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A stratigraphical framework for the Lower Cretaceous of England

Research Report RR/08/03

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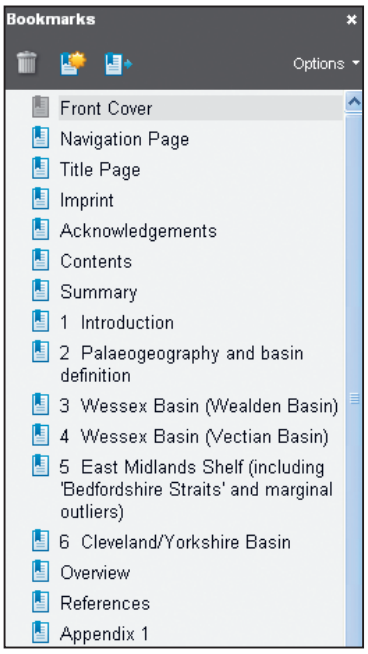

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- from each figure, plate or table caption to the first place that figure, plate or table is mentioned in the text and
- from each page number back to the contents page.

RETURN TO CONTENTS PAGE

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Front cover

Ferruginous Sand Formation exposed above a significant landslide founded in the Atherfield Clay Formation, Red Cliff, Sandown Bay, Isle of Wight (P683788).

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A stratigraphical framework for the Lower Cretaceous of England

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Peter Hopson, Ian Wilkinson and Mark Woods.

Contents

FIGURES

TABLES

Summary

This report describes the Lower Cretaceous strata of England appearing on maps and major texts from the British Geological Survey and seeks to clarify the lithostratigraphical terminology, relationships and distribution of the various units. The report considers the successions in England within defined sedimentological basins: the Wessex Basin (including the Wealden Basin and Vectian Basin — sub-basins of some authors), the East Midlands Shelf covering Lincolnshire, South Yorkshire and Norfolk (strictly not a basin in its own right) and the Cleveland–Yorkshire Basins are described. The marginal basin successions of north Wiltshire to Bedfordshire (the 'Bedfordshire Straits') are included in the descriptions for the East Midlands Shelf area.

The base of the Lower Cretaceous is taken at the base of the Berriasian Stage that occurs in the lower part of the Purbeck Group of the English succession. Consequently the Lulworth Formation is described herein as it is principally of Berriasian age. The Haddenham Formation, a new term proposed herein, covers those beds formerly called the Purbeck Limestone Formation within the marginal basin areas in Wiltshire, Oxfordshire and Buckinghamshire. These are probably of latest Jurassic, Portlandian Stage, but show strong lithological affinities to the restricted salinity environments of the Purbeck Group rather than the open marine conditions of the Portland Group. The Purbeck Group is divided into a lower Lulworth Formation and an upper Durlston Formation in its type area where the division is placed at the base of the Cinder Bed. Within the Wealden Basin successions of this group an equivalent to the Cinder Bed can be recognised and the two formations adopted in the type area are described.

In the Wessex Basin, a simplified hierarchy is proposed and the name 'Hastings Beds' (Group/ Subgroup/ Formation) in the literature is abandoned in favour of a more inclusive Wealden Group, with constituent formations that can be applied in both the Wealden and Vectian basins. The term 'Carstone', of the Isle of Wight, is abandoned because of the confusion with the Carstone described in the East Midlands Shelf area. It is replaced with the new term Monk's Bay Sandstone Formation. The use of the terms 'lower' and 'upper' to describe divisions of the same unit is abandoned (other than as an informal term). For example the Tunbridge Wells Sand Formation includes informal lower and upper divisions where the Grinstead Clay Member is present.

Clear terminology and relationships exist over the East Midlands Shelf and needs little adjustment at formation and member level.

In the marginal area of the Wessex Basin from north Wiltshire to Bedfordshire, a number of new terms (at formation level) are proposed for the thin isolated units encountered; more research may clarify their relationships and require a further reappraisal of these terms used herein and in the literature. The Whitchurch Sand Formation is now considered to be of Valanginian age and includes those beds formerly described as the Shotover Ironsands. The isolated outcrops attributed to the Lower Greensand Group are all given formation status. The terms 'Calne Sand' and 'Seend Ironstone (Ironsand of some authors)' are firmly emplaced within the literature and are retained. The Faringdon Sand Formation has been introduced and includes the Faringdon Sponge Gravels Member, Baulking Sand Member and Fernham Sand Member. Terms such as the 'Red Sands' of Uffington, 'Junction Beds' and 'Transition Beds' have been abandoned and the unnamed outcrops around Clifton Hampden incorporated into the newly defined Baulking Sand Member, Fernham Sand Member and Munday's Hill Phosphatic Sandstone Formation; the latter including the Shenley Limestone Member.

The term 'Selborne Group' is formally introduced to include the Gault Formation and Upper Greensand Formation. In the Norfolk area the Hunstanton Formation is demonstrably gradational from the Gault Formation but in Lincolnshire and Yorkshire the formation is considerably thicker and can be related directly to the Rødby Formation of the Cromer Knoll Group in the offshore basin. The extension of the term Selborne Group to include the Hunstanton Formation is not formalised in this document but it may be a consideration for future research particularly if the Cromer Knoll Group, that covers the entire Early Cretaceous, is considered as a supergroup in the fullness of time.

In the Yorkshire Basin the complex bed numbering system of the Speeton Clay Formation is well established. The erection of a set of member names for units to enhance the understanding of units previously defined by alphanumeric codes is considered a useful step for readers of descriptive texts. Their creation is beyond the scope of this report as it is unlikely that such members would appear as lithostratigraphical units on BGS maps as the outcrop is limited in extent, complicated by faulting and covered to a great extent by Chalk and superficial deposits.

1 Introduction

This Research Report sets out the terminology for the Lower Cretaceous used on BGS maps and within other publications, and includes the lexicon definitions of the terms used and attributes appropriate ranks to them.

Traditionally in southern England the base of the Cretaceous and of the Boreal Province Ryazanian Stage has been defined at the base of the Cinder Bed that marks the lower boundary of the Durlston Formation in the Purbeck Group. Elsewhere in England this boundary is within significant gaps in the sedimentary succession (see discussion below). This report adopts the stratigraphically older, internationally agreed boundary for the base of the Cretaceous, at the base of the Berriasian Stage of the Tethyan Province (Table 1). This base Berriasian boundary can be placed tentatively within all of the UK onshore successions. It must be noted however that the stages of the Early Cretaceous are not yet defined by Global Standard Section and Point (GSSP or 'Golden Spikes') designations. Indeed it is most likely that none of these 'Golden Spikes' will be defined within the UK successions. Readers are recommended to consult Rawson et al. (1996) and Rawson (2006) within which can be found the current usage of the standard Cretaceous stages.

Table 1 A comparison of stage boundaries commonly used in the British Isles.

<table>
<tr><th>Boreal</th><th colspan="2">STAGE</th><th>Tethyan</th><th>EPOCH</th></tr>
<tr><td colspan="4">Cenomanian</td><td>Late Cretaceous</td></tr>
<tr><td colspan="4">Albian</td><td rowspan="7">Early Cretaceous</td></tr>
<tr><td colspan="4">Aptian</td></tr>
<tr><td colspan="4">Barremian</td></tr>
<tr><td colspan="4">Hauterivian</td></tr>
<tr><td colspan="4">Valanginian</td></tr>
<tr><td colspan="3">Ryazanian</td><td rowspan="2">Berriasian</td></tr>
<tr><td rowspan="3">Volgian</td><td colspan="2">Portlandian</td><td rowspan="3">Late Jurassic</td></tr>
<tr><td colspan="2">Bolonian (Late Kimmeridgian sensu anglico)</td><td>Tithonian</td></tr>
<tr><td colspan="4">Kimmeridgian (Early Kimmeridgian sensu anglico)</td></tr>
</table>

1.1 THE BASE OF THE CRETACEOUS IN ONSHORE BASINS

In Dorset the base of the Berriasian Stage is judged to fall (although not formally defined) at the base of the Cypris Freestone within the Mupe Member of the Lulworth Formation near the base of the Purbeck Group. This base is identified by charophytes (Feist et al., 1995). In the Weald the base of the stage is placed at or about the Mountfield Adit Limestone (Lake and Holliday, 1978) near the base of their Broadoak Calcareous Member and a short distance above their Gypsiferous Beds Member. The Mountfield Adit Limestone is tentatively correlated with the basal limestones in the Cypris Freestone Member (e.g. Clements, 1993) in Dorset.

In Lincolnshire and Norfolk the situation is more complex with a number of time-gaps in the succession, particularly at the critical basal Berriasian Jurassic–Cretaceous boundary. The disconformable base of both the lower Spilsby Sandstone (Lincolnshire) and the Roxham Member of the Sandringham Sands Formation (Norfolk) are placed at the base of the ?*Titanites* (*Paracraspedites*) *oppressus* Zone of mid Portlandian (Cope, et al., 1980; but see also Cope 2006, p. 363 where the Oppresus Zone is abandoned) or Mid Volgian (Rawson et al., 1978) age. Casey (1973) first proved the presense of the Oppressus Zone in the Roxham Member but was uncertain whether the base of that unit was actually in the *Titanites giganteus* Zone, of Casey (now the *Titanites anguiformis* Zone; Cope, 2006). Callomon and Cope (1995), correlating the Dorset succession with Norfolk and Lincolnshire, place the base of the Berriasian higher in the standard zonal scheme between the *Subcraspedites preplicomphalus* Zone and the *Subcraspedites primitivus* Zone. Thus the base of the Berriasian falls, in Norfolk, within the lacuna between the Roxham and overlying Runcton members and somewhere within the lower Spilsby Sandstone Formation in Lincolnshire. However Hoedemaeker (1999) places the base of the Berriasian at the Oppressus/Primitivus zonal boundary and this would, according to Casey (1973), place the boundary either within or immediately above the Roxham Member and somewhat lower in the lower Spilsby Sandstone Formation.

The Commission of the Jurassic/Cretaceous systems, presented to the ISC, determined that on the Russian Platform the Jurassic/Cretaceous (base Berriasian Stage) boundary should be drawn below the *Kachpurites fulgens* ammonite Zone at the Mid/Late Volgian substage boundary (Rostovtsev and Prozorowsky, 1995). The *K. fulgens* and *Craspedites subditus* zones (Late Volgian) of the Russian Platform are coeval with the Primitivus Zone, recognised in the lower Spilsby Sandstone of Eastern England. Hence the Roxham Member (Oppressus Zone), which is uppermost Mid Volgian in age, is herein considered to be uppermost Jurassic and the Runcton Member (*Subcraspidites preplicomphalus* Zone), within the Late Volgian, is considered to be Early Cretaceous. Both units are coeval with the lower Spilsby Sandstone of Lincolnshire, which straddles the Jurassic/Cretaceous boundary.

Within the 'Bedfordshire Straits' and other marginal outcrop areas (north Wiltshire to Buckinghamshire) the Purbeck Limestone Formation as defined in Cope et al. (1980) is considered to be of Anguiformis Zone or very youngest Oppressus Zone age (i.e. older than the type Purbeck Group). It is therefore part of the highest Jurassic within the Portlandian or late Tithonian stage and

contemporaneous with the Portland Stone of the type area. It is the view of the authors that the lithological characteristics indicating a restricted depositional environment for these deposits firmly place these outliers within the Purbeck Group. If nothing else they should be given a local name of formational rank to distinguish them from the Purbeck Group of the type area.

Thus the most up-to-date interpretation would consider most of the Purbeck Group (with the proviso above), most of the Sandringham Sands Formation and most of the Spilsby Sandstone Formation to be within the Early Cretaceous.

This same, base Berriasian, stage boundary falls within a depositional gap (lasting some 9 million years) between the youngest Kimmeridge Clay Formation (of *Pectinatites* (*Pectinatites*) *pectinatus* Zone or locally *Pavlovia pallasioides* Zone age, Volgian/Tithonian Stage) and the Speeton Clay Formation (Late Ryazanian or latest Berriasian) in the Cleveland/Yorkshire Basin.

1.2 OFFSHORE CORRELATION

Our present understanding of the age of the offshore successions in the Southern North Sea would place the base-Berriasian Jurassic/Cretaceous (J/K) boundary within a deposition gap below the Spilsby Sandstone Formation of the Cromer Knoll Group, or in a similar gap between the Kimmeridge Clay Formation of the Humber Group (of Bolonian or Mid Volgian age) and the overlying Valhall Formation (of Late Ryazanian or Late Berriasian age). Within the Central and Northern North Sea the J/K boundary is within the Kimmeridge Clay Formation of the Humber Group whose age range is currently regarded as from Kimmeridgian to Late Ryazanian.

1.3 OTHER CONSIDERATIONS

The thin succession of phosphatic sandstones that occur between the top of the Lower Greensand Group and the base of the Gault Formation at Leighton Buzzard, and which have formerly been referred to as Junction Beds (Owen, 1972), are herein designated the Munday's Hill Phosphatic Sandstone Formation. This formation includes the locally developed Shenley Limestone Member. The phosphatic sandstones are of broadly similar age and lithology to the 'Junction Beds' of the Weald and the Carstone of the Isle of Wight (Monk's Bay Sandstone Formation) (Casey, 1961; Owen, 1992). Although these geographically separate successions have not been united into a single unit in this account, there appears to be scope for future rationalisation of stratigraphical nomenclature. The Carstone Formation of East Anglia and Lincolnshire although of similar age to the Munday's Hill Phosphatic Sandstone, is sufficiently distinctive lithologically (Gallois, 1994) and is also geographically separated to suggest that it should be considered as a separate lithostratigraphical unit.

The entries within the following Sections 3 to 6 include groups and formations that occur in more than one region. To avoid duplication only the first occurrence in the text carries the full formal national description; subsequent occurrences are cross-referenced to that earlier full lexicon entry.

2 Palaeogeography and basin definition

Sediments of Early Cretaceous age are preserved in the south and east of England within the Wessex and North Sea basins. To a large extent, with the exception of rocks of late Aptian to Albian age, their present distribution reflects the original palaeogeography (i.e. coastlines were not far from present outcrop patterns).

At the end of the Jurassic relative sea-level fall left much that is now England and Wales as land. Thus there were extensive areas of land, with the Pennine High (Pennine Landmass), in the north, the Welsh Massif (Welsh Landmass), in the north-west, the Cornubian Massif, in the west, the Armorican Massif, in the south, and the so-called East Anglian Massif (the London–Brabant Ridge, Anglo–Brabant Landmass) in the east. Between the Welsh and East Anglian massifs was an intermittently active 'seaway', often called the 'Bedfordshire Straits', though at times this area of restricted or marginal depositional environments extended from Cambridgeshire to Wiltshire. Lower Cretaceous deposition is essentially divided into northern and southern basins by the Welsh and East Anglian structural highs — see Figure 1 modified after Rawson (1992).

From Norfolk and Yorkshire and into the southern North Sea deposition, was essentially marine (contrasting with the Wessex Basin to the south) throughout the Early Cretaceous. Within this region the structural high of the Market Weighton Axis (High) separated a Cleveland Basin (Yorkshire Basin) from a shallower East Midlands Shelf. Different lithostratigraphical schemes have been adopted for these areas onshore but offshore the succession is represented entirely by the Cromer Knoll Group. The northern boundary of the Market Weighton Axis is marked by the Howardian–Flamborough Fault Belt that offshore is contiguous with the Dowsing Fault Belt. This belt offshore is thought to separate the successions of the shelf from the deeper-water sediments of the Cleveland Basin and southern North Sea.

In the Wessex Basin, south of the Welsh and East Anglian massifs, deposition commenced with short-lived restricted shallow marine, lagoonal and variable salinity to fresh water environments (the 'Purbeck' facies). This was followed by a long period of non-marine deposition (the Wealden 'facies' or 'group') brought to an end by marine transgressions dated around the Barremian–Aptian and Aptian–Albian stage boundaries and represented by the Lower Greensand Group and the Selborne Group (introduced herein) respectively. These transgressions progressively inundated the surrounding highs and in mid Albian times submerged the East Anglian Massif thus joining the northern and southern depositional areas into a single depositional region. Erosion during both transgressive phases has removed significant parts of earlier successions and this has left numerous outliers of variable lithologies and ages particularly in the Bedfordshire to Wiltshire areas.

During the Early Cretaceous within the Wessex Basin, two active depositional centres called the Wealden Basin and the Vectian (Channel) Basin (sub-basins of Stoneley, 1982) existed. This terminology is followed in this report. Rawson (2006) refers to separate Weald and Wessex basins equivalent respectively to the sub-basins of Stoneley (1982). In Underhill and Stoneley (1998) the Wessex Basin is defined as a series of depocentres and intra-basinal highs beneath Hampshire and Dorset together with parts of east Devon, Somerset and Wiltshire. The Weald Basin of Sussex, Surrey and Kent being regarded as a separate entity. This definition however admits to the north-eastern and north-western boundaries of the Wessex Basin being imprecise.

Within this report the Wessex Basin is discussed in relation to its broader and earlier definition that contains Weald and Vectian depocentres. These depocentres were separated until mid Albian times, by the Portsdown–Fordingbridge High (also known as the Hampshire–Dieppe High, the Portsdown Swell or to the west as the Cranborne –Fordingbridge High). This high was generally considered to be submerged but certainly hindered the movement of sediment from one basin to another and is known to have been emergent during part of the early Aptian at least in the Southampton, Portsmouth and South Downs areas. Its influence on the succession in the subcrop is known only in outline. In the subcrop to the west of the Wessex Basin, borehole evidence shows that there are no Lower Cretaceous sediments preserved over the high and that, to the north, the succession at outcrop in the western Weald can be traced into the Pewsey 'Basin' albeit at a considerably reduced thickness. South of the high, in the western outcrops of Dorset and Devon, correlation with the successions on the Isle of Wight can be made at group and formation level. The influence of this structural high on lithological successions in the Wealden Basin and the Vectian Basin has resulted in the creation of well-established lithostratigraphies for each area.

Within the northern and western Wessex Basin the pre-Aptian succession thins dramatically against the East Anglian Massif–Welsh Massif high. This is the result of, lack of accommodation space compared to the rest of the subsiding Wessex Basin, numerous short-lived erosional events within the basin margin sedimentary successions and erosion prior to the pre-Aptian and pre-Albian transgressions.

Following the major marine transgression in mid Albian times which overtopped both the Portsdown High and the East Anglian Massif, deposition was widespread with the Selborne Group (Gault Clay and Upper Greensand formations) being laid down over a large part of southern England south of The Wash. To the north the Hunstanton Formation and the higher part of the Speeton Clay Formation were deposited.

Figure 1 The palaeogeography at various times throughout the Early Cretaceous.

3 Wessex Basin (Wealden Basin)

There is a well-established terminology applied to the Wealden 'Beds'/ 'Series'/ 'Group' and younger Lower Cretaceous strata of the Wealden Basin with early workers establishing an essentially informal succession. The entire scheme for the Lower Cretaceous was developed during the primary survey of the Geological Survey and drawn together by W Topley (1875) in his seminal volume the Geology of the Weald, but this relied heavily on a number of earlier authors, most notably Fitton (1836) and Drew (1861, 1864). The table of strata published in the Topley memoir erroneously shows the Gault and Upper Greensand as being within the Upper Cretaceous.

The informal scheme given in Topley (1875) has been modified by various authors subsequently (not least in the memoirs of the British Geological Survey) in attempts to place each unit within an informal or formal hierarchy. However the rank applied to these units (whether actual or implied), the wish to retain allegiance to the former names and the repetition of names merely prefixed by a 'lower' or 'upper' epithet has led to some confusion and to a scheme that does not entirely conform to Hedbergian principles. Essentially, utilising either a top-down or bottom-up approach, there are too many terms and inter-relationships to fit within a simple hierarchy and the approach adopted herein (Table 2) regards some of the units as having only informal status. Many of these terms have been successfully carried into the subcrop to the north-west and west on seismic sections and within descriptions of the deeper boreholes, principally those relating to the search for hydrocarbons.

The Purbeck Group succession within the Sussex inliers is different to that of the type Purbeck area in Dorset. Howitt (1964) correlated his 'Main Gypsiferous Beds' and a lower unit termed by him the 'Broken Bands and Anhydrite' with the Dorset 'Cypris' Freestone, thus in modern parlance placing the Jurassic/Cretaceous boundary within the lowest 20 metres of the approximately 130 m-thick Purbeck Group in this basin. The Purbeck Group at outcrop and immediate subcrop in the Weald was formally divided into the Durlston and Lulworth formations by Lake and Shephard-Thorn (1987) as the 'Cinder Bed' of the type Purbeck region could be identified in the Sussex succession. This formal division is adopted herein, although there is an argument to adopt new names in the Weald Basin for these two formations. This argument centres on the fact that there is no lithological bed-by-bed correlation that can satisfactorily be made with the type area of Dorset. However, it is felt by the authors that this is an unnecessary complication that is unlikely to be applied to the limited outcrop in the Weald and would have little advantage in the subcrop. Lake and Shephard-Thorn (1987) further divided each formation into three members. Their full member-level scheme is unsatisfactory because of the continued use of the term 'beds' within member names and the reliance on lithological descriptors as opposed to locality names (e.g. Arenaceous Beds Member). Their Lulworth Formation comprises the Gypsiferous Beds Member (the Main Gypsiferous Beds of Howitt), the Broadoak Calcareous Member and the Plant and Bone Beds Member; and the Durlston Formation comprises the Cinder Bed Member, the Arenaceous Beds Member and the Greys Limestones Member. However, as these members do not form mappable units in the fault-bounded and limited outcrops in Sussex the scheme will remain informal.

The Broadoak Calcareous Member contains charophytes indicative of the Berriasian (see Lake and Shephard-Thorn, 1987). Feist et al. (1995) identify four charophyte zones (1 to 4 from the base) wholly or partially within the Broadoak Calcareous Member and place the Jurassic/Cretaceous boundary between their zones 1 and 2 near the base of the member. The boundary is situated at about the level of the Mountfield Adit Limestone (Lake and Holliday, 1978), which may approximate to the basal group of limestones in the Cypris Freestone Member (e.g. in Clements, 1993; and equivalent to the Ridgeway and upper part of the Mupe members of Westhead and Mather, 1996) of the stratotype Purbeck Group succession in Dorset. Charopytes indicate that the Tithonian/Berriasian boundary falls within the middle part of Ostracod Zone 2 sensu Anderson (1985).

In this report the term Hastings Beds/Group/Subgroup, traditionally used to cover the Ashdown, Wadhurst Clay and Tunbridge Wells Sand formations, is regarded as informal (or abandoned) and the succession has been defined on the basis of an extended Wealden Group that includes these formations and the superposed Weald Clay Formation. It is recommended that where necessary the term Hastings Beds be replaced by the term 'Ashdown, Wadhurst Clay and Tunbridge Wells Sand formations undivided'. The frequently used terms Lower Tunbridge Wells Sand Member and Upper Tunbridge Wells Sand Member are also considered as informal as they can only be successfully defined and mapped where the intervening Grinstead Clay Member is present. The lower and upper epithet should be in lower case when referring to these units

Similarly the 'lower' and 'upper' epithets used together with the Fittleworth Member, Marehill Clay Member and Pulborough Sandrock Member are regarded as informal and not therefore defined as stand-alone terms in their own right.

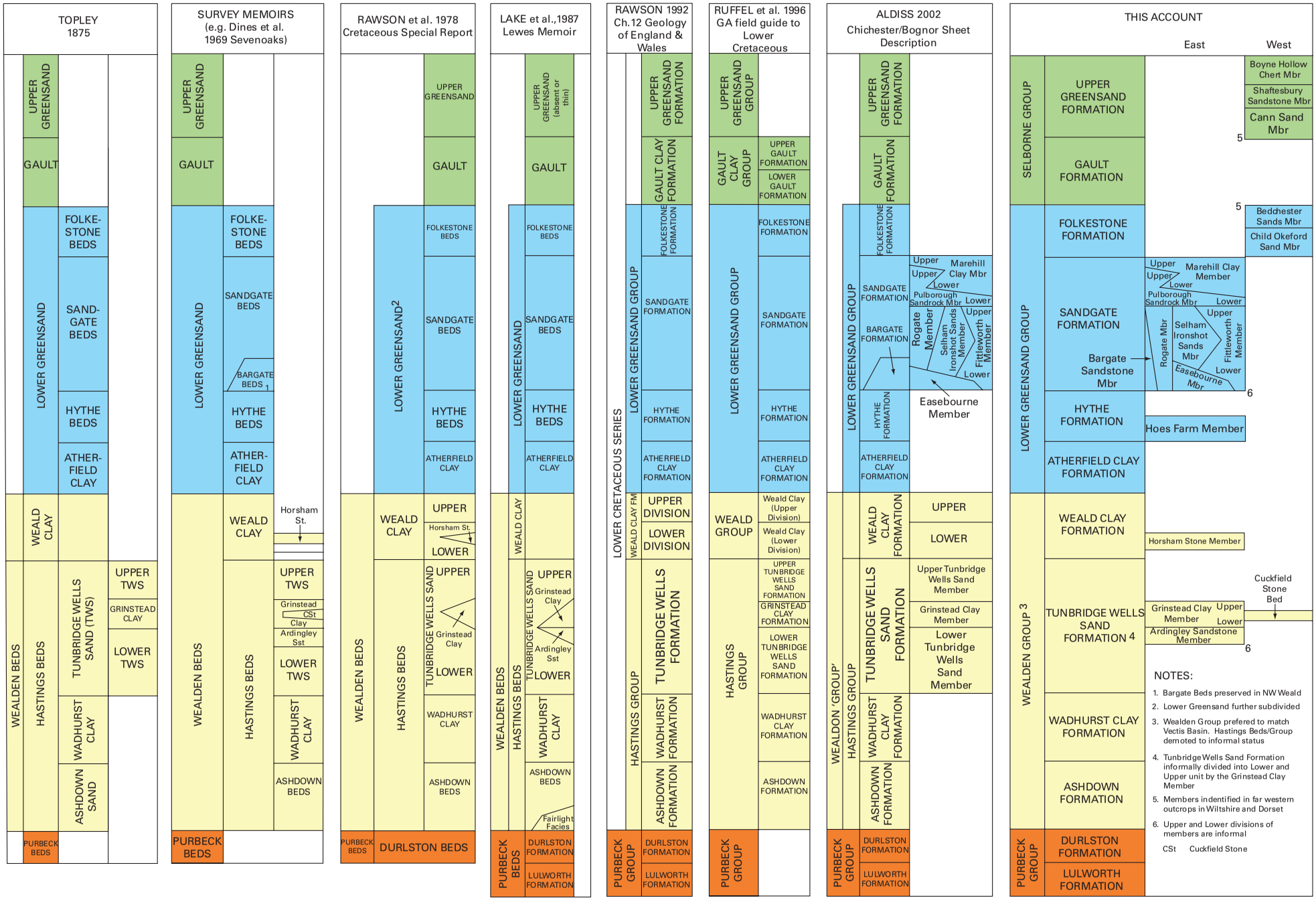
3.1 PURBECK GROUP

Name
The name is derived from the type area of the Isle of Purbeck. Traditionally defined as Lower, Middle and Upper Purbeck Beds or Divisions from texts in the middle of the 19th century (e.g. Forbes, 1851) the group is now defined by its contained Lulworth and Durlston Formations formalised by Townson (1975) but introduced by Casey (1963). Herein it includes a third Haddenham Formation (see Section 5.15.3) that includes the outliers along the northern margin of the Wealden Basin (e.g. Wiltshire, Oxfordshire and Buckinghamshire) that are older than those successions in the type area.

Type area
Isle of Purbeck, Dorset (coastal cliffs, and quarries) [SY87, SY88, SY97, SY98 and SZ07].

Primary reference section
Cliff section in Durlston Bay [SZ 03 77], south of Swanage, Dorset.

Table 2 Lithostratigraphical scheme for the Wealden Basin.



Formal subdivisions
The group (Purbeck Beds) was traditionally divided into Lower, Middle and Upper units ('beds') with a key marker, the Cinder Bed placed within the middle part of the Middle Purbeck Beds.

The formal scheme for the Wealden Basin was erected by Lake et al. (1987) who recognised Lulworth and Durlston formations; each divided into a number of members. These members are not formally used, not least because they mix the term 'bed' with 'member' for a number of units (e.g. Plant and Bone Beds Member). The terms may, however, be used informally without the member epithet to described the succession locally.

The Dorset succession, within the Vectian Basin, also comprising the Lulworth and Durlston formations, includes formal member definitions. These are described in Section 4.1 and subsections thereof.

For outliers in the marginal areas in Oxfordshire and Buckinghamshire the Haddenham Formation is proposed (see Section 5.15.3 under East Midland Shelf) to replace the term Purbeck Limestone Formation. These outliers are lithologically part of the group but slightly older (equivalent to charophyte zone 1 of Feist et al., 1995) than the deposits in the type area and thus not part of the Lulworth Formation as defined.

Lithology
Interbedded mudstones, limestones and evaporites of marginal freshwater, brackish and marine origin; detrital quartz occurs in parts.

Definition of upper boundary
Last occurrence of significant limestone before the monotonous sandy mudstones of the Wealden Group. Highest limestone rich in *Viviparus* and *Unio*.

Definition of lower boundary
First occurrence of laminated, ostracod-rich limestones above the more massive, shelly limestones of the Portland Group.

Thickness
From 45 to 120 m in south Dorset and from 77 to 186 m in the Weald. Succession incomplete in the Vale of Wardour.

Distribution
Occurs in a number of sub-basins across north Europe. In England, occurs in south Dorset (between Weymouth and Swanage), in the Weald (largely in subcrop), and as several inliers in the Vale of Wardour and Vale of Pewsey. Occurs in the subcrop throughout southern Britain (Wessex Basin) as far west as Wiltshire and Dorset, and as far north as Berkshire, Oxfordshire and Buckinghamshire. It outcrops within the core of the Weald and as outliers in Oxfordshire, Buckinghamshire and Bedfordshire.

Previous names
Purbeck
Purbeck Group
Purbeck Beds
Purbeck Formation
Purbeck Limestone Formation
Purbeck Stone
Purbeck Strata

Parent
None

Age
Portlandian to Berriasian, or Volgian to Ryazanian (including UK Portlandian).

References
Arkell, 1933, 1947a; Buckland, 1818; Clements, 1993; Cope, Clements and West, 1969; Damon, 1860; Feist, Lake and Wood, 1995; Fitton, 1836; Forbes, 1851; Horton et al., 1995; Howitt, 1964; Lake and Holliday, 1978; Lake et al., 1987; Phillips, 1818; Townson, 1975; Westhead and Mather, 1996; Wimbledon, 1980.

3.1.1 Lulworth Formation

Name
First formally defined in Townson (1975) from divisions first proposed by Casey (1963).

Type section
West side of Worbarrow Tout [SY 869 796].

Primary reference sections
Durlston Bay, between Durlston Head and the centre of the bay [SZ 0350 7800 to SZ 0414 7865].
BGS Broadoak Borehole near Heathfield, Sussex, TQ 62 SW 4 [6195 2214].

Formal subdivisions
In the Weald an equivalent of the Cinder Bed has been identified (e.g. Lake and Holliday, 1978; Lake et al., 1987) thus allowing the succession there to be considered within the formal terminology. A formal scheme was erected by Lake et al. (1987) for the Lulworth Formation seen in the central part of the Weald. Three members were proposed which are in ascending order the Gypsiferous Beds Member, the Broadoak Calcareous Member and the Plant and Bone Bed Member. This scheme is not adopted here, as it combines the term 'bed' with 'member' for a number of units. Furthermore the authors gave no indication of the correlation of these members to the succession in Dorset. The terms may, however, be used informally without the member epithet to describe the succession locally.

In Dorset the formation (Section 4.1.1) comprises three members, The Mupe Member, Ridgeway Member and Worbarrow Tout Member. These are fully described in Sections 4.1.1.1 to 4.1.1.3.

Lithology
Dominated in the lower part by pale-weathering, ostracod-rich calcarenites that are commonly rippled. Stromatolitic or algal, micritic limestone, with evaporitic material, is also common (particularly in east Dorset). The upper part of the formation comprises monotonous, interbedded dark grey mudstones and white-weathering micrites. Detrital quartz is common at several levels.

Definition of upper boundary
Top of the Cherty Freshwater Bed, comprising thick-bedded, chert-rich micrites. Overlain by the Cinder Bed at the base of the Durlston Formation.

Definition of lower boundary
First occurrence of laminated, ostracod-rich limestones above the more massive, shelly limestones of the Portland Limestone.

Thickness
In Dorset, 27 to 63 m. In the central Weald area boreholes

show the formation to be about 86 m thick (Broadoak Borehole TQ 62 SW 4 [6195 2214]). In the Vale of Wardour in Wiltshire the formation is up to 15 m thick.

Distribution
The unit can be identified in southern and south-east England, separated from the overlying Durlston Formation by the Cinder Bed. Away from the type area of Dorset, the formation has been described from outcrops from the Weald and to the west in Wiltshire (Vale of Wardour).

Previous names
Lulworth Beds

Parent
Purbeck Group

Age
Portlandian (late Tithonian) to Berriasian, or mid Volgian to Ryazanian.

References
Clements, 1993; Howitt, 1964; Lake and Holliday, 1978; Lake et al., 1987; Townson, 1975; Westhead and Mather, 1996.

3.1.2 Durlston Formation

Name
First formally defined in Townson (1975) from divisions originally proposed by Casey (1963).

Type section
Northern half of Durlston Bay SZ 0384 7842 to 0414 7865.

Primary reference sections
East cliff at Stair Hole [SY 8229 7983].
BGS Broadoak Borehole TQ 62 SW 4 [6195 2214].

Formal subdivisions
In the Weald, Lake et al. (1987) proposed a threefold division, comprising in ascending order: the Cinder Bed Member, the Arenaceous Beds Member and Greys Limestone Member but these have not been widely accepted. The terms can be used informally without the member epithet.

Within the Vectian Basin the formation (Section 4.1.2) is divided into the Stair Hole Member below and the Peveril Point Member above. These are described more fully in Sections 4.1.2.1 to 4.1.2.2.

Lithology
Dominated by interbedded, shelly limestones and dark mudstones. The shell material often contains *Unio* and *Viviparus*. Detrital quartz is present through much of the formation in south central Dorset (west of Stair Hole), but is confined to the Stair Hole Member in east Dorset (Worbarrow and Durlston). The Durlston Formation comprises two members in Dorset: the Stair Hole Member overlain by the Peveril Point Member. Elsewhere the formation is undivided, or is itself incorporated into an undivided Purbeck Group. The formation includes the informal Upper Purbeck Beds, and the upper part of the Middle Purbeck Beds, above the base of the Cinder Bed, of the traditional scheme. Within the Weald, an equivalent of the Cinder Bed has been identified, thus allowing the succession there to be considered within the formal terminology.

Definition of upper boundary
Unconformable to disconformable. Last occurrence of significant limestone before monotonous Wealden Group sandy mudstones.

Definition of lower boundary
Conformable. First occurrence of very shelly micrite (Cinder Bed) above more pure micrites at the top of the Lulworth Formation.

Thickness
From 18 to 57m

Distribution
The unit can be recognised in the Wessex Basin and south-eastern England, where it is separated from the underlying Lulworth Formation by the Cinder Bed. Away from the type area of Dorset, the unit has been described from the Weald (Lake et al., 1987) and the Vale of Wardour in Wiltshire.

Previous names
Durlston Beds

Parent
Purbeck Group

Age
Berriasian or Ryazanian

References
Clements, 1993; Howitt, 1964; Lake et al., 1987; Townson 1975; Westhead and Mather, 1996.

3.2 WEALDEN GROUP

Name
The term ‘Wealden Series’ first appears in Martin (1828) but ‘Weald’ has appeared in descriptions as early as 1812 (e.g. Weald Measures). The term Wealden Group is formally introduced herein, but has also been included within the BGS Lexicon and publications for a number of years, to replace the unsatisfactory use of the term Hastings Beds/Group/ Subgroup/Formation in older literature.

Type area
The Weald of Kent and Sussex. The first description of the constituent parts of the succession is by Drew (1861) in the northern Weald area, principally in the Tunbridge Wells Sheet 303 district (see descriptions for the constituent parts of the Group herein). Bristow and Bazley (1972) state ‘The designations of type sections in the Hastings Beds [Wealden Group herein] is impracticable. Complete natural sections are unknown for any of the formations… cored boreholes provide the most continuous sections available’… The details of the appropriate boreholes are given in the formation descriptions that follow.

The cliff sections from Compton Bay [SZ 36 85] to St Catherine’s Point [SZ 50 75] and in Sandown Bay [SZ 58 80 to SZ 62 85] on the Isle of Wight constitute the type sections for the individual formations designated in the Vectian Basin.

Primary reference section
There is no type section designated for the group; see instead the type and reference sections of the group’s constituent units.

Formal subdivisions
In the Wealden Basin the constituent units from the base upwards are: the Ashdown Formation, the Wadhurst Clay Formation, the Tunbridge Wells Sand Formation and the Weald Clay Formation. In the Vectian Basin the group comprises a lower Wessex Formation and an upper Vectis Formation on the Isle of Wight. Elsewhere the group is undivided or comprises thin marginal deposits such as the Whitchurch Sands Formation.

Lithology
Interbedded thick sandstone and mudstone formations and members. For full descriptions see the definitions of constituent parts.

Definition of upper boundary
Unconformable in the Wealden Basin at a sharp contact between the grey or red mudstones of the Weald Clay Formation with the overlying dark grey or black mudstones of the Atherfield Clay Formation (Lower Greensand Group).

Unconformable within the Vectian Basin (Isle of Wight) at the sharp contact between the dark finely bedded mudstones of the Vectis Formation (formerly the Wealden Shales) and the dark grey to black mudstones of the Atherfield Clay Formation (at the base of the 'Perna Beds' of Casey, 1961).

Elsewhere the top is erosional or unconformable with significantly younger beds (e.g. Lower Greensand Group or Gault Formation.

Definition of lower boundary
In the Wealden Basin conformable at the base of non-marine sandstones and siltstones of the Ashdown Formation on the calcareous mudstones and limestones of the Purbeck Group (Durlston Formation).

In the Vectian Basin at the conformable base of the undivided Wealden Group non-marine sandstones and siltstones (or at the base of the Wessex Formation on the Isle of Wight) resting on the calcareous mudstones and limestones of the Purbeck Group (Durlston Formation).

Towards basin margins the group is represented by thin deposits of limited age range and unconformable on a variety of older rocks.

Thickness
Up to 850 m (Wealden Basin) and about 500 m (Vectian Basin). Thins to a few metres in marginal areas.

Distribution
The Wealden Group is introduced herein and redefined to include the Weald Clay Formation. The group's precursors are used on map sheets and in memoirs in Kent, Surrey, Sussex, Hampshire, Dorset and Wiltshire within the Lower Cretaceous Wealden and Vectian Basins.

Previous names
Wealden Beds in Drew (1861), survey memoirs and Rawson et al. (1978)
Wealden facies in Rawson (1992)
Wealden Series Chatham Sheet 272
Wealden in Martin (1828)
Wealden Strata
Wealden Formation
Wealden

Parent
None

Age
Late Berriasian (late Ryazanian) to Barremian or earliest Aptian (Magnetochron CM-0, Chronozone M0r is situated in the upper part of the Shephard's Chine Member [Vectis Formation] of Kerth and Hailwood, 1988).

References
Bristow and Bazley, 1972; Casey, 1961; Drew, 1861; Kerth and Hailwood, 1988; Martin, 1828; Osbourne White, 1921; Rawson, 1992; Rawson et al., 1978; Topley, 1875.

3.2 1 Ashdown Formation

Name
Ashdown Formation introduced in Rawson (1992) as a formalisation of Ashdown Beds Formation (Allen, 1976) and equivalent Ashdown Sands. Drew (1861) introduced the Ashdown Sands. Allen (1959) introduced the term Ashdown Beds as a collective name for the Ashdown Sand and Fairlight Clay.

Type area
Ashdown Forest area. There are no complete stratotypes but many small exposures along stream courses throughout the 'High Weald'. Principal partial reference sections given below.

Primary reference sections
Hastings Cliffs, Hastings to Pett Levels (Cliff End at the Eastern end of Fairlight Bay), [TQ 765 080 to 890 130], (Topley, 1875; Allen 1962).
Jarvis Brook Brickworks, Crowborough [TQ 531 297].
Cuckfield No. 1 Borehole TQ22NE19 [2961 2731] (Lake and Thurrell, 1974).
Elphicks, near Goudhurst [TQ 699 381].
High Hurstwood [TQ 499 271].

Formal subdivisions
There are no formal subdivisions, but the term 'Fairlight Clays' is used informally to denote the argillaceous part of the Ashdown Formation in the south-east Weald.

Lithology
Siltstones and silty fine-grained sandstones with subordinate amounts of shale and mudstone arranged in rhythmic units ('cyclothems') often divided by thin pebble beds. In south-east Sussex, around Hastings, the argillaceous parts of the 'cyclothems' are well-developed and a series of clay seams, the informally named Fairlight Clays, is well exposed in the cliffs at Fairlight Cove. Here, this argillaceous part of the Ashdown Formation comprises dark grey shales and mudstones, commonly patchily red-stained and with abundant iron carbonate pellets (sideritic mudstones and sphaerosiderite nodules) at some levels. Northwards from Hastings, the Fairlight Clays become increasingly thin such that in the area of Ashdown Forest they are represented only by pebble beds overlain by thin siltstones within a generally arenaceous formation.

Definition of upper boundary
Conformable at the top of the informally named Top Ashdown Sandstone (see Allen, 1949) where this is identified, or at the basal bed of the Wadhurst Clay Formation informally termed the Top Ashdown Pebble Bed. In general, the top of the formation is taken at the change from underlying sandstone into overlying dark grey silty mudstones.

Definition of lower boundary
Conformable with the underlying Purbeck Group at the change from shales of the informally named Greys Limestones 'member' up into siltstones and sandstones of the Ashdown Formation.

Thickness
From 115 to 215 m in the Hastings district, but generally in the range 200–230 m.

Distribution
Outcrop in the central Weald. Extent at depth in the western Weald and into the Wessex Basin area not well known.

Previous names
Ashdown Sand (Drew,1861)
Ashdown Beds
Fairlight Clays for the more argillaceous part
Part of the informal Hastings Sands (also known as Group or Subgroup)

Parent
Wealden Group

Age
Late Berriasian (late Ryazanian) to Early Valanginian.

References
Allen, 1949, 1962; Bristow and Bazley, 1972; Dines et al., 1969; Drew, 1861; Gallois and Worssam, 1993; Lake et al., 1987; Lake and Thurrell, 1974; Topley, 1875; Worssam, 1963; Young and Lake, 1988.

3.2.2 Wadhurst Clay Formation

Name
The first formal use of the term Wadhurst Clay is in Drew (1861) and formalised as Wadhurst Clay Formation in Rawson (1992).

Type section
Numerous localities (partial type sections) within the Weald show parts of the succession.
Sharpthorne Brickworks [TQ 374 329].
Freshfield Lane Brickworks [TQ 382 266].
High Brooms Brickworks [TQ 594 418].
Quarry Hill Brickworks [TQ 585 450].

Primary reference sections
Wadhurst Park boreholes [TQ 632 291] (No.1 [6325 2991]; No. 2 [6308 2920]; No. 3 [6309 2902]).
Cuckfield No. 1 Borehole TQ22NE19 [2961 2731].

Formal subdivisions
No formal divisions published. Informal term of Tilgate Stone used for calcareous sandstones at various levels within the succession.

Lithology
Comprises soft, dark grey shales and mudstones with subordinate beds of pale grey siltstone, fine-grained sandstone (locally calcareous where it is known as Tilgate Stone or colloquially 'Hastings Granite'), shelly limestone, clay ironstone and rare pebble beds. The top metre or so of the Wadhurst Clay often comprises red-stained stiff clay due to penecontemporaneous weathering.

Definition of upper boundary
The junction is sharp at the change from siltstones into fine-grained silty sandstones of the Tunbridge Wells Sand Formation. The top of the Wadhurst Clay is a often red-stained at this junction.

Definition of lower boundary
The base is sharp and marked by the top of the Top Ashdown Pebble Bed but where this is absent the boundary is transitional, and placed in siltstones between the underlying fine-grained sandstones of the Ashdown Formation and the mudstones of the Wadhurst Clay Formation.

Thickness
The formation thickens westward from 30 m at Rye to 70 m at Cuckfield and 78 m at Worth.

Distribution
Occurs at outcrop in the Weald and at subcrop westward in the Wessex Basin where the succession is imperfectly known. Thins against the London Brabant Ridge to the north and the Hampshire–Dieppe High to the south.

Previous names
Wadhurst Clay
Wadhurst Formation in Rawson (1992)

Parent
Wealden Group

Age
Early to Late Valanginian

References
Allen, 1949, 1962, 1976; Anderson, Bazley and Shephard-Thorn, 1967; Bristow and Bazley, 1972; Dines et al., 1969; Drew, 1861; Gallois and Worssam, 1993; Lake et al., 1987; Lake and Thurrell, 1974; Topley, 1875; Worssam, 1963; Young and Lake, 1988.

3.2.3 Tunbridge Wells Sand Formation

Name
The Tunbridge Wells Sand Formation as defined is a formation in the Wealden Group. The commonly used 'upper' and 'lower' epithets are regarded as informal terms. Originally the whole unit was described as the Tunbridge Wells Sand by Drew (1861). Allen (1976) introduced the Lower Tunbridge Wells Sand Formation, Grinstead Clay Formation and Upper Tunbridge Wells Sand Formation. Rawson (1992) formalised the whole succession as the Tunbridge Wells Formation. Originally known as the Horsted Sand as in Mantell (1827).

Type section
No single section demonstrates the whole succession. There are many sections throughout the central Weald, each demonstrating part of the succession: lower Tunbridge Wells Sand at High Brooms Brickworks [TQ 594 418], Philpots Quarry [TQ3536 3215], natural crags of Ardingly Sandstone between Balcombe and Tunbridge Wells, Grinstead Clay Member at Freshfield Lane Brickworks access road [TQ 3830 2642] and the upper Tunbridge Wells Sand at Freshfield Lane Brickworks [TQ 386 264] and Hundred Acres Wood Brickworks [TQ 331 365].

Primary reference sections
Cuckfield No. 1 Borehole, TQ22NE19 [2961 2731] where much of the Tunbridge Wells Sand Formation is described (Lake and Thurrell, 1974).

Formal subdivisions
The formation includes the Ardingly Sandstone Member and the Grinstead Clay Member (including the Cuckfield Stone Bed). Informally divided into upper and lower parts where the Grinstead Clay Member is present.

Lithology
Predominantly fine- to medium-grained sandstone, siltstone and silty sand rhythms with shales and thin limestones. In the western High Weald (between Haywards Heath and Tunbridge Wells) the formation can be divided into three, the informally named lower and upper Tunbridge Wells Sand and the intervening Grinstead Clay Member. The succession commences with rhythmically bedded sandstones, siltstones and mudstones of the lower part of the Lower Tunbridge Wells Sand which pass up into the massive sandstones of the Ardingly Sandstone Member. These are overlain by the shales, mudstones and silty mudstones with subordinate clay ironstones and shelly limestones of the Grinstead Clay Member. This clay member is itself locally divided into upper and lower parts by the cross-bedded fine sandstone of the Cuckfield Stone Bed. Above the Grinstead Clay Member, the upper Tunbridge Wells Sand comprises a generally more argillaceous rhythmic succession, including mudstones, siltstones and silty sandstones.

Outside the western High Weald the Grinstead Clay Member is not recognisable and the succession is mapped as undivided Tunbridge Wells Sand Formation. There are a number of minor non-sequences or disconformities throughout the succession and a possible significant gap at the top of the formation which removes much of the upper Tunbridge Wells Sand.

Definition of upper boundary
This boundary is frequently cut out by faulting but it has been observed around Crawley and Horsham where it is conventionally placed at the top of the highest prominent fine-grained sandstone beneath the mudstones of the Weald Clay Formation. In places a pebble bed is developed at this horizon. Elsewhere, in full successions the prominent sandstone is absent and the boundary is gradational.

Definition of lower boundary
Conformable at the change from shales and mudstone of the Wadhurst Clay Formation into the thinly interbedded siltstones and silty fine-grained sandstones of the basal Tunbridge Wells Sand Formation. The boundary is often sharply defined because of the red staining in the upper part of the underlying Wadhurst Clay Formation.

Thickness
Generally about 75 m but ranges from 46 m around Hellingly to as much as 122 m around East Grinstead.

Distribution
Outcrops in the central Weald around Tunbridge Wells, Sevenoaks, Maidstone, Haslemere, Horsham, Tenterden, Brighton, Lewes and Hastings. Limited in the subcrop to the north by the London–Brabant Ridge and to the south by the Hampshire–Dieppe High . Its extension at subcrop to the west into the Wessex Basin is poorly known but the succession is known to thin greatly.

Previous names
Tunbridge Wells Sand
Tunbridge Wells Sand Subgroup
Tunbridge Wells Formation in Rawson (1992)

Parent
Wealden Group

Age
Late Valanginian

References
Allen, 1949, 1962, 1976; Bristow and Bazley, 1972; Dines et al., 1969; Drew, 1861; Gallois and Worssam, 1993; Lake et al., 1987; Lake and Thurrell, 1974; Topley, 1875; Worssam, 1963; Young and Lake, 1988.

3.2.3.1 Ardingly Sandstone Member

Name
The Ardingly Sandstone Member is defined as a revision of the informal Ardingly Sandstone. In the Horsham Sheet 302 district surveying by Dr Gallois and Dr Thurrell established that 'the Grinstead Clay is underlain by a distinctive massive quartzose sandstone ('sandrock') which occupies the upper part of the Lower Tunbridge Wells Sand: it commonly weathers to form natural crags, particularly in the Balcombe, Ardingly, West Hoathly and East Grinstead areas and the name Ardingly Sandstone is now proposed for it' (Gallois, 1965).

Type section
Natural crags of the member are common within the limits of the outcrop but notably at Stonehurst, Ardingly [TQ 344 317]; Balcombe Mill [TQ 317 305]; Chiddingly Wood, West Hoathly [TQ 349 321]; Stone Farm Rocks, Saint Hill Green [TQ 381 348]; Redleaf House, Penshurst [TQ 522 455]; Rustall Toad Rock, Tunbridge Wells [TQ 568 395]; Eridge Rocks [TQ 554 357]; Bowles Rocks, Boarstead [TQ 542 330]; The Rocks, Uckfield [TQ 464 217]. See also other sections in the memoirs.

Primary reference sections
The lower boundary of the member can be seen in a stream section near Ditton Place, Handcross [TQ 2821 2980].
In Cuckfield No. 1 Borehole TQ22NE19 [2961 2731], see Lake and Thurrell (1974).
Philpotts Quarry, West Hoathly [TQ 3536 3215] where the upper boundary of the member can be seen.

Formal subdivisions
None

Lithology
Fine- and medium-grained quartzose cross-bedded sandstone largely thickly bedded or massive. Often refered to as 'sandrock' meaning a clean white or greyish white soft quartzose sandstone. The member is believed to become finer-grained towards the south away from the Horsham–Ardingly type area. The member shows a tendancy to 'coarsen-upwards' and commonly contains 'stringers' of quartz and quartzite pebbles. Natural crags show a cyclic succession from almost parallel bedded units overlain by shallow trough cross-bedded sandstones and capped by massive units with thin units of contorted bedding.

Definition of upper boundary
Boundary conformable or erosional at the junction of the grey to greenish grey mudstones of the Grinstead Clay Member. In places the base of the Grinstead Clay Member is marked by a minor erosion surface on which is developed the informally named Top Lower Tunbridge Wells Pebble Bed (see Allen, 1967). The pebble bed is represented by a 'ripple-drift' (climbing ripple) bedded

fine- to medium-grained sand with small quartz pebbles. Locally the Cuckfield Stone Bed (which cuts out the lower part of the Grinstead Clay Member) rests directly on the Ardingly Sandstone Member. Here the boundary is clearly erosive with massive sandstones of the Ardingly Sandstone Member underlying the 'festoon-bedded' finely trough-cross-bedded sandstones of the Cuckfield Stone Bed.

Definition of lower boundary
This boundary is rarely exposed but where seen it is a sharp contact, possibly erosional, between thinly interbedded silty fine-grained sandstones and siltstones of the un-named lower part of the informal lower Tunbridge Wells Sand and the thick cross-bedded sandstones of the Ardingly Sandstone Member. For mapping purposes the boundary is placed either at the top of the highest discernible thinly-bedded siltstones and sandstones, or at the base of the prominent 'crags' characteristic of the Ardingly Sandstone Member outcrop.

Thickness
Maximum of 25–33 m but ranges down to 12.2 m at Cuckfield and 18–24 m around Haywards Heath.

Distribution
Ardingly Sandstone Member is known from the Horsham, Tunbridge Wells, Sevenoaks, Tonbridge, Lewes and Brighton districts of the central Weald and seems to mirror the known extent of the Grinstead Clay Member. Elsewhere in the Weald the absence of these two units prevents the informal division of the Tunbridge Wells Sand Formation into lower and upper units.

Previous names
Ardingly Sandstone used on the Sevenoaks and Tonbridge, Horsham, Tunbridge Wells, Lewes and Brighton–Worthing maps and in the memoirs.

Parent
Tunbridge Wells Sand Formation

Age
Valanginian

References
Bristow and Bazley, 1972; Dines et al., 1969; Gallois, 1965; Gallois and Worssam, 1993; Lake et al., 1987; Lake and Thurrell, 1974; Young and Lake, 1988.

3.2.3.2 Grinstead Clay Member

Name
Named (Drew, 1861) after its outcrops around East Grinstead and numerous partial sections, described in the memoirs for the Maidstone, Sevenoaks, Horsham, Tunbridge Wells, Brighton and Lewes sheet areas. Named the Grinstead Clay Formation by Bristow and Bazley (1972), a term adopted in Allen (1976), between the Upper and Lower Tunbridge Wells Sand formations but herein downgraded to a member of the Tunbridge Wells Sand Formation.

Type section
Complete section described from Freshfield Lane Brickworks access road [TQ 3830 2642]. Notable exposures at Philpotts Quarry, West Hoathly [TQ 3536 3215].

Primary reference section
Cuckfield No. 1 Borehole TQ22NE19 [2961 2731] 166.04 to 192.94 m depth.

Formal subdivisions
Contains the Cuckfield Stone Bed.

Lithology
Grey to greenish grey mudstones often very silty with subordinate thin beds of siltstone, nodular clay ironstone and shelly limestone. Rootlet horizons and plant-rich beds frequent. Over part of its outcrop the member is divided by a bed of calcareous sandstone, the Cuckfield Stone Bed, into the informaly named Lower and Upper Grinstead Clay. In places, the Cuckfield Stone Bed cuts out the Lower Grinstead Clay entirely and rests on the Ardingly Sandstone Member.

Definition of upper boundary
The upper boundary is placed at the sharp change from mudstones to siltstones and silty fine-grained sandstones of the informally named upper Tunbridge Wells Sand. The top of the Grinstead Clay commonly weathers to a red clay at, and emphasising, this boundary and the reddening can extend down through the whole unit to the top of the Cuckfield Stone Bed.

Definition of lower boundary
The base of the member is sharply marked by the Top Lower Tunbridge Wells Pebble Bed or by a minor erosion surface. Where this bed is recognised there is a marked change from the massive fine-grained sandstone of the Ardingly Sandstone Member to the mudstones of the Grinstead Clay Member. Where the Cuckfield Stone Bed cuts out the Lower Grinstead Clay the boundary is less clear. In this circumstance the finely trough-cross-bedded (characteristically 'festoon-bedded') fine sandstone of the Cuckfield Stone Bed rests on the massive Ardingly Sandstone Member at a sharp erosive contact.

Thickness
Maximum of 26.9 m in Horsham area, thinner elsewhere to as little as 6.1 m near Leigh to the north-west.

Distribution
The Grinstead Clay Member outcrops in the Central Weald within the Maidstone, Sevenoaks, Horsham, Tunbridge Wells, Brighton and Lewes geological sheet areas. The extent of the member at depth through the western Weald into the Hampshire Basin area is not well known. The subcrop of this member is limited northwards against the London Brabant structural high.

Previous names
Grinstead Clay (Drew 1961)
Grinstead Clay Formation (Bristow and Bazley, 1972)

Parent
Tunbridge Wells Sand Formation

Age
Late Valanginian

References
Allen, 1967; Bristow and Bazley, 1972; Dines et al., 1969; Drew, 1861; Gallois, 1965; Gallois and Worssam, 1993; Lake et al., 1987; Lake and Thurrell, 1974; Worssam, 1963; Young and Lake, 1988.

Cuckfield Stone Bed

Name
Named informally as the Cuckfield Stone (Gallois, 1963) from its type area and formalised herein.

Type section
There is no designated type section but extensive pits in the Whiteman's Green area near Cuckfield [around TQ 300 255] were famous for the dinosaur finds of Mantell; most of these pits are now backfilled and landscaped. The whole of the Cuckfield Stone Bed is exposed from time to time on the access road to Freshfield Lane Brickworks [TQ 383 265] and in the absense of an original designated site this provides the best complete paratype section. There are old quarries [TQ 2417 2467] south-east of Drewitts. There are many small exposures around Balcombe, Ardingley, West Hoathley and Cuckfield area of the Horsham Geological Sheet 302. The bed is also known from the Sevenoaks, Tunbridge Wells and Brighton sheet areas.

Primary reference section
Cuckfield No. 1 Borehole TQ22NE19 [2961 2731]

Formal subdivisions
None

Lithology
Sandstone, fine-grained, calcareous in part, pale yellow brown, fissile and flaggy (Tilgate Stone) with some parts showing trough cross-bedding ('festoon-bedding'), load casts and flute casts. Thin mudstone containing carbonaceous plant debris partings. Rare peletal and ferruginous shelly limestones developed in places towards base of unit.

Definition of upper boundary
At the erosional contact with the grey mudstones of the basal informally named Upper Grinstead Clay grey mudstones. In places the basal bed of the Upper Grinstead Clay is informally called the Cuckfield Pebble Bed, variously described as: pebbly sand with quartz and phosphatic pebbles; an iron cemented pellet bed of rolled sandstone and mudstone pebbles with plant debris and bones; or simply as a coarse pebble bed.

Definition of lower boundary
At the minor erosional contact between the grey mudstones of the informally named Lower Grinstead Clay and the yellow brown fine-grained sandstones of the Cuckfield Stone Bed. This boundary can be marked locally by a thin bed of peletal or ferruginous limestone. The upper part of the Lower Grinstead Clay mudstone is frequently reddened.

Thickness
From 1.5 to 4.4 m but up to 8.3 m in the Cuckfield No. 1 Borehole.

Distribution
Central Weald , Sevenoaks, Tunbridge Wells, Horsham and Brighton sheet areas.

Previous names
Tilgate Stone
Cuckfield Stone
Cuckfield Stone Member

Parent
Grinstead Clay Member

Age
Late Valanginian

References
Bristow and Bazley, 1972; Dines et al., 1969; Gallois, 1963; Gallois and Worssam, 1993; Young and Lake, 1988.

3.2.4 Weald Clay Formation

Name
The name was first mentioned in Conybeare and Phillips (1822) as Weald Clay. Formalised as the Weald Clay Group in Allen (1976) the term was downgraded to the Weald Clay Formation in Rawson (1992).

Type section
Type area of the Weald where there is no single complete exposure. Many partial reference sections in brickpits for example at Chailey Brickworks, Lewes [TQ 393 177]; Babylon Tileworks, Hawkenbury [TQ 802 461]; Pluckley, nr. Ashford [TQ 918 433]; Bookhurst Tileworks, Cranleigh [TQ 076 394]; Clockhouse Brickworks, Capel [TQ 177 385]; Baynards Brickworks, Horsham [TQ 068 353]; Smokejack Brickworks, Ockley [TQ 121 372]; South Holmwood and Beare Green, Newdigate [TQ 186 423]; Ashpark Brickyard, Plaistow [TQ 993 316]; Keymer Tileworks, Burgess Hill [TQ 334 192]; Langhurstwood, Horsham [TQ 175 350]; Laybrook Brickworks, Thakenham [TQ 115 188]; Rudgwick Brickworks, Rudgwick [TQ 083 343]. All are described within the memoirs covering the Weald (see references below).

Primary reference sections
Numerous deep wells and boreholes described in the memoirs for the Weald e.g. the Blacknest Borehole, Dunsfold SU93NE27 [9993 3533].

Formal subdivisions
Includes the Horsham Stone Member. Informally divided into upper and lower parts in some previous accounts.

Lithology
Dark grey shales and mudstones with subordinate siltstones, fine- to medium-grained sandstones, including calcareous sandstone (e.g. Horsham Stone Member), shelly limestones (the so-called 'Paludina Limestones') and clay ironstones.

Definition of upper boundary
Unconformable and sharp at the contact between the 'chocolate' (dark yellow brown) brown (dark grey or black coloured when unweathered) mudstones of the basal Atherfield Clay Formation and the drab, ochre-brown mudstones of the upper part of the Weald Clay.

Definition of lower boundary
Boundary generally poorly defined and gradational in complete successions, from the siltstones and silty fine-grained sandstones of the Tunbridge Wells Sand Formation up into the mudstones of the Weald Clay Formation. Locally, the basal beds of the Weald Clay are weakly sideritised. Elsewhere, the boundary is erosive and unconformable, with the Weald Clay resting on beds down to the Grinstead Clay Member (e.g. south-western part of the Maidstone Geological Sheet around Pearsons Green [TQ 694 433]).

Thickness
Up to 460 m around Guildford; 122 m at Hythe; 240 m south of Maidstone and 180 m at Eastbourne.

Distribution
The formation outcrops in the Weald. Known in the subcrop but thins and is cut-out against the Hampshire–Dieppe High in the south and the London–Brabant Ridge in the north. Disappears westward in the subcrop of the Wessex Basin.

Previous names
Weald Clay

Parent
Wealden Group

Age
Hauterivian to Barremian

References
Allen, 1949, 1962, 1976; Bristow and Bazley, 1972; Conybeare and Phillips, 1822; Dines et al., 1969; Drew, 1861; Fitton, 1836; Gallois and Worssam, 1993; Lake et al., 1987; Lake and Thurrell, 1974; Lake and Shephard-Thorn, 1987; Shephard-Thorn et al., 1966; Smart, Bisson and Worssam, 1966; Thurrell, Worssam and Edmonds, 1968; Topley, 1875; Worssam, 1963; Young and Lake, 1988.

3.2.4.1 Horsham Stone Member

Name
First used as Horsham Stone by Mantell (1827). Given formal member status herein.

Type section
The member has a general outcrop south and west of Horsham particularly in the area around Christ's Hospital [TQ 148 285]; it continues south-eastward onto the Brighton Sheet area around Cowfold [TQ 214 227] and onwards towards the area [TQ 320 206] north of Burgess Hill. It outcrops again north-eastward from Horsham towards Crawley [TQ 275 360]. The original described sections are within numerous now defunct exposures described in Topley (1875, pp.102–104). A new exposure to recover heritage stone for renovation of buildings has been opened recently at Lower Broadbridge Farm, Broadbridge Heath [TQ 1421 3138] and this can now be considered the parastratotype for the member.

Primary reference sections
Stone Quarry near Slinfold [TQ 1253 3122]
Warninglid No. 1 Borehole TQ22NW1 [2488 2701]

Formal subdivisions
None

Lithology
Sandstone, calcareous, generally fine-grained, micaceous, locally well laminated, pale grey to greenish/olive grey. Contains clayey partings and lignite fragments and rootlet traces. Frequently shows internal slumping and deformation. Informally subdivided by an interposed mudstone, south of Christ's Hospital [TQ 148 285] in the Horsham area.

Definition of upper boundary
Conformable at the change from fine-grained calcareous sandstone into mudstone.

Definition of lower boundary
Conformable at the change from mudstones and silty mudstone of the lowest part of the Weald Clay Formation into the fine-grained calcareous sandstone of the Horsham Stone. This horizon is known to be closely underlain by a significant but unnamed clay ironstone seam. Within the Warninglid Borehole TQ22NW1 [2488 2701] this change is marked by the change from greenish grey mudstone up into ripple marked sandstone with lignite laminae and mud-flake conglomerate.

Thickness
Between 1 and 2 m generally but up to 9 m in the type area.

Distribution
Central Weald, Surrey, Sussex. In a horseshoe-shaped outcrop centred around Horsham.

Previous names
Weald Clay Bed 1 (a&b)

Parent
Weald Clay Formation

Age
Hauterivian

References
Gallois and Worssam, 1993; Mantell, 1827; Topley, 1875; Worssam, 1978.

3.3 LOWER GREENSAND GROUP

Name
First used as the Lower Greensand by Webster (1826) and Murchison (1826) and later by Fitton (1836). Known as the Lower Greensand Formation in numerous Survey publications and given formal status in Rawson (1992).

Type section
Atherfield to Rocken End, Isle of Wight, [SZ 453 791 to SZ 490 755].

Primary reference section
Folkestone and Sandgate foreshore and inland, Kent [TQ 244 365 to TQ 200 350].

Formal subdivisions
In the Wealden Basin the group is subdivided into the Atherfield Clay Formation, Hythe Formation, Sandgate Formation (further subdivided at member level) and Folkestone Formation.

In the Vectian Basin the group is divided into the Atherfield Clay Formation, Ferruginous Sands Formation, Sandrock Formation and the Carstone Formation (Isle of Wight) herein renamed the Monk's Bay Sandstone Formation to remove the confusion with the Carstone Formation of the East Midlands Shelf area.

In the marginal areas and the 'Bedfordshire Straights' the Lower Greensand Group is shown undivided or on some geological sheets, incorrectly, as Lower Greensand Formation. Frequently, in this area, the Lower Greensand is given local names, as stand-alone units, such as the Woburn Sand Formation, Uffington Red Sands Formation, Faringdon Sponge Gravels Formation, Calne Sands Formation and Seend Ironstone Formation.

Lithology
Generally unconsolidated sands and sandstones of various grades interbedded in part with siltstones, mudstones, ironstones and limestones of marine derivation.

Definition of upper boundary
The boundary is everywhere placed at the base of the mudstones of the overlying Gault Formation.

In the Vectian Basin the boundary is placed at the apparently conformable contact between the ferruginous coarse-grained sandstone or clay with coarse-grained sand laminae of the top of the Monk's Bay Sandstone Formation (Carstone of the Isle of Wight) and the stiff blue-grey mudstone of the Gault Formation.

Definition of lower boundary
The boundary is placed at the unconformable and erosional contact between the Atherfield Clay Formation and the Wealden Group in both the Wealden Basin and Vectian Basin. This unconformable relationship becomes more apparent in the western outcrops of Dorset, Wiltshire and Oxfordshire and north-eastwards into Cambridgeshire where the group oversteps onto older Jurassic strata.

In the Wealden Basin the boundary is at a non-sequence at the sharp contact between the pale to dark grey mudstones of the Weald Clay Formation and the dark yellowish brown to pale grey mudstones of the Atherfield Clay Formation. In west Kent, Surrey and Sussex glauconite grains, an impersistent pebble bed and shelly, concretionary fine-grained sandstone (the 'Perna Bed') mark the base of the formation.

In the Vectian Basin the boundary is a sharp non-sequence at the base of the Perna Member. Here the finely-bedded, grey and blue-grey mudstones of the Shepherd's Chine Member of the Vectis Formation (formerly Wealden Shales) are overlain by green-grey, sandy clay (Perna Member). At some localities, resting on an erosion surface, phosphatic nodules with vetebrate bones (the Atherfield Bone Bed) forms the base of the Perna Member.

Elsewhere the base of the group is at a well-defined erosional overstepping contact between pale-coloured fine- to medium-grained sandstones and various older Jurassic strata.

Thickness
In the Wealden Basin the group is 50–215 m thick and shows westward thickening. Whilst in the Isle of Wight, the group thins westward from 240 to 180 m. In Dorset the Lower Greensand Group thins to about 60 m on the coast, and is absent in the far west of the county. On the Wessex Basin margin, towards the north-west, the group reduces to a few tens of metres with the exception of the Woburn Sand Formation, which is up to 120 m in thick.

Distribution
Southern England at depth, and at outcrop in Kent, Surrey, Hampshire, Sussex, Isle of Wight, Dorset, Wiltshire, Oxfordshire, Buckinghamshire, Bedfordshire and Cambridgeshire.

Previous names
Greensand
Lower Greensand
Lower Greensand Formation
Various local names in the marginal areas

Parent
None

Age
Aptian to Early Albian

References
Aldiss, 2002; Arkell, 1947; Dines et al., 1969; Drew, 1864; Fitton, 1836, 1847; Lake et al., 1987; Osborne White, 1921; Shephard-Thorn et al., 1994; Smart, Bisson and Worssam, 1966; Thurrell, Worssam and Edmunds, 1968; Topley, 1875; Worssam, 1963; Young and Lake, 1988.

3.3.1 Atherfield Clay Formation

Name
Named after Atherfield Point on the Isle of Wight by Fitton (1847). Formalised as Atherfield Clay Formation in Rawson (1992).

Type section
At the type site in Chale Bay (Shepherd's Chine to Whale Chine) on the Isle of Wight [SZ 4466 7982 to SZ 4684 7825] the formation is divided into five units referred to as members in Simpson (1985) (see below). These members have not been tested in terms of their mappability on the Isle of Wight and are not formally adopted.

Primary reference section
In the Weald, the Atherfield Clay is poorly exposed. The most complete sections are in boreholes the locations of which are given by Simpson (1985, figure 7). Simpson (1985) summarised the most significant localities although the majority of these are no longer available for inspection (e.g. the Haslemere railway cutting described by Salter (in Bristow, H W, 1862).

Formal subdivisions
At the type site in Chale Bay on the Isle of Wight, the formation is divided into 19 numbered beds and five units refered to as members in Simpson (1985). These are in ascending order the Perna Member, Chale Clay Member, Lower Lobster Member, the Crackers Member and Upper Lobster Member each divided into a number of beds. See Section 4.3.1 for definitions.

These members equate to the lowest three divisions (Perna Mulleti, Atherfield Clay and The Crackers) of Fitton (1847) although he reserved the term Atherfield Clay (essentially the Chale Clay Member) for his second division only. Subsequently in the work of the Survey the use of the term Atherfield Clay was extended to include the Perna Bed and the Lower Lobster Bed, and in other works now includes all of Fitton's third division (the Crackers).

Elsewhere the Atherfield Clay Formation is undivided.

Lithology
Generally massive yellowish brown to pale grey sandy mudstone throughout most of its outcrop, with an impersistent phosphatic pebble bed with vertebrate bones, gritty sandstone or very shelly sandy mudstone with glauconite, at the base. At the type site on the Isle of Wight, the predominant lithology is blue grey mudstone, variably sandy and with calcareous concretions, the formation includes beds of sandstone, clay ironstone and phosphatic nodules.

Definition of upper boundary
At the conformable boundary between the Atherfield Clay Formation and the Ferruginous Sand Formation on the Isle of Wight, and between the Atherfield Clay Formation and the Hythe Formation in the Weald.

On the Isle of Wight the boundary is placed at the change from interbedded mudstones with subordinate sandstones of the Upper Lobster Member (Simpson, 1985) and the fine-grained ferruginous sandstones of the Ferruginous Sand Formation.

In the Wealden Basin, the passage from the increasingly sandy and glauconitic mudstones of the Atherfield Clay Formation into the interbedded sandy limestones and calcareous argillaceous sandstones of the Hythe Formation is indistinct. On the ground this contact is obscured for the most part by weathered and landslipped debris derived from the Hythe Formation scarp.

Definition of lower boundary
Disconformable on the Wealden Group throughout the Wessex Basin, on the Vectis Formation in the Vectian Basin, and on the Weald Clay Formation in the Wealden Basin. This contact marks the Early Aptian marine transgression.

On the Isle of Wight, this boundary is placed at the sharp non-sequence where the dark grey mudstones of the Vectis Formation are overlain by coarse quartz grit passing up into grey brown and dark blue-grey, fossiliferous sandy mudstone containing glauconite, bone fragments, fish teeth, phosphatic nodules and rolled ammonites (the Lower Clay and Atherfield Bone Bed (Bed 1) of Simpson (1985)).

In the Wealden Basin, the base of the Atherfield Clay Formation is infrequently exposed. The junction is sharply marked by a colour change from yellow-brown mudstones of the Weald Clay to grey and dark blue-grey sandy mudstones of the Atherfield Clay Formation. This boundary is sometimes marked by a sandy, fossiliferous, glauconitic and pebbly clay with or without concretionary sandstone.

Thickness
Between 55 and 60 m on the Isle of Wight. In the Weald, the formation is 18 m thick in West Sussex and Surrey and thins eastward to about 10 m around Sevenoaks and Maidstone.

Distribution
The formation occurs at outcrop in the Weald of Kent, Surrey and Sussex and on the Isle of Wight. In the subcrop the formation is known to be overstepped and cut out towards the west and north of the Wessex Basin and to the north of the Wealden Basin against the London–Brabant landmass.

Previous names
Atherfield Clay, e.g. Fitton (1847), various survey memoirs
Atherfield Clay Series, Casey (1961)
Atherfield Clay 'Group' Rawson et al. (1978)

Parent
Lower Greensand Group

Age
Early Aptian

References
Aldiss, 2002; Bristow, 1862; Casey, 1961; Dines et al., 1969; Drew, 1864; Fitton, 1847; Lake et al., 1987; Osborne White, 1921; Rawson et al., 1978; Simpson, 1985; Smart, Bisson & Worssam, 1966; Thurrell, Worssam and Edmunds, 1968; Topley, 1875; Worssam, 1963; Young and Lake, 1988.

3.3.2 Hythe Formation

Name
Introduced in the memoir for Folkestone and Rye by Drew (1864). Formalised as the Hythe Formation in Rawson (1992).

Type section
Coastal exposures around Mill Point [TR 2218 3525 to TR 2177 3527], Folkestone.

Primary reference sections
Bognor Common Quarry [TQ 0080 2135], West Sussex.
Sunken Lane near Nutbourne [TQ 0731 1922], Sussex.
Hoes Farm Borehole SU91NE19 [9808 1962] near Petworth.

Formal subdivisions
Hoes Farm Member (Bristow et al., 1987) identified in the Hoes Farm Borehole but not mapped separately around the district. Other than this member, the British Geological Survey has not erected separate member names in the past for this formation. However there may well be scope to do so during future surveying where the distinct lithologies present may be differentiated spatially.

Lithology
In the western Weald, the formation comprises mainly fine- to medium-grained, sparsely glauconitic sands, sandstones and silts, locally pebbly, with calcareous or siliceous cement in beds or lenses in some areas. Some clay interbeds, including Fuller's Earth. In Kent and eastern Sussex the formation comprises, alternating sandy limestones ('Ragstone') and glauconitic sandy mudstones (Hassock).

Definition of upper boundary
The boundary is placed at the unconformable to disconformable contact at the base of heterogeneous sediments of the Sandgate Formation. Generally the boundary is identified at the change from sparsely glauconitic sands of the Hythe Formation to glauconitic medium-grained sands and silts with pebbles of the individual members of the Sandgate Beds. This boundary is not easy to recognise in much of Sussex.

Definition of lower boundary
At the incoming of fine- to medium-grained sands above the silty or sandy clays of Atherfield Clay and is generally sharply defined. See also Hoes Farm Member.

Thickness
Between 18 and 100 m

Distribution
Weald

Previous names
Hythe Beds

Parent
Lower Greensand Group

Age
Early and Late Aptian

References
Bristow, Morter and Wilkinson, 1987; Casey, 1961; Drew, 1864; Rawson, 1992; Ruffell, 1992.

3.3.2.1 Hoes Farm Member

Name
Named after the borehole locality in which it was originally recognised (Bristow et al., 1987)

Type section
Hoes Farm Borehole SU91NE19 [9808 1962]

Reference section
Thakeham Borehole TQ11NW17 [TQ 1084 1765]

Formal divisions
None

Lithology
The member is an alternation of fine, argillaceous sands and sandstones overlain by siltstones and, at the top of the succession, claystone in a sequence of five fining-upward cycles.

Definition of upper boundary
The claystone at the top of the highest cycle of the Hoes Farm Borehole is separated, at a burrowed erosion surface, from glauconitic, calcareously cemented, indurated, fine- to medium-grained sandstone, with phosphatic nodules at the base (upper part of the Hythe Formation undivided).

Definition of lower boundary
An olive-grey or brownish grey siltstone of the Atherfield Clay Formation is overlain by grey, argillaceous, fine-grained sandstone of the member.

Thickness
Up to 12.7 m thick at the type site and 12.5 m in the Thakeham Borehole (TQ11NW17).

Distribution
Recognised in the Hoes Farm and Thakeham Boreholes in West Sussex. Ruffell (1993) noted the member at Woolmer Hill [SU 8775 3322]. This member is not shown separately on BGS maps of the district.

Previous names
None

Parent
Hythe Formation

Age
Early Aptian, *deshayesi* Zone and basal *bowerbanki* Zone (*transitoria* Subzone)

References
Bristow, Morter and Wilkinson, 1987; Ruffell, 1990, 1992; Young and Lake, 1988.

3.3.3 Sandgate Formation

Name
First used in Drew (1864) as Sandgate Beds. Formalised as Sandgate Formation in Rawson (1992).

Type section
The formation has no single stratotype. Readers should refer to entries for the component members in the western Weald, namely: Bargate Sandstone Member, Rogate Member, Easebourne Member (where present), Selham Ironshot Sands Member, Fittleworth Member, Pulborough Sandrock Member (where present) and Marehill Clay Member (at top). Elsewhere the Formation is undivided. The formation takes its name from Sandgate [TR 20 35] on the coast near Folkestone, both here, around the town itself, and in the West Cliff [TR 235 364] at Folkestone the formation is extensively affected by landslides. The base of the formation was seen in the Goldwell Quarry south of Hothfield in the Maidstone district but this was not designated as a type site.

Primary reference section
None but see entries for constituent members.

Formal subdivisions
Divided into members, each with limited lateral extent, in Sussex, Hampshire and Surrey.

Lithology
Fine sands, silts and silty clays, commonly glauconitic; some sands limonitic or calcareous; some soft sandstones.

Definition of upper boundary
At the top of the dark clays of the Marehill Clay Member (where it is present); elsewhere at the upward change from argillaceous units into well-sorted, medium to coarse sands of the overlying Folkestone Formation. The boundary is generally sharp, but rarely exposed.

Definition of lower boundary
At the base of Easebourne Member, Fittleworth Member or Rogate Member, where present. Otherwise, at the base of a condensed succession, at the base of heterogeneous sediments of Sandgate Formation, overlying uniform Hythe Formation succession. Note that in much of Sussex the Sandgate Formation cannot be separated from the Hythe Formation with confidence (Young and Lake, 1988).

Thickness
Between 50 and 100 m in West Sussex.

Distribution
The Weald

Previous names
Sandgate Beds

Parent
Lower Greensand Group

Age
Late Aptian

References
Bristow, 1991b; Casey, 1961; Drew, 1864; Kirkaldy, 1933; Rawson, 1992; Young and Lake, 1988.

3.3.3.1 Bargate Sandstone Member

Name
Murchison (1826) introduced the term Bargate Stone later corrupted to Bargate Beds. Formalised as Bargate Sandstone Member herein.

Type section
Blackheath Lane [TQ 0483 4700], Albury

Primary reference section
Milford Bypass road cutting [SU 9435 4413]

Formal subdivisions
None

Lithology
In the Guildford district, the member comprises buff to brown, gritty, ferruginous, cemented, cross-bedded, coarse-grained sandstone with beds of pale grey calcareous sandstone. Locally a pebble bed occurs at the base, with clasts of Hythe Formation, glauconite pebbles, quartz granules, brown phosphatic pebbles and pebbles of Jurassic limestone. Locally, e.g. Milford Bypass [SU 9435 4413], the member is weakly calcareous and chert beds occur, including one at the base. Hard, calcareous sandstone concretions ('doggers') (Bargate Stone) have also been recorded near the top of the unit around Dorking. In the north-east part of the Alresford district it consists of friable, calcareous, glauconitic, fine- to medium-grained sandstones and cemented flagstones.

Definition of upper boundary
In the Alresford district (Farrant, 2002), the upper boundary

is characterised by a down-section change from grey, friable, well-sorted, fine-grained, glauconitic, weakly cross-bedded sandstone (Pulborough Sandrock Member) to brown, friable, calcareous, glauconitic sandstone, pebbly in part (Bargate Sandstone Member). In the Guildford district (Ellison et al., 2002) the argillaceous silts and fine- to medium-grained sandstones [of the undivided upper part of the Sandgate Formation] rest on brown, gritty, ferruginous, cemented, cross-bedded sandstone with beds of pale grey, calcareous sandstone (Bargate Sandstone Member).

Definition of lower boundary
The lower boundary is placed at a burrowed erosion surface where pebbly sand rests on pale grey, well-sorted, fine- to medium-grained, weakly cemented sandstone (Hythe Formation) (Ellison et al. 2002). Locally, in the Alresford district (Farrant, 2002), the cemented sandstones of the Bargate Member interdigitate with pebbly, glauconite- and limonite-rich clayey sands of the Rogate Member (Sandgate Formation). The lower boundary in this area is not closely observed and it is uncertain which member rests on the basal surface.

Thickness
The member is up to 35 m in the Alresford district and up to 20 m in the Guildford district.

Distribution
The outcrop is restricted to the Alresford and Guildford districts. It forms a broad plateau south and west of Godalming [SU 95 43]. There are small outliers near Shere [TQ 0780 4730] and Abinger [TQ 1020 4680]. It is discontinuous around Albury Heath [TQ 058 466], Blackheath [TQ 038 464] and Farley Heath [TQ 046 430] and it is restricted to the north-eastern part of the Alresford district.

Previous names
Bargate Beds
Bargate Formation
Bargate Member of the Sandgate Formation

Parent
Sandgate Formation

Age
Aptian

References
Bristow and Wyatt, 1983; Dines and Edmunds, 1929; Ellison, Williamson and Humpage, 2002; Farrant, 2002; Kirklady, 1933; Lake and Shephard-Thorn, 1985; Murchison, 1826.

3.3.3.2 Rogate Member

Name
Name used for the first time as Rogate Beds during the survey for Chichester and Bognor sheet by Bristow and Wyatt (1983). Formalised as Rogate Member on the Chichester and Bognor Geological Sheet 317 (England and Wales) and in the Sheet Explanation for that sheet (Aldiss, 2002).

Type area
Rogate village [SU 80 23] and surroundings (Bristow, 1991b).

Primary reference section
None

Formal subdivisions
None

Lithology
The member is a heterogeneous succession of coarse-grained pebbly sands, very glauconitic clayey pebbly sands, glauconitic pebbly and sandy clays, calcareously cemented pebble beds and coarse-grained pebbly sands with many polished limonite pebbles.

Definition of upper boundary
Conformable at the base of Pulborough Sandrock Member, marked by the top of a glauconitic pebbly sandy clay where present and elsewhere at the change from pebbly sands to the fine-grained, well-sorted Pulborough Sandrock Member (but note scattered coarse grains occur in basal metre or so of Sandrock).

Definition of lower boundary
Top of the Hythe Formation; incoming of pebbles (including pebbles of polished limonite), usually set in a slightly clayey, glauconitic sandy matrix.

Thickness
Between 4 and 46 m

Distribution
Western Weald; outcrop extends from Stedham, West Sussex, to north of Liss in Hampshire.

Previous names
Lateral equivalent of Selham Ironshot Sands Member.
Previously an undifferentiated part of the Sandgate Beds.
Rogate Beds.

Parent
Sandgate Formation

Age
Aptian

References
Bristow, 1991b; Bristow and Wyatt, 1983.

3.3.3.3 Easebourne Member

Name
Name used for the first time as Easebourne Beds during the survey for Chichester and Bognor sheet by Bristow and Wyatt (1983). Formalised as Easebourne Member on the Chichester and Bognor Geological Sheet 317 (England and Wales) and in the Sheet Explanation for that sheet (Aldiss, 2002).

Type section
Partial stratotypes at 'Lower Quarry' [SU 9041 2350], Easebourne (adjacent to Easebourne Street near Upper Sowter's) and the 'Upper Quarry' [SU 9052 2350], Easebourne (c.100 m east of Easebourne Street near Upper Sowter's).

Primary reference section
Reference section for basal contact is 'Winter's Pit' [SU 8942 2363], near Budgenor, Easebourne.

Formal subdivisions
None

Lithology
Fine- to medium-grained glauconitic sands, some very well cemented (calcareous), with minor clay interbeds.

Definition of upper boundary
Incoming of conspicuous clay-rich sands and clays at base of Fittleworth Member or at a sharp contact with purplish to reddish brown poorly sorted, medium- to coarse-grained limonitic sand of the Selham Ironshot Sand Member.

Definition of lower boundary
Sharply defined contact on similar but less well cemented sands of Hythe Formation.

Thickness
Between 0 and 40 m

Distribution
The outcrop is between Chithurst (Gatehouse) SU 83 23 and Petworth SU 98 20, south-western Weald (Sussex). The extent in the subcrop is unknown but is probably limited to the south against the Hampshire–Dieppe high.

Previous names
None

Parent
Sandgate Formation

Age
Aptian

References
Aldiss, 2002; Bristow, 1991b; Bristow and Wyatt, 1983; Casey, 1961; Holmes, 1963; Kirkaldy, 1933; Kirkaldy and Wooldridge, 1938; Samuel, 1994; Thurrell, Worssam and Edmonds, 1968.

3.3.3.4 Selham Ironshot Sands Member

Name
Name used for the first time as Selham Ironshot Sands during the survey for Chichester and Bognor sheet by Bristow and Wyatt (1983). Formalised as Selham Ironshot Sands Member on the Chichester and Bognor Geological Sheet 317 (England and Wales) and in the Sheet Explanation for that sheet (Aldiss, 2002).

Type area
Selham, [SU 935 235] near Petworth, Sussex

Primary reference section
Within the sunken lane south from A272 to Moorland Barns [SU 9175 2180 to SU 9170 2145], Easebourne–Lodsworth parish boundary, near Midhurst.

Formal subdivisions
None

Lithology
Sand, purplish-reddish-brown, cross-bedded, poorly-sorted, medium- to coarse-grained, with polished dark brown to black limonite grains to granule size locally and secondary iron-pan concretions in parts. From about 9 km from Stedham, West Sussex (NGR SU 86 22) to east of Selham, West Sussex [SU 94 20] the Fittleworth Member is divided by the Selham Ironshot Member. Samuel (1994) proposed the name 'Upper Fittleworth Beds' for these superposed beds (c.2 m thick).

Definition of upper boundary
Sharp junction of sand with upper part of Fittleworth Member (pale sandy clay, non-ferruginous, becoming very dark greenish-grey where thinning out) or of hardground-like ferruginous sandstone with fine well-sorted sand of Pulborough Sandrock, where Fittleworth Member is absent.

Definition of lower boundary
At the sharp junction between the purplish to reddish brown medium- to coarse-grained sand of the member with the sandy clay (which includes some limonite grains at this level) of the lower part of Fittleworth Member.

Thickness
Between 0 and 24.4 m (passes laterally into silty clay, Fittleworth Beds or Rogate Beds to west).

Distribution
West Sussex: from Cowdray Park in the north, possibly as far as Ambersham Common in the south, possibly also as far as the Stedham area in the west, to about 1 km east of Selham in the east.

Previous names
None

Parent
Sandgate Formation

Age
Aptian

References
Bristow and Wyatt, 1983; Humphries, 1964; Kirkaldy, 1933; Samuel, 1994; Reid, 1903; Thurrell, Worssam and Edmonds, 1968; Wooldridge, 1947; Young, Highley and Morgan, 1979.

3.3.3.5 Fittleworth Member

Name
Name used for the first time as Fittleworth Beds during the survey for Chichester and Bognor sheet by Bristow and Wyatt (1983). Formalised as Fittleworth Member on the Chichester and Bognor Geological Sheet 317 (England and Wales) and in the Sheet Explanation for that sheet (Aldiss, 2002).

Type section
A former brick pit [TQ 0143 1954] at Fittleworth village.

Primary reference section
None

Formal subdivisions
From about 9 km from Stedham, West Sussex [SU 86 22] to east of Selham, West Sussex [SU 94 20] the Fittleworth Member is divided by the Selham Ironshot Member. Samuel (1994) proposed the name 'Upper Fittleworth Beds' for the upper division (c.2 m thick). This is re-named informally the 'upper Fittleworth Member', with the lower division (to c.8m) named the 'lower Fittleworth Member'.

Lithology
Glauconitic sandy clays and clayey sands: orange-brown where weathered; bright green where unweathered.

Definition of upper boundary
In the area from Stedham to Storrington the change from glauconitic sandy clay and clayey sand with the incoming of fine-grained well-sorted sands of Pulborough Sandrock marks the boundary. From Storrington eastwards

the boundary is diffuse at the upward passage into silty clay of the Marehill Clay Member.

Definition of lower boundary
At the incoming of conspicuous glauconitic clayey sands and sandy clays at the top of fine-grained to medium-grained 'Bargate Beds' (now Easebourne Member) where present.

Thickness
Between 10 and 60 m

Distribution
From Stedham, West Sussex [SU 86 22] (where the combined Fittleworth Member and Selham Ironshot Sands Member are replaced by the Rogate Member) and probably eastwards to Heath Common [TQ 11 14].

Previous names
None

Parent
Sandgate Formation

Age
Aptian

References
Bristow and Wyatt, 1983; Samuel, 1994; Young and Lake, 1988.

3.3.3.6 Pulborough Sandrock Member

Name
Name, Pulborough Sandrock, introduced by Wooldridge (1928) and Kirkaldy (1933) and adopted by Bristow and Wyatt (1983). Formalised as Pulborough Sandrock Member on the Chichester and Bognor Geological Sheet 317 (England and Wales) and in the Sheet Explanation for that sheet (Aldiss, 2002).

Type section
Partial stratotypes are available in the railway cutting [TQ 0440 1875] and in the road cutting [TQ 0475 1875] on the north side of Pulborough, West Sussex.

Primary reference section
None

Formal subdivisions
The member is divided by the informally named lower Marehill Clay into lower Pulborough Sandrock and upper Pulborough Sandrock.

Lithology
Uniformly fine-grained, friable, well-sorted, fossiliferous sandstone; rarely cross-bedded; grey when fresh and yellowish-brown when weathered. Sparse coarse grains can be present near base. Coarse ferruginous sand locally present at top. Thin mudstone beds in places.

Definition of upper boundary
In the type area, the top of a thin cemented ironstone beneath the clays and silts of the Marehill Clay Member. Around Petersfield, at the change from mainly sand to mainly grey silty clay in a short gradational succession.

Definition of lower boundary
The lower boundary is identified at the upward change from poorly sorted sands, typically pebbly, limonitic and/or clayey (locally at a pebbly sandy clay), of the Fittleworth Member, Selham Ironshot Sands Member or the Rogate Member, to dominantly fine-grained, well-sorted sands.

Thickness
Between 0 and 35 m

Distribution
South-west Weald; eastern limit is Storrington, West Sussex [TQ 07 14]; northern limit not known.

Previous names
Previously treated as an undifferentiated part of the Sandgate Beds (Formation).

Parent
Sandgate Formation

Age
Aptian

References
Bristow, and Wyatt, 1983; Bristow, 1991b; Kirkaldy, 1933; Wooldridge, 1928.

3.3.3.7 Marehill Clay Member

Name
Introduced, as Marehill Clay, by Kirkaldy (1933) and adopted by Bristow and Wyatt (1983). Formalised as Marehill Clay Member on the Chichester and Bognor Geological Sheet 317 (England and Wales) and in the Sheet Explanation for that sheet (Aldiss, 2002).

Type section
Old sandpit [TQ 0647 1864] at Pulborough, near Marehill.

Primary reference section
None

Formal subdivisions
Informally divided into lower Marehill Clay and upper Marehill Clay by the upper Pulborough Sandrock.

Lithology
Dark grey, locally glauconitic, silty clay

Definition of upper boundary
Upward change to well-sorted medium to coarse sands of the Folkestone Formation. Contact generally sharp, but rarely exposed.

Definition of lower boundary
Upward change to silty clay (or clayey sand) from mostly well-sorted fine-grained sands (locally iron-cemented at top) of Pulborough Sandrock Member.

Thickness
Between 2 and 35 m

Distribution
South-western and western Weald

Previous names
Previously part of an undifferentiated Sandgate Beds (Formation)
Mare Hill Clay

Parent
Sandgate Formation

Age
Aptian

References
Bristow and Wyatt, 1983; Bristow, 1991b; Kirkaldy, 1933.

3.3.4 Folkestone Formation

Name
Introduced as the Folkestone Sands or Beds by Drew (1863). Formalised as Folkestone Formation in Rawson (1992).

Type section
East Cliff, [TR 24 36], Folkestone, Kent.

Primary reference section
None formally defined, but many partial reference sections available within the Weald.

Formal subdivisions
None in the Weald, but equivalent beds in the west are termed the Child Okeford Sand Member and the Bedchester Sands Member.

Lithology
In Sussex, Kent and Surrey the formation comprises medium- and coarse-grained, well-sorted cross-bedded sands and weakly cemented sandstones; elsewhere includes calcareous sandstones.

Definition of upper boundary
Generally the top of the formation is placed at the upward disappearance of sand at the base of Gault Formation. In places the top is at the base of a thin pebbly sandy clay condensed succession at the base of the Gault Formation. In Sussex the top of the formation is at the base of 'Iron Grit' (hard, pebbly, limonitic, coarse-grained sandstone) (see Casey, 1961).

Definition of lower boundary
Contact of sand or sandstone with underlying silty clay or clayey silt of Marehill Clay Member (Sandgate Formation) or with heterogeneous succession of clays, silts and sands (Sandgate Formation, undifferentiated). This boundary can be diffuse in places but generally marked by a colour change.

Thickness
Between 0.5 and 80 m

Distribution
West Sussex and south-east Hampshire; otherwise circum-Weald

Previous names
Folkestone Beds

Parent
Lower Greensand Group

Age
Late Aptian to Early Albian

References
Anderson, 1986; Bristow and Wyatt, 1983; Casey, 1961; Drew, 1864; Young and Lake, 1988.

3.3.4.1 Child Okeford Sand Member

Name
Introduced by Bristow (1991a) and the Shaftesbury Memoir (Bristow et al., 1995).

Type area
There is an extensive outcrop between Child Okeford and Bedchester [ST 830 130 to 860 180].

Primary reference sections
Borehole ST81SW22 [8358 1330] 600 m north of Child Okeford Church (4.4–8.6 m depth).
Old sandpit [ST 8558 1763], north of Piper's Mill, Bedchester (Jukes-Browne, 1891).

Formal subdivisions
None.

Lithology
Very fine-grained, poorly sorted, glauconitic sand with some beds of medium-grained sand, more clayey sands and thin ferruginously cemented beds.

Definition of upper boundary
Upward change to extremely clayey glauconitic sand and sandy clay of the Bedchester Sands, or, in its absence, to the sandy clay of the Gault Formation.

Definition of lower boundary
Rests unconformably on various Jurassic formations.

Thickness
Between 0 and about 10 m

Distribution
Across the northern part of the Shaftesbury Sheet (313), south-eastern part of the Wincanton Sheet (297) and onto the Salisbury Sheet (298), beyond which it has not been mapped to date.

Previous names
None

Parent
Lower Greensand Group

Age
Late Aptian

References
Bristow, 1991a; Bristow et al., 1995; Jukes-Browne, 1891; Osborne White, 1923.

3.3.4.2 Bedchester Sands Member

Name
Introduced by Bristow (1991a) and the Shaftesbury Memoir (Bristow et al., 1995).

Type section
Near Piper's Mill [ST 8568 1702], south-east of Bedchester (Jukes-Browne, 1891).

Primary reference section
Borehole ST81NE2 [850 170], 600 m north-east of crossroads at Bedchester (1.6–2.3 m depth).

Formal subdivisions
None

Lithology
Very clayey, fine-grained, poorly-sorted, glauconitic sand or very fine-grained sandy clay.

Definition of upper boundary
Usually capped by a thin pebble bed that marks the basal bed of the Gault Formation. Where the pebble bed is absent, the boundary is indistinct but drawn at the change from very clayey glauconitic sand, to glauconitic sandy clay.

Definition of lower boundary
Upward change from usually clay-free glauconitic sand (Child Okeford Sands) to very clayey, fine-grained sand.

Thickness
Between 0 and 5 m

Distribution
Patchy distribution across the south-western part of the Shaftesbury district (Sheet 313); more continuous outcrop between Child Okeford [ST 830 130] and [ST 860 180].

Previous names
None

Parent
Lower Greensand Group

Age
Latest Aptian to Early Albian

References
Bristow, 1991a; Bristow et al., 1995; Jukes-Browne, 1891; Osborne White, 1923.

3.4 SELBORNE GROUP

Name
The group is named after the locality of Selborne, Hampshire where the two major constituent formations crop out. Thus the Selbornian Stage of Jukes-Browne and Hill (1900) is formally modified to Selborne Group herein to represent its lithological counterpart.

Type section
Type area of the district around Selborne, Hampshire includes the type section designated in the three Selborne Boreholes: SU73SW22 [73200 34940], SU73SE39 [75400 34350] and SU73SE40 [75830 34000] (Hopson, Farrant & Booth, 2001).

Primary reference sections
Copt Point Cliff Section [TR 241 364] at Folkestone Kent (Price, 1874; Topley 1875; Jukes-Browne and Hill, 1900; Owen, 1971).
The Weald [TQ 59 00 to TQ 52 55] of Sussex and Hampshire.
East Anglia, Mundford C Borehole (TL79SE13) [7670 9132] (Gallois and Morter; 1982; Owen, 1972).
See discussion below under formal subdivisions, with respect to these following reference sections:
Hunstanton Cliff [TF 6725 4130 to TF 6786 4238], North Norfolk (Owen, 1995; Gallois, 1994).
South Ferriby Quarry [SE 9915 2045], Lincolnshire (Gaunt et al., 1992).
Speeton Cliffs [TA 162 752 to TA 192 744], Yorkshire (Mitchell, 1995).

Formal subdivisions
Gault Formation
Upper Greensand Formation
In the Norfolk area the Hunstanton Formation is demonstrably gradational from the Gault Formation but in Lincolnshire and Yorkshire the formation is considerably thicker and can be related directly to the Rødby Formation of the Cromer Knoll Group in the offshore basin. The extension of the term Selborne Group to include the Hunstanton Formation is not formalised in this document but it may be a consideration for future research particularly if the Cromer Knoll Group, that covers the entire Early Cretaceous, is considered as a supergroup in the fullness of time.

Lithology
Thick succession of glauconitic sandstones predominantly in the Hampshire and Western Weald (Upper Greensand Formation) passing laterally into mudstones (siltstones and claystones) in the Wealden area and northwards into the East Anglian region (Gault Formation); which in turn passes laterally northwards into interbedded limestones and marls (calcareous clays and clayey limestones often red in colour) of northern Norfolk, Lincolnshire and southern and eastern Yorkshire (Hunstanton Formation).

Definition of upper boundary
The upper boundary defined at the boundary between mudstones sandstones or interbedded limestones and marls and the basal unit of the Chalk Group. The erosion surface characterised by glauconitic sand and phosphatic nodules at the base of the Glauconitic Marl Member of the West Melbury Marly Chalk Formation or at a glauconitic chalk horizon stratigraphically higher in uplifted areas.

Definition of lower boundary
Generally at the base of a phosphatic pebble bed or gritty mudstone at the base of the Gault Formation where this overlies the Carstone in East Anglia, the Monk's Bay Sandstone Formation on the Isle of Wight or the Folkestone Formation of the Weald. Elsewhere in southern England the base of the Gault Formation rests on an unconformity and oversteps onto undivided Lower Greensand Group sandstones and ironstone, Wealden or Purbeck groups or onto various units of the Jurassic.

In the extreme west of the outcrop the overstep places the Gault Formation on Triassic mudstones and sandstones. On parts of the Sidmouth (Sheet 326) and Wellington (Sheet 311) districts the lower boundary at the base of the constituent Upper Greensand Formation is unconformable on the Mercia Mudstone Group, Penarth Group and Lias Group. Further west on Newton Abbot (Sheet 349) there is an unconformable contact with Permian, Carboniferous and Devonian strata.

In north Norfolk, Lincolnshire and south Yorkshire the boundary is placed at the base of the calcareous mudstones (marls often of a red or pink colour) of the Hunstanton Formation where they overstep various formations (generally mudstones) within the Jurassic.

Thickness
Up to 110 m in the Weald where the full succession is present. In marginal areas to the west and north the group may be a little as 5 m thick.

Distribution
The formation is known at outcrop and at depth throughout Southern England, from Devon to the Weald and on the Isle of Wight, throughout the Chilterns into East Anglia and in Lincolnshire and South Yorkshire.

Previous names
None lithostratigraphically, although the term Selbornian was coined by Jukes-Browne and Hill (1900) to cover the same interval in a biostratigraphical sense.

Parent
None

Age
Early, Mid and Late Albian, and earliest Cenomanian in Yorkshire and Devon

References
Gallois, 1994; Gallois and Morter, 1982; Gaunt, Fletcher and Wood, 1992; Hopson, Farrant and Booth, 2001; Jukes-Browne and Hill, 1900; Mitchell, 1995; Owen, 1971, 1972, 1992; Price, 1874; Topley, 1875.

3.4.1 Gault Formation

Name
First used by Hailstone (1816) in Cambridgeshire. The 'Golt Brick Earth' was first used by William Smith on his Geological Map of England and Wales (1815) and again in Norfolk (1819). The Reverend J Hailstone, however, read a paper to the Geological Society on November 18th 1814 (published in 1816) in which describes 'an extensive bed of blue clay, provincially called gault' and later refers to 'the bluish clay or marle called Gault'. Golt or Gault is a term of some antiquity but commonly regarded as being derived from 'gaulting', the practise of adding clay to limestone soils to aid moisture retention (a synonym for marling). Other derivations in English Rock Terms (Arkell and Tomkeiff, 1953) suggest its roots are Old Swedish from galt meaning barren or even Old French from golet meaning throat and used in Cambridge as the name used for watercourses e.g. Sutton Gault within which, presumably, the clay is found. Elsewhere gault probably refers to a common practice of calling many stiff brickclays gault because it was hard to dig as in OED 1575 'in grounde that was harde to dygge as in galte clay' but this could also allude to the digging of clay for gaulting. Formalised as Gault Formation in Rawson (1992).

Type section
Long regarded as Copt Point cliff section [TR 241 364] at Folkestone, Kent (Price, 1874; Topley, 1875; Jukes-Browne and Hill, 1900; Owen, 1971).

Primary reference sections
The Arlesey Borehole (Arlesey Brickpit) TL13SE45 [1887 3463] shows a complete section through the preserved Gault Formation 15.45–72.96 m (Hopson, 1992; Woods, Wilkinson and Hopson, 1995).
The three boreholes (1 to 3) at Selborne in Hampshire (SU73SW22 [7320 3494], SU73SE39 [7540 3435] and SU73SE40 [7583 3400]) together give a complete lower and upper Gault Formation succession (Hopson, Farrant and Booth, 2001).
Mundford C Borehole TL79SE13 [7670 9132] (Gallois and Morter, 1982).
Gayton Borehole TF71NW10 [7280 1974] (Gallois and Morter, 1982)
Marham Borehole TF70NW1 [7051 0803] (Gallois and Morter, 1982)

Formal subdivisions
Divided into a lower and upper part and into 13 'Beds' as defined by Price (1874) at the type section at Folkestone. Divided into 19 beds, in East Anglia, by Gallois and Morter (1982).

Lithology
Pale to dark grey or blue-grey clay or mudstone, glauconitic in part, with a sandy base. Discrete bands of phosphatic nodules (commonly preserving fossils), some pyrite and calcareous nodules. At Munday's Hill, Bedfordshire the base of the Gault Formation is brick-red mudstone called informally the 'Cirripede Bed'. In Norfolk, the Gault Formation becomes calcareous before passing northwards into the Hunstanton Formation ('Red Chalk').

Definition of upper boundary
Diachronous transition from mudstone into Upper Greensand Formation facies (glauconitic sand) westward of a line from Sevenoaks (Kent) to Lewes (Sussex). In eastern areas the upper boundary of the formation is the unconformable junction with the basal Grey Chalk Subgroup (argillaceous, glauconitic sandstone, chalky sandstone and sandy chalk, with common phosphatic nodules). In Cambridgeshire the mudstones of the Gault Formation are overlain at a sharp erosive junction by the strongly phosphatic sandstone of the Cambridge Greensand Member at the base of the Chalk Group (West Melbury Marly Chalk Member).

Definition of lower boundary
Unconformity. Rapid transition from sands of Lower Greensand Group and equivalents where these are present and at a marked break where the basal Gault Formation rests on rocks down to Triassic in age. Beneath London the lower part of the Gault Formation is absent or severely attenuated over the London–Brabant Ridge formed of Palaeozoic rocks.

Generally at the base of a phosphatic pebble bed or gritty mudstone at the base of the Gault Formation where this overlies the Carstone in East Anglia, the Redcliff Sandstone Formation on the Isle of Wight or the Folkestone Formation of the Weald. Elsewhere in southern England the base of the Gault Formation rest on an unconformity and oversteps onto undivided Lower Greensand Group sandstones and ironstone, may overlie attenuated Wealden and oversteps onto various units of the Jurassic. In the extreme west of the outcrop the overstep places the Gault Formation on Triassic mudstones and sandstones.

Thickness
About 2 m in north Norfolk, thickening southwards to 20 m in Cambridgeshire, 60 m in Bedfordshire, and 90–110 m in the Weald (104 m in the Glyndebourne Borehole TQ41SW16 [4420 1141]).

Distribution
Extensive outcrop in eastern England from Norfolk, south-westwards across the East Midlands and Home Counties to Devon, in the Isle of Wight and around the margins of the the Weald.

Previous names
Golt
Gault
Gault Clay

Parent
Selborne Group

Age
Early, Mid and latest Albian

References
Hailstone, 1816; Hancock, 1972 (editor); Hopson, 1992; Hopson, Farrant and Booth, 2001; Jukes-Browne and Hill, 1900; Owen, 1971, 1972, 1992; Price, 1874; Rawson et al., 1978; Topley, 1875; Woods, Wilkinson and Hopson, 1995.

3.4.2 Upper Greensand Formation

Name
First used by Webster in (1824) in his stratigraphical table as a formation between the Gault and Chalk Marl. Formalised as Upper Greensand Formation in Rawson (1992).

Type area
The Weald [TQ 59 00 to TQ 52 55] of Sussex and Hampshire.

Primary reference sections
Each of the designated sections for the regionalised members.
Selborne Borehole 1 SU73SW22 [7320 3494] in the western Weald.

Formal subdivisions
Within the Weald the Upper Greensand is undivided formally but see Hopson, Farrant and Booth (2001) where an informal fivefold division is given (units D, C, B Aii and Ai from base).

Subdivisions of the Upper Greensand in the eastern part of the Vectian Basin and north-west Wessex Basin include from the base the Cann Sand Member, Shaftesbury Sandstone Member and Boyne Hollow Chert Member. In the western part of the Vectian Basin the following subdivisions (in ascending stratigraphical order) are recognised, the Foxmould Member, Whitecliff Chert Member, Bindon Sandstone Member/Eggardon Grit Member. At the extreme western margin of the Vectian Basin (Newton Abbot district) the subdivisions are (in ascending stratigraphical order): Telegraph Hill Sands Member, Woodlands Sands Member, Ashcombe Gravels Member and Cullum Sands-with-Cherts Member.

Lithology
Generally fine-grained sand and sandstone, silty, glauconitic and shelly. To the west the formation includes significant chert beds and hard sandstone 'doggers' (locally called the Potterne Rock). On the western margins of its outcrop the formation becomes medium- to coarse-grained pebbly sands and sandstones and conglomeritic. To the east the formation passes laterally into the Gault Formation.

Definition of upper boundary
Sharp junction (often marked by a chert or phospatic pebble bed) at a disconformity where there is an upward change from a dominantly arenaceous succession to a dominantly calcareous mudstone (marly) or chalk succession with some glauconite grains of the Chalk Group (Grey Chalk Subgroup).

Definition of lower boundary
Upward change from sandy micaceous clay of the Gault Formation to silt and/or sand.

In parts of the Sidmouth (Sheet 326) and Wellington (Sheet 311) districts the lower boundary is unconformable on the Mercia Mudstone Group, Penarth Group and Lias Group. Further west on Newton Abbot (Sheet 349) there is an unconformable contact with Permian, Carboniferous and Devonian strata.

Thickness
Between 0 and 75 m

Distribution
Eastbourne to Sevenoaks in the western Weald, throughout the Wessex Basin and northwards to just north-east of Monks Riseborough in the Chilterns.

Previous names
Firestone, Upper Green-sand, Malmstone, Malm, Malm Rock of western Sussex, Merstham Beds, White Firestone alternating with Blue Rag, Upper Greensand of Devon.

Parent
Selborne Group

Age
Albian to earliest Cenomanian

References
Fitton, 1824; Hopson, Farrant and Booth, 2001; Mantell, 1822; Martin, 1828; Murchison, 1826; Webster, 1824; White, 1789.

4 Wessex Basin (Vectian Basin)

South of the Hampshire–Dieppe High deposition within the Vectis, Vectian or Channel Basin occurred throughout the Early Cretaceous. The basin includes the type Purbeck Group area within which the base of the Berriasian and hence the base of the Lower Cretaceous can be defined (see above).

Within the Vectian Basin the full scheme has been developed for the Wealden Group and Lower Greensand Group on the Isle of Wight. Equivalents can be traced westward for a short distance onto the mainland around Swanage but further west in Dorset the succession thins considerably and individual units are difficult to trace with any certainty. The succession is shown on recent BGS maps as the Wealden Formation and Lower Greensand Formation each being undivided. However, within the mainland outcrops of the Lower Greensand Formation, three units, each equated to the Isle of Wight succession, are discussed in texts. In these texts the units were given member status because they could not be traced reliably in mapping terms. It is, however, recommended that group and formation status be reintroduced for these mainland outcrops of the Wealden and Lower Greensand units to restore uniformity across the Wessex Basin. Further it is proposed to introduce the term Monk's Bay Sandstone Formation to replace the traditional term Carstone to avoid confusion with the term Carstone Formation as used in Lincolnshire and Norfolk.

The Gault Formation and Upper Greensand Formation (herein considered within the Selborne Group) have a wider distribution than the Wealden and Lower Greensand groups and they rest on progressively older strata westward. To the far west in Devon, the Upper Greensand is developed in different facies from that in Dorset and in the Vale of Wardour to the north-east.

The development of the terminology for the Vectian Basin is shown in Table 3. Whilst Insole et al. (1998) reintroduced the terminology of Fitton (1847) at member level for the Lower Greensand Group the mappability of these units has not been tested by a modern survey, they are however, included in the scheme adopted here for completeness. Similarly the members proposed for the Vectis Formation of the Wealden Group have not been tested in mapping away from their coastal outcrop but are included.

4.1 PURBECK GROUP

At the type site in Dorset, the Group is now formally divided into the Lulworth Formation, below and the Durlston Formation above, with the base of the Durlston Formation placed at the base of the Cinder Bed. The formation-level terminology can now be applied extensively in the outcrop and subcrop of the group.

In the type area of Dorset the Lulworth Formation is further divided (following Westhead and Mather, 1996), from the base, into the Mupe Member, the Ridgeway Member and the Worbarrow Tout Member. The Durlston Formation is divided into the Stair Hole Member below and the Peveril Point Member above. Clements (1993) gave formal member names throughout the group in Dorset that would now be considered as informal units.

See also entry in Section 3

4.1.1 Lulworth Formation

The Lulworth Formation comprises three members in Dorset, in ascending order: the Mupe Member, the Ridgeway Member and the Worbarrow Tout Member. Elsewhere the formation is undivided or is itself incorporated into an undivided Purbeck Group. The formation includes the informal 'Lower Purbeck Beds' and the lower part of the 'Middle Purbeck Beds' (up to the base of the Cinder Bed) of the traditional scheme used in older memoirs of the Geological Survey. Clements (1993) identified eight members in Dorset based on lithological variation but these are not considered as formal divisions.

See also entry in Section 3

4.1.1.1 Mupe Member

Name
Introduced by Westhead and Mather (1996)

Type section
West side of Mupe Bay (Bacon Hole) [SY 8394 7966]

Primary reference section
Old quarry at Upwey [SY 6701 8508]

Formal subdivisions
None

Lithology
In Dorset, the lower part comprises white-weathering marls and micrites containing algal laminations and some evaporitic material, with interbedded carbonaceous mudstones ('caps', 'dirt beds') and localised brecciated limestone pockets (broken beds). Limestones, particularly in the upper part of the member (lower part of Cypris Freestones), are commonly ostracod-rich micrites and sparites. Detrital quartz is rare. The ostracod-rich limestones contain abundant parallel laminations and ripples, particularly higher in the member. The member may show a crude coarsening-upwards succession, for example, at Stair Hole [SY 822 798], Lulworth [SY 8250 7975 and 827 797] and Worbarrow Tout [SY 869 795].

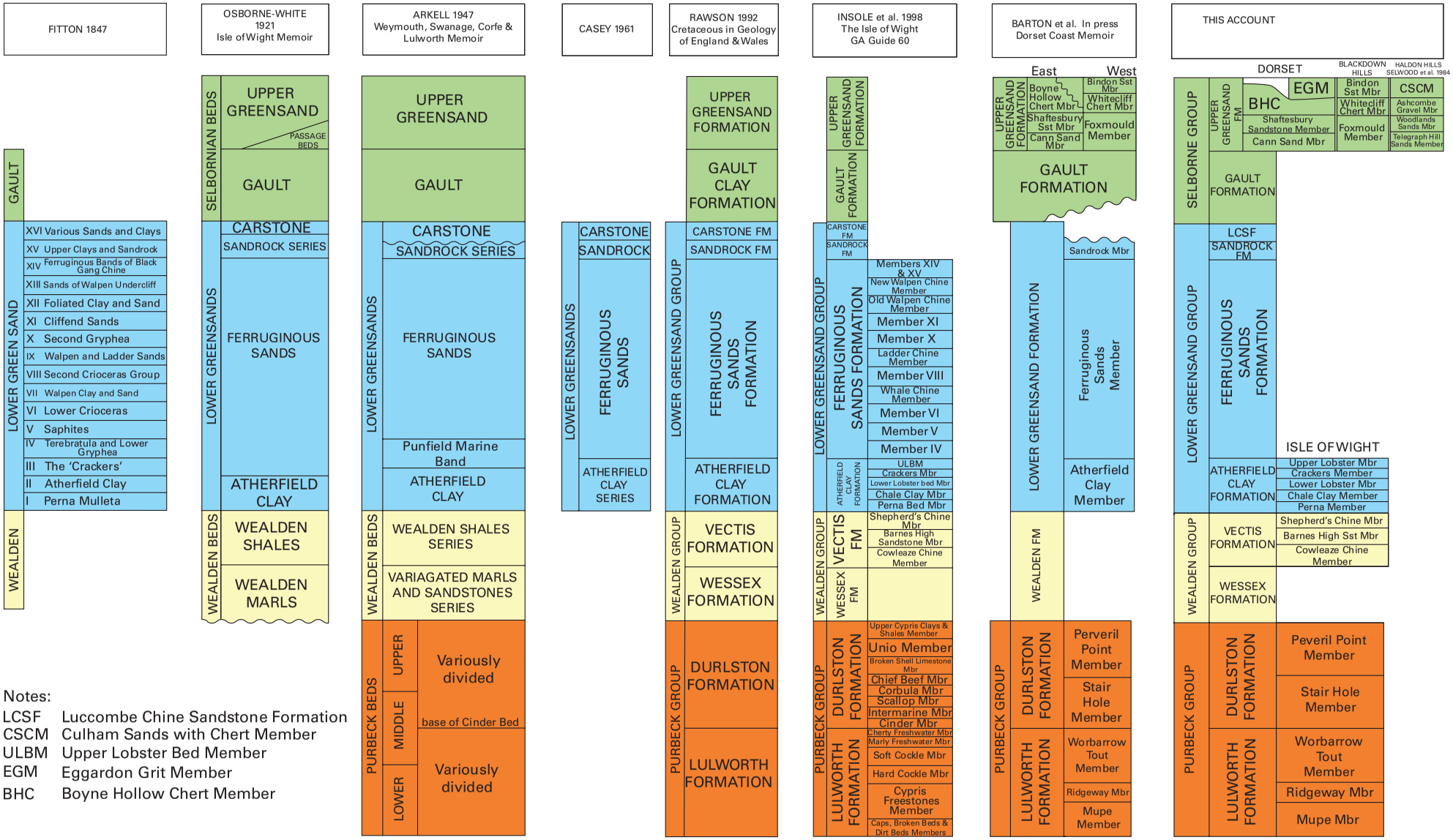
Definition of upper boundary
Conformable at the last occurrence of thickly-bedded, ostracod-rich limestone (Cypris Freestones) beneath Ridgeway Member mudstones.

Definition of lower boundary
Conformable at the base of the first occurrence of finely laminated, ostracod-rich limestones above the more massive, shelly limestones of the Portland Limestone Formation.

Thickness
Some 11 m in the west of Dorset increases to 16 m in the east. The member is abnormally thin (7 m) at Stair Hole [SY 822 798].

Distribution
Member defined in and limited to the Dorset coast region.

Table 3 Lithostratigraphical scheme for the Vectian Basin.



Notes:

LCSF	Luccombe Chine Sandstone Formation
CSCM	Culham Sands with Chert Member
ULBM	Upper Lobster Bed Member
EGM	Eggardon Grit Member
BHC	Boyne Hollow Chert Member

Previous names
None

Parent
Lulworth Formation

Age
Portlandian (sensu anglico). Tithonian to Berriassian (Tethyan).

References
Westhead and Mather, 1996

4.1.1.2 RIDGEWAY MEMBER

Name
Introduced by Westhead and Mather (1996)

Type section
Old quarry at Ridgeway [SY 6712 8515], near Upwey

Primary reference section
None

Formal subdivisions
None

Lithology
In south central Dorset, comprises dark greyish brown, carbonaceous muds and pale marls and micrites, commonly containing thin detrital quartz laminations that form isolated ripples. The mudstones are replaced in east Dorset by micritic limestone, and at Durlston Bay, where the succession becomes very monotonous, it is difficult to distinguish the member.

Definition of upper boundary
Conformable, at the top of mudstone beds beneath thick-bedded, ripple cross-laminated, quartz-detrital limestone of the overlying the Worbarrow Tout Member.

Definition of lower boundary
Conformable at the first significant occurrence of dark grey or brown mudstones above thickly-bedded, ostracod-rich limestone of the Mupe Member.

Thickness
Between 3 and 7 m

Distribution
Member defined in and limited to the Dorset coast region.

Previous names
None

Parent
Lulworth Formation

Age
Berriasian (Tethyan) or Late Volgian (Boreal)

References
Westhead and Mather, 1996

4.1.1.3 WORBARROW TOUT MEMBER

Name
Introduced by Westhead and Mather (1996)

Type section
West side of Worbarrow Tout

Primary reference section
None

Formal subdivisions
None

Lithology
In south central Dorset, the lower part of the member contains prominent brown-weathering limestones containing detrital quartz (Hard Cockle Beds) and exhibiting abundant ripple cross-laminations. The rest of the member comprises characteristic, regularly interbedded, white-weathering micrite and dark grey mudstone (Soft Cockle and Marly Freshwater beds). Salt pseudomorphs, hard grounds and rare algal laminations are present in the micrites, particularly in the middle part of the member. Algal lamination increases in significance in the east and may be associated with zones of multiple hardgrounds. Gypsum is present at Worbarrow Tout and Durlston Bay. The highest part of the member comprises thicker-bedded, chert-rich micrites (Cherty Freshwater Beds).

Definition of upper boundary
Conformable, at the top of thickly-bedded cherty pure micrites (Cherty Freshwater Beds) beneath very shelly micrite (Cinder Bed at the base of the Stair Hole Member).

Definition of lower boundary
Conformable. First occurrence of significant, commonly ripple cross-laminated, quartz-detrital limestone (base Hard Cockle Beds) above mudstones of the Ridgeway Member.

Thickness
Ranges from 17 m in south central Dorset to 39 m in the east.

Distribution
Member defined in and limited to the Dorset coast region.

Previous names
None

Parent
Lulworth Formation

Age
Berriasian (Tethyan)

References
Westhead and Mather, 1996

4.1.2 Durlston Formation

In Dorset the formation is divided into the Stair Hole Member below and the Peveril Point Member above.

See entry within Section 3

4.1.2.1 STAIR HOLE MEMBER

Name
Introduced by Westhead and Mather (1996)

Type section
Central part of Durlston Bay, Swanage, Dorset [SZ 0384 7842 to 0396 7856]

Primary reference section
East cliff at Stair Hole, Dorset [SY 8229 7983]

Formal subdivisions
None

Lithology
The member is characterised by calcarenites and calcirudites. These are thicker and dominant lower in the succession; the Cinder Bed at the base of the member comprises a package of biomicrites, with abundant oysters, and can be easily correlated across the region. This passes up into a succession of interbedded biosparites, biomicrites and mudstones (Intermarine and Scallop beds). The limestone may contain cross-stratification, particularly in the east. Thicker, carbonaceous mudstones, with numerous 'beef' (fibrous calcite) veins, become more common towards the top of the member (Corbula and Chief Beef beds), particularly in the east. The middle part of the member, across Dorset, contains detrital quartz. The upward decrease in shelly limestone defines a crude fining-upwards succession.

Definition of upper boundary
Conformable, at the top of thicker mudstones and finer grained biosparites or micrites beneath thickly bedded, coarse biosparite (base Broken Shell Limestone Bed) at the base of the overlying Peveril Point Member.

Definition of lower boundary
Conformable, at the first occurrence of very shelly micrite (Cinder Bed) above more pure micrites of the Worbarrow Tout Member.

Thickness
Ranges from 10 m in south central Dorset to 40 m in the east.

Distribution
Member defined in and limited to the Dorset coast region.

Previous names
None

Parent
Durlston Formation

Age
Berriasian (Tethyan) or early Ryazanian (Boreal)

References
Westhead and Mather, 1996

4.1.2.2 Peveril Point Member

Name
Introduced by Westhead and Mather (1996)

Type section
Peveril Point, north end of Durlston Bay, Dorset [SZ 0396 7856 to 0414 7865]

Primary reference section
Eastern part of Mupe Bay, Dorset around [SY 8432 7972]

Formal subdivisions
None

Lithology
Calcarenites and calcirudites (rich in bioclastic material) interbedded with carbonaceous clays. The base is defined by thick massive-bedded limestones containing fragmented shells (Upper Broken Shell Limestone Bed). This passes (and fines) upwards into a biomicrite and carbonaceous mud-dominated succession with glauconite-rich beds, which, in the west, are also commonly rich in detrital quartz (Unio Bed, Upper 'Cypris' Clays and Shales Beds). The limestones in this part of the member contain abundant Unio and Viviparus.

Definition of upper boundary
Last occurrence of significant limestone beds (containing Unio and Viviparus) beneath monotonous sandy mudstones of the Wealden Group.

Definition of lower boundary
At the first upward occurrence of thickly bedded, coarse biosparite limestones (i.e. the base of the Broken Shell Limestone Bed) resting on muds and finer-grained biosparites or micrites at the top of the Stair Hole Member.

Thickness
Between 7 and 17 m in Dorset

Distribution
Member defined in and limited to the Dorset coast region. Upwey to Swanage in Dorset.

Previous names
Friar Waddon Member
Upper Purbeck Beds (parts)

Parent
Durlston Formation

Age
Berriasian (Tethyan) or Late Ryazanian (Boreal)

References
Westhead and Mather, 1996

4.2 WEALDEN GROUP

Boundary definitions are repeated here from Section 3 for clarity.

Definition of upper boundary
Unconformable within the Vectian Basin (Isle of Wight) at the sharp contact between the dark finely bedded mudstones of the Vectis Formation (formerly the Wealden Shales) and the dark grey to black mudstones of the Atherfield Clay Formation (at the base of the 'Perna Beds' of Casey, 1961).

See also entry within Section 3.2

Definition of lower boundary
In the Vectian Basin at the conformable base of the undivided Wealden Group non-marine sandstones and siltstones (or at the base of the Wessex Formation on the Isle of Wight) resting on the calcareous mudstones and limestones of the Purbeck Group (Durlston Formation).

See also entry within Section 3.2

4.2.1 Wessex Formation

Name
Name adopted by Daley and Stewart (1979) to replace the traditional term Wealden Marls (Osborne White, 1921).

Type section
Coastal and landslipped section at Bacon Hole [SY 841 797] and Mupe Bay [SY 844 797 to 847 802], Dorset.

Primary reference section
Coastal section at Swanage Bay [SZ 038 808], Punfield Cove [SZ 037 807], Dorset.

Formal subdivisions
None

Lithology
Varicoloured (mainly red) mudstones with subordinate unconsolidated sandstones (generally white or pale yellow as well as red) and some ironstones. Sandstone units generally fine-upwards from basal conglomerates grading up into mudstone. The sandstone units that usually exhibit large-scale trough or planar cross-bedding, pass up into climbing ripple-laminated sandstones and are surmounted by interbedded sands and muds. Throughout the succession are plant-rich horizons (including large logs). Westward, on the mainland through Dorset, sandstone units thicken and some significant coarse sand, grit and pebble beds act as markers locally.

Definition of upper boundary
The top of the formation on the Isle of Wight is placed at the abrupt colour change from the predominantly red mudstones of the Wessex Formation up into the dull grey finely-bedded mudstone and sandstone of the Vectis Formation. This is also true in the Swanage section on the mainland.

Further west into Dorset, the Vectis Formation is absent due to pre-Lower Greensand or pre-Gault erosion, and the boundary is placed at the upward change from brightly coloured sandstones or calcareous mudstones (marls) of the undivided Wealden Group to dark siltstones, mudstones and ironstones or fine-grained sandstones of the Lower Greensand Group, or mudstones of the Gault Formation. In both cases the boundary can be marked by a pebble bed.

Definition of lower boundary
Base not seen on the Isle of Wight at outcrop but identified in the Arreton Borehole SZ58NW2 [5307 8564] (Falcon and Kent, 1960). Elsewhere, on the coast at Swanage, Lulworth Cove and Worbarrow Bay, the base is rarely seen. Strahan (1898) wrote 'no line can be drawn which does not either include beds of Purbeck type in the Wealden or beds of Wealden type in the Purbeck'. In practice the boundary is taken at the top of the last significant limestone in the top of the underlying Peveril Point Member of the Durlston Formation. The most complete sections are at Bacon Hole [SY 841 797] west of Mupe Bay [SY 844 797]. The the former is described in Strahan (1898, pp. 100–101) where he placed the boundary at the junction between a fossiliferous ironstone and a clay with laminae of sand. Hesselbo and Allen (1991) placed the boundary 2.35 m below a 'basal' fine-grained sandstone (their unit 1) at a point where thin sand laminae first appear in the succession.

Thickness
About 580 m on the Isle of Wight. Some 800–1000 m thick at Swanage and thins westward through Dorset to about 425 m at Worbarrow Bay and to 65 m at Durdle Cove, the formation's most westerly coastal outcrop.

Distribution
Isle of Wight and south Dorset from Swanage to Durdle Door. Other outcrops occur inland in the Upton Syncline, north of Ringstead Bay, Bincombe railway cutting and Arkell (1947a) records ?Wealden as far west as Friar Waddon near Weymouth.

Previous names
Wealden Marls
Variegated Marls and Sandstones

Parent
Wealden Group

Age
Late Ryazanian to Barremian

References
Arkell, 1947a; Daley and Stewart, 1979; Falcon and Kent, 1960; Hesselbo and Allen, 1991; Insole, Daley and Gale, 1998; Osborne White, 1921; Strahan, 1898.

4.2.2 Vectis Formation

Name
Name adopted by Daley and Stewart (1979) to replace the traditional term Wealden Shales (Reid and Strahan, 1889; Osborne White, 1921).

Type section
Brightstone Bay, Isle of Wight, from Atherfield Point [SZ 452 791] north-westward towards Barnes Chine [SZ 435 808] from where each of the three members have been defined by Daley and Stewart (1979), and Stewart (1981). The section from Atherfield Point to Hanover Point [SZ 379 837] shows the whole of the exposed Wealden Group in the degraded cliffs with the Wessex Formation forming the core of the Brightstone Anticline a cliff base. A repeat of the Vectis Formation is seen from Hanover Point north-westward along the cliff forming Compton Bay [SZ 36 85].

Primary reference section
Sandown Bay, Isle of Wight from the Yaverland [SZ 611 850] to Red Cliff [SZ 620 853].

Formal subdivisions
Divided into three members by Daley and Stewart, (1979) and Stewart (1981) based on the type site with, from the base, the Cowleaze Chine Member, the Barnes High Member and the Shepherd's Chine Member being defined.

Lithology
Dark grey siltstones and mudstones with subordinate beds of sandstone, shelly limestone, clay ironstone and ironstone. Often described as shale or paper shale and the whole is generally finely and evenly bedded.

Definition of upper boundary
At the change from grey mudstones with an eroded and burrowed upper surface in contact with the dark green to greyish green basal glauconitic very shelly sandstone of the Perna Bed Member (Insole et al., 1998) of the Atherfield Clay Formation. This boundary is generally some 4–5 m above a distinctive shelly limestone associated with a 'Beef-Bed' (fibrous calcite commonly showing cone-in-cone structures).

Definition of lower boundary
Conformable and marked by an abrupt colour change from the bright (usually red tinged) Wessex Formation friable sandstones and calcareous mudstones to the dull grey and

blue-grey mudstones of the Vectis Formation. In the Isle of Wight memoir the section at Brixton Bay (p. 13), now called Brightstone Bay, places the lower boundary at the base of 'red sand with bones' (the 'Hypsilophodon Bed') (Osborne White, 1921).This 'bone bed' (a red pedogenic siltstone) is now considered as being several metres below the base of the formation as alluded to in the footnote on that memoir page.

Thickness
Maximum of c. 66 m on the Isle of Wight

Distribution
Isle of Wight and Dorset in the vicinity of Swanage. Westward and northward the formation is removed by erosion.

Previous names
Wealden Shales

Parent
Wealden Group

Age
Barremian to earliest Aptian. The MO magnetochron appears in the upper part of the Shepherd's Chine Member (Kerth and Hailwood, 1988).

References
Arkell, 1947a; Daley and Stewart, 1979; Insole, Daley and Gale, 1998; Kerth and Hailwood, 1988; Osborne White, 1921; Stewart, 1981.

4.2.2.1 Cowleaze Chine Member

Name
Name adopted by Stewart (1978) and given formal member status by Daley and Stewart (1979).

Type section
West of Cowleaze Chine, [SZ 4426 8013] Brightstone Bay, Isle of Wight specifically from Barnes High [SZ 4373 8070] to just west of Shepherd's Chine [SZ 4462 7988].

Primary reference sections
Sandown Bay, Red Cliff, Isle of Wight, from [SZ 6178 8526] eastward.
Compton Bay, west of Shippard's Chine [SZ 3750 8440].

Formal subdivisions
Informal White Rock at the base of the member.

Lithology
Comprises finely interlaminated dark grey mudstone and pale grey silt/fine-grained sandstone. In places arranged into thin fining-upwards units. Mudstones intensely bioturbated. In some areas a 1 m thick white fine sandstone (the White Rock) occurs at the base.

Definition of upper boundary
The boundary is conformable at a variable change from grey mudstones into medium-grained yellow sandstone. In places the boundary is abrupt and in others gradational. The boundary is defined at the base of the first up-succession medium-grained yellow sandstone whether this is in the form of a continuous bed or a discontinuos lenticular layer (Insole et al., 1998).

Definition of lower boundary
Conformable and marked by an abrupt colour change from the bright (usually red tinged) Wessex Formation friable sandstones and calcareous mudstones to the dark grey and pale grey mudstones of the member. In places a bone-bed marks this boundary (the 'Hypsilophodon Bed') as described in the Isle of Wight Memoir (Osborne White, 1921).

Thickness
Between 7 and 10 m

Distribution
Isle of Wight

Previous names
Part of the Wealden Shales

Parent
Vectis Formation

Age
Barremian

References
Arkell, 1947a; Daley and Stewart, 1979; Insole, Daley and Gale, 1998; Kerth and Hailwood, 1988; Osborne White, 1921; Stewart, 1981.

4.2.2.2 Barnes High Sandstone Member

Name
Name adopted by Stewart (1978) and given formal member status by Daley and Stewart (1979).

Type section
Barnes High [SZ 4376 8068] to Shepherd's Chine [SZ 4466 7982] in Brightstone Bay, Isle of Wight.

Primary reference sections
Sandown Bay, Isle of Wight from Yaverland [SZ 6140 8510] to Red Cliff [SZ 6174 8524].
Compton Bay, west of Shippard's Chine [SZ 3750 8440].

Formal subdivisions
None, member is represented by one or more un-named sandstone units.

Lithology
Medium-grained yellow to grey sandstone as a single unit. In Compton Bay the member comprises three coarsening-upward sandstones separated by laminated mudstones. Topmost bed usually comprises a thin mudstone and bivalve conglomerate.

Definition of upper boundary
Conformable at a sharp but irregular contact between medium-grained sandstone (or mudstone/bivalve conglomerate) and rhythmically bedded fine-grained sandstones, siltstones and mudstones.

Definition of lower boundary
Conformable and marked by an abrupt or gradational change from grey mudstone and fine-grained sandstone to medium-grained yellow sandstone.

Thickness
Between 2.5 and 7 m

Distribution
Isle of Wight

Previous names
Sandstone of Cowleaze Down and Barnes High (Osborne White, 1921).

Parent
Vectis Formation

Age
Barremian

References
Arkell, 1947a; Daley and Stewart, 1979; Insole, Daley and Gale, 1998; Kerth and Hailwood, 1988; Osborne White, 1921; Stewart, 1981.

4.2.2.3 Shepherd's Chine Member

Name
Name adopted by Stewart (1978) and given formal member status by Daley and Stewart (1979).

Type section
Brightstone Bay, Isle of Wight, from Atherfield Point [SZ 452 791] north-westward towards Barnes Chine [SZ 435 808].

Primary reference sections
Sandown Bay, Isle of Wight from the Yaverland [SZ 6150 8514] to Red Cliff [SZ 6209 8532].
Compton Bay, west of Shippard's Chine [SZ 3750 8440].

Formal subdivisions
None but up to 65 thin fining-upwards units can be recognised.

Lithology
Light to dark grey fine-grained sandstones, siltstones and mudstones rhythmically-bedded in up to 65 thin fining upward units. Each unit comprises a light grey fine-grained sandstone or siltstone with a sharp and erosional contact at the base, passing up into dark grey mudstone. Several thin muddy limestones comprising bivalve and other shell concentrates occur in the higher parts of the succession together with a 'beef-bed' (see sections in Osborne White, 1921).

Definition of upper boundary
At the change from grey mudstones with an eroded and burrowed upper surface in contact with the basal dark green to greyish green, glauconitic, very shelly sandstone of the Perna Bed Member (Insole et al., 1998) of the Atherfield Clay Formation. This boundary is generally some 4–5 m above a distinctive shelly limestone associated with a 'Beef-Bed' (fibrous calcite commonly showing cone-in-cone structures).

Definition of lower boundary
Conformable at a sharp but irregular contact between medium-grained sandstone (or mudstone/bivalve conglomerate) and rhythmically-bedded fine-grained sandstones, siltstones and mudstones.

Thickness
About 50 m on the Isle of Wight

Distribution
Isle of Wight

Previous names
None

Parent
Vectis Formation

Age
Barremian to earliest Aptian. The MO magnetochron appears in the upper part of the Shepherd's Chine Member (Kerth and Hailwood, 1988).

References
Arkell, 1947a; Daley and Stewart, 1979; Insole, Daley and Gale, 1998; Kerth and Hailwood, 1988; Osborne White, 1921; Stewart, 1981.

4.3 LOWER GREENSAND GROUP

See entry within Section 3

4.3.1 Atherfield Clay Formation

See entry within Section 3

On the Isle of Wight five members have been identified in Chale Bay (Simpson, 1985) but only the lowest Perna Member can be identified with certainty elsewhere on the island or mainland outcrops of the Weald and Dorset. Brief definitions of the members are given below for completeness, however the names have been modified from those of Simpson (1985) and the word 'bed' has been removed to prevent confusion and conform to Hedbergian principles.

4.3.1.1 Perna Member

Name
Perna Beds Member of Simpson (1985) adapted herein to Perna Member

Type section
Defined as the coastal cliff section of Chale Bay Isle of Wight between Shepherd's Chine [SZ 4466 7982] and Whale Chine [SZ 4684 7825].

Primary reference sections
The coastal cliff section at Compton Bay [SZ 372 848], Isle of Wight.
The coastal cliff section at Red Cliff, Sandown [SZ 626 855].

Formal subdivision
None but divided into two subdivisions: 1 (Lower Clay and the Atherfield Bone Bed) and 2 (Upper Sandstone) in Simpson (1985). These correspond to beds 1 and 2 of Fitton (1847).

Lithology
Grey brown to dark blue, sandy mudstone with bivalves, overlain by greenish, calcareous, coarse-grained sandstone. The beds are fossiliferous throughout and the lower Bed 1 of Simpson (1985) includes basal coarse-grained quartz 'grit' with bone fragments, fish teeth, phosphatic nodules and rolled ammonites (the Atherfield Bone Bed of Simpson).

Definition of upper boundary
Boundary at the upward change from coarse-grained greenish sandstone (Simpson, 1985, Bed 2) into 'chocolate' brown to pale bluish grey mudstone (Simpson, 1985, Bed 3).

Definition of lower boundary
Disconformable contact between the grey rhythmically bedded sandstones and mudstones of the Shepherd's Chine Member (Vectis Formation) and the fossiliferous coarse-grained quartz 'grit' of the Atherfield Bone-Bed (Simpson, 1985)

Thickness
1.8 m

Distribution
The member is only clearly distinguished on the Isle of Wight. Elsewhere equivalents of the Atherfield Bone Bed or Perna Member are known from Dorset (Punfield Cove) and around the Weald in Sussex, Surrey and Kent.

Previous names
Perna Beds Member (Simpson, 1985)
The Perna Bed (Fitton 1847, Beds 1 and 2)
The Perna Mulleti Bed (Fitton, 1847)

Parent
Atherfield Clay Formation

Age
Early Aptian

References
Simpson, 1985; Fitton, 1847

4.3.1.2 Chale Clay Member

Name
Name proposed by Simpson (1985)

Type section
Defined as the coastal cliff section of Chale Bay Isle of Wight between Shepherd's Chine [SZ 4466 7982] and Whale Chine [SZ 4684 7825]. Specifically the steep cliff at Atherfield Point [SZ 4535 7905].

Primary reference sections
The coastal cliff section at Compton Bay [SZ 372 848], Isle of Wight.
The coastal cliff section at Red Cliff, Sandown [SZ 626 855].

Formal subdivision
None. Informally divided into four units (beds 3 to 6) by Simpson (1985).

Lithology
Pale bluish grey mudstone, 'chocolate' brown at the base. Bed 3 is a 'chocolate' brown mudstone 'gritty at base overlain by pale blue sandy mudstone with fragments of pyritised wood, bivalves and clay-ironstone nodules. Bed 5 is a brown mudstone with a cementstone at its base is overlain by the major part of the member that comprises pale bluish, poorly laminated grey mudstone with irregular small nodules and red clay-ironstone nodules.

Definition of upper boundary
The boundary is placed (Simpson, 1985) at the base of his Bed 7 that is identified by the upward change from pale grey, poorly-laminated mudstone (of Bed 6) into pale blue grey mudstone with small brown nodules.

Definition of lower boundary
Conformable at the boundary between hard, greenish, calcareous, coarse-grained sandstone (Simpson, 1985, Bed 2) and the slightly 'gritty' base of 'chocolate-brown' mudstone (Simpson, 1985, Bed 3).

Thickness
Between 18 and 19 m

Distribution
Isle of Wight at the type site. Not easily distinguished elsewhere in the outcrop or absent.

Previous names
Atherfield Clay sensu Fitton (1847 p. 296, part of Bed 3).

Parent
Atherfield Clay Formation

Age
Early Aptian

References
Simpson, 1985; Fitton, 1847

4.3.1.3 Lower Lobster Member

Name
Lower Lobster Bed Member of Simpson (1985) adapted herein to Lower Lobster Member.

Type section
Defined as the coastal cliff section of Chale Bay Isle of Wight between Shepherd's Chine [SZ 4466 7982] and Whale Chine [SZ 4684 7825].

Primary reference sections
The coastal cliff section at Compton Bay [SZ 372 848], Isle of Wight.
The coastal cliff section at Red Cliff, Sandown [SZ 626 855].

Formal subdivision
None, but informally divided into six units (Beds 7 to 12) by Simpson (1985).

Lithology
Pale blue grey mudstone with brown nodules (Bed 7) passing up into thin dark blue micaceous mudstone with yellow sand lenses (Bed 8), into brown sandy mudstone (Bed 9), dark blue micaceous mudstone with yellow sandy lenses (Bed 10), laminated and sporadically glauconitic brown sandy mudstone (Bed 11) and dark blue argillaceous sandstone (Bed 12).

Definition of upper boundary
Boundary placed at the upward conformable change from dark blue argillaceous sandstone of Simpson (1985) Bed 12 into the compact dark blue sandstone of Simpson (1985) Bed 13. This boundary is gradational.

Definition of lower boundary
The conformable boundary is placed (Simpson, 1985) at the base of his Bed 7 that is identified by the upward change from pale grey, poorly-aminated mudstone into pale blue grey mudstone with small brown nodules.

Thickness
Some 11.6 m at the type site

Distribution
Distiguished at the type site but difficult to delimit in other outcrops.

Previous names
Originally named by Charles Wheeler, Fitton's fossil collector. Part of the 'Crackers Group' of Fitton (1847, Bed 4 and part of Bed 3).

Parent
Atherfield Clay Formation

Age
Early Aptian

References
Simpson, 1985; Fitton, 1847

4.3.1.4 The Crackers Member

Name
The term Crackers Member used herin in the sense of Simpson (1985).

Type section
Defined as the coastal cliff section of Chale Bay Isle of Wight between Shepherd's Chine [SZ 4466 7982] and Whale Chine [SZ 4684 7825].

Primary reference sections
The coastal cliff section at Compton Bay [SZ 372 848], Isle of Wight.
The coastal cliff section at Red Cliff, Sandown [SZ 626 855].

Formal subdivision
None, but informally divided into two (Beds 13 and 14) by Simpson (1985).

Lithology
Dark blue well-packed sandstone (Bed 13), overlain by harder brown sandstone (Bed 14) with seams of phosphatic nodules near the base and top of the member. Both contain a single discontinuous seam of fossiliferous large doggers.

Definition of upper boundary
Boundary placed at the conformable upward change from hard brown sandstone (Bed 14) into sporadically glauconitic brown sandy mudstone (Bed 15).

Definition of lower boundary
Boundary placed at the upward conformable change from dark blue argillaceous sandstone of Simpson (1985) Bed 12 into the dark blue well-packed sandstone of Simpson (1985) Bed 13. This boundary is gradational.

Thickness
Some 6.0 m at the type site

Distribution
Isle of Wight and Dorset with equivalent beds in the Weald.

Previous names
Part of the 'Crackers Group' of Fitton (1847, Bed 5).

Parent
Atherfield Clay Formation

Age
Early Aptian

References
Simpson, 1985; Fitton, 1847

4.3.1.5 Upper Lobster Member

Name
Upper Lobster Bed Member of Simpson (1985) adapted herein to Upper Lobster Member.

Type section
Defined as the coastal cliff section of Chale Bay Isle of Wight between Shepherd's Chine [SZ 4466 7982] and Whale Chine [SZ 4684 7825]. Seen at beach level 0.9 km [SZ 4610 7880] west of Whale Chine.

Primary reference sections
The coastal cliff section at Compton Bay [SZ 372 848], Isle of Wight.
The coastal cliff section at Red Cliff, Sandown [SZ 626 855].

Formal subdivision
None, but informally divided by Simpson (1985) into five units (Beds 15 to 19).

Lithology
Alternations of dark grey sandy mudstone (Beds 15, 17 and 19) and medium to dark grey firm sandstone (Beds 16 and 18) with flat nodules in lower two 'beds'.

Definition of upper boundary
The boundary is placed at the rapid conformable change from dark grey sandy mudstone of Bed 19 (Simpson, 1985) up into the muddy glauconitic sandstones of the Ferruginous Sands Formation.

Definition of lower boundary
Boundary placed at the conformable upward change from hard brown sandstone (Bed 14) into sporadically glauconitic brown sandy mudstone (Bed 15).

Thickness
About 14.5 m at the type site

Distribution
Isle of Wight and in Dorset with equivalent beds around the Weald.

Previous names
Part of the 'Crackers Group' of Fitton (1847, Beds 6 to 10).

Parent
Atherfield Clay Formation

Age
Early Aptian

References
Simpson, 1985; Fitton, 1847

4.3.2 Ferruginous Sands Formation

Name
Term, as Ferruginous Sands, first used by Reid and Strahan (1889) in the second edition of the Geology of the Isle of Wight Old Series Memoir based on the work of Fitton (1847). The Ferruginous Sands Formation is used in Insole, Daley and Gale (1998).

Type section
Coastal section between Chale Bay [SZ 453 791], south-east of Atherfield Point to Rocken End [SZ 489 761], Isle of Wight.

Primary reference section
Coastal section at Punfield Cove [SZ 037 807] in Swanage Bay, Dorset.

Formal subdivisions
The succession at Chale Bay is divided into eleven units considered to be of member status in Insole et al. (1998) and whose numbering follows on from the members as defined by Fitton (1847, 'Groups' I, II and III) of the preceding Atherfield Clay Formation. The 'members' of Insole et al. (1998) are difficult to recognise and trace laterally away from the type site of Chale Bay and must therefore be regarded as informal terms within this report. The 'members', in ascending order, are Member IV, Member V, Member VI, Whale Chine Member, Member VIII, Ladder Chine Member, Member X, Member XI, Old Walpen Chine Member, New Walpen Chine Member, Member XIV and Member XV.

Lithology
The formation comprises a number of heavily bioturbated coarsening-upward units each comprising dark grey sandy muds or muddy sands passing up into fine- to medium-grained grey to green glauconitic sands. Weak cementation occurs at the top of many of the units producing discontinuous calcareous, phosphatic or pyritic concretions that are generally fossiliferous. The middle of the formation contains plant debris. Eleven units (IV to XV) described as 'members' are informally identified within the succession (see above). Full lithological descriptions for each of these informal members are given in Insole et al. (1998, pp. 65–68).

Definition of upper boundary
The upper boundary has been defined in a number of ways. Fitton (1847) and Casey (1961) placed the boundary at the top of their 'Group XV' (equivalent to Member XV), where coarsening-upward estuarine silty mudstones pass up into interlaminated black clays and white sands (of their Ferruginous Sands) and are overlain by the white, quartzose sands of the Sandrock Formation. This boundary (Fitton, 1847; Casey, 1961) is a scoured erosion surface separating the estuarine mudstones from marine sandstones with a highly burrowed and indurated top. It marks a sequence boundary and is the current definition of the base of that succeeding unit (Insole et al., 1998; Ruffell and Wach, 1998).

Wach and Ruffell (1990) placed the boundary within Member XV where the estuarine silty mudstone passes up into the interlaminated black clays and white sands. They regarded this unit as a transitional bed of estuarine mudstone passing up into the estuarine sands of the Sandrock Formation. The underlying ferruginous, glauconitic sands and sandstones are essentially marine.

Definition of lower boundary
The lower boundary is marked via a narrow transition from silty clays of the Upper Atherfield Clay Formation (the Upper Lobster Member) up into ferruginous sands and sandstones with concretions.

Thickness
Up to about 161 m

Distribution
Isle of Wight and southern Dorset

Previous names
Ferruginous Sand
Ferruginous Sands

Parent
Lower Greensand Group

Age
Early and Late Aptian

References
Arkell, 1947b; Casey, 1961; Fitton, 1847; Insole, Daley and Gale, 1998; Reid and Strahan, 1889; Ruffell and Wach, 1998; Strahan, 1898; Wach and Ruffell, 1990.

4.3.3 Sandrock Formation

Name
Term Sandrock Series first used by Reid and Strahan (1889) in the second edition of the Geology of the Isle of Wight Old Series Memoir. Sandrock Formation appears in Insole, Daley and Gale (1998).

Type section
Chale Bay [SZ 47], Rocken End [SZ 4908 7554] to Blackgang Chine [SZ 4850 7692].

Primary reference sections
Compton Bay [SZ 370 850]
Punfield Bay [SZ 037 807]
Luccombe Bay and Luccombe Chine [SZ 583 793]
Red Cliff [SZ 619 853], Sandown Bay

Formal subdivisions
None

Lithology
The Sandrock Formation comprises up to four upward coarsening sedimentary rhythms. Although rarely complete, a full rhythm comprises in ascending order: pebble beds overlying a scoured surface; bioturbated very dark grey mudstone and finely laminated, fine-grained sands and silts; well-sorted fine to coarse-grained sands, frequently cross-bedded with a scoured top.

Sands with small-scale cross-bedding are believed to have been deposited as migrating shoals in shallow water, estuarine conditions, whereas the large scale cross-bedded sands are considered to be subtidal channels (Wach and Ruffell, 1990; Insole, Daley and Gale, 1998; Ruffell and Wach, 1998a, b).

Definition of upper boundary
The top of the formation is an eroded surface where there is a change from rhythmical bedded fine- to coarse-grained sands, with generally large- and small-scale cross-bedding, dark grey mudstones and pebble beds below, up into gritty, reddish-brown sandstone with pebbles and phosphatic nodules (the Monk's Bay Sandstone Formation herein and equivalent to the Carstone Formation of the Isle of Wight) above. This depositional break is called the 'Mid *tardefurcata* break' by Casey (1961).

Definition of lower boundary
The lower boundary is defined at the base of a conspicuous thick band of black muds at the base of the upward-coarsening rhythmical succession of pebble beds, dark glauconitic mudstone, fine to coarse-grained, generally cross-bedded, sandstone of the Sandrock Formation. This rests on the grey and green glauconitic sands of the uppermost member of the Ferruginous Sands Formation.

Thickness
Up to 70 m

Distribution
Isle of Wight and in the neighbourhood of Punfield Bay, Dorset. The unit is not separately mapped on the mainland having been incorporated into an undivided Lower Greensand Group.

Previous names
Sandrock Series
Sandrock [Isle of Wight]

Parent
Lower Greensand Group

Age
Late Aptian to Early Albian

References
Arkell, 1947b; Casey, 1961; Fitton, 1847; Insole, Daley and Gale, 1998; Osborne White, 1921 [1994 reprint]; Rawson et al., 1978; Reid and Strahan, 1889; Ruffell and Wach, 1998; Strahan, 1898; Wach and Ruffell, 1990.

4.3.4 Monk's Bay Sandstone Formation (formerly the Carstone Formation (Isle of Wight))

Name
The term carstone has been used historically to denote a lithological unit characterised by ferruginous, coarse-grained sand and sandstone. It has become used in a quasi-formal way for deposits on the Isle of Wight (Reid and Strahan, 1889) and within the East Midland Shelf area (Strahan, 1886 in Lincolnshire; Whitaker and Jukes-Browne, 1899 in Norfolk) for two distinct units. It is proposed that the Carstone of the Isle of Wight be renamed the Monk's Bay Sandstone Formation to avoid the common confusion caused by this dual use.

Type section
The Monk's Bay cliff section [SZ 579 780] is the parastratotype as it does not contain the full succession. The section exposes 10.5 m of ferruginous and pebbly sandstones and grit between the Sandrock Formation at the base and Gault Formation at the top (Osborne White, 1921). See also Red Cliff section below.

Primary reference sections
The unit is seen at the top of the cliff on either side of Luccombe Chine [583 793] and then to the south and south-westward to Bonchurch where the 'Carstone is finely displayed' (Osborne White, 1921). Access is frequently difficult although the beach is strewn with blocks of this unit.

Near the chalybeate spring (a term denoting iron-rich waters or a mineral spring) about 200 m north-west of South View House, south-east of Blackgang Chine [SZ 485 767] (Osborne White, 1921).

The coastal section north of Red Cliff [SZ 627 856] where about 22 m of brown sandstones and argillaceous gritstones are situated between the Sandrock and Gault formations represents the thickest succession on the island but access is difficult (Osborne White, 1921, p. 30). Although Red Cliff would be the natural name for this unit the principal red units in the cliffs are those of the Ferruginous Sand with only a relatively inaccessible red bed at the top of the cliffs being the 'Carstone'.

Formal subdivisions
None

Lithology
Osborne White (1921) described the formation as 'highly ferruginous coarse sand or grit' and Casey (1961) described it as 'gritty, reddish-brown sands with pebbles and phosphatic nodules.' There is a concentration of nodules at the base. The nodules contain abundant shelly material including ammonites, gastropods and bivalves.

Definition of upper boundary
The upper boundary is gradational, where the reddish brown ferruginous coarse-grained sandstones of the Monk's Bay Sandstone Formation pass up into dark grey mudstones of the Gault Formation.

Definition of lower boundary
The base of the formation is a sharp eroded surface where there is a marked down-section change from gritty, reddish-brown sandstone to the yellow and white quartz sandstone at the top of the underlying rhythmical succession of the Sandrock Formation. This depositional break is called the 'Mid *tardefurcata* break' by Casey (1961).

Thickness
Up to 21.9 m at Red Cliff. Thickens towards the north-east from as little as 5 cm at Punfield on the Dorset coast, and on the Isle of Wight, to 1.8 m at Compton Bay, 3.7 m at Blackgang, 9.1 m at Bonchurch (Osborne Wight, 1921).

Distribution
The Monk's Bay Sandstone Formation outcrops between Red Cliff, in the east, and Compton Bay, in the west, although away from the coast it is rarely seen in section. It is also present between Luccombe Bay and Chale Bay on the southern part of the island, although here landslides obscure the unit in some areas. A few centimetres thickness of this unit was recorded at Punfield Cove [SZ 039 810], on the Dorset coast (Osborne White, 1921), although this is shown as undivided Lower Greensand on 1:50 000 scale Sheet 343.

Previous names
Group XVI (part) Fitton (1847)
Carstone (e.g. Reid and Strahan, 1889; Osborne White, 1921; Casey, 1961)

Parent
Lower Greensand Group

Age
Early Albian

References
Casey, 1961; Fitton, 1847; Insole, Daley and Gale, 1998; Osborne White, 1921 (1994 reprint); Reid and Strahan, 1889; Strahan, 1886; Whitaker and Jukes-Browne, 1899.

4.4 SELBORNE GROUP

See entry within Section 3

4.4.1 Gault Formation

See entry within Section 3

4.4.2 Upper Greensand Formation

See entry within Section 3

4.4.2.1 Cann Sand Member

Name
Name introduced by Bristow (1989) and formally described in Bristow et al. (1995).

Type area
The member is well developed around the hamlet of Cann [ST 871 211], south-east of Shaftesbury.

Primary reference section
Church Farm No.2 Borehole, Shaftesbury, ST82SE46 [8555 2223] (1.96–5.21 m depth).

Formal subdivisions
None

Lithology
Sand, fine-grained, glauconitic, micaceous with fine lenses or bioturbated laminae of micaceous, very fine-grained sand and silt.

Definition of upper boundary
The boundary is not usually observed and is probably gradational with an upwards decrease in silt and clay grade material and mica up into fine- to medium-grained glauconitic partially cemented sands. In field mapping terms the boundary is a well-marked feature break, presumably coinciding with incoming of cemented sandstone in the overlying Shaftesbury Sandstone.

Definition of lower boundary
Sharp incoming of fine-grained glauconitic sand above the dark grey sandy clay of the Gault Formation. Base commonly marked by a spring line.

Thickness
Between 16 and 30 m

Distribution
Outcrops in Dorset and Wiltshire including the Frome (281), Devizes (282), Wincanton (297), Salisbury (298), Shaftesbury (313), Bridport (327), Dorchester (328), and West Fleet & Weymouth (341 & 342) sheet areas.

Previous names
Glauconitic and micaceous sands of the zone of *Mortoniceras inflatum*.

Parent
Upper Greensand Formation

Age
Late Albian

References
Bristow, 1989; Bristow et al., 1995; Osborne White, 1923.

4.4.2.2 Shaftesbury Sandstone Member

Name
Name introduced by Bristow (1989, 1991a) and formally described in Bristow et al. (1995).

Type section
Old quarry [ST 8737 2227], 110 m at 295° from Mayo Farm, on north-east side of Boyne Hollow. Face now degraded, but section recorded by Jukes-Browne and Hill, 1900.

Primary reference section
None

Formal subdivisions
None but includes the informally named Ragstone at the top of the member.

Lithology
The member is an alternating succession of fine- to medium-grained glauconitic sand and sandstone. At the top, a massive, 2–3 m thick, shelly calcareous sandstone called the Ragstone is present in some areas.

Definition of upper boundary
In general the boundary is placed at the facies change from indurated, shell-rich sandstone without chert ('Ragstone') of the Shaftesbury Sandstone Member, to less indurated sandstone with regularly developed beds of chert of the Boyne Hollow Chert Member. Where the 'Ragstone' is absent the boundary is placed below the lowest chert bed or at a disconformity immediately beneath. The boundary is sometimes marked by phosphatic nodules in the Shaftesbury (Sheet 313) district, and may also be disconformable thereabouts. In some parts of the Shaftesbury district, the upper boundary is the unconformable contact with the Bookham Conglomerate Bed at the base of the Chalk Group.

Definition of lower boundary
The boundary is not usually observed and is probably gradational with an upwards decrease in silt and clay grade material and mica of the underlying Cann Sand Member up into fine- to medium-grained glauconitic partially cemented sands. In field mapping terms the boundary is a well-marked feature break, presumably coinciding with incoming of cemented sandstone in the overlying Shaftesbury Sandstone.

Thickness
Between 0 and 25 m (3.9 m exposed at type locality, of a total thickness of about 15 m).

Distribution
Found in Dorset and Wiltshire. Main outcrop from Fontmell Magna [ST 865 170] northwards across the Shaftesbury Sheet (313) and onto the Wincanton Sheet (297) but extends onto the Frome (281), Devizes (282), Wincanton (297), Salisbury (298), Ringwood (314), Bridport (327), Dorchester (328), West Fleet & Weymouth (341 & 342) sheet areas.

Previous names
Ragstone and Freestone Beds (Osborne White, 1923)
Ragstone Beds (Osborne White, 1923)
Ragstone (Drummond, 1970)

Parent
Upper Greensand Formation

Age
Late Albian

References
Bristow, 1989, 1991a; Bristow et al., 1995; Drummond, 1970; Jukes-Browne and Hill, 1900; Osborne White, 1923.

4.4.2.3 Boyne Hollow Chert Member

Name
Name introduced by Bristow (1989) and formally described in Bristow et al. (1995).

Type section
Old quarry [ST 8737 2227], 110 m at 295° from Mayo Farm near Shaftesbury, on the north-east side of Boyne Hollow. Section now obscured, but recorded by Jukes-Browne and Hill, 1900, p.160.

Primary reference section
None

Formal subdivisions
None

Lithology
Glauconitic sand and sandstone with regularly developed nodular and tabular beds of chert.

Definition of upper boundary
The upper boundary was originally defined as 'Above the highest bed of chert', in field mapping terms. It is best defined as the top of the highest few metres of the Boyne Hollow Chert Member frequently lacking in chert, which in boreholes and sections is more precisely defined by the base of the glauconitic, marl-rich, fossiliferous phosphatic nodule bed at the base of the overlying Melbury Sandstone Member (basal Chalk Group).

Definition of lower boundary
The boundary is placed generally at the base of loose shelly and phosphatic sands resting on the 'Ragstone' at the top of the Shaftesbury Sandstone Member. Elsewhere where the Ragstone is absent the boundary is placed at the base of the first chert bed or more frequently at an erosive contact between glauconitic sands a short distance below the first chert bed.

Thickness
Between 0 and 15 m (6.3 m+ at the type locality). Variable over the Mid-Dorset Swell (Drummond, 1970).

Distribution
In its type area is is seen from Compton Abbas [ST 870 185] northwards across the Shaftesbury sheet (313), and then across the Wincanton sheet (297). Further mapping has extended its distribution into the whole of Dorset and Wiltshire including 1:50 000 scale sheets 281 (Frome); 282 (Devizes); 298 (Salisbury); 314 (Ringwood); 341 and 342 (West Fleet and Weymouth).

Previous names
Chert Beds

Parent
Upper Greensand Formation

Age
Late Albian

References
Bristow, 1989; Bristow et al., 1995; Drummond, 1970; Jukes-Browne and Hill, 1900.

4.4.2.4 Eggardon Grit Member

Name
Term Eggardon Grit first used by Welch in Wilson et al. (1958) for the area around Bridport and Yeovil. Appears as Eggardon Grit Member on Geological Sheet 327 Bridport (England and Wales) (2005).

Type area
Eggardon Hill [SY 540 950], Dorset

Primary reference section
None

Formal subdivisions
None

Lithology
The lower part of the member is a white or grey, soft, friable calcite cemented sandstone, rich in shell fragments. The quartz grains are subangular to moderately well-rounded. The upper part of the member is less bioclastic and includes very coarse-grained sandstone formed of polished rounded quartz grains in a matrix of finer sand, with calcite cement. Scattered glauconite occurs in the upper part, but is usually insufficient to colour the rock. Locally, lumps of chert occur in the member (e.g. Thorncombe, Dorset). The top of the member is a phosphatised hardground (possibly equivalent to the Small Cove Hardground). Records of Cenomanian ammonites (Kennedy, 1970) may be from burrow infills at the base of the overlying Grey Chalk Subgroup.

Definition of upper boundary
At the top of the phosphatised Small Cove Hardground at the junction with the overlying Glauconitic Marl Member of the Grey Chalk Subgroup.

Definition of lower boundary
At the sharp contact between cemented calcareous shelly sandstone with the underlying glauconitic fine- to medium-grained sand of the Boyne Hollow Chert Member.

Thickness
Up to 3 m

Distribution
In Dorset on the Bridport Sheet 327

Previous names
Calcareous Grit (Wilson et al., 1958)

Parent
Upper Greensand Formation

Age
Late Albian

References
Jukes-Browne and Hill, 1900; Kennedy, 1970; Wilson et al., 1958.

4.4.2.5 Foxmould Member

Name
The term Foxmould was first used by De la Beche (1826) to describe part of the succession beneath the Chalk in the area around Lyme Regis and Beer in Devon. Appears as Foxmould Member on Geological Sheet 326 (pt 340) Sidmouth, (England and Wales, 2005).

Type section
Whitecliff and adjacent cliff sections [SY 235 895 to 234 893] at Seaton Hole, 2 km west of Seaton Esplanade, Devon.

Primary reference section
None

Formal subdivisions
None

Lithology
Sandstone, glauconitic, calcareous in part, greenish grey weathering to foxy brown (reddish-brown) sand; concretionary (doggers) and tabular sandy limestones at several levels.

Definition of upper boundary
The boundary is at the base of a mineralised hardground surface (Culverhole Hardground) above which concretionary calcareous sandstones are absent and cherts are common in the Whitecliff Chert Member.

Definition of lower boundary
In west Dorset's coastal sections there is a conformable and gradational transition from the sandy mudstones of the Gault Formation to the sandstones of the Foxmould Member. Elsewhere the boundary is placed at an unconformity where the Foxmould Member rests on strata ranging from Triassic (in west) to Lower Jurassic (in east).

Thickness
Between 30 and 32 m

Distribution
Devon and west Dorset. Mapped on Sheets 326 (Sidmouth) and 327 (Bridport); continuation on Sheet 311 (Wellington). Known to be present in the subcrop at least as far north as the Winterborne Kingston Borehole SY89NW1 [8470 9790] (300–324 m depth) (Rhys et al., 1982).

Previous names
Foxmould and Cowstone Beds
Foxmould
Foxmould Sands
Greensands

Parent
Upper Greensand Formation

Age
Late Albian

References
De la Beche, 1826; Edwards, Gallois and Hamblin, 2004; Jukes-Browne and Hill, 1900; Rhys, Lott and Calver, 1982; Woodward and Ussher, 1911.

4.4.2.6 Whitecliff Chert Member

Name
The term Whitecliff was first used by De la Beche (1826) to describe part of the succession beneath the Chalk in the area around Lyme Regis and Beer in Devon. The name as defined was adopted during the survey of the Sidmouth sheet (Edwards, Gallois and Hamblin, 2004).

Type section
Whitecliff, cliff section [SY 235 895 to 234 893] at Seaton Hole, 2 km west of Seaton Esplanade, Devon.
Primary reference section
None

Formal subdivisions
None

Lithology
Glauconitic and calcareous sandstones with numerous horizons of lenticular cherts; mineralised surfaces, pebble beds and shell detritus at several levels.

Definition of upper boundary
The boundary is placed at the hardground surface (Whitecliff Hardground) at top of member.

Definition of lower boundary
The boundary is placed at the hardground surface (Culverhole Hardground) overlying the Foxmould Member, below which chert is absent and calcareous sandstone doggers/ lenses are common.

Thickness
Up to 32 m

Distribution
Devon and west Dorset. Mapped on Sheets 326 (Sidmouth) and 327 (Bridport): continuation on Sheet 311 (Wellington).

Previous names
Chert Beds

Parent
Upper Greensand Formation

Age
Late Albian

References
De la Beche, 1826; Edwards, Gallois and Hamblin, 2004; Jukes-Browne and Hill, 1900; Rhys, Lott and Calver, 1982; Jukes-Browne and Hill, 1900; Woodward and Ussher, 1911.

4.4.2.7 Bindon Sandstone Member

Name
Name first used in the survey of the Sidmouth Sheet area and described first in Woods (1999), published in Edwards, Gallois and Hamblin (2004).

Type section
Bindon Cliff [SY 277 897], south-east of Axmouth, Devon.

Primary reference section
Shapwick Grange Quarry [SY 3130 9190], Edwards, Gallois and Hamblin (2004).

Formal subdivisions
None

Lithology
Fine- to coarse-grained, glauconitic sandstone, locally very shelly and with thin lenticular and tabular beds of chert. Locally developed thin glauconite-rich horizons and complex bedding, including slump bedding.

Definition of upper boundary
The top of the member is marked by the Small Cove Hardground, immediately below the base of the Beer Head Limestone Formation. In most areas the boundary is a sharp upward facies change from glauconitic sandstone to indurated limestone. A less-pronounced facies change occurs where the Bindon Sandstone is locally overlain (e.g. Hooken Cliff) by the Wilmington Sandstone Member (nodular calcareous bioclastic sandstone) of the Beer Head

Limestone Formation, but the Small Cove Hardground is a persistent feature.

Definition of lower boundary
Immediately above the Whitecliff Hardground, at the top of the Whitecliff Chert Member. Chert horizons are generally much thinner and less regularly developed than in the Whitecliff Chert Member.

Thickness
Up to 8 m

Distribution
Sheet 326 (Sidmouth)

Previous names
Top Sandstones (Smith, 1961)

Parent
Upper Greensand Formation

Age
Late Albian

References
Edwards, Gallois and Hamblin, 2004; Jukes-Browne and Hill, 1900; Smith, 1961; Woods, 1999, 2000.

4.4.2.8 Telegraph Hill Sands Member

Name
Term used informally without the member status by Hamblin and Wood (1976) as part of their fourfold division of the Upper Greensand of the Haldon Hills. Given member status herein.

Type section
Road cutting [SX 912 836], Telegraph Hill, Great Haldon, Selwood et al. (1984).

Primary reference section
Temporary road cutting at Woodlands Goyle [SX 902 840], at the north end of Great Haldon, Selwood et al. (1984).

Formal subdivisions
None

Lithology
Green and red glauconitic sandstone, generally fine-grained, clay-free and well-sorted, with several layers of chertified sandstone. A massive basal conglomerate is locally developed and in places strongly silicified, with oyster-encrusted pebbles and scattered corals. Lenses of shelly, indurated sandstone containing silicified bivalves occur in the lower part of the member.

Definition of upper boundary
Contact with the overlying Woodlands Sands Member, marked by an upward facies change to coarser, less well-sorted and more clay-rich sandstone.

Definition of lower boundary
Unconformable contact with Permian breccias. In some places the unconformity is irregular and overlain by a massive, locally silicified, highly fossiliferous conglomerate, elsewhere the unconformity is relatively flat and overlain by a bed of derived pebbles.

Thickness
Up to 5.26 m

Distribution
Haldon Hills in Devon (Sheet 339)

Previous names
Part of the Haldon Sands

Parent
Upper Greensand Formation

Age
Late Albian

References
Hamblin and Wood, 1976; Jukes-Browne and Hill, 1900; Selwood et al., 1984; Ussher, 1913.

4.4.2.9 Woodlands Sands Member

Name
Term used informally without the member status by Hamblin and Wood (1976) as part of their fourfold division of the Upper Greensand of the Haldon Hills. Given Member status herein.

Type section
Temporary road cutting at Woodlands Goyle [SX 902 840], at the north end of Great Haldon, Selwood et al. (1984).

Primary reference section
None

Formal subdivisions
None

Lithology
Glauconitic, clayey sandstone and shell beds containing layers of siliceous concretions. Very locally developed thin shelly limestones. Coral-rich bed at base, locally replaced by coarse gravel. Bands of quartz gravel are locally developed.

Definition of upper boundary
Contact with the overlying Ashcombe Gravels Member, marked by the upward facies-change to interbedded sandstone and gravel.

Definition of lower boundary
The contact with the underlying Telegraph Hill Sands Member, marked by the upward facies-change from finer-grained, clay-free sandstone (Telegraph Hill Sands) to coarser, less well-sorted, clay-rich sandstone (Woodlands Sands). A coral-rich horizon (Haldon Coral Bed) usually marks this boundary. Where the Telegraph Hill Sands are absent, the Woodlands Sands Member unconformably overlie Devonian and Carboniferous strata, and a coarse gravel marks the basal part of the Woodlands Sands Member.

Thickness
4.14 m

Distribution
Haldon Hills, Devon, Sheet 339

Previous names
Haldon Sands (part) (Jukes-Browne and Hill, 1900); Haldon Sands Formation (part) (Hamblin and Wood, 1976)

Parent
Upper Greensand Formation

Age
Late Albian

References
Hamblin and Wood, 1976; Jukes-Browne and Hill, 1900; Selwood et al., 1984; Ussher, 1913.

4.4.2.10 Ashcombe Gravel Member

Name
Term used informally without the member status by Hamblin and Wood (1976) as part of their fourfold division of the Upper Greensand of the Haldon Hills. Given member status herein.

Type section
Temporary road cutting at Woodlands Goyle [SX 902 840], at the north end of Great Haldon, Selwood et al. (1984).

Primary reference section
Babcombe Copse Sandpit [SX 869 766], Selwood et al. (1984).

Formal subdivisions
None

Lithology
The member comprises three beds of coarse-grained sandstone and quartz gravel, separated by two coarse-grained, poorly sorted sandstone units which show local cross-bedding and contain clay seams. The only common fossils are silicified oysters in the basal gravel.

Definition of upper boundary
Contact with overlying Cullum Sands-with-Cherts Member, marked by the upward facies change from coarse-grained sandstones and gravels (Ashcombe Gravels Member) to sandstones containing chert horizons (Cullum Sands-with-Cherts Member).

Definition of lower boundary
Contact with the underlying Woodlands Sands Member. Upward facies-change from glauconitic clayey sandstones (Woodlands Sands Member) to coarse sandstones and gravels (Ashcombe Gravels Member).

Thickness
5.28 m

Distribution
Haldon Hills, Devon, Sheet 339

Previous names
Haldon Sands (part) (Jukes-Browne and Hill, 1900);
Haldon Sands Formation (part) (Hamblin and Wood, 1976).

Parent
Upper Greensand Formation

Age
Late Albian to possibly earliest Cenomanian

References
Hamblin and Wood, 1976; Jukes-Browne and Hill, 1900; Selwood et al., 1984; Ussher, 1913.

4.4.2.11 Culham Sands with Cherts Member

Name
Term used informally without the member status by Hamblin and Wood (1976) as part of their fourfold division of the Upper Greensand of the Haldon Hills. Given member status herein.

Type section
Temporary road cutting at Woodlands Goyle [SX 902 840], at the north end of Great Haldon, Selwood et al. (1984).

Primary reference section
Cullum Goyle [SX 893 830], near race course on Great Haldon, Selwood et al. (1984).

Formal subdivisions
None

Lithology
Sandstone with horizons of chert, overlain by chert-free, clayey, laminated sandstone with cross-bedded lenses. Thin green clay-rich horizons occur in the basal part of the member, associated with glauconitic and pebbly sandstone. Tourmaline-rich sandstones locally form the highest part of the member.

Definition of upper boundary
Unconformable contact with overlying Eocene flint-rich gravels.

Definition of lower boundary
Contact with underlying Ashcombe Gravels Member, marked by the upward facies change from pebbly sands and gravels (Ashcombe Gravels Member) to sandstones with cherts (Cullum Sand-with-Cherts Member).

Thickness
6.71 m

Distribution
Haldon Hills, Devon, Sheet 339

Previous names
Haldon Sands (part) (Jukes-Browne and Hill, 1900); Haldon Sands Formation (part) (Hamblin and Wood, 1976).

Parent
Upper Greensand Formation

Age
Cenomanian

References
Hamblin and Wood, 1976; Jukes-Browne and Hill, 1900; Selwood et al., 1984; Ussher, 1913.

5 East Midlands Shelf (including 'Bedfordshire Straits' and marginal outliers)

There is a well-established lithostratigraphical framework for the East Midlands Shelf with comparable but different schemes having been erected in the Norfolk and Lincolnshire areas and in the subcrop beneath Quaternary cover in The Wash district (Wingfield et al., 1978). The relationships of the lithological units of the East Midlands Shelf are shown in Figure 2 (after Rawson, 1992). In Lincolnshire the first comprehensive summary of the succession is in Swinnerton (1935), and his scheme has been followed to a greater or lesser degree by later workers particularly in the Regional Guides of the Survey (e.g. Kent,1980) and elsewhere (e.g. Kirkaldy, (1939). The works of Judd (1867, 1870) and Jukes-Browne (1887, 1893) are pre-eminent in the earlier development of the lithostratigraphy.

Casey and Gallois (1973) updated the lithostratigraphy of the Sandringham Beds of Norfolk and gave tentative correlations with the successions in Lincolnshire and more speculatively with the Wealden area. Gallois (1994), in the Kings Lynn Memoir, placed the whole Lower Cretaceous succession within a modern context building upon earlier works reviewed in the East Anglia Regional Guide (Chatwin, 1961).

The development of the scheme for the East Midlands Shelf area is shown in Table 4 and follows the formal framework of Rawson (1992).

Table 5 shows the deposits preserved in the 'Bedfordshire Straits' and adjacent outliers in Buckinghamshire, Oxfordshire and Wiltshire. These western outliers, containing variously named lithostratigraphical units, are equated for the most part with the Lower Greensand Group (of Aptian and Early Albian age). The Whitchurch Sands were formerly regarded as Ryazanian in age, and equated with the Cinder Bed at the base of the Durlston Formation of the Purbeck Group. A more modern appraisal suggests that they are equivalent to the Shotover Ironsands and of Valanginian age (Horton et al., 1995). The Whitchurch Sands and Shotover Ironsands are regarded as a single deposit and termed the Whitchurch Sand Formation; they are therefore considered as isochronous with the Claxby Ironstone Formation of Norfolk and the Tunbridge Wells Sand Formation of the Weald.

Excluding the Whitchurch Sands, the Purbeck Group deposits preserved in outliers through Wiltshire, Oxfordshire and Buckinghamshire (previously termed the Purbeck Limestone Formation) are regarded as of Oppressus Zone age or older and are therefore of latest Jurassic (Portlandian–Tithonian) age. This strata comprises up to 13 m of fossiliferous, marginal marine and lagoonal limestones, with calcareous sands and sandstones. This indicates that the onset of restricted environments of deposition, characteristic of the 'Purbeck', was earlier in this region than in Dorset. At present these deposits have been called, variously, Purbeck Limestone, Purbeck Limestone Formation, Portland Beds and Portland Formation (e.g. Blake, 1880; Wimbledon, 1976, 1980; Cox et al., 1994; Horton et al., 1995; Cox, 1996). The deposits are in part equivalent in age to the oldest Roxham Beds of the Sandringham Sands Formation within the East Midlands Shelf area. It is suggested that all of these deposits are included within a single Haddenham Formation (in an expanded Purbeck Group) named after their principal outcrop in Oxfordshire; and the use of the term Purbeck Limestone Formation for these outcrops should cease.

Whether all of the lithologically variable Lower Greensand Group outcrops are each related to different episodes of marine incursion through a still extant 'Straits', or whether those, in the west particularly, just represent marginal marine facies of two phases of a single extensive marine transgression of the Wessex Basin is open to debate. They are principally composed of medium to coarse sand and pebbly sand becoming coarser towards the west, and all are variably cemented with ferruginous and less frequently calcareous cements. With the exception of the large outcrop of the Lower Greensand Group in Bedfordshire (the Woburn Sands Formation) and Cambridgeshire, there is little lateral continuity within these outlying deposits. The isolated outcrops frequently show quite different lithological characteristics and are of variable ages. Consequently it is proposed that each of these outliers (or group of related outcrops) is referred to a differently named unit. The rank of these deposits, relative to the main basinal successions is difficult to determine in a regional sense but the complete succession in each outcrop is given the status of formation (in some cases divisible into members). Their rank may need revision when more detail comes to light of the subcrop units preserved beneath the overstepping Gault Clay–Upper Greensand to the south, and the Gault Clay–Carstone to the north.

In this account the Woburn Sands Formation is regarded as a single mappable unit of the Lower Greensand Group that extends from the Dunstable area in Bedfordshire north-eastward to beyond Ely in Cambridgeshire, where it is cut out beneath the Carstone. The Woburn Sand Formation includes a number of informal members defined on the basis of lithology or outcrop area. These lithological units are not used on BGS maps and no formal designation is proposed. The basal deposits of the formation become progressively older towards the north-east.

To the west, lithological terms such as Seend Ironstones, Calne Sand (Calne Sands Formation), and Faringdon Sponge Gravel are well established in the literature and deserve formation status. The Red Sands of Uffington are barely discussed in the literature and the term is abandoned and replaced by the Furze Hill Sand Formation above the Baulking Formation, both new terms encompassing those beds above the Farringdon Sponge Gravel Formation.

In Dorset and south Wiltshire the Bedchester Sand Member and Child Okeford Sand Member constitute the Lower Greensand as published in Bristow et al. (1995). They are designated herein as members of the Lower Greensand Group because at present no suitable parent at formation level has been designated for these very limited occurrences to the south of Shaftesbury. Owen (1971) reviewed the biostratigraphy of the Lower Greensand at the Okeford Fitzpaine brickpit [ST 815 109] within which Bristow et al. (1995) identified representatives of both members. If this site is regarded as a reference section for the Lower Greensand in south Wiltshire then the name Okeford Fitzpaine Sands Formation would be appropriate.

Definitions for units within the whole district are given below commencing with those pertaining to north Norfolk,

Age of the numbered unconformities:

9 Early Albian ('mid-*tardefurcata* break') base of Carstone Fm.
8 Base late Aptian (base of *martinioides* Zone)
7 Base Aptian (base of *fissicostatus* Zone)
6 Mid Hauterivian (base of *inversum* Zone)
5 Latest Ryazanian (high *albidum* Zone)
4 Late Ryazanian (base of *stenomphalus* Zone)
3 Early Ryazanian (base of *kochi* Zone)
2 Late Volgian (base of *preplicomphalus* Zone)
1 Mid Volgian (base of *oppressus* Zone)

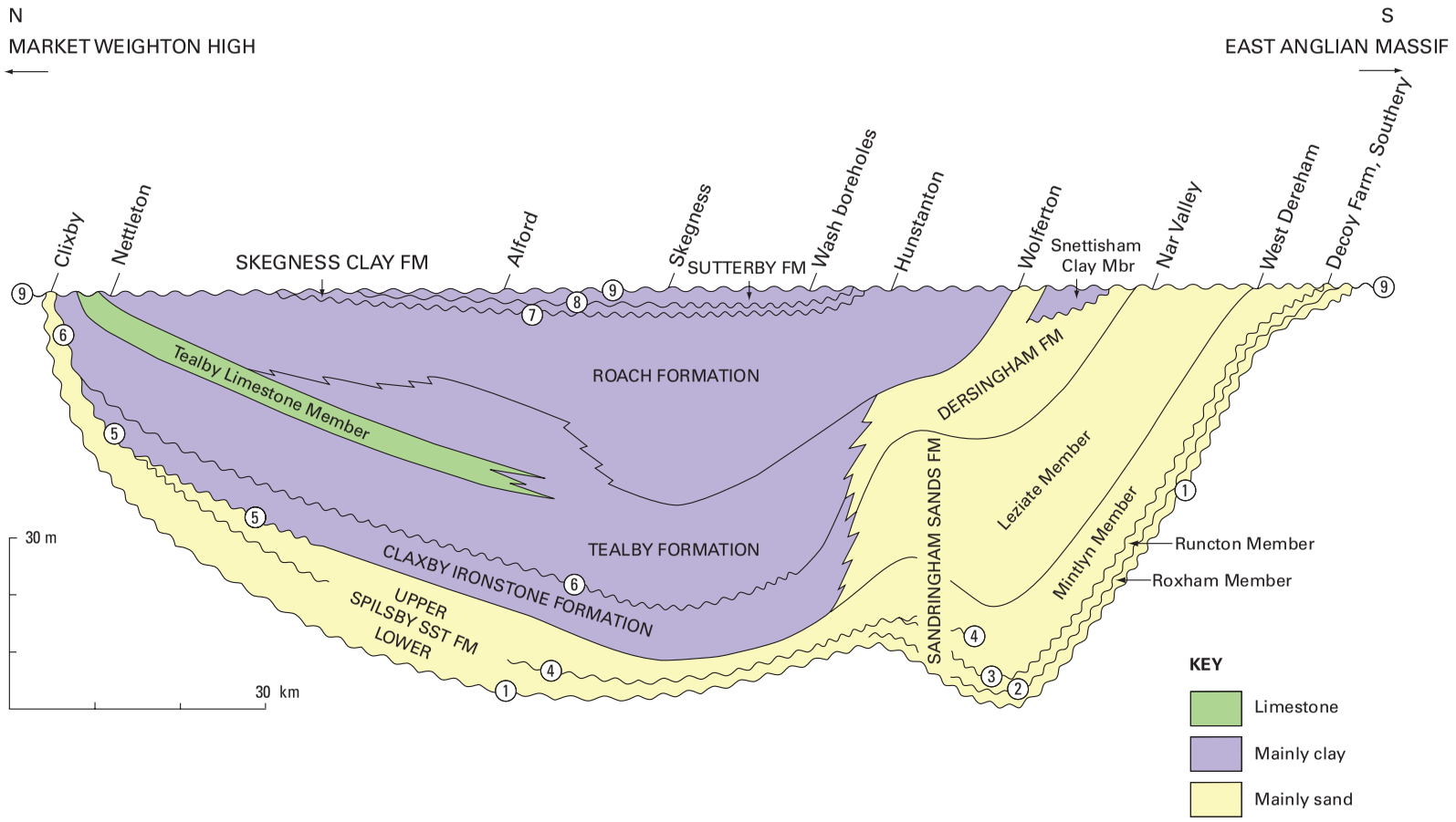
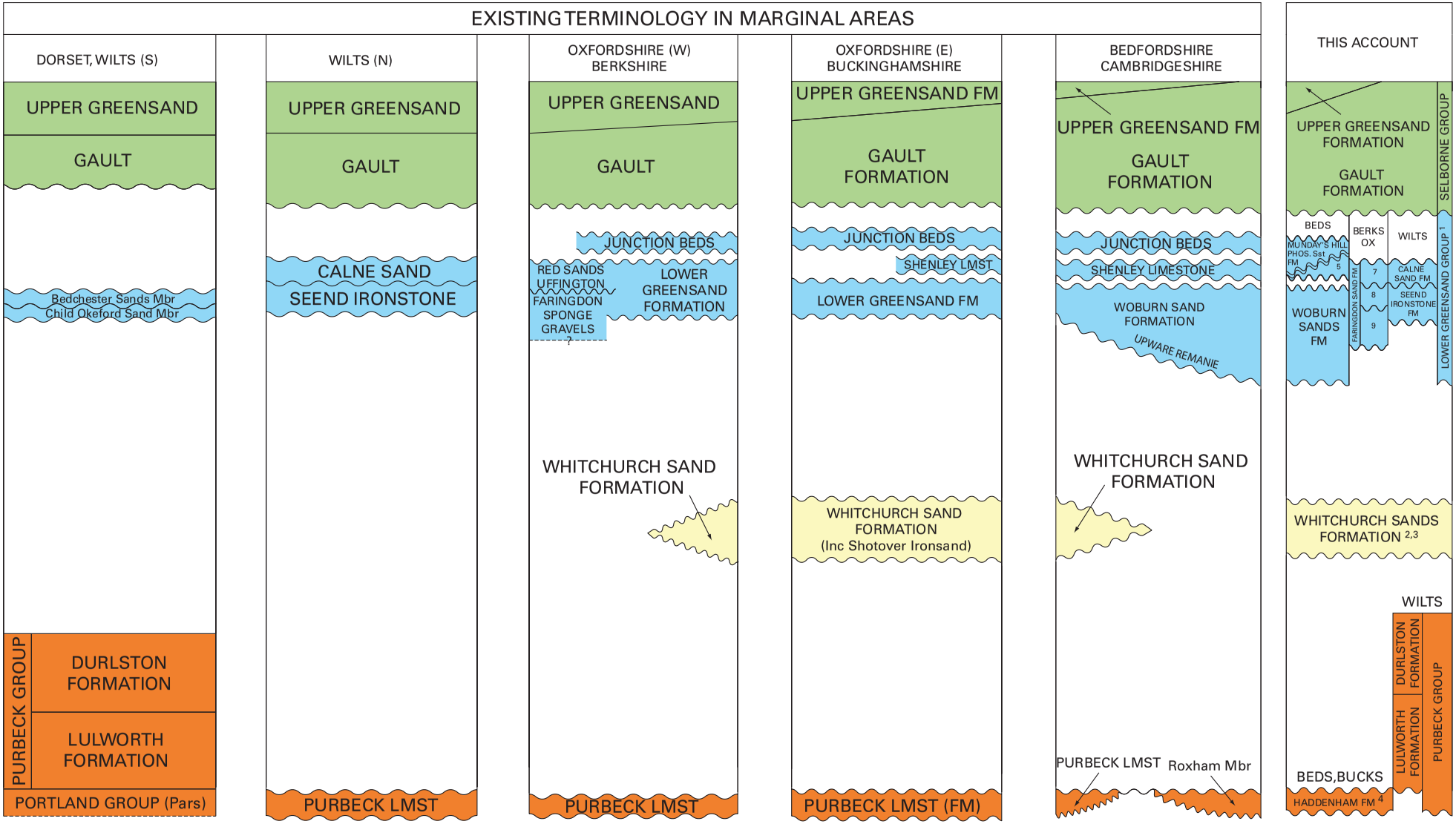


Figure 2 The relationship of the litholgies within the East Midlands Shelf area.

Table 4 Lithostratigraphical scheme for the East Midlands Shelf.

Table 5 Deposits of the 'Bedfordshire Straits' and related areas.



1. Named units to be given formation status, other units to remain informal or of member status
2. Considered to be age-equivalent to the Weald Clay Formation
3. Formerly considered to be age-equivalent to the 'Cinder Bed' or mid-Wealden group.
4. Proposed herein to replace the Purbeck Limestone (Fm) of Portlandian age.
5. Shenley Limestone Member
6. Bedchester Sands Member and Childokeford Sand Member in South Wiltshire.
7. Fernham Sand Member (Wilkinson in press)
8. Baulking Sand Member (Wilkinson in press)
9. Faringdon Sponge Gravel Member (Wilkinson in press)

followed by those for Lincolnshire and finally those relating to the marginal facies within the 'Bedfordshire Straits'.

NORTH NORFOLK

5.1 SANDRINGHAM SANDS FORMATION

Name
The name was introduced by Whitaker and Jukes-Browne (1899) in the memoir for the borders of The Wash as the Sandringham Sands. It was formalised as the Sandringham Formation with its constituent parts given member status in Rawson (1992). A lithological descriptor has been added.

Type section
Some 800 m at 320º from Church Farm, Bawsey, [TF 6530 2010], (Casey, 1973; Casey and Gallois, 1973).

Primary reference sectionss
BGS Wash Borehole 72/77B, [TF 6313 4835] (Wingfield et al., 1978; Gallois, 1994)
Brook Farm, North Runcton, [TF 6370 1630] (Gallois, 1994)
Gayton Borehole, TF71NW10 [7280 1974] (Gallois, 1994)
Hunstanton Borehole, TF64SE11 [6857 4078] (Gallois, 1994)
Manor Farm, North Runcton, [TF 6515 1555] (Casey, 1973; Casey and Gallois, 1973)
Marham Borehole, TF70NW1 [7051 0803] (Gallois, 1994)
Western end of Galley Hill, West of Mintlyn Wood, [TF 6508 1987 to 6530 2010] (Casey, 1973; Casey and Gallois, 1973)
Wissington Railway Bridge to Pratt's Bridge, Roxham, [TL 662 996 to 639 995] (Casey, 1973; Casey and Gallois, 1973)

Formal subdivisions
Four members are recognised (Casey and Gallois, 1973; Gallois, 1984, 1994). In ascending order they are the Roxham Member (entirely Jurassic in age but included for completeness), Runcton Member, Mintlyn Member and Leziate Member.

Lithology
The formation comprises silty and clayey sands, occasional clay ironstones, with cleaner quartz sands at the top. The Roxham Sand Member comprises grey and yellow-green, pyritic, silty sands with an indurated basal pebbly sandstone with phosphatic nodules and derived Kimmeridgian debris. Overlying this member the Runcton Member comprises green, glauconitic, clayey sands with abundant phosphatic nodules. The Mintlyn Member is formed of glauconitic, clayey, grey and green sands with bands and 'doggers' of brown weathering clay-ironstone and seams of phosphatic nodules (picking out erosion surfaces). A prominent band of phosphatic nodules occurs at the base of the Mintlyn Member. The Leziate Member comprises unconsolidated, moderately clean, pale grey (occasionally green, yellow or orange), fine-to-medium-grained, cross-bedded quartz sands with subordinate bands of silt or clay. Pyrite nodules are present and glauconite is locally abundant.

Definition of upper boundary
South of Gayton, the pebbly sands of the Carstone Formation overstep the silty, clayey and clean sands of the Sandringham Sands Formation, resting progressively on the Roxham and Runcton members, the Mintlyn Member and finally the Leziate Member. In northern Norfolk, the upper boundary is defined by the down-section change from the clayey sands (Dersingham Formation) to unconsolidated, generally clean quartz sands (Leziate Member, Sandringham Sands Formation). Beneath The Wash, the Leziate Member passes into the Claxby Ironstone Formation and the overlying Dersingham Formation passes laterally into the Tealby Formation (Gallois, 1994).

Definition of lower boundary
The boundary is placed at the down-section change from sands, with a pebbly base, to mudstones of the Kimmeridge Clay Formation. An erosion surface separates the two formations.

Thickness
Up to about 50 m

Distribution
The Sandringham Sands Formation outcrop is confined to Norfolk and extends beneath The Wash where it apparently merges with the Claxby Ironstone Formation and Spilsby Sandstone Formation (Casey and Gallois, 1973; Wingfield et al. 1978; Gallois, 1994). Its outcrop has been traced from the Hunstanton area southwards to near West Dereham.

Previous names
Sandringham Sands

Parent
None

Age
Portlandian (Volgian) to Valanginian

References
Casey, 1973; Casey and Gallois, 1973; Gallois, 1984, 1994; Rawson, 1992; Wingfield et al., 1978; Whitaker and Jukes-Browne, 1899.

5.1.1 Roxham Member

Name
The term Roxham Beds was used by Casey and Gallois (1973), Gallois (1984, 1994) and given member status in Rawson (1992).

Type section
Pratt's Bridge [TL 639 995], Roxham Farm, West Dereham

Primary reference sections
BGS Wash Borehole 72/77B, [TF 6313 4835] (Wingfield et al. 1978; Gallois, 1994)
Gayton Borehole TF71NW10 [7280 1974] (Gallois, 1994)
Hunstanton Borehole TF64SE11 [6857 4078] (Gallois, 1994)
Marham Borehole TF70NW [7051 0803] (Gallois, 1994)

Formal subdivisions
None

Lithology
Grey and yellow-green, pyritic, silty sands with an indurated basal pebbly sandstone with black chert, phosphatic nodules and derived Kimmeridgian debris. Bioturbation and burrows

occur in the unit and may extend down into the top of the underlying Kimmeridge Clay.

Definition of upper boundary
Disconformable, where green, glauconitic, clayey sands with abundant black phosphatic nodules of the Runcton Member overlies grey and yellow-green, pyritic, silty sands of the Roxham Member.

Definition of lower boundary
Unconformable contact at the down-section change from sands, with a pebbly base, to mudstones of the Kimmeridge Clay Formation. An erosion surface separates the two units.

Thickness
Up to 6 m

Distribution
The member crops out between the Babingley River, southwards to near Southery, where it disappears beneath the Methwold Fens. It has been penetrated by a number of boreholes at Hunstanton, North Wootton, Gayton, Mundford and Little Ouse. The member extends under The Wash and has been recognised in borehole 72/77B (see above), but passes laterally into the lower part of the Spilsby Sandstone Formation.

Previous names
Roxham Beds
Roxham Sand Member

Parent
Sandringham Sands Formation

Age
Portlandian

References
Casey, 1973; Casey and Gallois, 1973; Gallois, 1984, 1994; Wingfield et al., 1978; Whitaker and Jukes-Browne, 1899.

5.1.2 Runcton Member

Name
The term Runcton Beds was used by Casey and Gallois (1973) and Gallois (1984, 1994) and given member status in Rawson (1992).

Type area
North Runcton [TF 65 15]

Primary reference section
Temporary trench (No. 2 Gas Feeder Trench) at Manor Farm [TF 6515 1555], North Runcton once exposed the complete member (Casey, 1973).

Formal subdivisions
None

Lithology
The Runcton Member comprises 'bright green, glauconitic, clayey sands with much nodular phosphorite' and, at North Runcton, the 'friable brown phosphatic nodules contain *Subcraspedites* (V.) *lamplughi*' (Casey, 1973). A horizon of black phosphatic nodules occurs at the base. At West Dereham, the Runcton Member is reduced to a single band of rolled phosphatic nodules 0.15–0.30 m thick.

The member can be traced offshore into The Wash, where it passes into the lower part of the Spilsby Sandstone Formation (lower Spilsby Sandstone) (Wingfield et al., 1978).

Definition of upper boundary
'Glauconitic clayey sands with bands of brown-weathering clay ironstone and (especially near the base) seams of phosphorite' (Mintlyn Member) rests with a sharp disconformable contact on 'bright green, glauconitic, clayey sands with much nodular phosphorite' (Runcton Member) (Casey, 1973).

Definition of lower boundary
Green, glauconitic, clayey sand with a basal black phosphatic nodule horizon (Runcton Member), rests with a sharp disconformable contact, on grey and yellow-green silty sands with pyrite (Roxham Member).

Thickness
Up to 2 m

Distribution
The member is kown best in the Runcton–Mintlyn region, Norfolk, but has been mapped from east of King's Lynn (sheets 145 and 146) south to the east of Downham Market (sheets 159 and 160). Although included in the vertical section of sheet 129, the member is not shown on the face of the map, and is presumed to be obscured by superficial deposits. Offshore, in The Wash, boreholes have penetrated the member, although it is not clear where the Runcton Member passes laterally into the lower part of the Spilsby Sandstone Formation (which is recorded on the northern side of The Wash, in southern Lincolnshire).

Previous names
Runcton Beds (a formation within the Sandringham Sands Group) (Casey and Gallois, 1973; Casey, 1973).

Parent
Sandringham Sands Formation

Age
Berriasian

References
Casey, 1973; Casey and Gallois, 1973; Wingfield et al., 1978.

5.1.3 Mintlyn Member

Name
The Mintlyn Beds of Casey and Gallois (1973) and Gallois (1984, 1994) and given member status in Rawson (1992).

Type section
Some 100 m west of Wissington Railway Bridge [TL 662 996]
About 100 m east of Pratt's Bridge [TL 639 995], Roxham
Galley Hill [TF 6508 1987 to 6530 2010], west of Mintlyn Wood

Primary reference sections
BGS Wash Borehole 72/77B [TF 6313 4835] (Wingfield et al. 1978; Gallois, 1994)
Hunstanton Borehole TF64SE11 [6857 4078] (Gallois, 1994)
Marham Borehole TF70NW1 [7051 0803] (Gallois, 1994)
Severals House Borehole (Wissington Estate Methwold C) TL69NE9 [6930 9650]

Formal subdivisions
None

Lithology
Glauconitic, clayey, grey and green sands with bands and 'doggers' of brown weathering clay-ironstone and seams of phosphatic nodules (picking out erosion surfaces). A prominent band of phosphatic nodules occurs at the base. Casey and Gallois (1973) stated that the member could be divided into two based on ammonites faunas, a lower 'Hectoroceras Beds' and an upper division 'in which *Surites* and allies predominate'.

Definition of upper boundary
Unconsolidated, moderately clean, pale grey (occasionally green, yellow or orange), fine- to medium-grained, cross-bedded quartz sands with subordinate bands of silt or clay (Leziate Member) overlies glauconitic, clayey, grey and green sands with bands and 'doggers' of brown weathering clay-ironstone and seams of phosphatic nodules (Mintlyn Member).

Definition of lower boundary
Glauconitic, clayey, grey and green sands with bands and 'doggers' of clay-ironstone and phosphatic nodules (Mintlyn Member) overlies green, glauconitic, clayey sands with abundant phosphatic nodules (Runcton Member).

Thickness
Up to about 15 m

Distribution
The member is known from the east of Gaywood; King's Lynn By-pass (where it is up to 15 m thick, e.g. the cutting at Mintlyn Wood); South of Middleton Stop Drain to the North Runcton area and south as far as the West Dereham area. Several boreholes have penetrated the member, including Hunstanton Borehole (9.7 m thick), Marham Borehole (10.3 m thick) and Severals House Borehole (0.5 m thick-the southward truncation being due to the overstepping Carstone). The member has been traced beneath The Wash (Borehole 72/77B) and apparently passes laterally into the upper Spilsby Sandstone–basal Claxby Ironstone formations. A division containing *Surites* and considered as laterally equivalent to the member, is found in the upper Spilsby Sandstone Formation of South Lincolnshire (Casey and Gallois, 1973).

Previous names
Mintlyn Beds
Mintlyn Sand Member

Parent
Sandringham Sands Formation

Age
Ryazanian to Valanginian

References
Casey, 1973; Casey and Gallois, 1973; Gallois, 1984, 1994; Rawson, 1992; Wingfield et al., 1978.

5.1.4 Leziate Member

Name
The Leziate Beds of Casey and Gallois (1973) and Gallois (1984, 1994), are given member status in Rawson (1992).

Type sections
Former Bawsey Brickworks, [TF 6843 1935], Brow of the Hill
Railway cutting, [TF 6680 3359], Locke Farm

Primary reference sections
BGS Wash Borehole 72/77B, [TF 6313 4835]
Gayton Borehole TF71NW10 [7280 1974]
Hunstanton Borehole TF64SE11 [6587 4078] 53.42–65.02 m depth

Formal subdivisions
None

Lithology
Unconsolidated, moderately clean, pale grey (occasionally green, yellow or orange), fine- to medium-grained, cross-bedded quartz sands with subordinate bands of silt or clay. Pyrite nodules are present and glauconite is locally abundant.

Definition of upper boundary
In the King's Lynn district, the upper boundary is defined by a down-section change from thinly-bedded, fine-grained, silty sands and sandstones (Dersingham Formation) to unconsolidated, moderately clean, pale grey, (occasionally green, yellow or orange), fine- to medium-grained, cross-bedded quartz sands with subordinate bands of silt or clay. Locally, medium to dark grey clay (? Snettisham Clay) rests on the sands of Leziate Member (Gallois, 1994). In the Gayton–Marham area, pebbly, ferruginous sandstones (Carstone Formation) overstep the unconsolidated, moderately clean, pale grey Leziate Member.

Definition of lower boundary
Down-section change from unconsolidated, moderately clean, pale grey (occasionally green, yellow or orange), fine- to medium-grained, cross-bedded quartz sands with subordinate bands of silt or clay (Leziate Member) to glauconitic, clayey, grey and green sands with bands and 'doggers' of brown weathering clay-ironstone and seams of phosphatic nodules (Mintlyn Member).

Thickness
Up to 30 m

Distribution
The Leziate Member occurs in boreholes in The Wash and in Norfolk, and extends from Heacham southwards to Denver. North of King's Lynn it forms a steep feature capped by the sandstones of the Dersingham Formation, but south of King's Lynn, the feature is masked beneath the Carstone. The member occurs in the heathland areas of Dersingham Heath, Sandringham Warren, Roydon Common, Leziate Heath and Shouldham Warren. It is known from a number of boreholes in West Norfolk, including Hunstanton and Gayton boreholes. It passes into the Claxby Ironstone Formation beneath The Wash.

Previous names
Leziate Beds

Parent
Sandringham Sands Formation

Age
Valanginian

References
Casey, 1973; Casey and Gallois, 1973; Gallois, 1984, 1994; Rawson, 1992; Wingfield et al., 1978.

5.2 DERSINGHAM FORMATION

Name
The Dersingham Beds of Casey and Gallois (1973) and Gallois (1984, 1994) and given member status in Rawson (1992).

Type section
Dersingham Common [TF 6853 2953 to 6872 2926]

Primary reference sections
Dersingham Sand Pit [TF 6814 2937]
South-western end of Roydon Common [TF 6796 2223 to 6876 2192]
Warren Farm Stone Pit [TF 6737 2215]

Formal subdivisions
Includes the Snettisham Clay Member

Lithology
The formation comprises a rhythmic succession of thinly interbedded, fine-grained sands, ferruginous sandstones, silts and clays. The formation varies laterally from ferruginous fine-grained sands and sandstones around Dersingham and Roydon Common, to silts in the Hunstanton Borehole TF64SE11 [6587 4078]. Clay (Snettisham Clay Member) is present at the top of the formation, such as in the Hunstanton Borehole, at Dersingham and at Snettisham. It passes laterally into the Tealby Formation below The Wash.

Definition of upper boundary
Ferruginous, medium-grained, generally and pebbly sand, locally clayey at the base of the Carstone Formation, overlies mudstone of the Snettisham Clay Member around Dersingham and Snettisham. At Hunstanton, silty, pebbly clays at the base of the Roach Formation overlies a rhythmic succession of brown and red clay and clayey silt, in part, and separated by an interburrowed erosion surface.

Definition of lower boundary
A downward change from ferruginous, fine-grained sandstone to unconsolidated, fine- to medium-grained, cross-bedded, generally clean, pale quartz sands of the Leziate Member of the Sandringham Sands Formation.

Thickness
Up to about 16 m

Distribution
Crops out at Heacham to Babingley River and Roydon to Ashwicken, and outliers occur at Rising Lodge, and East Winch. It is cut out by the overstepping Carstone in the vicinity of East Winch. Boreholes at Gayton and Hunstanton penetrated the formation.

Previous names
Dersingham Beds
Sandringham Sands (parts)

Parent
None

Age
Hauterivian to Barremian

References
Casey and Gallois, 1973; Gallois, 1984, 1994; Whitaker and Jukes-Browne, 1899.

5.2.1 Snettisham Clay Member

Name
Name of Snettisham Clay introduced by Whitaker and Jukes-Browne (1899) from the type locality of the Heacham Brickyard. Called Snettisham Clay facies in Rawson (1992) and given member status herein.

Type section
Heacham Brickworks [TF 678 364], Mount Pleasant

Primary reference sections
Dersingham Common [TF 6853 2953 to 6872 2926]
Feathers Hotel [TF 6935 2997], Dersingham
Gayton Borehole TF71NW10 [7280 1974], between 30.48 and 32.6 m depth

Formal subdivisions
None

Lithology
At Heacham, Jackson (1911) recorded greyish brown clay with a seam of fossiliferous clay ironstones in the upper part and ironstone concretions scattered throughout. Sand partings are present and, in the Gayton Borehole, bioturbation is represented by tracks, trails and burrows (Gallois, 1994). A rich shelly fauna has been recovered from the Snettisham Clay Member. Locally (between Heacham and Appletone), a pebble bed is present at the base and at Snettisham Brickworks, a hard clay ironstone occurs in the lower part of the member.

Definition of upper boundary
At Dersingham Common, Snettisham and in the Gayton Borehole, pebbly, ferruginous sands (Carstone Formation) rests on clay and silty clay (Snettisham Clay Member) with an erosion surface between. At Dersingham Common, a spring line picks out the Carstone–Snettisham Clay boundary. The boundary appears to be conformable in the Hunstanton Borehole where ooidal, silty and sandy mudstones (Roach Formation) rest on red-brown mudstone (Snettisham Clay Member).

Definition of lower boundary
The base is probably an erosion surface. In the Leziate, Ashwicken and East Winch areas the Snettisham Clay appears to have cut out the lower and middle parts of the Dersingham Formation and rests on the clean sands of the Leziate Sandstone Member, Sandringham Sands Formation. At Heacham and Snettisham, silts and clays of the Snettisham Clay Member rest on pale yellow sands of the Dersingham Formation. At Dersingham Common, silty clay rests on a pebble bed comprising quartz, quartzite, chert, limestone and phosphate, which in turn rests on soft, brown and white, fine-to medium grained sands.

Thickness
Between 1.5 and 6 m

Distribution
The member crops out between Heacham and Ashwicken and is present in boreholes (e.g. Gayton Borehole).

Previous names
Snettisham Beds

Snettisham Clay
Snettisham Clay Formation

Parent
Dersingham Formation

Age
Barremian

References
Casey and Gallois, 1973; Gallois, 1984, 1994; Jackson, 1911; Larwood, 1961; Whitaker and Jukes-Browne, 1899.

5.3 ROACH FORMATION

Name
Originally the Fulletby Beds of Swinnerton (1935) which comprised the Lower Roach, Roach Stone and Upper Roach. Called the Roach Formation in Rawson (1992).

Type area
As the Fulletby Beds around Fulletby [TF 300 780] north-east of Horncastle, in Lincolnshire.

Primary reference sections
Alford Borehole, 'In the grounds of the pumping station', TF47NW12 [44630 75583], (Swinnerton, 1935)
Hunstanton Beach, [TF 6712 4152 to 6715 4177]
Hunstanton Borehole, TF64SE11 [6587 4078], 36.86–53.42 m depth
Skegness Borehole, TF56SE9 [5711 6398], 68.27–46.53 m depth
Wash Borehole BGS 72/78 [TF 6313 4835] 24.60–46.30 m depth

Formal subdivisions
None

Lithology
Sandy, bioturbated, ooidal-mudstones and very fine-grained, very clayey, bioturbated, partly ooidal sands. Calcite-cemented, ooidal ironstones occur locally. At Hunstanton, sandy, phosphatic ironstone nodule horizons contain shelly fossils. In Lincolnshire, the formation has been informally divided into 'Upper Roach' and 'Lower Roach', separated by an indurated calcareously cemented, ooidal sandstone known as 'Roach Stone'. Boreholes at Hunstanton, Skegness and The Wash (Borehole 72/78) show a rhythmic succession of interburrowed and interbedded clay, 'chamosite' mud, chamosite ooids, quartz sand and small pebbles of quartz and ironstone. In Northern Lincolnshire it comprises ferruginous, sandy limestone and ferruginous, ooidal mudstones.

Definition of upper boundary
In Norfolk, the upper boundary is marked by an erosion surface separating the very pebbly, ooidal clay at the base of the Carstone Formation, from the fine-grained clayey sand of the Roach Formation. Burrows extend down about 30 cm into the top of the Roach Formation. Boreholes at Skegness and beneath The Wash prove the junction between medium and dark grey mudstone with *Prodeshayesites bodei* and iridescent fragments of other ammonites (Skegness Clay) and the ooidal mudstones of the underlying Roach Formation. Further north, pale grey, fossiliferous, calcareous mudstones (Sutterby Formation) are separated from the ooidal mudstones of the Roach Formation by an erosion surface.

Definition of lower boundary
In northern Lincolnshire, near Brigg, ooidal and ferruginous mudstones, sandstones and limestones (Roach Formation) rest unconformably on friable ferruginous limestone of the Tealby Limestone Formation. In southern Lincolnshire, the base is a minor erosion surface where the ooidal and pebbly mudstones and very fine sandstones (Roach Formation) rest on the smooth, fossiliferous clays (Upper Tealby Clay Member of the Tealby Formation). In Norfolk, the erosion surface separates the Roach Formation from the underlying interbedded, fine-grained sands, ferruginous sandstones, silts and clays (Dersingham Formation) or mudstones (Snettisham Clay Member).

Thickness
Up to c.22 m

Distribution
In Norfolk, the Roach is seen on the coast at Hunstanton and in boreholes, but it disappears further south (it is not present in Gayton Borehole). Its distribution beneath The Wash is known from a number of boreholes and it is identified in Lincolnshire from boreholes and occasionally outcrops, although it apparently disappears in northern Lincolnshire and is absent at Nettleton Bottom [TF 1257 9856] and Acre House [TF 1117 9701].

Previous names
Roach
Roach Stone
Fulletby Beds

Parent
None

Age
Barremian

References
Gallois, 1975a, 1994; Gaunt, Fletcher and Wood, 1992; Owen and Thurrell, 1968; Swinnerton, 1935; Wingfield et al., 1978.

5.4 CARSTONE FORMATION

Name
Originally defined as Carstone in Lincolnshire by Strahan (1886) and in Norfolk by Whitaker and Jukes-Browne (1899) in the old series memoir for The Wash. First mentioned but not defined in Rose (1862).The term was given formation status in Rawson (1992).

Type area
Hunstanton, Norfolk

Primary reference section
Hunstanton Cliff and Foreshore at Hunstanton to St Edmund's Point, [TF 6725 4130 to 6786 4238].

Formal subdivisions
None

Lithology
The typical lithology of the Carstone Formation is greenish-brown (orange brown when weathered), massive cross-bedded, ooidal ferruginous sandstone. The formation is medium- to coarse-grained and pebbly in part, especially

at the base where it becomes a conglomerate. Pebbles comprise quartz, quartzite, pyritised sandstone, ironstone, grey siltstone and rolled ammonites. Some beds are silty and/or contain clay wisps. Glauconite may be present in variable amounts. The Carstone Formation is burrowed in places with common *Arenicolites* and *Skolithos*.

Definition of upper boundary
In southern and central Norfolk, the upper boundary is defined by a down-section transition from pale to medium grey mudstones and siltstones (Gault Clay Formation) to greenish-brown, massive, cross-bedded, bioturbated, ooidal ferruginous sandstone. In northern Norfolk and Lincolnshire the boundary is marked by a sharp (in places gradational) down-section change from red, pink or cream limestones and marls (Hunstanton Chalk Formation) to greenish-brown, massive cross-bedded, bioturbated, ooidal, ferruginous sandstone.

Definition of lower boundary
The Carstone Formation oversteps many different lithostratigraphical units. Its base is erosional and sometimes burrowed into the underlying strata. The base can be recognised by a downward change from greenish-brown, massive cross-bedded, frequently bioturbated, ooidal, ferruginous, medium- to coarse-grained and pebbly sandstone into, from south to north; Palaeozoic successions on the London Platform (e.g. Four Ashes Borehole); quartz sands and thin mudstones (Dersingham Formation) in Cambridgeshire and south Norfolk; buff and grey, clayey ferruginous sands and quartz sands (Sandringham Sands Formation), in central Norfolk, between Leziate and West Dereham; pale grey and grey clays (Kimmeridge Clay Formation) in central Norfolk (Mudford–Great Ellingham); pale grey and grey, very fine- to fine-grained, bioturbated, shelly sandstones with phosphatic nodules (Roach Formation) in northern Norfolk; shelly, calcareous mudstone (Sutterby Formation) in southern Lincolnshire; ironstone (Fulletby Formation) in central Lincolnshire; dark, sometimes glauconitic, mudstones and limestones (Tealby Formation) in northern Lincolnshire; brown, shelly ooidal ironstone (Claxby Ironstone Formation); Late Jurassic mudstones (Kimmeridge Clay and Ampthill Clay Formations) and coarse-grained sandstone (Elsham Sandstone Member) at the Humber Estuary; pale grey to grey, fine- to medium-grained sandstones and dark mudstones (Kellaways Formation) in southern Yorkshire; Upper Lias mudstones on the south side of the Market Weighton High.

Thickness
Usually up to about 5 m, but it reaches its maximum thickness of 18.9 m in the Hunstanton Borehole.

Distribution
The southern limit of the formation is between Duxford and Soham, Cambridgeshire, and south-east of the Four Ashes Borehole, on the London Platform, although it is not seen at outcrop in these areas. The Carstone extends northwards through Norfolk and it is best exposed in the cliffs and foreshore at Hunstanton. North of The Wash, the Carstone is present in Lincolnshire, beneath the Wolds and forming a narrow outcrop along their western margin. In northern Lincolnshire, it is thin and locally absent. North of the Humber the Carstone is again thin and patchy, but it has been recorded near South Cave, Goodmanham, Millington and Kirby Underdale, finally disappearing on the Market Weighton High.

Previous names
Lower Carstone and Upper Carstone Members
Sand and Clay and Carstone Grit of the Langton Series
Carstone
Thoresway Sand

Parent
None

Age
Early Albian and oldest Mid Albian

References
Gallois, 1973, 1975a, 1984, 1994; Gallois and Mortimer, 1982; Gaunt, Fletcher and Wood, 1992; Owen, 1991, 1995; Rose, 1862; Strahan, 1886; Wilkinson, 2006; Whitaker and Jukes-Browne, 1899.

5.5 SELBORNE GROUP

See entry within Section 3 and note the discussion concerning the lateral equivalence of the Hunstanton Formation with the Gault Formation in Section 3.4.

5.5.1 Gault Formation

See entry within Section 3

LINCOLNSHIRE

5.6 SPILSBY SANDSTONE FORMATION

Name
The name Spilsby Sandstone was first introduced by Strahan (1886) who states that he was using 'Survey nomenclature'; a year later the unit was defined as the Spilsby Sandstone Series by Jukes-Browne (1887) in the memoir for east Lincolnshire. Called the Spilsby Formation in Rawson (1992).

Type area
Around Spilsby east of Horncastle in Lincolnshire.

Primary reference sections
Boston Corporation Waterworks boreholes [TF 416 714], Fordington, 8 km north of Spilsby
Nettleton Top Barn [TF 108 988] south-west of Caistor
Railway cutting between Benniworth and Donnington-on-Bain [TF 224 825 to 227 824]
Skegness Borehole, TF56SE9 [5711 6398]

Formal subdivisions
Informally into a lower and upper part. Lower division spanning the Jurassic–Cretaceous boundary.

Lithology
The formation comprises two members which are further divided.

Lower Spilsby Sandstone Member. Coarse-grained, pebbly, glauconitic sands and sandstones with calcareous 'doggers' and occasional phosphatic nodules towards the Top, this unit equates with the lower part of Swinnerton's, 1937, ('Glauconitic Sands'). The base of the member comprises thin grey sandstone with phosphatic nodules (the Basement Beds of Swinnerton, (1937), and Beds A and D of Swinnerton, (1935)).

Upper Spilsby Sandstone Member. Thin, coarse-grained, grey or brown pebble sandstone with iron ooliths (Ferruginous Grit of Swinnerton (1937)), underlain by fine- to medium-grained, buff, yellow and white sands with sparse calcareous 'doggers' (the upper part of Swinnerton's (1937) 'Glauconitic Sands'). The latter sands become coarser and greener towards the base of the member. A bed of phosphatic nodules and small (generally chert) pebbles occurs at the base (the Mid Spilsby Nodule Bed of Casey (1963, 1973)).

Definition of upper boundary
Down-section change from purple-grey and brown mottled mudstones with occasional iron ooliths (Hundleby Clay Member, Claxby Ironstone Formation) or argillaceous ooidal ironstone (Claxby Ironstone Formation) to pale yellow, medium-grained sand and sandstone (Upper Spilsby Sandstone Member).

Definition of lower boundary
A down-section change from grey sandstone with phosphatic nodules (the 'Basement Beds' of the lower Spilsby Sandstone Member) to mudstone (Kimmeridge Clay).

Thickness
Up to about 24 m

Distribution
Onshore, the Spilsby Sandstone Formation is restricted to the southern part of Lincolnshire. It extends offshore into The Wash, but its extent is unknown as it quickly passes laterally into the lower part of Sandringham Sands Formation (Wingfield et al., 1978). Offshore in the Southern North Sea, the formation has been recognised in quadrants 47, 48, 51–54. In the offshore region it forms the basal part of the Cromer Knoll Group (Lott and Knox, 1994). It is not clear how the 'Spilsby Sand Formation' equivalent (Cromer Knoll Group, parts) offshore relates to the Spilsby Sand Formation and the Sandringham Sands Formation onshore.

Previous names
Greensand and Sandstone
Lower Sand and Sandstone
Spilsby Beds of Spilsby Series
Spilsby Sandstone

Parent
None

Age
Portlandian (Volgian) to Valanginian

References
Casey, 1963, 1973; Dikes and Lee, 1837; Judd, 1867; Jukes-Browne, 1887; Lott and Knox, 1994; Strahan, 1886; Swinnerton, 1935, 1937 (for 1936); Wingfield et al., 1978.

5.7 CLAXBY IRONSTONE FORMATION

Name
The term Claxby Ironstone was first used by Strahan (1886) and defined as the Claxby Ironstone of the Tealby Beds in Ussher et al. (1888,) and Ussher (1890). Rawson used the term Claxby Formation (1992) but reverted to Claxby Ironstone Formation in 2006.

Type section
Originally defined at the Acre House Mine [Shaft TF 11466 96762], south of Nettleton near Caistor, Lincolnshire.

Primary reference sections
Alford Borehole TF47NW12 [44630 75583], 'In the grounds of the pumping station'
BGS Wash borehole 72/77B [TF 6313 4835]
Nettleton Hill Quarry [TF 109 995]
Nettleton Top [TF 108 988], south-west of Caistor
Railway cutting [TF 224 825 to 227 824], between Benniworth and Donnington-on-Bain
Skegness Borehole TF56SE9 [5711 6398]

Formal subdivisions
Includes the Hundleby Clay Member

Lithology
Pale grey to dark brown, ferruginous, silty clay with varying concentrations of ooid-rich ironstone and pink or cream, calcareous, siltstone seams at some levels. Chert and quartz grit are found at some horizons. Phosphatic nodules, which occur at some horizons, contain moulds of shelly fossils, including ammonites, belemnites and bivalves. In southern Lincolnshire, the lower part of the formation comprises pale, purple-grey, mottled brown, silty clay (Hundleby Clay Member). The top of the formation is more calcareous and has been termed 'calcareous beds' by some authors.

Definition of upper boundary
The Claxby Ironstone Formation grades into the overlying Tealby Formation, although a minor erosion surface has been used to separate the calcareous mudstones, at the top of the Claxby Ironstone Formation (Upper Claxby Ironstone Member of Gaunt et al., 1992), from the overlying ferruginous-rich mudstones of the Tealby Clay Formation.

Definition of lower boundary
Between Benniworth and Donnington-on-Bain (Lincolnshire) the base is defined by a down-section change from grey and brown, ferruginous, mudstones (Hundleby Clay Member, Claxby Ironstone Formation) (Casey, 1973) into pebbly sandstones of the Spilsby Sandstone Formation. Further north, where the Hundleby Clay Member is missing, argillaceous ironstone is separated from the underlying pale-yellow sandstones (upper part of Spilsby Sandstone Formation) by an erosion surface. At Nettleton a basal conglomerate contains derived fossils from the Spilsby Sandstone Formation (Casey, 1973; Kelly and Rawson, 1983). Borehole evidence suggests that below The Wash, bioturbated, shelly silt and glauconitic sand (which appears to be the Hundleby Clay Member) overlies brown ironstone and fine-grained, silty sand (Mintlyn Member of the Sandringham Sands Formation) (Wingfield et al., 1978).

Thickness
Up to 9 m [an estimated 9 m was recorded at Dalby by Owen and Thurrell, 1968].

Distribution
The formation extends through southern Lincolnshire as far north as the Brigg district and finally disappears north of Audleby where the Tealby Formation oversteps it. Southwards the Claxby Ironstone Formation occurs beneath The Wash. It is present in Wash Borehole 72/77A, but does not reach the Norfolk coast, where the coeval upper part of the Sandringham Sands Formation is found.

Previous names
Ferruginous Band
Lower Sand and Sandstone
Claxby Beds
Claxby Ironstone

Parent
None

Age
Valanginian to Hauterivian

References
Casey, 1973; Dikes and Lee, 1837; Gaunt, Fletcher and Wood, 1992; Judd, 1867; Kelly and Rawson, 1983; Owen and Thurrell, 1968; Swinnerton, 1935; Wingfield et al., 1978; Ussher, 1890; Ussher, Jukes-Browne and Strahan, 1888.

5.7.1 Hundleby Clay Member

Name
Introduced as the Hundleby Clay by Casey (1973). Given formal status as Hundleby Member in Rawson (1992) and Hundleby Clay Member in (2006).

Type section
None

Primary reference sections
Belchford [TF 290 750]
Disused railway cutting between Benniworth and Donnington-on-Bain [TF 224 825 to 227 824]
East Keal [TF 375 645]
Hundleby [TF 385 640]

Formal subdivisions
None

Lithology
Purple-grey, brown-mottled mudstone that becomes progressively sandier towards the top. The member interdigitates with the ironstone of the Claxby Ironstone Formation. Between Belchford and Hundleby it comprises 'unctuous, plastic clay' throughout (Owen and Thurrell, 1968).

Definition of upper boundary
Down-section change from ironstones (upper part of the Claxby Ironstone Formation) to mudstone (Hundleby Clay Member).

Definition of lower boundary
An erosion surface separates the mudstones of the Hundleby Clay Member from the sandstones of the Upper Spilsby Sandstone Formation in southern Lincolnshire and The Wash. The member overlies the Mintlyn Member further south. In other parts of Lincolnshire (e.g. Langton, Mavis Enderby, Mardon Hill and Raithby to Hundleby), the base of the member is placed at a down-section change from mudstones (Hundleby Clay Member) to ironstone (Claxby Ironstone Formation). As a result of interdigitation, the local base of the member may be higher within the Claxby Ironstone Formation.

Thickness
Up to about 5.5 m

Distribution
Confined to southern Lincolnshire. The northern feather-edge of the member is between Cawkwell and Stenigot according to Owen and Thurrell (1968) and the member extends to the south-east around Spilsby. It occurs in the Skegness Borehole and apparently extends below The Wash where similar mudstones situated between two sandstones occurs above the Sandringham Sands Formation and below the Tealby Formation.

Previous names
Hundleby Clay
Hundleby Clay Facies
Hundleby Clay Formation

Parent
Claxby Ironstone Formation

Age
Youngest Berriasian (youngest Ryazanian) to Valanginian

References
Casey, 1973; Owen and Thurrell, 1968; Wingfield et al., 1978.

5.8 TEALBY FORMATION

Name
The Tealby Series of Judd (1867) and the Tealby Series of Swinnerton (1935) includes the Fulletby Beds, Tealby Beds and Claxby Beds. Tealby Clay Formation of Rawson (1992) later modified to Tealby Formation (Rawson, 2006).

Type section
None

Primary reference sections
Alford Borehole, TF47NW12 [44630 75583] 'in the grounds of the pumping station' 48.7–78.4m depth [metricated] (Swinnerton, 1935)
Thoresway Borehole TF19NE14 [1646 9632] 46.3–61.9 m depth

Formal subdivisions
Includes the Tealby Limestone Member that, where present, informally divides the Tealby Formation into lower and upper units.

Lithology
The formation comprises brown and grey mudstones, ooid-rich and glauconitic in part, and with a sandy limestone in the middle part of the formation. It can be divided into three units. The lower unit comprises blue-grey mudstone, glauconite-rich in some horizons and ooid-rich at the base ('Lower Tealby Clay'). The middle unit comprises sandy limestones and ooid-rich mudstones (Tealby Limestone Member); these limestones are thicker and more indurated in northern Lincolnshire, becoming thinner, softer and more argillaceous towards the south. The upper unit comprises grey and buff mudstones, that are silt-rich at some horizons, occasionally glauconitic, and locally ooid-rich horizons towards the top ('Upper Tealby Clay').

Definition of upper boundary
In southern Lincolnshire and The Wash a rythmic succession of interburrowed and interbedded mudstone, 'chamosite' mud, 'chamosite' ooliths, quartz sand and small pebbles of

quartz and ironstone (Roach Formation) rest on grey and buff mudstones, silt-rich at some horizons, occasionally glauconitic and locally ('Upper Tealby Clay'). In central to northern Lincolnshire ferruginous, sandy limestones and ferruginous, mudstones (Roach Formation) rest on grey and buff mudstones, silt-rich at some horizons, sporadically glauconitic and locally ('Upper Tealby Clay'). In northern Lincolnshire, between Nettleton Top and Audleby, sandstones of the overstepping Carstone Formation rest on the limestones of the Tealby Limestone Member, and between Audleby and Clixby the arenaceous Carstone Formation rests on mudstones of the 'Lower Tealby Clay'.

Definition of lower boundary
The base is an erosion surface where there is a down-section change from blue-grey clay, glauconite-rich at some horizons and silty and ooidal in the lower part (Lower Tealby Clay Member) to clayey, ooidal ironstone (Claxby Ironstone Formation).

Thickness
Up to about 31 m

Distribution
The Tealby Formation is present in boreholes beneath The Wash, the southern-most successions being in BGS boreholes 72/77 and 72/78 (Wingfield et al., 1978). Further south, it apparently passes laterally into the Roach and Dersingham formations (e.g. in the Hunstanton Borehole). The Tealby Formation occurs beneath the Lincolnshire Wolds, disappearing north of the Audleby area in northern Lincolnshire. Its presence around Elsham, northern Lincolnshire, recorded in early publications, is due to the erroneous correlation of Kimmeridgian Elsham Sandstone and Kimmeridge Clay Formation with Neocomian deposits.

Previous names
Greystone (Tealby Limestone Member) (Dikes and Lee, 1837; Judd, 1867)
Tealby Beds
Tealby Clay Formation (Rawson, 1992)
Tealby Formation (Rawson, 2006)

Parent
None

Age
Hauterivian to Barremian

References
Dikes and Lee, 1837; Gaunt, Fletcher and Wood, 1992; Judd, 1867; Rawson, 1971b; Swinnerton, 1935; Wingfield et al., 1978.

5.8.1 Tealby Limestone Member

Name
Originally refered to as Tealby Limestone on a figure in Keeping (1882). Formalised as a member in Rawson (1992).

Type section
None

Primary reference sections
Alford Borehole, TF47NW12 [44630 75583] 'In the grounds of the pumping station' 48.7–64.94 m depth (metricated).
Thoresway Borehole TF19NE14 [1646 9632] 46.3–46.79 m depth

Formal subdivisions
None

Lithology
Comprises sandy limestone with ooid-rich mudstones. The limestones are thicker and more indurated in northern Lincolnshire, becoming thinner, softer and more argillaceous towards the south.

Definition of upper boundary
In much of Lincolnshire, grey and buff mudstones, silt-rich in some horizons and occasionally glauconitic ('Upper Tealby Clay'), rest on sandy limestones with ooid-rich mudstones (Tealby Limestone Member). In the Brigg District, to the north of Normandy, ferruginous limestone (Roach Formation) rests on sandy limestones (Tealby Limestone Member). In the Audleby–Nettleton Top area, pebbly sandstone (Carstone Formation) rests on Tealby Limestone Member.

Definition of lower boundary
Sandy limestones and ooid-rich mudstones (Tealby Limestone Member) rest on blue-grey mudstone, glauconite-rich in some horizons and silty and ooid-rich in the lower part ('Lower Tealby Clay').

Thickness
Generally up to about 4 m, but estimated to be 6 m at North Willingham (Owen and Thurrell, 1968).

Distribution
Confined to Lincolnshire. It was not seen in the Skegness Borehole or beneath The Wash. According to Owen and Thurrell (1968) it is present between Belchford and Cawkwell and in the south of the county and is 3.4 m thick at Thorseway. It thins and disappears to the north of Audleby.

Previous names
Greystone
Tealby Limestone

Parent
Tealby Formation

Age
Barremian

References
Dikes and Lee, 1837; Gaunt, Fletcher and Wood, 1992; Judd, 1867; Owen and Thurrell, 1968; Rawson, 1971b, 1992; Swinnerton, 1935.

5.9 ROACH FORMATION

See Section 5.3

5.10 SKEGNESS CLAY FORMATION

Name
Introduced by Gallois (1975b) as Skegness Clay. Given formal status as Skegness Clay Formation herein and in Rawson (2006).

Type section
Skegness Borehole TF56SE9 [5711 6398] 44.58–46.56 m depth.

Primary reference section
BGS Borehole 72/78 [TF 6494 4972] 23.34–24.60 m depth.

Formal subdivisions
None

Lithology
The Formation comprises medium and dark grey mudstone with *Prodeshayesites bodei* and iridescent fragments of other ammonites, some of which are partially pyritised and phosphatised. In borehole 72/78 the lower part of the formation becomes brownish grey, with scattered, cream-coloured phosphatic nodules. Burrows occur, sometimes filled with limonite ooids.

Definition of upper boundary
The upper boundary is defined by a downward change from pale grey, calcareous, mudstone (Sutterby Formation) to grey and dark grey mudstone with ammonites, some of which are partially pyritised and phosphatised.

Definition of lower boundary
In the type section, the base is defined by a downward change from grey and dark grey mudstone with partially pyritised and phosphatised ammonites to black, pyritous mudstone with scattered ooids (Roach Formation). The boundary is apparently conformable, although the junction is bioturbated and the top of the underlying Roach Formation is burrowed.

Thickness
1.98 m in the type section

Distribution
Confined to The Wash and southern part of Lincolnshire, but not known at outcrop. The formation occurs only in the Skegness Borehole and BGS Borehole 72/78 beneath The Wash. It has not been recognised in Norfolk, but it appears to extend under The Wash to within two kilometres of Hunstanton (Wingfield et al., 1978). Swinnerton (1935), mentioned 1.83 m of a similar lithology below the Sutterby Formation in the Alford and Maltby boreholes, and although he made no reference to the fauna, this deposit may be the Skegness Formation.

Previous names
None

Parent
None

Age
Early Aptian

References
Gallois, 1975b, 1984, 1994; Swinnerton, 1935; Wingfield et al., 1978.

5.11 SUTTERBY MARL FORMATION

Name
Term Sutterby Marl introduced by Swinnerton (1935). Given formal status herein and in Rawson (2006).

Type section
'A little valley immediately east of the hamlet of Sutterby' [TF 391 726] (Swinnerton, 1935). The grid reference is after Kaye and Barker (1965) who later revisited the site (although they appear to have transposed the northings and eastings).

Primary reference sections
Alford Borehole TF47NW12 [44630 75583] 'In the grounds of the pumping station' (Swinnerton, 1935)
BGS Wash Borehole 72/78 [TF 6494 4972] 22.20–23.34 m depth

Formal subdivisions
None.

Lithology
The formation comprises thin, poorly exposed, pale grey calcareous mudstone. It is usually strongly bioturbated and contains a rich and diverse macrofauna, including ammonites, belemnites, bivalves, brachiopods, rare echinoids and corals, together with coccoliths, foraminifera and ostracods.

Definition of upper boundary
The upper boundary is placed at an erosion surface where there is a downward change from sandstones (Carstone Formation) to calcareous mudstones.

Definition of lower boundary
The base is taken at the erosion surface immediately below a phosphatic nodule horizon. In the type section the base is marked by a downward change from pale grey, fossiliferous, calcareous clay to sandstones (Roach Formation). In southern Lincolnshire and below The Wash, there is a downward change from pale grey, fossiliferous, calcareous mudstone to grey to dark grey, sparsely fossiliferous, clay with iridescent ammonite fragments (Skegness Clay).

Thickness
Up to about 3.14 m in boreholes, but 1–2 m at outcrop in the type area.

Distribution
Southern Lincolnshire and The Wash. The Sutterby Formation extends as far north as the Oxcombe–Scamblesby area. Southwards, the formation disappears below The Wash, approximately 2 km north of the Norfolk coast.

Previous names
Sutterby Marl
Sutterby Marl Formation

Parent
None

Age
Late Aptian

References
Casey, 1961; Gallois, 1994; Gossling, 1929; Kaye and Barker, 1965; Swinnerton, 1935; Wingfield et al., 1978.

5.12 CARSTONE FORMATION

See Section 5.4

5.13 HUNSTANTON FORMATION

Name
The term Hunstanton Formation was used in Rawson (1992). It is a modification of a number of previous names given to the beds with a distinctive red colour (in part), below a strongly developed erosion surface at the base of the Chalk Group (and from which the formation is specifically excluded). Although principally of Albian age the top of the formation is known to be of earliest Cenomanian age in the Cleeveland Basin (Mitchell, 1995). See also discussion in Section 3.4.

Type section
Hunstanton Cliff [TF 6725 4130 to 6786 4238], north Norfolk (Owen, 1995; Gallois, 1994).

Primary reference sections
South Ferriby Quarry [SE 9915 2045], Lincolnshire (Gaunt et al., 1992)
Speeton Cliffs [TA 162 752 to 192 744].

Formal subdivisions
None. In describing the thick succession at outcrop near Speeton in the Cleveland Basin, Mitchell (1995) divided the Hunstanton Formation into five members. These are in ascending order the Queens Rocks Member, Speeton Beck Member, Dulcey Dock Member, Weather Castle Member and the Red Cliff Hole Member. They span the Albian–Cenomanian boundary with this horizon being placed within the Weather Castle Member. These divisions are not readily recognisable in successions away from this area and are considered of informal status herein.

Lithology
Rubbly to massive chalks with marl bands; typically pink to brick-red (due to disseminated hematite), but locally upper part grey due to secondary alteration of the iron minerals. The lower part of the formation is commonly weakly sandy.

Definition of upper boundary
Erosion surface, locally developed as a hardground, overlain by nodular chalk (lowest Cenomanian) of Paradoxica (or Sponge) Bed or (in Cleveland Basin) Crowe's Shoot Member (Mitchell, 1995); this horizon (the base of the 'Lower' Chalk in Norfolk, or elsewhere of the Ferriby Formation) may or may not correspond with the upper limit of red chalks.

Definition of lower boundary
Sharp or (apparently) gradational boundary of marly chalks with ferruginous sandstones of Carstone Formation or (in Cleveland Basin) with mudstone of Speeton Clay Formation; commonly marked by a line of phosphatic nodules (burrow-fills).

Thickness
About 1 m at the type section in Norfolk, typically 3 m in Lincolnshire and south Yorkshire, thinning over the Market Weighton High, but expanding up to an estimated 30 m in Cleveland Basin with about 24 m exposed in the cliffs at Speeton.

Distribution
Present throughout Yorkshire (including the Cleveland Basin where it attains its maximum development) and Lincolnshire and extends southwards to its type locality of Hunstanton on the north Norfolk coast. The formation passes laterally into the Gault Formation south of Dersingham in Norfolk.

Previous names
Red Chalk
Hunstanton Limestone
Hunstanton Red Rock
Hunstanton Chalk Formation
Hunstanton Red Chalk Formation (Owen, 1995 and Mortimore et al., 2001)
Hunstanton Chalk Member (Wood and Smith, 1978)

Parent
A stand-alone formation beneath and excluded from the definition of the Chalk Group. See discussion in Section 3.4.

Age
Mid to Late Albian throughout most of its outcrop but includes the earliest Cenomanian in Yorkshire.

References
Gallois, 1994; Gaunt, Fletcher and Wood, 1992; Mitchell, 1995; Mortimore, Wood and Gallois, 2001; Owen, 1995; Sumbler, 1996, 1999; Wood and Smith, 1978; Wright, 1968.

'BEDFORDSHIRE STRAITS' AND ADJACENT AREAS

5.14 SANDRINGHAM SANDS FORMATION

See entry within Section 5 North Norfolk

5.14.1 Roxham Member

See entry within Section 5 North Norfolk

5.15 PURBECK GROUP

See entry within Section 3

5.15.1 Lulworth Formation

See entry within Section 3

5.15.2 Durlston Formation

See entry within Section 3

5.15.3 Haddenham Formation

Name
Name introduced to cover all of the thin marginal beds formerly identified as the Purbeck Limestone in Wiltshire, Oxfordshire and Buckinghamshire.

Type area
Thame to Aylesbury area
BGS Hartwell Borehole SP71SE1 [7926 1223]

Primary reference sections
Bugle Pit [SP 794 121], Hartwell
Swindon Old Town Railway Cutting
Town Gardens Quarry, Swindon

Formal subdivisions
None

Lithology
Fossiliferous marine limestones and lagoonal limestones together with calcareous and commonly glauconitic, sandstones and sands.

Definition of upper boundary
Overlain unconformably by generally non-calcareous and commonly ferruginous sands and sandstones of the Lower Greensand or Whitchurch Sand Formation, or by calcareous mudstones of the Gault Formation.

Definition of lower boundary
Upwards change from fully marine limestones with large molluscan fossils of the Portland Stone Formation (Portland Group) to lagoonal fine-grained limestones and marls of the Haddenham Formation (Purbeck Limestone Formation on BGS maps), the base of which is commonly marked either by laminated, ostracod-bearing or oyster-bearing marl, or by a sharp nonsequential junction.

Thickness
Up to 13 m thick

Distribution
Outliers from Swindon, in north Wiltshire, through Oxfordshire to Aylesbury in Buckinghamshire, and possibly an outlier in the Vale of Pewsey near Devizes, though this is currently rather poorly known (Wimbledon, 1980).

Previous names
Purbeck Limestone Formation
Purbeck Limestone
Portland Beds
Portland Formation

Parent
Purbeck Group

Age
Portlandian

References
Arkell, 1935; Blake, 1880; Cox, Gallois and Sumbler, 1994; Cox, 1996; Horton at al., 1995; Townson, 1975; Wimbledon, 1976, 1980; Wimbledon and Cope, 1978.

5.16 WEALDEN GROUP

See entry within Section 3

5.16.1 Whitchurch Sands Formation

Name
Term first used as Whitchurch Sands by Casey and Bristow (1964). Formalised herein as Whitchurch Sands Formation and in Rawson (2006).

Type area and sections
Oxford to Aylesbury area SP 57 06 to 79 21, Shotover Hill to Whitchurch and the Oving Hills, Buckinghamshire and Oxfordshire.
Temporary trench section [SP 7590 8110 to 7970 7990], Whitchurch, Bucks.

Primary reference section
Monks Farm Pit [SP 5654 0642], Risinghurst, Shotover Hill, Oxford

Formal subdivisions
None

Lithology
White, buff, yellow, orange and red to dark brown, generally unconsolidated fine to medium-grained sand, with seams and irregular masses of limonite-cemented sandstone and rare siliceous or calcareous concretions, localised beds of grey to white silt and clay or mudstone, and rare limonitic ironstone.

Definition of upper boundary
Discordant contact with coarse gritty sandstones of the Lower Greensand Group, or calcareous mudstones of the Gault Formation. Mostly occurs as outliers without succeeding strata.

Definition of lower boundary
Unconformable contact on limestone, calcareous sandstone or calcareous mudstones of the Haddenham Formation (formerly the Purbeck Limestone Formation) or on fossiliferous limestones or calcareous sandstones of the Portland Group, or rarely mudstones or siltstones of the Kimmeridge Clay Formation.

Thickness
Up to 20 m thick

Distribution
Outliers in the Aylesbury to Oxford area, Swindon and in the Vale of Pewsey near Devizes, Wiltshire (Casey and Bristow, 1964; Horton et al., 1995).

Previous names
Lower Greensand
Lower Greensand Group
Portland Group
Portland Pubeck
Purbeck Group
Shotover Sands
Shotover Ironsands
Whitchurch Sands

Parent
Wealden Group

Age
Valanginian

References
Casey and Bristow, 1964; Horton et al., 1995.

5.17 LOWER GREENSAND GROUP

See entry within Section 3

5.17.1 Woburn Sands Formation

Name
The Woburn Sands was a name proposed by Cameron (1892) to cover the Lower Greensand of Bedfordshire, Buckinghamshire and the Midlands. The name became restricted in usage to the principal outcrop in Bedfordshire and formalised as Woburn Sands Formation in Rawson (1992).

Type area and section
Type area around Woburn district from Clophill [TL 08 38] to Leighton Buzzard [SP 91 25].
Disused fuller's earth workings centred around [SP 930 340] (now mostly backfilled) between Woburn Sands to the north-west and Woburn to the south-east.

Primary reference sections
Fuller's Earth Pit at Old Wavendon Heath [SP 932 345]. (Composite: described in Shephard-Thorn and others, 1993).
Clophill Quarry [TL 0800 3800]
Mundays Hill Quarry [SP 937 282] and contiguous Nine Acre Pit [SP 940 277]
Ascot Farm Sand Pit [SP 9090 2405]
Description of Gault Clay–Woburn Sands junction in the Hitchin (221) district (Hopson, 1992)
Arlesey Brickpit Borehole TL13SE45 [1887 3461] 72.96–83.49 m depth
No single section illustrates lithological variation.

Formal subdivisions
None, but several distinct lithological units recognised in working pits. From base to top these are, Brown Sands, Silver Sands, Silty Beds and Red Sands. Eyers (1991) proposed two divisions into a Lower Woburn Sands Formation (equivalent to the Brown Sands) and an Upper Woburn Sands Formation, but the lateral variation of the succession means these are not mappable.

Lithology
Sandstone (or loose sand), fine- to coarse-grained, rounded, quartz sand, glauconitic in part and commonly silty with some clay wisps or seams. Locally clean grey or 'silver' sands. Locally cemented to iron pan or gritty ferruginous sandstone. Cross-bedded. Some pebbles and phosphatic nodules to base. Typically grey or greenish grey weathering to ochreous yellow-brown. Minor lignite and pyrite. Local developments of fuller's earth. Fossils are rare but fossiliferous nodule layers are known near to the base of the formation as at Upware and Brickhill.

Definition of upper boundary
Unconformity. Overlapped by grey mudstone of the Gault Formation and locally overlain by the so called 'Junction Beds' a term applied by Shephard-Thorn et al. (1994) to include the Shenley Limestone (pale brown phosphatic limestone) which passes laterally into glauconitic sandy marl (calcareous mudstones) with 'carstone' (ferruginous sandstone) fragments and gritty quartz sand with 'carstone' and 'boxstone fragments'.

Definition of lower boundary
Unconformably overlies Jurassic or older strata in boreholes. Jurassic strata comprise predominantly mudstones such as Kimmeridge Clay, Ampthill Clay and Oxford Clay.

Thickness
Up to 120 m. Rapid variation, resulting from uneven underlying topography and pre-Gault Formation erosion. Thins to the south-east on to London Platform. Some 85 m are proved at Woburn, 60 m proved east of Leighton Buzzard. Absent west of Leighton Buzzard.

Distribution
Outcrop Leighton Buzzard to Cambridge through Bedfordshire, Buckinghamshire and Cambridgeshire an area often described as the 'Bedfordshire Straits' during the Early Cretaceous. This 'strait' linked the Weald Basin (Folkestone and Sandgate formations) in the south to the Eastern England Shelf (Carstone and Sutterby formations) in the north.

Previous names
Leighton Buzzard Sands
Lower Greensand

Parent
Lower Greensand Group

Age
Early to Late Aptian

References
Cameron, 1892; Casey, 1961; Edmonds and Dinham, 1965; Eyers, 1991; Hancock, (editor), 1972; Hopson, 1992; Kirkaldy, 1939, 1963; Rawson et al., 1978; Shephard-Thorn et al., 1994.

5.17.2 Munday's Hill Phosphatic Sandstone Formation

Name
New name proposed to cover those beds (formerly called the 'Junction Beds', sensu Shephard-Thorn et al. (1994); 'Junction facies' sensu Eyers (1995); 'Shenley Limestone and Junction Beds' sensu Wonham and Elliott (1995)) at the top of the Lower Greensand Group and beneath the Gault Formation.

Type area
Sand pits in the Leighton Buzzard area, Bedfordshire, with particular reference to Munday's Hill Pit [SP 9394 2798]. The northern Weald area.

Primary reference section
None

Formal subdivisions
Includes the Shenley Limestone Member

Lithology
In the stratotype area, the formation generally comprises poorly cemented pebbly ferruginous sandstone and argillaceous, glauconitic and phosphatic fine- to coarse-grained, locally pebbly, sandstone and sandy mudstone including 'carstone' and 'boxstone' clasts. Dark or buff-coloured phosphatic concretions and worn and reworked phosphatic pebbles and fossils are common, and generally form several discrete horizons. Locally, in the stratotype area and some nearby localities, a thin (about 0.6 m), pale to pinkish-yellow to pale brown micritic limestone (Shenley Limestone Member) occurs in the lower part of the formation, associated with thin ironstone horizons. In the northern Weald, the lithology becomes more argillaceous, but can always be distinguished from the mudstones of the overlying Gault Formation by its sandier and more glauconitic character. In East Anglia, coeval strata are represented by the Carstone Formation.

Definition of upper boundary
The upper boundary is a non-sequence, usually marked by a phosphatic nodule–pebble bed horizon, and coincident with the facies change from dark, greenish-grey, clayey, glauconitic sandstone with common horizons of phosphatic nodules–pebbles of the underlying Munday's Hill Phosphatic Sandstone, to dark-grey, smooth-textured mudstone of the Gault Formation. In some places the base of the Gault Formation is represented by about 1.2 m of red fissile mudstone which has been termed the 'Red Clay' or 'Cirripede Bed' (Toombs, 1935).

Definition of lower boundary
In the stratotype area, the lower boundary is an unconformity, marked by the facies change from clayey siltstone or

trough cross-bedded sandstone of the underlying Woburn Sand Formation, to pale micritic limestone of the Shenley Limestone Member. Where the Shenley Limestone is absent, the common phosphatic nodules, ferruginous sandstone and pebbles in dark, greenish-grey, clayey glauconitic sandstone of the Munday's Hill Phosphatic Sandstone serve to distinguish it from the pale or ferruginous facies of the underlying Woburn Sand Formation.

Thickness
Up to 2.5 m in the Munday's Hill area

Distribution
Bedfordshire, Buckinghamshire

Previous names
Junction Beds (parts) of Owen (1992)
Junction Beds (parts) of Owen et al. (1996)
Junction Beds (parts) of Wonham and Elliott (1996)
Transition Series (Carstone and Shenley Limestone) of Johnson and Levell (1995)

Parent
Lower Greensand Group

Age
Early Albian

References
Casey, 1961; Eyers, 1992, 1995; Johnson and Levell, 1995; Lamplugh, 1922; Owen, 1972, 1992; Owen, Shephard-Thorn and Sumbler, 1996; Shephard-Thorn et al., 1994; Smart, 1997; Toombs, 1935; Wonham and Elliott, 1996.

5.17.2.1 Shenley Limestone Member

Name
The Shenley Limestone was used by Lamplugh and Walker (1903) to describe a fossiliferous band at the top of the Lower Greensand near Leighton Buzzard.

Type area
Shenley Hill [SP 93 27] near Leighton Buzzard

Primary reference sections
Bryants Lane Quarry [SP 929 286], north of Leighton Buzzard
Munday's Hill [SP 937 282], 420 m north-west of Mile Tree Farm, Heath and Reach

Formal subdivisions
None

Lithology
Lenticular beds of a pale brown, phosphatic limestone with scattered polished goethite ooids (Owen 1972; Smart, 1997). It may be slightly limonitic and glauconitic. Brachiopods common.

Definition of upper boundary
The Shenley Limestone Member phosphatic limestone is overlain by a 1.2 m thick fissile, red mudstone informally called 'Red Clay' or 'Cirripede Bed' of the Gault Formation.

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

Thickness
Up to c. 0.1 m

Distribution
Restricted to the area around Leighton Buzzard (sheet 220).

Previous names
Shenley Limestone

Parent
Munday's Hill Phosphatic Sand Formation

Age
Lower Albian

References
Casey, 1961; Eyers, 1991; Lamplugh, 1922; Lamplugh and Walker, 1903; Owen, 1972; Shephard-Thorn et al., 1994; Smart, 1997.

5.17.3 Faringdon Sand Formation

Name
Proposed herein and named after the village in the type area.

Type areas and section
At the type sites for the constituent members.
Old gravel pits between Faringdon and Little Coxwell, Oxfordshire. Grid reference [SU 288 943] is for the pit labelled as 'Faringdon Pit' by Arkell (1947).
In the vicinity of Baulking [SU 31 90], Oxfordshire.
In the vicinity of Furze Hill [SU 29 92] and Fernham [SU 293 919], Oxfordshire.

Primary reference sections
The Fernham boreholes (Nos. 1 to 14; SU29SE 1 to 9 and SU39SW 13 to 17) and Baulking boreholes (Nos. 1 to 11; SU39SW 2 to 4 and 24 to 31) [SU 28 29 to SU 32 90] (see Poole and Kelk, 1971; Poole et. al., 1971 for details).
Laporte Earths Quarry [SU 323 912], at Baulking, Oxfordshire.
Furze Hill Borehole SU29SE16 [2905 9281] and boreholes 'F10' (SU29SE5 [2982 9242]), 'F12' (SU29SE7 [2925 9288]) and 'F13' (SU29SE8 [2950 9305]) described in Poole et al. (1971), all located near Fernham, Oxfordshire. The Furze Hill Borehole contains the thickest development of the Fernham Sand Member.

Formal subdivisions
Three members proposed from the base as Faringdon Sponge Gravel Member, the Baulking Sand Member and the Fernham Sand Member.

Lithology
The Faringdon Sponge Gravel Member comprises cross-bedded pebbly sands and highly fossiliferous gravels composed predominantly of the remains of calcareous sponges, with brachiopods, echinoderms and bryozoa. Bored mudstone and limestone clasts and phosphatised fossils, derived from the underlying Kimmeridge Clay and Corallian Group strata, occur at the base of the formation and at higher levels within the succession. Two subdivisions,

comprising lower 'yellow gravel' and upper (iron-oxide stained) 'red gravel', have previously been recognised, separated by a non-sequence. According to Poole et al. (1971), cross-bedding diminishes upwards from the 'yellow gravel' into the 'red gravel', and there is a change in current direction as indicated by apparent dips.

The Baulking Member comprises fine- to medium-grained siltstone and sandy mudstone with horizons of fuller's earth. Locally richly glauconitic with some horizons of shelly sand. The lower part of the interval is usually sandier, with horizons of fuller's earth and slumped beds. The upper part of the formation is mostly dark grey, thin current-bedded mudstone, with ironstone locally developed in the lower part of the interval. The mudstone contains white, fine-grained sandy and silty wisps and laminae.

The Ferham Sand Member comprises reddish-brown, ferruginous, cross-bedded, shell-fragmental, medium- to coarse-grained, clean sandstone. There are scattered pebbles, bands of conglomeratic grit and minor horizons of mudstone.

Definition of upper boundary
Not seen. The Fernham Sand Member occurs as hill-cappings in the Baulking area. The top of the formation is locally defined by the depth of the present-day weathered zone.

Definition of lower boundary
Unconformable, channelled, at the basal contact of the 'yellow gravel' with underlying Kimmeridge Clay mudstones, or locally, Corallian Group limestones.

Thickness
Variable depending on local superposition of constituent members that have maximum thicknesses of about 50 m (Faringdon Sponge Gravel Member), up to 48 m (Baulking Sand Member) and at least 24 m (Fernham Sand Member).

Distribution
In the Faringdon and Baulking to Uffington areas, and around Little Coxwell and Fernham, Oxfordshire.

Previous names
Newly defined

Parent
Lower Greensand Group

Age
Aptian

References
Arkell, 1947; Austen, 1850; Casey, 1961; Meyer, 1864; Poole and Kelk, 1971; Poole et al., 1971; Rawson et al., 1978; Wilkinson, 2006.

5.17.3.1 Faringdon Sponge Gravel Member

Name
Proposed as the Faringdon Sponge Gravel in Austen (1850) and formalised herein.

Type section
Old gravel pits between Faringdon and Little Coxwell, Oxfordshire. Grid reference [SU 288 943] is for the pit labelled as 'Faringdon Pit' by Arkell (1947).

Primary reference section
None

Formal subdivisions
None. Informally divided into a lower 'Yellow Gravel' and an upper 'Red Gravel'.

Lithology
Cross-bedded pebbly sands and highly fossiliferous gravels comprising predominantly the remains of calcareous sponges, but also including common brachiopods, echinoderms and bryozoa. Bored mudstone and limestone clasts and phosphatised fossils, derived from underlying Kimmeridge Clay and Corallian Group strata, occur at the base of the formation and at higher levels within the succession. Two subdivisions, comprising lower 'yellow gravel' and upper (iron-oxide stained) 'red gravel', have previously been recognised, separated by a non-sequence. According to Poole et al. (1971), cross-bedding diminishes upwards from the 'yellow gravel' into the 'red gravel', and there is a change in current direction as indicated by apparent dips.

Definition of upper boundary
The upper boundary of the formation is the upward facies change from gravelly, fossiliferous sandstone to non-pebbly, poorly fossiliferous sandstone and mudstone containing horizons of chert and ironstone of the Baulking Sand Member.

Definition of lower boundary
Unconformable, channelled, at the basal contact of the 'yellow gravel' with underlying Kimmeridge Clay mudstones, or locally, Corallian Group limestones.

Thickness
About 50 m

Distribution
Faringdon area, Oxfordshire

Previous names
None

Parent
Lower Greensand Group

Age
Aptian

References
Arkell, 1947; Austen, 1850; Casey, 1961; Meyer, 1864.

5.17.3.2 Baulking Sand Member

Name
New name proposed for strata described in Poole and Kelk (1971) and Poole et al. (1971). Rawson (1978 et al., fig. 3) appears to suggest that these deposits are best regarded as equivalent to the Seend Ironstone Formation to the west.

Type area
In the vicinity of Baulking [SU 31 90] in Oxfordshire.

Primary reference sections
The Fernham Boreholes (Nos. 1 to 14; SU29SE 1 to 9 and SU39SW 13 to 17) and Baulking Boreholes (Nos. 1 to 11; SU39SW 2 to 4 and 24 to 31) [SU 28 29 to SU 32 90] (see Poole and Kelk, 1971; Poole et. al., 1971 for details).
Laporte Earths Quarry [SU 323 912], at Baulking, Oxfordshire.

Formal subdivisions
None

Lithology
Fine- to medium-grained siltstone and sandy mudstone with horizons of fuller's earth. Locally the member is richly glauconitic, with some horizons of shelly sand. The lower part of the interval is usually sandier, with horizons of fuller's earth and slumped beds. The upper part of the formation is mostly dark grey, thin current-bedded mudstone, with ironstone locally developed in the lower part of the interval. The mudstone contains white, fine-grained sandy and silty wisps and laminae.

Definition of upper boundary
The top of the formation is the unconformable contact with the Fernham Sand Member, marked by the sharp upward facies change from mudstone to ferruginous sandstone.

Definition of lower boundary
The base of the formation is the unconformable contact with Jurassic strata (Corallian Group limestones or Kimmeridge Clay Formation mudstones) or they lie conformably above the coarse, pebbly sandstones of the Faringdon Sponge Gravel Member.

Thickness
Up to 48 m in the Uffington Borehole SU38NW1 [3065 8948] (Poole et al., 1971).

Distribution
Baulking to Uffington area, Oxfordshire

Previous names
Division 3 (sandy clays) of Meyer (1864), mapped as undivided Lower Greensand in Abingdon district.

Parent
Lower Greensand Group

Age
Aptian

References
Arkell, 1947; Casey, 1961; Meyer, 1864; Poole and Kelk, 1971; Poole et al., 1971; Rawson, Curry et al., 1978.

5.17.3.3 Fernham Sand Member

Name
New name proposed to cover the ferruginous sands overlying the Baulking Sand Member.

Type area
In the vicinity of Furze Hill [SU 29 92] and Fernham [SU 293 919], Oxfordshire.

Primary reference sections
Furze Hill Borehole SU29SE16 [2905 9281] and boreholes 'F10' (SU29SE5 [2982 9242]), 'F12' (SU29SE7 [2925 9288]) and 'F13' (SU29SE8 [2950 9305]) described in Poole et al. (1971), all located near Fernham, Oxfordshire. The Furze Hill Borehole contains the thickest development of the Fernham Sand Member.

Formal subdivisions
None

Lithology
Reddish-brown, ferruginous, cross-bedded, shell-fragmental, medium- to coarse-grained, clean sandstone. There are scattered pebbles, bands of conglomeratic grit and minor horizons of mudstone.

Definition of upper boundary
Not seen. The Fernham Sand Member occurs as hill-cappings in the Baulking area. The top of the formation is locally defined by the depth of the present-day weathered zone.

Definition of lower boundary
Unconformable contact with the underlying Baulking Sand Member, marked by the upward facies change from the predominantly mudstone facies of the upper part of the Baulking Formation, to the ferruginous sandy facies of the Fernham Sand Member.

Thickness
At least 24 m in the Furze Hill Borehole SU29SE16 [2905 9281] (Poole et al., 1971).

Distribution
Area around Little Coxwell and Fernham, Oxfordshire.

Previous names
Division 4 (sands with chert and ironstone) of Meyer (1864); 'Ferruginous sands and sandstones' of Poole et al. (1971), and possibly the so-called 'Red Sands of Uffington' of Casey (1961).
Furze Hill Sandstone Formation.

Parent
Lower Greensand Group

Age
Aptian

References
Arkell, 1947; Casey, 1961; Meyer, 1864; Poole and Kelk, 1971; Poole et al., 1971; Rawson et al., 1978.

5.17.4 Calne Sands Formation

Name
Sands described from the area around Calne by Ramsey, Aveline and Hull (1958). Named as Calne Sands Formation by Hesselbo et al. (1990).

Type section
Sand pit ('Pearce's Old Pit') [SU 017 713] near Calne, Wiltshire.

Primary reference section
None

Formal subdivisions
None

Lithology
Cross-bedded, well-sorted, sub- to well-rounded quartzose sandstone. The lower part of the formation is fine- to medium-grained; the upper part is medium-grained sandstone and is more argillaceous. Thin mudstone drapes occur on cross-bedded surfaces in both units, and fossil wood, including logs, is common or abundant. The contact between the two units is either gradational or marked by a scoured surface.

Definition of upper boundary
A sharp erosive junction with the overlying coarse-grained, poorly sorted ferruginous sandstone of the Carstone

Formation, marked by a concentration of quartz pebbles in the base of the Carstone and large burrows that penetrate the top of the Calne Sands Formation.

Definition of lower boundary
Unconformable, burrowed erosion surface with the underlying mudstones of the Kimmeridge Clay Formation. The surface is marked by a pyritic, phosphatic and quartz pebble bed, containing derived Kimmeridgian fossils and lignite.

Thickness
Between 5.5 and 7.8 m according to Hesselbo et al. (1990), although Owen et al. (1996) recorded up to 12 m.

Distribution
North Wiltshire

Previous names
None

Parent
Lower Greensand Group

Age
Aptian (*H. jacobi* Zone sensu Casey, 1961)

References
Casey, 1961; Hesselbo et al., 1990; Knox, 1999; Owen, Shephard-Thorn and Sumbler, 1996; Ramsey, Aveline and Hull, 1858.

5.17.5 Seend Ironstone Formation

Name
Described as Lower Greensand (Cunnington, 1850) the term Seend Ironstone has been used informally in much of the literature. Casey (1961) used the term Iron Sands of Seend. Called the Seend (Ironstone) Formation in Rawson (1992).

The strata forming the upper 16.5 m of succession reported above the Faringdon Sponge Gravels Formation at Badbury Hill [SU 2609 9436] comprise sandy clays and sandstone with chert and ironstone (Meyer, 1864; Arkell, 1947), and are regarded as equivalent to the Seend Ironstone Formation in Rawson et al. (1978, fig. 3); herein these deposits are named the Baulking Sand Member of the Faringdon Sand Formation. See also entry 5.17.3.2 Baulking Sand Member.

Type section
Old ironstone workings [ST 938 608 to 937 610], near the village of Seend, Wiltshire.

Primary reference section
Hogshaw Hill Farm [SP 746 218], 1.6 km north of Quainton, Buckinghamshire.

Formal subdivisions
None

Lithology
Dark brown to red-brown, cross-bedded, highly ferruginous sandstone. The sandstone is generally poorly sorted and medium- to very coarse-grained or pebbly. At some localities there are veins of limonite, white chert pebbles and mudstone-rich partings. There is a rich marine macrofossil fauna dominated by brachiopods and molluscs, including occasional ammonites.

Definition of upper boundary
The upper boundary of the Seend Ironstone is the unconformable base of the Carstone Formation, Gault Formation or Quaternary sediments. Where the latter are absent, the base of the present day weathered zone marks the top of the formation.

Definition of lower boundary
Known occurrences of Seend Ironsand unconformably overlie mudstones of the Kimmeridge Clay Formation or finer-grained ferruginous sandstone of the Whitchurch Sand Formation. Possible equivalent strata described by Jukes-Browne (1905) from the Devizes district also unconformably overlie Portland Group sandstones. At Faringdon (see above), strata apparently representing the Seend Ironstone Formation occur above the Faringdon Sponge Beds Formation. Here the lower boundary of the Seend Ironstone equivalent (Baulking Sand Member) is marked by the downward facies change to coarse, sponge-rich gravels.

Thickness
Estimated to be not more than 12.2 m (Jukes-Browne, 1905)

Distribution
Wiltshire, Oxfordshire, Buckinghamshire

Previous names
Iron Sands of Seend (Casey, 1961)

Parent
Lower Greensand Group

Age
Aptian

References
Arkell, 1947; Casey, 1961; Casey and Bristow, 1964; Cunnington, 1850; Hesselbo, Coe, Batten and Wach, 1990; Jukes-Browne, 1905; Meyer, 1864; Rawson et al., 1978.

5.18 SELBORNE GROUP

See entry within Section 3

5.18.1 Gault Formation

See entry within Section 3

5.18.2 Upper Greensand Formation

See entry within Section 3

6 Cleveland/Yorkshire Basin

Within the Cleveland Basin, the greater part of the Lower Cretaceous succession is represented by the Speeton Clay Formation, ranging in age from the Late Berriasian (Ryazanian) to the Mid Albian. Overlying this formation is the Hunstanton Formation ('Red Chalk') that is described, for the Speeton area, in Mitchell (1995) and Mitchell and Underwood (1999). The Greensand Streak (Bed A4 or Bed UA4) of the Speeton Clay Formation is correlated in part with the Carstone of Lincolnshire and Norfolk and acts as a major correlation datum over the Market Weighton Axis (High). The Scheme shown in Table 6 is essentially that of Lamplugh (1889) who divided the strata into five lettered units from youngest to oldest. Study of the Speeton type section is hampered by the unstable nature of the cliff sections, at times variously hidden by slipped strata of higher beds or exposed by tidal scour; parts of the succession are only rarely seen and in many cases the bed succession is derived from slipped and often internally deformed masses. However, Lamplugh's framework has stood the test of time and been greatly refined by various authors working on parts of the succession between 1934 and 1973. Some details were added and the full succession brought together in Rawson et al. (1978) within the Geological Society Special Publication on Cretaceous correlations. This scheme was again modified by further work published in Rawson and Mutterlose (1983), Mitchell (1995) and Mitchell and Underwood (1999).

It is possibly now the time, to aid detailed discussion, for the plethora of alphanumeric beds to be formalised into a member framework within the Speeton Clay Formation (or perhaps as formations within a Speeton Group or Cromer Knoll Group?). Such a framework for members is beyond the scope of this report and it is not proposed that any such names below formation level be applied to BGS maps. Indeed it is unlikely that finer divisions of the Speeton Clay Formation would to be traceable within the limited outcrops available as much of the Speeton Clay inland is buried beneath the Chalk and Quaternary deposits.

6.1 SPEETON CLAY FORMATION

Name
First used by Phillips (1829) as the Speeton Clay. Named after the village of Speeton situated on the Yorkshire coast at Reighton Bay. Given formal status in Rawson et al. (1978).

Type section
A 1.5 km length of coast at the southern end of Filey Bay between Reighton Gap and Dulcey Dock [TA 143 764 to 749 167], Speeton Cliffs.

Primary reference section
None

Formal subdivisions
No formal names in the current literature. Divided into 'beds' designated E to A from the base up, and further divided by a large number of alphanumeric notations. It is suggested that formal member names for the constituent parts of the formation are considered but it is beyond the scope of this report to do so. Offshore in the Southern North Sea Basin the equivalent of the Speeton Clay Formation is divided into two seismic formations and informal members (Lott, and Knox, 1994).

Lithology
The Speeton Clay Formation comprises mudstones, cementstones and occasional bentonites. It was divided by Lamplugh (1889), into five units (E–A from the base related to its belemnite content) and these divisions are still maintained.

Bed E: The basal bed comprises mainly phosphatic nodules with occasional rolled and fragmented, pyritised and phosphatised bivalves, ammonites and bone and is usually referred to as the Coprolite Bed (Lamplugh, 1923). There is a marked break in the succession at the base of this bed and a less obvious one at the top.

D Beds: Black shale is overlain by greenish-brown, brown and grey clays and includes the Blue Bed (D6), the Ligula Bed (D5) and the Astarte Bed (D4). A compound nodular bed (Bed D1) occurs at the top of the 'D beds'. A significant break in the succession occurs between Beds D2D and D2E. Historically known also as the Lateralis Beds (Lamplugh, 1923).

C Beds: Alternations of pale and dark grey clays and shaley clays are characteristic of these beds. Nodules and glauconite occur at some levels. Includes the Main Speetonensis Bed (C6) and the Echinospatangus Bed (C3). Historically known also as the Jaculum Beds (Lamplugh, 1923).

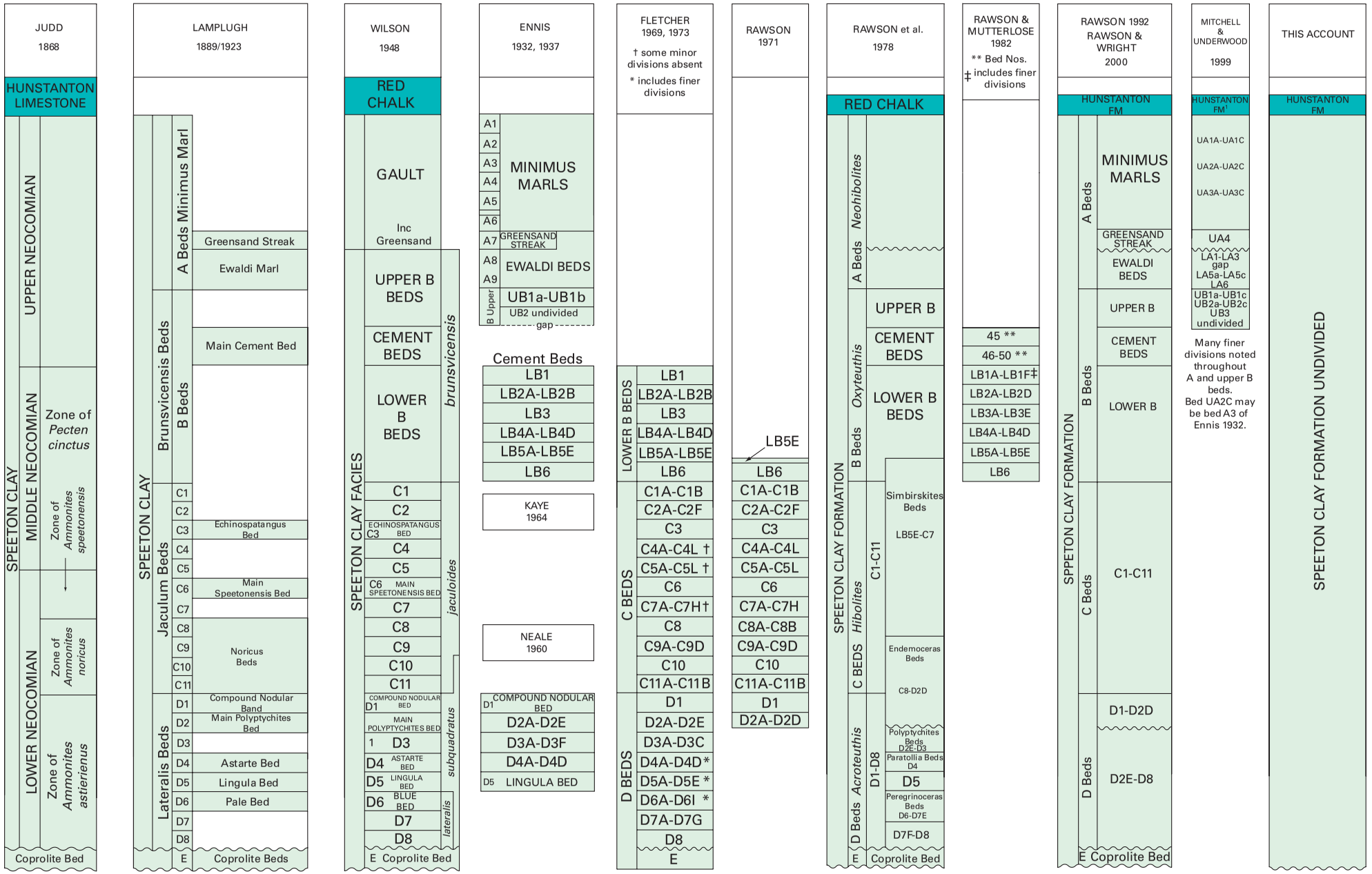
B Beds: A lower part of pale and dark grey and blue-grey clays with nodules and pyritous in some horizons passes upwards into the 'Cement Beds' and into an upper succession of striped blue, black and grey clays with nodules. Historically known also as the Brunsvicensis Beds (Lamplugh, 1923).

A Beds: Grey and brown calcareous clays passing up into glauconitic clays with nodules (the 'Greensand Streak', Bed A7) and up into grey, red and mottled calcareous clays. Known as the 'Ewaldi Marl' below and the 'Minimus Marl' above the Greensand Streak (Lamplugh, 1923) (Ewaldi Beds and Minimus Marls of Rawson (1992) and Rawson and Wright (2000)).

Definition of upper boundary
Sharp contact with the Hunstanton Formation comprising nodular and almost entirely red limestone (one bed near the base is white) underlain by brown and grey-green, glauconitic and calcareous clays, with horizons of phosphatic nodules, that form the A Beds of the Speeton Clay.

Definition of lower boundary
Grey and black clays (D Beds of the Speeton Clay Formation) rest on a thin, but prominent, pyritised and phosphatised basal bed (Bed E). The underlying dark grey to black mudstones (Kimmeridge Clay) has an eroded upper boundary.

Table 6 Lithostratigraphical scheme for the Cleveland/ Yorkshire Basin.



1 Member names used by Mitchell & Underwood, 1999 for Hunstanton Formation.

Thickness
Up to 100 m at outcrop, but possibly up to c.400 m in boreholes (Rawson et al., 1978).

Distribution
The formation is exposed along the coast at the southern end of Filey Bay. The outcrop is rarely exposed inland, but extends as a narrow strip along the northern edge of the chalk wolds to Granton, East Heslerton, West Heslerton to south of Knapton (1:50 000 scale geological sheets 54 and 55). It has been penetrated in several boreholes, located on the chalk wolds, including the Fordon 1 Borehole TA07NE1 [05834 75713], North Fordon G1 Borehole TA07NW1 [04138 76860], Fordon G2 TA07NW2 [04724 75377], Fordon G3 TA07NW3 [02027 76395], Reighton Borehole TA17NW12 [1465 7581] and Hunmanby TA17NW10 [1301 7588]. It is also said to have been penetrated in boreholes in the Great Driffield district (sheet 64). The formation was recognised in the North Sea by Rhys (1974), but the offshore succession has since been divided into the Carrack and Valhall formations (Johnson and Lott, 1993; Lott and Knox, 1994).

Previous names
Neocomian Strata
Speeton Clay
Speeton Series
Upper Shale

Parent
None

Age
Late Berriasian (Ryazanian) to Late Albian.

References
Ennis, 1932, 1937; Fletcher, 1969; Johnson and Lott, 1993; Judd, 1868, 1870; Kaye, 1964; Knox and Fletcher, 1978; Lamplugh, 1889, 1896, 1923; Lott and Knox, 1994; Mitchell and Underwood, 1999; Neale, 1960, 1962, 1968, 1974; Phillips, 1829; Rawson et al., 1978; Rawson and Mutterlose, 1983; Rhys, 1974; Swinnerton, 1936–1955; Young and Bird, 1822.

6.2 HUNSTANTON FORMATION

See entry within Section 5 Lincolnshire

6.2.1 Queens Rock Member

Name
The member was defined by Mitchell (1995).

Type section
Foreshore near Crab Rocks, Filey Bay, Yorkshire [TA 1528 7519]

Primary reference section
None

Formal subdivisions
None, but Mitchell divided it into seven beds.

Lithology
Comprises red marly limestone with occasional seams of pale limestone nodules. The member is divided into two parts by an erosion surface.

Definition of upper boundary
The boundary is placed at a change from marly limestone and bands of limestone nodules upwards into strongly rhythmically bedded marls and marly clay with limestones of the Speeton Beck Member.

Definition of lower boundary
Clays with sporadic ‘potato stones’ (the A Beds of the Speeton Clay Formation) overlain by marly limestones with seams of limestone nodules.

Thickness
4.95 m

Distribution
Recognised only on the Yorkshire coast near Speeton.

Previous names
None

Parent
Hunstanton Formation

Age
Albian

References
Mitchell, 1995

6.2.2 Speeton Beck Member

Name
Member named by Mitchell (1995).

Type section
Double Rocks to Red Cliff Hole, Filey Bay, Yorkshire [TA 1520 7516 to 1548 7510]

Primary reference section
None

Formal subdivisions
None, but Mitchell (1995) recognised 19 informal beds

Lithology
Member comprises rhythmically bedded white and pink limestones and grey or red marls or calcareous clays. The colouration of the argillaceous beds is paler in the lower part, but reddening becomes darker up-sequence. The limestones become harder upwards and the clays become marly and nodular.

Definition of upper boundary
The boundary is placed at the change from alternating white and pink limestones and clays up into nodular limestones (Dulcey Dock Member).

Definition of lower boundary
The boundary is placed at a change from marly limestone and seams of limestone of the Queens Rock Member into rhythmically bedded limestones, marls and clays.

Thickness
3.49 m

Distribution
Recognised only on the Yorkshire coast near Speeton.

Previous names
None

Parent
Hunstanton Formation

Age
Albian

References
Mitchell, 1995

6.2.3 Dulcey Dock Member

Name
Name proposed by Mitchell (1995).

Type section
Crab Rocks to Red Cliff Hole, Filey Bay, Yorkshire, to the east of Dulcey Docks where the lowest bed forms a step onto the beach [TA 1548 7510 to 1523 7515].

Primary reference section
None

Formal subdivisions
None, but Mitchell (1995) divided the member into 22 beds.

Lithology
The member comprises red nodular limestone. The presence of *Inoceramus lissa*-rich, *Biplicatoria hunstantonensis*-rich horizons and the breccia nodule bed (sensu Jeans, 1973) are important marker horizons.

Definition of upper boundary
The boundary is defined by the change from nodular limestones of the member to brick-red marls and marly limestones of the overlying Weather Castle Member.

Definition of lower boundary
The boundary is placed at the change from alternating white and pink limestones and grey or red mals or clays of the Speeton Beck Member into nodular limestones.

Thickness
6.7 m

Distribution
Recognised only on the Yorkshire coast near Speeton.

Previous names
None

Parent
Hunstanton Formation

Age
Albian

References
Jeans, 1973; Mitchell, 1995.

6.2.4 Weather Castle Member

Name
Proposed by Mitchell (1995).

Type section
Weather Castle, Filey Bay, Yorkshire [TA 1649 7494]

Primary reference section
None

Formal subdivisions
None

Lithology
The member comprises 'brick'-red marls and marly limestones in six ill-defined rhythms. A thick bed of red marl at the top exhibits internal poorly defined rhythmicity. *Aucellina* occurs throughout.

Definition of upper boundary
Thick red marl bed passes upwards into nodular limestones of the Red Cliff Hole Member.

Definition of lower boundary
Defined as the change from nodular limestones of the Dulcey Dock Member up into the rhythmically bedded marls and marly limestones of this member.

Thickness
2.81 m

Distribution
Recognised only on the Yorkshire coast near Speeton.

Previous names
Red uniform chalk of Phillips (1875)
Smooth red chalk containing belemnites of Hill (1888)

Parent
Hunstanton Formation

Age
Albian and earliest Cenomanian

References
Hill, 1888; Mitchell, 1995; Phillips, 1875.

6.2.5 Red Cliff Hole Member

Name
Proposed by Mitchell (1995).

Type section
Red Cliff Hole, Filey Bay, Yorkshire [TA 1566 7502]

Primary reference section
None

Formal subdivisions
None, but divided into five beds each further subdivided by Mitchell (1995).

Lithology
Dark red and grey nodular limestones. *Aucellina* and brachiopds common throughout, belemnite-rich at the base.

Definition of upper boundary
Up-section change from dark red and grey strongly nodular limestone into white chalks of the Ferriby Chalk Formation.

Definition of lower boundary
Boundary placed at the change from marly limestone of the Weather Castle Member into red and grey strongly nodular limestones. Jeans (1973, 1980) took the Red Cliff Hole Member–Weather Castle Member boundary to define the top of his Red Chalk.

Thickness
5.6 m

Distribution
Recognised only on the Yorkshire coast near Speeton.

Previous names
None

Parent
Hunstanton Formation

Age
Earliest Cenomanian

References

Jeans, 1973, 1980; Mitchell, 1995.

Overview

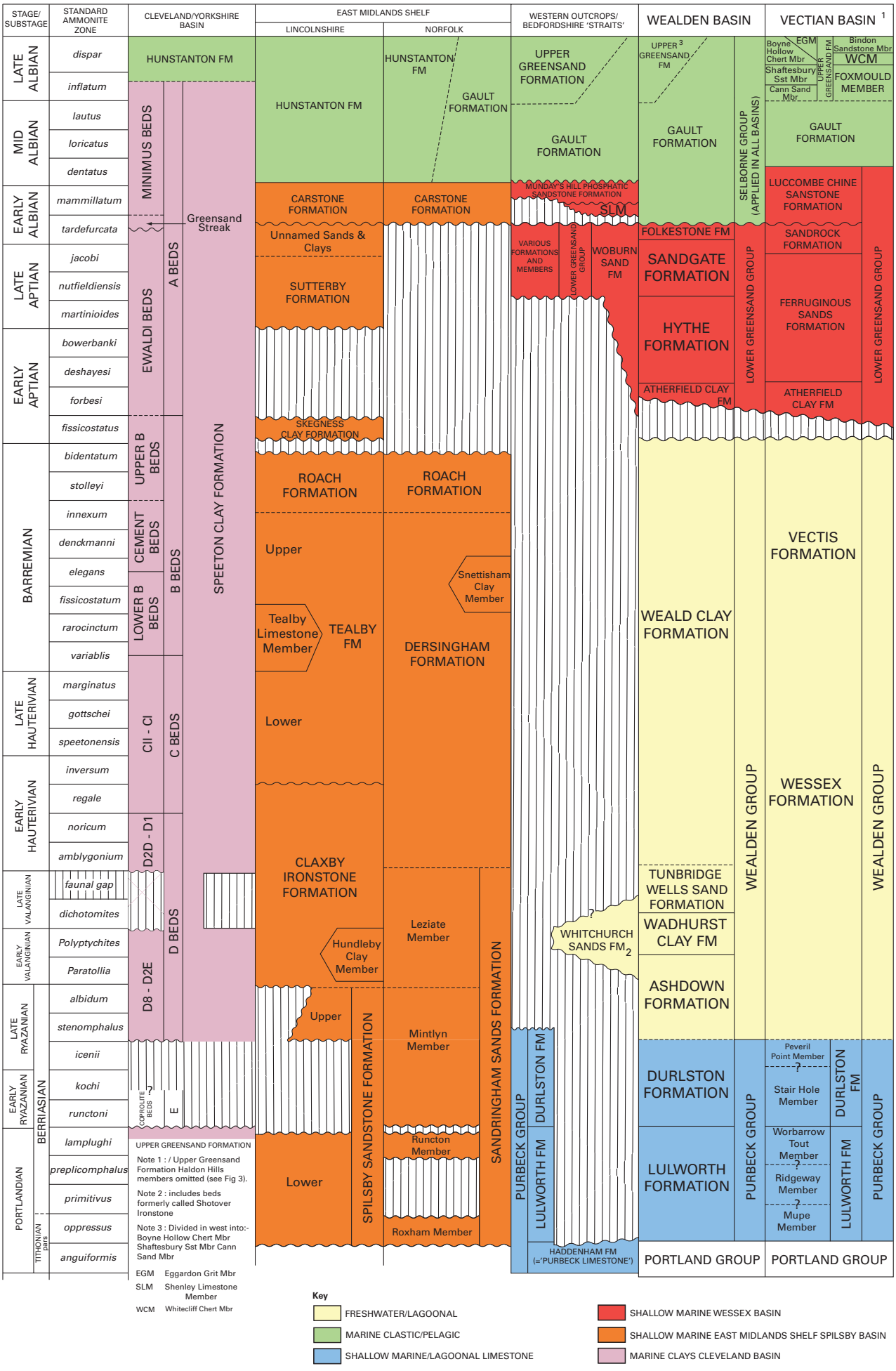
The inter-relationship of the units preserved in each of the structurally defined areas is shown in Table 7. This uses as its template Table 12.2 in Rawson (1992) but it should be noted that finer divisions of the terms given in Table 7 are shown on the individual regional summary Tables (2 to 6).

New terms have been introduced to clarify relationships e.g. Wealden Group, Selborne Group, Monk's Bay Sandstone Formation, Haddenham Formation, Faringdon Sand Formation (and members therein); and others recommended for withdrawal to avoid confusion e.g. Hastings Series/ Group/Sub-group, Carstone (Isle of Wight).

It is open to debate whether the extended use of the terms Lulworth and Durlston formations of the Purbeck Group, within the Weald area, is appropriate. Despite the continuity of the bounding surfaces for these two formations being present in both the Vectian and Weald basins lithological differences may be regarded as sufficient justification for the erection of a separate lithostratigraphy for this (mainly concealed) succession.

It is regarded as beyond the scope of this report, but nonetheless suggested, that formal member level entries be determined for the Ferruginous Sands Formation (to enhance understanding of the present alphanumeric scheme) and possibly the Sandrock Formation on the Isle of Wight and for the Speeton Clay Formation (to enhance understanding of the alphanumeric scheme) of the Cleveland/Yorkshire Basin.

Table 7 Overview of the Lower Cretaceous.



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Appendix 1 Alphabetical list of Lower Cretaceous lithostratigraphical units referred to in this report

Name	Map code	Lexicon code	Parent unit	Page*
Ardingly Sandstone Member	ARS		Tunbridge Wells Sand Formation	10
Ashcombe Gravel Member			Upper Greensand Formation	40
Ashdown Formation	ASD		Wealden Group	9
Atherfield Clay Formation	AC	AC	Lower Greensand Group	15
Bargate Sandstone Member	Bt	BT	Sandgate Formation	17
Barnes High Member			Vectis Formation	30
Baulking Sand Member			Faringdon Sand Formation	59
Bedchester Sands Member	BedS	BEDS	Folkestone Formation	21
Bindon Sandstone Member		BDNS	Upper Greensand Formation	38
Boyne Hollow Chert Member	BHC	BHC	Upper Greensand Formation	37
Calne Sands Formation			Lower Greensand Group	60
Cann Sand Member	CanS	CANS	Upper Greensand Formation	36
Carstone Formation	Ca	CA	None	49
Chale Clay Member			Atherfield Clay Formation	32
Child Okeford Sand Member	Cho	CHOS	Folkestone Formation	21
Claxby Ironstone Formation	Cl	Cl	None	51
Cowleaze Chine Member			Vectis Formation	30
Cuckfield Stone Bed	CKST	CkSt	Grinstead Clay Member	12
Culhan Sands with Chert Member			Upper Greensand Formation	40
Dersingham Formation	DeB	DEB	None	48
Dulcey Dock Member			Hunstanton Formation	65
Durlston Formation	Durl, Durn	DURN	Purbeck Group	8
Easebourne Member	Eb	EBO	Sandgate Formation	18
Eggardon Grit Member		ECG	Upper Greensand Formation	37
Faringdon Sand Formation			Lower Greensand Group	58
Faringdon Sponge Gravel Member	FSG	FSG	Farindon Sand Formation	59
Fernham Sand Member			Faringdon Sand Formation	60
Ferruginous Sands Formation	FrS	FRS	Lower Greensand Group	33
Fittleworth Member	FiB	FIB	Sandgate Formation	19
Folkestone Formation	F	FO	Lower Greensand Group	21
Foxmould Member	Fx	FXMD	Upper Greensand Formation	37
Gault Formation	G	GLT	Selborne Group	23
Grinstead Clay Member	GrC	GRC	Tunbridge Wells Sand Formation	12
Haddenham Formation			Purbeck Group	55
Hoes Farm Member			Hythe Formation	16
Horsham Stone Member	HSt	HST	Weald Clay Formation	14
Hundleby Clay Member	HbC	HBC	Claxby Ironstone Formation	52
Hunstanton Formation	HuCK	HUCK	Selborne Group	55
Hythe Formation	H	HY	Lower Greensand Group	16
Leziate Member	LzB	LZB	Sandringham Sands Formation	47
Lower Greensand Group	LGS	LGS	None	14
Lower Lobster Member			Atherfield Clay Formation	32
Lulworth Formation	Lulw	LULW	Purbeck Group	7
Marehill Clay Member	MhC	MHC	Sandgate Formation	20
Mintlyn Member	MnB	MNB	Sandringham Sands Formation	46
Monk's Bay Sandstone Formation			Lower Greensand Group	35

Name	Map code	Lexicon code	Parent unit	Page*
Munday's Hill Phosphatic Sandstone Formation			Lower Greensand Group	57
Mupe Member	Mup	MUP	Lulworth Formation	25
Perna Member			Atherfield Clay Formation	31
Peveril Point Member	PEP	PEP	Durlston Formation	28
Pulborough Sandrock Member	PSk	PBS	Sandgate Formation	20
Purbeck Group	PB	PBS	None	5
Queens Rock Member			Hunstanton Formation	64
Red Cliff Hole Member			Hunstanton Formation	65
Ridgeway Member	Lulw	LULW	Lulworth Formation	27
Roach Formation		ROH	None	49
Rogate Member	RoB	RGTB	Sandgate Formation	18
Roxham Member	RxB	RXB	Sandringham Sands Formation	45
Runcton Member		RNB	Sandringham Sands Formation	46
Sandgate Formation	SaB	SAB	Lower Greensand Group	17
Sandringham Sands Formation	SaS	SAS	None	45
Sandrock Formation	SRS	SIOW	Lower Greensand Group	34
Seend Ironstone Formation			Lower Greensand Group	61
Selborne Group			None	22
Selham Ironshot Sands Member	SIS	SIS	Sandgate Formation	19
Shaftesbury Sandstone Member	Shy	SHYS	Upper Greensand Formation	36
Shenley Limestone Member			Munday's Hill Phosphatic Sand Formation	58
Shephard's Chine Member			Vectis Formation	31
Skegness Clay Formation	SkC	SKEG	None	53
Snettisham Clay Member	SnC	SNC	Dersingham Formation	48
Speeton Beck Member			Hunstanton Formation	64
Speeton Clay Formation	Spc	SPC	None	62
Spilsby Sandstone Formation	SyS	SYS	None	50
Stair Hole Member	Sho	SHO	Durlston Formation	27
Sutterby Marl Formation	SbM	SBM	None	54
Tealby Formation	TbF	TBF	None	52
Tealby Limestone Member		TALTal	Tealby Formation	53
Telegraph Hill Sands Member			Upper Greensand Formation	39
The Crackers Member			Atherfield Clay Formation	33
Tunbridge Wells Sand Formation	TWS	TWS	Wealden Group	10
Upper Greensand Formation	UGS	UGS	Selborne Group	24
Upper Lobster Member			Atherfield Clay Formation	33
Vectis Formation			Wealden Group	29
Wadhurst Clay Formation	WDC	WdC	Wealden Group	10
Weald Clay Formation	WC	WC	Wealden Group	13
Wealden Group	W	W	none	8
Weather Castle Member			Hunstanton Formation	65
Wessex Formation			Wealden Group	28
Whitchurch Sands Formation	WhS	WHS	Wealden Group	56
Whitecliff Chert Member	WCh	WHCH	Upper Greensand Formation	38
Woburn Sands Formation	Wbs	WBS	Lower Greensand Group	56
Woodlands Sand Member			Upper Greensand Formation	39
Worbarrow Tout Member	WoT	WOT	Lulworth Formation	27

* First occurence in text. Later regional entries may be present.

Appendix 2 Discontinued and obsolete stratigraphical terms

Most terms utilised in this report have a history of previous names and these are shown in each entry. Listed below are those terms that should no longer be used without qualification as to their meaning.

Purbeck Formation (Purbeck Limestone Formation)
These terms should be abandoned in favour of the Purbeck Group.

Hastings Beds (Formation, Subgroup, Group or Supergroup)
These terms, adopted to describe the undivided Ashdown, Wadhurst Clay and Tunbridge Wells Sand formations, are abandoned as formal stratigraphical units.

Shotover Sands
This term should be abandoned in favour of Whitchurch Sands Formation.

Junction Beds
This term, as used to describe the beds between the Lower Greensand Group and Gault Formation, is abandoned in favour of Munday's Hill Phosphatic Sand Formation within the Lower Greensand Group.

Faringdon Sponge Beds
This unit is now regarded as a formal member (the Faringdon Sponge Gravel Member) within the Faringdon Sand Formation within the Lower Greensand Group.

Carstone (Isle of Wight)
This term is abandoned in favour of **Monk's Bay Sandstone Formation** to prevent confusion with the Carstone of the north Norfolk and Lincolnshire (East Midlands Shelf) area.

Red Chalk
This term should be abandoned in favour of the Hunstanton Formation in north Norfolk, Lincolnshire and Yorkshire.