas, the Upper Greensand Formation has been subdivided into a number of units, including the Haldon Sands, Foxmould Sands, Top Sandstone, some of which are treated as members.

Lithological characteristics

Deposits of the Upper Greensand vary considerably from silty sands, pebbly sands and shelly sands to gravel. They are generally glauconitic and contain chert beds and chert nodules in places. Although undivided in some areas, the formation has been subdivided elsewhere into local units (such as Malmstone, Potterne Rock Bed, Eggardon Grit, Foxmould and Blackdown Sand). In some cases, members have been formally described and named. These are discussed separately.

In the area around Shaftesbury, Wincanton (Figure 35) and south of Frome, Bristow et al. (1995) divided the Upper Greensand into the Melbury Sandstone (Cenomanian), Boyne Hollow Chert (Albian), Shaftesbury Sandstone (Albian) and Cann Sand (Albian) members. These form a sequence of glauconitic sands and sandstones, with shell beds, sandstone doggers and chert beds at various horizons.

The Blackdown Sands at Blackdown [SX 094 072] and Yarcombe [SX 233 079] are non-calcareous, and comprise fine, glauconitic sands at the base, passing up into glauconitic, cherty and siliceous sandstone.

The Haldon Sands Formation in Devon (see Figure 36) has been subdivided into four members (Hamblin and Wood, 1976). The Cullum Sands Member is equivalent to part of the Cenomanian Limestones on the south-east Devon coast and is not considered further here; the Ashcombe Gravels Member is equivalent in part to the Chert Beds, 'Coarse Band' sensu Smith, 1961, and Top Sandstones on the south-east Devon coast; the Woodlands Sands Member is equivalent to part of the Chert Beds on the south-east Devon coast; and the Telegraph Hill Sands Member is equivalent to 'Foxmould Sands' on the south-east Devon coast.

In the Sidmouth area, the Upper Greensand is divided into the Foxmould, Whitecliff Chert and Bindon Sandstone members (Woods, 1999). They form a sequence of two glauconitic, fine sandstone units separated by cherty calcarenites.

Stratigraphical relationships

The Upper Greensand grades into the Gault. In Kent, the upper part of the Gault becomes siltier and more glauconitic in Bed XII and the base of Bed XIII, before returning to pale grey and fawn marly clay. However, a little further east, in Surrey, the 'Green Streak' of Bed XII is overlain by a sequence of siltstone and sandstone, coeval with Bed XIII of the Gault at Folkestone, Kent.

Regional variation

The Upper Greensand occurs from Bedfordshire and Buckinghamshire, where it is relatively thin, through to Dorset, Wiltshire, the Isle of Wight and eastern Devon, where it is appreciably thicker. The formation is extremely variable and for this reason has been given a large number of local names.

The Upper Greensand crops out as a narrow strip, forming a shelf along the Chiltern escarpment. There it comprises fine-grained sands and bioturbated siltstones. Its base is transitional with the underlying Gault, but commonly forms a spring line. In the Sundon Borehole, Bedfordshire [TL 0405 2724], the Upper Greensand comprises 3.41 m of calcareous, glauconitic siltstone, typical of the 0 to 6 m sequence indicated by, for example, Shephard-Thorn et al. (1994). Near Thame, thicknesses of 20 m and 16 m have been recorded at Watlington [SU 6845 9375] and Tetsworth [SP 698 005], respectively. In Buckinghamshire and Oxfordshire, the siliceous sands of the Upper Greensand have been referred to as Malmstone, whilst in Wiltshire the Devizes Sand and Potterne Rock Bed are recognised (Jukes-Browne and Hill, 1900; Drummond, 1970). Drummond (1970) showed that the Upper Greensand reaches a thickness of about 39 m in the Wessex Trough, but recent mapping has shown thicknesses of up to about 60 m near, for example, Shaftesbury (Bristow et al., 1995, see Figure 37); similar thicknesses are known near Wincanton.

The formation is not well exposed on the Isle of Wight, but Jukes-Browne and Hill (1900) estimated the minimum thickness to be about 30–35 m. At Redcliff and Rookley, Owen (1971) and Rawson et al. (1978) showed the Gault to extend up into the lower part of the Upper Albian, but most of the Upper Albian to be of Upper Greensand facies (of *dispar* and *inflatum* zone age). Drummond (1970) showed the 'Freestones' to reach a maximum thickness of 5.5 m near Gatcombe, but at Culver they are thin, condensed and have concentrations of phosphatic nodules. They are missing at Compton Bay. The 'Chert Beds' reach a maximum of about 6.5 m at Ventnor, thinning to 1.8 m at Compton Bay. The remainder of the Upper Greensand on the island is argillaceous greensand, cherty at the bottom and with limestone doggers at the top. Jukes-Browne and Hill (1900) divided the Upper Greensand off the Isle of Wight into six 'divisions' (A to F from the base upwards) (see Table 3). Few details of measured sections have been published, and the best known sections remain those described by Jukes-Browne and Hill (1900) and White (1921), e.g. The Gore Cliff, near Blackgang.

The Upper Greensand attains thicknesses of 50 to 60 m in western Dorset and eastern Devon (Figure 36). In Devon only arenaceous deposits occur, e.g. at Whitecliff, west of Seaton [SY 235 895]. Silty 'Gault' of *loricatus* Zone age occurs at the base in eastern Dorset (Lang, 1914; Hancock, 1969). However, the rest of the sequence, as far west as Sidmouth (Figure 35), consists of glauconitic sands (i.e. Foxmould) overlain by calcarenites with chert beds (Jukes-Browne and Hill, 1900; Tresise, 1960; Smith, 1961; Drummond, 1970). The Foxmould can be traced into Dorset and has been recorded in, for example, the Winterborne Kingston Borehole (Morter, 1982) (see Figure 38). The overlying calcarenites and Whitecliffe Chert Member can be placed within the *dispar* Zone (Drummond, 1970, prefered to use 'Vraconian') and not the Cenomanian as Hart (1973) suggested (see below).

Tresise (1960) described the non-calcareous Blackdown Greensand, which has yielded silicified molluscs (Downes, 1882) and can be correlated with the Foxmould Sands. The latter forms the lowest member of the Upper Greensand around Sidmouth (Figure 35). It is overlain by cherty calcarenites (Whitecliff Chert Member) and shelly, glauconitic sands (Bindon Sandstone Member) each of which is separated by a hardground.

The Haldon Sands (sensu Hamblin and Wood, 1976) comprise a sequence of sands, silty sands and gravels, which can be divided into four 'members', three of which are Albian in age: Telegraph Hill Sands (equivalent to Foxmould), Woodlands Sands (equivalent to part of the Chert Beds) and Ashcombe Gravels (equivalent in part to the Chert Beds, 'Coarse Band' sensu Smith, 1961, and Top Sandstones). The fourth member, the Cullum Sands, is Cenomanian. The thickest measured sequence of the Upper Greensand Formation of the Haldon area (i.e. Haldon Sands of Hamblin and Wood, 1976) is 28 m at that at Smallacombe Goyle Quarry [SX 923 768] (Jukes-Browne and Hill, 1900, p.223) (the section is no longer exposed), but it thins to 7.3 m at SX 9015 8385 (Hamblin and Wood, 1976). However, it is also an inferred 84 m to the south of Harcombe Goyle (Durrance and Hamblin, 1969). The 'Haldon Sands', being decalcified, fall within the Blackdown Greensand sensu Tresise (1960). The type section is at Woodlands Goyle (Hamblin and Wood, 1976; Selwood et al., 1984) (see Figures 39 and 40).

In Surrey, 27 m of Upper Greensand were proved in the Fetcham Mill Borehole, Leatherhead [TQ 1581 5650] (Gray, 1965; Owen, 1976), but the formation thins rapidly eastwards so that only about 12.5 m occur at Merstham Interchange [TQ 303 539] (Owen, 1976) (see Figure 41).

Chronostratigraphical position

The Upper Greensand in the Sundon Borehole has yielded finely striated *Aucellina* and A. *gryphaeoides cycloides*,

Table 3 Subdivision of the Upper Greensand on the Isle of Wight after Jukes-Brown and Hill (1900).

	Lithology	**Thickness (feet)**
F	Sands with layers of calciferous concretions, often partly phosphatised	c.6
E	Chert Beds	22–24
D	Firestones and freestones (8-18 feet)	30–40
C	Sandstones with phosphatic nodules and courses of large calcareous doggers	
B	Rough sandstones with irregular concretions	30–40
A	Bluish sandy clay or micaceous silt (Passage Beds)	43–50

implying the *M. rostratum* Subzone of the S. *dispar* Zone (Morter and Wood, 1983). Ammonites characteristic of the *dispar* Zone have been recovered near Chinnor, but the Upper Greensand at Tetsworth extends down into the upper part of the *auritus* Subzone (*inflatum* Zone) (Horton et al., 1995).

In southern England, in Dorset and Devon, faunas of the *inflatum* Zone (*varicosum* to *auritus* subzones) and *dispar* Zone have been recorded in the Upper Greensand. The formation ranges through the uppermost Albian (which Drummond, 1970, preferred to refer to as Vraconian). The *S. dispar* Zone (*rostratum* subzone) and *inflatum* Zone have also been proved in Surrey.

Hart (1973) and Carter and Hart (1977) considered the upper parts of the Upper Greensand Formation to be of Early Cenomanian age. This conclusion was based mainly on the occurrence of the foraminifer *Orbitolina lenticularis* (= *O. concava* of some authors). They preferred to liken the species to Cenomanian forms from France, despite pointing out that 'the British specimens from the Upper Greensand are completely contained within Group IV [sensu Hofker, 1963]' (Carter and Hart, 1977, p.20), a Late Albian to Late Cenomanian morphological group. Faunas from the Upper Greensand of Wolborough, south Devon, are accompanied by microfossils with a Late Albian aspect (Hart et al., 1979) and those from the Woodlands Sands at Woodlands Goyle are succeeded by deposits of *dispar* age (i.e. the Ashcombe Gravels) (Hamblin and Woods, 1976; Selwood et al., 1984). The macrofaunas are typically Late Albian. Hence, the local inception of *Orbitolina* should be considered characteristic of the Late Albian and not the Cenomanian, a conclusion also reached by Simmons and Williams (1992).

Temporary exposures of the 'Blackdown Greensand' at Blackborough, Devon [ST 0998 0947] have yielded a diverse macrofauna (Woods and Jones, 1996), with numerous bivalves, including *Actinoceramus sulcata*, the gastropod *Turritella* (*Torquesia*) *granulata* and the ammonite *Hysteroceras varicosum*. The *varicosum* and *auritus* subzones (*inflatum* Zone) are indicated confirming the conclusions of Hancock (1969).

Selected references

Bristow et al., 1995; Carter and Hart, 1977; Downes, 1882; Drummond, 1970; Durrance and Hamblin, 1969; Gray, 1965; Hamblin and Woods, 1976; Hancock, 1969; Hart, 1973; Hart et al., 1979; Horton et al., 1995; Jukes-Browne and Hill, 1900; Lang, 1914; Morter, 1982; Morter and Wood, 1983; Owen, 1971, 1976; Rawson et al., 1978; Selwood et al., 1984; Shephard-Thorn et al., 1994; Simmons and Williams, 1992; Smith, 1961; Tresise, 1960; Woods and Jones, 1996; Woods, 1999a, b.

Locality details

Sundon Borehole (Section 6.10.1)
M40, south east of Tetsworth (Section 6.10.2)
Postcombe Underpass (Section 6.10.3)
Melbury Quarry, Melbury, Dorset (Section 6.10.4)
Boyne Hollow, Mayo Farm, near Shaftesbury (Section 6.10.5)
Baycliffe, Wiltshire (Section 6.10.6)
Maiden Bradley Quarry (Section 6.10.7)
Longbridge Deverill Pit, Wiltshire (Section 6.10.8)
Cann, Piston sampler hole, Dorset (Section 6.10.9)
Bookham Farm, between Dungeon Hill and Buckland Newton, Dorset (Section 6.10.10, Figure 42)
Winterborne Kingston Borehole (Section 6.10.11, Figure 38)
Gore Cliff, near Blackgang, Isle of Wight (Section 6.10.12)
Whitecliff between Seaton Hole and Beer Roads, Devon (Section 6.10.13)
Dunscombe Cliffs to Kempstone Rocks, south of Dunscombe (Section 6.10.14, Figure 35)
Eastern end of the cliff at Peak Hill, west of Sidmouth (Section 6.10.15)
Punfield Cove, Swanage (Section 6.10.16, Figure 35)
White Nothe, Dorset (Section 6.10.17, Figure 35)
Snowdon Hill, Chard (Section 6.10.18, Figure 35)
Fetcham Mill Borehole, Leatherhead (Section 6.10.19, Figure 41)
Merstham Interchange (Section 6.10.20, Figure 41)
Woodlands, near Great Haldon (Section 6.10.21, Figures 39 and 40)
Babcombe Copse Sandpit (Section 6.10.22, Figure 39)

2.2.8.1 Members of the Upper Greensand Formation

Table 4 Correlation of the Upper Greensand in Devon and Dorset.

S Devon	**E Devon/W Dorset**	**E Dorset**
Ashcombe Gravels	Bindon Sandstone	Boyne Hollow Chert
Woodlands Sands	Whitecliff Chert	Shaftesbury
Telegraph Hill Sands	Foxmould Sands	Cann Sand

2.2.8.2 Telegraph Hill Sands Member

Derivation of name

The basal member of the 'Haldon Sands Formation' (Hamblin and Wood, 1976), named after a reference section at Telegraph Hill [SX 912 836]. The stratotype, like the other members of the formation is at Woodlands Goyle, near Great Haldon [SX 902 840] (Figures 39 and 40).

Lithological characteristics

A basal conglomerate overlain by fine sands and sandstones, with chert concretions and burrow fills at some horizons.

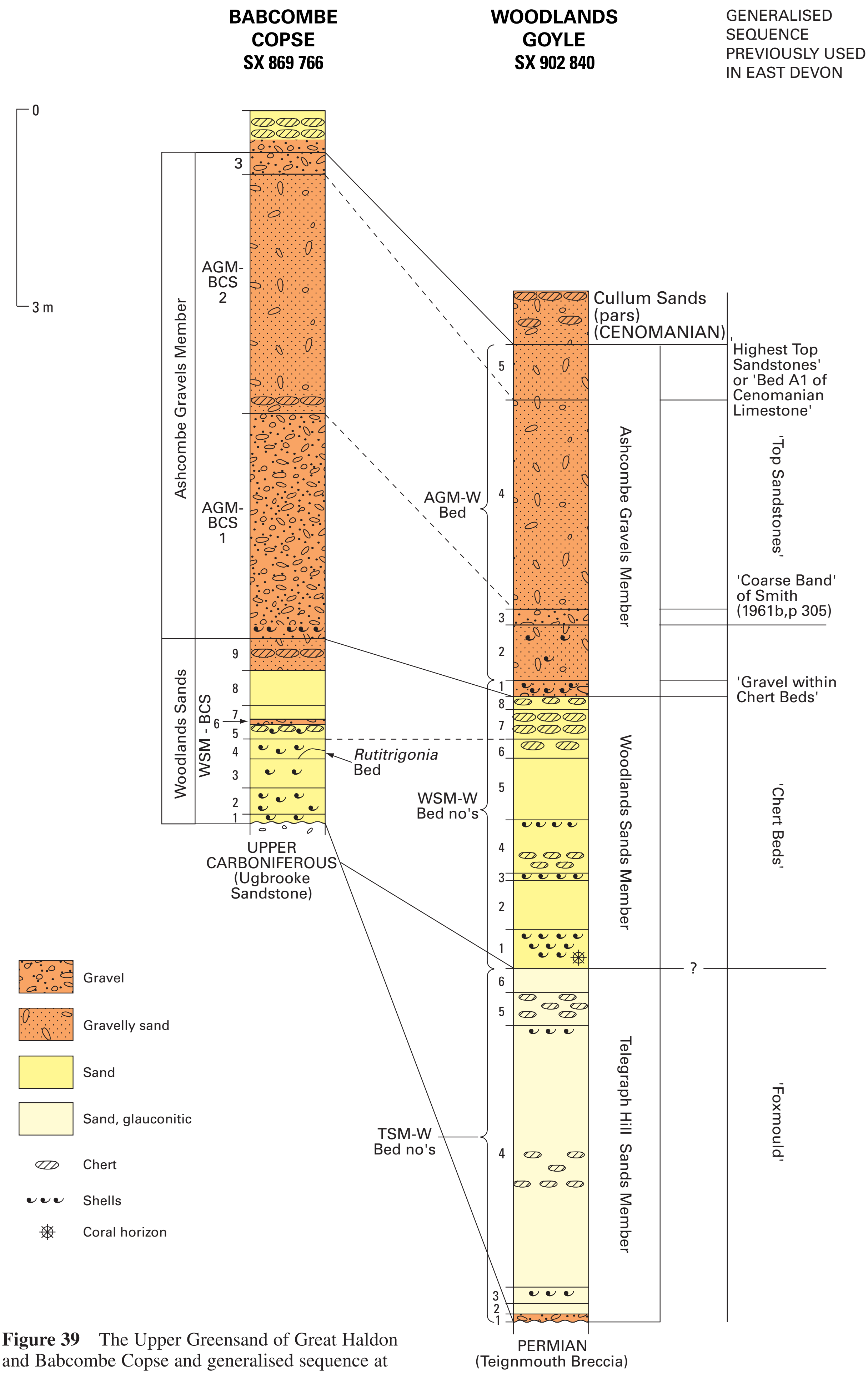


Figure 39 The Upper Greensand of Great Haldon and Babcombe Copse and generalised sequence at Seaton, east Devon (after Selwood et al., 1984).

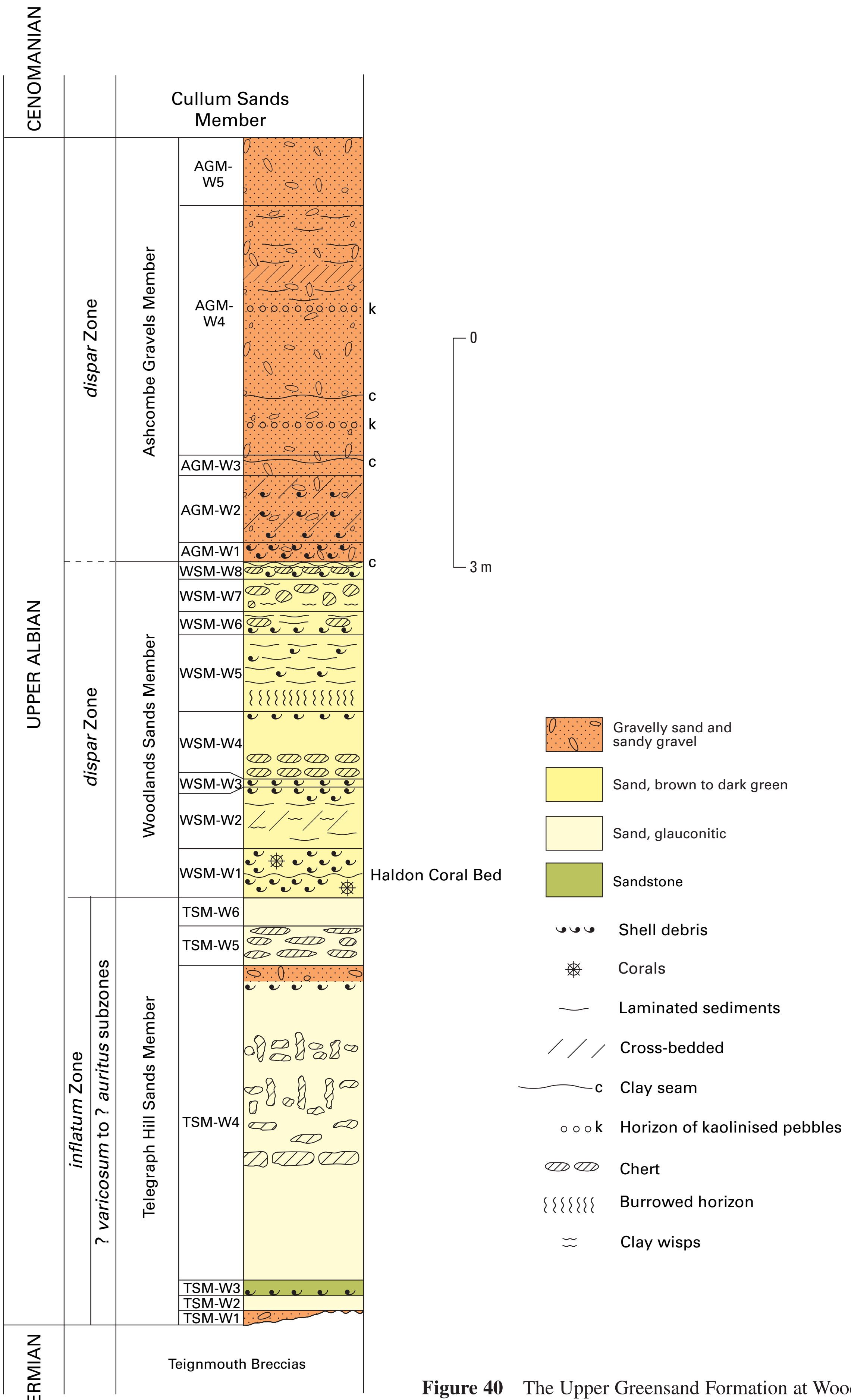


Figure 40 The Upper Greensand Formation at Woodlands [SE 902 840] (after Hamblin and Wood, 1976).

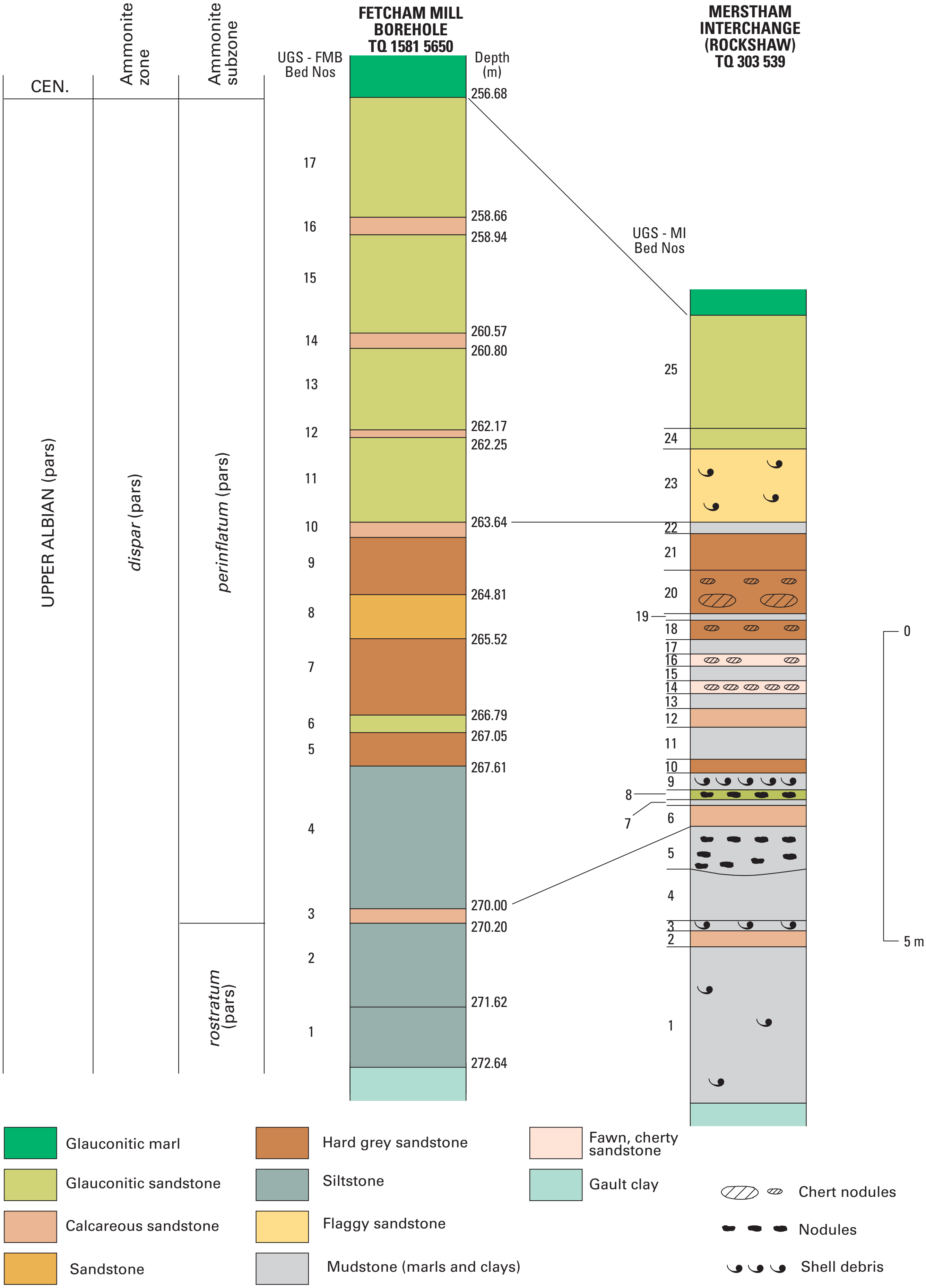


Figure 41 The Upper Greensand in north Surrey (after Gray, 1965; Owen, 1976).

Stratigraphical relationships

The Telegraph Hill Sands are coeval, at least in part, with the Foxmould Member of the east Devon Coast (although the lowest part is probably missing). Most species from the fossiliferous bed TSM–W3 (Haldon Sands Bed 3 sensu Hamblin and Wood, 1976) are known from the 'Blackdown Greensand' of the Blackdown Hills, to the north of Honiton.

Regional variation

Hamblin and Wood (1976) reported the Haldon Sands to vary in thickness from 15 to 84 m, but there is little specific information on the Telegraph Hill Sands due to poor exposure. The member is 5.26 m thick at Woodlands, near Great Haldon [SX 902 840] (Figure 39 and 40), but is not present at Babcombe Copse pit [SX 869 766] (Figure 39) where the Woodlands Sands rest on Upper Carboniferous strata.

Chronostratigraphical position

The gastropods and other molluscs reported from the Telegraph Hill Sands Member are considered to be of Albian affinity. However, many of the museum specimens cited as indicators of the *auritus* and *varicosum* subzones have doubtful provenances, and may even be French. The molluscs are similar to those from the proven Upper Albian Foxmould and Blackdown Greensand. A fragment of ammonite may be of *auritus* or *varicosum* subzone age (Hamblin and Wood, 1976). The orbitolines indicate the Albian or Cenomanian, and suggest Tethyan influence and shallow waters.

Selected references

Durrance and Hamblin, 1984; Hamblin and Wood, 1976.

2.2.8.3 Woodlands Sands Member

Derivation of name

Named after Woodlands Goyle by Hamblin and Wood (1976) (see Figures 39 and 40).

Lithological characteristics

The member comprises a variable sequence of glauconitic clayey sands, sand with siliceous concretions, and shell beds, and has the Haldon Coral Bed at its base. The Haldon Coral Bed comprises dark brown sands with abundant oysters, common *Neithea gibbosa* and other bivalves. Bryozoa and sponges are common and corals are diverse. The overlying deposits are green sands and shelly sands that become brown in places and are locally cross-bedded. Concretions of cherty sandstone occur in the upper part.

Stratigraphical relationships

The Woodlands Sands Member is equivalent to part of the 'Chert Beds' of Tresise (1960, 1961) and Smith (1961) on the south-east Devon Coast, according to Hamblin and Wood (1976). Selwood et al. (1984) considered it to correlate with the lower and middle parts of the Chert Beds, correlating the gravel in the upper part of that unit with the basal bed of the Ashcombe Gravels Member. The member is situated between the Telegraph Hill Sands and Ashcombe Gravels members.

Regional variation

Cherty concretions are less developed at Woodlands, compared to Telegraph Hill. Beds of quartz gravel occur to the south-west, e.g. at Babcombe Copse. The member is 4.14 m thick at Woodlands. Three gravels overlain by glauconitic limestones with green and reddish-brown glauconitic sands, shelly in part and occasionally crowded with large foraminifera (*Orbitolina*), are found near Wolborough [SX 855 700]. They have been assigned to this member, although the validity of this assignment is not certain (Hamblin and Wood, 1976; Edwards, 1979; Hart et al., 1979).

Chronostratigraphical position

Fragments of *Mortoniceras* (*Cantabigites*) and *Callihoplites*, both with a matrix resembling the Haldon Coral Bed or possibly higher within the Woodlands Member, indicate the *dispar* Zone. Carter and Hart (1977) correlated the Woodlands Sands Member with the 'Chert Beds', placing them in foraminiferal Zone 8 (Cenomanian).

The *Orbitolina*-rich limestones and associated glauconitic sand and gravel near Wolborough (Edwards, 1979) are reported to be coeval with the Woodlands Sand Member (Hamblin and Wood, 1976), but the evidence is not strong. Hart et al. (1979) considered the foraminifera to be Late Albian–Early Cenomanian, although they bear a resemblance to Early Cenomanian foraminifera from Sarthe (France) and the Iberian Peninsula.

Selected references

Carter and Hart, 1977; Durrance and Hamblin, 1969; Edwards, 1979; Hamblin and Wood, 1976; Hart et al., 1979; Smith, 1961; Tresise, 1960, 1961.

2.2.8.4 Ashcombe Gravels Member

Derivation of name

Named after a locality close to the stratotype by Hamblin and Wood (1976), west of Ashcombe [SX 9045 7947].

Lithological characteristics

Sandy quartz gravels (beds AGM-W1, W3 and W5 at Woodlands) alternate with coarse gravelly quartz sands. Cross-bedding occurs at some horizons. Oyster fragments may also occur, but are restricted to Bed 15 of Hamblin and Wood (1976).

Stratigraphical relationships

The 'Coarse Band' used by Smith (1961) to define the base of the 'Top Sandstones' appears to equate to Bed AGM-W3 of the Ashcombe Gravel Member (Bed 17 of the Haldon Sands sensu Hamblin and Wood, 1976).

Bed AGM-W1 (Bed 15 of the Haldon Sands sensu Hamblin and Wood, 1976) is a thin quartz gravel rich in fragments of exogyrine oysters, but the rest of the member is unfossiliferous. *Exogyra digitata* occurs in a 0.30 m thick shelly gravel in the upper part of the Whitecliff Chert Member, 7.9 m below the base of the Cenomanian Limestone at Kempstone Rocks (Jukes-Browne and Hill, 1900, p.209; Hamblin and Wood, 1976; Selwood et al., 1984). The stratigraphical position of the gravel in the Whitecliff Chert Member appears to be similar to that of Bed AGM-W1. However, *Exogyra digitata* has not been found in the Haldon area, so biostratigraphical evidence to support any postulated correlation is not available.

Bed AGM-W5 (Bed 19 of the Haldon Sands sensu Hamblin and Wood, 1976) is stratigraphically the highest gravel in the member. It may correlate with the coarse top of the 'Top Sandstones' or the 'quartz-rich Bed A1' of Smith (1961, fig.2), at the base of the Cenomanian Limestone (Hamblin and Wood, 1976).

Regional variation

The three gravels can be traced over wide areas, but become less well sorted in places (e.g. Babcombe Copse [SX 869 767] (Figure 39). The member is 5.28 m thick at Woodlands [SX 902 840] (Figures 39 and 40), and 7.33 m thick at Babcombe Copse.

Chronostratigraphical position

No biostratigraphically useful fossils are known (the only fossils recorded are the oyster fragments mentioned above). The member is inferred to be Late Albian in age, by correlation with the highest Whitecliff Chert Member or the base of the Bindon Sandstone Member of Shapwick Quarry [SY 3118 9180] near Lyme Regis, which has yielded *Callihoplites* cf. *tetragonus*, *Dischoplites* aff. *transitorius*, *D. daedalius*, *Stoliczkaia dispar* and *Stromhamites venetzianus*, amongst others (Hamblin and Wood, 1976).

Selected references

Hamblin and Wood, 1976; Jukes-Browne and Hill, 1900; Smith, 1961.

2.2.8.5 Foxmould Sands Member

Derivation of name

The name is a local quarrying term for a yellowish-brown sand in the Lyme Regis district. De la Beche used the term 'fox-mould' in his accounts of the geology of Cornwall, Devon and West Somerset in 1826 and 1839.

Lithological characteristics

In general terms, the Foxmould Member comprises soft, glauconitic, argillaceous and calcareous sandstone (weathering to a brown sand), with more indurated beds of calcareous sandstone and sandy limestone in some places. Calcareous concretions ('Cowstones') occur near the base of the member. Shell beds also occur. Jukes-Browne and Hill (1900), Tresise (1960, 1961) and Woods (1999a) provide descriptions.

Stratigraphical relationships

The Foxmould Member is coeval with the lower part of the Upper Gault. It rests on silty mudstones of the Gault (*M. inflatum* Zone) or unconformably on Triassic to Lower Jurassic strata. The top of the member comprises a mineralised hardground surface (Culverhole Hardground), separating the member from the overlying cherty sandstones of the Whitecliff Chert Member (BGS Lexicon).

Regional variation

Woodward and Ussher (1911) recorded 100–150 feet (30.5–45.7 m) of 'Cowstones' and Foxmould in the Sidmouth-Lyme Regis area. The member reaches a thickness of about 26 m (Woods, 1999a) in the Beer–Seaton area, for example at Black Ven [SY 2344 8942], Hooken [SY 2170 8795] and Peak Hill [SY 109 871]. The Foxmould Member can be seen along the coast at Dunscombe Cliff near Sidmouth [ST 155 877], Haven Cliff near Seaton [ST 265 897] and White Nothe, Dorset [ST 770 811]. Inland it is over 30 m thick at Snowdon Hill near Chard [ST 313 089] (see Figure 35). The thickness of the member is not clear in the Winterborne Kingston Borehole (Figure 38) due to core loss, but Morter (1982) placed the 'Cowstones' at a depth of approximately 317 m, and the top of the member (Lang Bed 10) was placed at 299.80 m indicating an approximate thickness of 7.20 m.

Chronostratigraphical position

The Foxmould Member has yielded ammonites, including *Mortoniceras* (*D.*) *cunningtoni*, *M.* (*D.*) *bipunctatum*, *M.* (*D.*) *albensis*, *Hysteroceras varicosum* and *Callihoplites auritus* (Hancock, 1969). These place the member in the *H. varicosum* and *C. auritus* subzones of the *M.* (*M.*) *inflatum* Zone. The member may be as old as the *H. orbignyi* Subzone if the bivalves recorded as *Inoceramus sulcatus* (Jukes-Browne and Hill, 1900; Woodward and Ussher, 1911) are correctly identified and in situ. Carter and Hart (1977) considered the foraminifera from the Foxmould Member at Pinnacles [SY 221 879] to indicate benthonic foraminifera Zone 6 (Late Albian).

Selected references

De la Beche, 1826, 1839; Hancock, 1969; Jukes-Browne and Hill, 1900; Morter, 1982; Tresise, 1960, 1961; Woods, 1999a; Woodward and Ussher, 1911.

2.2.8.6 Whitecliff Chert Member

Derivation of name

This member of the Upper Greensand Formation, recognised in the Sidmouth and Bridport districts of Devon and Dorset, was named after the type locality (BGS Lexicon, 1999; Edwards et al., in press). The member equates with the 'Chert Beds' of Tresise (1960, 1961) and Smith (1961).

Lithological characteristics

The member comprises coarse-grained, grey, glauconitic calcarenites with iron stained, black, grey or brown-cored nodules and lenses of chert (Jukes-Browne and Hill, 1900; Smith, 1961; Tresise, 1960, 1961; Durrance and Lambing, 1985; Williams, 1986; Woods, 1999a, b). The lower boundary with the Foxmould Member is also a hardground surface. The change in lithology from the chert-free Foxmould Member to the chert-rich Whitecliff Chert Member, is particularly marked. An indurated sandstone that marks the top of the member at Whitecliff [SY 2344 8942] and Storridge Hill [ST 316 044] is interpreted as a hardground (Whitecliff Hardground) (BGS Lexicon, 1999; Woods, 1999a, b).

Stratigraphical relationships

The Whitecliff Chert Member is coeval with part of the Upper Gault. Between Branscombe and Kempstone Rocks, a pebble bed rich in *Exogyra digitata* may correlate with Bed AGM–W1 at the base of the Ashcombe Gravels Member at Great Haldon [SX 902 849] (Bed 15 of Hamblin and Wood, 1976), and with AGM–BCS2ii at Babcombe Copse Sandpit [SX 869 766] (Bed 11ii of Selwood et al., 1984). However, neither correlation has been proved conclusively.

Regional variation

The member is up to 21–24 m thick. Chert extends throughout the member in some areas, but is confined to the lower part in others. There is a decrease in the thickness of chert-bearing beds between Whitecliff [SY 2344 8942], the type locality, and Kempstone Rocks [SY 164 881] (Jukes-Browne and Hill, 1900; Hamblin and Wood, 1976; Woods, 1999). Pebble beds occur in some areas e.g. Bindon, Hooken Cliff, Branscombe and Kempstone Rocks. The Whitecliff Chert Member can be seen along the coast at Dunscombe Cliff near Sidmouth [ST 155 877], Haven Cliff near Seaton [ST 265 897], and White Nothe, Dorset [ST 770 811]. Inland it forms part of Snowdon Hill near Chard [ST 313 089] (see Figure 35).

Chronostratigraphical position

Rare ammonites have been found in the member (Spath, 1926, 1943), including *M.* ex gr. *Stoliczkaia*. The *S. dispar* Zone has been suggested. Carter and Hart (1977) considered the foraminifera to indicate benthonic foraminifera zone 8 (basal Cenomanian), and the macrofauna to be reworked. However, the Albian macrofauna recorded at a higher stratigraphical level at Shapwick Quarry means that a Cenomanian age is unlikely.

Selected references

Durrance and Lambing, 1985; Edwards et al., in press; Hamblin and Wood, 1976; Jukes-Browne and Hill, 1900; Smith, 1961; Spath, 1926, 1943; Tresise, 1960, 1961; Williams, 1986; Woods, 1999a, b.

2.2.8.7 Bindon Sandstone Member

Derivation of name

Originally called the Shapwick Member after Shapwick Quarry [SY 3130 9190] (BGS Lexicon), this unit has been renamed the Bindon Sandstone (Edwards and Gallois, 2004) after the locality of that name.

Lithological characteristics

The member comprises shelly, glauconitic, partly cross-bedded sandstone, with lenticular and tabular cherts in the upper part. It occurs on the coast at Seaton and at Shapwick Quarry [SY 3130 9190]. The base of the member is at the Whitecliff Hardground. Its upper boundary at the junction with the Cenomanian Limestone is a burrowed, current-scoured hardground (Small Cove Hardground of Jarvis and Woodroof, 1984).

Stratigraphical relationships

The Bindon Sandstone Member is coeval with the upper part of the Gault. The member equates with the 'Chert Beds' of, for example, Jukes-Browne and Hill (1900) and Smith (1961), and includes the 'Top Sandstone' of Smith (1961). The Eggardon Grit of the Bridport area, Membury [ST 276 042], Storridge Hill [ST 316 044] and Snowdon Hill [ST 313 089], which appears to be at a similar stratigraphical position between the Whitecliff Chert and the Cenomanian Limestone, contains a fauna of Cenomanian aspect, as discussed by Wright and Kennedy (1984).

Regional variation

At Shapwick Quarry, where the member is 3.5 m thick, approximately the highest 2 m contains less chert and resembles the Eggardon Grit. The member can be seen along the coast at Dunscombe Cliff near Sidmouth [ST 155 877], Haven Cliff near Seaton [ST 265 897], and White Nothe, Dorset [ST 770 811] (Figure 34). Inland it forms part of Snowdon Hill near Chard [ST 313 089] where it varies from 21.34 m to 1.75 m in thickness.

Chronostratigraphical position

Late Albian, *S. dispar* Zone, *M.* (*D.*) *perinflatum* Subzone. Ammonites from Shapwick Quarry include *Callihoplites* sp. (*tetragonus* or *seeleyi*), *Discohoplites* aff. *transitorius*, *D. daedalius*, *Stoliczkaia dispar*, *Stromohamites* and *Idiohamites* (Hamblin and Wood, 1976). There are minority views as to the age of the member. Hart et al. (1979) recorded a Late Albian to Early Cenomanian calcareous microfauna from Shapwick, and Carter and Hart (1977) considered the foraminifera from the 'Top Sandstones' at Pinnacles (SY 221 879) to indicate benthonic foraminiferal Zone 9 (Cenomanian).

Selected references

Carter and Hart, 1977; Edwards et al., in press; Hamblin and Wood, 1976; Hart, Weaver and Harris, 1979; Jarvis and Woodroof, 1984; Woods, 1999a, b.

2.2.8.8 Cann Sand Member

Derivation of name

Bristow (1989) introduced this term for the lowest part of the Upper Greensand on the Shaftesbury Sheet. It was named after the village of Cann, where an exposure of the Cann Sand can be seen [ST 872 213].

Lithological characteristics

The member comprises fine-grained, micaceous sand and weakly cemented sandstone that forms a shelf below the Shaftesbury Sandstone escarpment. It has been described from Cann and Bookham Farm (between Dungeon Hill and Buckland Newton, Figure 42).

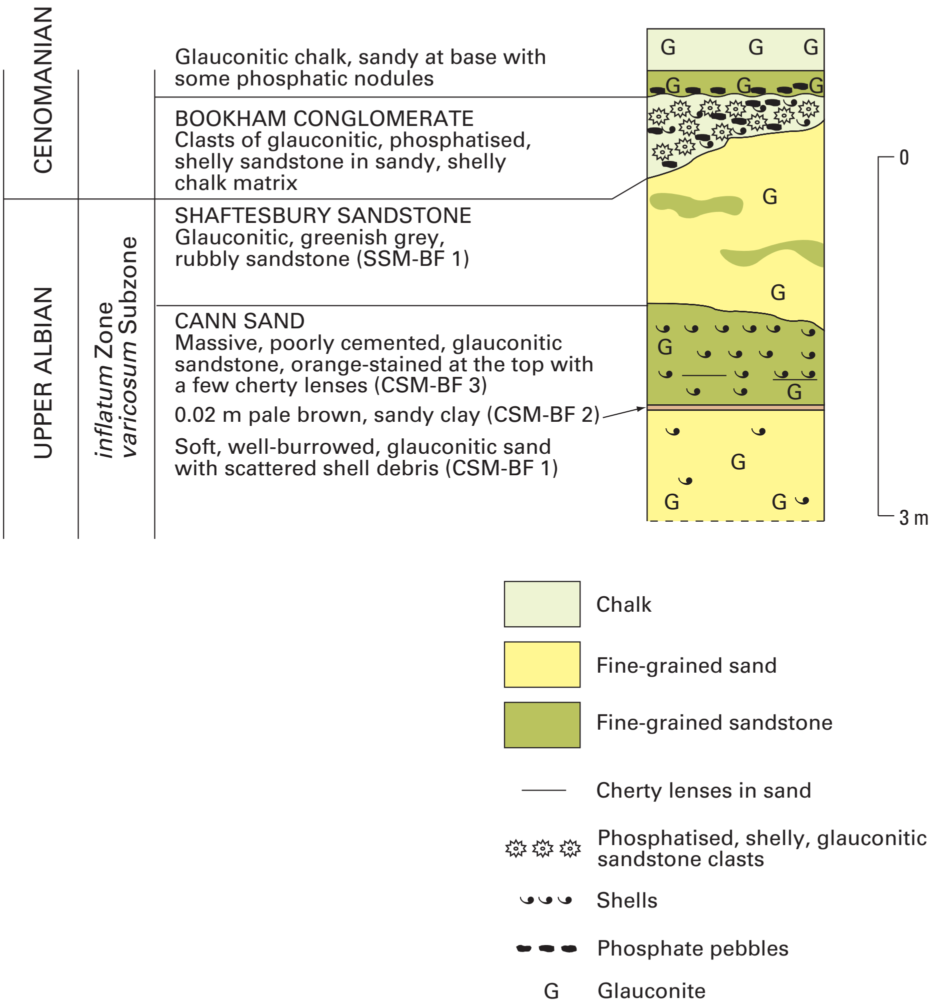
Stratigraphical relationships

The Cann Sand forms the basal member of the Upper Greensand on the Shaftesbury, Wincanton and southern part of the Frome sheets, and appears to be contemporaneous with the Foxmould Member. It is equivalent to the 'Malmstone' of Jukes-Browne and Hill (1900).

Regional variation

This member is reported to be up to 30 m thick in the Shaftesbury district (Bristow et al., 1995). In the area around Wincanton, it varies between 5 and 18 m (Bristow et al., 1999). A borehole at Melbury [TL 8853 2032] penetrated only 9.4 m. At Cann up to 6.95 m have been proved, although upper and/or lower boundaries are generally obscured. The lower boundary is clearly recognisable

Figure 42 The Upper Greensand of Bookham Farm [ST 7064 0415] (after Bristow et al., 1995).



where the fine-grained silty sand rests on the dark grey sandy clay of the Gault. This contact forms a spring line. The upper boundary of the Cann Sands Member is not exposed, but is taken at the base of the negative feature formed by the Shaftesbury Sandstone Member.

Chronostratigraphical position

The transition beds of the underlying Gault have yielded a fauna of *varicosum* Subzone age (Mottram, 1957; Bristow and Owen, 1991; Bristow et al., 1995). Evidence from the overlying Shaftesbury Sandstone Member can be used to infer that the Cann Sand Member is also of *varicosum* Subzone age. An *auritus* Subzone age given by Wilson et al. (1958) is based on an ammonite from a slipped mass near Mosterton [ST 4748 0569].

Selected references

Bristow, 1989; Bristow and Owen, 1991; Bristow et al., 1995; 1999; Mottram, 1957; Wilson et al., 1958.

2.2.8.9 Shaftesbury Sandstone Member

Derivation of name

From the town of Shaftesbury (Bristow, 1989). This name replaces 'Ragstone Beds' (sensu White, 1923, p.46), 'Ragstone and Freestone Beds' (sensu White, 1923, p.51) and 'Ragstone' (of Drummond, 1970).

Lithological characteristics

The member comprises fine-grained, glauconitic sands and calcite-cemented sandstone capped by an indurated shelly sandstone ('ragstone'). It forms a prominent escarpment. The member is often obscured, but one of the quarries mentioned by Jukes-Browne was used as the stratotype (Bristow, 1989; Bristow et al., 1995). The base of the member has not been seen. The top of the member is at the top of the 'ragstone' (White, 1923, p.46; Drummond, 1970, fig. 2), for example at Longbridge Deverill [ST 8693 4129] (Woods and Bristow, 1995; Bristow et al., 1999).

Stratigraphical relationships

The Shaftesbury Sandstone is correlated with the 'Exogyra Sandstone' and 'Exogyra Rock' of south-west and south Dorset (Drummond, 1970).

Regional variation

In the Shaftesbury and Wincanton areas, the member is about 20–25 m thick, but it is reduced to approximately 10 m in the eastern part of the area covered by the Shaftesbury sheet. It thins rapidly to the south-west, and is thin or absent over the Mid Dorset Swell. Only 1.2–1.5 m occur at Bookham Farm [ST 7064 0415] (see Figure 42).

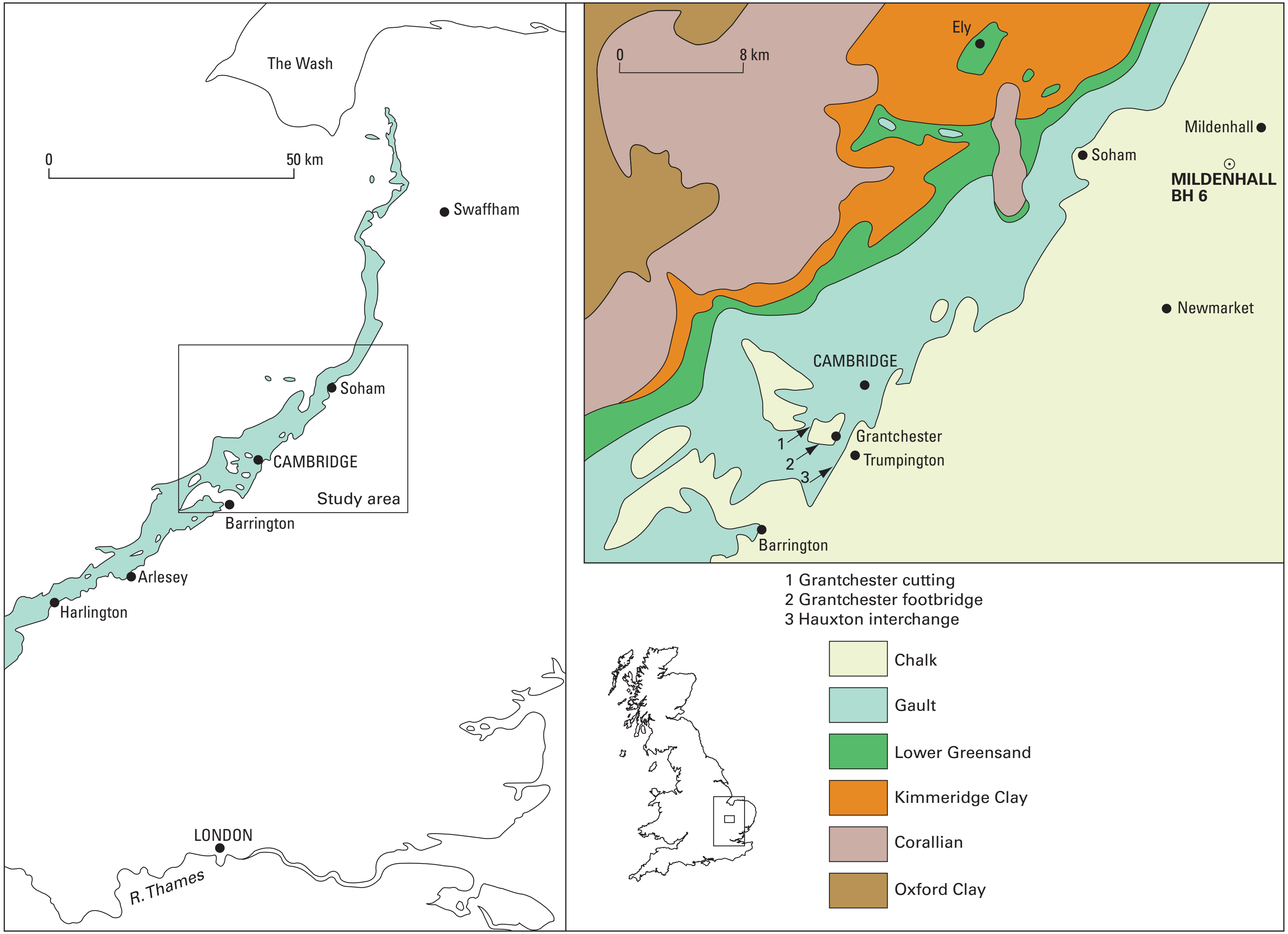


Figure 43 The outcrop of Albian deposits in Central England and East Anglia together with a geological sketch map of the area around Cambridge showing sites where Cambridge Greensand has been recorded.

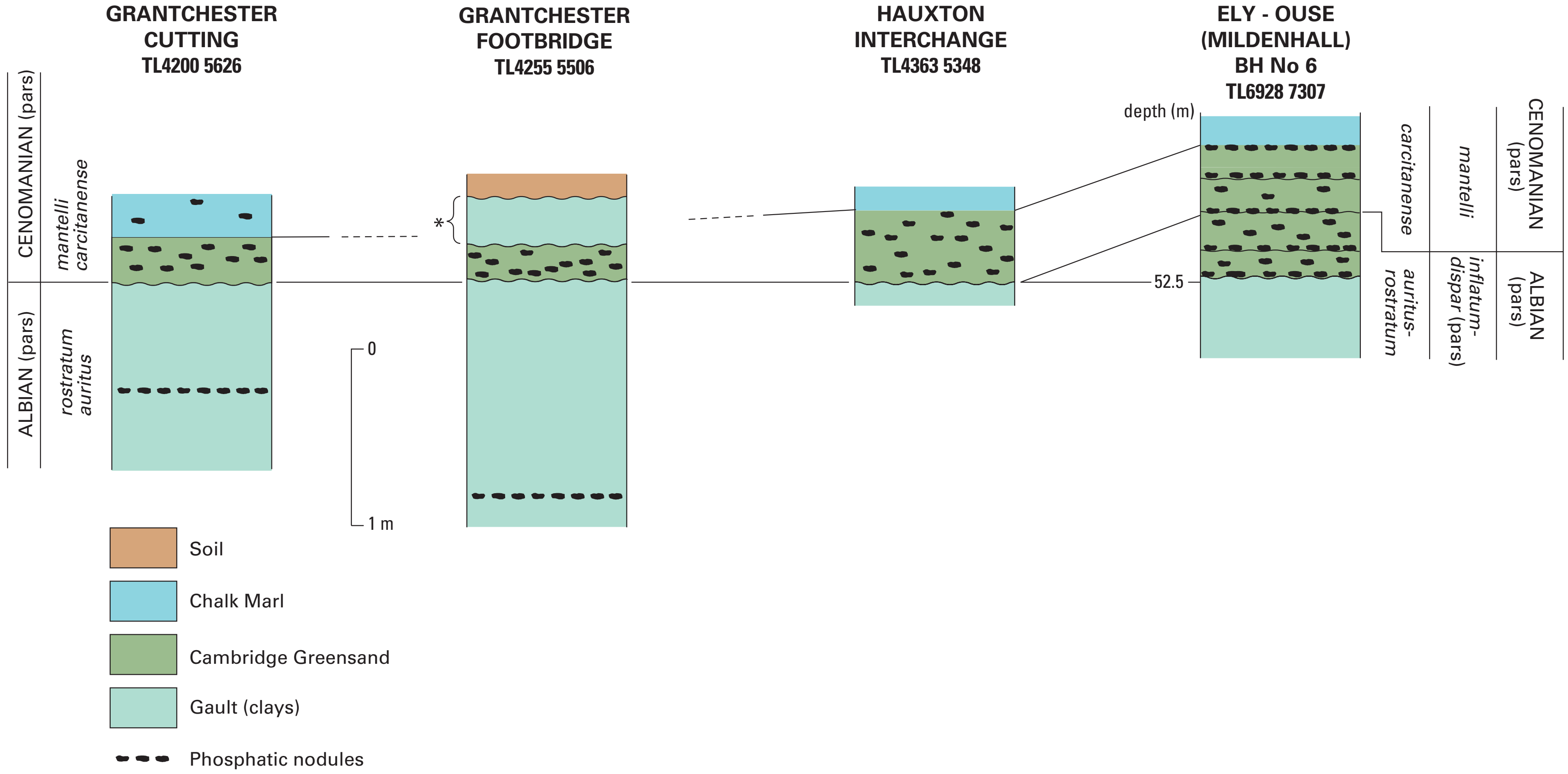


Figure 44 The stratigraphical relationship of the Cambridge Greensand, near Cambridge (after Wilkinson, 1990).
* Redeposited Gault during extraction by 'coprolite' diggers.

Chronostratigraphical position

The presence of '*Exogyra columba*' sensu Woods (non Lamark) and *Amphidonte obliquatum* may indicate the *auritus* Subzone, but there is evidence that the 'Ragstone' is of *varicosum* Subzone age (Bristow et al., 1995). *Pycnodonte* (*Phygraea*) *vesiculosum* is extremely abundant in the upper part of the Shaftesbury Sandstone Member, which also suggests an *auritus* Subzone age. Macrofaunal evidence (based on a fragment of *Mortoniceras*) from field brash at East Compton [ST 8770 1892] implies an early *auritus* or more likely *varicosum* Subzone age. Field brash at Hill Farm [ST 7725 0678] yielded *Mortoniceras* (*M.*) *cunningtoni*, *Anahoplites picteti* and *Idiohamites* sp., indicative of the late *varicosum* or early *auritus* subzones. Hence, although evidence is not unequivocal because the specimens were not in situ, the member is apparently of *varicosum* Subzone age, with the upper part being of early *auritus* Subzone age.

Selected references

Bristow, 1989; Bristow et al., 1995; Bristow et al., 1999; Drummond, 1970; White, 1923; Woods and Bristow, 1995.

2.2.8.10 Boyne Hollow Chert Member

Derivation of name

After Boyne Hollow, near Shaftesbury (Bristow, 1989), where the member was formerly well exposed in a quarry [ST 8737 2227].

Lithological characteristics

Glauconitic quartz sand and sandstone with cherty and siliceous concretions. The basal bed comprises shelly glauconitic sand and weakly cemented sandstone up to 1 m thick, with phosphatic nodules. Jukes-Browne and Hill (1900) reported this basal bed to be shelly at Melbury Hill [ST 8690 1935]. The top of the member is taken at the top of the highest chert bed.

Stratigraphical relationships

The basal sandstone with phosphatic nodules may be coeval with the Horish Wood Greensand of Kent (Owen, 1976) and Bed XII at Folkestone.

Regional variation

The member is reported to be approximately 15 m thick on the Shaftesbury Sheet (BGS 1:50 000 Sheet 313, England and Wales), although very rarely is it fully exposed. At Baycliffe [ST 8193 3994], 4.60 m of glauconitic silts and sands are exposed. The top of the member was formerly seen in the Maiden Bradley Quarry [ST 7980 3891], where the Cenomanian Melbury Sandstone Member overlies 3.81 m of glauconitic sands representing the Boyne Hollow Chert. The base of the member is seen at Longbridge Deverill [ST 8693 4129], where 0.46 m of white cherty sandstone overlies the Shaftesbuty Sandstone.

Chronostratigraphical position

Fossils are not common but they indicate a probable *dispar* Zone age.

Selected references

Bartlett and Scanes, 1916; Bristow et al., 1995; Bristow, 1989; Jukes-Browne and Hill, 1900; Jukes-Browne and Scanes, 1901; Owen, 1976; Woods and Bristow, 1995; Wright and Kennedy, 1984.

2.2.9 Cambridge Greensand Formation

Derivation of name

Named after Cambridge. It was termed 'coprolite bed' by several 19th Century geologists. It is essentially Cenomanian in age, but see below.

Lithological characteristics

Silty sands and sandy silts with abundant phosphatic nodules.

Stratigraphical relationships

Situated disconformably on the Gault, it passes up into the Lower Chalk (Cenomanian).

Regional variation

The formation is found in parts of western Norfolk, Cambridgeshire, Bedfordshire and Suffolk (see Figure 43), and is rarely more than 0.3–0.6 m thick. It is 1.07 m thick in the Arlesey Borehole [TL 1887 3463] (Figure 21), between depths of 14.38 and 15.45 m (Hopson et al., 1996). Worssam and Taylor (1969) recorded thicknesses of up to 1.5 m in other boreholes. Morter and Wood (1983) considered that the upper boundary, usually drawn at the top of the horizon of abundant nodules, should be placed higher in the Cenomanian Chalk Marl.

Chronostratigraphical position

Although the deposit contains a large number of Albian macrofossils, these have been regarded as entirely reworked by some authors. The deposit is often assigned to the *carcitanense* Subzone of the basal Cenomanian, although this is questionable as discussed by Gallois (1988). In the Ely Ouse Borehole No. 6 [TL 6928 7307] (see Figure 44), the Cambridge Greensand occurs between the depths of 51.78 and 52.50 m. *Neohibloites praeultimus* is present in the basal 0.38 m of the unit (Morter, 1982), together with Albian ostracods (Wilkinson, 1988). The first appearance of Cenomanian ostracods is immediately above an erosion surface at a depth of 52.12 m. Wilkinson (1988) suggested that this basal part of the Cambridge Greensand is of Albian age (*Cythereis* (*R.*) *luermannae hannoverana* ostracod Zone, *Planileberis scrobicularis* Subzone), and postulated that where the Cambridge Greensand is more fully developed, as in Ely Ouse Borehole No. 6, the lower part may be of *M.* (*M.) rostratum* Subzone age.

Selected references

Bristow, 1990; Gallois, 1988; Hopson et al., 1996; Morter, 1982; Morter and Wood, 1983; Wilkinson, 1988; Worssam and Taylor, 1969.

Locality details

Ely-Ouse Borehole No. 6 (= Mildenhall Borehole No. 6) (Section 6.11.1, Figure 44)

3 Biostratigraphy

Biostratigraphical studies were initially carried out using macrofossils such as ammonites, belemnites and bivalves, the standard zonal scheme being based on the distribution of the first of these. The second half of the 20th century, however, saw an increase in the number of boreholes, drilled particularly for hydrogeology and hydrocarbons, and the value of microfossils was recognised. Biostratigraphical zonal schemes for dinoflagellate cysts, coccoliths, foraminifera and ostracods have been developed, which complement and enhance the standard macrofaunal scheme and allow high resolution subdivision and correlation (Figure 2).

3.1 AMMONITE BIOSTRATIGRAPHY

The ammonite zonal scheme presented here follows that of Casey (1961a), with modifications by Owen (1988b) for the Lower Albian and Owen (1971, 1976) for the Middle and Upper Albian.

3.1.1 *Leymeriella tardefurcata* Partial Range Zone

Definition

The base of the zone is defined by the first occurrence of *Leymeriella*. The use of *L. tardefurcata* as the zonal index was established as long ago as 1856 by Strombeck. The top of the zone is defined by the first appearance of *L. regularis*. The zone is a partial range zone, the eponymous *Leymeriella tardefurcata* being recorded in the overlying *L. regularis* Zone of south-east England, for example at Arnold's Pit, Billington Crossing and Leighton Buzzard, Bedfordshire, and at Wrecclesham, Surrey, and on the continent (Kennedy et al., 2000).

Identification of the zone may be complicated by provincialism, and the four subzones that have been recognised by some authors cannot be recognised throughout north-west Europe. In Britain, the zone has been divided into the *Farnhamia farnhamensis*, *Hypacanthoplites milletioides* and *Leymeriella regularis* subzones (a fourth, the *Leymeriella schrammeni* Subzone, has not being recognised in Britain). However, the first two are rarely identifiable, usually very condensed, and consequently poorly known. The *Leymeriella regularis* Subzone has been elevated to zonal rank (see below).

Due to the difficulty in recognising the *F. farnhamensis* and *H. milletioides* subzones, Owen (1996) and Ruffell and Owen (1995) combined these two subzones and regarded them as being contemporaneous with the German *Leymeriella acuticostata* Subzone (although the eponymous subzonal index has not been found in Britain). However, Kennedy et al. (2000) argued that the *Farnhamia farnhamensis*, *Hypacanthoplites milletioides* and *Leymeriella acuticostata* subzones should be subsumed into an undivided *L. tardefurcata* Zone.

Lithostratigraphy

Mitchell (1995) placed Bed A5A of the Speeton Clay, Bed A4 (The Greensand Streak) and the basal part of Speeton Clay Bed A3 in the *tardefurcata* Zone.

3.1.2 *Leymeriella regularis* Total Range Zone

Definition

The zone is defined by the presence of *L. regularis*. Other ammonites present include *L. tardefurcata*, *L. pseudoregularis*, *Anadesmoceras strangulatum*, *Anadesmoceras* spp., *Pictetia depressa* and *Douvilleiceras* sp. The bivalve *Oxytoma pectintum* may be locally common. Other taxa include bivalves *Exogyra latissima*, *Lopha diluviana*, *Entolium orbiculare*, *Aptolinter aptiensis*, *Tortarctica similis*, *Cucullanea glabra*, *Pterigonia mantelli* and *Inoceramus coptensis*; echinoids *Holaster* (*Labrotaxis*) *cantianus* and *Phyllobrisus artesianus*; annelid *Serpula articulata*; brachiopod '*Rhynchonella*' *gibbisiana*; polyzoan *Siphodictyum gracile*; and sponge spicules.

The zone was originally treated as a subzone of the *L. tardefurcata* Zone (Casey, 1961; Ruffell and Owen, 1995; Owen, 1996c), but Kennedy et al. (2000) argued that it should be elevated to zonal rank.

Lithostratigraphy

The zone is geographically widespread, being recognised throughout south-east England and in France and Germany. In Britain, the zone occurs in the Folkestone Beds at East Cliff, Folkestone (Kent), and at Wrecclesham (Surrey), Chalvington (Sussex), and Chamberlain Barn Pit (Leighton Buzzard, Bedfordshire).

3.1.3 *Douvilleiceras mammillatum* Superzone (Owen, 1988b)

Definition

This is the *D. mammillatum* Zone sensu Casey, 1961a. It is divided into two zones, the lower one being characterised by early species of *Sonneratia* and the upper zone by species of *Otohoplites*.

3.1.4 *Sonneratia chalensis* Total Range Zone

Definition

Defined by the total range of *S. chalensis* (Owen 1988b). The zone is divided into the *Sonneratia* (*Globosonneratia*) *perinflata*, *Sonneratia kitchini* and *Cleoniceras floridum* subzones.

Lithostratigraphy

Carstone of the Isle of Wight and West Dereham, the Junction Beds of Leighton Buzzard, and the Gault/Greensand 'Junction Beds' near Westerham, Kent, East Cliff, Folkestone and Eastwell Lane, near Ashford, Kent.

3.1.4.1 *Sonneratia (Globosonneratia) perinflata* Subzone (Owen, 1988b)

Defined by the total range of the index species, sediments of this age are sparse. The subzone is known from the Carstone of the Isle of Wight and West Dereham, but in the condensed Junction Beds of the Leighton Buzzard area, the subzonal index is found together with the earlier *regularis* and later *kitchini* zonal/subzonal indices.

3.1.4.2 *Sonneratia kitchini* Subzone (Casey, 1961a, emended Owen, 1988b)

Defined by the range of *S. kitchini*. In Reeth Bay, Isle of Wight, the subzonal index may be found together with a diverse fauna listed by Casey (1961a): *Anadesmoceras baylei*, *Beudanticeras dupinianum*, *Otohoplites* sp., *Sonneratia* spp. and *Douvilleiceras mammillatum*. Bivalves may be common and include *Inoceramus coptensis*, *Cuneolus lanceolatus*, *Entolium orbiculare*, *Anthonya cantiana*, *Senis wharburtoni* and *Pinna robinaldina*; gastropods *Claviscala clementina*, *Tessarolax fittoni*, *Gyrodes genti*, *Anchura* (*Perissoptera*) cf. *parkinsoni* and *Semisolarium moniliferum*; echinoids *Toxaster murchisonianus*, *Holaster* (*Labrotaxis*) *cantianus* and *Polydiadema* cf. *wiltshirei*; and the crab *Plagiophthalmus nitonensis*.

Faunas of this age have been recorded from the basal Carstone of the Isle of Wight; from the Folkestone Formation (Wrecclesham Member) in Bed WM-SMP3 (Casey, 1961a, p.543; Owen, 1992) of the Squerryes Main Pit, near Westerham, Kent (Owen, 1971, 1992); from Bed 28 at East Cliff, Folkestone; and at Eastwell Lane, near Ashford, Kent. Elsewhere, e.g. in the Junction Beds of Leighton Buzzard, the subzonal index is found together with indices of both younger and older subzones.

3.1.4.3 *Cleoniceras (Cleoniceras) floridum* Subzone (Casey, 1961a)

Douvilleiceras mammillatum, *D. monile*, *Beudanticeras newtoni*, *B. dupinianum*, *Cleoniceras* (*Neosaynella*) *inornatum*, *Protanisoceras acteon* and *Hamites* cf. *praegibbosus* have been recorded with *S.* (*C.*) *floridum* in Kent by Casey (e.g. Casey, 1960, p.660; Casey, 1961a; Owen, 1972). The subzone is known in north-west Kent and east Surrey, but in many places has been removed by erosion (e.g. Bed 33 at Folkestone). Part of the Carstone in the Isle of Wight belongs to this subzone, and it is also present in the Junction Beds of Leighton Buzzard with reworked *regularis* and *kitchini* indices (Owen, 1972).

3.1.5 *Otohoplites auritiformis* Assemblage Zone

Definition

The base of this zone is defined by the appearance of *O. auritiformis*, and its top is recognised by the inception of the succeeding zonal index (Owen, 1988b). The zone is divided into four subzones. *O. auritiformis* is found in the lowest three (*raulinianus*, *puzosianus* and *bulliensis* subzones), but is not present in the highest subzone, which is recognised by the occurrence of *Pseudosonneratia* (*Isohoplites*) *steinmanni*.

Lithostratigraphy

Recorded in the Lower Greensand Folkestone Formation.

3.1.5.1 *Otohoplites raulinianus* Partial Range Subzone (Casey, 1961a)

This is a partial range subzone, because the index species ranges up into the *puzosianus* Subzone (Casey, 1961a, Owen, 1972). *Pseudosonneratia* (*Isohoplites*) and *Otohoplites* have their inceptions in the subzone, but are not confined to it. *Otohoplites waltoni* is characteristic of the subzone and also ranges up into the overlying subzone. However, the absence of *Prohoplites* (*Prohoplites*) and *P.* (*Hemisonneratia*) and other species of *Otohoplites* characteristic of the *puzosianus* Subzone is important biostratigraphically. Casey (1961a) listed the following from the subzone in Kent: *Douvilleiceras mammillatum*, *D. monile*, *Beudanticeras newtoni*, *Otohoplites raulinianus* and *Pseudosonneratia* sp.

The subzone is known from west Kent (Casey, 1961a) and Leighton Buzzard (Owen, 1972) It is also known at Folkestone, Kent, where the zonal index species occurs with underlying *floridum* Subzone taxa.

3.1.5.2 *Protohoplites (Hemisonneratia) puzosianus* Total Range Subzone (Casey, 1961a)

The subzone is defined by the total range of *P.* (*H.*) *puzosianus*. *Protohoplites* (*Protohoplites*) *latisulcatus* has a similar range. Casey (1961a) listed a number of other taxa from the subzone in Kent, including *Douvilleiceras mammillatum*, *D. monile*, *D. orbignyi*, *Beudanticeras arduennense*, *Otohoplites elegans*, *Protohoplites* (*P.*) *archiacianus*, *P.* (*P.*) *michelinianus*, *P.* (*Hemisonneratia*) *gallicus*, *Tetrahoplites* cf. *subquadratus*, *Sonneratia dutempleana*, *Tegoceras gladiator*, *T. mosense* and *Protanisoceras cantianum*.

The subzone is recognised at Folkestone, Kent, from the Main Mammillatum Bed (Bed 33 of Casey, 1961a, pp.528–31) to the 'Sulphur Band' (Bed 35). It is also known from Ford Place Pit, Trotticliffe, Kent (Owen, 1988b).

3.1.5.3 *Otohoplites (Isohoplites) bulliensis* Total Range Subzone (Destombes, 1973)

Defined by the total range of *O.* (*I.*) *bulliensis*. Although recognised in northern France, the subzone is not well known in Britain. Between Sevenoaks, Kent, and Oxted, Surrey, poorly fossiliferous deposits characterise the stratigraphical succession between the *puzosianus* and *steinmanni* faunas. Owen (1988b) postulated that these poorly fossiliferous beds might belong to the *bulliensis* Subzone.

3.1.5.4 *Pseudosonneratia* (*Isohoplites*) *steinmanni* Total Range Subzone (Casey, 1961a, emended Owen, 1988b)

Defined by the total range of *P.* (*I.*) *steinmanni*. Casey (1961a) used *Hoplites* (*Isohoplites*) *eodentatus* as the subzonal index, but this proved to be a junior synonym of *P.* (*I.*) *steinmanni*. The subzone has often been placed at the base of the *Hoplites dentatus* Zone. However, Owen (1984, 1985, 1988b) regarded it as the highest part of the *mammillatum* Superzone, *auritiformis* Zone, although the zonal index (*Otohoplites auritiformis*) has not been recorded at this level.

Owen (1971, pp.52, 54) proved the *steinmanni* Subzone on the Isle of Wight and at Okeford Fitzpaine in Dorset. It can also be recognised in the Junction Beds at Leighton Buzzard (Owen, 1972).

3.1.6 *Hoplites (Hoplites) dentatus* Total Range Zone

Definition

The zone is defined by the total range of *H. (H.) dentatus*. It comprises the *L. lyelli* and *H. spathi* subzones.

Lithostratigraphy

The zone can be identified in Gault Beds G1 to basal G3 (sensu Gallois and Morter, 1982) in eastern England, and the lower part of Gault Bed I Price (1879, 1880) of southern

England. The Carstone is generally considered to be of Early Albian age, but in Hunstanton, at least, the *spathi* Subzone is recognised in the highest part of that formation and extends up into the base of the Hunstanton Formation (Bed HC-HC1). The zone disappears on the flanks of the London Platform.

3.1.6.1 *Lyelliceras lyelli* Total Range Subzone

The subzone is defined by the total range of the index species, although it may be very rare or absent in the very highest part. However, the subzone can also be indicated by the associated fauna, e.g. *Beudanticeras* spp., *Protanisoceras* spp., *Hoplites* (*Hoplites*) aff. *pseudodeluci* and abundant '*Ostrea*' *papyracea*. The index has not been found in East Anglia, but the associated fauna in Gault Bed G1 (Gallois and Morter, 1982) implies that the subzone is present. It is well preserved at Small Dole, Upper Beeding, Sussex (Owen, 1971, p.35), and the top of the subzone is seen at Caen Hill, near Devizes (Owen, 1971, p.60 and 122). Mitchell (1995) placed the highest part of the Speeton Clay within the *lyelli* Subzone. In southern England, it is confined to the basal part of Gault Bed I (Price, 1879, 1880).

3.1.6.2 *Hoplites* (*Hoplites*) *spathi* Total Range Subzone

The subzone is defined by the total range of *H.* (*H.*) *spathi*. *Birostrina concentrica* and *Neohibolites minimus* are common. The subzone is confined to the lower part of Bed I (Price, 1879, 1880) and Beds G2 and lower G3 (sensu Gallois and Morter, 1982). It is well seen at Small Dole, Upper Beeding, Sussex (Owen, 1971, p.35).

3.1.7 *Euhoplites loricatus* Partial Range Zone

Definition

The base of the zone is defined by the appearance of *E. loricatus*, and its upper boundary by the appearance of *Euhoplites lautus*. It almost corresponds to the total range of *E. loricatus*. It is divided into four subzones based on the ranges of *Anahoplites intermedius*, *Dimorphoplites niobe*, *Mojsisovicsia subdelaruei* and *Euhoplites meandrinus*.

Lithostratigraphy

The zone extends from the upper part of Gault Bed I to the top of Bed IV (Price, 1879, 1880) in southern England, and throughout much of Gault Bed G3 to the top of Bed G8 (sensu Gallois and Morter, 1982).

3.1.7.1 *Anahoplites intermedius* Total Range Subzone

Originally defined by Spath (1923). The base of the subzone coincides with the base of the *loricatus* Zone. The top of the subzone is characterised by an abrupt decline and then extinction of the *Anahoplites intermedius* group, which does not occur in the overlying subzone.

Euhoplites is diverse in the *A. intermedius* Subzone (e.g. *E. loricatus*, *E. microceras*, *E. subtabulatus* and *E. pricei*), and *Falciferella milbournei* may be locally abundant. A similar fauna has been recorded in East Anglia (Gallois and Morter, 1982), where bivalves are also common: *Anomia* cf. *carregozica*, *Birostrina concentrica braziliensis*, *Entolium orbiculare*, *Inoceramus* aff. *anglicus* and *Pseudolimea gaultina*.

The subzone spans from the upper part of Gault Bed I to the top of Gault Bed II (Price,1879, 1880) in southern England, and from the upper part of Gault Bed G3 to the top of Bed G5 (sensu Gallois and Morter, 1982) in East Anglia.

The best sequence displaying this subzone is at Folkestone (Owen, 1971, p.14). Though condensed, the section at Small Dole displays the lower and upper boundaries.

3.1.7.2 *Dimorphoplites niobe* Partial Range Subzone

Originally defined by Spath (1924). No species are restricted to the subzone, but it is recognised by the absence of *Anahoplites intermedius* and the presence of *A. planus* and *A. splendens* as well as the eponymous marker, *Dimophoplites niobe*. The upper boundary is defined by the first appearance of the genus *Mojsisovicsia*.

In southern England, the subzone occurs in Gault Bed III (Price,1879, 1880). The *niobe* Subzone is poorly known in East Anglia, but may be represented in Gault Bed G6 (sensu Gallois and Morter, 1982). The zone is present at a number of localities in southern England, notably Leighton Buzzard, Folkestone and Small Dole.

3.1.7.3 *Mojsisovicsia subdelaruei* Total Range Subzone

Although originally defined by Spath (1923), his concept of the subzone included the *meandrinus* Subzone. Owen (1971) showed that the base of the subzone can be defined by the first appearance of *M. subdelaruei*, which evolves into *M. remota* in the upper part of the subzone. The top of the subzone is defined by the last occurrence of *M. remota*, but as this species is rare in Britain, the development of *Euhoplites* and *Dimorphoplites* in the base of the overlying *meandrinus* Subzone provides a better criterion for recognition of the upper boundary.

The subzone is confined to Gault Bed IV (of Price, 1879, 1880) in southern England. In East Anglia, there is little evidence of the subzone, and the Tethyan genus *Mojsisovicsia* has not been found. However, *Dimorphoplites* cf. *pinax* has been recovered from a *Birostrina concentrica*-rich horizon at the base of Gault Bed G7 (Gallois and Morter, 1982), and this is interpreted as being indicative of the subzone.

Unlike most sections in Britain, uncondensed sequences occur at Ford Place, Wrotham (Owen, 1971, p.22) and Sevenoaks (Owen, 1971, p.25).

3.1.7.4 *Euhoplites meandrinus* Total Range Subzone

Owen (1960) defined this subzone. It is characterised by *E. meandrinus* and closely related forms such as *E. cantianus* and *E. beaneyi*, together with *Dimorphoplites doris* and *D. pinax*. The genus *Mojsisovicsia* is not present.

In southern England the subzone is confined to the base of Gault Bed V (of Price, 1879, 1880). In East Anglia, the subzone extends throughout most of Gault Bed G7 and to the top of Bed G8 (sensu Gallois and Morter, 1982), where it is accompanied by common *Hamites* sp., *Entolium orbiculare* and *Hemiaster* sp. It is present at Small Dole, (Owen, 1971, p.40), but in other areas it is condensed and sometimes represented by a nodule horizon.

3.1.8 *Euhoplites lautus* Partial Range Zone

Definition

The base is characterised by the appearance of species of *Euhoplites* with a channelled venter, but they are rare or absent at the top of the zone, and the upper boundary is more readily defined by the appearance of markers of the overlying zone. The zone almost coincides with the total range of *E. lautus*. The zone is divided into two subzones based on the distribution of *Euhoplites nitidus* and *Anahoplites daviesi*.

Lithostratigraphy

Gault Bed V (above the basal nodule bed) to the top of Bed VII (Price,1879, 1880) in southern England, and Gault Beds G9 and G10 (Gallois and Morter, 1982) in East Anglia.

3.1.8.1 *Euhoplites nitidus* Total Range Subzone

Although originally defined by Spath (1923), there was some confusion in the interpretation (as outlined by Owen, 1971). The base is defined by the appearance of species of *Euhoplites* with a channelled venter (e.g. *E. lautus*, *E. nitidus*), and the upper boundary is defined by the first appearance of the index species of the overlying subzone. The fauna of the *nitidus* subzone was discussed by Owen 1958, 1971; Hancock, 1965)

The subzone spans Gault Bed V (immediately above the basal nodule bed), Bed VI and the lower part of Bed VII (of Price, 1879, 1880) in southern England. In East Anglia it is poorly developed, but rare *Euhoplites* of the *nitidus* group have been found in Gault Bed G9 and G10 (sensu Gallois and Morter, 1982).

3.1.8.2 *Anahoplites daviesi* Total Range Subzone

This subzone, originally described by Spath (1925), is characterised by the *Anahoplites daviesi* group (Owen 1958, 1971; Hancock, 1965). It is confined to the top of Gault Bed VII (Price, 1879, 1880) in southern England, where it is best developed at Folkestone.

The subzone is unknown in East Anglia. A fauna characteristic of the *A. davies:* Subzone has been recorded, but is not in situ, having been eroded and reworked into the nodule horizon at the base of the *Mortoniceras inflatum* Zone.

3.1.9 *Mortoniceras inflatum* Total Range Zone

Definition

The base of the zone is defined by the first appearance of the *Diploceras cristatum* group, *Mortoniceras* spp. and *Hysteroceras* s.s. sp. Its upper boundary is marked by the first appearance of *Stoliczkaia*. It is divided into four subzones based on the ranges of *Diploceras cristatum*, *Hysteroceras orbignyi*, *H. varicosum* and *Callihoplites auritus*.

Lithostratigraphy

The zone extends from the base of Gault Bed VIII to the top of Bed XI (of Price, 1879, 1880) in southern England, and from Gault Beds G11 to G16 (sensu Gallois and Morter, 1982) in East Anglia. In some areas in the region around Cambridge, erosion prior to the accumulation of the Cambridge Greensand and Chalk has removed the Gault down to Bed G16.

3.1.9.1 *Diploceras cristatum* Assemblage Subzone

The base of the subzone is recognised by the appearance of *Mortoniceras* and *Diploceras* such as *D. cristatum* and *D. bouchardianum*. The bivalve *Birostrina sulcata* also occurs. The top of the subzone is defined by the appearance of marker species for the overlying subzone, *Euhoplites inornatus*.

The *D. cristatum* Subzone in southern England extends from the erosion surface with phosphatic nodules at the base of Gault Bed VIII (of Price, 1879, 1880) to the middle of Bed IX, which, at Folkestone, is marked by a phosphatic nodule horizon. In East Anglia the subzone is confined to the lower and middle parts of Gault Bed G11, the base of which is an erosion surface.

3.1.9.2 *Hysteroceras orbignyi* Assemblage Subzone

The base of the *orbignyi* Subzone is recognised by the appearance of *Euhoplites inornatus*. *Hysteroceras* becomes common at the same level. The bivalve *Birostrina sulcata* is characteristic of the subzone. *Birostrina concentrica gryphaeoides* and *Inoceramus anglicus* are common at some levels. The belemnite *Neohibolites minimus* is present in the lower part of the subzone, but is largely replaced by *Neohibolites oxycaudatus* within the subzone. *Hamites* is similarly replaced by *Idiohamites*.

In terms of the bed notation for southern England (Price, 1879, 1880), the subzone is restricted to the upper part of Gault Bed IX. In East Anglia, it comprises the upper part of Gault Bed G11, and the whole of G12 and G13 (Gallois and Morter, 1982).

3.1.9.3 Hysteroceras varicosum Assemblage Subzone

The ammonite fauna diversifies in this subzone. In addition *Birostrina concentrica* is present.

In East Anglia, the subzone is divided into two (Gallois and Morter, 1982). The lower part of the subzone, in the lower part of Gault Bed 14 (of Gallois and Morter, 1982), contains an ammonite fauna similar to that of the Leighton Buzzard area (Owen, 1972), with common species of *Euhoplites* and *Hysteroceras* including *Hysteroceras varicosum*. Bivalves are common, particularly *Birostrina* cf. *concentrica*, but also *Moutonithyris dutempleana* and *Inoceramus* cf. *anglicus*. Belemnites are very common (*Neohibloites ernsti*, *N. oxycaudatus* and rare late morphs of *N. minimus*).

The upper part of the subzone, the upper part of Gault Bed G14 (of Gallois and Morter, 1982), is rich in belemnites including *Neohibolites ernsti*, *N. oxycaudatus* and *N. praeultimus*. *Euhoplites alphalautus*, *Hysteroceras*, *Idiohamites*, *Mortoniceras* and *Semenovites* are present, although the subzonal index is not found. The rest of the fauna is less diverse than that in the lower part of the subzone, but includes *Birostrina concentrica*, '*Inoceramus*' *anglicus*, common *Pycnodonte* (*Phygraea*) aff. *vesicularis* and *Inoceramus lissa*.

3.1.9.4 *Callihoplites auritus* Total Range Subzone

The subzone is defined by the occurrence of *Callihoplites auritus*. *Aucellina gryphaeoides* replaces *Birostrina concentrica* as the most dominant bivalve. In East Anglia, the subzone extends from the upper part of Gault Bed G14 to the top of Bed G16 (of Gallois and Morter, 1982). In southern England, it ranges through Bed XI (of Price, 1879, 1880).

Gallois and Morter (1982) divided the subzone into two in East Anglia. The lower part of the subzone, encompassing the upper part of Bed G14 and the whole of Bed G15, is characterised by abundant fragments of the bivalve *Inoceramus lissa*. This species is particularly abundant in the 'Barnwell Hard Band' at the base of Bed G15 (Fearnsides, 1904; Gallois and Morter, 1982). This part of the subzone contains a diverse *Callihoplites* fauna, including *C. auritus*, *Hysteroceras*, *Lepthoplites*, *Mortoniceras*, *Prohysteroceras* and *Stomohamites*, as well as belemnites (dominated by *Neohibolites praeultimus*) and bivalves (including *Moutonithyris dutempleana*, *Kingena spinulosa*, *Entolium orbiculare*, *Birostrina* cf. *concentrica* and abundant *Inoceramus lissa*).

The upper part of the subzone occurs in Bed G16, where *C. auritus* has not been found, above a shelly phosphatic pebble bed (the Milton Brachiopod Bed) rich in *Moutonithyris dutempleana*. The fauna is transitional between that from the lower part of the subzone and the fauna from the overlying *dispar* Zone.

3.1.10 *Stoliczkaia dispar* Total Range Zone

Definition

The base of the zone is defined by the first appearance of *Stoliczkaia*. The zone extends up to the first appearance of the Cenomanian genus *Mantelliceras*. The zone is divided into two subzones based on the ranges of *Mortoniceras* (*Mortoniceras*) *rostratum* and *Mortoniceras* (*Durnovarites*) *perinflatum* (Spath, 1923–43, emended Owen, 1976).

Lithostratigraphy

The zone extends from the phosphatic nodule horizon at the base of the highly glauconitic mudstone of Bed XII (informally the 'Green Streak') to the Gault/Glauconitic Marl boundary at the top of Bed XIII (of Price, 1879, 1880). In East Anglia, the zone extends throughout Bed G17 and G18 (and locally into Bed G19), but the highest part of the Gault has been removed by erosion so that the top of the formation is locally within the *Mortoniceras rostratum* Subzone.

Around Cambridge, where it is developed more fully, the base of the Cambridge Greensand is of Albian age, although the bulk of that deposit accumulated during the Cenomanian. In some areas of eastern England, erosion prior to accumulation of the Cambridge Greensand and Chalk removed the *Stoliczkaia dispar* Zone, as well as the top of the underlying zone (in Bed G16).

3.1.10.1 *Mortoniceras* (*Mortoniceras*) *rostratum* Total Range Subzone

The base of the subzone is recognised by the occurrence of *Stoliczkaia dispar*, *M.* (*M.*) *rostratum* and *M.* (*M.*) *alstonensis*, which are generally common, together with rare *Stoliczkaia* (*Faraudiella*). The subzone's eponymous index is confined to the lower part of the *dispar* Zone.

Other taxa present in the subzone include *Callihoplites* (including rare *C. glossonotus*), *Pleurohoplites*, *Lepthoplites*, *Anisoceras* and *Idiohamites*. In East Anglia, *Aucellina coquandiana* is abundant and *Neohibolites* is also frequently found. *Globigerinelloides bentonensis* occurs in flood abundance in both Bed G17 and Bed XII.

The subzone is not well constrained in East Anglia, but is believed to extend through Beds G17 and G18 (and locally into G19). Bed G17 of East Anglia is believed to be coeval with Bed XII of southern England. In southern England, the subzone occurs in the lower part of Bed XIII, but it is not possible to locate its top with accuracy.

3.1.10.2 *Mortoniceras* (*Durnovarites*) *perinflatum* Total(?) Range Subzone

The base of the subzone is defined by the first appearance of *Mortoniceras* (*Durnovarites*) *perinflatum*. However, the subzone has a sparse ammonite fauna, so the exact position of the base is uncertain. The subzone occurs in the upper part of Bed XIII in southern England. It has not been recognised in East Anglia.

According to Gale et al. (1996), the top of the *perinflatum* Subzone and the succeding *Arrhaphoceras* (*P.*) *briacensis* Subzone of France and northern Germany are not present in Britain, having been removed by erosion prior to the accumulation of Cenomanian deposits.

3.1.11 Selected references

Casey, 1954, 1961a; Gale et al., 1996; Gallois and Morter, 1982; Kennedy, 2000; Mitchell, 1995; Owen, 1971, 1972, 1976, 1984b, 1988b; Price, 1879, 1880; Shepherd, 1934; Spath, 1923–49; Wright and Wright, 1942.

3.2 BELEMNITE BIOSTRATIGRAPHY

Much of the early work on Albian belemnites was taxonomic, and the stratigraphical occurrences were not documented in detail. The zonation below follows work by Spaeth (1973) and Mutterlose (1990). Five zones based on *Neohibolites* can be recognised in the Albian of north-west Europe, although not all have been recognised with confidence in Britain.

3.2.1 *Neohibolites strombecki* Partial Range Zone

Definition

The base of the zone is defined by the appearance of *Neohibolites strombecki*, and its top is identified by the appearance of *Neohibolites minor*.

Correlation

Proleymeriella schrammeni Zone and *Leymeriella tardefurcata* Zone (*farnhamensis* and *millitioides* subzones sensu Casey, 1961).

Comments

No satisfactory records exist for this species being present in Britain.

3.2.2 *Neohibolites minor* Partial Range Zone

Definition

The base of the zone is defined by the inception of *Neohibolites minor*. Its top is defined by the inception of the succeeding index species.

Correlation

Upper *tardefurcata* Zone to *chalensis* Zone (Mutterlose, 1990).

Comments

There are no satisfactory records of *N. minor* from Britain. Although there is a possibility that it reaches Britain in the middle *chalensis* zone, this cannot be proved.

Bioevents

The extinction of *N. strombecki* takes place within the basal part of the *N. minor* Zone.

3.2.3 *Neohibolites minimus* Partial Range Zone

Definition

The base of the zone is defined by the inception of *Neohibolites minimus*. Its top is characterised by the inception of the succeeding index species.

Correlation

auritiformis to *lautus* zones

Lithostratigraphy

Gault Beds G1–G10 and I–VII, Hunstanton Formation Bed HC1 and HC2 and equivalents, Speeton Clay Beds A2 to A3.

Bioevents

According to Spaeth (1973) three subzones can be recognised on the total ranges of the three subspecies, *N. minimus pinguis*, *N. minimus minimus* and *N. minimus obtusus*. The extinction of *N. minor* is within the basal part of the *Neohibolites minimus* Partial Range Zone.

3.2.4 *Neohibolites oxycaudatus* Partial Range Zone

Definition

The base of the zone is defined by the inception of *Neohibolites oxycaudatus*. Its top is characterised by the inception of the succeeding index species.

Correlation

This is with the *inflatum* Zone (*cristatum* and *orbignyi* subzones) according to Mutterlose (1990). In Britain, it presence below the *orbignyi* Subzone is questionable.

Lithostratigraphy

Gault Beds (G11) G12 and (VIII)–IX, Hunstanton Formation Beds HC3–5.

Bioevents

N. minimus becomes extinct in the lower part of the *N. oxycaudatus* Zone and *N. ernsti* appears in the upper part of the *N. oxycaudatus* Zone.

3.2.5 *Neohibolites praeultimus* Total Range Zone

Definition

The zone is defined by the range of *N. praeultimus*.

Correlation

With the *inflatum* Zone (upper *orbignyi*, *varicosum* and *auritus* subzones) and *dispar* Zone.

Lithostratigraphy

Gault Beds G13–19 and top IX–XIII, Hunstanton Formation Beds HC8 (upper part) — HC11 and the Speeton Beck, Dulcey Dock, Weather Castle member and into Cenomanian deposits.

Bioevents

The extinction of *N. ernsti* is within the lower part of the *N. praeultimus* Zone. Unlike the range given by Mutterlose (1990), the zone has been traced to the top of the Albian and into the Cenomanian. In Yorkshire, the base of the zone is in the Speeton Beck Member of the Hunstanton Formation (upper *orbignyi* Zone) (Mitchell, 1995).

3.2.6 Selected references

Mitchell, 1995; Mutterlose, 1990; Spaeth, 1973.

3.3 CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY

There has been a great deal of research on Albian nannofossils, both internationally and in the British succession, the latter concentrated on the Speeton Clay, Gault and offshore in the North Sea Basin. The Gault and A Beds of the Speeton Clay have yielded numerous and diverse floras, but the coeval Hunstanton Chalk has yielded only sparse associations. Much of the work has been taxonomic. Black (1972, 1973, 1975) described floras from the Gault; Thierstein (1971, 1973) compared assemblages from the Gault of south-eastern England and the Tethyan region; and the flora from the Gault of Munday's Hill, near Leighton Buzzard, was described by Crux (1991). Taylor (1982) discussed British nannofossil biostratigraphy, Jakubowski (1987) considered the zonal sequence in the Moray Firth area of the North Sea Basin, and a summary of the bioevents recognised in the North Sea was given by Hine (in Wilkinson et al., 1993, 1994).

A biostratigraphical zonation for the Albian published by Jeremiah (1996) incorporated data from southern and eastern England, the southern North Sea Basin, France and Germany. The fifteen zones were correlated with the standard macrofaunal zonation. Jeremiah (2001) introduced a nannofossil zonation for the Lower Cretaceous of the North Sea Basin as a whole, but used mainly the Speeton section onshore to recognise eight Albian zones. The two zonations of Jeremiah are very similar for the Albian, although the numbering of the zones is different, those erected in 1996 being numbered from the base up, whereas those of 2001 are numbered from the top down. Bown et al. (1998) utilised the findings of Crux (1991) and Jeremiah (1996), modifying them to produce a biostratigraphical zonation that was more global in scope. Biostratigraphical data from Britain were incorporated into the broader zonal schemes of Sissingh (1977), Taylor (1978a) and Perch-Nielsen (1979). The zonation used herein is based principally on those of Jeremiah (1996, 2001).

3.3.1 *Rhagidiscus asper* Interval Zone

Definition

Although the authors listed here all agree that the zone exists, they recognise it in different ways, and there appears to be some difference of opinion regarding the ranges of the key species used to define the zone. It equates with *Bukrylithus ambiguus* Zone (NLK 6) (Jakubowski, 1987), NAL1 (Jeremiah, 1996) and SK8B (Jeremiah, 2001).

The base of the zone is often obscured by non-calcareous nature of the succession. Bown recognised the base by the presence of *Prediscosphaera colomnata*, but Jeremiah (1996, 2001) shows the inception of this species to be stratigraphically higher. Jeremiah (2001) states that an influx of *Repagulum parvidentatum*, *Acaenolithus galloisii* and *Tegumentum stradneri* is a characteristic of the basal part of Rødby R1 and Speeton LA1, but as the first is Mid Albian in age and the second is *regularis* in age, it is difficult to define a zone by their occurrence. Jeremiah also shows *Acaenolithus viriosus*, the index for NAL 2 (Jeremiah, 1996) (= LK8A of Jeremiah, 2001) to be in LK8B (Jeremiah, 2001) (= NAL1 of Jeremiah 1996). Due to this conflict, the base of the zone is herein placed at the last occurrence of abundant *Rhagidiscus asper* at the base of the *tardefurcata* Zone (and possibly within the highest part of the Aptian, see below).

The top is recognised by the appearance of the species charateristic of the overlying zone, with an influx of abundant *Seribiscutum primitivum* and *Tegumentum stradneri*.

Correlation

The base of the zone is in the *tardefurcata* Zone in Britain.

Lithostratigraphy

Speeton Clay (equivalent to Bed A5 according to Jeremiah, 1996, and LA1 according to Jeremiah, 2001) and Carrack Formation (Jeremiah, 1996, 2001).

Bioevents

Jeremiah (1996, 2001) considered *Rhagodiscus asper* to become greatly reduced in numbers in the Early Albian, and used this bioevent to correlate dark grey mudstones in Shell-Esso Borehole 49/25a-9 with the lower part of Speeton Clay Bed A5. Bown et al. (1998) indicated that the top of the acme of *R. asper* is in the Upper Aptian (the *nutfieldiensis* Zone), but in the *schrammeni* Zone according to Jeremiah (2001) (N.B. Jeremiah, 2001, considered the *schrammeni* Zone to be in the basal Albian).

3.3.2 *Seribiscutum primitivum-Acaenolithus viriosus* Concurrent Range Zone

Definition

The base of the zone is defined by the inception of *S. primitivum*, and its top is at the extinction of *A. viriosus*. The zone equates with NAL2 (Jeremiah, 1996) and LK8A (Jeremiah, 2001).

Correlation

The zone equates with the late *regularis* Zone to the *bulliensis* Subzone of the *auritiformis* Zone (Jeremiah, 2001).

Lithostratigraphy

Mudstone at Chamberlain's Barn, near Leighton Buzzard, and the Speeton Clay of West Heslerton No. 2 Borehole (Jeremiah, 1996, 2001).

Bioevents

Jeremiah (1996, 2001) considered the first appearance datum (FAD) of *Acaenolithus viriosus* to be in the Early Albian, and further considered it to be a characteristic element of the Speeton Clay in the Heslerton No. 2 borehole and the Speeton coastal section, as well as contemporaneous deposits in Germany. Kennedy et al. (2000) recorded it immediately below the base of the *mammilatum* Superzone in the Tethyan region. Its extinction at or near the top of the *bulliensis* ammonite Subzone is a useful bioistratigraphical event. However, it should be noted that Bown et al. (1998) recorded it in the uppermost Aptian (upper part of the *jacobi* Zone).

3.3.3 *Acaenolithus viriosus-Crucicribrum anglicum* Interregnum Zone

Definition

The base of the zone is defined by the last appearance datum (LAD) of *A. viriosus*. Its top is placed at the inception (FAD) of the succeeding index species, *Crucicribrum anglicum*, together with *Tranolithus phacelosus* and *Ceratolithina cruxii*. The zone equates with NAL3 of Jeremiah (1996) and LK7B of Jeremiah (2001).

Correlation

auritiformis Zone (*steinmanni* Subzone and questionably the uppermost *bulliensis* Subzone)

Lithostratigraphy

Minimus Marl (Bed A3) of Speeton, and the Junction Beds of Chamberlain's Barn Pit (Jeremiah, 1996, 2001).

Bioevents

This zone is used here in the sense of Jeremiah's *Crucicribrum anglicum* interregnum Zone (1996) and LK7B (2001). The base of the zone is an event that is used by Thierstein (1976), Sissingh (1977), Perch-Nielsen (1979, 1983), Jakubowski (1987) and Jeremiah (1996, 2001). The FAD of consistent *Prediscosphaera colomnata* occurs at the base of the zone.

3.3.4 *Crucicribrum anglicum-Braloweria boletiformis* Concurrent Range Zone

Definition

The zone is defined by the FAD of *Crucicribrum anglicum* (together with *Tranolithus phacelosus* and *Ceratolithina cruxii*) and the LAD of *Braloweria boletiformis*. It equates with NAL4 of Jeremiah (1996), the *T. orianatus* Zone of Bown et al. (1998) and LK7A of Jeremiah (2001).

Correlation

Mid Albian: *dentatus* Zone (*lyelli* Subzone) to early *loricatus* Zone (*niobe* Subzone).

Lithostratigraphy

Gault Beds I to III and G1 to G6 of southern and eastern England; Upper Speeton Clay and Lower Queen Rocks Member of the Hunstanton Formation in Yorkshire; lower Rødby Formation of the North Sea Basin.

Bioevents

Braloweria boletiformis disappears from the record at the *niobe/subdelaruei* subzonal boundary (*loricatus* Zone) (Jeremiah, 1996). The inceptions of *Ceratolithina cruxii* and *Crucicribrum anglicum* are at the base of the zone. The first upsequence occurrence of common and consistent *Tranolithus phacelosus* is at the base of the zone (it is rare in the underlying zone) (Jeremiah, 1996, 2001).

3.3.5 *Braloweria boletiformis-Axopodorhabdus albianus* Interregnum Zone

Definition

Between the extinction of of *B. boletiformis* and the first upsequence occurrence of consistent *A. albianus* and *Ceratolithina bicornuta*. The zone equates with the lower part of NAL5 of Jeremiah (1996) and LK6B of Jeremiah (2001).

Correlation

loricatus Zone (*subdelaruei* Subzone)

Lithostratigraphy

Gault Formation Bed IV and Bed 7. Rarely seen in the Rødby Formation of the North Sea Basin due to condensation (Jeremiah, 1996, 2001).

3.3.6 *Axopodorhabdus albianus–Ceratolithina bicornuta* Concurrent Range Zone

Definition

The base of the zone is defined by the first upsequence appearance of consistent *A. albianus* and *Ceratolithina bicornuta*. Its top is defined by the extinction of *C. bicornuta* and the appearance of the succeeding zonal index. The zone equates with LK6A of Jeremiah (2001) and the upper part of NAL5 to NAL6 of Jeremiah (1996).

Correlation

loricatus Zone (*meandrinus* Subzone) to *lautus* Zone (*daviesi* Subzone) (Jeremiah, 2001)

Lithostratigraphy

Recognised in Gault Beds IV to VIII of south-eastern England and G10 of East Anglia. Rare in the Rødby Formation of the North Sea Basin.

Bioevents

A. albianus has been used as a zonal marker by Cepek and Hay (1969), Thierstein (1976) and Roth (1978). The zone is equivalent to subzone NC9A of Bralower et al. (1993). The zonal concept of Bown et al. (1998) is based on the first occurrence of *A. albianus*, but in the early part of its range the species is very rare and patchily distributed, reducing its usefulness. *Ceratolithina hamata* and *Owenia hillii* have FADs within the zone.

3.3.7 *Ceratolithina bicornuta-Tegulalithus tessellatus* Interregnum Zone

Definition

Defined by the last appearrance of *Ceratolithina bicornuta* and the inceptions of *Tegulalithus tessellatus* and *Gartnerago praeobliquum*. The zone equates with NAL7 (Jeremiah, 1996) and LK5B (Jeremiah, 2001).

Correlation

Late Albian: early *inflatum* Zone (*cristatum* to *varicosum* subzones).

Lithostratigraphy

Gault Beds VIII-X and G11 to G14. Also recognised in the upper part of the Queens Rocks, Speeton Beck and lower part of the Dulcey Dock members of the Hunstanton Formation in Yorkshire.

Bioevents

The upper boundary coincides with the LAD of abundant *Axopodorhabdus albianus* and the FAD of abundant *Rhagodiscus splendens*. Crux (1991) considered the inception of *Owenia hilli* at the base of the Upper Albian (*cristatum* Subzone) to be biostratigraphically useful, but it was shown to have its inception at the base of the *lautus* Zone by Bown et al. (1998). *Braarudosphaera primula* and *B. quinqecostata* are common or abundant in the *orbignyi* and *varicosum* subzones of Yorkshire, East Anglia and the southern North Sea.

3.3.8 *Tegulalithus tesselatus* Acme Zone

Definition

The first up-section ocurrence of *Tegulalithus tesselatus* marks the base of the zone, and the last appearance of abundant *Tegulalithus tesselatus* together with the FAD of *Staurolithus angustus* marks the top. The zone equates with NAL8 of Jeremiah (1996) and LK5A of Jeremiah (2001).

Correlation

Late Albian: late *inflatum* Zone (early part of the *auritus* Subzone).

Lithostratigraphy

Gault Beds XI and G15; lower Dulcey Dock Member of the Hunstanton Formation in Yorkshire.

Bioevents

The inception of *Gartnerago praeobliquum* occurs at the base of the zone. In the North Sea, *Tegulalithus tesselatus* is restricted to the zone, but onshore very rare occurrences have been recorded through to the top of the *auritus* Subzone. It forms a characteristic assemblage at Folkestone, Munday's Hill, Burwell as well as in northern France (Jeremiah, 1996, 2001).

3.3.9 *Staurolithus angustus* Partial Range Zone

Definition

The base is recognised by the FAD of the eponymous index and the last occurrence of common *Tegulalithus tessellatus*. The top is defined by the appearance of the superadjacent zonal index *Eiffellithus monechiae* and *E. turriseiffeli*. It equates with NAL9 of Jeremiah (1996) and LK4B of Jeremiah (2001).

Correlation

Late Albian: late *inflatum* Zone ('mid' *auritus* Subzone).

Lithostratigraphy

Gault Beds XI and G16, and the Rødby Formation of the North Sea Basin.

Bioevents

Radiolithus hollandicus appears at the base of the zone. The LAD of *Braarudosphaera stenorhetha* is within the zone in the southern North Sea Basin. Also in the Southern North Sea Basin, *S. angustus* is confined to the zone, but onshore it extends up into the late *auritus* Zone and the contemporaneous nannofossil zone (Jeremiah, 1996, 2001). *Eiffellithus monechiae* appears for the first time in the uppermost part of the zone at Munday's Hill, Bedfordshire (Crux, 1991, Jeremiah, 1996, 2001), at a horizon that is generally very condensed in the North Sea Basin, and often removed by erosion onshore (e.g. at Folkestone, South Ferriby and Speeton). For this reason, the FAD of *E. monechiae* is often at the base of the overlying zone.

3.3.10 *Eiffellithus turriseiffeli* Partial Range Zone

Definition

The base of the zone is defined by the FAD of *Eiffellithus turriseiffeli*, and its top by the LAD of abundant *Eiffelithus monchiae* and the FAD of the superadjacent index species. The zone equates with NAL10–11 and LK4A of Jeremiah (1996 and 2001 respectively).

Correlation

Late Albian: late *inflatum* Zone (late *auritus* Subzone) to earliest *dispar* Zone (earliest *rostratum* Subzone).

Lithostratigraphy

Gault Beds XI–XII and G16–17; Hunstanton Formation (Dulcey Dock Member) of Speeton, Yorkshire.

Bioevents

Eiffellithus monechiae becomes abundant at the base of the zone (but see the comments relating to the underlying zone) and is often a better index for the base of the zone than the rarer *E. turriseiffelii*. The evolutionary sequence leading to the inception of *E. turriseiffeli* has been used as a biostratigraphical marker event by a number of authors (Roth, 1973; Thierstein, 1976; Sissingh, 1977; Taylor, 1982; Jakubowski, 1987; Jeremiah, 1996). *Bownia glabra*, which is common throughout much of the Albian becomes rare and *Tegulalithus tessellatus* disappears in the basal part of the zone.

3.3.11 *Radiolithus hollandicus* Partial Range Zone

Definition

The base of the zone is defined by the disappearance of abundant *E. monechiae*, and appearance of common *Eiffellithus turriseiffeli*. Its top is recognised by the extinction of the eponymous index species. The zone equates to LK3 of Jeremiah (2001) and NAL12 of Jeremiah (1996).

Correlation

Upper Albian, *dispar* Zone ('mid' *rostratum* Subzone).

Lithostratigraphy

Onshore, the zone occurs in uppermost part of Gault Bed XII and the lower part of Bed XIII, and in Beds 18–19. It occurs in the Rødby Formation of the North Sea Basin (Jeremiah, 1996).

Bioevents

The FADs of *Crucibiscutum hayii* and *Staurolithites rotatus* are at or close to the base of the zone.

3.3.12 *Gartnerago praeobliquum* Acme Zone

Definition

The acme of *Gartnerago praeobliquum* between the LAD of abundant *Radiolithus hollandicus*, and the FADs of *Gartnerago theta/nanum*, *G. chiasta* and abundant *Broinsonia enormis*. The zone equates with NAL13 of Jeremiah (1996) and LK2 of Jeremiah (2001).

Correlation

Late Albian *dispar* Zone (late *rostratum–perinflatum* subzones).

Lithostratigraphy

Gault Bed XIII, glauconitic marl of southern England and, offshore, the Rødby Formation in the southern North Sea Basin (Jeremiah, 1996, 2001). In Yorkshire the zone is recognised in the uppermost Dulcey Dock Member and the Albian part of the Weather Castle Member of the Hunstanton Formation (Jeremiah, 2001).

Bioevents

The last appearance of *Hayesites albiensis* is in the lower part of the zone.

3.3.13 *Broinsonia enormis* Acme Zone

Definition

The base of the zone is defined by the FAD of abundant *Broinsonia enormis* together with the presence of *Gartnerago theta/nanum* (Jeremiah, 1996, 2001). The zone equates with the LK1 of Jeremiah (2001).

Correlation

Latest Albian: uppermost *dispar* Zone (uppermost *perinflatum* Subzone) extending into the Cenomanian in southern France (Gale et al., 1996; Jeremiah 1996, 2001). However, in Britain and the North Sea the base of the zone marks the base of the Cenomanian.

Lithostratigraphy

Chalk Group and the Cenomanian part of the Weather Castle Member and Red Cliff Hole Member of the Hunstanton Formation in Yorkshire (Jeremiah 1996, 2001).

Bioevents

The FADs of *Gartnerago theta*, *G. nanum* and *G. chiasta* occur at the base of the zone. On the continent, *Calculites anfractus* first appears in the Upper Albian, uppermost *dispar* Zone (upper part of the *briacensis* Subzone), but this horizon is missing in Britain and its first occurrence is in the base of the Cenomanian in the earliest *mantelli* Zone (*carcitanense* Subzone) (Gale et al., 1996, Jeremiah, 1996, 2001; Bown et al., 1998).

3.3.14 Selected references

Black, 1972, 1973, 1975; Bown et al., 1998; Crux, 1991; Gale et al., 1996; Hine (in Wilkinson et al.) 1993, 1994; Jakubowski, 1987; Jeremiah, 1996, 2001; Kennedy et al., 2000; Perch-Nielsen, 1979; Sissingh, 1977; Taylor, 1978, 1982; Thierstein, 1971, 1973.

3.4 DINOFLAGELLATE CYST BIOSTRATIGRAPHY

The dinoflagellate cyst zonal scheme is based on a very few publications. There is a large amount of unpublished data, but much of it was collected for commercial reasons and remains confidential. Cookson and Hughes (1964), reinterpreted by Davey and Verdier (1973), examined floras from Upper Albian to Lower Cenomanian of Cambridgeshire, and Duxbury (1983) discussed dinoflagellate cysts from the Aptian to Lower Albian (Lower Greensand) of the Isle of Wight. Heilmann-Clausen described floras from the Danish Central Trough and there have been a number of regional studies that incorporated the Albian, including those by Duxbury (1978) and Williams and Bujak (1985). Costa and Davey (1992) summarised the information available for the Albian and showed the distribution of key dinoflagellate cysts through the stage. Riding (in Wilkinson et al., 1993, 1994) showed a series of biomarkers that have biostratigrapghical significance in the sedimentary succession in the North Sea Basin.

3.4.1 *Pterodinium aliferum-Xenasculus ceratioides* Concurrent Range Zone

Definition

The zone is defined by the inception of *Xenasculus ceratioides* at the base of the Albian. Its top is defined by the extinction of *Pterodinium aliferum*.

Correlation

tardefurcata to *auritiformis* zones

Lithostratigraphy

Lower Greensand

Bioevents

Two key species make their first appearance at the base of the Albian: *Xenasculus ceratioides* and *Kleithriasphaeridium loffrense*. A further species, *Litosphaeridium arundum* has its inception a little above the base, within the *regularis* Zone

The top of the *tardefurcata* Zone coincides with the extinction of seven species which originate in the Aptian: *Dingodinium albertii*, *Discorsia nanna*, *Hystrichosphaerina schindewolfi*, *Kleithiasphaeridium simplicispinum*, *Meiourogonyaulax stoverii*, *Occisucysta tentorium* and *Subtilisphaera perlucida*. *Surculosphaeridium trunculum* is a long-ranging species, but becomes extinct at or immediately below the upper boundary of the *mammillatum* Superzone. These key species permit a subdivision of the dinoflagellate zone into two subzones.

3.4.1.1 *Kleithriasphaeridium loffrense-Subtilisphaera perlucida* Concurrent Range Subzone

The base of the subzone is defined by the inception of *Kleithriasphaeridium loffrense*, together with *Xenasculus ceratioides*. Its top (and the base of the overlying *trunculum* Subzone) is marked by the extinction of *Subtilisphaera perlucida* and the other six species listed above.

3.4.1.2 *Surculosphaeridium trunculum* Partial range Subzone

The top of the subzone is defined by the extinction of *Surculosphaeridium trunculum* and the inception of indices of the overlying zone.

3.4.2 *Sytematophora cretacea* Total Range Zone

Definition

Defined by the total range of *Systematophora cretacea*.

Correlation

Mid Albian

Lithostratigraphy

Gault

Bioevents

Stephodinium coronatum has its inception at the same level as *Systematophora cretacea*, but extends up into the Upper Cretaceous. *Muderongia asymmetrica* and *Ovoidinioum diversum* become extinct at the top of the zone and are thus useful supplementary indices for the upper boundary.

The extinction of *Kleithriasphaeridium*? *sarmentum* and the abrupt reduction in numbers of *Carpodinium granulataum* in the middle part of the zone (at the top of the *dentatus* Zone) are potentially of subzonal importance. The inception of *Carpodinium obliquicostatum* and *Isabelidinium gallium* near the top of the zone (at the base of the *lautus* Zone), together with the continued occurrence of *S. cretacea*, also has potential at the subzonal level. As a result, three subzones are identified within the zone.

3.4.2.1 *Stephodinium coronatum-Kleithriasphaeridium sarmentum* Concurrent Range Subzone

The lowest subzone is defined by the inception of *Stephodinium coronatum* (at the base of the *dentatus* Zone) and the extinction of *Kleithriasphaeridium sarmentum* (at the top of the *dentatus* Zone).

3.4.2.2 Un-named subzone

This interval (of the *loricatus* Zone) lacks diagnostic dinoflagellate cysts and is defined by the top and base of the underlying and overlying subzones.

3.4.2.3 *Isabelidinium gallium-Muderongia asymmetrica* Concurrent Range Subzone

The top subzone is defined by the inception of *Isabelidinium gallium* (at the base of the *lautus* Zone) and the extinction of *Muderongia asymmetrica* (at the top of the *lautus* Zone).

3.4.3 *Pervosphaeridium truncatum* Total Range Zone

Definition

The zone is defined by the range of *P. truncatum*.

Correlation

Late Albian

Lithostratigraphy

Gault

Bioevents

The base of the *truncatum* dinoflagellate Zone (correlating with the base of the *inflatum* Zone) is characterised by the first appearance of the eponymous index together with *Coronifera striolata*, *Ellipsodinium rugulosum*, *Litosphaeridium conispinum* and *Psaligonyaulax deflandrei*. The top of the zone is marked by the extinction of *Ellipsoidictyum imperfectum*, *Endoceratium turneri*, *Gonyaulacysta helicoidea*, *Ovoidinium scabrosum* and the zonal index.

The zone can be divided into a lower *Litosphaeridium conispinum* Total Range Subzone and an upper *Ovoidinium verrucosum–Pervosphaeridium truncatum* Concurrent Range Subzone.

3.4.3.1 *Litosphaeridium conispinum* Total Range Subzone

The lower subzone is defined by the total range of the index, *Litosphaeridium conispinum*, which is confined to the *cristatum* macrofaunal Zone. The extinction of the index species, at the top of the *inflatum* macrofaunal Zone, coincides with the exinction of several other species: *Litosphaeridium arundum*, *Batioladinium micropodum*, *Protellipsodinium spinosum*, *Protoellipsodinium spinocristatum* and *Stiphrosphaeridium anthophorum*. Three species appear within the upper part of the subzone, *Apteodinium maculatum grande*, *Epelidosphaeridium spinosa* and *Litosphaeridium siphoniphorum*.

3.4.3.2 *OVOIDINIUM VERRUCOSUM-PERVOSPHAERIDIUM TRUNCATUM* CONCURRENT RANGE SUBZONE

The subzone is defined by the concurrent range of *Ovoidinium verrucosum* and *Pervosphaeridium truncatum*. The inception of *Endoceratium dettmanniae* is at the base of the subzone. Most species present are long ranging, extending up into the Cenomanian. Exceptions are *Palaeohystrichsphaeridium* cf. *infusoriodes* of Costa and Davey (1992), *Ellipsoidictyum imperfectum*, *Endoceratium turneri*, *Gonyaulacysta helicoidea* and *Ovoidinium scabrosum*, which become extinct at the top of the Albian. *Apteodinium maculata grande* becomes extinct in the lower part of the subzone (at the top of the *rostratum* Subzone of the *dispar* Zone).

3.4.4 Selected references

Cookson and Hughes, 1964; Costa and Davey, 1992; Davey and Verdier, 1973; Duxbury, 1978, 1983; Riding, 1993, 1994; Williams and Bujak; 1985.

3.5 FORAMINIFERIDA BIOSTRATIGRAPHY

Albian foraminifera have been discussed in some detail by Hart (1973a, b), Carter and Hart (1977), Price (1977), Hart et al. (1989), Harris (1982). The zonal scheme herein follows those of Price (for zones 1 and 2) and Carter and Hart (1977) with later modifications (Hart, 1993) where appropriate.

3.5.1 *Rhizammina* cf. *dichotoma* Partial Range Zone (Zone 1 modified from Price, 1977)

Definition

The total range of *Rhizammina* cf. *dichotoma*.

Correlation

tardefurcata Zone

Lithostratigraphy

Clays of the Lower Saxony Basin

Remarks

The zone is only known with certainty in Germany. Price (1977) indicated that *Reophax minuta* also became extinct at the top of the zone. However, Mitchell and Underwood (1999) recorded *R. minuta* from the Aptian (*deshayesi* Zone) through to the top of the *auritiformis* Zone in the Speeton Clay Formation of Yorkshire. Further study on the Lower Albian formations is required before foraminifera can be used meaningfully in Britain.

3.5.2 *Reophax minuta* Partial Range Zone (Zone 2 modified from Price, 1977)

Definition

The extinction of *Rhizammina* cf. *dichotoma* defines the lower zonal boundary and the extinction of *Reophax minuta* and the inception of indices of the succeding zone defines the upper zonal boundary.

Correlation

mammillatum Superzone

Lithostratigraphy

Clays of the Paris Basin. Some elements of the biozone can be recognised in the Carstone (which contains only a sparse fauna) and the A Beds of the Speeton Clay Formation.

Bioevents

The inception of *Arenobulimina macfadyeni*, *Lingulogavelinella albiensis* and *L. ciryi* occurs here. The planktonic foraminifera *Blefuscuiana infracretacea* and *Hedbergella planispira* occur for the first time within the zone and may prove to be biostratigraphically useful.

Remarks

Recognisable in the A2 and A3 Beds of the Speeton Clay Formation (Mitchell and Underwood, 1999). Further study on the Carstone and Folkestone formations is required before this zone can be used meaningfully in southern England.

3.5.3 *Epistomina spinulifera-Conorboides lamplughi* Zone

Definition

Based on the inception of *Epistomina spinulifera* and disappearance of common *Conorboides lamplughi*.

Correlation

lyelli to *niobe* subzones

Lithostratigraphy

Gault Beds I to III

Bioevents

Inception of *Guembelitria cenomana* and *Siphogeneria asperula* (at the base of the zone), *Quinqueloculina antiqua*, *Hoeglundina carpenteri*, *Gasvelinella* cf. *baltica* and *Vaginulina mediocarinata*.

Remarks

This zone equates with Zone 3 (sensu Hart) and subzones 3i, 3ii, 3iii and lower part of 3iv (sensu Price).

3.5.3.1 SUBZONE 3I (SENSU CARTER AND HART)

Definition

The base of the subzone correlates with the base of the zone. The inception of *Hoeglundina carpenteri* defines the top of the subzone.

Correlation

lyelli and *spathi* subzones

Lithostratigraphy

Gault Bed I (lower part)

Remarks

Inception of *Guembelitria cenomana* is also a good marker for the base of the subzone.

3.5.3.2 *Hoeglundina carpenteri* Subzone

Definition

The base is defined by the inception of *H. carpenteri* and the top is recognised by the first occurrence of the succeeding subzonal index.

Correlation

spathi Subzone

Lithostratigraphy

Upper part of Gault Bed I

Bioevents

The inception of *Quinqueloculina antiqua* coincides with the base of the subzone, but the species is very rare.

Remarks

This subzone equates with the upper part of Subzone 3i (sensu Hart) and Subzone 3ii (sensu Price).

3.5.3.3 *Quinqueloculina antiqua* Subzone

Definition

The base is marked by the occurrence of consistent *Quinqueloculina antiqua* and the occurrence of common *Siphogeneria asperula* and *Hoeglundina carpenteri*. The top is defined by the inception of the overlying subzonal index.

Correlation

intermedius Zone

Lithostratigraphy

Gault Bed I (upper part) and Bed II

Remarks

This subzone equates with the lower part of Subzone 3ii (sensu Hart) and Subzone 3iii (sensu Price). N.B. Rare specimens of *Q. antiqua* have been recorded from the *spathi* Subzone.

3.5.3.4 *Vaginulina mediocarinata* Subzone

Definition

The base is defined by the inception of *Vaginulina mediocarinata*. The top is defined by the extinction of common *Conorboide lamplughi*.

Correlation

niobe Zone

Lithostratigraphy

Gault Bed III

Bioevents

Gavelinella sp. cf. *G. baltica* (sensu Price) and *Planularia cenomana* appear at the base of the subzone.

Remarks

This equates to the top of Subzone 3ii of Hart and base of 3iv of Price. *Epistomina spinulifera* and planktonic species such as *Hedbergella delrioensis*, *H. planispira* and *H. infracretacea* become more common.

3.5.4 *Dorothia filiformis* Zone

Definition

The inception of *D. filiformis* marks the base. The upper boundary is defined by the inception of the succeeding zonal index.

Correlation

subdelaruei and *meandrinus* subzones (*loricatus* Zone)

Lithostratigraphy

Gault Bed IV

Bioevents

Nodobacularia nodulosa appears for the first time at the base of the foraminiferal zone. *Epistomina spinulifera* becomes abundant.

Remarks

Equates with the basal part of Zone 4 sensu Hart and upper part of Subzone 3iv of Price (1977).

3.5.5 *Citharinella pinnaeformis* Zone

Definition

The base is defined by the inception of *C. pinnaeformis*. The top is defined by the extinction of *Hoeglundina carpenteri* and *Epistomina spinulifera*.

Correlation

nitidus to basal *cristatum* subzones (*lautus* and basal *inflatum* zones)

Lithostratigraphy

Gault Beds V to VIII

Bioevents

Appearance and local disappearance of *Favusella washitensis*.

Remarks

Equates with the upper part of Zone 4 sensu Hart and Zone 4 sensu Price. Price and Hart note that rare specimens of *Epistomina spinulifera* may be reworked into the higher zone.

3.5.6 *Arenobulimina chapmani–Arenobulimina macfadyeni* Zone

Definition

The inception of *Arenobulimina chapmani* defines the base of the zone and the extinction of *Arenobulimina macfadyeni* marks the top.

Correlation

Upper part of the *cristatum* Subzone.

Lithostratigraphy

Gault Bed IX (lower part)

Bioevents

Inception of *Spiroloculina papyracea*.

Remarks

Lower part of Zone 4a sensu Hart and Zone 4i of Price. Price notes that a small number of reworked specimens of *A. macfadyeni* may be found in the succeeding zone.

3.5.7 *Eggerellina mariae* Zone

Definition

The base is recognised by the inception of *E. mariae*. The upper boundary is defined by the appearance of the index species of the succeeding zonal index.

Correlation

orbignyi Subzone

Lithostratigraphy

Gault Bed IX (upper part)

Bioevents

The inception of *Citharinella laffitei* and *Pleurostomella barroisi* occurs at the base of the zone. The inception of *Hedbergella moremani* is in the middle part of the zone.

Remarks

This zone equates with the upper part of Zone 4a and lower part of Zone 5 of Hart and Zone 5 of Price.

3.5.8 *Textularia chapmani* Zone

Definition

The base of the zone is defined by the inception of *Textularia chapmani*.

Correlation

varicosum Subzone (*inflatum* Zone)

Lithostratigraphy

Gault Bed X

Bioevents

The inception *Arenobulimina praefrankei* is at the base of the zone (*A. frankei* in Price 1977). The inception of *Gavelinella cenomanica* is at the base of this zone according to Price (1977), much lower than that shown by Carter and Hart (1977) although at a similar level to that indicated by Hart (1973b).

Remarks

Equivalent to the middle part of Zone 5 of Hart and Zone 6 of Price.

3.5.9 *Arenobulimina sabulosa* Zone

Definition

The base of the zone is marked by the inception of *A. sabulosa*. The upper boundary is marked by the index of the succeeding zone.

Correlation

Lower *auritus* Zone

Lithostratigraphy

Gault Bed XI (lower part)

Bioevents

The base of the zone also coincides with the inception of *Lingulogavelinella jarzevae* and *Arenobulimina truncata*, according to Price (1977). *Gavelinella cenomanica* becomes common in the zone.

Remarks

Upper part of Zone 5 sensu Hart and lower part of Subzone 7i of Price. Note that the base of 7i of Price has not been seen in England, but according to Price (1977), the inception of *A. sabulosa* is lower than stated by Hart.

3.5.10 *Marsonella ozawai* Zone

Definition

The base is marked by the inception of *M. ozawai*. The upper boundary is defined by the first occurrence of the succeeding index species.

Correlation

Upper *auritus* Zone

Lithostratigraphy

Gault Bed XI (upper part)

Bioevents

The inception of *Globigerina bentonensis* is at the base of the zone, although it is rare (a major influx of the species is characteristic of the succeeding zone). The extinction of *Citherinella pinnaeformis* is at or near the upper boundary of the zone.

Remarks

Zone 5a of Hart and the upper part of Subzone 7i of Price.

3.5.11 *Globigerina bentonensis* Zone

Definition

The base of the zone is based on the sudden influx of abundant *G. bentonensis*.

Correlation

rostratum Subzone

Lithostratigraphy

Gault Bed XII to lower XIII

Bioevents

The inception of *Plectina mariae* and abundant *Hedbergella brittonensis* coincides with the base of the zone. The appearance of *Arenobulimina frankei* with a triangular cross-section (rather than quadrate to rounded as in the lower part of its range) is at the base of the zone according to Price (1977).

Remarks

The base of Zone 6 of Hart, the base of Subzone 7ii of Price and the base of Gault Bed XII coincide. The position of Bed XII has been confused in the past, and has incorrectly been included in the *auritus* Subzone. However, it can be placed, without doubt, in the base of the *rostratum* Subzone of the *dispar* Zone. Previous references to an influx of *Globigerina* and other criteria that take place in this bed, and considered to be characteristic of the uppermost *auritus* Subzone, should instead be refered to the *rostratum* Subzone.

3.5.12 *Gavelinella baltica* Zone

Definition

The inception of *Gavelinella baltica* marks the base of the zone. The extinction of *Arenobulimina chapmani* defines its top.

Correlation

perinflatum Zone

Lithostratigraphy

Gault Bed XIII (upper part)

Bioevents

Hart (1993) recognised a horizon, characterised by floods of *Globigerinoides* sp., in the lower part of the zone, which he used to seperate a '6m' subzone from the underlying '6l' and overlying '6u' subzones.

Remarks

The zone equates with Zone 6ii of Hart and Zone 8 of Price. Although by no means certain, the incoming of *Orbitolina* in the uppermost Upper Greensand of south-west England may correlate with a level in this zone.

3.5.13 *Flourensina intermedia* Partial Range Zone

Definition

The base of the zone is defined by the inception of *Flourensina intermedia*. Its top is marked by the incoming of the Cenomanian taxa *Plectina mariae* and *Arenobulimina anglica*.

Correlation

perinflatum Subzone (highest part)

Lithostratigraphy

Gault Bed XIII (uppermost part)

Bioevents

Price (1977) shows a number of bioevents in his equivalent Zone 9, but these have yet to be definitely recognised in the UK. The first record of *Flourensina intermedia*, *Arenobulimina advena*, the crenulate morph of *Arenobulimina sabulosa* and *Gaudryina austinana*, all of which are characteristic of the Cenomanian, occur in benthonic foraminifera Zone 6a (Carter and Hart, 1977), as do the last occurrences of *Citharinella laffittei*, *Tritaxia singularis*, *Arenobulimina chapmani*, *Arenobulimina frankei* and typical triangular *Arenobulimina sabulosa*, all of which are characteristically Albian. Carter and Hart noted a possible stepwise change in the fauna, and the bioevents recognised by Price (1977) may exist in Britain, although further work is required to confirm this.

Remarks

Foraminifera zones 9i, 9ii and 9iii of Price (1977) were erected in the Netherlands and cannot be recognised in Britain with certainty. The *intermedia* Zone equates with Zone 6a sensu Carter and Hart (1977).

3.5.14 Selected references

Carter and Hart, 1977; Harris, 1982; Hart et al., 1989; Hart, 1970, 1973a, b, 1993; Price, 1977.

3.6 OSTRACOD BIOSTRATIGRAPHY

The Lower Albian of Britain is represented by the Carstone, which contains very sparse faunas, but the Middle and Upper Albian Gault and Hunstanton formations have yielded a diverse ostracod fauna. Neale (1978a) placed the entire Middle and Upper Albian in a single zone (recognised by *Mandocythere harrisiana*), which was subdivided into six subzones based on variations noted by Hart, (1973b). Further work on the Gault and Hunstanton formations (Wilkinson and Morter, 1981; Wilkinson 1988a, 1988b, 1990; Mitchell and Underwood, 1999) provides the basis for the zonation presented herein.

3.6.1 *Protocythere nodigera* Partial Range Zone

Definition

The ostracod zone is defined in Britain by the first and last occurrence of *Protocythere nodigera*. Kemper (1982) showed the range of the index species extending into the *dentatus* zone in Germany.

Correlation

The zone is restricted to the *tardefurcata* to *auritifomis* macrofaunal zones (although it is rare in the lower part of its range and its exact inception point is unclear). Mitchell and Underwood (1999) found it to be restricted to the *regularis* Zone in Yorkshire. It has also been recognised in the Lower, but not lowest Albian in Germany (Kemper, 1982).

Lithostratigraphy

A Beds of the Speeton Clay Formation to the upper part of the Carstone.

Bioevents

The appearance of *Cornicythereis cornueli* within the *nodigera* Zone, at the base of the *chalensis* macrofaunal Zone (i.e. the base of the *mammillatum* Superzone) is possibly of subzonal value, although its rarity reduces its usefulness. *Clithrocytheridea heslertonensis*, *Cornicytheries cornueli* and *Neocythere lingenensis* appear for the first time in the lower part of A3B of the Speeton Clay Formation, near the base of the *chalensis* Zone. The first and last occurrence of *Pseudobythocythere goerlichi* (in A5A and A4 Beds of the Speeton Clay Formation, *regularis* Zone and basal *chalensis* Zone) is also of biostratigraphical significance.

3.6.1.1 *Pseudobythocythere goerlichi* Total Range Subzone

The extinction of the index species at or near the top of the *regularis* Zone marks the top of the subzone, but the inception of the species is uncertain. In Yorkshire it is in the *regularis* zone Mitchell and Underwood (1999), but in Germany it is also known in the Upper Aptian (Mertens, 1956).

3.6.1.2 *Clithrocytheridea heslertonensis* Partial Range Subzone

The subzone is currently known with certainty only in Yorkshire. It is defined by the range of *C. heslertonensis* in the A3B to A1B beds of the Speeton Clay. The top of the subzone is difficult to locate due to gaps in the sequence.

3.6.2 *Protocythere albae-Dolocytheridea* (*P.*) *vinculum* Concurrent Range Zone

Definition

The zone is defined by the concurrent range of *Protocythere albae* and *Dolocytheridea* (*P.*) *vinculum*.

Correlation

lyelli Subzone to the lower part of the *intermedius* Subzone (of the *dentatus* and lowest *loricatus* zones)

Lithostratigraphy

Gault Beds G1 to G3 and, by inference, Bed I of the Kent sequence.

Bioevents

Inception of *Paranotacythere* (*Paranotacythere*) *fordonensis*, *Schuleridea jonesiana* and *Habrocythere fragilis*. Extinction of *Matronella corrigenda*, *Batavocythere gaultina* and *Platycythereis laminata*.

3.6.3 *Protocythere albae-Dolocytheridea bosquetiana* Concurrent Range Zone

Definition

The lower boundary of the zone is defined by the inception of *Dolocytheridea bosquetiana*. Its upper boundary is recognised by the extinction of *Protocythere albae*.

Correlation

intermedius to *subdelaruei* subzones

Lithostratigraphy

Gault Beds G4 to the lower part of G7 and Hunstanton Formation Bed HC2 and, by inference, Gault Beds I (uppermost part) to IV of the Kent sequence.

Bioevents

Inception of *Cythereis* (*Cythereis*) *hirsuta* and extinction of *Cornicythereis cornueli* and *Cythereis* (*Cythereis*) *reticulata*.

3.6.4 *Cythereis* (*R.*) *luermannae luermannae-Neocythere* (*N.*) *ventrocostata* Concurrent Range Zone

Definition

The base is defined by the inception of *C.* (*R.*) *luermannae luermannae*. The upper boundary is recognised by the extinction of *Neocythere* (*N.*) *ventrocostata*.

Correlation

The ostracod zone equates with the *meandrinus* to *varicosum* subzones (upper *loricatus* to mid *varicosum* zones). *Neocythere* (*N.*) *ventrocostata* ranges up from the Aptian to become extinct in the *varicosum* Subzone, whereas *C.* (*R.*) *luermannae luermannae* first appears at or a little above the base of the *meandrinus* Subzone and extends up to the *varicosum* Subzone.

Lithostratigraphy

Gault Beds G7 (upper part) to G14 (lower part) and Hunstanton Formation Beds HC2 (uppermost part) to HC7. By inference, Gault Beds IV (upper part) to X (lower part) of the Kent sequence.

Bioevents

The inception of *Neocythere* (*Physocythere*) *steghausi* and *Neocythere* (*Neocythere*) *vanveenae*, and the extinction of *Neocythere* (*Physocythere*) *lingenensis*.

3.6.4.1 *Saxocythere notera senilis* Partial Range Subzone

The base is defined by the inception of *Saxocythere notera senilis*, and its upper boundary is placed at the incoming of the succeeding subzonal index. It ranges from the highest part of the *meandrinus* Subzone (*loricus* Zone) and the *lautus* Zone, in Gault Bed 7 (upper part) to G12. The extinction of *Neocythere* (*Physocythere*) *lingenensis* is within the subzone.

3.6.4.2 *Cytherelloidea stricta* Partial Range Subzone

The base is defined by the inception of *Cytherelloidea stricta*, and the top can be recognised by the inception of the overlying index species. The subzone ranges from the *cristatus* to the lower part of the *orbignyi* macrofaunal subzones, lithostratigraphically in Gault Beds G11–G12.

3.6.4.3 *Cythereis (C.) folkestonensis* Partial Range Subzone

The inception of *Cythereis* (*Cythereis*) *folkestonensis* and extinction of *Cythereis* (*Rehacythereis*) *luermannae luermannae* defines the subzone. It can be recognised between the mid *orbignyi* Subzone to the lower part of the *auritus* Subzone (*inflatum* Zone) in Gault Beds G13 to G14 (lower part). Several bioevents occur within the subzone, including the inception of *Neocythere* (*N.*) *vanveenae* and *N.* (*P.*) *steghausi* (at the top of the *orbignyi* Subzone) and the extinction of *Saxocythere notera senilis*.

3.6.5 *Cythereis (R.) hannoverana* Partial Range Zone

Definition

The inception of *Cythereis (R.) hannoverana* marks the base of the ostracod zone. Its top is defined by the inception of the succeeding zonal index.

Correlation

Upper part of the *varicosum* Subzone (*inflatum* Zone) to the *perinflatum* Subzone (*dispar* Zone).

Lithostratigraphy

Gault Beds G14 (upper part) to G19 and Hunstanton Formation Beds HC7 (uppermost part) to HC11. By inference, Gault Beds X (uppermost part) to XIII (lower part) of the Kent sequence.

Bioevents

The inception of *Neocythere* (*Physocythere*) *semiconcentrica*, *Alatacythere robusta langi*, *Cythereis* (*Rehacythereis*) *humilis* and *Phthanoloxoconcha icknieldensis*, and the extinction of *Paranotacythere* (*Paranotacythere*) *fordonensis* and *Neocythere* (*Centrocythere*) *denticulata*.

3.6.5.1 *Cythereis (R.) hannoverana*-*Cythereis (C.) folkestonensis* Concurrent Range Subzone

The base of the subzone coincides with the base of the zone, and its upper boundary is taken at the extinction of *C.* (*C.*) *folkestonensis*. The subzone extends from the upper part of the *varicosum* Zone to the 'mid-*auritus* break', Gault Bed G13 to the lower part of G16. The inception of *Platycythereis chapmani* is within the ostracod subzone, although it is generally rare.

3.6.5.2 *Planileberis scrobicularis* Partial Range Subzone

The base of the subzone is defined by the inception of *Planileberis scrobicularis*, and its top is at the inception of the succeeding zonal index species. The subzone extends from the upper part of the *auritus* Subzone to the top of the Albian, in Gault Beds G16 (middle part) to G19. The inception of very rare specimens of *Alatacythere robusta langi* is within the subzone, and this may be 'Zone F' which was recognised in the Paris Basin by Damotte (1979).

3.6.6 *Cythereis* (*R.*) *bemerodensis* Partial Range Zone

Definition

The base of the zone is defined by the inception of *Cythereis* (*R.*) *bemerodensis*. Its upper boundary is placed at the inception of the succeeding zonal index.

Correlation

The *Cythereis* (*R.*) *bemerodensis* Zone is equated with the *perinflatum* Subzone (*dispar* Zone) and basal Cenomanian in Germany and Britain (Kemper, 1984; Morter and Wood, 1984; Wilkinson 1990). However, its lower and upper boundaries have yet to be fixed accurately.

Lithostratigraphy

Gault Bed XIII (upper part) and basal Chalk.

Bioevents

The extinction of *Isocythereis fissicostis* and *Eucythere trigonalis*.

3.6.7 Selected references

Hart, 1973b; Kemper, 1982; Mertens, 1956; Neale, 1978; Wilkinson and Morter, 1981; Wilkinson 1988a, 1988b, 1990.

4 Other stratigraphical methods

4.1 CHEMOSTRATIGRAPHY

There is a general lack of chemostratigraphically useful information for the Albian. Mitchell (1995) considered the stable isotope $\delta^{13}C$ curve in the upper part of the Hunstanton Formation of Yorkshire useful in identifying the Albian-Cenomanian boundary.

Jones et al. (1994) presented a strontium isotope curve for the Middle and Upper Jurassic through to the Lower Cretaceous of Britain (see Figure 45). These authors analysed belemnites from the Gault Formation of Bedfordshire and Folkestone, and noted that the dip in the Aptian part of the curve is replaced by a gradual rise through the Albian. The steady increase in $^{87}Sr/^{86}Sr$ ratios is potentially useful stratigraphically.

4.2 GEOPHYSICAL METHODS

Geophysical methods, including geophysical log interpretation and seismic stratigraphy, are of great importance on the continental shelf and are used widely in the commercial sector. Whilst useful in correlation and subdivision of sequences over large distances, geophysical data must be calibrated using other stratigraphical methods.

Examples of seismic methods can be seen in the North Sea where the Rødby (mainly marls and limestones), Carrack (predominantly mudstones) and Wick Sandstone formations have been widely recognised by the employment of these methods (see Figure 5). Johnson and Lott (1993) show the value of geophysical methods in correlating the Albian sequence in the North Sea Basin.

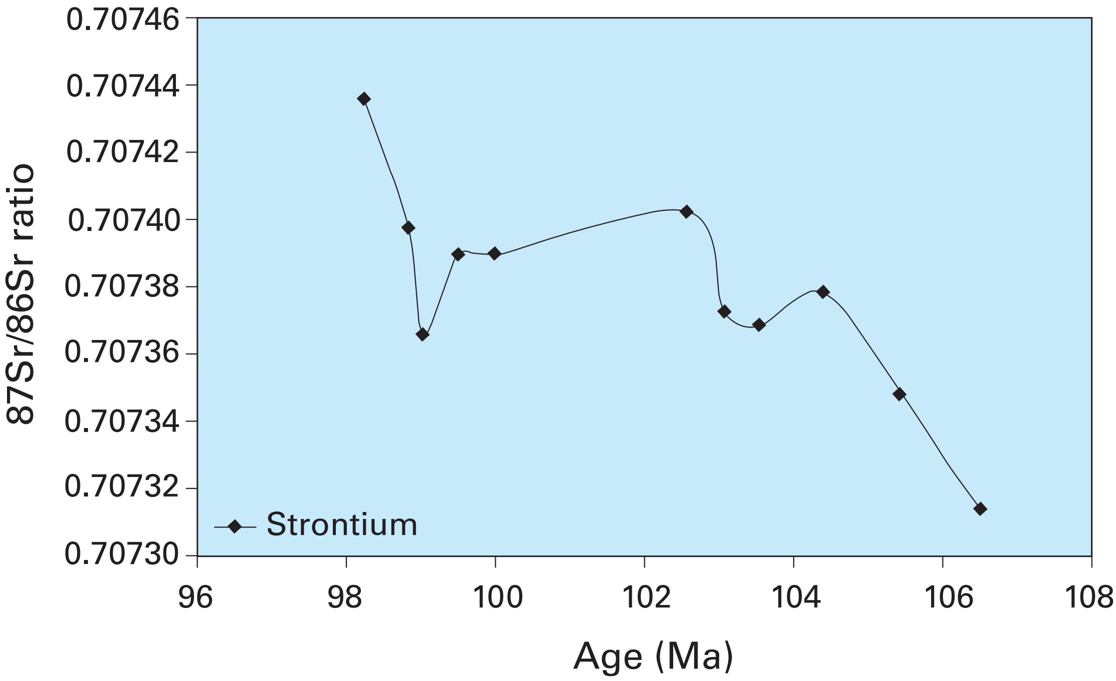
Geophysical logs are used less widely onshore, but nevertheless play a useful role in correlation. An example is the spike in the gamma-ray log marking the Cambridge Greensand, as seen in the Arlesey Borehole (see Figures 21 and 26). Another example is seen in the Winterborne Kingston Borehole, where the gamma log picks out the nodule horizons at depths of 345.62 and 287.67 m (see Figure 26). Gamma values are relatively high between 345.62 and 324 m due the natural radioactivity of the Gault, but falls away rapidly upsequence with the reduction in clay content through the glauconitic Upper Greensand. A similar signature is seen in the Lower Greensand. The sonic log picks out the harder horizons, such as the nodule horizons and the limestones in the Gault. The geophysical signature can thus be used to correlate between boreholes with accuracy.

Density logs have been used to correlate the Gault and Upper Greensand exposed at Compton Bay and Redcliff, Isle of Wight, with borehole logs across the island and in the English Channel (Gale et al., 1996). The logs reflect porosity and so the high values pick out the sandier horizons (e.g. Redcliff beds G-RED3-6, G-RED11 and the Upper Greensand) and low values are characteristic of the clay intervals (e.g. Redcliff beds G-RED2, G-RED7-9 and G-RED16-19) (see Figure 28). They also indicate the generally sandy nature throughout the Gault in the west and the sand and clay rich units towards the east. The logs in turn can be related to the biostratigraphy, showing the Gault-Greensand junction to young across the Isle of Wight.

4.3 MAGNETOSTRATIGRAPHY

The Albian falls entirely within a long period of normal polarity (Chron C34), so that this stratigraphical method is of little value.

Figure 45 Strontium isotope curve through the Albian (after Jones et al., 1994).



4.4 SEQUENCE STRATIGRAPHY

Sequence stratigraphy has become widely used, particularly for hydrocarbon exploration. It is useful on a regional scale, but the boundaries become more difficult to identify at a more local level due to small-scale variations of limited geographical extent. The eustatic sea level curves and sequence boundaries shown, for example, by Haq, Hardenbol and Vail (1988) can be partly recognised in the British succession. Important sequence boundaries have been identified at:

i. The base of Supercycle UZA-1, and the base of Cycle 1.1, a major sequence boundary at the *tardefurcata/regularis* ammonite zonal boundary, towards the top of the *tardefurcata* Zone (when accumulation of the Carstone began).

ii. The base of Cycle 1.2, a minor sequence boundary within the *chalensis* ammonite Zone.

iii. The base of Cycle 1.3, where a medium sequence boundary occurs within the *auritiformis* Zone.

iv. The base of Cycle 1.4, a minor sequence boundary, at the *dentatus/loricatus* ammonite zonal boundary.

v. The base of Cycle 1.5, a medium sequence boundary at the *lautus/inflatum* ammonite zonal boundary, forming a marked erosion surface at the base of the *cristatum* Subzone (the 'base *inflatum* erosion surface').

vi. The base of Supercycle UZA-2, and Cycle 2.1, a major sequence boundary at the *varicosum/auritus* subzonal boundary towards the top of the *inflatum* Zone.

Depositional sequences noted at outcrop in south-east England were discussed by Hesselbo et al. (1990). They recognised five significant breaks in the sequence.

1. LG3, within the Folkestone Formation, includes the Aptian-Albian boundary. Fossils of the *anglicus* Subzone (*jacobi* Zone) (Aptian) are found below the surface and reworked above it. This boundary can be recognised at, for example, East Folksetone, West Folkestone, Newington and Sandling (Hesselbo et al., 1990). It matches the 107.5 Ma sequence boundary (Haq et al., 1988), which was generated by a very high rate of sea-level fall (Type I sequence boundary). However, there is no sedimentological evidence for a sea level fall in south-east England (the cause may be a failure of sediment supply and/or winnowing).

2. Sediments of *chalensis* and *auritiformis* Zone age (*mammillatum* Superzone) are condensed, making it difficult to recognise sequence boundaries, but LG4 can be placed either between the regularis and *chalensis* zones (LG4A of Hesselbo et al.) or in the *puzosianus* Subzone (*auritiformis* Zone) at the phosphatic nodules of the 'Main Mammillatum Bed' (LG4B of Hesselbo et al.), an erosive event recognised by Casey (1961) and Owen (1988). The erosion event may be the 106 Ma sequence boundary formed by moderate rates of sea-level fall (Type II). However the more prominent erosion surface at LG4B, coincides with a condensed interval of Haq et al. (1988). There are, therefore a number of problems with this erosion event.

3. The Folkestone-Gault formational boundary is abrupt and referred to as G1 by Hesselbo et al. (1990). Although the condensed succession causes difficulties, the top of the 'Suphur Band' at the top of the *bulliensis* Subzone (*auritiformis* Zone) is the probable position for the boundary. This surface matches the 103 Ma surface (Haq et al., 1988), formed by moderate rates of sea-level fall (Type II).

4. G2 is a major erosive episode, positioned at the junction between the Lower and Upper Gault, at the *lautus/inflatum* zonal boundary. It is considered to be of early *cristatum* Subzone age, and corresponds to the 99 Ma, medium-sized, Type II sequence boundary of Haq et al. (1988). The *cristatum* Subzone represents the recommencement of sediment accumulation, and contains derived faunas from the underlying *nitidus*, *daviesi* and *meandrinus* subzones. Hesselbo et al. (1990) suggested that the surface might have been the result of storm winnowing during a period of lowered sea level rather than being entirely due to tectonic activity.

5. G3 is placed towards the top of the *auritus* Subzone. At Folkestone, it is placed at a remanié horizon represented by a seam of phosphatic nodules. This event corresponds to the 98 Ma, major Type I sequence boundary of Haq et al. (1988).

Several condensed sequences occur through the Albian (Haq et al., 1988), and Heselbo et al. (1990) related these to the succession in south-east England. Condensed intervals are usually rich in glauconite and phosphate and represent maximum flooding surfaces. Heselbo et al. (1990) recognised the following in south-eastern England:

1. At Folkestone, the sediments of the *regularis/acuticostata* boundary interval are rich in phosphatic nodules, lack evidence of faunal gaps and represent the 107 Ma maximum flooding surface of Haq et al. (1988).

2. The 104 Ma maximum flooding surface cannot be recognised with certainty.

3. The maximum flooding surface at 101 Ma (Haq et al., 1988) occurs in the *spathi* Subzone of the *dentatus* Zone. Condensation can be observed at, for example, the '*dentatus* nodule bed' at Folkestone.

4. The major maximum flooding surface of 99.5 Ma occurs close to the *orbignyi/varicosum* subzonal boundary in the middle part of the *inflatum* Zone. Condensation can be recognised throughout the Wessex Basin.

A sequence stratigraphical approach has also been taken by Wonham and Elliott (1996) in their discussion of the Albian sequence in the Leighton Buzzard area of southern England. The upper part of the succession comprises 'Red Sands', Shenley Limestone and Junction Beds, which are placed into the 'Red Sands sequence'.

1. The Red Sands are estuarine deposits. They represent a period of renewed sedimentation during a transgression that followed a low stand. The formation of goethite ooids is associated with low sediment supply, reworking of the substrate by tidal currents, lateritic iron-rich cements associated with the basal unconformity of the Red Sands sequence, and the supply of iron for ooid formation. The base of the Reds Sands is considered to be a sequence boundary.

2. Further transgression resulted in marine flooding and the accumulation of the Shenley Limestone, with littoral and sublittoral fossil faunas, overlying a shoreface ravinement surface. The Shenley Limestone is a highly condensed deposit associated with very low sedimentation rates in a high-energy environment.

3. The Junction Beds, with wave-formed structures, sands, pebble beds and phosphatic nodule horizons, accumulated early in the phase of transgression that culminated in deposition of the Gault.

4.5 SELECTED REFERENCES

Casey, 1961; Gale et al., 1996; Haq, Hardenbol and Vail, 1988; Hesselbo, Coe and Jenkyns, 1990; Johnson and Lott, 1993; Jones, Jenkyns, Coe and Hesselbo, 1994; Mitchell, 1995; Owen, 1988; Wonham and Elliott 1996.

5 Holostratigraphical events of the Albian Stage

A holistic approach to stratigraphy provides a high precision tool for subdividing the Albian succession of the UK and its continental shelf. Thirty seven holostratigraphical markers can be recognised based on lithostratigraphy, various biostratigraphies, sequence stratigraphy, etc (Figure 2).

5.1 HOLOSTRATIGRAPHICAL EVENT ALB 1

The Aptian-Albian stage boundary.

Base of the *L. tardefurcata* ammonite Zone.

Base of the *P. nodigera* ostracod Zone.

Base of the *P. aliferum/X. ceratioides* dinoflagellate cyst Zone; *K. loffrense/S. perlucida* Subzone.

The base of the Albian is difficult to locate accurately in Britain due to facies and biostratigraphical difficulties (the Aptian *L. schrammeni* and *L. germanic* zones and the Early Albian *N. strombecki* Zone of mainland Europe are not recognised).

5.2 HOLOSTRATIGRAPHICAL EVENT ALB 2

Base of the *L. regularis* ammonite Zone.

Major sequence boundary at the base of cycle 1.1 of Haq et al (1987) and 'Mid-*tardefurcata* Break' (of Casey, 1961).

The base of the *S. primitivus* nannofossil Zone appears to be immediately above this event. The delay was presumably due to environmental conditions associated with changes in sea level.

5.3 HOLOSTRATIGRAPHICAL EVENT ALB 3

Base of foraminifera Zone 2 of Price (1977).

Base of the *S. trunculum* dinoflagellate cyst Subzone.

Base of the *Clithrocytheridea heslertonensis* ostracod Subzone.

5.4 HOLOSTRATIGRAPHICAL EVENT ALB4

Base of the *S. kitchini* ammonite Subzone.

5.5 HOLOSTRATIGRAPHICAL EVENT ALB 5

Minor sequence boundary forming the base of Cycle 1.2 of Haq et al. (1987).

5.6 HOLOSTRATIGRAPHICAL EVENT ALB 6

Base of the *C.* (*C.*) *floridum* ammonite Subzone.

5.7 HOLOSTRATIGRAPHICAL EVENT ALB 7

Base of the *O. auritiformis* ammonite Zone (*raulinianus* ammonite Subzone)

The inception of *Hedbergella planispira* and *Blefuscuiana infracretacea* occurs here.

5.8 HOLOSTRATIGRAPHICAL EVENT ALB 8

Base of *Neohibolites minimus* belemnite Zone.

5.9 HOLOSTRATIGRAPHICAL EVENT ALB 9

Base of the *P.* (*H.*) *puzosianus* ammonite Subzone.

5.10 HOLOSTRATIGRAPHICAL EVENT ALB 10

Medium sequence boundary at the base of Cycle 1.3 of Haq et al. (1987).

5.11 HOLOSTRATIGRAPHICAL EVENT ALB 11

Base of the O. (*I.*) *bulliensis* ammonite Subzone.

5.12 HOLOSTRATIGRAPHICAL EVENT ALB 12

Base of the *P.* (*I.*) *steinmanni* ammonite Subzone.

Base of the *A. viriosus-C. anglicum* nannofossil *Interregnum* Zone.

5.13 HOLOSTRATIGRAPHICAL EVENT ALB 13

Base of the *H.* (*H.*) *dentatus* ammonite Zone (*L. lyelli* ammonite Subzone).

Base of *E. spinulifera-C. lamplughi* foraminiferal Zone (= Zone 3i of both Price, 1977, and Carter and Hart, 1977) and base of Subzone 3i (sensu Carter and Hart, 1977).

Base of the *P. albae-D. vinculum* ostracod Zone (and extinction of *P. nodigera*).

Base of the *S. cretacea* dinoflagellate cyst Zone (*S. coronatum-K. sarmentum* Subzone).

Base of the *C. anglicum-B. boletiformis* nannofossil Zone.

The '*dentatus* flooding surface' approximates to this event.

5.14 HOLOSTRATIGRAPHICAL EVENT ALB 14

Base *H.* (*H.*) *spathi* ammonite Subzone.

Base of the *H. carpenteri* foraminifera Zone (= Zone 3ii of Price 1977).

The inceptions of the ostracod *Habrocythere fragilis* and the dinoflagellate *cyst A. perforatum* occur at or near the event.

A medium condensed sequence approximates with this event, although is apparently slightly later.

5.15 HOLOSTRATIGRAPHICAL EVENT ALB 15

Base of the *E. loricatus* ammonite Zone (*A. intermedius* ammonite Subzone).

Base of the *Q. antiqua* foraminiferal Subzone (= Zone 3iii of Price, 1977, and Zone 3ii of Carter and Hart, 1977).

Top of the *S. coronatum-K. sarmentum* dinoflagellate cyst Subzone.

Minor sequence boundary at the base of Cycle 1.4 Haq et al. (1987).

Extinction horizon of ostracods *Matronella corrigenda*, *Batavocythere gaultina* and *Platycythereis laminata*.

5.16 HOLOSTRATIGRAPHICAL EVENT ALB 16

Base of the *P. albae-D. bosquetiana* ostracod Zone.

The extinction of the ostracod *Cornicythereis cornueli* takes place immediately above the event.

5.17 HOLOSTRATIGRAPHICAL EVENT ALB 17

Base of the *D. niobe* ammonite Subzone.

Base of the *Vaginulina mediocarinata* foraminifera Subzone (= Zone 3iv of Price, 1977).

The ostracod *Cytheries hirsuta* appears at this event.

5.18 HOLOSTRATIGRAPHICAL EVENT ALB 18

Base of the *M. subdelaruei* ammonite Subzone.

Base of the *Dorothia filiformis* foraminiferal Zone (= Zone 4 of Carter and Hart, 1977).

Base of the *B. boletiformis-C. albianus* interregnum Zone.

The ostracod *Cythereis reticulata* disappears from the record at this event.

5.19 HOLOSTRATIGRAPHICAL EVENT ALB 19

Base of the *C.* (*R.*) *leurmannae-N* (*N.*) *ventrocostata* ostracod Zone and the *S. senilis* ostracod Subzone.

5.20 HOLOSTRATIGRAPHICAL EVENT ALB 20

Base of the *E. meandrinus* ammonite Subzone.

Base of the *A. albianus* nannofossil Zone; *C. bicornutum* nannofossil Subzone.

The last record of consistently present *C. parva* (dinoflagellate cyst) is at or near this event.

5.21 HOLOSTRATIGRAPHICAL EVENT ALB 21

Base of the *E. lautus* ammonite Zone; *E. nitidus* ammonite Subzone.

Base of the *Citherinella pinnaeformis* foraminiferal Zone (= Zone 4 of Price, 1977).

Base of the *I. gallium-M. asymmetrica* dinoflagellate cyst Subzone.

Position of a medium condensed section within Supercycle UZA-1, cycle 1.4.

5.22 HOLOSTRATIGRAPHICAL EVENT ALB 22

Base of the *A. daviesi* ammonite Subzone.

5.23 HOLOSTRATIGRAPHICAL EVENT ALB 23

Base of the *M.* (*M.*) *inflata* ammonite Zone; *D. cristatum* ammonite Subzone.

Base of the *N. oxycaudatus* belemnite Zone.

Base of the *C. stricta* ostracod Subzone.

Base of the *P. truncatum* dinoflagellate cyst Zone; *L. conospinum* Subzone.

Base of the *C. bicornuta-T. tesselatus* nannofossil interregnum Subzone.

Medium sequence boundary at the base of cycle 1.5 of Haq et al., (1987) ('*inflatum* erosion surface').

5.24 HOLOSTRATIGRAPHICAL EVENT ALB 24

Base of the *A. chapmani-A. macfadyeni* foraminifera Zone (= Zone 4a of Carter and Hart, 1977, and Zone 4i of Price, 1977).

5.25 HOLOSTRATIGRAPHICAL EVENT ALB 25

Base of the *H. orbignyi* ammonite Subzone.

The base of the *E. mariae* foraminiferal Zone (= Zone 5 sensu Price, 1977) is located at this event.

5.26 HOLOSTRATIGRAPHICAL EVENT ALB 26

Base of the *C.* (*C.*) *folkestonensis* ostracod Subzone. Carter and Hart (1977) placed the base of their foraminiferal Zone 5 here.

5.27 HOLOSTRATIGRAPHICAL EVENT ALB 27

Base of the *H. varicosum* ammonite Subzone.

Base of the *N. praeultimus* belemnite Zone.

Base of *Textularia chapmani* foraminiferal Zone (= Zone 6 of Price, 1977).

The inception of the dinoflagellate cyst *L. siphoniphorum* is at this event.

A major condensed section within sequence stratigraphy Cycle 1.5.

5.28 HOLOSTRATIGRAPHICAL EVENT ALB 28

Base of the *C.* (*R.*) *luermannae hannoverana* ostracod Zone.

5.29 HOLOSTRATIGRAPHICAL EVENT ALB 29

Base of the *C. auritus* ammonite Subzone.

Base of *Arenobulimina sabulosa* foraminiferal Zone (= Zone 7i of Price, 1977).

Base of the *T. tesselatus* nannofossil Subzone.

Major sequence boundary at the base of Cycle 2.1 of Haq et al. (1987).

The extinction of *N.* (*C.*) *denticulata* and the inception of *N.* (*P.*) *semiconcentrica* occur at this event.

5.30 HOLOSTRATIGRAPHICAL EVENT ALB 30

Base of the *S. angustus* nannofossil Subzone.

5.31 HOLOSTRATIGRAPHICAL EVENT ALB 31

Base of the *Marssonella ozawai* foraminifera Zone (= Zone 5a of Carter and Hart, 1977).

Base of the *P. scrobicularis* ostracod Subzone.

Base of the *E. turriseiffelii* nannofossil Zone.

5.32 HOLOSTRATIGRAPHICAL EVENT ALB 32

Base of the *S. dispar* ammonite Zone; *M.* (*M.*) *rostratum* ammonite Subzone.

Base the *G. bentonensis* foraminiferal Zone (= Zone 6i of Carter and Hart, 1977, 6l of Hart, 1993, and 7ii of Price, 1977).

Base of the *O. verrucosum-O. scabosum* dinoflagellate cyst Subzone.

5.33 HOLOSTRATIGRAPHICAL EVENT ALB 33

Base of the *R. hollandicus* nannofossil Subzone.

5.34 HOLOSTRATIGRAPHICAL EVENT ALB 34

Base of the *G. praeobliquum* nannofossil Subzone.

The ostracod genus *Phthanoloxoconcha* appears for the first time at this event, the first species being *P. icknieldensis*.

5.35 HOLOSTRATIGRAPHICAL EVENT ALB 35

Base of the *M.* (*D.*) *perinflatum* ammonite Subzone.

Base of the *G. baltica* foraminiferal Zone (= Zones 6ii of Carter and Hart, 1977, 6m of Hart 1993, and Zone 8 of Price 1977).

Base of the *C.* (*R.*) *bemerodensis* Zone.

Minor sequence boundary at the base of Cycle 2.2 of Haq et al. (1987).

The inception of *C. torulosa* and extinction of *A. moculatum* (dinoflagellate cysts) occur at this event.

5.36 HOLOSTRATIGRAPHICAL EVENT ALB 36

Base of the *F. intermedia* foraminiferal Zone (= Zone 6a of Carter and Hart, 1977, and Zone 9 of Price, 1977). Price subdivided his Zone 9 into three subzones, but these have not yet been recognised in the UK.

There are no diagnostic macrofossils in the highest Albian of England. According to Gale et al. (1996), the highest *M.* (*D.*) *perinflatum* and the *A.* (*P.*) *briacensis* subzones, as recognised in France and north-west Germany, are not found in Britain, having been removed by erosion.

5.37 HOLOSTRATIGRAPHICAL EVENT ALB 37

The Albian–Cenomanian stage boundary.

Base of the *M. mantelli* Zone (*N. carcitanense* Subzone).

The extinction of indicators of the *S. dispar* ammonite Zone.

Base of the Cenomanian *Calculites anfractus* nannofossil Zone.

A number of dinoflagellate cysts disappear from the record (including *O. scrabrosum*), and notably the index of the *P. truncatum* Zone.

Base of foraminiferal Zone 7 or where absent Zone 8 (sensu Carter and Hart, 1977). Extinction of typical Albian foraminiferal species (e.g. *Tritaxia singularis*, *Citherinella laffittei*, *Arenobulimina chapmani* and *Arenobulimina frankei*) takes place in the *F. intermedia* foraminiferal Zone (Zone 6a, of Carter and Hart, 1977, and Zone 9 of Price, 1977). This may take place in a step-wise fashion (as Price, 1977, describes on the mainland of Europe), but further work is needed to confirm this in Britain. Cenomanian foraminifera such as *Plectina mariae* and *Arenobulimina anglica* appear for the first time above the stage boundary.

Several microfossils disappear from the record at the top of the Albian, including the ostracod *C. globosa*.

6 Albian localities in the United Kingdom

6.1 SPEETON CLAY FORMATION ('A' BEDS)

Only the 'A' Beds of the coastal section are known in detail (Judd, 1868; Lamplugh, 1889, 1924; Ennis, 1937; Wright, in Swinnerton, 1955; Kaye, 1964a; Neale, 1974; Mitchell, 1995; Mitchell and Underwood, 1999). Measurements below are from Mitchell and Underwood (1999).

6.1.1 Speeton, Yorkshire [TA 152 754 to 163 752]

Remarks

Mitchell and Underwood (1999) described the sequence in detail and their subdivision is followed here with slight modification in Bed A5. The order of bed numbering is from the top down. This follows a convention that has been applied to the Speeton Clay Formation for over a century, and is adopted here to avoid any confusion that might result from numbering the succession from the base upwards.

See Figure 6 for details of the Speeton Clay succession ('A' Beds; A1–A6) at Speeton.

6.2 CARSTONE FORMATION

6.2.1 West Dereham [TL 639 995 to 662 996]

		Thickness m
C-WD 13	Sand, silty, brownish grey	0.30
C-WD 12	Phosphatic nodules in pebbly sand. *Douvilleiceras mammillatum* and *Beudanticeras* present	0.15–0.20
C-WD 11	Sandstone, silty, dark grey, pebblywith phosphatic nodules. Bioturbated with horizontal burrows and dark grey, phosphatic infill	0.20
C-WD 10	Sand, brown, coarse-grained with grey clay wisps	0.25–0.40
C-WD 9	Sandstone, dark grey with wisps of clay. Small pebbles of ironstone present. Occasional black phosphatic nodules at base with impressions of macrofossils, including *Leymeriella*	1.20
C-WD 8	Sand and sandstone, dark grey and brown, coarse-grained and pebbly with a clay matrix	0.20
C-WD 7	Sandstone, grey, medium-grained, micaceous	0.10
C-WD 6	Sand, dark grey, silty	0.10–0.15
C-WD 5	Sandstone, grey, medium-grained, micaceous	0.05
C-WD 4	Sand, dark grey, coarse-grained, silty with abundant pebbles; passing down into indurated, cross-bedded sandstone	0.60
C-WD 3	Sandstone, grey, micaceous with occasional pebbles. Gradational base	0.60
C-WD 2	Sandstone, red-brown, conglomeratic, with pebbles up to 20 cm across	1.40
C-WD 1	Basal pebble bed. Pebbles up to 75 mm. Boulders of the underlying Mintlyn Beds reach 0.6 m across. Reworked, green nodules, Early Aptian ammonites, Hauterivian *Craspedodiscus* and Early Albian brachiopods	0.03–0.20

6.2.2 Marham Borehole [TF 7051 0803]

		Thickness m
C-MB 1	Sand, brownish grey, fine and medium-grained, weakly cemented, glauconitic. Bioturbated giving a green-brown mottling and wisps of green and grey mudstone. Occasional small pebbles (<6 mm). Cross-bedded in part. Situated between depths 45.03 and c.50.6 m (base not seen due to core loss between 47.68 and 50.60 m. Base fixed by geophysical logs)	2.65 (plus c.2.90 of core loss)

6.2.3 Gayton Borehole [TF 7280 1974]

		Thickness m
C-GB2	Sand, silty, dark greenish grey, pebbly in part, and soft sand, becoming glauconitic in the lower part. Occasional cross-bedding Bioturbated throughout; sandy, phosphatic burrow infillings near the top and occasional vertical *Skolithus*-type burrows. Pebbles small (generally <6 mm), composed of quartz, ironstone and chalky limestone. Ferruginous cementation in part; oolitic in part	8.43
C-GB1	Pebble bed. Pebble comprising quartz, quartzite, pyritised sandstone, ironstone, grey siltstone and rolled ammonites, up to 50 mm across. Glauconitic, silty sand matrix. Lower boundary irregular, bioturbated, erosion surface with the underlying Snettisham Clay	0.05

6.2.4 Mundford 'C' Borehole [TL 7670 9132]

		Thickness m
C-MCB1	Sand, greenish grey to brown, medium and coarse-grained Pebbly and oolitic in part. Burrowed with grey infill. The top is marked by a seam of cream phosphatic burrow fills. Seen between 107.67 and 110.28 m.	2.61

6.2.5 Hunstanton Cliff [TF 6725 4130 to TF 6786 4238]

See Figure 7

		Thickness m
C-HC5	Sandstone, orange-brown, soft, loamy, fine-grained, ferruginous, in part oolitic with weathered limonite ooliths. Rare, widely spaced phosphatic nodules in the lower part. Heavily bio-turbated with burrow infills of pink and red mudstone brought down from above. The lower boundary is transitional	0.13–0.42
	C-HC5 equates with Owen's (1995) highest three beds of the Upper Carstone Member (Beds 2ii to 2iv):	
	2iv. Sand, soft, yellow and reddish-brown clayey (0.02–0.04 m)	
	2iii. Sand, olive green and brownish loamy (0.04–0.08 m)	
	2ii. Sand, dark brick-red, loamy with a phosphatic nodule seam 0.08 m below the top and scattered nodules below (0.07–0.30 m)	
C-HC4	Sandstone, orange-brown, ferruginous, fine to medium-grained, but pebbly. Small, brown, phosphatic nodules. Some bioturbation indicated by burrows infilled with phosphatised sand. Horizon of ferruginous see page at the base. This is is the Upper Carstone Member, Bed 2i of Owen (1995)	0.80
C-HC3	Sand, brown and yellow, ferruginous with mud drapes and, in the upper part occasional phosphatic nodules. Pebbly throughout, but passing down into a basal pebble bed which rests on an irregular erosion surface. This is the Upper Carstone Member, Bed 1 of Owen (1995)	2.00–2.50
C-HC2	Sandstone, dark brown, massive-bedded, pebbly, oolitic, ferruginous, gritty in part (Bed 3 of Gallois, 1984). It passes down into a basal phosphatic pebble bed (Bed 4 of Gallois, 1984) containing reworked Aptian ammonites, including *Cheloniceras*, *Dufrenoyia*, *Prodeshayesites* and *Tropaeum* (Casey, 1961a; Gallois, 1984)	c.13.90
C-HC1	Clay, oolitic, pebbly, sandy in part, with rare, large, rounded nodules of fossiliferous, sandy, phosphatic ironstone near the top ('iron grit' nodules of Keeping, 1883, p.33). Sharp, irregular, burrowed basal boundary with the underlying Roach. (Bed 2 of Gallois, 1984)	1.30

6.2.6 Hunstanton Borehole [TF 6857 4078]

Carstone Formation between depths of 17.96 and 36.86 m.

		Thickness m
C-HB4	Sandstone, orange-brown, fine to medium grained, earthy texture, ferruginous. Bioturbation: red to brown, mudstone burrowfills down to 0.3 m below the contact with The Hunstanton Formation. The bed becomes more indurated with depth, becoming greenish and yellow brown sandstone, with ooliths of limonite and a chamosite-mud cement. Burrow-mottled in part. Small pebbles present in the lower part. Lower boundary gradational. C-HB4 equates with C-HC5 and C-HC4 of the coastal sequence. (The phosphatic nodule horizon of could not be recognised in the borehole)	1.75
C-HB3	Oolite, chamositic, with fine-grained quartz sand (grains coated with limonite); small quartz and ironstone pebbles in some parts. Very sandy in part, dark brown in colour with some burrow-mottling. Very pebbly in part, with ironstone pebbles up to 3 cm across	3.79
C-HB2	Pebbly oolite and sandy oolite, burrowed at some horizons. Occasional cross-bedding and graded bedding present. Green chamosite-mud cement in some parts. Lower part becomes grey-green sandstone, fine to medium grained, very oolitic, with pale green chamosite-mud cement. Passing down to coarser grained and pebbles (quartz, ironstone, chert, white chalky limestone and green to brown mudstone)	12.27

		Thickness m
C-HB1	Clay, brown and greenish yellow-brown, very sandy and pebbly, burrow-mottled. Becoming sandier with depth. Irregular boundary with the underlying Roach	1.07

6.2.7 The Wash (Borehole 72/78) [TF 6494 4972]

Carstone Formation between depths of 11.00 and 17.35 m.

		Thickness m
C-TW3	Mudstone, pink and dark red, silty and gritty, interburrowed with yellow-brown, sandy, limonitic mudstone; passing down into sand, with phosphatic nodules near the base, and pink mudstone burrow-fills. Resting on fine-grained, partly pebbly, partly indurated sand with dark grey mudstone wisps. Belemnites and terebratulids rare. Wood fragments rare	3.05
C-TW2	Sandstone, yellowish-green, fine grained, very oolitic (chamosite and limonite), with small pebbles of quartz in places; ironstone and oolitic ironstone in places with green chamositic cement. Grey mudstone wisps at some levels. Base not seen due to core loss between 16.80 and 17.10 m	2.75 (0.30 m core loss at base)
C-TW1	Sandstone, fine and medium grained, weakly cemented; scattered pale brown ooliths. Bioturbated, with grey-green, oolitic silty sand burrow infills. Pyrite-cemented, bioturbated base overlying a thin 0.05 m mottled green clay of presumed Sutterby Marl	0.25

6.2.8 Skegness Borehole [TF 5711 6398]

Carstone Formation between depths of 40.42 and 42.60 m.

		Thickness m
C-SB1	Sand, orange-brown with a burrowed upper suface	2.18

6.2.9 Nettleton Bottom Quarry [TF 1249 9823]

The Carstone is 4.58 m thick.

		Thickness m
C-NBQ3	Sand, orange brown, silty with calcareous horizon in the upper 15 cm. A single *Burrirhynchia* specimen has been collected from a calcareous horizon near the top	1.53
C-NBQ2	Sands, orange, coarse, pebbly in part. Large boudin-like goethitic boxstones, with irregular, hard, purplish-brown Liesegang rings and goethite filled pipes and joints are characteristic	2.45
C-NBQ1	Sand, orange, coarse ferruginous with pebbles and nodules in the basal 5 cm (containing derived Ryazanian ammonites)	0.60

6.2.10 South Ferriby Quarry [SE 9915 2045]

The Carstone is up to 0.80 m thick.

		Thickness m
C-SF1	Sand, dark brown, coarse ferruginous with pebbles. It is more calcareous in the upper 15 cm and fossiliferous. *Burrirhynchia leightonensis* and *Neithea* aff. *quinquecosta* are present near the top (Smart and Wood, 1976; Morter, 1979; Gaunt Fletcher and Wood, 1992). Rare, reworked Jurassic ammonites and reptile bones are present. A phosphatic pebble bed is located at the base and *Diplocraterion* are seen penetrating the underlying Jurassic rocks from the base of the formation	up to 0.80

6.2.11 Elsham Interchange (Melton Gallows) [TA 0498 1102]

		Thickness m
C-EI1	Sand, dark, glauconitic with phosphatic nodules at the base and thin shelled bivalves and brachiopods. Fauna as for Melton Bottoms (see below) plus *Entolium orbiculare*, *Exogyra conica* (striate variety), *Oxytoma* ex gr. *pectinatum*, *Rastellum macropterum*, *Neohibolites minimus* and *N.* cf. *pinguis*. An *auritiformis* Zone is indicated. The foraminifera *Arenobulimina macfadyeni*, *Osangularia schloenbachi*, *Marginulinopsis cephalotes*, *Saracenaria bononiensis* and long ranging ostracods are also present	0.20

6.2.12 Melton Bottoms [SE 973 273]

		Thickness m
C-MB2	Quartz sand, yellow and orange, argillaceous, with abundant	

		Thickness m
	limonite ooliths and phosphatic pebbles	0.60–0.90
C-MB1	The above passes down into brownish-green fine chamositic sand. Calcareous nodules are present at the base, at the junction with the Ampthill Clay (Jurassic)	0.15–0.25

Kaye (1964) and Owen et al. (1968) reported *Burrirhynchia leightonensis*, *Cyclothyris mirabilis*, *Modestella festiva*, *Aetosteon latissimum*, *Neithea* sp. and *Rastellum colubrinium* in situ, a fauna that was considered to be similar to that of the *tardefurcata* Zone in the Shenley Limestone of Bedfordshire. Dilley (1969) reported the foraminifer *Osangularia schloenbachi*, which occurs in the Greensand Streak (A4) and basal A3 Bed of Speeton.

6.3 FOLKESTONE FORMATION

6.3.1 Parrat's Pit, Wrecclesham, Surrey [SU 8265 4485]

The description below is based on that of Owen (1992), with additional information from Casey (1961a) (see Figures 10, 11 and 12).

Upper part of the Folkestone Formation

Lyelliceras lyelli and *Pseudosonneratia* (*I.*) *steinmanni* subzones

		Thickness m
FF-PP14	Clay, grey-brown and green-brown sandy with wisps of grey clay. Phosphatic nodules scattered throughout the bed, but with a concentration 0.3 m above the base. *A. lyelli* subzonal fauna is present above the concentration, and a *steinmanni* subzonal fauna below it, but the exact position of the sub-zonal boundary has not been fixed. (Bed 13 of Casey, 1961a)	0.33

Pseudosonneratia (*I.*) *steinmanni* Subzone

FF-PP13	Septarian phosphatic nodule, brown in a matrix of brown sandy clay	0.07
FF-PP12	Clay, grey, sandy with occasional scattered phosphatic nodules. (Bed 13 of Casey)	0.28
FF-PP11	Phosphatic nodules, grey in a matrix of grey-brown streaked sandy clay (Bed 12 of Casey, 1961a)	0.15

?Otohoplites bulliensis Subzone

FF-PP10	Sandy clay, grey-brown streaked with phosphatic nodule layers in the basal, middle and uppermost parts	0.48

Protohoplites (Hemisonneratia) puzosianus Subzone

		Thickness m
FF-PP9	Sandy clay, grey-brown streaked with phosphatic nodule layers in the lower and upper parts (Bed 12 of Casey, 1961a)	0.30
FF-PP8	Sandy clay, grey with wisps of grey clay. (Bed 11 of Casey, 1961a)	0.41

Cleoniceras floridum and *Otohoplites raulinianus* subzones

FF-PP7	Phosphatic nodules, white in a matrix of grey, sandy clay (Bed 10 of Casey)	0.75
FF-PP6	Pebbly grit, grey to yellow, ferruginous with sporadic scattered phosphatic nodules, particularly in a nodule horizon 1.37m above the base of the bed and in the top 0.3m. The upper part can be placed in the *Cleoniceras floridum* Subzone Casey divided this bed into four (his beds 6–9), although this could not be confirmed by Owen (1992): 9. Sand, grey clayey with thinly scattered phosphatic nodules 8. Sand, buff 7. Sand, grey, clayey 6. Sand, buff, course	1.96

regularis Zone

FF-PP5	Phosphatic nodules, cream and grey in a matrix of coarse grained, yellow, pebbly sand and grey clay (Bed 5 of Casey, 1961a). This bed is rich in ammonites (Casey, 1960–1980; Owens, 1992) including *Pictetia depressa*, *Douvilleiceras leightonense*, *Anadesmoceras strangulatum*, *A.subbaylei*, *A. costatum*, *A. nudum*, *Cleoniceras* (*Cleoniceras*) *antiquum*, *C.* (*C.*) *morgani*, *Leymeriella consueta*, *L. magna*, *L. regularis*, *L. intermedia*, *L. pseudoregularis*, *L. rudis* and *L. ?renascens*	0.07
FF-PP4	Clayey sand, yellow, coarse with sparse phosphatic nodules *Leymeriella regularis* Subzone (ammonites recovered include *Anadesmoceras strangulatum*, *A. costatum*, *Leymeriella tenuic stata*, *L. pseudoregularis* and *L. regularis*) (Bed 4 of Casey)	0.81
FF-PP3	Gritty sand, brick-red, impersistant lenses of ferruginous (Bed 3 of Casey, 1961a)	0.30

Lower part of the Folkestone Formation

FF-PP 2	Sand, buff, coarse with occasional friable phosphatic nodules (Bed 2 of Casey, 1961a)	1.22
FF-PP 1	Sand, buff, coarse, current-	

		Thickness m
	bedded, ferruginous in part (Bed 1 of Casey, 1961a)	12.20

Owen, 1992; Casey, 1961a.

6.3.2 Coxbridge Pit, Farnham, Surrey [SU 8258 4595]

The beds referred to here were described by Owen (1992). Upper part of the Folkestone Formation

mammillatum Superzone

		Thickness m
FF-COX 16	Phosphatic nodules, dark brown	0.03
FF-COX 15	Sand, grey, clayey	0.08
FF-COX 14	Phosphatic nodules, dark brown	0.03
FF-COX 13	Sand, grey, clayey	0.10
FF-COX 12	Phosphatic nodules, small, grey in a matrix of silty sand	0.025
FF-COX 11	Sand, grey, clayey	0.08
FF-COX 10	Phosphatic nodules, small, grey in a matrix of silty sand	0.025
FF-COX 9	Sand, grey, silty	0.26
FF-COX 8	Phosphatic nodules, small, grey in a matrix of silty sand	0.03
FF-COX 7	Silty sand with lenticles of grey clay	0.10
FF-COX 6	Phosphatic nodules, small, grey in a matrix of silty sand	0.03
FF-COX 5	Sand, green, silty with occasional scattered phosphatic nodules	0.23
FF-COX 4	Phosphatic nodules, small, grey in a matrix of silty sand	0.08

Biostratigraphy unknown

FF-COX 3	Sand, ferruginous	0.20
FF-COX 2	Sand, green-grey to yellow coarse-grained	0.68

Leymeriella regularis Zone

FF-COX 1	Phosphatic nodules, grey, in a coarse-grained, yellow to grey pebbly sand Ammonites recovered include *Anadesmoceras strangulatum*, *A. costatum*, *Leymeriella pseudoregularis* and *L. regularis*	0.05

Owen, 1992

6.3.3 Squerryes Main Pit, Westerham, Kent [TQ 4330 5395]

Gault on:

Upper part of the Folkestone Formation (see Figures 10, 12 and 13).

Lyelliceras lyelli Subzone

		Thickness m
FF-SMP 20	Clay, dark grey, glauconitic pyritic in part with *Lyelliceras lyelli* and other ammonites (Bed 16 of Casey, 1961a; Bed 16 of Owen, 1992)	0.15
FF-SMP 19	Phosphatic nodules, black, in a matrix of dark grey clay (base of Bed 16 of Casey, 1961a; Bed 15 of Owen, 1992)	0.03
FF-SMP 18	Clay, dark grey, sandy and patches of glauconitic sand. *Hoplites baylei*, *Lyelliceras* and *Isohoplites* have been recorded (Bed 15 of Casey, 1961a; Bed 14 of Owen, 1992)	0.70
FF-SMP 17	Phosphatic nodules, dark grey to black in dark grey clay matrix (Bed 15 of Casey, 1961a; Bed 13 of Owen, 1992)	0.03

Pseudosonneratia (*Isohoplites*) *steinmanni* Subzone

FF-SMP 16	Clay, dark grey, sandy with patches of glauconitic sand and scattered septarian phosphatic nodules(Bed 14 of Casey, 1961a; Bed 12 of Owen, 1992). *Pseudosonneratia* (*Isohoplites*) *steinmanni* Subzone	0.50
FF-SMP 15	Phosphatic nodules, dark grey large, septarian in a very dark grey glauconitic sandy clay (basal Bed 14 of Casey, 1961a; Bed 11 of Owen, 1992)	0.10

?*Otohoplites bulliensis* Subzone

FF-SMP 14	Clay, blue-green, sandy, glauc-onitic with scattered phosphatic nodules (Bed 13 of Casey, 1961a; Bed 10 of Owen, 1992). Barren, but possibly falls within the *Otohoplites bulliensis* Subzone	0.84

Protohoplites (*Hemisonneratia*) *puzosianus* Subzone

FF-SMP 13	Phosphatic nodules, small, grey in a matrix of grey-green, glauconitic sandy clay (Bed 12 of Casey, 1961a; Bed 9 of Owen, 1992). *Protohoplites* (*Hemisonneratia*) *puzosianus* Subzone. *Otohoplites subchloris* is present	0.08
FF-SMP 12	Clay, dark grey-green, glauconitic, sandy with scattered brown-grey phosphatic nodules (Bed 11 of Casey 1961a; Bed 8 of Owen, 1992). *Protohoplites* (*Hemisonneratia*) *puzosianus* Subzone	0.30
FF-SMP 11	Phosphatic nodules, grey in a glauconitic sandy clay (Bed 10 of Casey, 1961a; Bed 7 of Owen, 1992). *Protohoplites* (*Hemi-sonneratia*) *puzosianus* Subzone. *Otohoplites raulinianus* subsp. and *O. auritiformis*	0.10
FF-SMP 10	Clay, dark grey green, glauconitic, sandy (Bed 9 of Casey, 1961a; Bed 6 of Owen, 1992). *Protohoplites* (*Hemisonneratia*) *puzosianus* Subzone	0.30

		Thickness m

?*Otohoplites raulinianus* Subzone

FF-SMP 9	Phosphatic nodules, brown-grey in a very dark grey-green glauconitic sandy clay (Bed 9 of Casey, 1961a; Bed 5 of Owen, 1992). ?*Otohoplites raulinianus* Subzone	0.08
FF-SMP 8	Clay, dark grey-green, glauconitic, sandy with few scattered phosphatic nodules (Bed 8 of Casey, 1961a; Bed 4 of Owen, 1992)	0.18

Cleoniceras floridum Subzone

FF-SMP 7	Phosphatic nodules, brown-grey, in a matrix of dark green, glauconitic sandy clay (Bed 7 of Casey, 1961a; Bed 3 of Owen, 1992). *Cleoniceras floridum* Subzone. The bed is ammonite-rich: *Protanisoceras* (*P.*) *cantianum*, *P.* (*P.*) *vaucherianum*, *P.* (*P.*) *actaeon*, *P.* (*P.*) *hengesti*, *Cleoniceras* (*C.*) *cleon*, *C.* (*C.*) *dimorphum*, *C.* (*C.*) *sublaeve*, *C.* (*C.*) *seunesi*, *C.* (*C.*) *floridum*, *C.* (*Neosaynella*) *inornatum*, *C.* (*N.*) *cantianum*, *Sonneratia* (*S.*) *caperata*, *S.* (*S.*) *flava* and *Parengonoceras ebrayi*	0.08
FF-SMP 6	Clay, blue-grey, dicey, glauconitic and pyritic. Occasional, pale brown, phosphatic nodules in the top 5 cm (Bed 6 of Casey, 1961a; Bed 2 of Owen, 1992). *Cleoniceras floridum* Subzone	1.18
FF-SMP 5	Sand, grey, clayey with purple, green and yellow streaks. The bed becomes more clayey up sequence and passes up, with very little transition to bed FF-SMP4 (Bed 5 of Casey, 1961a; Bed 1c of Owen, 1992). ?*Cleoniceras floridum* Subzone	0.38–0.76
FF-SMP 4	Sand, yellow, orange and green mottled, clayey with a thin iron pan at the base (Bed 4 of Casey, 1961a; Bed 1b of Owen, 1992). ?*Cleoniceras floridum* Subzone	0.36–0.61

Sonneratia kitchini Subzone

FF-SMP 3	Phosphatic nodules, white, sometimes iron stained, in a matrix of ferruginous, pebbly sand (Bed 3 of Casey, 1961a; Bed 1a of Owen, 1992). *Sonneratia kitchini* Subzone. The ammonites include the following: *Sonneratia kitchini*, *S. rotator*, *Anadesmoceras baylei*, and *Cleonoceras morgani*	0.10

		Thickness m

Lower part of the Folkestone Formation

FF-SMP 2	Sand, brown, silty with wisps of grey sand, passing down into current-bedded, sand and grit, pebbly in part (especially 6.1 m above the base) (Bed 2 of Casey, 1961a)	25.91
FF-SMP 1	Silt, buff and grey (base not seen). (Bed 1 of Casey, 1961a)	1.83

Casey, 1961a; Owen, 1988, 1992.

6.3.4 Sandling Pit, Saltwood, Kent [TR 1470 3690]

Described by Casey (1961a) and Owen (1971, 1992). The sequence followed here is taken from Owen (1992) and falls within Bed 16 of Casey (1961a), his Beds 1–15 being placed within the 'Folkestone Beds' (see Figures 10 and 12).

Lower Gault (Bed 9 sensu Owen, 1971) disconformably overlying:

Upper part of the Folkestone Formation

		Thickness m

?*Lyelliceras lyelli* Subzone

FF-SP 14	Clay, grey, slightly glauconitic	0.30
FF-SP 13	Phosphatic nodules, scattered, small in a matrix of slightly glauconitic grey clay	0.03

Pseudosonneratia (*Isohoplites*) *steinmanni* Subzone

FF-SP 12	Clay, yellow, green, grey, mottled, sandy, becoming more argillaceous up-sequence	0.46
FF-SP 11	Phosphatic nodules, ferruginous in a matrix of mottled glauconitic sandy clay	0.08
FF-SP 10	Clay, mottled, glauconitic, sandy with sporadic phosphatic nodules	0.10

Protohoplites (*Hemisonneratia*) *puzosianus* Subzone

FF-SP 9	Clay, grey, sandy with ferruginous phosphatic nodules	0.08
FF-SP 8	Phosphatic nodules, ferruginous in cemented grit The bed is rich in ammonites including: *Douvilleiceras* spp., *Beudanticeras* spp., *Protanisoceras* (*P.*) *cantianum*, *P.* (*P.*) *vaucherianum*, *Cleonoceras* (*C.*) *quercifolium*, *Sonneratia* (*S.*) *dutempleana*, *Pseudosonneratia* (*Isohoplites*) *occidentalis*, *Otohoplites elegans*, *O. polygonalis*, *O. waltoni*, *O. destombesi*, *O. oweni*, *Protohoplites* (*P.*) *latisulcatus*, *P.* (*P.*) *michelinianus*, *Protohoplites* (*Hemisonneratia*) *puzosianus*, *P.* (*H.*) *cantianus*, *P.* (*H.*) *gallicus*	0.08–0.15

Hypacanthoplites milletioides Subzone (= *acuticostata* Subzone of Owen, 1992)

		Thickness m
FF-SP 7	Sand, yellow, with occasional scattered phosphatic nodules Species present: *Hypacanthoplites trivialis* and *H. milletioides*	0.15–0.22

Lower part of the Folkestone Formation

FF-SP 6	Sandstone, grey-green, bioturbated in the upper part. *Oxytoma* abundant (Bed 15 of Casey, 1961a, p.533)	0.33
FF-SP 5	Sand, grey-green (Bed 14 of Casey, 1961a, p.533)	1.02
FF-SP 4	Limestone, hard, grey passing laterally into white spicular sandstone with sandy intercalations (Bed 13 of Casey, 1961a, p.533)	0.56
FF-SP 3	Sand, grey-green, cross-bedded (Bed 12 of Casey, 1961a, p.533)	0.33
FF-SP 2	Limestone, hard, grey, sandy (Bed 11 of Casey, 1961a, p.533)	0.66
FF-SP 1	Sandstone, yellow, coarse-grained, glauconitic, cross-bedded (Bed 10 of Casey, 1961a, p.533). Resting on black phosphatic nodules (*jacobi* Zone, Aptian)	0.91

Casey, 1961a; Owen, 1971, 1992.

6.3.5 East Cliff, Folkestone, Kent [TR 240 364]

The sequence herein is based on that given by Casey (1961a). The section is not exposed in its entirety and more isolated exposures between the harbour and the foreshore in East Wear Bay now have to be sought (Owen, 1992) (see Figures 8, 9, 10 and 12).

Upper part of the Folkestone Formation

		Thickness m

Lyelliceras lyelli Subzone

FF-EC 36	The 'Greensand Seam' (Bed Iii of Casey, 1950). Clay, highly glauconitic, sandy, shelly towards the top with three phosphatic nodule horizons at the base, middle (about 0.2 m above the base) and top of the bed (Bed Iii, iii and iv of Owen, 1992). The *Lyelliceras lyelli* Subzone is recognised at the top of the bed on the basis of the presence of *Hoplites* (*Hoplites*) cf. *baylei* and *Beudanticeras* sp. The basal nodule horizon contains *Pseudosonneratia* (*Isohoplites*) *steinmanni*	0.28–0.36

Otohoplites bulliensis Subzone to *Protohoplites* (*Hemisonneratia*) *puzosianus* Subzone

		Thickness m
FF-EC 35	'Sulphur Band' (Bed Ii of Casey, 1950 and of Owen, 1992). Phosphatic nodules, large, grey, pyrite-coated in a matrix of pyritic sandy clay. Casey (1961a, p.530) recorded the presence of *Inoceramus salomoni*, fragments of *Protohoplites* and *Pseudosonneratia*, *Cleoniceras* cf. *quercifolium* and *Otohoplites*, together with longer ranging *Douvilleiceras mammillatum*, *D. monile* and *Beudanticeras newtoni*. Casey (1960–1980) alsorecorded *Protohoplites* (*Hemisonnerata*) *puzosianus*. He was in no doubt that this was of *P.* (*H.*) *puzosianus* Subzonal age. Owen (1992) found no ammonites at Folkestone, but recorded rare *Otohoplites crassus* in the same bed to the north of Folkestone which indicates the *bulliensis* Subzone. There is, therefore, a conflict in the subzonal age and it would Appear that there is a mixing of subzones in the bed, perhaps by reworking	0.15–0.33

Protohoplites (*Hemisonneratia*) *puzosianus* Subzone

FF-EC 34	Sand, yellow, coarse-grained, glauconitic with burrow-fills of grey clay passing up into grey, glauconitic, pyritic, sandy clay (Bed 34 of Casey, 1961a; Bed 7 of Owen, 1992). The presence of *Otohoplites waltoni* suggests the *Protohoplites* (*Hemisonneratia*) *puzosianus* Subzone	0.43–0.61
FF-EC 33	'Main Mammillatum Bed' (pars). Sand and grit, grey clayey, secondary concretionary induration in part (Bed 33 of Casey, 1961a; Bed 6ii of Owen, 1992)	0.15–0.41
FF-EC 32	'Main Mammillatum Bed' (pars). Phosphatic nodules in a matrix of grit silty sand that has been effected by secondary concretionary induration (Basal Bed 33 of Casey, 1961a; Bed 6i of Owen, 1992). Most fossils from the 'Main Mammillatum Bed' come from this nodule bed. Casey (1961a, p.530) listed several dozen species, noting that the nodule horizon represented a remanié as a number of them were derived from the *floridum* and *raulinianus* subzones. However indigenous taxa include *Protohoplites*, *Sonneratia dutempleana* and *Otohoplites guersanti* of the *Protohoplites* (*Hemisonneratia*) *puzosianus* Subzone	0.15

		Thickness m
?*floridum* Subzone		
FF-EC 31	Sand, coarse yellow, gritty, the uppermost part of which has suffered secondary concretionary induration (Bed 32 of Casey, 1961a; Bed 5 of Owen, 1992). Owen (1992) suggested a *floridum* subzonal age, although fossils are wanting	0.31–0.46
FF-EC 30	Sand, yellow, slightly glauconitic, (Bed 31 of Casey, 1961a; Bed 4 of Owen, 1992)	0.92
FF-EC 29	Sand and grit, indurated, yellow (Bed 30 of Casey, 1961a; Bed 3 of Owen, 1992)	0.38
FF-EC 28	Sand and grit, coarse, pebbly, (Bed 29 of Casey, 1961a; Bed 2 of Owen, 1992)	0.66
Sonneratia kitchini Subzone		
FF-EC 27	'*Sonneratia kitchini* Bed' (Casey, 1961a). Sand, yellow coarse with small black phosphatic nodules (Bed 28 of Casey, 1961a; Bed 1 of Owen, 1992). *Sonneratia kitchini* and *Douvilleiceras mammillatum* have been found here (Casey, 1961a)	0.10–0.20
Lower part of the Folkestone Formation		
FF-EC 26	Sand and grit, coarse, yellow, (Bed 27 sensu Casey, 1961a)	0.66
FF-EC 25	Grit, indurated, calcareous (Bed 26 sensu Casey, 1961a)	0.36
FF-EC 24	Greensand, yellowish with small ferruginous nodules (Bed 25 sensu Casey, 1961a)	3.05
FF-EC 23	Sandstone, spicular, porcellanous and cherty in part (Bed 24 sensu Casey, 1961a)	0.23
FF-EC 22	Greensand, yellowish with lenticles of sandstone. Comminuted bivalves (Bed 23 sensu Casey, 1961a)	0.35
FF-EC 21	Greensand, yellowish (Bed 22 sensu Casey, 1961a)	1.14
FF-EC 20	Sandstone, spicular, porcellanous and cherty in part (Bed 21 sensu Casey, 1961a)	0.15–0.25
FF-EC 19	Greensand, yellowish (Bed 20 sensu Casey, 1961a)	0.35
FF-EC 18	Sandstone, spicular, impersistant porcellanous and cherty in part (Bed 19 sensu Casey, 1961a)	0–0.13
FF-EC 17	Greensand, yellowish (Bed 18 sensu Casey, 1961a)	0.74
FF-EC 16	Sandstone, hard grey, calcareous (Bed 17 sensu Casey, 1961a)	0.42
FF-EC 15	Greensand, yellowish (Bed 16 sensu Casey, 1961a)	0.28
FF-EC 14	Sandstone, spicular, impersistent, porcellanous and cherty in part (Bed 15 sensu Casey, 1961a)	0–0.08

		Thickness m
FF-EC 13	Greensand, yellowish (Bed 14 sensu Casey, 1961a)	0.91
FF-EC 12	Sandstone, hard, grey, calcareous (Bed 13 sensu Casey, 1961a)	0.23–0.31
FF-EC 11	Sandstone, spicular, porcellanous and cherty in part (Bed 12 sensu Casey, 1961a)	0.23–0.31
FF-EC 10	Sand, yellow-green, clayey with iron staining (Bed 11 sensu Casey, 1961a)	1.32
FF-EC 9	Sandstone, impersistent, spicular, porcellanous and cherty in part (Bed 10 sensu Casey, 1961a)	0–0.08
FF-EC 8	Sand, yellow-green, clayey with iron staining (Bed 9 sensu Casey,1961a)	c.2.00
FF-EC 7	Sandstone, spicular, porcellanous and cherty in part (Bed 8 sensu Casey, 1961a)	0.15
FF-EC 6	Mudstone, greenish, sandy (Bed 7 sensu Casey, 1961a).	0.37
FF-EC 5	Sand, green, clayey (Bed 6 sensu Casey, 1961a)	0.42
FF-EC 4	Phosphatic nodules, and small black chert pebbles. *Exogyra* common. (Bed 5 sensu Casey, 1961a)	0–0.05
FF-EC 3	Sandstone, hard, grey-green, glauconitic, calcareous sandstone (Bed 4 sensu Casey, 1961a)	0.54
FF-EC 2	Phosphatic nodules, and small black chert pebbles. *Exogyra* common. (Bed 3 sensu Casey, 1961a)	0–0.05
FF-EC 1	Greensand, clayey with abundant shell fragments and very small pebbles of black chert (Bed 2 sensu Casey, 1961a) On pebbly, glauconitic silty sand with phosphatic nodules (*jacobi* Zone, Aptian) (Bed 1 of Casey, 1961a)	0.61

Casey, 1961a; Owen, 1992.

6.3.6 Horton Wood Borehole No. 9, Small Dole, near Upper Beeding, West Sussex [TQ 207 127]

Gault (dark grey, slightly silty and micaceous clay; *dentatus* Zone) resting on:

Folkestone Formation (including 'basement beds of the Gault' of some authors) between 12.19 m and 17.38 m (depth). The 'basement beds of the Gault' fall within the *steinmanni* Subzone (*auritiformis* Zone).

		Thickness m
FF-HWB4	Age unknown. Clay, hard, grey, green glauconitic, sandy with pockets and channels of sand, algal filaments and a few dark phosphatic nodules	2.43
FF-HWB3	*steinmanni* Subzone. Loam, hard, dark green, glauconitic	

		Thickness m
	with rafts of clay and pockets and channels of coarse sand; sandy phosphatic nodules and small pebbles; pyritic nodules at top; hard pebbly band at a depth of 16.5–16.6 m. *Hoplites* or *Isohoplites* at a depth of 16.2 m	2.59
FF-HWB2	?*mammillatum* Superzone. Phosphatic nodules, dark, gritty and small pebbles in glauconitic,sandy clay	0.17

Horton Wood Clay Member (between 17.38 m and 21.03 m).

regularis Zone

HWC-HWB1	Clay, dark grey, non calcareous with hard, flat, whiteish nodules, especially at the top, a few pyritic nodules and numerous algal filaments; some threads of glauconitic sand; washed residues full of glauconite, mica, and a few foraminifera. *Aconeceras* and *Leymeriella* with iridescent test; crustacean limbs fairly common (Casey, 1961a, p.558)	3.65

Folkestone Formation (between 21.03 m and 21.94 m)

milletioides Subzone

FF-HWB1	Clay, green, glauconitic sandy with phosphatic nodules	0.91

Casey, 1961a, pp.557–560.

6.3.7 Horton Hall clay pit, Upper Beeding, West Sussex [TQ 2075 1230]

Folkestone Formation (including 'basement beds of the Gault'). The 'Basement Beds of the Gault' are of *steinmanni* Subzone age.

		Thickness m
FF-HH2	Clay, dark grey, glauconitic, shelly in the upper 0.30 m, becoming increasingly glauconitic down section (Bed 1ii of Owen, 1971)	2.44
FF-HH1	Clay, hard, dark green, glauconitic, silty and sandy clay with pockets of coarse sand, sandy phosphatic nodules and small pebbles. Pyritic nodules occur at the top. A pebbly band is situated c.0.60 m from the base (Bed 1i of Owen, 1971)	2.60

Owen, 1971

6.4 SANDROCK FORMATION

6.4.1 Chale Bay, Rocken End to Blackgang Chine [SZ 4910 7570 to 4850 7670]

The Sandrock Formation at this locality (Figure 14) is overlain by arenaceous deposits referred to as 'Carstone'. The latter has a pebble bed at the base, overlying an erosion surface. The stratigraphical relationship between the 'Carstone' of the Isle of Wight and the Carstone Formation of eastern England is unclear. It is not possible to trace the unit from the Isle of Wight into eastern England.

Sandrock Formation: *L. tardefurcata* Zone; *H. milletioides* Subzone sensu Casey, 1961; Lower Albian

		Thickness m
SF-REBC4	g. Sand, medium-grained (coarser towards the top), bioturbated, muddy (pebbly in places, especially at the base)	5.50–6.00
	f. Clay and sand, interlaminated	1.5–1.75
	e. Quartz sand, white to yellow, medium- to coarse-grained, pebbly in places, bioturbated	4.6
	d. Clay and sand, interlaminated	1.5
	c. Quartz sand, medium- to coarse-grained, with cross-bedding and mud laminations in places	3.25
	b. Sand, grey, muddy with horizontal stratification, passing up into c	4.75
	a. Mud and silt, dark grey resting on an erosion surface, passing up into b	5.50
SF-REBC3	e. Quartz sand, medium- (to coarse- at the top) grained, burrowed, glauconitic, cross-bedded in part, with erosion channels (unit 49 and third sandrock of Fitton, 1847) (partly obscured)	7.50
	d. Sand, grey, muddy sands with horizontal stratification	8.75
	c. Sand, medium-grained, cross-bedded sand resting on a scoured surface	Up to 1.75
	b. Sand, grey, muddy with horizontal stratification, passing up into c	5.25–5.75
	a. Mud and silt, dark grey passing up into b	2.75

Sandrock Formation: *jacobi* Zone; *H. anglicus* and *H. rubricosus* subzones (SF-REBC2; SF-REBC1b–e), *N. nolani* Subzone (SF-REBC1a); Aptian?

SF-REBC2	d. Quartz sand, white, medium- (to coarse- at the top) grained, burrowed, cross-bedded with erosional channels	0.50
	c. sandy mud and muddy sand, grey, glauconitic with calcareous nodules near the top	5.50
	b. Mud and silt, dark grey, bioturbated glauconitic, (unit 48 of Fitton, 1847), passing up into c	5.25
	a. Pebble bed on a scoured surface	0.30

		Thickness m
SF-REBC1	e. Quartz sand, white, medium-grained, burrowed, resting on a scoured surface (the sands of SF-REBC1c–e form unit 47 and the 2nd Sandrock of Fitton, 1847)	1.50
	d. quartz sand,white, medium-grained, cross-bedded, with black clay drapes resting on a scoured surface. Plant debris	2.25
	c. Quartz sand, white, medium-grained, burrowed, muddy in the lower part	2.55
	b. Mud, interlaminated grey sandy and muddy sands, passing up into c	0.45
	a. Mud and silt, dark grey and black, glauconitic (unit 46 of Fitton, 1847), unfossiliferous except for lignite, passing up into b	12.5

Fitton, 1847; Insole et al., 1998; Ruffell and Wach, 1998a, b; Wach and Ruffell, 1990.

6.4.2 Compton Bay [SZ 3665 8520]

As at Chale Bay (see above), the Sandrock Formation at this locality is overlain by arenaceous deposits referred to as 'Carstone'. The latter has a pebble bed at the base, overlying an erosion surface (see Figure 15).

		Thickness m
SF-CB4	Mud and silt, very dark grey, glauconitic resting on a burrowed erosion surface	0.80
SF-CB3	b. Sand, medium-grained, glauconitic, bioturbated with plant debris particularly in the lower part	3.70
	a. Pebble bed (up to c.0.7 m) on a scoured surface	0.70
SF-CB2	c. Sand, medium-grained, with cross-wavy and flaser bedding. Bioturbated. Occasional pyritised wood	2.15
	b. Mud and silt, dark grey and greenish glauconitic passing up into grey sandy mud and muddy sand (middle part of the bed obscured) passing up into c	11.77
	a. Pebble bed, thin	0.15
SF-CB1	c. Quartz sand, yellow and white, medium- passing up into coarse-grained, sand with cross-, wavy and flaser bedding and black mud drapes. Bioturbated in part. Plant remains present	4.70
	b. Mud and silt, black, bioturbated, glauconitic passing up into grey sandy muds and muddy sands ('foliated series')	7.20
	a. Pebble bed, thin resting on a scoured surface on the Ferruginous Sands Formation	0.30

Osborne Wight, 1921; Strahan, 1889; Wach and Ruffell, 1990.

6.5 LOWER GREENSAND 'FORMATION' (BEDCHESTER SANDS MEMBER)

6.5.1 Child Okeford, near Shaftesbury [ST 8358 1330]

		Thickness m
Gault	Clay, sandy, orange-grey, pebbly, resting on Bedchester Sands	2.00
BSM-CO2	Sand, fine-grained, glauconitic, silty	0.10
BSM-CO1	Sand, fine-grained, very silty, glauconitic resting on Child Okeford Sand	4.40

Bristow et al., 1995

6.5.2 Piper's Mill, near Shaftesbury [ST 8568 1702]

		Thickness m
Gault	Mudstone, brown-grey, mottled, pebbly in the lower part, resting on Bedchester Sands	0.61
BSM-PM5	Sand, greenish-brown, with clay mottling	0.61
BSM-PM4	Mudstone, soft, purple-brown (0.3 m); passing down into dark green sandy mudstone with patches of green brown sand; passing down into mottled brown, yellow and green sand	1.52
BSM-PM3	Mudstone and sand, purple-black, laminated	0.30
BSM-PM2	Greenish black, glauconitic mudstone	0.76
BSM-PM1	Sandstone, indurated, brown, ferruginous, resting on Child Okeford Sands	0.15

Bristow et al., 1995; Jukes-Browne, 1891.

6.5.3 Hartgrove Farm pit, near Shaftesbury [ST 8389 1819]

		Thickness m
Gault	Clay, silty, orange grey, mottled passing down into a medium grey mudstone (1.2 m thick) resting on Bedchester Sands	
BSM-HF4	Sandstone, fine-grained, ferruginous	0.30
BSM-HF3	Sand, fine-grained with lenses of poorly sorted, coarse-grained sand	0.30
BSM-HF2	Sand, fine-grained, silty, glauconitic with thin beds and	

		Thickness m
	lenses of purplish-brown mudstone	0.30
BSM-HF1	Sand, fine grained, silty, glauconitic, bioturbated resting on Kimmeridge Clay	0.70

Bristow et al., 1995.

6.5.4 Winterborne Kingston Borehole [SY 8470 9796]

		Thickness m
Gault	Gault (base not seen) overlies Bedchester Sands (the latter including 'Basement beds of the Gault')	
BSM-WK3	Mudstone, dark grey-green, shelly, sandy. Bivalves include *Birostrina* cf. *salomoni*, *C. gaultinus*, *E. orbiculare*, *Mimachlamys robinaldina*, *N. carinata* and *Oxytoma pectinatum* (*auritiformis* Zone)	Between depths 345.24 and 345.55 (top not seen)
BSM-WK2	Mudstone, sandy, ferruginous, oolitic with fragments of *Sonneratia kitchini* Subzone	Between depths 345.62 and 346.23
BSM-WK1	Mudstone, grey, silty and sand. *mammillatum* Super-zone? (below the *kichini* Subzone?) The 'basement beds of the Gault' fall within the *mammillatum* Superzone	Between depths 346.35 and 346.40 (base not seen)

Morter, 1982

6.6 GAULT FORMATION (EASTERN ENGLAND: BEDFORDSHIRE TO NORFOLK)

6.6.1 Mundford 'C' Borehole [TL 7670 9132]

The Mundford 'C' Borehole is the reference section for the Gault Formation of East Anglia and the English Midlands (Middle and Upper Albian). Nevertheless, the Mundford 'C' Borehole section is incomplete, as a higher bed (G19) is present in the Gayton Borehole (TF 7280 1974) (Figure 17).

Bed numbers follow Gallois and Morter (1982). The Cambridge Greensand Formation overlies Upper Gault at a depth of 89.59 m.

Upper Gault (89.59–100.25 m depth)

dispar Zone, *rostratum* Subzone

		Thickness m
G18-MCB	Mudstone, very pale grey, very calcareous, smooth, bioturbated with *Chondrites*. Pale brown phosphatic burrow infills common. Sparsely shelly: *Aucellina coquandiana*, *Entolium orbiculare*, *Plicatula radiola gurgitis Plagiostoma globosa* (bivalves) and *Holaster* cf. *laevis* (echinoid); *Neohibolites praeultimus* (belemnite); *Anisoceras* sp., *Cantabrigites cantabrigense*, *C. minor*, *Callihoplites glossonotus*, *Lechites* sp., *Lepthoplites* cf. *pseudoplanus*, *Mortoniceras* sp. (ammonites); fish debris, ostracods, foraminifera, calcareous nanofossils and dinoflagellate cysts	1.93
G17-MCB	Mudstone, very pale grey, smooth, bioturbated, shelly (*Aucellina coquandiana*-rich). Pyritised burrow-fills common. Base marked by a burrowed surface on which lie black phosphatic pebbles. Abundant *Aucellina coquandiana* and sparse *Entolium orbiculare* (bivalves); *Anisoceras* cf. *exoticum*, *Callihoplites* cf. *cratus*, *C. glossonotus*, *C.* cf. *leptus*, *C.* cf. *pulcher*, *C.* spp., *Lepthoplites cantabrigiensis*, *L.* spp. (ammonites); *Neohoplites praeultimus*, *N. minimus*, *N.* spp. (belemnites); ostracods, foraminifera, calcareous nano-fossils and dinoflagellate cysts	1.19

inflatum Zone, *auritus* Subzone

G16-MCB	Mudstone, pale grey becoming darker with depth, smooth, fossils very rare (*Aucillina* spp., *Neohibolites minimus*, *Isocrinus legeri*, *Nielsenicrinus* aff. *cretaceus*). Burrowed surface at the base. The basal 3 cm is a shelly pebble bed comprising phosphatic burrow-fills and pebbles in a silty, medium grey, mudstone matrix (Milton Brach-iopod Band). Fossils common within the basal bed, including *Moutonithyris dutempleana*, *Terebratulina* cf. *martiniana*, oysters, *Mortoniceras* sp. (*rostratum* group)	1.55
G15-MCB	Mudstone, pale grey, smooth, becoming siltier with depth; upper part bioturbated (including *Chondrites*), burrow fills being darker mudstone. Shelly, '*Inoceramus*' *lissa* being common; ammonites are common, including *Callihoplites* cf. *pulcher*, *C.* cf. *strigosus*, *C.* cf. *variabilis*, *Hysteroceras bucklandi*, *Lepthoplites* cf. *falcoides*, *L.* cf. *ornatus*, *Mortoniceras* (*M.*) *fissicostatum*, *M.* (*M.*) *inflatum*, *Stomohamites* cf. *subvirgulatus* and *Prohysteroceras* (*Goodhallites*)	

Thickness m

sp.; *Kingena spinulosa* and *Moutonithyris dutempleana* (brachiopods); *Aucellina coquandiana*, *Callicymbula* cf. *phaseolina*, *Entoplium orbiculare*, *Plagiostoma globosa*, *Plicatula radiola gurgitis* and *Pycnodonte* sp. (bivalves); *Neohibolites minimus*, *N. praeultimus*, and, in the basal part, *N. ernsti*. Phosphatised *Thallasinoides* burrow-fills occur in the lower part of the bed. The basal part of the bed is silty, glauconitic and shelly with *Inoceramus prisms* and abundant ostracods and foraminifera (and locally cemented to form a limestone called the Barnwell 'Hard Band'). The base is a burrowed surface with phophatised burrow-fills and *Dentalium* — 1.70

varicosum Subzone

G14-MCB — Mudstone, pale grey, smooth, becoming siltier and darker at the base with common *Chondrites*. Lower boundary is a burrowed erosion surface. Four marker bands may be recognised: *Euhoplites alphalautus*-rich band near the top, *Neohibolites*-rich b and in the upper part of the bed, *Anahoplites*-rich band in the middle part and *Birostrina* cf. *concentrica*-rich band at the base. The fauna comprises, characteristically: common *Neohibolites minimus*, *N. ernsti*, with, in the upper part, *N. praeultimus*, and in the lower part *N. oxycaudatus*; *Euhoplites alphalautus*, *E. vulgaris*, *Hysteroceras binum*, *H.* cf. *orbignyi*, *H. varicosum binodosa*, *Idiohamites* cf. *spinulosus*, *I.* cf. *subspiniger*, *Mortoniceras* (*M.*) sp., *Semenovites* sp.; *Inoceramus lissa* in the top of the bed and *I. anglicus* in the lower part, and *Birostrina* cf. *concentrica*. Other fossils include *Cyclocyathus fittoni*, *Parsimonia antiquata*, *Kingena spinulosa*, *Moutonithyris dutempleana*, *Terebratulina* cf. *martiniana*, *Barbatia marullensis*, *Eopecten studeri*, *Nucula pectinata*, *Pycnodonte* (*P.*) aff. *vesicularis*, *Turnus*, *Nielsenicrinus cretaceus* and *Stereocidaris gaultina* — 0.81

orbignyi Subzone

G13-MCB — Mudstone, medium grey, slightly silty, bioturbated with *Chondrites*. Burrow fills

Thickness m

comprise a paler grey mudstone. A *Birostrina concentrica*-rich band occurs in the top part and an *Actinoceramus sulcata*-rich band is situated in the upper part of the bed. Ammonites are abundant, particularly *Euhoplites armatus*, *E. inornatus*, *E. proboscideus*, *E. subcrenatus* and *E. trapezoidalis*, but others are also present: *Anahoplites* sp., *Dipoloceras* sp., *Hysteroceras binum*, *H. carinatum*, *H. orbignyi*, *Mortoniceras* (*D.*) sp., hamitids, *Idiohamites* (in the upper part), *Hamites intermedius* (in the lower part); *Trochocyathus*, *Parsimonia antiquata*. *Kingena spinulosa*, *Moutonithyris dutempleana*, *Atreta* sp., *Nucula pectinata*, *Plicatula* sp.,*Pycnodonte* aff. *vesicularis*, *Neohibolites oxycaudatus*, *N. ernsti*, *Nielsencrinus cretaceus*, *Cirocerithium subspinosum*, *Dentalium* sp. and *Inoceramus anglicus*. Lower part of the bed is less fossiliferous, but with common *Actinoceramus sulcata*, *B. subsulcata* and *Neohibolites minimus* and rare ammonites. The lower boundary is burrowed — 2.49

G12-MCB — Mudstone, very pale grey, smooth, very calcareous, burrow-filled with dark grey mudstone. Sparsely fossiliferous, but includes common *Actinoceramus sulcata* and *Inoceramus anglicus*, together with occasional *Jurassiphorus fittoni*, *Nucula pectinata*,. *Plicatula* sp., *Pycnodonte* aff. *vesicularis*, *Euhoplites inornatus*, *E.* sp., *Neohibolites minimus*, and *Nielsenicrinus cretaceus*. Phosphatised burrows at the base. The lower boundary is an erosion surface — 0.31

orbignyi–cristatum subzones

G11-MCB — Mudstone, medium grey, slightly silty in part, with thin pale interbeds. Bioturbated (including *Chondrites*). Fossiliferous: common *Actinoceramus*, including *Actinoceramus sulcata*, *B. subsulcata* and, in the upper part, *B. concentrica gryphaeoides*; common *Neohibolites minimus*; and less common, *Inoceramus anglicus*, *Cyclocyathus fittoni*, *Anchura carinata*, *Jurassiphorus fittoni*, *Nucula pectinata*, *Turnus*, Thickness m

sp., *Niesenicrinus cretaceus* and ammonites, *Anahoplites* spp., *Euhoplites inornatus* (near the top of the bed), *E. ochetonotus*, *E. trapezoidalis*, *Metaclavites* sp. and *Mortoniceras* sp. *Phosphatic* pebbles in a silty, shelly mudstone matrix overlie the burrowed basal junction — 1.49

Lower Gault (100.25–107.67 m depth)

lautus Zone, *nitidus* Subzone

G10-MCB — Mudstone, medium grey, silty, shelly. Base is a burrowed erosion surface with phosphatic pebbles. *Birostrina concentrica* and *Neohibolites minimus minimus* are common. Also present are *Cyclocyathus fittoni*, *Lingula* sp., *Nucula pectinata*, *Anahoplites* sp., *Dimorphoplites* sp., *Euhoplites nitidus*, *E.* cf. *opalinus* and *Hamites maximus* — 0.79

G9-MCB — Mudstone, very pale, brownish grey. Bioturbated (including *Chondrites*), burrows having darker grey infill. Macrofossils sparse: *Dentalium* (*Fissidentalium*) *decussatum*, *Birostrina concentrica*, *Callicymbula phaseolina*, *Inoceramus* cf. *anglicus*, *Pinna* sp., *Neohibolites minimus*, *Dimorphoplites* sp., *Euhoplites* spp., *Stereocidaris gaultina*. Phosphatic pebbles rest on a basal erosion surface — 0.28

loricatus Zone, *meandrinus* Subzone

G8-MCB — Mudstone, interbedded pale and medium grey. Bioturbated. *Birostrina concentrica* and *Entolium orbiculare* rich bands occur. Also present are *Euhoplites* cf. *bilobus*, *E.* cf. *cantianus*, *Nucula pectinata*, *Neohibolites minimus* and *Turnus* sp. The pebble bed that overlies the basal erosion surface comprises angular pebbles of pale green and reddish brown mudstone accompanied by a large amount of shell debris — 0.54

meandrinus–subdelaruei subzones

G7-MCB — Mudstone, pale grey, smooth, shelly, particularly in the lower part. Bioturbated (including *Chondrites*), burrows picked out by darker grey and green mudstone. *Birostrina concentrica*, *Neohibolites minimus* and *Nucula pectinata* abundant; *Dimophoplites*-rich band in some areas, includes *D.* cf.

Thickness m

doris, *D.* aff. *pinax* and *D.* sp.; *Hamites* locally common. Also present, *Trochocyathus conulus*, *Kingena spinulosa*, *Inoceramus* aff. *anglicus*, *Plicatula* sp., *Hemiaster* cf. *asterias*. A *Birostrina concentrica*-rich band, sometimes accompanied by phosphatic pebbles, overlies the basal erosion surface — 0.76

niobe Subzone

G6-MCB — Mudstone, pale to medium grey, slightly greenish, becoming silty down section. *Birostrina concentrica* common. *Euhoplites loricatus* common in the lower part. *Trochocyathus* sp., *Neohibolites minimus* and *Falciferella milbournei* also occur. *Birostrina* and phosphatic pebbles overlie the basal erosion surface — 0.94

intermedius Subzone

G5-MCB — Mudstone, pale grey, shelly, bioturbated (including *Chondrites*) with darker grey burrow infilling. *Anomia* cf. *carregozica* rich band in the upper part. *Birostrina concentrica* common and *B. concentrica braziliensis* rare. *Neohibolites minimus* common in the lower part. Also present are *Entolium orbiculare*, *Anahoplites intermedius* and *Hemiaster* sp. — 0.38

G4-MCB — Mudstone, bioturbated to give a green/brown grey mottling. Macrofossils are sparse, but include *Anomia carregozica*, *Birostrina concentrica*, *Bakevellia rostrata*, *Anahoplites mantelli*, *Dimorphoplites* sp. and *Neohibolites minimus* — 0.25

loricatus–dentatus zones, *intermedius–spathi* subzones

G3-MCB — Mudstone, pale and medium grey, becoming darker and siltier towards the base. Bioturbated. Shelly, including *Birostrina concentrica*, '*Ostrea*' *papyracea*, *Anahoplites intermedius*, *Dimorphoplites* sp., *Euhoplites microceras* gr., *E. loricatus* (in the upper part), *Hoplites* aff. *vectense*, *Moutonithyrus* sp., *Anticonulus conoideus*, *Rissoina sowerbii*, *Entolium orbiculare*, *Inoceramus* aff. *anglicus*, *Pycnodonte* sp., *Ludbrookia tenuicosta*, *Neithea* spp.,

		Thickness m
	Nucula pectinata, *Neohibolites minimus minimus*, *N. minimus pinguis*, *Hemiaster baylei*. *Birostrina*-rich bed near the base. Dentatus Nodule Bed at the base comprises phosphatic pebbles (with fragments of *Hoplites* cf. *dentatus* and *H.* cf. *spathi*) in a silty mudstone overlying a burrowed erosion surface	1.83

spathi Subzone

G2-MCB	Mudstone, pale and medium grey, and siltier in the lower part. Bioturbation (including *Chondrites*) with paler grey burrow-fills. Shelly: *Birostrina concentrica* and *Ostrea papyracea* common; *Cyclocyathus fittoni*, *Kingena spinulosa*, *Moutonithyrus dutempleana*, *Tamarella* cf. *oweni*, *Nucula pectinata*, *Pseudolimea gaultina*, *Pycnodonte* sp., *Rastellum* sp., *Neohibolites minimus*, *Hoplites dentatus*, *Hoplites spathi*. *Birostrina* and phosphatic pebbles in a silty matrix rest on a burrowed erosion surface	0.81

lyelli Subzone

G1-MCB	Mudstone, very pale, slightly brown, grey, becoming sandy with pebbles towards the base. Bioturbated, burrow infills being brown sand with ooliths. Macrofossils sparse, but with an *Ostrea papyracea*-rich bed locally. Other macrofossils include *Birostrina concentrica*, *Pycnodonte* sp., *Neohibolites minimus Hoplites* cf. *pseudoluci* and *H.* spp. This bed passes down into the Carstone (present between depths of 107.67 m and 110.28 m	0.84

Gallois and Morter, 1982

6.6.2 Gayton Borehole [TF 7280 1974]

The Cambridge Greensand Formation overlies Upper Gault at a depth of 13.03 m. The Upper Gault is present between 13.03 m and 20.55 m, the Lower Gault between 20.55 m and 22.00 m. The Gault Formation overlies the Carstone Formation, present between depths of 22.00 m and 30.48 m (Figure 17).

		Thickness m
Upper Gault 13.03–20.55 m		
G19-GAY	Mudstone, very pale, calcareous, smooth, interbedded with off-white marl. Macrofossils sparse; *Aucellina coquandiana*, *Neohibolites praeultimus*, *N.* spp. common	0.76
G18-GAY	Lithologies of Beds G1–18 as for Mundford 'C' Borehole	0.82
G17-GAY		0.48
G16-GAY		0.94
G15-GAY		0.81
G14-GAY		1.17
G13-GAY		1.34
G12-GAY		0.16
G11-GAY		1.04
Lower Gault 20.55–22.00 m		
G10-GAY		absent
G9-GAY		absent
G8-GAY		
G7-GAY		0.33
G6-GAY		(condensed)
G5-GAY		
G4-GAY		0.23
G3-GAY		0.25
G2-GAY		0.18
G1-GAY		0.46

Gallois and Morter, 1982; Wilkinson, 1990; Wilkinson and Morter, 1981.

6.6.3 Marham Borehole [TF 7051 0803]

The Cambridge Greensand Formation overlies Upper Gault at a depth of 33.43 m. The Upper Gault is present between 33.43 m and 41.58 m, the Lower Gault between 41.58 m and 45.03 m. The Gault Formation overlies the Carstone Formation, present between depths of 45.03 m and c.50.6 m (core loss) (see Figure 17).

Bed G19 at the top of the Upper Gault is missing from Marham Borehole.

		Thickness m
Upper Gault 33.43–41.58 m		
G18-MAR		0.71
G17-MAR		0.38
G16-MAR		1.22
G 15-MAR		1.27
G 14-MAR		1.83
G 13-MAR		1.42
G 12-MAR		0.35
G 11-MAR		0.97
Lower Gault 41.58–45.03 m		
G10-MAR	bioturbated with Bed G9	0.41
G9-MAR		
G8-MAR		0.05
G7-MAR		0.71
G6-MAR		absent
G5-MAR		0.10
G4-MAR		0.13
G3-MAR		0.96
G2-MAR		0.31
G1-MAR		0.78

Gallois and Morter, 1982; Wilkinson, 1990; Wilkinson and Morter, 1981.

6.6.4 Clare Borehole [TL 7834 4536]

The Cambridge Greensand Formation overlies Upper Gault at a depth of 221.20 m. The Upper Gault is present between

221.20 m and 232.13 m, the Lower Gault between 232.13 m and 232.28 m. The Gault Formation overlies Palaeozoic strata.

Beds G17, G18 and G19 at the top of the Upper Gault are missing from the Clare Borehole, as are Beds G1–G9 at the base of the Lower Gault. The lowest bed is G10.

	Thickness m
Upper Gault 221.20–232.13 m	
G16-CLA	0.78
G15-CLA	0.30
G14-CLA	7.72
G13-CLA	1.37
G12-CLA	0.23
G11-CLA	0.53
Lower Gault 232.13–232.28 m	
G10-CLA	0.12

Pattison, et al., 1993

6.6.5 Four Ashes Borehole [TM 0230 7187]

The Cambridge Greensand Formation overlies Upper Gault at a depth of c.265.20 m. The Upper Gault is present between c.265.20 m and 277.83 m, the Lower Gault between 277.83 m and c.279.96 m. The Gault Formation overlies the Carstone Formation, present between c.279.96 m and 280.36 m.

Bed G19 at the top of the Upper Gault is missing from the Four Ashes Borehole, as are Beds G1–G4 at the base of the Lower Gault. The lowest bed is G5.

		Thickness m
Upper Gault c.265.2–277.83 m		
G18-FAB	Not cored	11.0
G17-FAB		
G16-FAB		
G 15-FAB		
G14-FAB		
G13-FAB		
G12-FAB		0.66
G11-FAB		0.97
Lower Gault 277.83–c.279.96 m		
G10-FAB		0.53
G9-FAB		0.53
G8-FAB		Absent
G7-FAB		0.31
G6-FAB		0.48
G5-FAB		0.28

Gallois and Morter, 1982

6.6.6 Ely–Ouse Borehole No. 2 (Mildenhall Borehole No. 2) [TL 7008 6976]

The Cambridge Greensand Formation overlies Upper Gault at a depth of 77.30 m. The Upper Gault is present between 77.30 m and 90.65 m, the Lower Gault between 90.65 m and c.98.96 m (Figure 17).

Bed G19 at the top of the Upper Gault is missing from Ely–Ouse Borehole No. 2.

	Thickness m
Upper Gault 77.3–90.65 m	
G18-EOB2	0.22
G17-EOB2	2.16
G16-EOB2	1.39
G15-EOB2	c.4.40 (core loss)
G14-EOB2	c.2.01 (core loss)
G13-EOB2	1.40
G12-EOB2	0.20
G11-EOB2	1.95
Lower Gault 90.65–c.98.6 m (core loss)	
G10-EOB2	1.65
G9-EOB2	0.20
G8-EOB2	0.95
G7-EOB2	3.15
G6-EOB2	Absent
G5-EOB2	1.10
G4-EOB2	0.31
G3-EOB2	c.0.59
G2-EOB2	(core loss)
G1-EOB2	

Bristow 1990

6.6.7 Ely–Ouse Borehole No. 11 (Mildenhall Borehole No. 11) [TL 6973 7802]

The Cambridge Greensand Formation overlies Upper Gault at a depth of 35.45 m. The Upper Gault is present between 35.45 m and 47.51 m, the Lower Gault between 47.51 m and 54.40 m. The Gault Formation overlies the Carstone Formation, present between 54.40 m and 55.38 m (base not seen) (Figure 17).

Bed G19 at the top of the Upper Gault is missing from Ely–Ouse Borehole No. 11.

	Thickness m
Upper Gault 35.45–47.51 m	
G18-EOB11	1.67
G17-EOB11	1.03
G16-EOB11	c.2.00 (base lost)
G15-EOB11	0.17
G14-EOB11	3.68
G13-EOB11	1.64
G12-EOB11	0.42
G11-EOB11	1.79
Lower Gault 47.51–54.40 m	
G10-EOB11	0.78
G9-EOB11	0.26
G8-EOB11	1.08
G7-EOB11	3.32
G6-EOB11	absent
G5-EOB11	0.23
G4-EOB11	(G4/G5 boundary lost)
G3-EOB11	2.72
G2-EOB11	0.13
G1-EOB11	0.28

Morter, 1982

6.6.8 Ely–Ouse Borehole No. 14 (Mildenhall Borehole No. 14) [TL 6962 8115]

The Cambridge Greensand Formation overlies Upper Gault at a depth of 29.18 m. The Upper Gault is present between 29.18 m and 40.79 m, the Lower Gault between 40.79 m and 48.10 m (base not seen).

	Thickness m
Bed G19 at the top of the Upper Gault is missing from Ely–Ouse Borehole No. 14.	
Upper Gault 29.18–40.79 m	
G18-EOB14	1.91
G17-EOB14	0.91
G16-EOB14	2.09
G15-EOB14	1.32
G14-EOB14	c.1.59
G13-EOB14	c.1.86
G12-EOB14	0.41
G11-EOB14	1.52
Lower Gault 40.79–48.10 m (base not seen)	
G10-EOB14	1.12
G9-EOB14	0.28
G8-EOB14	0.53
G7-EOB14	c.1.78
G6-EOB14	Absent
G5-EOB14	c.0.51
G4-EOB14	0.56
G3-EOB14	1.47
G2-EOB14	0.23
G1-EOB14	0.83
	(base not seen)

References
Morter, 1982b

6.6.9 Arlesey Borehole [TL 1887 3463]

The Cambridge Greensand Formation overlies Upper Gault at a depth of 15.45 m. The Upper Gault is present between 15.45 m and 68.29 m, the Lower Gault between 68.29 m and 72.80 m. The Gault Formation overlies the Carstone Formation, present between 72.80 m and 83.49 m (base not seen).

Bed G19 at the top of the Upper Gault is missing from the Arlesey Borehole. Boundaries of some beds in the Lower Gault cannot be recognised (see Figures 21 and 22).

	Thickness m
Upper Gault 15.45–68.29 m	
G18-ARL	2.80
G17-ARL	19.21
G16-ARL	14.69
G15-ARL	6.14
G14-ARL	6.62
G13-ARL	1.38
G12-ARL	0.52
G11-ARL	1.48
Lower Gault 68.29–72.8 m	
G10-ARL	
G9-ARL	core loss
G8-ARL	
G7-ARL	
G6-ARL	0.20
G5-ARL	1.13
G4-ARL	
G3-ARL	
G2-ARL	1.69
G1-ARL	

References
Wood, Wilkinson and Hopson, 1995

6.7 GAULT FORMATION (SOUTHERN ENGLAND: DORSET TO KENT)

6.7.1 Copt Point, Folkestone [TR 243 365]

This is the type area for the Gault of southern England. Beds follow Price (1874, 1875). Glauconitic marl (Cenomanian) overlies Upper Gault (Middle and Upper Albian), 30.15–30.20 m thick. The Gault Formation rests on Lower Greensand (Figure 18).

		Thickness m
Upper Gault, 30.15–30.20 m		
G XIII-CPF	Mudstone, fawnish grey, marly mottled light grey and fawnish grey in the middle part, with a blue-grey marly clay in the lower part. Glauconite-rich at the base	13.71
G XII-CPF	Mudstone, pale grey, glauconite-rich with scattered phosphatic nodules. Phosphatic nodule bed at the base	0.99
G XI-CPF	Mudstone, pale grey, marly. Phosphatic nodule bed at the base	10.67
G X-CPF	Mudstone, pale grey, marly with two phosphatic nodule seams, one at the top of the bed and the other towards the middle (0.8 m above the base of the bed). Indurated	1.55
G IX-CPF	Mudstone, pale grey, marly. Phosphatic nodules in an indurated seam at the top of the bed. Marlestone lenticles 0.75–1.70 m above base of the bed	2.85
G VIII-CPF	Mudstone, mid-grey, shelly. *Inoceramus sulcatus* abundant. Phosphatic nodule seams at the top and at the base of the bed	0.38–0.43
Lower Gault, 10.06–10.20 m		
G VII-CPF	Mudstone, mid grey, with shell seams comprising pyritised fossils and scattered phosphatic nodules	2.44
G VI-CPF	Mudstone, mid grey, with lenticles of pale grey mudstone. Bioturbation extensive, burrow fills of dark grey mudstone	0.31
G V-CPF	Mudstone, mid-grey, shelly, with scattered brown phosphatic nodules. Burrowed	0.46–0.48
G IV-CPF	Mudstone, dark grey, shelly, with black phosphatic nodules (c.50 mm thick) at the top and buff phosphatic nodules with partly phosphatised bivalves (c.25 mm thick) at the base	0.15–0.17
G III-CPF	Mudstone, fawn-grey, with shell seams and partly phosphatised macrofossils. Occasional lenticles of indurated ferruginous marl. Lower boundary transitional, passing down into:	1.83

		Thickness m
G II-CPF	Mudstone, dark grey, with seams of partly pyritised crushed and fragmented macro-fossils. Lenses of fawn clay in the upper part. A band of phosphatic nodules is situated 0.7 m above the base. A 5 cm band of irregular phosphatic nodules and partly phosphatised and crushed shells is located at the base of the bed	1.57
G I-CPF	Mudstone, dark grey, slightly silty, shelly (1.57 m thick); on gritty, grey, sparsely shelly mudstone, becoming more gritty and glauconitic down sequence (1.22 m thick); on phosphatic nodule band with numerous ammonite casts ('Dentatus Nodule Bed') (0.5–0.6 m above base of the bed); on highly glauconitic mudstone with occasional black phosphatic nodules; on a seam of septarian phosphatic nodules (c.0.3 m above base of bed); on very glauconitic mudstone, with black phosphatic nodules (0.25 mm thick)	3.30–3.40

Black, 1972, 1973, 1975; De Rance, 1875; d'Orbigny, 1842; Hart, 1973b; Jukes-Browne, 1900; Owen, 1971a, 1973, 1975; Price, 1874, 1875; Taylor, 1982.

6.7.2 Glyndebourne Borehole [TQ 442 114]

The Glauconitic Marl overlies Upper Gault at 48.35 m. The Upper Gault is present from 48.35–126.55 m, and the Lower Gault from 126.55–152.60 m.

	Thickness m
Upper Gault, 48.35–126.55 m	
G XIII-GLY	18.00
G XII-GLY	Not recognised
G XI-GLY	39.85
G X-GLY	6.28
G IX-GLY	5.41
G VIII-GLY	8.66
Lower Gault, 126.55–152.60 m	
G VII-GLY	
G VI-GLY	
G V-GLY	1.79
G IV-GLY	2.99
G III-GLY	1.21
G II-GLY	9.86*
G I-GLY	10.2*

* The boundary between Beds I an II is unclear, but may be at the shell bed at a depth of 142.4 m.

Casey and Morter, 1977; Harris, 1982; Hart, 1993.

6.7.3 Rockshaw Interchange, Merstham [TQ 3088 5295]

Upper Greensand overlies Upper Gault (Upper Albian), 39.53 m thick. The bed descriptions and thicknesses follow Owen (1996).

		Thickness m
auritus Subzone		
G-RIM 10	Mudstone, pale, shelly, glauconitic with small black phosphatic nodules	0.64
varicosum Subzone		
G-RIM 9	v. Clay, dark grey, silty, micaceous with buff phosphatic nodules and shells scattered throughout	2.15
	iv. Clay, dark grey, silty, sparsely fossiliferous, but with a shell seam at 1.5 m above the base. Small phosphatic nodules scattered throughout	6.00
	iii. Mudstone, dark grey, very silty with shell seams and pyritic concretions at the top. Pyritic ammonites throughout. Weathering results in ferruginous lenses	9.00
	ii. Clay, mid grey with occasional crushed fossils, especially 2.4 to 2.56 m above the base	6.61
	i. Calcareous mudstone, ferruginous, two seams separated by thin, mid-grey clay with occasional fossils	0.30
varicosum (iii–v) and *orbigny* (i–ii) subzones		
G-RIM 8	v. Clay, mid-grey, sparsely shelly.Four shell seams occur at 1.4, 2.6, 4.9 and 7.9 m above the base	8.10
	iv. Mudstone, light grey, calcareous shelly, ferruginous weathering	0.10
	iii. Clay, mid grey with scattered shells including ammonites,passing down into:	5.41
	ii. Clay, light grey, very shelly	0.51
	i. Mudstone, lenses of pale grey, calcareous, fossiliferous	0.10
orbignyi Subzone		
G-RIM 7	Clay, pale grey, shelly	0.61

Owen, 1996

6.7.4 Church Farm Borehole No. 2 [ST 8555 2223]

Upper Greensand overlies Upper Gault at a depth of 5.21 m, and the Gault Formation (Middle and Upper Albian) overlies Lower Greensand at a depth of 22.86 m (Figure 29).

		Thickness m
Upper Gault, 5.21–13.80 m		
G-CF12	Siltstone, sandy	0.39
G-CF11	Sand, dark grey, silty, glauconitic in part, bioturbated	3.75
G-CF10	Siltstone, medium grey, clayey, brecciated in the lower part	c.1.52
G-CF9	Siltstone, clayey, micaceous with scattered pyrite nodules.	

		Thickness m
	Lower boundary is a burrowed erosion surface	2.80
G-CF8	Sand, fine grained, clayey and silty with a burrowed erosion surface at the base	0.13
Lower Gault, 13.80–22.86 m		
G-CF7	Siltstone, with burrows of fine-grained sand, becoming sandier and more glauconitic down section	2.22
G-CF6	Siltstone, dark grey in two levels becoming sandy siltstone downward. Intensely bioturbated	0.73
G-CF5	Siltstone, dark grey, passing down into a sandy siltstone. Bioturbated	0.50
G-CF4	Siltstone, medium grey, bio-turbated passing down into a basal sandy, micaceous siltstone. *Chondrites* burrows	2.31
G-CF3	Siltstone, medium grey, passing down into sandy glauconitic siltstone. Heavily bioturbated	1.87
G-CF2	Siltstone, pale to medium grey, glauconitic becoming increasingly sandy in the the basal part. Bioturbated	1.19
G-CF1	Siltstone, glauconitic, sandy in part, with pyrite nodules and pebbles at the base	0.24

Bristow et al., 1995

6.7.5 Winterborne Kingston Borehole [SY 8470 9796]

See Figure 26
Cowstones overlying:

G-WK 2	Sandstone, dark grey-green, glauconitic, argillaceous, shelly, rich in *Rotularia concava* and other bivalves (between 325.30 and 327.28 m. Base not seen)
G-WK 1	Clay, silty, shelly, micaceous with *Birostrina concentrica* and other bivalves, together with gastropods and ?*Anahoplites*. ?*A. intermedius* Subzone. (Between 328.40 and 343.60 m. Base not seen) Underlain by Bedchester Sands (including 'Basement beds of the Gault')

The 'Basement Beds of the Gault' fall within the *mammillatum* Superzone.

Morter, 1982

6.7.6 Rookley Brick Pit, Isle of Wight [SZ 5133 8395]

See Figures 27 and 30

		Thickness m
Middle and Upper Albian		
G-IOW 7	Clay, grey, ferruginous with scattered phosphatic nodules in the lower part, resting on an erosion surface (beds 13–14 of Owen, 1971)	0.6–1.23
G-IOW 6	Clay, ochreous, ferruginous in part, with large septarian phosphatic nodules (Bed 11 of Owen, 1971), resting on an erosion surface, overlain by dark grey clay with ochreous streaks (Bed 12 of Owen, 1971)	1.23–1.52
G-IOW 5	Clay, dark grey with phosphatic and partly pyritised shells passing up into a paler, ochreous-mottled clay. Thin ferruginous clay 0.69 m above the base	1.88
G-IOW 4	Clay, brownish grey with scattered phophatic nodules and pyritised macrofossils including *H.* (*H.*) *spathi* and *H.* (*H.*) *dentatus*, resting disconformably on Bed G-IOW2 (Bed 7 of Owen, 1971)	0.30
G-IOW 3	Clay, dark grey resting on an erosion surface (Bed 6 of Owen, 1971). Unfossiliferous. ?*lyelli* Subzone	0.23
G-IOW 2	Clay, dark grey, glauconitic, sandy with an *Inoceramus concentricus*-rich band 0.97–1.35 m from the base (Bed 3 of Owen, 1971). Becoming brownish and less sandy in the upper 0.25–0.48 m. Unfossiliferous, but believed to be of *lyelli* Subzone age (Beds 2–6 of Owen, 1971)	3.15–3.35
G-IOW 1	Clay, glauconitic, pebbly, sandy, false bedded in the lower part and resting disconformably on Carstone (Bed 1 of Owen 1971)	0.13–0.28

Owen, 1971

6.7.7 Redcliff, east of Sandown, Isle of Wight [SZ 6275 8500]

Upper Greensand (*auritus* Subzone) on Upper Gault (Middle and Upper Albian, *spathi* to *varicosum* subzones). See Figures 27 and 28.

		Thickness m
Upper Gault: *inflatum* Zone; *varicosum* Subzone		
G-RED 20	Silt and fine sand, grey and beige, unfossiliferous	0.90
G-RED 19	Silt and sand, mid-grey in thin, irregular laminations. Macrofossils not seen, but microfossils are present	2.00
G-RED 18	Clay, brown, sandy, limonitic, with gypsum. Unfossiliferous	0.15
G-RED 17	Clay, mid-grey, sandy and silty, unfossiliferous (base not seen)	0.80
Gap of approximately 6.5 m		
G-RED 16	Clay, mid-grey, silty with pyrite and rare apatite concretions	

		Thickness m
	(top not seen). Sandier, glauconite-rich horizon 2 m above the base. *Mortoniceras* present in the lower part of the bed	c.10.00
G-RED 15	Clay, dark grey, silty with common pyrite (weathering to limonite) concretions. Rare *Entolium orbiculare* and *Gryphaeostrea canaliculata*	2.50
G-RED 14	Clay, dark grey, unfossiliferous, silty	0.85
G-RED 13	Clay, dark grey, silty. Shelly (*Birostrina concentrica* common, *Entolium orbiculare* and *Gryphaeostrea canaliculata* rare)	0.75

inflatum Zone; *orbignyi* to *cristatum* subzones

G-RED 12	Sandy clay to fine-grained sand, mid-grey, glauconite-rich. Shelly (*Actinoceramus sulcata*, *Entolium orbiculare* and *Gryphaeostrea canaliculata* are frequent and *Mortoniceras* and *Beaudanticeras* rare and poorly preserved.)	0.30
G-RED 11	Clay, sandy, silty to fine grained, clayey sand. Glauconitic. Bioturbated (*Chondrites* and *Planolites*). Rare *Actinoceramus sulcata* occur	2.25
G-RED 10	Sand, green, glauconitic. Eroded and burrowed base. *Thalassinoides* burrows extend 0.25–0.30 m into underlying bed	0.20

Lower Gault: *lautus* Zone; *nitidus* Subzone

G-RED 9	Clay, grey, sandy clay with yellow patches of jarosite and scattered elliptical concretions in the upper 0.10 m	0.90
G-RED 8	Clay, grey, glauconite-rich, silty with common concretions (apatite). Shelly (including the gastropod *Anchura* sp., bivalves such as *Nucula* (*Pectinucula*) *pectinata*, *Birostrina concentrica* and *Entolium orbiculare*, and ammonites *Dimorphoplites glaber*, *D. biplicatus*, *Euhoplites aspasia cantiana* and *Anahoplites planus*)	0.65

loricatus Zone; ?*subdelaruei*, ?*meandrinus* and *niobe* subzones

		Thickness m
G-RED 7	Clay, mid-grey, sandy silty. *Chondrites* common	4.90

loricatus Zone; *niobe* Subzone

		Thickness m
G-RED 6	Clay, mid-grey, sandy, silty with occasional small apatite concretions, pale grey, fine-grained sand lenses and pyritised *Chondrites*. Shelly (abundant bivalves including *Birostrina concentrica*, *Nucula* (*Pectinucula*) *pectinata* and *Entolium orbiculare*, and ammonites *Anahoplites* sp., *Hamites* sp. and *Dimorphoplites niobe*	0.75

loricatus Zone; *intermedius* Subzone

G-RED 5	Clay, mid-grey, sandy with *Planolites* and *Chondrites*	0.90
G-RED 4	Clay, mid-grey, sandy silty to fine-grained, clayey, silty sand with burrow fills of fine grained, yellow sand. Shelly (*Birostrina concentrica* and common fragments of *Anahoplites* sp. and *Hamites* sp.)	0.70

loricatus Zone; *intermedius* Subzone, and *dentatus* Zone; *spathi* Subzone (boundary is situated within bed G-RED 3)

G-RED 3	Clay, grey-brown, silty, sandy with frequent apatite concretions. Weakly glauconitic in the lower part and and weakly jarositic in the upper part. Bioturbated (*Chondrites*). Shelly horizon 0.2 m above the base contains *Hoplites* sp., *Hamites* sp. and *Birostrina concentrica*	1.80
G-RED 2	Clay, sandy and silty, glauconite-rich (the glauconite decreases up sequence) with common *Chondrites* and rare, pale brown apatite nodules. *Hoplites* sp. occurs in the lower part of the bed. Passing down through a transitional boundary into:	3.10
G-RED 1	Sand, brown-grey, clayey with grains of quatrz and glauconite. Rare *Hoplites* sp. occur. Lower boundary transitional, passing down into:	0.90

Douvilleiceras mammillatum Zone; *Pseudosonneratia* (*Isohoplites*) *steinmanni* Subzone

Carstone	Sand, yellow and red, coarse-grained, poorly sorted, limonitic with quartz gravels (22 m thick). By comparison with Reeth Bay, Ventnor, and Rookly Brick Pit (Casey, 1961a; Owen, 1971, 1988), the Carstone is considered to belong to the *Douvilleiceras mammillatum* Zone and *Pseudosonneratia* (*Isohoplites*) *steinmanni* Subzone	

Casey, 1961a; Gale et al., 1996; Owen, 1971, 1988.

6.7.8 Horton Hall Clay Pit, Upper Beeding, Sussex

[TQ 2075 1230]

Upper Greensand on Gault (Middle and Upper Albian). See Figures 24 and 25.

		Thickness m
Gault; *cristatum* Subzone		
G-HH 12 (equates with Bed 7i with Owen, 1971)	Clay, very dark grey with thin of seams of brown phosphatic nodules	0.025
nitidus Subzone		
G-HH 11 (equates with Bed 6v–vii of Owen, 1971)	iii. Clay, brownish grey, marly with cementstone nodules (0.53 m) ii. clay, dark grey with scattered phosphatic nodules (0.36 m). i. Clay, brownish grey, shelly with scattered phosphatic nodules and and part phosphatised, part pyritised fossils (0.41 m)	1.30
meandrinus Subzone		
G-HH 10 (equates with Bed 6iv of Owen, 1971)	Clay, dark grey with lighter bands, some of which contain scattered cementstone nodules, and shell bands occur throughout	4.90
subdelarui Subzone		
G-HH 9 (equates with Bed 6iii of Owen, 1971)	Clay, fawn with sporadic phosphatic nodules and part phosphatised fossils	0.025
niobe Subzone		
G-HH 8 (equates with Bed 6i–ii of Owen, 1971)	ii. Clay, brownish grey, shelly marly with occasional cement-stones (0.56 m), passing down into i. Clay, mid-grey with scattered shells (0.66 m).	1.22
G-HH 7 (equates with Bed 5iv of Owen, 1971)	Clay, brownish grey, shelly marly with large cementstone nodules passing down into	1.22
intermedius Subzone		
G-HH 6 (equates with Bed 5i–iii of Owen, 1971)	iii. Clay, dark grey, slightly micaceous, shelly with scattered phosphatic nodules and a concentration between 0.76 and 1.3 m above the base of the bed. Crushed fossils occur throughout. The topmost part of the bed may be *niobe* subzonal age (3.66 m) ii. Marly seam, brown, weathering ferruginous (0.30 m) i. Clay, dark grey, slightly micaceous, shelly with numerous shell seams (2.44 m)	6.40
spathi Subzone		
G-HH 5 (equates with Bed 4iv of Owen, 1971)	Marl, blocky, brownish grey with cemenstone nodules in the lower half	0.61
G-HH 4 (equates with Bed 4i–iii of Owen, 1971)	iii. Clay, dark grey, slightly micaceous shelly with scattered shell seams, alternating with lighter bands with partly phosphatised nodules (9.35 m) ii. Clay, brownish grey, shelly, in two bands with small nodules of cementstone, separated by darker grey clay containing many crushed shells. The nodules of the lower band are more tabular and ferruginous. Phosphatised shells are present in both of the brownish grey clay bands (2.54 m) i. Clay, dark grey, shelly with crushed fossils alternating with more brownish grey clay with occasional partly phosphatised ammonites (3.87 m)	15.76
G-HH 3 (equates with Bed 3ii–3iv of Owen, 1971)	iii. Clay, pale brown, shelly with cementstone concretions and part phosphatised fossils (0.61 m) ii. Clay, dark grey shelly, with a few partly phosphatised fossils (0.69 m) i. Clay, pale brown, shelly with a shell seam at the base and top containing partly phosphatised fossils. Cement-stones occur at the base (0.46 m)	1.76
G-HH2 (equates with Bed 3i of Owen, 1971)	Clay, dark grey, shelly with many crushed *Hoplites* and *Inoceramus concentricus*, and a few scattered phosphatic nodules	4.12
lyelli Subzone		
G-HH 1 (equates with Bed 2 of Owen, 1971)	vi Clay, brown-grey, shelly with large part-phosphatised in soft marly concretions (0.30 m) vi. Clay, brown-grey, shelly with large part-phosphatised ammonites in soft marly concretions (0.30 m)	

		Thickness m
	v. Clay, mid-grey to brownish grey, shelly (0.20 m) iv. Clay, brownish grey, shelly, 1.12 m, with large, partly phosphatised ammonites. A shell seam 0.1 m above the base of the bed contains partly pyritised and partly phosphatised fossils. Passing down into iii. Clay, darker grey, 0.36 m, with fewer fossils than ii, passing down into ii. Clay, pale brownish grey, shelly, 0.30 m, passing down into i. Clay, blocky mid-grey clay, 2.31 m, becoming darker upwards. Phosphatic nodules scattered throughout. Very shelly at the base, but less fossiliferous above. Resting on 'Basement Beds of the Gault' (Bed 1 of Owen 1971)	4.59

Owen, 1971

6.8 GAULT FORMATION ('JUNCTION BEDS' MEMBER)

6.8.1 Bryants Lane Quarry [SP 929 286]

The Junction Beds (Shenley Limestone) of Early Albian age underlie the Gault Formation (c.4.0 m thick), and rest on the Woburn Sands 'Silty Beds' (Aptian). (see Figure 31)

		Thickness m
JB-BLQ 1	Limestone, buff and brown, phosphatic. Brachiopods common	up to 0.10

Casey, 1961a; Owen, 1972; Shephard-Thorn et al., 1994.

6.8.2 Reach Lane Quarry [SP 933 284] (see Figure 31)

The Gault Formation (c.8.0 m of mudstone, blue-grey and grey-green with phosphatic nodules) rests on Junction Beds (early Albian). The latter overlie Woburn Sands 'Silty Beds' (Aptian).

		Thickness m
JB-RLQ 1	Conglomerate of ferruginous 'boxstone' nodules and glauconite in a sandy clay matrix	0.40

Casey, 1961a; Owen, 1972; Shephard-Thorn et al., 1994.

6.8.3 Munday's Hill [SP 937 282]

The Gault Formation (0.3 m of brick-red mudstone, the 'Cirripede Bed', yielding *Cretiscalpellum unguis* and *Pycnolepas rigida*) overlies the Junction Beds (Shenley Limestone) of Early Albian age. The latter rest on the Woburn Sands ('Red Sands') of Aptian age.

		Thickness m
JB-MH 1	Limestone, pale brown, phosphatic; slightly limonitic and glauconitic. Brachiopods common	up to 0.10

Casey, 1961a; Owen, 1972; Shephard-Thorn et al., 1994.

6.8.4 Chamberlain Barn [SP 9285 2662 to 9313 2641]

Details

Lower Gault (*H. spathi* Subzone), comprising grey mudstone, shelly, with phosphatic nodules and abundant *Neohibolites minimus*, overlies the Junction Beds (Early Albian). The latter rests on the Woburn Sands Formation (brown, pebbly sand) of Aptian age (Figures 31 and 32).

		Thickness m
JB-CB 7	Clay, grey with lenticles of brown sand and small, scattered phosphatic nodules with pale rinds. *Hoplites pseudodeluci* indicates the *lyelli* Subzone (*dentatus* Zone)	0.30
JB-CB 6	Clay, dark brown, light rinded, septarian phosphatic nodules. The basal nodule bed has yielded a *steinmanni* Subzone fauna (*auritiformis* Zone)	0.07–0.12
JB-CB 5	Clay, streaked brown-grey, pebbly silty	0.25
JB-CB 4	Clay, buff streaked-grey, highly argillaceous	0.07–0.17
JB-CB 3	Clay, grey-brown streaked, silty with phosphatic nodules v. Phosphatic nodules, gritty in a matrix of silty clay, 0.07 m. A mixture of *regularis* Zone and *kitchini* Subzone fossils occurs here, and the *floridum* Subzone was suggested by Owen (1972, p.305) iv. Clay, grey-brown streaked, pebbly, silty, 0.10 m. Unfossiliferous iii. Phosphatic nodules, large, pebbly with brown interiors but pale rinds, in grey-brown streaked silty clay, 0.07 m. A mixture of *regularis* Zone and *kitchini* Subzone fossils occurs here, and the *floridum* Subzone was suggested by Owen (1972, p.305) ii. Clay, grey-brown streaked, poorly sorted, pebbly silty, 0.15 m, with partially phosphatised ammonites. *Douvilleiceras mammillatum* and *Beudanticeras newtoni* of *mammillatum* Zone age occur with a mixture of *regularis* Zone and *chalensis* Zone faunas; *Douvilleiceras alternans* and *Otohoplites*	

		Thickness m
	destombesi imply either the *puzosianus* or *bulliensis* subzones. *Cleoniceras* (*Cleoniceras*) *floridum* has also been found, indicating the *floridum* Subzone (Smart, 1997, pp.290–291) i. Phosphatic nodules, gritty in a matrix of grey-brown streaked, pebbly silty clay, 0.07 m, with partially phosphatised ammonites (*Douvilleiceras mammillatum* and *Beudanticeras newtoni* of *mammillatum* Zone age, a mixture of *regularis* Zone and *kitchini* Subzone fossils, and *Cleoniceras* (*Cleoniceras*) *floridum* indicating the *floridum* Subzone; Owen, 1972, p.305; Smart, 1997, pp.290–291)	0.46
JB-CB 2	Sand, coarse, poorly sorted, glauconitic, clayey with, in the middle part, large cobbles of sandstone and limestone (Shenley Limestone); with iron pan seams, boxstones, indigenous *Leymeriella* and derived Jurassic ammonites	0.37
JB-CB 1	Sand, brown, poorly sorted pebbly (‘Carstone conglomerate’ of some authors), resting on Woburn Sands Formation (brown, pebbly sand; Aptian)	0.10–0.22

Casey, 1961a; Owen, 1972; Shephard-Thorn et al., 1994; Smart, 1997.

6.8.5 Billington Crossing Pit (or Pratt’s Pit)
[SP 930 241]

Gault, comprising grey mudstone, sandy in part, rests on Junction Beds (Early Albian). The latter overlie Woburn Sands (‘Silver Sands’) (Figures 31 and 32).

		Thickness m
JB-BC2	Mudstone, brownish, sandy, (1.48 m thick), with four bands of phosphatic nodules 0.27–0.34 m (Band I), 0.64–0.79 m (Band II), 1.04–1.19 (Band III, which may be a double bed of nodules) and 1.39–1.41 m (Band IV) above the top of the Woburn Sands/Junction Beds boundary	1.52
JB-BC1	Pebble bed in a matrix of indurated sand	0.6–0.75

Casey, 1961a; Owen, 1972; Shepard-Thorn et al., 1994.

6.8.6 Grovebury Pit [SP 9230 2288]

Basal Gault (dark grey mudstone, silty, with glauconitic patches and phosphatic nodules, 0.60 m thick) rests on Junction Beds (Early Albian). The latter overlie Woburn Sands (current-bedded sands). See Figures 31 and 32.

		Thickness m
JB-GP 4	Mudstone, glauconitic grey with streaks of brown sand, passing down to become more sandy and pebbly. Occasional phosphatic nodules	0.60
JB-GP 3	Mudstone, brown, sandy, pebbly with streaks of grey clay	0.17
JB-GP 2	Phosphatic nodules, large, pale brown-cream in a brown grit matrix	0.10
JB-GP 1	Sand, brown, coarse-grained, with large phosphatic nodules and pebbles of Shenley Limestone	0.35

Owen, 1972; Shepard-Thorn et al., 1994.

6.9 HUNSTANTON FORMATION

6.9.1 Red Cliff Hole, Filey Bay, Yorkshire
[TA 1566 7502]

Red Cliff Hole Member, *carcitanense* Subzone (Cenomanian).

		Thickness m
HC-RCH5	Chalk, red, marly with a burrowed horizon at the top (?*Skolithus*), the burrow infill being red mudstone. The lower part is composed of an alternation of three marls and two chalks	0.66
HC-RCH4	Chalk, pale red, weakly flasered with a white horizon and associated pebble bed in the lower part	0.76
HC-RCH3	Chalk, pale red, *Thalassinoides*-burrowed chalk	0.33
HC-RCH2	Chalk, red, seven ill-defined units	1.83
HC-RCH1	Chalk, red, seven flaser-bedded units separated by marl partings. Common brachiopods throughout and belemnites in the lower part. A pebble bed is locally developed near the base. A bed of grey pyritic chalk is situated in the lower part, the red coloration having been removed by the action of pore fluids (as discussed by Wiltshire, 1862; Philips, 1875, Blake, 1878; Hill, 1888; Wright and Wright, 1955; Wright, 1968; Jeans, 1973; 1980; Mitchell, 1995)	2.03

Blake, 1878; Hill, 1888; Jeans, 1973; 1980; Mitchell, 1995; Philips, 1875; Wiltshire, 1862; Wright and Wright, 1955; Wright, 1968.

6.9.2 Weather Castle, Filey Bay, Yorkshire
[TA 1649 7494]

Weather Castle Member (see Figure 33)

HC-WC 7	Marl, thick red, comprising three poorly defined rhythms	0.66

		Thickness m
HC-WC 6	Marl, brick-red, and marly chalk in ill-defined rhythms of clayey marl passing up into marl	0.31
HC-WC 5	Marl, brick-red, and marly chalk in ill-defined rhythms of clayey marl passing up into marl	0.43
HC-WC 4	Marl, brick-red, and marly chalk in ill-defined rhythms of clayey marl passing up into marl	0.41
HC-WC 3	Marl, brick-red, and marly chalk in ill-defined rhythms of clayey marl passing up into marl	0.31
HC-WC 2	Marl, brick-red, marls and marly chalk in ill-defined rhythms of clayey marl passing up into marl	0.34
HC-WC 1	Marl, brick-red, marls and marly chalk in ill-defined rhythms of clayey marl passing up into marl	0.35

Bed HC-WC7 straddles the Albian–Cenomanian boundary. Its base is in the upper part of the *rostratum* Zone (Mitchell, 1995).

Mitchell, 1995

6.9.3 Crab Rocks to Red Cliff Hole, Filey Bay, Yorkshire [TA 1548 7510 and 1523 7515]

Dulcey Dock Member; [TA 1523 7515] (see Figure 33)

		Thickness m
HC-DD 22	Marl, red nodular, passing up into a nodular chalk	0.43
HC-DD 21	Marl, red nodular, passing up into a white nodular chalk	0.27
HC-DD 20	Marl, red, nodular, shelly, passing up into a pale red chalk	0.21
HC-DD 19	Marl, well-developed, overlain by a red chalk	0.17
HC-DD 18	Marl, red nodular, overlain by a pale red chalk	0.23
HC-DD 17	Chalk, red nodular, overlain by a pale chalk	0.15
HC-DD 16	Marl, red, passing up into red marly chalk, becoming white at the top	0.27
HC-DD 15	Marl, red, overlain by nodular red marl overlain by red chalk	0.37
HC-DD 14	Marl, red, nodular, overlain by pale red chalk. FAD of common *Aucellina*	0.23
HC-DD 13	Marl, red, nodular, overlain by red nodular chalk	0.16
HC-DD 12	Marl, red, nodular, overlain by white nodular chalk	0.15
HC-DD 11	As for DD12	0.19
HC-DD 10	As for DD12	0.13
HC-DD 9	Chalk, red, nodular, marly passing up into white chalk	0.19
HC-DD 8	Marl, red, passing up into white chalk	0.20
HC-DD 7	Marl, red, nodular, overlain by red nodular chalk	0.28
HC-DD 6	Clay, dark red, overlain by red nodular chalk	0.19

Dulcey Dock Member, [TA 1548 7510]

HC-DD 5	Chalk nodules, white, in two bands, reworked and fractured, separated by a red nodular marl ('Breccia Nodule Band' of Jeans, 1973)	0.26
HC-DD 4	Chalk, weakly nodular, marly and pale nodule band	0.78
HC-DD 3	Chalk, white, nodular, two bands separated by a red marl. *Biplicatoria hunstantonensis* present	0.16
HC-DD 2	Chalk, marly with two prominent nodular horizons	0.92
HC-DD 1	Chalk, marly with abundant *Inoceramus lissa* and crinoid columnals. 'Band with fragments of *Inoceramus*' (of Jeans, 1973) which can be traced throughout eastern England in the Hunstanton Formation and Gault	0.49

The *auritus* and *rostratum* subzones.

Jeans, 1973; Mitchell, 1995.

6.9.4 Double Rocks to Red Cliff Hole, Filey Bay, Yorkshire [TA 1520 7516 to 1548 7510]

Speeton Beck Member, [TA 1548 7510] (see Figure 33)

		Thickness m
HC-SB 19	Marl, soft, red	0.15
HC-SB 18	Chalk, red nodular, rich in *Inoceramus lissa*, *Neohibolites ernsti* and *N. praeultimus* at the top	0.20
HC-SB 17	Chalk, red, nodular, becoming more nodular upwards	0.24
HC-SB 16	Marl, red nodular, chalky, passing up into red chalk	0.35
HC-SB 15	Chalk, red nodular, with a local scour with chalk pebbles at the top	0.30
HC-SB 14	Marl, red, that becomes nodular upwards and particularly in the middle part of the bed	0.17
HC-SB 13	Chalk, pale red, with a *Thalassinoides*-burrowed upper surface	0.18

Speeton Beck Member, [TA 1520 7516]

		Thickness m
HC-SB 12	Marl, red to grey	0.13
HC-SB 11	Chalk, grey to pink, with a *Thalassinoides*-burrowed upper surface	0.08

		Thickness m
HC-SB 10	Marl, grey to pink, with *Chondrites* and *Planolites* burrows	0.04
HC-SB 9	Chalk, grey, with a *Thalassinoides*-burrowed upper surface	0.08
HC-SB 8	Clay, grey marly, with abundant *Chondrites* burrows in the upper part	0.06
HC-SB 7	Marl, grey marl, passing up into a grey chalk, which in turn becomes nodular at the top. Rich in *Chondrites* and *Planolites* burrows with dark red infill	0.20
HC-SB 6	Clay, red marly	0.06
HC-SB 5	As for HC-SB7	0.20

Speeton Beck Member, [TA 1528 7519]

HC-SB 4	Clay, red marly, with *Chondrites* and *Planolites* burrows with grey infill	0.40
HC-SB 3	Chalk, white	0.16
HC-SB 2	Marl, red, with occasional white chalk nodules	0.20
HC-SB 1	Clay, grey and red, marly, with abundant burrows of *Chondrites* and *Planolites*	0.50

The Speeton Beck Member extends from the upper part of the *orbignyi* Subzone to the top of the *varicosum* Subzone. Mitchell, 1995

6.9.5 Foreshore near Crab Rocks, Filey Bay, Yorkshire [TA 1528 7519]

Queen Rocks Member (see Figure 33)

		Thickness m
HC-QR 7	Chalk, red, marly	0.30
HC-QR 6	Chalk, white nodules	0.05
HC-QR 5	Chalk, red, marly	0.45
HC-QR4	Chalk nodules, white, three bands	0.25
HC-QR 3	Chalk, dark red, marly with sparse, *Chondrites*-rich, chalk nodules at six horizons. Common *Inoceramus anglicus* present	c.1.90
HC-QR 2	Chalk, red, marly with sporadic red and pink chalk nodules	1.20
HC-QR 1	Marl, red, with glauconite streaks and common *Planolites* and *Chondrites* burrows with grey clay infills	0.80

The Queen Rocks Member is divided into two parts by an erosion surface. The upper part can be placed in the *cristatum* (QR3) and *orbignyi* (QR4–7) subzones. The lower part of the member (QR1–2) is of *lyelli* to *intermedius* Subzone age.

Mitchell, 1995.

6.9.6 South Ferriby Quarry, Lincolnshire
[SE 9915 2045]

See Figure 34

rostratum Subzone

		Thickness m
HC-SF11	Limestone, brick-red, massive, indurated, chalky, burrowed in the upper part (*Thalassinoides paradoxica*). Abundant *Aucellina* and *Neohibolites*. Also present are: *Concinnithyris subundata*, *Ornatothyris pentagonalis*, *Aucellina* ex gr. *gryphaeoides*, *A.* ex gr. *uermanni*, *Neohibolites praeultimus*, *N.* sp., and *Holaster* sp. The top is marked by an erosion surface separating it from a 0.025 m bed of iron-stained, silty marl which forms the basal part of the overlying Cenomanian Paradoxica Bed (Gaunt et al., 1992). The base is marked by a weak separation plane	0.50

auritus Subzone

HC-SF10	Limestone, brick red, massive, rubbly, indurated, chalky with marly wisps and partings; manganese on joints. *Neohibolites* common, terebratulids frequent. Other species present, *Conncinnithyris* cf. *subundata*, *Ornatothyris pentagonalis*, *Aucellina* ex gr. *gryphaeoides*, *A.* ex gr. *uermanni*, *Plicatula minuta* and *Neohibolites praeultimus*	0.68–0.69
HC-SF9	Marl, red with chalky pebbles and *Biplicatoria hunstantonensis*. The base is a phosphatised hardground	0.03–0.04
HC-SF8	Limestone, pale yellow and rusty, indurated nodular, chalky; manganese on joints. Abundant *Inoceramus lissa* (mainly fragments); *Neohibolites ernsti*-rich band at the base. Other species include *Biplicatoria hunstantonensis*, *B.* sp., *Tamerella* cf. *oweni*, *Pycnodonte* aff. *vesicularis*, *Neohibolites* sp. (transition between *N. ernsti* and *N. praeultimus*), *Hemicrinus canon*, *Nielsenicrinus* aff. *cretaceus* and, questionably, *Mortoniceras inflatum* (Kent, 1980, pl. 21)	0.30

varicosum Subzone

HC-SF7	Limestone, dark, brick-red, marly. Abundant *Neohibolites*, common brachiopod and	

		Thickness m
	inoceramid shell fragments; and *Biplicatoria ferruginea*, *Birostrina* cf. *concentrica*, *Neohibolites ernsti*, *N.* sp. (transitional between *N. ernsti* and *N. oxycaudatus*), *N.* cf. *oxycaudatus* and *N. minimus*. The base is a strong separation plane	0.24
HC-SF6	Limestone, yellow, gritty, indurated, massive, chalky with pyrite nodules and inoceramid shell fragments and a thin irregular marl seam with belemnite, crinoid and fish remains. The low diversity macrofauna includes *Biplicatoria ferruginea*, *Neohibolites minimus* and *N. oxycaudatus*	0.20

orbignyi Subzone

HC-SF5	Marl, brick-red, slightly greenish at the top with *Inoceramus* fragments. *Actinoceramus sulcata* and *Neohibolites* spp. (*N. minimus*, *N. oxycaudatus*, *N.* spp.) are common, and the following are also present: '*Rotularia*' cf. *umbonata*, *Kingena spinulosa*, *Biplicatoria ferruginea*, *Terebratulina martiniana*, *Eopecten studeri*, *Inoceramus anglicus* and *Pycnodonte* sp.	0.14–0.18
HC-SF4	Limestone, pale brick-red chalky with an irregular base. Fossil-iferous. *Neohibolites* spp. (including *N. minimus*) common; *Biplicatoria ferruginea*, *Capillarina diversa rubicunda*, *Terebratula* cf. *martiniana*, *Actinoceramus sulcata*, *Inoceramus anglicus*, *I.* cf. *anglicus*, *Plicatula minuta* and fish remains	0.13

cristatum Subzone — Mid Albian

		Thickness m
HC-SF 3	Marl, dark red-brown with, in the middle part of the bed, chalky limestone cobbles, phosphatic nodules and polished pebbles. Shelly. *Neohibolites* spp. (including *N. minimus*) abundant, especially near the base. *Rotularia* cf. *umbonata*, *Biplicatoria ferruginea*, *Capillarina diversa rubicunda*, *Kingena spinulosa*, *Atreta* sp., *Birostrina concentrica* (?derived), *Inoceramus anglicus*, *Plicatula* spp. (including *P. minuta*), *Nielsenicrinus cretaceus* and fish debris. Immediately overlying the base, the fauna comprises *Biplicatoria ferruginea*, *Birostrina concentrica*, *Gryph-aeostrea canaliculata* and *Neohibolites minimus*. The *cristatum* Subzone at the top, but Mid Albian below the cobbles	0.20–0.26

Mid Albian

HC-SF 2	Limestone, pale red-brown, silty, rubbly, chalky, massive in some areas but blocky with marl envelopes around the blocks in other areas. *Birostrina concentrica*, *Neohibolites minimus* and terebratulids present	0.30–0.35
HC-SF 1	Marl, red-brown, sandy with common *Neohibolites minimus* and *N.* sp. pebbles and phosphatised burrow fills. The basal contact with the underlying Carstone is gradational	0.15

Kent, 1980; Morter, in Gaunt, Fletcher and Wood, 1992.

6.9.7 Elsham Interchange, Lincolnshire [TA 052 111]

See Figure 34

		Thickness m
HC-EI 11	Limestone, off-white with *Paradoxica* burrows	0.30
HC-EI 10	Limestone, off-white	0.69
HC-EI 9	Marl, greenish ochre	0.05
HC-EI 8	Limestone, red rich in *Inoceramus* fragments	0.45
HC-EI 7	Limestone, greenish, marly with *Inoceramus* fragments and *Neohibolites oxycaudatus*	0.20
HC-EI 6	Limestone, hard, off-white	0.17
HC-EI 5	Marl, deep red with paler streaks and greenish at the top. *Inoceramus* fragments and *Neohibolites* present	0.18
HC-EI 4	Chalk, hard, pale red	0.10
HC-EI 3	Marl, deep red with greenish streaks in places, and a thin pale red limestone in the middle of the bed. Marked erosion surface at the base. *Neohibolites minimus* and *N. minimus pinguis* present	0.32
HC-EI 2	Limestone, hard, pale red	0.20
HC-EI 1	Marl, yellowish, chalky	0.10

Morter, in Gaunt, Fletcher and Wood, 1992.

6.9.8 Skegness Borehole, Lincolnshire [TF 5711 6398]

See Figure 34

		Thickness m
HC-SB 11	Limestone, pale red, massive with marl wisps. Burrowed in the upper part. *Neohibolites praeultimus*, *N. minimus*, *N.*	

		Thickness m
	sp., *Aucellina coquandiana* and *Concinnithyris subundata* present. Upper boundary an erosion surface and abrupt colour change. Basal boundary marl seam (25 mm thick) on erosion surface	0.43
HC-SB 10	Limestone, chalky, red, becoming more marly in the lower part. *Aucellina coquandiana*, *Neohibolites* cf. *praeultimus*, *Neohibolites* cf. *minimus* and terebratulids. Sponges also present	0.22
HC-SB 9	Marl, soft with chalk pebbles. *Neohibolites* present	0.04
HC-SB 8	Limestone, pale pink to brown, nodular with marl wisps. *Inoceramus* fragments abundant, especially *Inoceramus lissa*, together with common *Moutonithyris dutempleana* and abundant *Neohibolites ernsti* near the base	0.13
HC-SB 7	Limestone, marly with nodular limestone patches, passing down into brownish-red marl. Belemnites abundant, notably *Neohibolites ernsti*, *N. minimus* and, near the base, *N. oxycaudatus*. *Inoceramus* fragments common. Strong separation surface at the base	0.35
HC-SB 6	Limestone, pink and yellow-cream, gritty, nodular with *Inoceramus* fragments, brownish-red marly partings and wisps. *Neohibolites minimus* and *N.* cf. *oxycaudatus* common, *Neohibolites ernsti*/ *oxycaudatus* group present near the base. *Inoceramus* cf. *concentricus* also present near the base	0.28
HC-SB 5	Marl, red and brownish red becoming siltier towards the base. *Actinoceramus sulcatus* is common, and the following are also present: *Inoceramus* cf. *anglicus*; *Terebratulina* cf. *martiniana*, *Neohibolites minimus* and *N. oxycaudatus* gr. Basal boundary a marked erosion surface	0.33
HC-SB 4	Limestone, pale to reddish brown, marly. Marked erosion surface at the base	0.05
HC-SB 3	Marl, red with a red and brown mottled pebble bed at the base. Fossils include *Eopecten studeri*, *Terebratulina* cf. *martiniana* and *Neohibolites minimus*	0.18
HC-SB 2	Limestone, silty, brownish-red, marly with marl partings. Burrows with grey-brown infill at some levels. *Neohibolites minimus obtusus* and *Neohibolites minimus minimus* are common in the upper part, *Inoceramus concentricus* common in the middle part. *Pycnodonte* sp., ?*Isocrinus* sp., *Moutonithyris* sp. and *Ostrea papyracea* also present. Base not seen due to core loss	c.0.46 seen
HC-SB 1	Marl, brownish red, silty passing down into a bioturbated, burrowed, marly sand. *Inoceramus concentricus* and *Ostrea papyracea* common; *Neohibolites minimus pinguis* and *N. minimus minimus* also present	c.0.23

Morter, 1977

6.9.9 Hunstanton Cliff, north Norfolk

[TF 6725 4130 to TF 6786 4238]

Hunstanton Formation overlies Carstone Formation at Hunstanton Cliff (see Figure 34).

		Thickness m
HC-HC 11	Limestone, separated from Bed HC-HC10 by a very thin, irregular marl seam, this bed is similar to that below in being rubbly chalky and indurated, mottled pink to brick red. However, *Thalassinoides paradoxica* burrows are more common. *Concinnithyris* cf. *subundata*, *Ornatothyris* cf. *obtusa*, *O.* cf. *pentagonalis*, *Rectithyris* aff. *bouei*, *Aucellina coquandiana*, *A. gryphaeoides*, *A. krasnopolskii*, *A.* spp., *Ceratostreon rauliniana*, *Neohibolites praeultimus*, ? *N. menjailenkoi*, *N.* spp., *Cyclocrinus variolaris*, indeterminate sponges and stromatolites have been recorded	0.05–0.15
HC-HC 10	Limestone, mottled pink to brick red, rubbly, chalky indurated, *Neohibolites praeultimus*, *Aucellina coquandiana* indicate the *dispar* Zone (*rostratum* Subzone)	0.05–0.08
HC-HC 9	Marl, brick-red, locally laminated, indurated, thin (up to 0.02 m thick). The base of Bed HC-HC9 is a slight erosion surface, represented by a separation plane with deep red to purplish staining. This may be also found in burrow fills in the underlying bed	0.02
HC-HC 8	Limestone, indurated, blocky, pale pink and reddish with	

		Thickness m
	seams and coatings of brick-red marl. Bioturbated. Locally darker in the upper part and paler in the lower part, separated by a marl seam. Equates to the upper part of Bed 5a of Gallois (1995) and Bed Aiv of Owen (1995). It yields abundant *Inoceramus* fragments (mainly *I. lissa*), common *Moutonithyris* aff. *oroseina* and *Pycnodonte* aff. *vesicularis*, together with *Rotularia* cf. *umbonata*, *Concinnithyris* cf. *subundata*, *Moutonithyris dutempleana*, *Ceratostreon rauliniana*, *Neohibolites ernsti*, *N. oxycaudatus*, indeterminate sponges and stromatolites	0.18–0.34
HC-HC 7	Marl, red and pink, very thin, tough, indurated, laminated (stromatolitic?), that separates the lower and upper parts of Bed 5a of Gallois (1995). Equivalent to Bed Aiii of Owen (1995). Fossils are not known. Its age is therefore unknown	0.02–0.06
HC-HC 6	Limestone, pale band, pink, sometimes. greenish, cobbly gritty equates with the lower part of Bed 5a of Gallois (1995) and Bed Aii of Owen (1995). It has yielded common *Neohibolites ernsti*, *N. minimus* and *N. oxycaudatus*, together with *Kingena spinulosa*, *Moutonithyris dutempleana*, *M.* cf. *ichnusae*, *M.* aff. *oroeiana*, *Birostrina concentrica*, *B. transversa*, *Mortoniceras* cf. *cunningtoni*, *Semenovites* sp. (late form), *Holaster* cf. *latissimus* and indeterminate sponges, *varicosum* Subzone, possibly the upper part	0.09–0.14
HC-HC 5	Marl, red-brownish, very calcareous, earthy texture, sandy, with common small, angular quartz and ironstone pebbles. Irregular base. Belemnites abundant, including *Neohibolites ernsti*, *N.* cf. *ernsti* and *N. minimus*. Other macrofossils include *Flucticularia* cf. *sharpei*, *Rotularia* cf. *umbonata*, *Kingena spinulosa*, *Moutonithyris dutempleana*, *Platythyris diversa rubicunda*, *Birostrina* cf. *concentrica*. Equivalent to Bed 4 of Gallois (1995) and Bed Ai of Owen (1995)	up to 0.03
HC-HC 4	Limestone, pink red in colour, knobbly, pebbly with an indurated brick-red marl matrix containing belemnites and fragments of large bivalves (Owen, 1995). This bed equates with the upper part of Bed 3 sensu Gallois (1995) or Bed Biv of Owen (1995). The macrofauna includes *Moutonithyris dutempleana*, *Terebratulina* cf. *martiniana*, *Birostrina* cf. *concentrica*, *B. sulcata*, *Turnus* sp., *Inoceramus anglicus*, *Neohibolites minimus*, *N. oxycaudatus* (common), *N.* spp., *Holaster* cf. *perezii* and *Holaster* sp. Gallois suggested that the bed could be placed within the *orbignyi* Zone. Owen (1995) mentioned the occurrence of *E. inornatus*, which implied the lower part of the *orbignyi* Subzone, but gave no details of its location other than Bed Biii to Biv of Hunstanton	0.10
HC-HC 3	Limestone, dark red, pebbly, in blocks with numerous greenish chert pebbles, in a matrix of soft brick-red marl (Owen, 1995). This equates with the middle part of Gallois' (1995) Bed 3 and Bed Biii of Owen (1995). It is characterised by *Actino-ceramus sulcata*, *Moutonithyris dutempleana*, *M.* aff. *oroseina*, *Kingena spinulosa*, *Neohibolites minimus* (common) and *Inoceramus anglicus*. Owen (1995) listed the ammonites: *Beudanticeras sphaerotum*, *Euhoplites ochetonotus*, *E. solenotus*, *E. sublautus*, *E. trapezoidalis*, *E. armatus*, *E. subcrenatus* and *Epihoplites* (*Metaclavites*) spp. Owen (1995) placed it in the *cristatum* Subzone (probably the upper part) and Gallois (1995) suggested that the top may be within the *orbignyi* Subzone	0.25
HC-HC 2	Marly limestone with occasional pebbles and wisps and seams of red silty clay, becoming more marly down section. This bed equates with the lower part of Gallois' Bed 3. This unit includes Owen's (1995) beds Ciii, Bi and Bii: Bii. Limestone, soft, pink, bedded, pebbly with seams of brick-red marl Bi. Marl, very dark red to brown, highly calcareous. Ciii. Limestone, marly, brick red, pebbly, sandy with	

		Thickness m
	indurated patches. This bed has yielded *Birostrina concentrica*, *Moutonithyris dutempleana* and variants, and *Neohibolites minimus*. Owen (1995) mentions the presence of *Hoplites canavarii* and *H. canavariiformis* with Ciii (see below) matrix in museum collections (indicating the *spathi* Subzone). Bed Bii contains *Euhoplites microceras*, *E. loricatus*, *E.* cf. *pricei*, *Anahoplites intermedius*, *A. praecox*, *Neohibolites minimus* and *Birostrina concentrica*, indicating the *A. intermedius* Subzone (the tendency towards lautiform ribbing implies the upper part of that subzone; Bi presumably represents the rest of the subzone)	0.18
HC-HC 1	Sand, highly calcareous (Bed 1 of Gallois, 1995) with a burrowed surface at the base. Becoming harder, deep red, sandy marl at the top, not more than 0.07 m thick and locally missing (Bed 2 of Gallois, 1995). *Moutonithyris dutempleana*, *M.* cf. *dutempleana*, *M.* aff. *dutempleana*, *Birostrina concentrica*, '*Ostrea*' *papyracea*, *Neohibolites minimus* and *Hoplites* sp. have been recorded. Owen (1995) divided this unit (which equates to the lower part of his unit C) into two beds: ii. Ferruginous earth, red, pebbly with scattered brachiopods and other fossils. Owen (1995) recorded several of the taxa listed above from this bed i. Sand, brick red, calcareous, pebbly with inclusions of yellow to brown sand	0.25–0.30

Gallois, 1994; Morter, in Gallois, 1994; Owen, 1995.

6.10 UPPER GREENSAND FORMATION

6.10.1 Sundon Borehole [TL 0405 2724]

Lower Chalk resting on Upper Greensand (between the depths 46.20 and 49.61 m). Upper Greensand: Late Albian, *dispar* Zone.

		Thickness m
UGS-SB 7	Siltstone, medium to dark greenish-grey, calcareous with occasional phosphatic nodules. Glauconitic silt and shell debris infilling burrowed	1.05
UGS-SB 6	Siltstone, calcareous, micaceous darker than above, scattered small phosphatic nodules. Bioturbated	0.85
UGS-SB 5	Siltstone, pale grey, micaceous and glauconitic. Base not seen due to about 0.06 m of core loss	0.10
UGS-SB 4	Siltstone, marly, darker grey than above. Intensely bioturbated	0.11
UGS-SB 3	Siltstone, pale grey with darker burrow-fills	0.10
UGS-SB 2	Siltstone, dark grey. Bioturbated	0.40
UGS-SB 1	Siltstone, pale grey, micaceous, calcareous, glauconite-speckled passing down into Upper Gault	0.74

Shephard Thorne et al., 1994

6.10.2 M40, south-east of Tetsworth [SP 7022 0015 to SP 6070 0070]

Late Albian, latest *inflatum* Zone(?) (latest *auritus* Subzone?) and *dispar* Zone.

		Thickness m
UGS-TET 3	Siltstone, soft pale cream flaggy. Prominent shell seam 1.37 m above bed base containing large *Mortoniceras rostratum* and *Callihoplites* indicating the *rostratum* Subzone	3.05
UGS-TET 2	Sandstone, pale buff with greyish chert. Very hard and cherty near the top	1.37
UGS-TET 1	Sandstone, soft, buff-brown with occasional hard layers, becoming silty and marly down section. Yellowish sandy burrow infills. Layer of small buff phosphatic nodules 1.37 m below the top of the bed containing *Callihoplites* implying the late *auritus* Subzone.Base not seen	5.49

Owen, in Horton et al., 1995

6.10.3 Postcombe Underpass [SU 7075 9930]

Late Albian, *dispar* Zone.

		Thickness m
UGS-POST 3	Sandstone and silty sandstone, greyish buff, poorly bedded	1.50
UGS-POST 2	Sandstone, tough, blocky with a *M. perinflatum* Subzone fauna	0.20
UGS-POST 1	Sandstone and silty sandstone, greyish buff, poorly bedded, calcareous containing *M. rostratum* Zone fossils (?upper part of Bed UGS-TET 3). Base not seen	1.36

Owen, in Horton et al., 1995

6.10.4 Melbury Quarry, Melbury, Dorset
[ST 8753 2015]

Melbury Sandstone (3.20 m) (Cenomanian) on Boyne Hollow Chert Member (Late Albian, *dispar* Zone).

		Thickness m
BHC-MQ 1	Sandstone, soft, fine-grained, glauconitic with *Exogyra conica*	1.83

Bristow et al., 1995; Jukes-Browne and Hill, 1900; White, 1923.

6.10.5 Boyne Hollow, Mayo Farm, near Shaftesbury
[ST 8737 2227]

Boyne Hollow Chert Member (BHC) overlying Shaftesbury Sandstone Member (SSM). Late Albian. The Boyne Hollow Chert Member is placed in the *dispar* Zone, and the Shaftesbury Sandstone Member in the upper part of the *inflatum* Zone. Soil and rubble (0.46 m) on:

		Thickness m
BHC-BH 9	Sandy stone, soft, pale grey, with siliceous cherty concretions	1.07
BHC-BH 8	Sand, soft, grey, glauconitic with small siliceous concretions	1.37
BHC-BH 7	Siliceous-phosphatic masses, brown, in layer	0.23
BHC-BH 6	Sand, firm, grey, glauconitic silty	0.61
BHC-BH 5	Sandstone, firm, greyish with grey cherty concretions	1.07
BHC-BH 4	Sandstone, pale grey, powdery, full of hard calcareo-siliceous concretions, some of which have centres of blue-grey chert	1.22
BHC-BH 3	Chert, blue-grey, in a massive layer with thick whitish rind	0.61
BHC-BH 2	Sand, firm, grey, glauconitic with a layer of small brownish concretions at the base	0.38
BHC-BH 1	Sandy rock, greenish grey, very glauconitic, with a few brown phosphates	0.61
SSM-BH 3	Sandstone 'rag', very hard, glauconitic, semi-crystalline (i.e. calcitic) fossiliferous at the top	0.91
SSM-BH 2	Sandstone, softer, but firm, compact glauconitic with calcite cement (freestone)	1.37
SSM-BH 1	Sand, soft, greenish grey, glauconitic (base not seen)	0.61

Bristow et al., 1995; Jukes-Browne and Hill, 1900.

6.10.6 Baycliffe, Wiltshire [ST 8193 3994]

Boyne Hollow Chert Member

		Thickness m
BHC-BAY9	Silt, marly, pale buff, with angular fragments of chert	0.36
BHC-BAY8	Chert bed, pale grey	0.15
BHC-BAY7	Silt, marly, buff, sparsely glauconitic	0.61
BHC-BAY6	Sandstone, spiculiferous, grey	0.15
BHC-BAY5	Sand, glauconitic, greenish grey, fine grained, soft and laminated; with small irregular, spongiform concretions	0.41
BHC-BAY4	Sandstone, grey, glauconitic, spiculiferous with irregular seam of yellowish sand and granular sandstone	0.81
BHC-BAY3	Sandstone, calcareous, spiculiferous	0.38
BHC-BAY2	Sand, glauconitic, greenish grey, with large irregular masses of chert	0.91
BHC-BAY1	Marly silt, greyish white	0.36

Shaftesbury Sandstone

SSM-BAY1	Sandstone, calcareous, grey	0.46

Bristow et al., 1999; Jukes-Browne and Scane, 1901; Woods and Bristow, 1995.

6.10.7 Maiden Bradley Quarry [ST 7980 3891]

Melbury Sandstone (Cenomanian) on Boyne Hollow Chert Member

		Thickness m
BHC-MBQ 7	Sand, glauconitic, with some calcareous concretions	0.84
BHC-MBQ 6	Sand, greyish white, with siliceous sponge spicules and grey chertnodules	1.07
BHC-MBQ 5	Sand, grey, fine-grained, glauconitic, with large echinoderms and broken *Neithea*	0.61
BHC-MBQ 4	Chert, large blocks	0.46
BHC-MBQ 3	Sand, grey, fine-grained, glauconitic	0.30
BHC-MBQ 2	Sandstone, hard, granular, with siliceous sponge spicules	0.53
BHC-MBQ 1	Sand, pale grey (top only seen)	

Jukes-Browne and Scane, 1901

6.10.8 Longbridge Deverill Pit, Wiltshire
[ST 8693 4129]

Late Albian, *inflatum* Zone, *varicosum* Subzone.

Boyne Hollow Chert Member

		Thickness m
BHC-LDP 1	Cherty stone, white, weathered and broken	0.46

Shaftesbury Sandstone Member

SSM-LDP 3	Sand, green with a layer of large calcareous concretions and some smaller ones ('Ragstone')	0.46
SSM-LDP 2	Sand, greyish, very coarse with rough, calcareous masses full of shells ('Ragstone')	0.61
SSM-LDP 1	Sand, sharp, green, less coarse, but with some large grains, indistictly bedded	3.05

Woods and Bristow, 1995

6.10.9 Cann, piston sampler hole, Dorset
[ST 8667 2147]

Cann Sand Member, Late Albian, upper part of the *inflatum* Zone. Resting on Gault (dark grey, micaceous, sandy mudstone, 0.10 m seen).

		Thickness m
CSM-Ca 4	Sand, stony, brown	1.20
CSM-Ca 3	Sand, fine to medium grained, glauconitic, with 0.6 m of bright green sand 2.5 m from the top	c.3.80
CSM-Ca 2	Sand, fine to medium grained, firm	1.25
CSM-Ca 1	Sand, fine-grained, glauconitic	0.70

Bristow et al., 1995

6.10.10 Bookham Farm, between Dungeon Hill and Buckland Newton, Dorset [ST 7064 0412]

The Bookham Conglomerate (Cenomanian) rests disconformably, with an irregular contact, on the Shaftesbury Sandstone Member. The latter overlies the Cann Sand Member. The Shaftesbury Sandstone and Cann Sand members are placed in the Late Albian *inflatum* Zone, *varicosum* Subzone (see Figure 42).

		Thickness m
Shaftesbury Sandstone Member		
SSM-BF 1	Sandstone, greenish grey, glauconitic, rubbly, shelly. *Proliserpula* sp, '*Rotularia' concava* s.l., *Cyclothyris* cf. *punfieldensis*, *Amphidonte obliquatum*, *Ceratostreon*? *undata*, *Entolium orbiculare*, *Neithea gibbosa* and *Discoides* cf. *subuculus*	1.20–1.50
Cann Sand Member		
CSM-BF 3	Sandstone, poorly cemented, bioturbated, glauconitic shelly with a few cherty sandstone lenses. Abundant *Amphidonte obliquatum*, together with *Neithea gibbosa*, *Mimachlamys* ex gr. *robinaldina* and *Lima subovalis*	0.65
CSM-BF 2	Clay, pale brown, sandy	0.02
CSM-BF 1	Sand, soft, burrowed, glauconitic with *Amphidonte obliquatum* (base not seen)	1.00

Bristow et al., 1995; Jukes-Browne and Hill, 1900; Kennedy, 1970; Smart, 1955.

6.10.11 Winterborne Kingston Borehole
[SY 8470 9796]

Due to core loss the full sequence remains unclear and bed bases are frequently missing. Late Albian, *inflatum* Zone, *varicosum* Subzone, and *dispar* Zone (see Figure 38).

		Depth m
'Glauconitic calcareous grit'		
GCG-WK 4	Sandstone, glauconitic with serpulids and bivalves including *Entolium orbiculare*, *Idonearca*? sp., *Neithea gibbosa* and *Syncyclonema* sp. (?*dispar* Zone) (= Glauconitic Calcareous Grit of Drummond, 1970) (base not seen)	287.67–292.00
Foxmould Member		
FOX-WK 3	Sandstone, glauconitic, phosphatic in part. Shelly. *Rotularia concava* (serpulid) and the bivalves *Cucullaea* (*Idonearca*) *obesa*, *Neithea gibbosa*, *Syncylonema* sp. (*inflatum* Zone, *auritus* Subzone). (= Bed 10 of Lang, 1903; = top of the Foxmould of Jukes-Brown and Hill, 1900; = Potterne Rock, Drummond, 1970; = Exogyra Rock and Rag and Freestone of Drummond, 1970.) (Base not seen)	299.80–c.311.00
FOX-WK 2	Sand, glauconitic with a thin limestone at the top, and common *Rotularia*, rare *Hysteroceras* cf. *varicosum* and common bivalves. (*inflatum* Zone, *varicosum* Subzone) (this is the basal Foxmould and can be correlated with Bed X of Folkestone.) (Base not seen)	c.311–312
	Core loss	
FOX-WK 1	Sandstone, hard, glauconitic with thin limestones, *Entolium orbiculare* and oyster fragments. (Late Albian). Resting on silty mudstones (Gault)	317.00–325.30

Morter, 1982

6.10.12 Gore Cliff, near Blackgang, Isle of Wight
[SZ 493 762]

Late Albian, *inflatum* Zone.

		Thickness m
'Division F'		
UGS-IOW 18	Sands, greenish grey, glauconitic with two layers of calciferous concretions having brown phosphatised rinds	1.52
'Division E'		
UGS-IOW 17	Sandstone, soft, grey, glauconitic with conspicuous layers of black or grey chert	3.05
UGS-IOW 16	Similar sandstone with layers of calcareo-siliceous concretions, which here and there pass into chalcedonic chert	3.66
'Division D'		

		Thickness m
UGS-IOW 15	Sandstone, grey, glauconitic with a layer of calcareous lumps or cornstones at the base	0.61
UGS-IOW 14	Sandstone, 'Bastard Freestone', smooth, fine-grained glauconitic weathering to a yellowish-grey or buff colour	0.30
UGS-IOW 13	Sandstone, 'Freestone': massive, fine-grained weathering a yellowish grey	1.52

'Division C'

UGS-IOW 12	Sandstone, grey, weathering buff, containing small brown phosphatic nodules, and small ragstone lumps which weather out as rough projections	1.07
UGS-IOW 11	Sandstones, grey, smooth with small brown phosphatic nodules	1.52
UGS-IOW 10	Sandstone, calcareous, in a series of large doggers or masses in grey sand	1.22
UGS-IOW 9	Sandstone, firm, grey, weathering as usual, with some phosphatic nodules and a layer of calcareous concretions in the lower part	2.29
UGS-IOW 8	Course of large calcareous doggers, which are grey inside and often enclose pieces of brown phosphate	0.46

'Division B'

UGS-IOW 7	Sandstone, grey, firm, weathering irregularly into harder and softer portions; a few phosphates	3.06
UGS-IOW 6	Similar sandstone, but without phosphates	4.88
UGS-IOW 5	Course of hard and heavy doggers of compact bluish-grey siliceous limestones	0.23–0.30

'Division A' (Passage Beds)

UGS-IOW 4	Sand, yellowish, firm mottled with bluish-grey	0.91
UGS-IOW 3	Sand, bluish-grey marly micaceous mottled buff	3.20
UGS-IOW 2	Similar sand with less of the buff mottling	1.83
UGS-IOW 1	Sand or silt, bluish-grey, fine micaceous with a layer of smooth rounded doggers of grey siliceous limestone at the base	2.74

Jukes-Browne and Hill (1900); White (1921).

6.10.13 Whitecliff between Seaton Hole and Beer Roads, Devon [SY 235 895 to SY 232 892]

inflatum Zone and *dispar* Zone.

		Thickness m
Whitecliff Chert Member		
WCM-Wh 22	Sandstone, hard, nodular with occasional chert nodules, becoming less calcareous down section (=Top Sandstone sensu Smith, 1961). Its base is marked by a thin bed of pebbly greensand forming a recess in the cliff (= Coarse Band sensu Smith, 1961)	2.44
WCM-Wh 21	Sandstone, yellow with large brown chert nodules	0.91
WCM-Wh 20	Quartz, sand, coarse yellowish green with glauconite	0.46
WCM-Wh 19	Sandstone, yellow with lenticular beds of brown chert	1.22
WCM-Wh 18	Sandstone, green, nodular calcareous. *Exogyra digitata*-rich	1.22
WCM-Wh 17	Sandstone, grey with grey chert	3.66
WCM-Wh 16	Sandstone, shelly. *Exogyra*-rich	0.91
WCM-Wh 15	Sand and sandstone, yellow with irregular masses of ferruginous chert. Layers of buff 'calcareous stone' near the base	2.13
WCM-Wh 14	Sand, grey, glauconitic with calcareous sandstone concretions	1.07
WCM-Wh 13	Sand, grey, glauconitic with black chert	1.22
WCM-Wh 12	Sandstone, grey, shelly with occasional cherts in the upper part	0.92
WCM-Wh 11	Sandstone, grey calcareous with black cherts	0.91
WCM-Wh 10	Sand, brown, argillaceous with large chert concretions in the middle part and calcareous concretions above and below	1.52
WCM-Wh 9	Sand, dark grey, glauconitic, becoming argillaceous down-section with calcareous sand-stone concretions at the base	0.61
WCM-Wh 8	Sandstone, nodular, greenish grey, calcareous. Pebbly in part and fossiliferous in part	0.46
WCM-Wh 7	Sand, green with thin grey partings	0.30

Foxmould or 'Lower Division' of Jukes-Browne and Hill (1900)

FOX-Wh 6	Sandstone, brown, calcareous glauconitic and shelly at the base	0.76
FOX-Wh 5	Sand, pale grey with occasional calcareous concretions	4.27
FOX-Wh 4	Sands, greenish grey with layers of calcareous sandstone	2.44
FOX-Wh 3	Sand, dark purplish-grey argillaceous with occasional layers of calcareous sandstone. *Exogyra conica* and *Serpula concava* common	9.15
FOX-Wh 2	Sand, dark grey and green with lenticular concretions of calcareous stone (Cowstones)	4.57
FOX-Wh 1	Sand, very dark green. (Base not seen)	4.57

Jukes-Browne and Hill, 1900

6.10.14 Dunscombe Cliffs to Kempstone Rocks, south of Dunscombe [SY 150 877 to 161 881]

'Cenomanian Limestone' disconformably overlies the Bindon Sandstone Member. The Bindon Sandstone, Whitecliff Chert and highest bed of the Foxmould Member (FOX-DUN 7) are seen at Kempstone Rocks, south of Dunscombe (Jukes-Browne and Hill, 1900, p.209), and the lower beds of the Foxmould Member (FOX-DUN 1–6) at Dunscombe Cliff (Jukes-Browne and Hill, 1900, p.202). Late Albian (see Figure 35).

		Thickness m
Bindon Sandstone Member		
BSM-DUN 9	Quartz grit, coarse (= upper bed of the Top Sandstone sensu Smith, 1961) passing down into:	0.76
BSM-DUN 8	Sandstone, calcareous, shelly becoming coarser and more quartziferous down section	2.44
BSM-DUN 7	Quartz sand, very coarse grained, yellow	1.83
BSM-DUN 6	Sandstone, fine-grained, calcareous, shelly	1.83
BSM-DUN 5	Sandstone, calcareous, glauconitic becoming nodular in the upper 0.61 m	1.83
BSM-DUN 4	Shell bed of *Exogyra* fragments and occasional sandstone pebbles	0.30
BSM-DUN 3	Sandstone, greenish-grey, shelly with lumps of hard calcareous stone. *Exogyra digitata* abundant	3.96
BSM-DUN 2	Sandstone, white calcareous	0.91
BSM-DUN 1	Sandstone, grey with a thin pebble bed at the base (?base of Top Sandstone sensu Smith, 1961)	1.98
Whitecliff Chert Member		
WCM-DUN 4	Sandstone, buff, calcareous with lenticular layers of grey-brown chert that become thinner up-sequence. Possibly *rostratum* Subzone (= Chert Beds)	1.83
WCM-DUN 3	Bed rich in silicified *Exogyra conica* and occasional chert	0.46
WCM-DUN 2	Sand, yellow with occasional lumps of calcareous stone	0.46
WCM-DUN 1	Sand, buff with irregular chert and occasional calcareous concretions	2.43
Foxmould Member		
FOX-DUN 7	Sand, dark green with small sandstone pebbles	0.30
FOX-DUN 6	Sandstone, greenish calcareous	c.1.83
FOX-DUN 5	Sand, buff with layers of 'calcareous stone'	c.6.10
FOX-DUN 4	Sand, greenish with thin layers of siliceous stone in the upper part	c.4.88
FOX-DUN 3	Sand, greyish with a few small doggers of calcareous stone	c.3.05
FOX-DUN 2	Sand, grey with large doggers and lenticular layers of fine grey calcareous stone	c.4.57
FOX-DUN 1	Sand, grey glauconitic (basal part not seen, but the base is marked by a spring line)	10.67

Jukes-Browne and Hill, 1900; Smith, 1961; Tresise, 1961.

6.10.15 Eastern end of the cliff at Peak Hill, west of Sidmouth [SY 113 868] (approximately — exact location not given)

Late Albian. After Jukes-Browne and Hill (1900): sand and gravel on

		Thickness m
Bindon Sand Member		
BSM-PH 1	Sand, clean, buff	3.05
Whitecliff Chert Member		
WCM-PH 2	Sand, buff with siliceous concretions and thin layers of siliceous stone. Possibly *rostratum* Subzone	3.66
WCM-PH 1	Sand, grey, fossiliferous with sandy nodular concretions. Fossils are silicified. Possibly *rostratum* Subzone	3.05
Foxmould Member		
FOX-PH 1	Sand, clean, light grey, weathering yellow, overlying red marl	9.15–10.67

Jukes-Browne and Hill, 1900; Tresise, 1960, 1961.

6.10.16 Punfield Cove, Swanage [SZ 0395 8105]

Cenomanian Chalk overlying Late Albian (see Figure 35).

		Thickness m
Bindon Sandstone Member		
BSM-PUN 1	Sand, dark green, with calcareous nodules. Fossiliferous with ammonites and *Exogyra*-rich bed at the base	1.83
Foxmould Member		
FOX-PUN2	Sand, green with occasional stone bands (Beds 4 and 5 of Arkell, 1947, pp.185–186)	
	iv. Sand, green, fossiliferous,	3.66
	iii. Sand, green with calcareous nodules,	0.73
	ii. Sand, green, fossiliferous, 1.10 m	
	i. Doggers, calcareous with bivalves, (Bed 4 of Arkell, 1947), 0.46 m	5.95
FOX-PUN1	'Loam', black, argillaceous with nodules at the base	
	ii. Silt, black, argillaceous, sandy (Bed 3 of Arkell, 1947), 4.12 m	

		Thickness m
	i. Calcareous nodule, fossiliferous, bed, (Bed 2 of Arkell, 1947), 0.30 m Overlying Gault Clay Formation (Bed 1 of Arkell, 1947)	4.42

Arkell, 1947; Tresise, 1960.

6.10.17 **White Nothe, Dorset** [SY 770 811]

Cenomanian Chalk overlying Late Albian (see Figure 35).

		Thickness m
Bindon Sandstone Member		
BSM-WN 1	Sand, glauconitic with calcareous nodules	1.75
Whitecliff Chert Member		
WCM-WN 1	Sand, glauconitic with calcareous and chert nodules	1.90
Foxmould Member		
FOX-WN 10	Silt, dark green-grey, glauconitic, sandy with phosphatic and pyritic nodules and phophatised bivalves and ammonites, passing down into bioturbated, pale green, glauconitic, calcareous sand	0.75
FOX-WN 9	Calcareous nodules in glauconitic sand	0.30
FOX-WN 8	Silt, dark green-grey, shelly, glauconitic, sandy with phosphatic and pyritic nodules, becoming less shelly and calcareous in the lower part	1.30
FOX-WN 7	Sand, glauconitic	0.70
FOX-WN 6	Limestone (= 'Exogyra Rock')	2.25
FOX-WN 5	Sand, glauconitic with calcareous nodules	1.50
FOX-WN 4	Sand, quartz with calcreous nodules	2.40
FOX-WN 3	Sand, shelly, glauconitic	1.20
FOX-WN 2	Sand, quartz	4.75
FOX-WN 1	Silt, sandy (= 'loam' of Tresise, 1960) with calcareous nodule	11 m+ (base 7.5 m below the top of the bed not seen)

Tresise, 1960, 1961

6.10.18 **Snowdon Hill, Chard** [SY 313 008]

See Figure 35

Cenomanian Chalk on

		Thickness m
Bindon Sandstone Member		
BSM-SHC 3	Quartz sand, pebbly with nodules	0.08
BSM-SHC 2	Quartz sand, glauconitic with calcareous nodules	0.90
BSM-SHC 1	Quartz sand, glauconitic	1.90
Whitecliff Chert Member		
WCM-SHC 3	Sand, buff, cherty with common chert nodules	8.70
WCM-SHC 2	Sand, glauconitic with calcareous nodules	1.30
WCM-SHC 1	Sand, glauconitic, shelly, cherty with chert nodules	2.90
Foxmould Member		
FOX-SHC 1	Sand, glauconitic green passing down into quartz sand (base not seen)	30+

Tresise, 1960, 1961

6.10.19 **Fetcham Mill Borehole, Leatherhead** [TQ 1581 5650]

See Figure 41. Late Albian

		Thickness m
UGS-FMB 17	Sandstone, soft fine-grained, green marly glauconitic with small phosphatic nodules and burrow fills of grey clay	1.98
UGS-FMB 16	Sandstone, firm, grey-white, calcareous	0.28
UGS-FMB 15	Sandstone, soft, green, fine-grained, glauconitic and micaceous	1.63
UGS-FMB 14	Sandstone, hard, grey-white, fine-grained, calcareous	0.23
UGS-FMB 13	Sandstone, firm, grey-green, fine-grained, glauconitic, slightly micaceous	1.37
UGS-FMB 12	Sandstone, hard, grey-white	0.08
UGS-FMB 11	Sandstone, soft, grey-green, fine-grained, glauconitic becoming grey and less glauconitic downwards	1.40
UGS-FMB 10	Sandstone, hard, grey-white, fine-grained, calcareous	0.23
UGS-FMB 9	Sandstone, hard, grey, fine-grained, becoming softer and darker grey downwards	0.94
UGS-FMB 8	Sandstone, soft, light grey, fine-grained with some glauconite	0.71
UGS-FMB 7	Sandstone, hard, light grey, fine-grained, becoming glauconitic towards the base	1.27
UGS-FMB 6	Sandstone, firm, grey-green, fine-grained, with glauconite and sparse, small phosphatic nodules	0.25
UGS-FMB 5	Sandstone, hard, grey-green, fine-grained, glauconitic towards the base	0.56
UGS-FMB 4	Siltstone, grey-green, calcareous with phosphatic nodules. Becoming white in the lower part	0.23
UGS-FMB 3	Sandstone, hard, light grey	2.36
UGS-FMB 2	Siltstone, dark grey, streaky calcareous	1.42

		Thickness m
UGS-FMB 1	Siltstone, dark grey, friable, calcareous with sparse glauconite and mica	1.02

Gray, 1965; Owen, 1976.

6.10.20 Merstham Interchange [TQ 303 539]

(After Owen 1976) Beds 1–5 are *rostratum* Zone; Beds 6–14 are *perinflatum* Subzone (*dispar* Zone) (see Figure 41).

		Thickness m
Division D sensu Owen (1976)		
UGS-MI 25	Sandstone, soft, greenish-grey, glauconitic marly	1.83
UGS-MI 24	Sandstone, soft glauconitic, earthy, ferruginous weathering	0.30
UGS-MI 23	Sandstone, soft, greenish-grey, flaggy glauconitic, ferruginous weathering. Sparsely shelly	1.22
Division C sensu Owen (1976)		
UGS-MI 22	Marly earth, cream-fawn with white marl patches	0.20
UGS-MI 21	Sandstone, tough, greenish-light grey, massive-bedded	0.61
UGS-MI 20	Sandstone, very hard, pale cream to grey with nodules of bluish white chert (larger nodules being situated in the lower part)	0.73
UGS-MI 19	Marl, soft, sandy, earthy	0.07
UGS-MI 18	Sandstone, tough, massive-bedded, micaceous with cherty nodules	0.30
Division B sensu Owen (1976).		
UGS-MI 17	Marl, soft, slightly glauconitic, sandy, earthy	0.23
UGS-MI 16	Sandstone, tough, creamy fawn with hard cherty centres	0.20
UGS-MI 15	Marl, soft creamish, earthy sandy	0.20
UGS-MI 14	Sandstone, tough, blocky cream-fawn with chert centres	0.20
UGS-MI 13	Clay, toughish, pale, calcareous *Mortoniceras* (?*D.*) sp.	0.23
UGS-MI 12	Sandstone, cream, hard iron-stained, calcareous	0.30
UGS-MI 11	Marl, soft fawnish	0.48
UGS-MI 10	Sandstone, whitish, tough fine silty	0.23
UGS-MI 9	Clay, soft, fawnish-cream fossiliferous calcareous. *Stoliczkaia* cf. *rhamnonotus*, *Mortoniceras* (*D.*) sp., *Lepthoplites pseudoplanus*, *Callihoplites vraconensis*, *C.* cf. *tetragonus*, *C. acanthonotus*, *C. advena*, C. sp., *C. seeleyi*, *Arrhaphoceras studeri*, *Pleurohoplites subvarians*, *P.* cf. *renauxianus*, *Anisoceras* sp., *Idiohamites* sp., *Lechites gaudini*, *Ostlingoceras puzosianum*	0.28
UGS-MI 8	Sandstone, whitish, nodular, fine silty	0.15
UGS-MI 7	Malm, buff soft	0.07
UGS-MI 6	Sandstone, tough, whitish, fine silty with dark grains. *Stoliczkaia rhamnonotus*	0.30
Division A of Owen (1976) (*rostratum* Subzone, *dispar* Zone)		
UGS-MI 5	Mudstone, soft, silty, calcareous, blocky, cream-grey, fossiliferous with courses of indurated stones	0.61–0.91
UGS-MI 4	Clay, soft, silty, blocky, cream-grey calcareous with much limonitic material in nodules and streaks	0.61–0.91
UGS-MI 3	Clay, pale cream, silty calcareous clay with fossils. *Puzosia* sp. cf. *sharpei*, *Stoliczkaia* spp., *Mortoniceras* (*M.*) *rostratum*, *M.* (*M.*) *fallax*, *M.* (*M.*) *alstonensis*, *Lepthoplites pseudoplanus*, *L. falcoides*, *Callihoplites vraconensis*, *C. acanthonotus*, *C. tetragonus*, *C.* cf. *paradoxus*, *C.* spp., *Anisoceras picteti*, *Idiohamites elegantulus*	0.15
UGS-MI 2	Clay, mottled pale grey-buff calcareous with some streaks of grey clay	0.23
UGS-MI 1	Clay, pale cream-buff, soft calcareous with ferruginous streaks and pipings; mottled grey (clayey) and creamy (silty) in the basal 0.31 m. Sparingly fossiliferous (*Puzosia* sp.)	2.33–2.54

Owen, 1976

6.10.21 Woodlands, near Great Haldon [SX 902 840]

See Figures 36, 39 and 40. Cullum Sands Member (6.71 m) (Cenomanian) on Late Albian:

		Thickness m
Ashcombe Gravels Member		
AGM-W 5	Sand, green and brown, coarse, gravelly (Bed 19 of Hamblin and Wood, 1976)	0.84
AGM-W 4	Sand, brown and green coarse gravelly, poorly sorted cross bedded in parts. Two seams of kaolinised pebbles occur in the lower part (Bed 18 of Hamblin and Wood, 1976)	3.16
AGM-W 3	Quartz gravel, fine, clayey in part (Bed 17 of Hamblin and Wood, 1976)	0.26
AGM-W 2	Sand, dark green, brown and black poorly sorted and cross bedded in part (Bed 16 of Hamblin and Wood, 1976)	0.81

		Thickness m
AGM-W 1	Quartz gravel, fine, shelly, rich in fragments of exogyrine oysters (Bed 15 of Hamblin and Wood, 1976)	0.25

Woodlands Sands Member

WSM-W 8	Sand, green and black, clayey (Bed 14 of Hamblin and Wood, 1976)	0.20
WSM-W 7	Sand, brown, clayey (Bed 13 of Hamblin and Wood, 1976)	0.42
WSM-W 6	Sand, variagated (Bed 12 of Hamblin and Wood, 1976)	0.28
WSM-W 5	Sand, dark green and red (Bed 11 of Hamblin and Wood, 1976)	0.94
WSM-W 4	Sand, greenish grey (Bed 10 of Hamblin and Wood, 1976)	0.84
WSM-W 3	Shell drift, dark green (Bed 9 of Hamblin and Wood, 1976)	0.10
WSM-W 2	Sand, grey, brown and green (Bed 8 of Hamblin and Wood, 1976)	0.76
WSM-W 1	Sand, dark brown with oysters (Haldon Coral Bed) (Bed 7 of Hamblin and Wood, 1976)	0.59

Telegraph Hill Sands Member

TSM-W 6	Sand, pale greenish-brown, poorly consolidated, becoming coarser and argillaceous upwards (Bed 6 of Hamblin and Wood, 1976)	0.38
TSM-W 5	Chert concretions, four courses in matrix of green sandstone, oyster-rich (Bed 5 of Hamblin and Wood, 1976)	0.51
TSM-W 4	Sand, soft, green with chert concretions and burrowfills in the middle part of the bed and a shelly gravel at the top. Molluscs are common in the bed (Bed 4 of Hamblin and Wood, 1976)	3.96
TSM-W 3	Sandstone, 'Basal Shell Bed'. Green, glauconitic, quartz with chalcedonised shells. Bivalves and gastropods are diverse. (Bed 3 of Hamblin and Wood, 1976)	0.20
TSM-W 2	Sands, soft, green (Bed 2 of Hamblin and Wood, 1976)	0.18
TSM-W 1	Basal conglomerate, fossiliferous with pebbles encrusted with oysters. Bivalves, brachiopods and corals present. Fragmentary orbitolines (Bed 1 of Hamblin and Wood, 1976). Resting on Teignmouth Breccias (Permian)	0.03

Hamblin and Wood, 1976

6.10.22 Babcombe Copse Sandpit [SX 869 766] (see Figure 36)

The Cullum Sands (Cenomanian) rest on the Ashgrave Gravel Member, considered to be Late Albian (*S. dispar* Zone). The Woodlands Sand Member is Late Albian (*dispar* Zone) (see Figures 35 and 38).

		Thickness m

Ashcombe Gravel Member

AGM-BCS 3	Gravel	0.34
AGM-BCS 2	v. Sand and gravel, brown and brown-green becoming clayey downwards (2.89 m)	
	iv. Clay, green, manganese-stained	0.02
	iii. Sand, green and buff, clayey with wisps and bands of grey clay, gravelly bands and manganese specks (0.4 m)	
	ii. Sand, coarse and gravelly, clayey with manganiferous concretions, which are locally large and fossiliferous with well-preserved bryozoa and exogyrine oysters	0.28
	i. Sand, clayey, olive green, locally coarse and gravelly with seams of olive green clay (0.05 m)	3.64
AGM-BCS 1	Gravel, clayey, sandy some glauconite, iron pans and ferruginous nodules; persistent clay seam 0.3 m above the base. Shelly in the lower part, particularly the basal 0.15 m (= Bed AGM-W1)	3.35

Woodlands Sand Member

WSM-BCS 9	Gravel, sandy with bands of sand, yellow-brown and green-brown mottling and banding, becoming less sandy down section. Pinkish white concretions (some containing exogyrine oysters) form a discontinuous band in the middle of the bed	0.50
WSM-BCS 8	Sand, buff, slightly clayey, poorly bedded, with manganiferous patches	0.50
WSM-BCS 7	Sand, pale yellowish brown to pale greenish brown with horizons of brownish grey clay	0.25
WSM-BCS 6	Gravel, fine, reddish brown in the upper part and green in the lower part	Up to 0.02
WSM-BCS 5	Sand, greenish and yellowish brown, clayey with dark brown concretions at the top. Shell fragments	0.27
WSM-BCS 4	Sand, fine grained glauconitic, clayey mottled dark green and brown. Shelly (*Rutitrigonia* and *Helicocryptus*, together with *Callistina*, *Crenella*, *Limatula*, *Protocardia*, *Pterotrigonia*, *Trigonarca*, *Avellana* and small orbitolines, including conical forms)	0.22–0.32

		Thickness m
WSM-BCS 3	Sand, greenish brown, fine to medium grained, clayey, glauconitic with shell fragments	0.41
WSM-BCS 2	Sand, dark olive-brown, fine to medium grained glauconitic oyster shell fragments abundant. Clasts of Ugbrooke Sandstone (Carboniferous) at the base	0.43
WSM-BCS 1	Sand, dark green medium grained, clayey, glauconitic and scattered pebbles and oyster shell fragments. Resting on Ugbrooke Sandstone (Carboniferous)	0.12

Sellwood et al., 1984

6.11 CAMBRIDGE GREENSAND FORMATION

6.11.1 Ely-Ouse Borehole No. 6 (= Mildenhall Borehole No. 6) [TL 6928 7307]

The Cambridge Greensand Formation is present between the depths of 51.78 and 52.50 m. CG-EOB1–3 are placed in the *scrobicularis* ostracod Subzone of the *hannoverana* Zone, and therefore by inference in the *rostratum* Subzone (*dispar* Zone). Beds CG-EOB4-6 are of Cenomanian age (*Bythoceratina* spp. ostracod Zone, and therefore by inference the *carcitanense* Subzone of the *mantelli* Zone). The Albian–Cenomanian boundary is placed at an erosion surface at 52.12 m (i.e. at about the base of CG-EOB4) (see Figure 44).

		Thickness m
CG-EOB6	Marl, medium to pale grey, silty with small phosphatic nodules at the top of the bed, and in the middle part of the bed. Shelly in the lower part (*Aucellina uerpmanni*). Brown phosphatic nodules in a glauconitic silt on an erosion surface	0.14
CG-EOB5	Marl, medium to pale grey silty, shelly near the base (*Aucellina uerpmanni* and *A. gryphaeoides*) and a basal layer of phosphatic nodules in a silty matrix on an erosion surface	0.10
CG-EOB4	Siltstone, pale grey, glauconitic calcareous with scattered phosphatic nodules in the middle part of the bed	0.09
CG-EOB3	Phosphatic nodules and pebbles, brown in a glauconitic, calcareous silt (with *Aucellina uerpmannae* and *A. gryphaeoides*) and an erosion surface at the base	0.09
CG-EOB2	Siltstone, pale grey micaceous marly with scattered phosphatic nodules. A phosphatic nodule layer, with pebbles and a sandy matrix overlies an erosion surface at the base (with *Aucellina uerpmannae* and *A. gryphaeoides*).	0.11
CG-EOB1	Marl, silty with scattered phosphatic nodules, and with *Aucellina gryphaeoides* and *Neohibolites praeultimus* at the base. Strongly eroded and burrowed base	0.19

Morter, 1982b; Morter and Wood, 1983; Wilkinson, 1988.

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Most of the references listed below are held in the Libraries of the British Geological Survey at Edinburgh and Keyworth, Nottingham. Copies of the references can be purchased subject to the current copyright legislation. BGS Library catalogue can be searched online at: http://geolib.bgs.ac.uk

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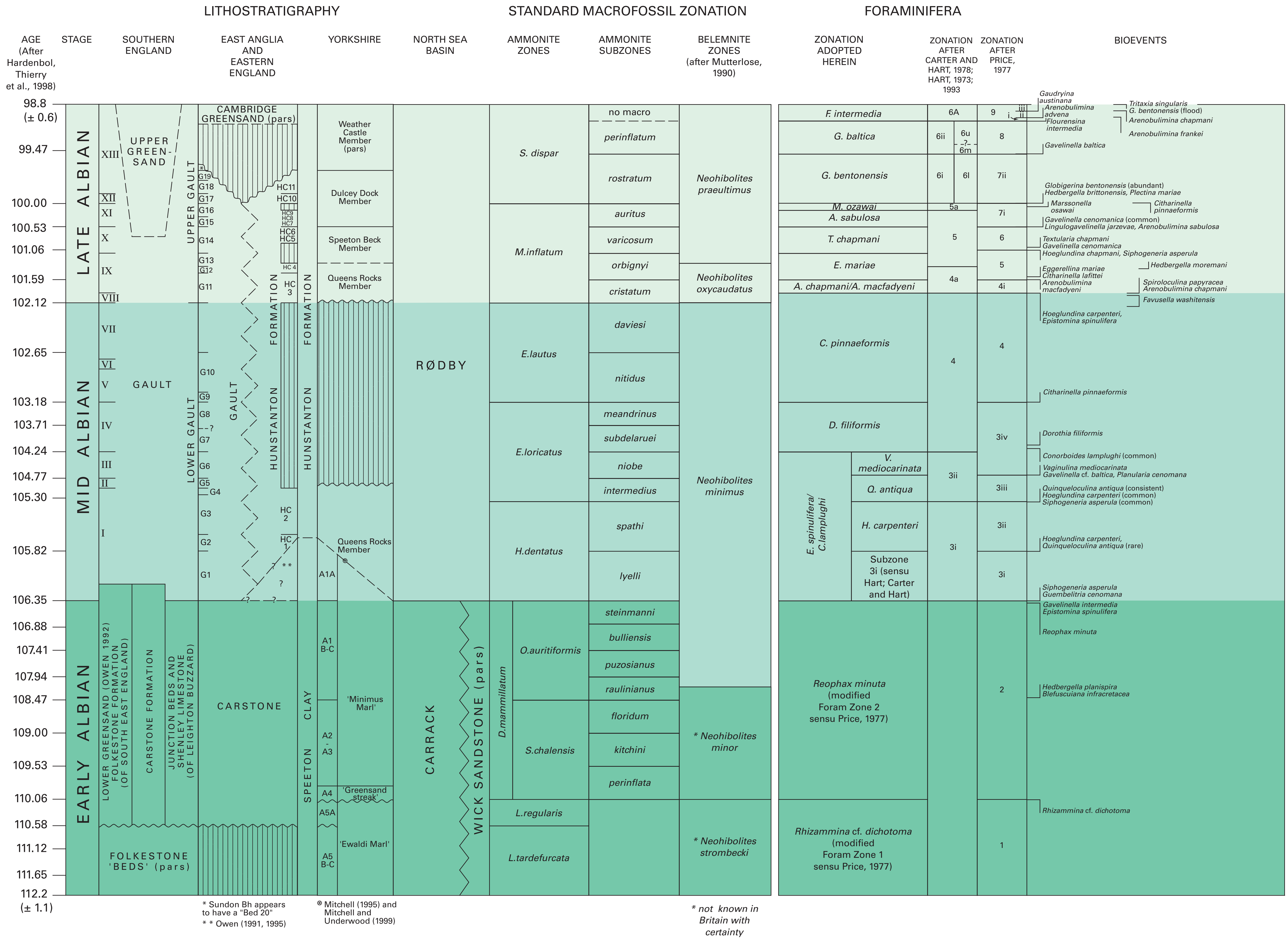

Figure 2 The Albian holostratigraphical scheme.

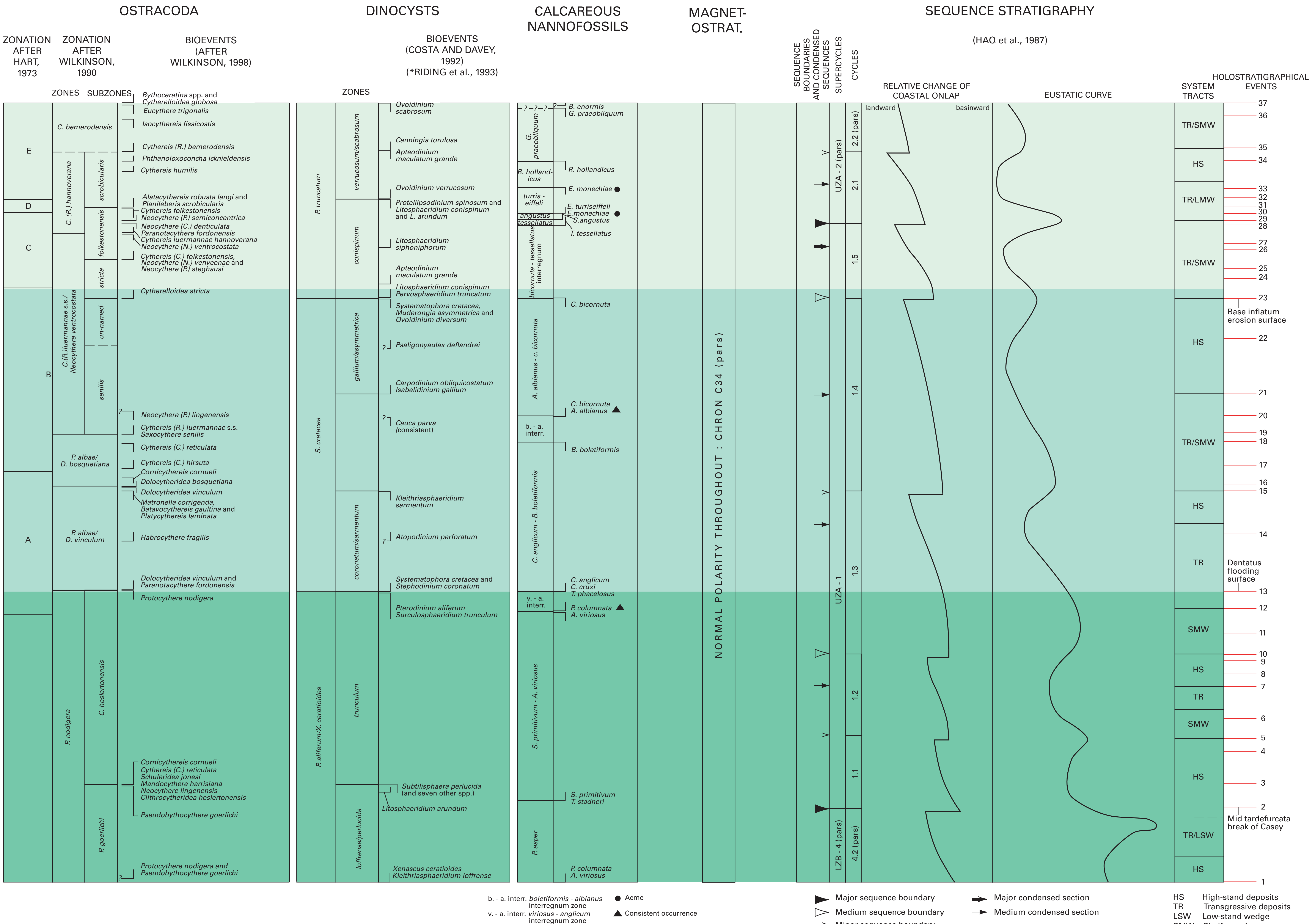

Figure 2 *Continued.*