CUCKMERE TO SEAFORD

OS Grid Reference: TV515976–TV488982

Introduction

Cuckmere to Seaford forms a 3 km sea-cliff section between Cuckmere Haven in the east and the Seaford Sewer Outfall groyne in the west, at the eastern end of the Seaford Town coast road (Figure 3.96). It is one of the most complete, continuous and accessible sections in the White Chalk Subgroup in the Southern Province, with excellent wave-washed exposures. This highly fossiliferous section spans the higher part of the Lewes Nodular Chalk Formation, the stratotype Seaford Chalk Formation, the Newhaven Chalk Formation and the basal part of the Culver Chalk Formation. The major lithological changes from the relatively gritty chalks of the Lewes Nodular Chalk Formation to the less gritty, pure white chalks of the Seaford Chalk Formation, followed by the entry of regular marl seams in the Newhaven Chalk Formation, are all well displayed. The site additionally constitutes the type section for the bases of the Seaford Chalk and the Newhaven Chalk formations. The entire Coniacian and Santonian stages, as well as the lower part of the Lower Campanian Substage are exposed and the section is currently being investigated as a candidate Global boundary Stratotype Section and Point (GSSP) for both the Santonian and Campanian stages.

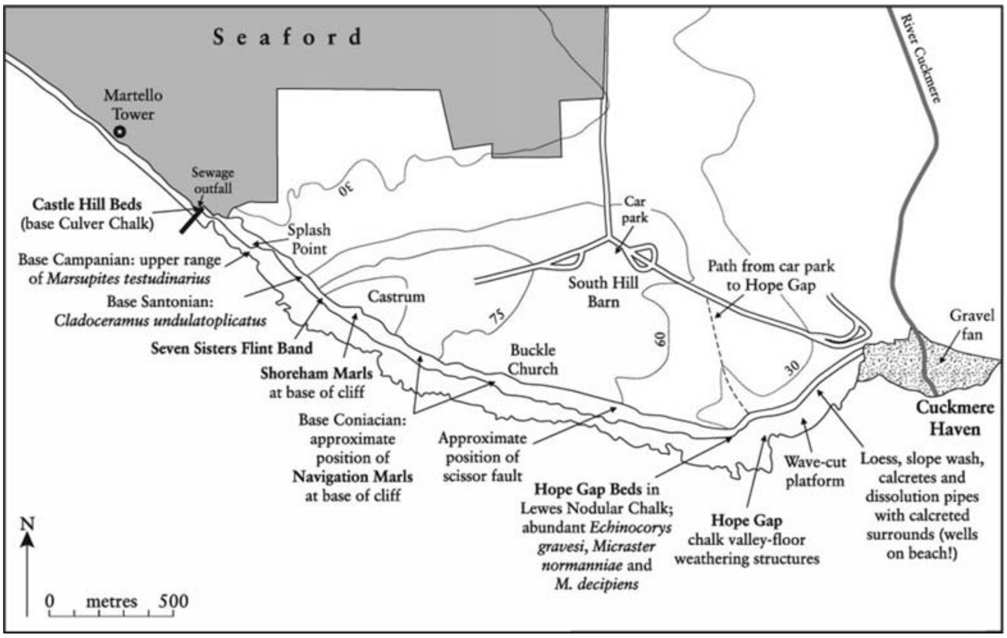

Figure 3.96: Map of the Cuckmere to Seaford GCR site indicating the main geological features.

The coastal geomorphology is also outstanding. The east side of Seaford Head provides the finest view across the Cuckmere Valley to the classic truncated-valley Chalk cliff-line of the Seven Sisters, within which the conspicuous dark line of the Seven Sisters Flint Band, dipping south-east towards Birling Gap, is clearly visible. At the eastern end, at Hope Gap, the cliffs are capped by Quaternary loess. West of Hope Gap, dissolution pipes are present, filled with a mixture of Clay-with-flints and/or loess. Towards the Castrum these pipes extend deeply into the Chalk giving a castellated skyline (Mortimore, 1997). At the western end of the cliff, the Chalk section is terminated by the sub-Palaeogene unconformity, above which are the sands, lignites and clays of the Early Palaeogene that are also seen at Castle Cliff, Newhaven.

Description

There are two major parts to the GCR Site. The first encompasses what Rowe (1900) described as ‘the finest section for collecting fossils in the *Micraster cortestudinarium* Zone (upper Lewes

Nodular Chalk Formation) in England'. This stretches for about 1.5 km from the Old Coast Guard cottages at Cuckmere Haven, eastwards through Hope Gap, to the point in the high cliff known as the Castrum, and includes the Turonian–Coniacian boundary. The second part of the site, from the Castrum westwards to the Sewer Outfall Groyne (Figure 3.96), exposes perhaps the most accessible, continuous section in the Upper Coniacian, Santonian and Lower Campanian substages in Europe. It includes the Coniacian–Santonian and Santonian–Campanian boundaries in beds that dip gently north at 10º, giving access to each bed in turn in clean, wave-washed sections. The site includes the cliff and its associated wave-cut platform. Both are essential for the measurement of sections, and for the collection of fossils and rock samples from this internationally important section.

Barrois (1876) commented briefly on the Chalk from Cuckmere to Seaford, but erroneously correlated the Seven Sisters Flint Band at Birling Gap with Whitaker's 3-inch Flint Band of the **Thanet Coast**. He also correlated the Cuckmere Sponge Bed, 6 m above the flint band, with a similar sponge bed on Thanet (Barrois' Sponge Bed). Consequently, Barrois placed much of the cliff in the *Marsupites* Zone. Rowe (1900) was aware of this error, and coined the name 'Barrois' Spurious Sponge Bed' for the Sussex sponge bed. He was the first worker to give details of the site. Rowe recognized the *Micraster cortestudinarium* Zone in the eastern part of the site, overlain in turn by the *Micraster coranguinum* Zone, the '*Uintacrinus* band' and '*Marsupites* band' of the *Marsupites testudinarius* Zone and the lower part of the *Actinocamax* (i.e. *Gonioteuthis*) *quadratus* Zone in the western part. The *Offaster pilula* Zone had not been introduced at that time, although Rowe realized the usefulness of *Cardiaster* (i.e. *Offaster*) *pilula* as a guide fossil to the lower part of the then current concept of an *Actinocamax quadratus* Zone.

Rowe (1900) thought that lithological marker beds could not be used for correlation, citing Barrois' mistake as supporting evidence, but he nevertheless chose lithological beds as boundaries to his zones. Beneath the Castrum at Seaford Head (Figure 3.96) he took the upper of two marls (the 'closed marl') (i.e. Shoreham Marl 2), as the boundary between the *M. cortestudinarium* and *M. coranguinum* zones. This marl contrasted with his 'open marl' (Shoreham Marl 1) below, and additionally formed a conspicuous failure plane in the cliff above and eastwards, making a '...hanging ledge'. Rowe drew the base of the *Uintacrinus* band of the *Marsupites* Zone (i.e. the base of the *Uintacrinus socialis* Zone) at the upper of two strong flint bands, 9 ft (3.7 m) apart, located 760 ft (230 m) measured horizontally along the beach from the old groynes at the western end of the site. These flint bands are the Exceat and Buckle flint bands respectively (Mortimore, 1986a; Figure 3.101, p. 231) and the accuracy of Rowe's measurement was confirmed during reinvestigation of this stretch of beach in the 1970s. Rowe also recorded a horizontal measurement of 242 ft (73 m) from the Buckle Flint to the Upper Shoreham Marl (i.e. the *Micraster coranguinum* Zone) and he recognized that the cliffs at the western end of the site (Newhaven Chalk Formation) were '...seamed with marl'.

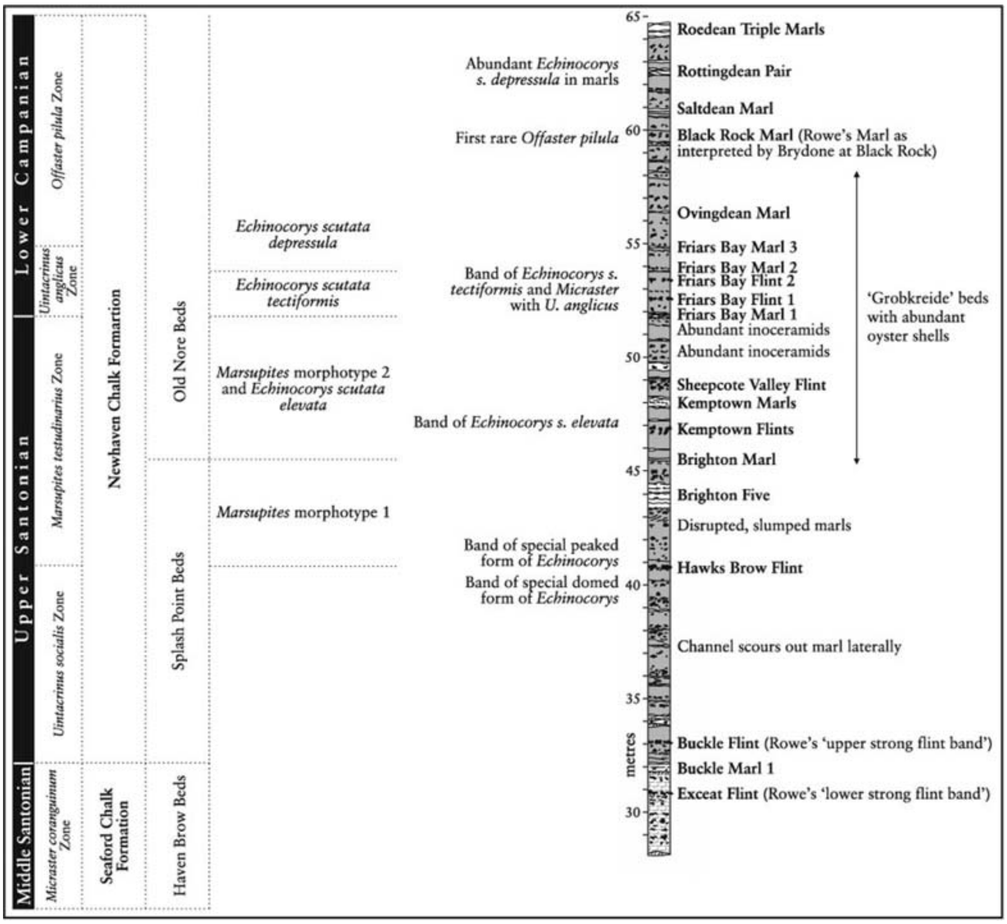

Figure 3.101: Seaford Head: the lower half of the Newhaven Chalk Formation, including the Santonian–Campanian boundary.

Subsequent researchers followed Rowe's biostratigraphical approach, but Brydone (1914) included measurements between some of the marl seams in the Newhaven Chalk. E.R. Martin's unpublished field notes (1923–1955) through this section also provide some detailed measurements and photographs of the state of the cliffs at that time. Martin also made an extensive collection of *Micraster* from the site. The first detailed account, making use of a correlatable, formalized lithostratigraphy as a framework for the ranges of common fossils, was introduced by Mortimore (1983, 1986a, 1997). The base of the Culver Chalk Formation in this section is taken at Castle Hill Marl 2.

Cuckmere to Seaford is on the crest of the Seaford Head Anticline, which dips north at 10°, bringing the Lewes Nodular Chalk Formation to the wave-cut platform east of the Castrum (Figures 3.96 and 3.97). Palaeogene sediments are preserved northwards beneath Seaford Town in the complementary syncline. There is no direct correlation from the eastern end of Seaford Head across Cuckmere Haven to the exposures visible in the first of the Seven Sisters. These coast sections are oblique to the southerly dip, and the dip across the gap in exposure formed by Cuckmere Haven could account for the different levels in the Chalk on the two sides of the Haven. However, Elsden (1909) and Gaster (1939) both required a fault along the Cuckmere Valley offset to Jevington, in order to account for the stratigraphical discrepancy between the two sides of the valley. The possibility of a north-east-trending fault is supported by seismic evidence (Smith and Curry, 1975). Small-scale slump beds in the Lewes Nodular Chalk Formation at Hope Gap provide evidence for intra-Chalk (Coniacian) tectonic movements that can be related to the Ilsede Phase of Subhercynian tectonism (Mortimore and Pomerol, 1997; Mortimore *et al*., 1998). A sequence stratigraphical interpretation for the Coniacian and Santonian part of this section has been given by Grant *et al*. (1999). The cliffs between Hope Gap and the Castrum expose highly fossiliferous beds in the topmost Turonian and basal Coniacian strata. To the west, the northerly dip caused by the Seaford Head Anticline brings each bed to shore-level in turn.

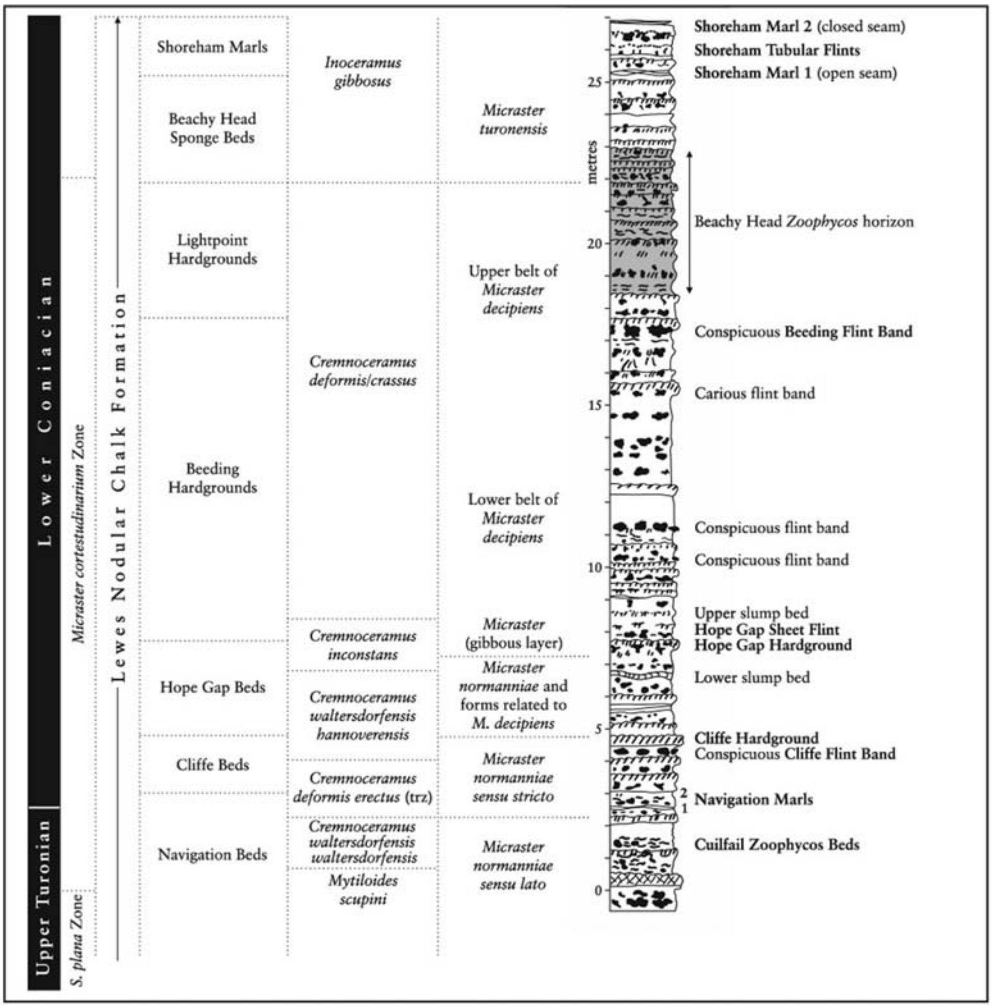

Figure 3.97: Lower Coniacian upper Lewes Nodular Chalk Formation at Seaford Head west beneath the Castrum. (trz = total range zone.)

Lithostratigraphy

Seaford Head cliffs are cut entirely in the White Chalk Subgroup, exposing the upper part of the Lewes Nodular Chalk Formation, the Seaford Chalk and Newhaven Chalk formations, and the basal part of the Culver Chalk Formation. It is the stratotype section for both the Seaford Chalk and Newhaven Chalk formations.

Lewes Nodular Chalk Formation

The eastern part of the cliff from the Castrum towards Cuckmere Haven and Hope Gap Steps is entirely in Lewes Nodular Chalk Formation (Figures 3.96 and 3.97). Because of the dips on the Seaford Head Anticline, the oldest Lewes Nodular Chalk is brought to the surface just east of the Castrum. From this point, both east and west, there is a complete, continuous section through most of the upper Lewes Nodular Chalk, from the Navigation Hardgrounds up to the Shoreham Marls at the boundary between the Lewes Nodular Chalk and Seaford Chalk formations. Mortimore (1986a) divided the upper Lewes Nodular Chalk Formation into a number of sedimentary packages or beds defined by the most conspicuous marker beds, which are generally mineralized hardgrounds or marl seams (Figure 3.97).

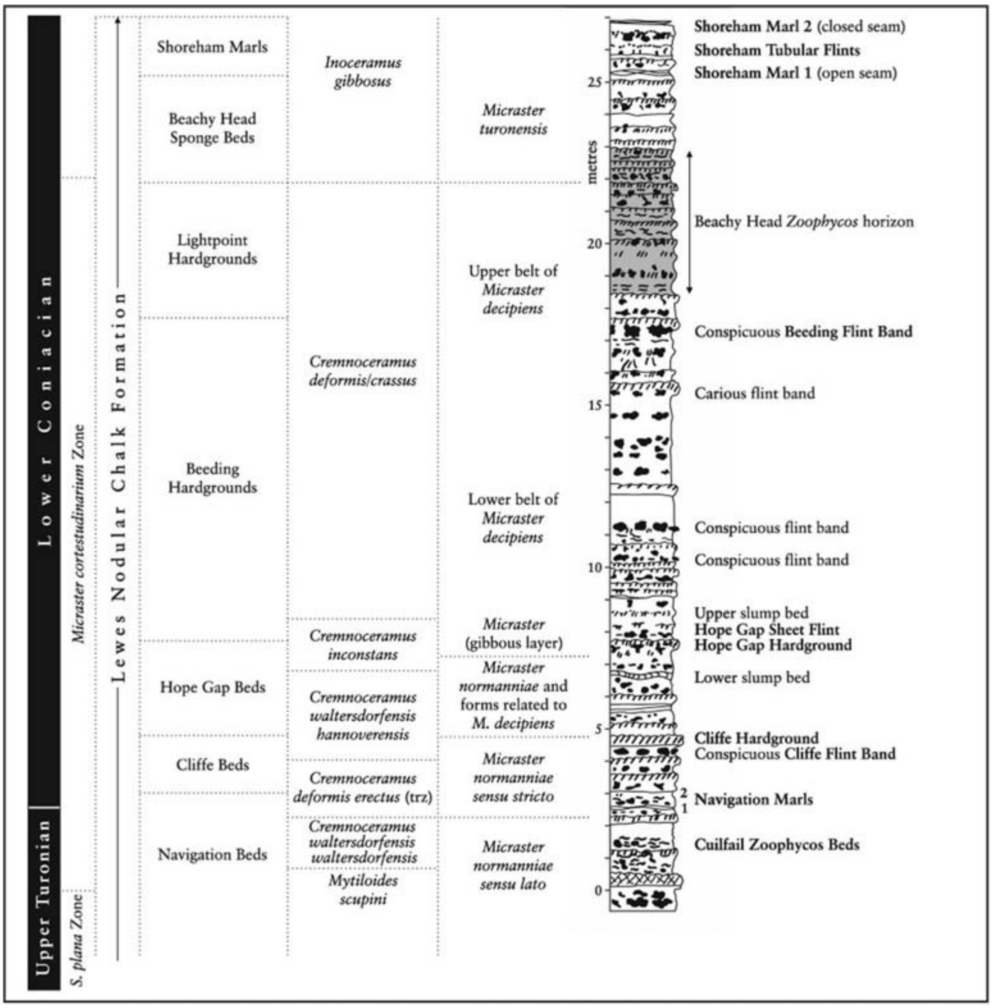

Figure 3.97: Lower Coniacian upper Lewes Nodular Chalk Formation at Seaford Head west beneath the Castrum. (trz = total range zone.)

At the base of the cliffs, just east of the Castrum, the two well-developed, 0.05–0.07 m thick Navigation Marls, are 0.5 m apart and are associated with layers of intraclasts. The top surface of the upper Navigation Marl is taken as the boundary between the Navigation and Cliffe beds. Beneath the marls are two indurated and mineralized, 'knobbly' hardgrounds of the Navigation Beds. To the east, the beds above the Navigation Marls are progressively exposed, including excellent sections of the Cliffe and Hope Gap hardgrounds.

The Hope Gap Steps cliff section (Figure 3.97) shows good examples of the commonly occurring alternation between a lower very grey, soft chalk, and the overlying red, iron-stained nodular layers in which the grey sediment forms the burrow-fill. These are the A (grey) and B (nodular) units, which together form a single bed of chalk or couplet. The Hope Gap Hardground, 20 m west of the 'Steps', is the uppermost of a series of red, iron-stained nodular and hardground surfaces. It is overlain by a conspicuous sheet-flint, which crudely follows the 'streaky' Beeding Marl seam. The sheet-flint is overlain by 1.6 m of very soft, calcarenitic chalks with layers containing slump overfolds and 'laminae with shattered flints' (Mortimore and Pomerol, 1997). In the beds above there are several conspicuous, carious flint bands that are traceable through these cliffs and farther afield.

In large fallen slabs of chalk from the Light Point Hardgrounds and Beachy Head Sponge Beds, the trace fossil *Zoophycos* is abundant and occurs as a conspicuous, colour-contrasting post-omission suite of traces within the fills of earlier *Thalassinoides* burrows. The concentration of certain types of trace fossil at specific levels may indicate large-scale changes in oceanography, such as depth, causing changes in the burial or oxidation of organic matter (Mortimore and Pomerol, 1991b). This horizon of *Zoophycos* has provided a conspicuous correlation marker band in cored boreholes from the Thurrock area, Essex (Mortimore *et al.*, 1990), beneath

London, as far as the the Chiltern Hills, where it is exposed in the **Kensworth Chalk Pit** in the Chiltern Hills. It is also extremely well developed across the Paris Basin and in the Northern Province at **Enthorpe Railway Cutting** (see GCR site report, this volume).

At the base of the cliff below the Castrum at Seaford Head (Figure 3.96), the two conspicuous Shoreham Marls are present (Figure 3.97). Between the Shoreham Marls are the Shoreham Tubular Flints, a conspicuous band that is easily followed in field brash inland. Both these flints and the marls have great lateral continuity (e.g. Thurrock and Faircross borehole cores) and hence provide most useful lithostratigraphical markers. Layers of red, iron-stained nodular chalks are common up to these marls, and similar bands are locally found in the 3–5 m of overlying beds. The top surface of the upper Shoreham Marl is taken as the boundary between the nodular and flinty Lewes Nodular Chalk Formation and the much purer, softer and featureless, flinty chalks of the Seaford Chalk Formation.

Seaford Chalk Formation

In contrast to the underlying gritty, generally nodular Lewes Nodular Chalk Formation, the Seaford Chalk Formation consists of a very pure, soft white chalk with several conspicuous flint bands (Figures 3.98 and 3.99). Mortimore (1986a) divided the Seaford Chalk into three groups of beds. Each of these is well exposed here (Figures 3.98 and 3.100). In the lowest, Belle Tout Beds, there are the three Belle Tout Marls, each associated with inoceramid bivalve shell debris horizons. At the boundary between the Belle Tout and the overlying Cuckmere beds is the most conspicuous lithological marker in the Seaford Chalk, the Seven Sisters Flint Band. The northerly dip brings this flint band to the base of the cliff just west of the Castrum (TV 493 978), where the over-silicified *Thalassinoides* burrow network gives the flint a vermiform structure. It varies between 0.2 and 0.3 m in thickness and it contains patches of red iron staining and sponges.

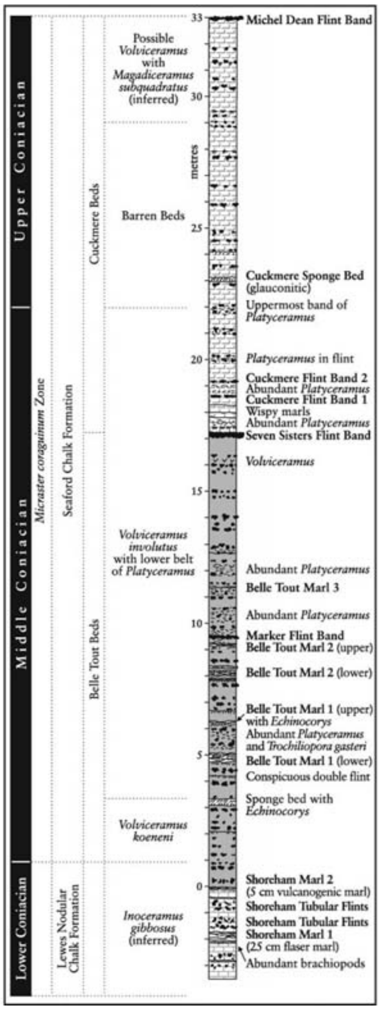

Figure 3.98: Topmost Lewes Nodular Chalk and lower part of the Seaford Chalk Formation, Cuckmere to Seaford GCR site.

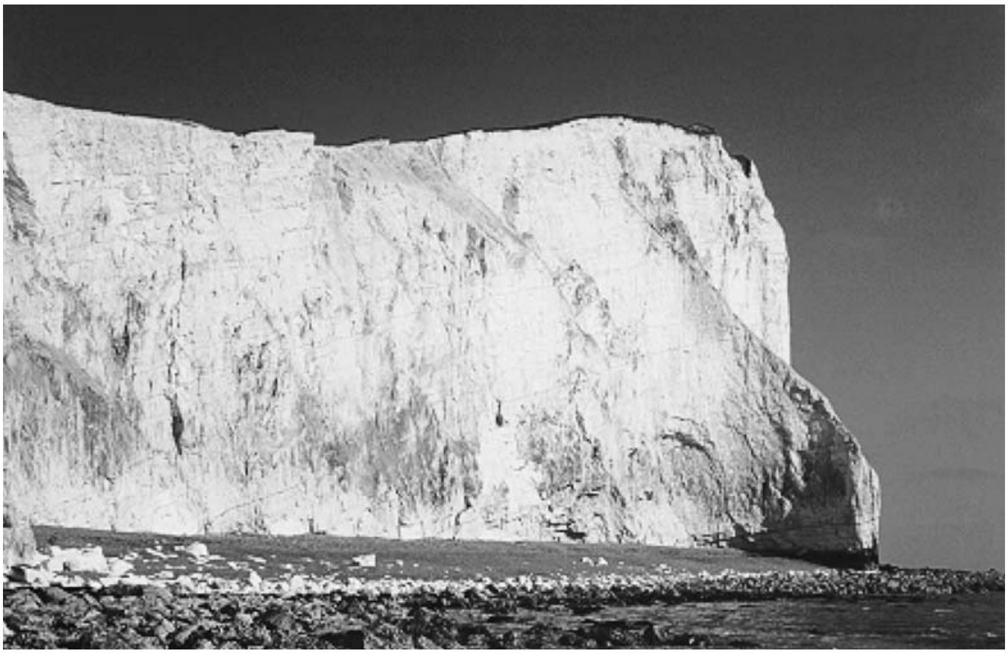

Figure 3.99: Coniacian–Santonian boundary section, Seaford Head, Sussex. (CU = Basal Santonian beds with Cladoceramus undulatoplicatus; PV = top of lower belt of Platyceramus with Volviceramus; SSFB = Seven Sisters Flint Band (Belle Tout Beds–Cuckmere Beds boundary).) (Photo: R.N. Mortimore.)

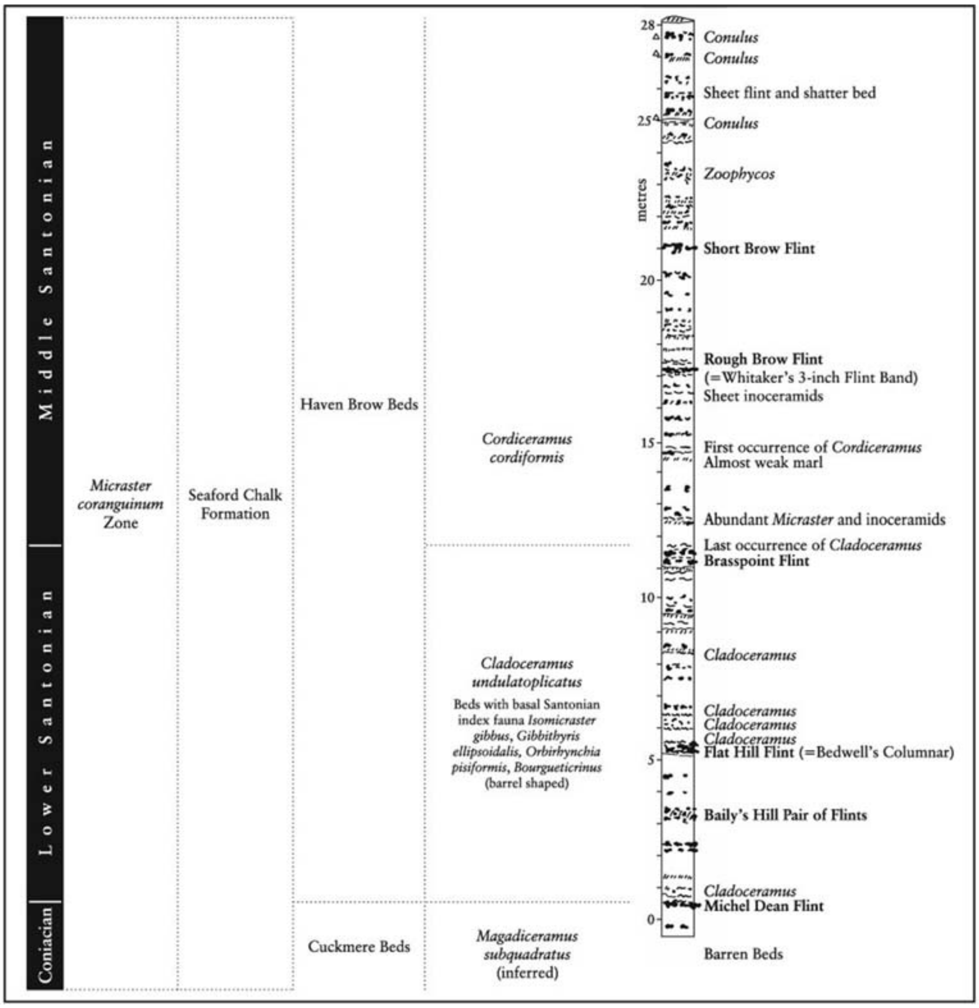

Figure 3.100: Seaford Head: the Coniacian–Santonian boundary and the higher part of the Seaford Chalk Formation.

In practice, especially in core-logging, because flints are destroyed by coring, the boundary between the Belle Tout and Cuckmere beds is taken at the last level of abundant *Platyceramus* fragments, which occurs slightly higher, between the Cuckmere Flints. The Cuckmere Beds are conspicuously less fossiliferous than the Belle Tout Beds, comprising rather pure white, generally featureless chalks. One of the two soft, nodular, red iron-stained sponge beds towards the top of the Cuckmere Beds is the 'Barrois' Spurious Sponge Bed' (see above).

Within the Seaford Chalk Formation, there is a conspicuous group of three bands of almost semi-tabular flints (the Michel Dean, Baily's Hill and Flat Hill flints), which is at beach level some 50 m west of the Seven Sisters Flint Band (Figure 3.99). The top surface of the lowest of this trio (Michel Dean) is taken as the boundary between the Cuckmere and Haven Brow beds (Figure 3.100). The Haven Brow Beds contain four additional conspicuous semi-tabular flint bands: the Brasspoint Flint, the Rough Brow Flint, the Short Brow Flint and the Exceat Flint, in ascending order.

Newhaven Chalk Formation (TV 491 981)

The return of marl seams in the Upper Santonian crinoid zones (*Uintacrinus socialis* and *Marsupites testudinarius* zones) is a lithological change that is maintained throughout much of the Southern Province (except in Kent). This change is used to distinguish the Newhaven Chalk Formation from the Seaford Chalk Formation (Mortimore, 1983, 1986a; Mortimore and Pomerol, 1987; Bristow *et al*., 1997). At Seaford Head this junction is often seaweed-covered in the summer (winter storms usually clean the section). The lowest marl seam (Buckle Marl 1) is a strongly developed griotte or flaser seam, the base of which is taken as the boundary between the Newhaven Chalk and Seaford Chalk formations and the base of the Splash Point Beds, (Figure 3.101). The remaining Buckle Marls are accessible in the various caves that lead round to Splash Point (TV 490 981).

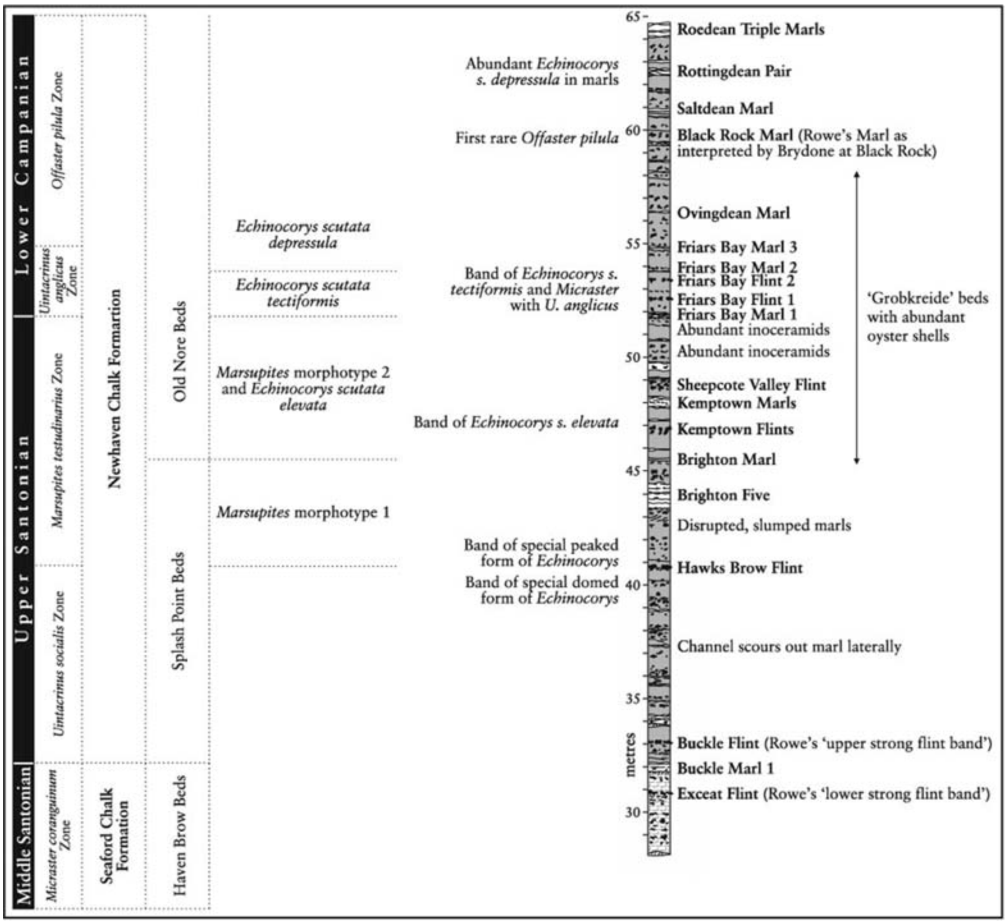

Figure 3.101: Seaford Head: the lower half of the Newhaven Chalk Formation, including the Santonian–Campanian boundary.

There are numerous distinctive grey marl seams and flint bands in the Newhaven Chalk Formation. The most important of these, in ascending order, are as follows (Figures 3.101–3.103):

· an abundance of *Zoophycos*-like flints in the Splash Point Beds;

· the Hawks Brow Flint at Splash Point, which comprises some very large nodules;

· the Brighton Marl, a closed marl seam forming a conspicuous groove, underlain by a unit with five interlacing marls (Brighton Five) in hard, nodular (*Micula*) chalks with some flints; the Brighton Marl is taken as the boundary between the Splash Point and Old Nore beds;

· the Kemptown and Sheepcote Valley flints, which are broad scattered seams of horny nodules, in contrast to the more rounded and confined seams of the Friars Bay Flints;

· the Friars Bay Marl 1 (Figure 3.101), a conspicuous, laminated marl in which inoceramid bivalve shell fragments are common, overlying a unit of chalk with abundant inoceramid fragments;

· the group of marls comprising the Rottingdean, Roedean and Old Nore marls are the most conspicuous (Figures 3.101 and 3.102), and they maintain that aspect as they are traced westwards all the way to East Grimstead Quarry, Salisbury;

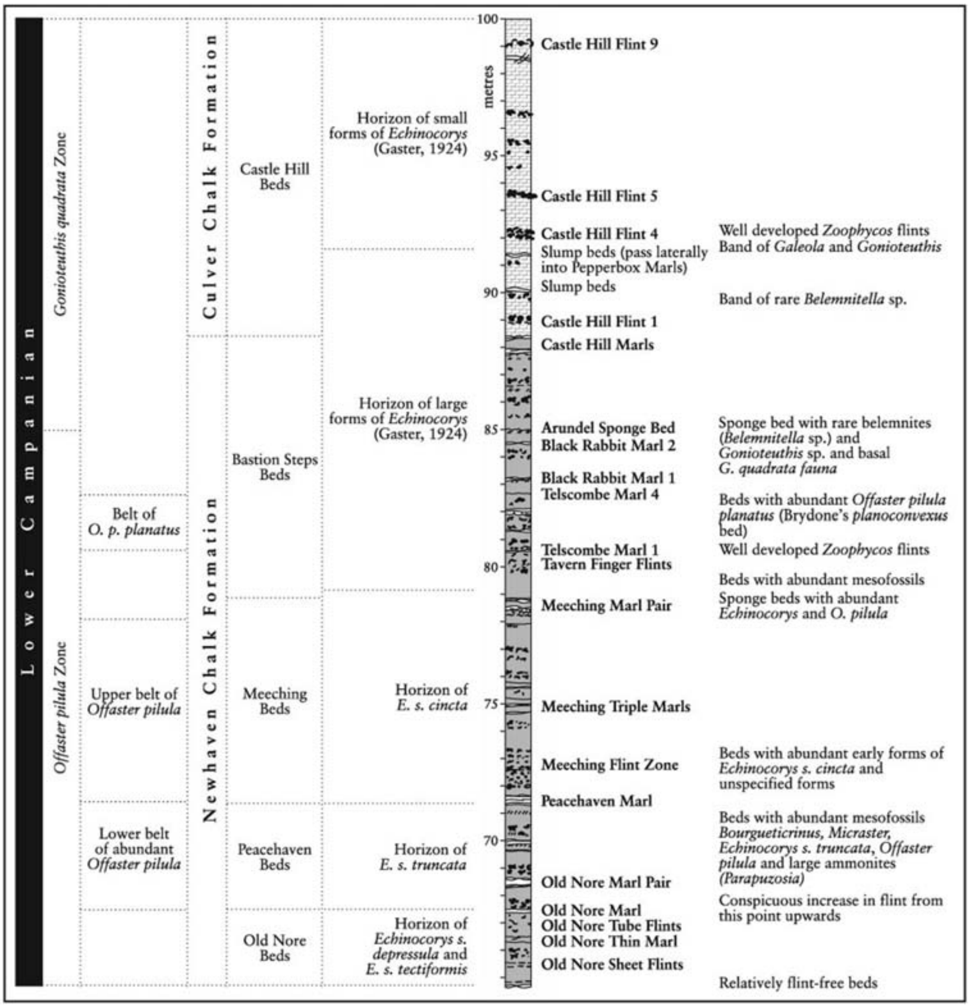

Figure 3.102: Seaford Head: the youngest Chalk from the Old Nore Beds, Newhaven Chalk Formation, to the Castle Hill Beds, Culver Chalk Formation (Lower Campanian).

· a band of very hard, pure white chalk containing an abundance of the nanno-fossil*Micula* (see Mortimore and Fielding, 1990), and traversed by numerous small cracks, present beneath the Rottingdean Marls;

· the Peacehaven Beds (Figures 3.102 and 3.104) have at their base the best developed marl in the Newhaven Chalk (Old Nore Marl = Barrois' Four Inch Marl or Brydone's 2-Inch Marl). A large ammonite, associated with intraclast conglomerates, from the upper part of these beds, had encrusters attached to the ‘chalk' infill rather than the shell. The fact that the encrusters were on the underside suggests that the heavy, chalk-filled ammonite had been ripped-up, transported and re-buried, an indication of powerful currents or slumping on the chalk seabed. The Peacehaven Beds are characteristically rich in red, iron-stained sponges, sponge nodular beds and the bivalve *Spondylus spinosus* (J. Sowerby);

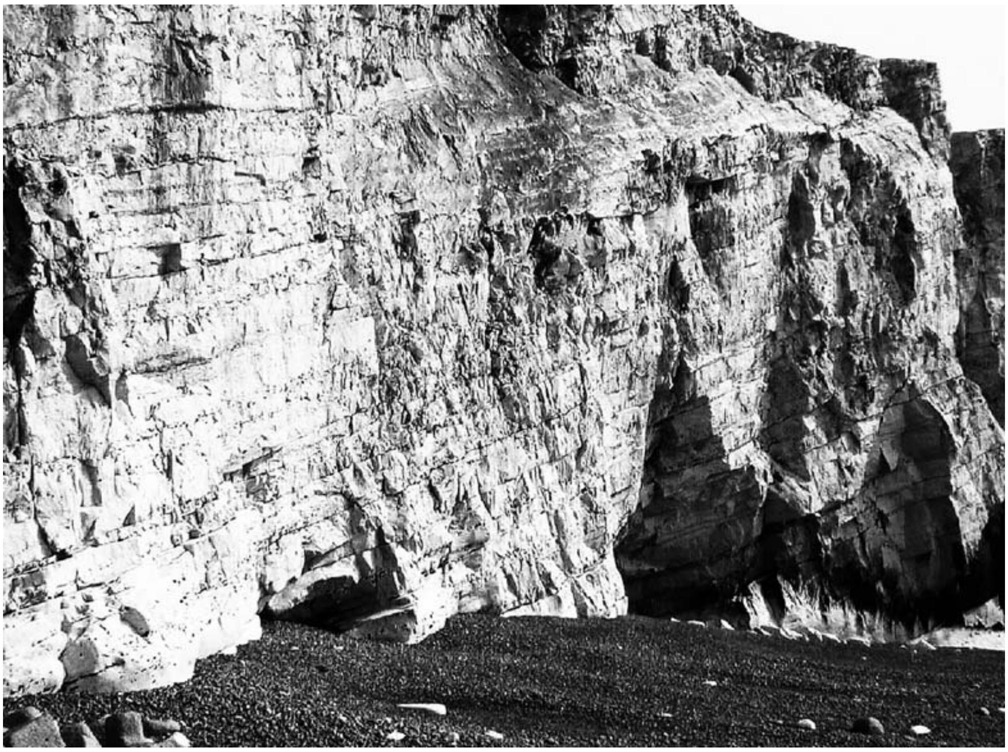

Figure 3.104: Seaford Head, Newhaven Chalk Formation, Lower Campanian Offaster pilula Zone. (BSB = Bastion Steps Beds; MB = Meeching Beds; ONB = Old Nore Beds; PB = Peacehaven Beds.) (Photo: R. N. Mortimore.)

· The boundaries between the Peacehaven Beds and the overlying Meeching Beds, and between the Meeching Beds and the Bastion Steps Beds, are the upper surfaces of the Peacehaven Marl and the upper Meeching Double Marl respectively (Figures3.102 and 3.104). Telscombe Marl 1 with its intraclast pebble conglomerate is also a key marker;

· The exposures adjacent to the groynes and the sewage outfall (TV 488 982) are in the uppermost Bastion Steps Beds and the Castle Hill Beds. The base of the Castle Hill Beds (also the base of the Culver Chalk Formation and the Tarrant Chalk Member in this section) is taken along the top surface of the last marl seam in the section, the upper Castle Hill Marl. The Culver Chalk, like the Seaford Chalk, is largely free of marl seams and layers of nodular chalk, but contains evident flint seams. Eleven Castle Hill Flints and associated*Echinocorys* bands are present in the section adjoining the undercliff walk (Figure3.105);

Figure 3.105: Seaford Head, western end, Newhaven and Culver Chalk formations; beds dip 10° north on the Seaford Anticline. (Photo: R.N. Mortimore.)

· Pale-weathering bands of convolute, slump laminae are found in the broad, flint-free chalk intervals between Castle Hill Flints 3 and 4, and 5 and 6. To the west, in the Brighton Station exposures (Mortimore, 1988), and in the Western Lawns (Hove) and Shoreham Harbour cored boreholes, the horizons of small-scale slump laminae between Castle Hill Flints 3 and 4 are replaced by the Pepperbox Marls.

Coniacian Stage

The lowest beds exposed in the Cuckmere to Seaford site are at the Turonian–Coniacian boundary. The combined effects of a normal fault and the slight easterly dip bring the Navigation Marls into view at the base of the cliff (TV 499 975) (Mortimore, 1997). These marls mark the approximate boundary between the traditional *Sternotaxis plana* Zone and the *Micraster cortestudinarium* Zone. In this section, the more refined division into *Micraster normanniae* and *M. decipiens* zones is used in place of the *M. cortestudinarium* Zone. The beds below the marls yield *M. normanniae* Bucaille *sensu stricto*. In and above the Navigation Marls, poorly preserved basal Coniacian inoceramid bivalves have been collected, including the basal Coniacian marker taxon, *Cremnoceramus deformis erectus* (Meek), and *C. waltersdorfensis* (Andert). These records support observations made at Shoreham Cement Works and at Southerham Pit, Lewes, where the Turonian–Coniacian boundary appears to be marked by the top of the Navigation Hardgrounds.

On the foreshore and in the cliffs 20 m west of Hope Gap Steps are exposed the Cliffe and Hope Gap beds, which here contain abundant *Echinocorys gravesi* Desor and *Micraster*. The upper surface of the Hope Gap Hardground is the boundary between the Hope Gap and Beeding beds, and it is also taken as the boundary between the *Micraster normanniae* and *M. decipiens* zones in this section.

Large inoceramid bivalves (*Cremnoceramus*) have been collected from within the Hope Gap Hardground, while inflated ‘gibbous' varieties of *Micraster decipiens* (Bayle) occur on the surface of the hardground and in the ‘streaky' Beeding Marl seam above.

Micraster decipiens is relatively common in the Beeding and Light Point beds, associated with *Cremnoceramus crassus crassus* (Petrascheck). The first exposures in the wave-cut platform and base of the cliff to the west of the sea wall beneath the old coastguard cottages at

Cuckmere Haven yield abundant *C. c. crassus*, *Micraster decipiens* and large forms transitional to *M. turonensis* (Bayle), together with large forms of *Echinocorys*. In Rowe's (1900) terms, this interval would be placed in the topmost *Micraster cortestudinarium* Zone. Numerous large *C. c. crassus* are also found in the Beachy Head Sponge Beds.

Rowe took the 'closed marl' (Shoreham Marl 2) as his boundary between the traditional *M. cortestudinarium* and *M. coranguinum* zones. The basal index fossil of the Middle Coniacian Substage, *Volviceramus koeneni* (Müller) has not been collected here. On the basis of correlation with the section at Shoreham Cement Works, it should occur in the 3 m belt above Shoreham Marl 3. In the overlying Seaford Chalk Formation, fossils are not common until the Belle Tout Marls, which contain abundant shell fragments of the inoceramid bivalve *Platyceramus mantelli.* There are also several horizons of *Volviceramus* ex gr. *involutus*. Fine specimens of *Volviceramus involutus* (J. de C. Sowerby), close to the type, occur in abundance in a band 1.6 m below the Seven Sisters Flint Band.

The interval from the Cuckmere Flints to the Michel Dean Flint contains very few macrofossils, but is relatively rich in colour-contrasting trace-fossils. This unit was informally designated the 'barren beds' (Mortimore, 1990) on the basis of core-logging experience, notably in the London area.

Santonian Stage

The entry of the basal Santonian index fossil, the inoceramid bivalve *Cladoceramus undulatoplicatus* (Roemer), with its distinctive corrugated ribbing, is seen on the top surface of the Michel Dean Flint. Sporadic *Cladoceramus* occur with the Michel Dean and Baily's Hill flints, but it reaches its maximum abundance in and above the Flat Hill Flint (Figure 3.100). Because of this association, and the presence of 'paramoudra columns', this flint is correlated with the 'Bedwell's Columnar Flint Band' of the Kent coast sections (see Thanet Coast GCR site report, this volume). However, since paramoudra columns also occur with the lower two flint bands, such flint bands with associated paramoudras cannot be used in isolation for correlative purposes. The interval above the Michel Dean Flint contains the characteristic basal Santonian assemblage, including the brachiopods *Orbirhynchia pisiformis* Pettitt and *Gibbithyris ellipsoidalis* Sahni, the barrel-shaped columnals of the crinoid *Bourgueticrinus*, and the echinoids *Cardiotaxis aequituberculatus* (Cotteau) and *Micraster gibbus* (Lamarck).

The four conspicuous semi-tabular flints in the Haven Brow Beds (Figures 3.100 and 3.101) can be safely used for correlation because of their association with particular fossils:

i the Brasspoint Flint is associated with abundant *Conulus albogalerus* (Leske);

ii the Rough Brow Flint is associated with abundant *Platyceramus* and sporadic *Cordiceramus* and is hence equated with the Whitaker's 3-inch Flint Band of Kent;

iii the Short Brow Flint is generally barren of fossils;

iv the Exceat Flint, the lower of Rowe's (1900) 'two flints 9 ft apart' is at the base of the *Uintacrinus socialis* Zone.

Micraster coranguinum sensu stricto (Leske) is characteristic in this interval, as well as *Micraster gibbus*, particularly towards the base of these beds. By comparison with the Kent coast sections, belemnites and ammonites in the Seaford Chalk in Sussex are exceedingly rare.

The zonal index crinoid for the base of the Upper Santonian succession, *Uintacrinus socialis* Grinnell, enters in and above Buckle Marl 1. It is relatively common at the base of its range, becomes rare in the middle part of the Zone and then is abundant again towards the top of its range, commonly forming a grit in the flints. One band of abundant pyramid-shaped *Echinocorys* ('pre-*elevata* ') is a feature towards the top of the *U. socialis* Zone.

The *U. socialis* and *M. testudinarius* zones can be distinguished by the distribution of species of the rhynchonellid brachiopod genus *Cretirhynchia*. *C. plicatilis* (J. Sowerby) characterizes the *U. socialis* beds, and *C. exsculpta* Pettitt the *Marsupites* Zone, respectively. Both species are common at Seaford Head (Mortimore, 1986a). The change from *Marsupites* calyx plates with a simple central fold on each edge to plates with numerous small folds occurs at the level of the Brighton Marl (A.S. Gale, pers. comm., 2000). The chalk of the higher part of the *Marsupites* Zone is commonly gritty with shell debris, particularly comminuted shells of the oyster *Pseudoperna boucheri* (Woods *non* Coquand). This is the equivalent to the Grobkreide of northern Germany (see discussion under the Newhaven to Brighton GCR site report, this volume).

Santonian–Campanian Boundary (Figure 3.103)

The currently recommended base of the Campanian Stage (Hancock and Gale, 1996) is the extinction-level of *Marsupites*, which here, and in the correlative **Newhaven to Brighton** sections, is in Friars Bay Marl 1. In the corner cave at Splash Point, the two conspicuous nodular, horn-flint seams (Friars Bay Flints), immediately above Friars Bay Marl 1, mark the interval containing *Uintacrinus anglicus* Rasmussen, the eponymous index crinoid of the basal Campanian zone. The calyx plates and brachial ossicles of this crinoid are relatively small and are consequently difficult to find in this wave-washed section. In this interval *Echinocorys scutata tectiformis* Griffith and Brydone and *Micraster rogalae* Nowak are abundant.

Campanian Stage

The remaining beds above the Friars Bay interval in the higher Newhaven Chalk Formation contain:

· The entry of very small forms of *Offaster pilula* (*O. p. nana*; Brydone, in manuscript) above the Black Rock Marl.

· The presence of mixed forms of *Echinocorys*, some related to *E. scutata depressula* Brydone, and others to forms that show affinities with *E. s. tectiformis,* but with a different aspect, occurs in the interval from the Rottingdean Marls to above the Roedean Marls.

· The Peacehaven Beds coincide with the lower belt of abundant *Offaster pilula* (Lamarck) associated with *E. s. truncata* Brydone.

· *Offaster pilula* (upper belt) occur in the beds above the Meeching Pair up to the Tavern Flints.

· The larger *Offaster pilula planatus* (Brydone, in manuscript; Ernst) occur between the Telscombe Marls.

· The base of the *Gonioteuthis quadrata* Zone (*sensu* Brydone) is taken at the Telscombe Marl 4 (Figure 3.102), above which the Arundel Sponge Bed is identified as a key bio-event (Bailey *et al*., 1983, 1984).

· The boundary between the 'large and small forms' of *Echinocorys* (Gaster, 1924) occurs at Castle Hill Flint 4.

Bailey *et al*. (1983, 1984), Mortimore (1986a), and Wood and Mortimore (1988) published the first and last occurrences and ranges of the key common macrofossils, microfossils and nannofossils in relation to this lithostratigraphical framework. A much more detailed study is currently being undertaken (Mortimore *et al*., in prep.). Barchi (1995) investigated the micropalaeontology, geochemistry and palaeomagnetism of the Chalk from the base of the *Uintacrinus* Zone to the top of the exposure.

Interpretation

Compared with the Kent succession, the Cuckmere to Seaford section extends stratigraphically much higher and is overall much more accessible. It also appears to be more expanded, particularly in the higher part of the *M. coranguinum* Zone and in the crinoid zones. Moreover, unpublished work on the ranges of foraminifera in relation to the Whitaker's 3-inch Flint Band and its Sussex equivalent indicate that there may well be up to 6 m more section preserved at Seaford at this level than in the **Thanet Coast** GCR site (H.W. Bailey, pers. comm., 1998). The Isle of Wight sections at **Whitecliff** and Scratchell's Bay are also excellent, but the chalk is intensely hard whereas the Seaford Head section is in soft chalk that is ideal for processing microfossils and nannofossils and for collecting macrofossils. The soft chalks have actually yielded a much greater diversity and abundance of microfossils compared to the Isle of Wight sections at the same levels (H.W. Bailey, pers. comm., 1998). In addition, the relatively gentle dip of 10º, compared with 70º on the Isle of Wight, allows greater lengths of beds to be exposed for collecting macrofossils on the wave-cut platform and in the cliff.

For the above reasons, the International Subcommission on Cretaceous Stratigraphy is investigating the Cuckmere to Seaford GCR site (Seaford Head section), as a candidate Global boundary Stratotype Section and Point (GSSP) for both the Santonian and Campanian stages. The inoceramid bivalve marker for the base of the Santonian Stage, *Cladoceramus undulatoplicatus*, has its entry point on top of the Michel Dean Flint. The currently accepted base of the Campanian Stage is taken at the extinction point of the crinoid *Marsupites testudinarius*, (Schlotheim), which here is located in Friars Bay Marl 1. Another commonly cited proxy for the base of the Campanian Stage is the first occurrence of the nannofossil *Broinsonia parca parca* (Stradner) Bukry. This subspecies, as well as its precursors, are well represented in the Seaford Head section. However, *B. parca parca* enters here well above the extinction point of *Marsupites*, demonstrating the difficulty of using this nannofossil as the international basal boundary index fossil. An additional proxy for the base of the Campanian Stage is the palaeomagnetic reversal from magneto Chron 34 Normal to Chron 33 Reverse, which has been identified beneath the Old Nore Marl at Seaford Head by Barchi (1995), but in the *Uintacrinus socialis* Zone by Montgomery *et al*. (1998) (see p. 26, Chapter 1 and Figure 2.3, Chapter 2). The same palaeomagnetic reversal was identified at Précy-sur-Oise, Paris Basin, northern France (Barchi, 1995), as well as at a correlative horizon beneath the M1 marl in the northern German Chalk standard section at Lägerdorf, Schleswig-Holstein Schönfeld and Schulz, 1996). The Seaford Head section clearly demonstrates that this reversal is well above the currently accepted base of the Campanian Stage and is actually approximately coincident with the first occurrence of *B. parca parca*.

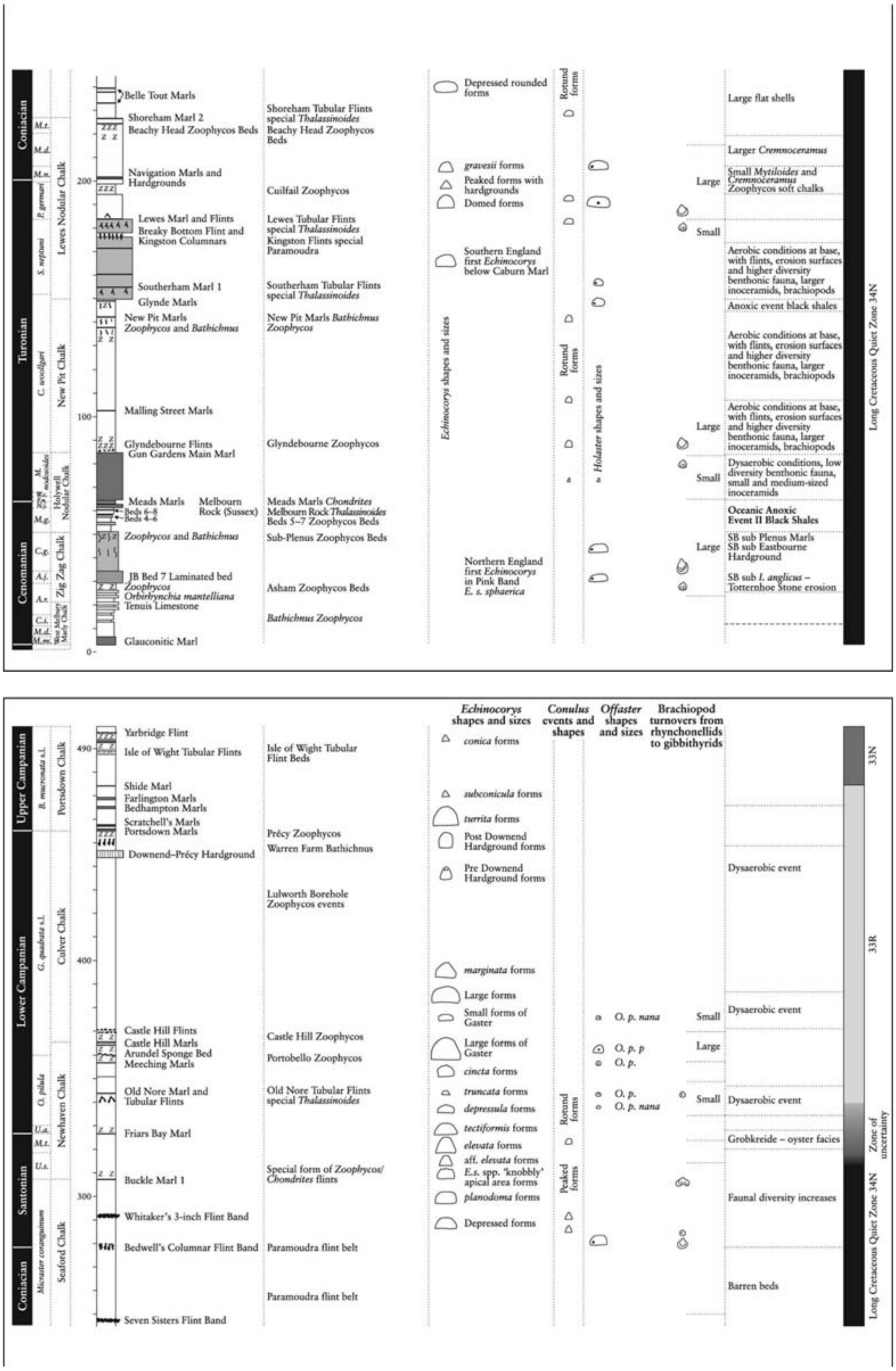

Figure 2.3: Integration of trace fossil events with shape and size changes in some key benthic fossils, and the magnetostratigraphy for the Upper Cretaceous succession in southern England. See Figure 1.5, Chapter 1, for full details of zonal fossils.

The ease with which fossils from this section can be collected and related to a well-defined lithostratigraphical framework is assisting in the construction of an integrated biostratigraphical zonal and subzonal scheme that can be applied throughout the Southern Province and Anglo-Paris Basin. In addition, an international scheme for substage divisions of the Coniacian, Santonian and Campanian stages is currently under discussion and the Seaford Head section is critically important in this respect.

Widespread trace-fossil events, such as the Beachy Head Zoophycos Beds and the Shoreham

Tubular Flints at the boundary between the Lewes Nodular Chalk and Seaford Chalk formations, contrast with more local (tectonically induced?) events, such as the flint shatter-beds and slump-folds at Hope Gap. The widespread events need a more global cause, such as sea-level change, which may change the rate of burial of organic matter and the preservation potential of burrow systems as flint. A similar widespread event is the appearance of chalks with marl seams at the base of the Newhaven Chalk Formation. In North Sea Basin petroleum geology this would be inferred to represent a sea-level fall, with increased clastic input to the Chalk sea.

The Hope Gap complex of shattered flint tectonite layers, passes laterally onto the axis of the Seaford Head Anticline, where the Cliffe and Hope Gap beds are progressively attenuated and the mineralization of the Hope Gap Hardground intensifies (Mortimore, 1977, 1997). Concomitant cracking of lithified hardground nodules is a brittle response to the plastic flow deformation seen in the small-scale slump beds below and above the hardground. These structures at Seaford Head have preserved the early stages of the movement that lead eventually to major slumps such as those seen at **Downend Chalk Pit**, Portsdown. The plastic flow micro-faults and vein fabrics associated with the Hope Gap slides are also typical of chalks that have moved (Mortimore, 1977, 1979, 1997). The greater the movement, the more extensive the pore-pressure release fabric that develops, ultimately leading to the sedimentary dykes seen in the Paulsgrove Chalk Pit on Portsdown. These movements at Seaford Head correspond to the Late Turonian–Early Coniacian Ilsede Phase of the Subhercynian Tectonism (Mortimore and Pomerol, 1997; Mortimore *et al.*, 1998). The effects of coeval tectonic events are seen at Shoreham Cement Works, Upper Beeding, on the flanks of the Pyecombe Anticline.

Other horizons indicative of intra-Cretaceous tectonism include the numerous small laminated slide-planes with chalk intraclasts that occur throughout the Seaford Chalk Formation. For this reason, Mortimore (1979) originally referred to the Seaford Chalk as the ‘Seaford Sponge Bed and Laminate Chalk Member'. A characteristic feature of the Splash Point Beds, at the base of the Newhaven Chalk Formation, is the disturbed nature of many of the beds, especially the marly wisps in the group of marls named the ‘Brighton Five'. Higher in the section, the main sheet-flint horizons around the Rottingdean, Roedean and Old Nore marls are probably related to low-angle sliding. Each of these events coincides with pulses of movement related to the Wernigerode Phase (Late Santonian–Early Campanian age) of Subhercynian tectonism (Stille, 1924; Mortimore *et al.*, 1998). In this context, the characteristic concentration of intraclasts in Telscombe Marl 1, at the top of the upper belt of abundant *Offaster pilula*, and below the beds with *O. pilula planatus*, is of particular interest. The intraclasts are relatively small, millimetre size, at Seaford Head and Newhaven, but they increase to centimetre-sized clasts westwards (e.g. on the A27 Slonk Hill road cuttings on the west side of Brighton), where all the marl seams are also thicker. This intraclast marl probably relates to the final pulse of the Wernigerode movements of Subhercynian tectonism and to the onset of the *Offaster pilula* transgression (Niebuhr, 1995; Mortimore and Pomerol, 1997).

At Beachy Head, from 300 m west of the lighthouse, there is a comparable stratigraphy to that of the Cuckmere to Seaford section for the interval from the Navigation Marls to the Shoreham Marls. The lower three Light Point Hardgrounds coalesce here (TV 565 954) to form a synsedimentary mound (cf. the **White Nothe** GCR site). The very gentle dip of the chalk towards Birling Gap, in the axis of the Birling Gap Syncline, provides long sections through the upper part of the Lewes Nodular Chalk and the lower Seaford Chalk formations. In the Belle Tout Beds of the Seaford Chalk Formation, horizons with *Volviceramus involutus* and associated *Micraster* cf. *turonensis* are well exposed. The Seven Sisters Flint Band forms a spectacular solid mat of flint on the wave-cut platform at Birling Gap (TV 552 960). Just out of reach in the cliff here is the pale green, glauconite-coated Cuckmere Sponge Bed (Barrois' ‘Spurious Sponge Bed'), containing opalized wood.

The Cuckmere to Seaford Head GCR site provides the standard reference section (Jenkyns *et al.*, 1994, fig. 6) for the stable isotope stratigraphy (*^{13}C, *^{18}O) of the interval from the Middle Santonian (*Micraster coranguinum* Zone, Whitaker's 3-inch Flint Band) to the middle of the Lower Campanian (basal *Gonioteuthis quadrata* Zone, Castle Hill Flints). These stable isotope curves link on to the top of the curves for the East Kent composite section (Jenkyns *et al.*, 1994, figs 3, 4). There is a significant shift to more positive values in both the *^{13}C and *^{18}O curves at about the Peacehaven Marl. The two curves show covariance, suggesting that the isotope values have been modified by diagenetic effects.

The Cuckmere to Seaford GCR site links to five other GCR sites described in this chapter; **Newhaven to Brighton**, the **Thanet Coast**, **Whitecliff**, **Compton Bay**, and **White Nothe**.

Conclusions

The Cuckmere to Seaford GCR site is one of the most important sections in Europe for the Coniacian, Santonian and Campanian stages in terms of basal boundary points, subdivisions of the stages and completeness of the sections. It is a proposed boundary stratotype section for the base of the Santonian and Campanian stages. The various types of evidence informing discussions on nannofossil and microfossil entry points and ranges, the extinction of the index crinoid *Marsupites* and magnetostratigraphy at the base of the Campanian Stage are all well represented here. Cuckmere to Seaford is also a standard reference section for stable isotope stratigraphy. The importance of the section is enhanced by the abundance of internationally useful inoceramid bivalves, and by the soft chalks that yield excellent microfossil and nannofossil data. The biostratigraphy is easily related to lithological marker beds that have long-range correlation potential in the Southern Province and beyond. Unpublished studies of the foraminifera have shown that at certain lithological marker horizons, such as Whitaker's 3-inch Flint Band, more sediment is preserved here than in the**Thanet Coast** sections.

Because of the completeness and continuous exposure through a large part of the White Chalk Subgroup, the Seaford Head section is used as the standard against which variation in other sections is measured.

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