Folkestone to Kingsdown: Folkestone–Dover and Dover–Kingsdown, Kent

[TR 242 365]–[TR 316 402] and [TR 339 422]–[TR 381 478]

Introduction

The Folkestone to Kingsdown site forms the classic White Chalk cliffs of England and has two distinct parts. Part 1: Folkestone–Dover, incorporates 'The Warren' and Shakespeare Cliff in the Grey Chalk Subgroup and the lower part of the White Chalk Subgroup (Plenus Marls Member and the Holywell Nodular Chalk, New Pit Chalk and lower Lewes Nodular Chalk formations) at Aker's Steps and Shakespeare Cliff. Part 2: Dover–Kingsdown, includes East Cliff, Dover, St Margaret's Bay and the sections north of the South Foreland. This second part is entirely in the White Chalk Subgroup (Lewes Nodular Chalk Formation, Seaford Chalk Formation and basal Margate Chalk Member).

The exposures in these cliffs are some of the most studied Upper Cretaceous rocks in the British Isles and essential to the historical development of the stratigraphy of the Chalk. Phillips' (1818, 1819) remarkably detailed description of the strata can be fairly regarded as the first attempt to produce a lithostratigraphical classification of part of the English Chalk. The chalks are generally softer than those farther south and west in the Southern Province because the site is located on the southern edge of the Anglo-Brabant Massif ((Figure 1.8), Chapter 1). As a result, the Dover sections are famous for their fossils, primarily because of their excellent preservation in soft chalk. The standard French macrofossil zones of the Chalk of the Paris Basin were first applied to the English Chalk by Hebert (1874) and Barrois (1876) at Dover. In addition, these sections have provided many type and figured specimens, notably the holotype of the international inoceramid bivalve index fossil *Inoceramus lamarcki* Parkinson. It was here that the medical doctor, Arthur Rowe of Margate, carried out the work that led to his still classic evolutionary study (Rowe, 1899) of the Chalk echinoid *Micraster,* and laid the foundations, together with Charles Sherborn, for his series of equally important papers (1900–1908) on '*The Zones of the White Chalk of the English coast'.*

Part 1: Folkestone–Dover, includes one of the most important Cenomanian successions in the UK, which, because it is the most complete, is generally regarded as the standard British succession for the stage (Kennedy, 1969; Gale, 1989, 1995; Robaszynski *et al.,* 1998). It also exposes a highly condensed Holywell Nodular Chalk Formation at Shakespeare Cliff which has yielded Lower Turonian ammonites of biostratigraphical importance, including the zonal index fossils *Fagesia catinus* (Mantell) and *Mammites nodosoides* (Schlotheim). It is also a key component in establishing the link from the expanded successions on the south coast to the condensed successions in the Transitional Province.

The 7 km of sea cliffs from Dover–Kingsdown (Part 2), are the classic 'White Cliffs of Dover'. Much of the White Chalk Subgroup stratigraphy here, can be correlated in detail with the standard succession in the Southern Province. One of the most conspicuous features of these cliffs is the so-called 'Basal Complex', the succession of exceptionally large flints and marl seams that was formerly taken by the British Geological Survey to mark the base of the *Sternotaxis plana* Zone and hence of the traditional Upper Chalk. The 'Basal Complex' is overlain by beds of highly fossiliferous nodular chalks which are known as the 'Dover Chalk Rock' and represent a condensed and, in some aspects, a more fossiliferous development of the Kingston Nodular Beds of Sussex. These beds contain Upper Turonian ammonites and inoceramid bivalves that are critical for international correlation. Dover is one of the few localities in the Southern Province where the succession of these ammonites established in expanded successions in Germany can be recognized. Condensation at this level also results in loss of some biostratigraphy, particularly the species of *Micraster* found elsewhere.

The stratigraphy of the Folkestone to Kingsdown sections has been important since Napoleonic times when attempts to construct a link to mainland Europe began seriously, and the geology was paramount to route selection and method of construction. Both onshore and offshore exploration identified the continuity of the strata across the English Channel and, from the very earliest proposals, the Lower Chalk (i.e. Grey Chalk Subgroup) was considered the best medium for tunnelling. The knowledge of the stratigraphy of the Folkestone sections was critical to correlation of boreholes, geological interpretation and understanding the construction problems encountered during building of the Channel Tunnel (1988–1992; see papers in Harris *et al.,* 1996a).

Description

The Folkestone–Dover cliffs (Figure 3.118) expose continuous sections from the West Melbury Mady Chalk Formation of the Grey Chalk Subgroup up to and including the lower beds of the Lewes Nodular Chalk Formation of the White Chalk Subgroup. Near Folkestone, the highest beds exposed in the cliff belong to the Holywell Nodular Chalk Formation. Farther east, the gentle easterly dip brings the Plenus Marls Member at the base of the Holywell Nodular Chalk Formation to the foot of Shakespeare Cliff, on the west side of Dover.

At the western end of the Folkestone–Dover cliffs in East Wear Bay (Figure 3.118), between Copt Point, on the east side of Folkestone, and the western end of Abbot's Cliff; the Gault mudstones beneath the Chalk Group are exposed at and above sea level. Landslip failure in the Gault mudstones has led to the development of a vast, and now extensively overgrown, area of rotated slipped blocks of Grey and White Subgroup chalks, which is known as 'The Warren'. From Abbot's Cliff eastwards, the dip takes the Gault below sea level, and consequently the same beds are exposed in near-vertical cliffs, up to 50 m high. Apart from exposures at beach level, these sections are accessible only at the back of areas of stabilized rock falls, or in those places where zig-zag paths down the face of the cliff provide air-weathered exposures.

The Folkestone to Shakespeare Cliff sections collectively constitute the type succession for the division by Jukes-Browne and Hill (1903) of the traditional Lower Chalk into nine component beds, of which Jukes-Browne Bed 7, the White Bed (Bed 8) and the Plenus Marls (Bed 9) still form part of the modern lithostratigraphical scheme (Figure 3.119). The section at the base of Abbot's Cliff (Gale and Friedrich, 1989) provides the only uncondensed succession through the basal part of the Cenomanian Stage in the Southern Province. Folkestone, in conjunction with Southerham Grey Pit, provides one of the standard sections for the orbitally controlled cyclostratigraphy of the Cenomanian succession of northern Europe (Gale, 1995). The macrofossil and microfossil biostratigraphy, stable isotope stratigraphy and cylostratigraphy of the Middle Cenomanian strata at Folkestone have been studied in minute detail (Paul *et al.,* 1994; Mitchell and Carr, 1998). Despite being greatly condensed compared with Eastbourne, the Plenus Marls Member at Shakespeare Cliff has been subject to more intense study than elsewhere (Jarvis *et al.,* 1988b; Jeans *et al.,* 1991; Lamolda *et al.,* 1994).

From Dover–Kingsdown (Figure 3.120) there are four key sections. East Cliff (1) and Langdon Stairs (2), Dover, expose beds from near the base of the Lewes Nodular Chalk Formation to beds up to Whitaker's 3-inch Flint Band in the Seaford Chalk Formation. The accessible sections at the base of the cliffs from Langdon Stairs to the South Foreland (3), are primarily cut in the lower beds of the Lewes Nodular Chalk Formation. The inaccessible parts of the cliff expose the upper beds of the Lewes Nodular Chalk Formation and the Seaford Chalk Formation with its conspicuous marker flint bands. The highest points in these cliffs are capped by a small thickness of Margate Chalk Member. The cliff line is broken at St Margaret's Bay, which forms a natural divide; just to the south, the cliff direction changes at the South Foreland, and trends northwards to Kingsdown (4). This is the down-dip direction, and higher beds in the Lewes Nodular Chalk and Seaford Chalk formations, up to the Bedwell's Columnar Flint Band, are progressively brought down to accessible levels in a northerly direction.

Lithostratigraphy

As in Sussex, the first records of the geology of these cliffs were published early in the 19th century. Phillips (1818, 1819) was the first to describe the sections. He divided the Chalk (republished in Conybeare and Phillips, 1822) on the basis of the presence, absence or relative abundance of flints and of 'organic remains'. As noted by Whitaker (1872), the 'organic remains' probably included nodularity of the chalk as well as fossils. Whitaker (1865a, 1872) and Dowker (1870) followed Phillips' divisions, but gave some of them local geographical names taken from the Thanet Coast and Dover coast. Whitaker (1872) also provided some supplementary descriptive notes. In descending order, Phillip's divisions (and their subsequent modifications) are provided in (Table 3.2).

The highest (flintless) Chalk in the Isle of Thanet was separated by Whitaker (1865a), followed by Dowker (1870), and subsequent workers (Whitaker, 1872; Mortimore 1983, 1986a; Robinson, 1986; Bristow *et al.,* 1997), as the Margate Chalk.

Jukes-Browne and Hill (1904, p. 2) did not regard the divisions of Phillips, Whitaker and Dowker as correlatable or mappable horizons and concentrated instead on identifying macrofossil zones within their threefold framework of Lower, Middle and Upper Chalk.

Whitaker (1872) considered that Phillips' 'Grey Chalk' included beds that should properly be included in the Chalk Marl. He noted that 'near the top there was a massive bed, about 8 ft (3.4 m) thick, which at Hay Cliff has small hard projections, some being pyrites, some fossils and others stony lumps'. He also commented that the bed of 'soft marl' recorded by Phillips at the top of his overlying unit was about 6 ft (1.8 m) thick and contained belemnites. Price (1877) attempted a revision of the Phillips classification and proposed a complex subdivision based on a combination of lithostratigraphical and biostratigraphical criteria. As noted by Jukes-Browne and Hill (1903), this new scheme was unsatisfactory. Instead, following a reassessment of the section by Hill, they established a standard succession of nine beds, of which Beds 1–5 were assigned to the Chalk Marl, Bed 6 and Bed 7 (the bed with stony lumps) to the Grey Chalk, Bed 8 (which they termed the 'White Bed') corresponded to Phillips' Chalk without flints and few organic remains', and Bed 9 (their 'Belemnite marl') equated with the 'soft marl with belemnites', the Plenus Marls Member of the modern classification.

(Table 3.2) Lithostratigraphy of Phillips (1818).

Lithostratigraphy (Phillips, 1818)	Thickness	Modifications (Whitaker, 1865a, Dowker, 1870)
The Chalk with numerous flints	*c.* 350 ft (107 m)	
I with few organic remains		Broadstairs Chalk of Whitaker, 1865a; Ramsgate Chalk of Dowker, 1870
II bed of organic remains and interspersed flints		St Margaret's Chalk of Dowker, 1870
The Chalk with few flints	*c.* 130 ft (40 m)	Dover Chalk of Dowker, 1870
The Chalk without flints	140 ft (43 m)	
I a stratum containing very numerous and thin beds of organic remains	90 ft (27 m)	
II a stratum (of soft and white chalk) with few organic remains	*c.* 50 ft (15 m)	
The Grey Chalk which graded down into	not less than 200 ft (61 m)	
Chalk Marle and Greensand		

Kennedy (1969) divided the Lower Chalk of Folkestone (excluding the Plenus Marls) into 14 'bands' and described the lithostratigraphy in detail, providing a graphic log (his fig. 2) and grid references for localities at which the various bands could be examined. He drew particular attention to two prominent limestones at the top of his Band 6, a unit (Band 9) with abundant specimens of the rhynchonellid brachiopod *Orbirhynchia mantelliana* (J. de C. Sowerby), which he named the '*Orbirhynchia mantelliana* Band', and additionally noted that Jukes-Browne Bed *7* (Band 13) was characterized by abundant 'laminated structures'.

Robinson (1986) introduced a formal lithostratigraphical scheme for the Lower Chalk from Folkestone–Dover, in which he recognized three formations. He assigned the succession below Jukes-Browne Bed 7 to the East Wear Bay Chalk Formation, distinguishing the basal Glauconitic Marl as a member. The overlying Abbot's Cliff Chalk Formation comprised two members, the Hay Cliff Member (Jukes-Browne Bed 7) and the Capel-le-Ferne Member (the White Bed). These were followed by the Plenus Marls Formation. This scheme has not met with general acceptance and is not used today.

Gale (1989, 1995, and in Jenkyns *et al., 1994,* fig. 13a) revised Kennedy's stratigraphy and, from better exposures, documented (Gale, 1989, figs 3, 4) additional strata at the base of the succession, above the Glauconitic Marl. Gale (1989) showed that the lower of Kennedy's (1969) two prominent limestones was underlain by a bed of dark fossiliferous marl, and that the higher limestone was overlain by the bed of silty marl that Price (1877) had named the 'Cast Bed' in view of the abundance in it of composite moulds ('casts) of gastropods. He also demonstrated that Kennedy's

Orbirhynchia mantelliana Band was the highest of three similar bands. The higher of the two limestones marks the top of the West Melbury Marty Chalk Formation (Bristow *et al.,* 1997). This limestone is named the l'enuis Limestone' from the occurrence in it, at the Southerham Grey Pit GCR site, of the inoceramid bivalve *Actinoceramus tenuis* (Mantell). It also marks the boundary between the 'Craie Bleue' and the 'Craie Grise' units used for the French side of the Channel Tunnel site investigation. Gale subdivided the Lower Chalk into three traditional units, the Chalk Marl, Grey Chalk and Plenus Marls. He drew the lower boundary of his Grey Chalk at a level, *c.* 10 m above the base of the Zig Zag Chalk Formation, where rhythms (couplets) of thick marls and thin limestones gave way to couplets comprising thin marls and thicker limestones. This level also corresponded to an up-section change in carbonate content to values over 80% (Destombes and Shephard-Thorn, 1971). Although Gale and Hancock (1999) argued convincingly for the validity of this boundary, it is nevertheless incapable of being mapped (Bristow *et al.,* 1999).

Mortimore (1983, 1986a,b) developed a formal lithostratigraphical scheme for the traditional Middle and Upper Chalk (subdivisions) of the South Downs and Southern Province, which is directly applicable to the post-Plenus Marls succession of the Folkestone to Kingsdown site. The scheme has been progressively modified (Mortimore and Pomerol, 1987, 1996; Bristow *et al.,* 1997; Rawson *et al.,* 2001) and it is this modified scheme that is used in this account. The succession comprises the White Chalk Subgroup divided into the Holywell Nodular Chalk, New Pit Chalk, Lewes Nodular Chalk and Seaford Chalk formations, with a thin capping of Margate Chalk Member. The (flintless) Margate Chalk Member, previously recognized by Whitaker (1865a) and subsequent workers, equates with the flinty and marl-rich Newhaven Chalk Formation of the standard Southern Province succession.

Robinson (1986) introduced a formal lithostratigraphy for the traditional Middle and Upper Chalk of the North Downs, which, with the exception of the highest beds, was based on the coast sections between Folkestone and Kingsdown. He replaced the existing informal subdivisions by two formations, each divided into three members, and gave new names to all of the marker horizons (particularly marl seams) that had already been established in the South Downs by Mortimore (1983, 1986a,b). He used the same geographical names as Whitaker (1865a, 1872) and Dowker (1870) for some of his units, but chose different intervals of rock and different lithological concepts (see discussion by Mortimore, 1987, 1988; Bristow *et al.,* 1999). Since the lithostratigraphical succession, except in small details, is virtually identical to that of the South Downs, Robinson's scheme is largely redundant and has increasingly fallen out of use, and is now (Rawson *et al.,* 2001) replaced by the modified Mortimore scheme.

Grey Chalk Subgroup

The Grey Chalk Subgroup (Figure 3.119) occupies most of the lower part of the cliffs at The Warren' and Abbot's Cliff and is now divided into two formations, the West Melbury Marty Chalk (with the Glauconitic Marl Member at the base) and the Zig Zag Chalk formations (Bristow *et al.,* 1997; Rawson *et* al., 2001). The Glauconitic Marl Member is 7 m thick at Abbot's Cliff (Gale, 1989) but is very variable in thickness, being only 0.4 m in the Craelius No. 1 (Aycliff) Borehole drilled for the Channel Tunnel investigation.

The key sections in the basal beds of the West Melbury Marty Chalk Formation are visible at low tide on the foreshore below the sea wall, 200 m east of an air-weathered rotated block of Holywell Nodular Chalk Formation known as the 'Horse's Head' [TR 256 382]. Here marine erosion has truncated rotated landslipped blocks. One of these blocks [TR 261 383] provides a continuous succession from the contact between the Chalk Group and the underlying Gault mudstones, through the basal Glauconitic Marl Member (here 7 m thick), into the basal part of the West Melbury Marty Chalk Formation (Gale, 1989, fig. 2). This exposure, known as the 'rotated slab', includes several conspicuous or otherwise distinctive limestones and/or erosion surfaces that have been designated as marker horizons (M1–M6 of Gale, 1989) and used for correlation with sections elsewhere in the UK and in northern Europe (Gale, 1995). M1 and M2 correspond to the basal contact of the Glauconitic Marl Member and to a thin limestone at the top of the member respectively. M3 is a massive, burrowed limestone containing three-dimensional ammonites and inoceramid bivalves. M4 is a dark, silty marl containing small phosphate intraclasts. It rests on pale marly chalk with conspicuous colour-contrasting *Thalassinoides* burrows. M5 is a thin limestone equating with 'The Rib' of Southerham Grey Pit GCR site, and M6 comprises a closely spaced pair of thin spongiferous limestones at the top of the equivalent of The Bank' of the same locality, and the Dixoni Limestone of the Chiltern Hills (see p. 301, Chapter 4). The rotated slab is faulted to the east against the highly fossiliferous basal beds of the Zig Zag Chalk Formation.

An even better section of the basal beds of the West Melbury Marly Chalk Formation, beginning immediately above the Glauconitic Marl Member, and terminating in the massive burrowed limestone, M3, is intermittently exposed at low tide on the foreshore at the foot of the eastern end of the sea wall below Abbot's Cliff [TR 269 384]. This section, which is part of the *insitu* succession on the far side of the back-wall fault of The Warren' landslip, is highly fossiliferous and exposes the best section in the UK through the *Sharpeiceras schlueteri* ammonite Subzone (Gale and Friedrich, 1989, fig. 4; and below).

The upward continuation of this section, beginning with the spongiferous limestones (M6), was formerly exposed at the foot of Abbot's Cliff, immediately to the east, but this section (1999) is currently largely buried beneath an extensive cliff-fall that took place in 1989. The brachiopod-rich marly chalks above M6 (*Orbirhynchia mantelliana* Band 1), and the overlying dark recessing marl from which water flows (Gale, 1995, fig. 3), are exposed beside the top of the sea wall to the east of the adit leading to the Beaumont Tunnel.

Between Abbot's Cliff [TR 271 385] and Lydden Spout [TR 279 386], the easterly dip brings the beds of the West Melbury Marly Chalk Formation progressively down to the base of the cliff. There are accessible exposures of the highest beds and the lower part of the Zig Zag Chalk Formation above the western end of a plateau-like area of long-stabilized cliff-fall. Here there is an air-weathered section (Gale, 1995, fig. 7B) of the remainder of the Grey Chalk Subgroup and the overlying Plenus Marls Member, which clearly shows the sedimentary rhythmicity The coarse-grained Jukes-Browne Bed 7 weathers slightly proud, and the overall green coloration of the Plenus Marls Member contrasts with the underlying chalks of the White Bed (Jukes-Browne Bed 8) and with the pale coloured, indurated Holywell Nodular Chalk Formation limestones. Wave-washed exposures showing the sedimentary details of the highest beds of the West Melbury Marly Chalk are found near Lydden Spout, on the far side of the same fall (see Gale, 1995, fig. 8).

There was never a clear division between the traditional Chalk Marl and Grey Chalk at Folkestone, because the marl-limestone rhythms continue up to the base of Jukes-Browne Bed 7. Nevertheless, there is a change from 'Chalk Marl' to 'Grey Chalk' type rhythms *c.* 10 m above the Tenuis Limestone. The Tenuis Limestone and overlying 'Cast Bed' of Price (1874) are, however, easy to identify. Within the Zig Zag Chalk Formation, the numbered beds recognized by Jukes-Browne and Hill (1903), particularly Jukes-Browne Bed 7, the 'Bed of laminated structures' of Kennedy, (1969), and the White Bed (Bed 8), are widely employed. Their Bed 9 is always now referred to as the Plenus Marls Member. These higher beds are exposed at Abbot's Cliff and farther to the east, on Aker's Steps and at Shakespeare Cliff.

White Chalk Subgroup

The Plenus Marls Member, and the air-weathered 'Grit Beds' constituting the condensed Holywell Nodular Chalk Formation, are exposed above the sea wall at the eastern end of Shakespeare Cliff [TR 307 398]. The Plenus Marls are not as thick (about 2 m compared to 11 m at Eastbourne) nor conspicuously rhythmic as they are in Sussex. Nevertheless, Jefferies (1962, 1963) recognized all of his eight numbered beds here. A slipped block at the back of the sea wall [TR 263 384], provides an air-weathered section through the Plenus Marls Member in which the individual beds can be clearly seen. This is a better section than the one exposed above the sea wall at the foot of Shakespeare Cliff.

The Holywell Nodular Chalk Formation: Phillips' (1818, 1819) 'Chalk without flints but with many thin beds of organic remains' corresponds to the Holywell Nodular Chalk Formation, but may include the lower part of the overlying New Pit Chalk Formation, which here is slightly nodular. The Holywell Nodular Chalk Formation was referred to as the 'Melbourn Rock' by the British Geological Survey (Shephard-Thorn, 1988) and as the 'Melbourn Rock Beds' by Robinson (1986). Strictly, the Melbourn Rock in its type area of Cambridgeshire does not include the shell-debris beds typical of the higher part of the Holywell Nodular Chalk Formation. At Dover, the lowest part of the formation is nodular and very hard, but without shell-debris, as is typical elsewhere. (This corresponds to the Melbourn Rock as defined in Sussex by Mortimore (1986a); Gale (1996) named this unit the 'Ballard Head Member').

The condensed nature of the Holywell Nodular Chalk Formation at Shakespeare Cliff has resulted in the loss of the many marker beds recognized in this unit in Sussex. Because of this, there are spectacular concentrations of *Mytiloides* shell-debris bands in the air-weathered sections on the Lydden Spout track, at Aker's Steps and Shakespeare Cliff. These concentrations gave rise to the descriptive term 'Grit Bed' in the earlier literature. The condensation also results in a sharp break with the smoother, softer New Pit Chalk Formation above. This lithological change is well exposed and accessible only on the Aker's Steps and Lydden Spout cliff paths.

The Gun Gardens Main Marl (Mortimore, 1983, 1986a; Mortimore and Pomerol, 1987, 1996) (the 'Lulworth Marl' of Gale, 1996) is taken as the boundary between the Holywell Nodular Chalk and New Pit Chalk formations. Marker marl seams characterize the New Pit Chalk, including New Pit Marls 1 and 2 and the Glynde Marls (the 'Maxton Marls' of Robinson, 1986). These marker beds have been correlated through field sections and on geophysical borehole logs throughout the North Downs (Mortimore and Pomerol, 1987).

Air-weathered sections in the Holywell Nodular Chalk and New Pit Chalk formations are found on steep, and now rather dangerous, paths from the cliff top down to beach level at Abbot's Cliff [TR 268 385], Lydden Spout [TR 283 387], and Aker's Steps [TR 297 393]. The most easterly of these paths (Aker's Steps) additionally exposes the basal beds of the Lewes Nodular Chalk Formation, providing the link with the Athol Terrace and Langdon Bay sections to the east of Dover. This is also the standard section for the foraminiferal zonation of the Turonian strata of southern England and for the stable isotope stratigraphy (Jenkyns *et al.,* 1994, figs 3, 4).

Lewes Nodular Chalk Formation: The base of the Lewes Nodular Chalk Formation is taken at the entry of nodular chalk, which occurs above the Glynde Marls, and is best exposed in the Aker's Steps section. Regular flint bands also enter the rock column in this interval. The white Chalk cliffs beneath Dover Castle (Figure 3.11) expose a magnificent, air-weathered section from the Glynde Marls, through the Lewes Nodular Chalk Formation, up to the Belle Tout Beds at the base of the Seaford Chalk Formation. In these cliffs the Lewes Nodular Chalk forms conspicuous layers of red-stained rough nodular chalk and the basal nodular beds are exposed along Athol Terrace at the eastern end of this cliff. The Athol Terrace exposures are stratigraphically below those in the cliffs at the base of Langdon Stairs and in Langdon Bay and, with the Aker's Steps section, illustrate the entry of nodular chalk and flint well below the 'Basal Complex'.

At beach level in Langdon Bay, between Langdon Stairs and the Eastern Arm of Dover Harbour (Figure 3.121) and (Figure 3.122), the two Southerham Marls and underlying Southerham Tubular Flints are exposed. Southerham Marl 1 is a conspicuous, plastic marl, and the underlying flints retain their Sussex features of mixed small tubular and large nodular flint character. Beneath these flints, iron-stained nodular sponge beds indicate the presence of nodular chalks in the Glynde Beds in the Lewes Nodular Chalk.

Langdon Stairs [TR 345 425] is a narrow zigzag cliff path leading down to Langdon Bay that exposes an air-weathered 50 m section, from the Caburn Marl, in the lower Lewes Nodular Chalk Formation, up to just above the Seven Sisters Flint Band in the Belle Tout Beds of the Seaford Chalk Formation (Figure 3.123). The Caburn Marl, with the underlying Caburn Sponge Bed and flints, is present on the lowest bench on Langdon Stairs ((Figure 3.7); Mortimore, 1997). The flints between the marl and the tough, nodular Caburn Sponge Bed are small, pink and characteristically carious, retaining the detail also present in Sussex.

In the lower part of the cliff in Langdon Bay (Figure 3.7) and at the foot of the cliffs in the adjacent Fan Bay (Figure 3.122), the most conspicuous feature is the 'Dover Chalk Rock' and its underlying 'Basal Complex' of Bridgewick Marls and the associated Bridgewick and Bopeep flints (Jukes-Browne and Hill, 1903, fig. 18; 1904, fig. 45; Mortimore and Wood, 1986, fig. 2.2). The Bridgewick Marls and Bridgewick Flints were taken by the British Geological Survey to map the base of the former Upper Chalk in the North Downs (Holmes, pers. comm., in Mortimore, 1987; Mortimore and Wood, 1986). Jukes-Browne and Hill (1903, fig. 68; 1904, fig. 45) used the section in Fan Bay to illustrate this succession. Their 'two marls 4 feet apart' (their Bed 12) are the Southerham Marls, the 'seam of grey marl forming an open crevice' (Bed 10) is the Caburn Marl, and the 'seam of grey marl' (Bed 6) is Bridgewick Marl 1. Bridgewick Marl 2 is in their Bed 3, 'a band of smooth chalk with a marl in the middle'.

The 'Dover Chalk Rock' comprises a series of nodular chalks separated by softer layers above the Bridgewick Marls, with the lower nodular beds, in particular, containing ammonites. At Dover, this represents a condensation of the Kingston Beds and the beds immediately above the Lewes Marl. The Lewes Marl is occluded but the characteristic Lewes Tubular Flints are still present. It is informally called the 'Dover Chalk Rock' because these beds represent only the top hardground suite of the complete Chalk Rock succession of the type area in Berkshire–Wiltshire (Bromley and Gale, 1982; see Charnage Down Chalk Pit, Fognam Quarry, and Kensworth Quarry GCR site reports, this volume).

Exposed on the first corner from the bottom on Langdon Stairs is a conspicuous horizon of *Zoophycos* streaky chalk seen below the Navigation Hardgrounds. This is the Cuilfail Zoophycos of the Sussex sections ((Figure 3.10)a). The Navigation Hardgrounds are represented by the so-called 'Dover Top Rock' (Mortimore, 1983; Bailey *et al., 1983,* 1984). The section on Langdon Stairs from the Cuilfail Zoophycos upward is outstanding, particularly for sedimentological detail. Each one of the hardground complexes of the upper Lewes Nodular Chalk of the standard succession in the Cuckmere to Seaford and Southerham Pit GCR sites, and their associated flints, can be readily identified. The Cliffe, Hope Gap and Beeding hardgrounds and the large Cliffe and Hope Gap flints are conspicuous features (Figure 3.123). The Light Point Hardground is particularly well developed here, with a glauconitized surface overlain by a lag of glauconitized pebbles. This aspect of the hardground is even better seen at beach level on the north side of St Margaret's Bay. The Beachy Head Sponge Beds also develop nodular chalk bands, and the soft chalks between are packed with spectacular *Zoophycos.* These same Beachy Head Zoophycos Beds are accessible above the sea wall on the north side of St Margaret's Bay. The Shoreham Tubular Flints between the Shoreham Marls are very strongly developed ((Figure 3.10)b).

Between Langdon Bay and Frenchman's Fall, there are excellent, partly sea-washed and partly air-weathered sections through the Basal Complex and 'Dover Chalk Rock'. The Bridgewick Marl cuts out locally on a hardground between Fan Bay and Frenchman's Fall. Near Frenchman's Fall, the individual beds of nodular Chalk Rock, and the associated Lewes Tubular Flints (Phillips, 1819, p. 46), can be clearly seen. Eastwards, towards the South Foreland, the sedimentological details of the Cuilfail Zoophycos chalks and the overlying Navigation Hardgrounds can be examined in long wave-washed sections. These are probably the best exposures of this interval in the Southern Province. Fallen flints on the beach include giant paramoudras from Bedwell's Columnar Flint Band in the Seaford Chalk Formation.

The wave-cut platform on the south side of St Margaret's Bay is formed along the surface of the Navigation Hardgrounds above which there are exposures rich in the rhynchonellid brachiopod *Cretirhynchia subplicata* (Mantell) up to the Hope Gap Hardground. The Hope Gap Hardground, with its distinctive overlying sheet-flint is also clearly seen.

Seaford Chalk Formation: As in Sussex, there is a marked upward change in lithology from coarse, rough chalk with regular beds of nodular chalk (Lewes Nodular Chalk Formation) to the smooth, pure white Seaford Chalk with conspicuous large flint bands (Figure 3.124). This is the classic 'White Chalk' of authors. The Belle Tout Beds, from the Shoreham Marl 2 to the Seven Sisters Flint Band, contain three conspicuous groups of marls, the Belle Tout Marls, associated with abundant inoceramid bivalve shell debris. Shell debris horizons are present from 3.5 m above the Shoreham Marl 2, to the two Cuckmere Flint Bands, 2 m above the Seven Sisters Flint band. The semi-continuous Seven Sisters Flint Band (the 'East Cliff Semi-Tabular Flint' of Gale and Smith, 1982; and the 'Oldstairs Bay Flint' of Robinson, 1986), 17 m above the Shoreham Marls, is conspicuous in an air-weathered section on the top flight of Langdon Stairs and in the East Cliff section.

To the north of St Margaret's Bay ((Figure 3.9)b), there are long, wave-washed exposures through the Belle Tout Beds at the base of the Seaford Chalk Formation around Hope Point (Figure 3.124) and up to the Seven Sisters Flint Band. The Cuckmere Beds, with the Seven Sisters Flint Band and Cuckmere Flints at their base, and the Michel Dean Flint at the top, can also be examined in the East Cliff section, but are inaccessible in the cliffs between Langdon and St Margaret's Bay. At Kingsdown, higher beds in the Seaford Chalk (e.g. the Cuckmere Beds) are exposed in the cliffs behind the old Army range where they can be reached using a ladder. These beds are largely barren of macrofossils (hence the designation 'Barren Beds' by Mortimore, 1997) but they contain horizons rich in trace fossils, some possibly related to unsilicified *Bathichnus* sp., and two iron-stained sponge beds.

The highest accessible sections are just into the Haven Brow Beds (cf. (Figure 3.100)). Many cliff-falls between Langdon Stairs and St Margaret's Bay yield blocks of this chalk containing the basal *Cladoceramus* shell debris beds. Numerous fallen paramoudra flints from the interval that includes the Michel Dean, Baily's Hill and Bedwell's Columnar flints can also be found on the beach. Whitaker's 3-inch Flint Band is conspicuous near the top of the cliffs.

Margate Chalk Member: The (flintless) Margate Chalk Member is present only in the highest parts of the cliff between Dover–Kingsdown. The base is marked by a yellow sponge bed (the Barrois' Sponge Bed of the Thanet Coast), a short distance above the conspicuous Whitaker's 3-inch Flint Band. Apart from poor exposures in the shallow cutting for the old construction railway near Langdon Hole, the Margate Chalk is inaccessible, and details of the stratigraphy are given in the Thanet Coast GCR site report, this volume.

Biostratigraphy

The biostratigraphy of the site is essentially that of the standard Southern Province successions. There are huge collections of fossils from these cliffs held by the British Geological Survey (Keyworth) and the Natural History Museum, London. The British Geological Survey also holds comprehensive bed-by-bed collections of brachiopods, echinoids (notably *Micraster*), inoceramid bivalves and belemnites from the White Chalk Subgroup. The old collections contain numerous rare fossils, including rudists and reptile bones. Rowe (1899, 1900), investigated the detailed palaeontology of the 'White Chalk' zones

Cenomanian Stage

The burrowed contact between the Upper Albian Gault mudstones and the lowest beds of the West Melbury Marly Chalk Formation is exposed on the faulted wave-cut platform at the eastern end of the groynes in East Wear Bay [TR 261 383]. These exposures, described by Gale (1989, Locality 3), take the Cenomanian stratigraphy below levels exposed at the Southerham. Grey Pit. Here the locally thick Glauconitic Marl Member contains common sponges, including the former zonal index sponge, *Stauronema carteri* Sollas, and indeterminate inoceramid bivalve hinges. The terminal thin limestone, M2, has yielded a single specimen *of Neostlingoceras carcitanense* (Matheron), the basal Cenomanian subzonal index species (Gale, 1989). Where the Glauconitic Marl is thin, for example in the Channel Tunnel Craelius No. 1 (Aycliff) Borehole it contains well-preserved specimens of the thin-shelled bivalve *Aucellina* (illustrated in Morter and Wood, 1983), indicative of the *Neohibolites ultimus/Aucellina gryphaeoides* event of European event stratigraphy (Ernst *et al*., 1983).

The section at the base of Abbot's Cliff (Gale and Friedrich, 1989) is the most important section of the Lower Cenomanian *Sharpeiceras schlueteri* Subzone of the *Mantelliceras mantelli* Zone in Europe. The 3 m section of marl-limestone rhythms above the Glauconitic Marl is extremely fossiliferous and has yielded a rich *S. schlueteri* subzonal ammonite assemblage. This comprises the large ammonites *Sharpeiceras schlueteri* Hyatt, *S. laticlavium* and *Utaturiceras vicinale* (Stoliczka) (illustrated by Wright and Kennedy, 1996), which are not found at other horizons in the Cenomanian succession, together with large, inflated *Mantelliceras* and heteromorphs such as *Hypoturrilites. Utaturiceras,* originally described from India, has not been found elsewhere in Britain. These ammonites are associated with large ornate oysters with a zig-zag commissure (*Rastellum colubrinum* (Lamarck)) and common large terebratulids (*Tropeothyris carteri* (Davidson) and related forms) which are likewise restricted to this level. This is also the inferred type horizon of *Inoceramus crippsi* Mantell, which is common at this level, but was originally described from the Hamsey pits near Lewes by Mantell (1822). The subzone terminates in the prominent massive M3 limestone, which contains abundant three-dimensionally preserved specimens of the former zonal index ammonite *Schloenbachia varians (J.* Sowerby). This is the inferred correlative of the Doolittle Limestone of the Chiltern Hills (see p. 300, Chapter 4).

The next section east (Abbot's Cliff to Lydden Spout) is one of the most important for the biostratigraphy of the Middle Cenomanian Substage in England, complementing that at Southerham Grey Pit (Kennedy, 1969; Gale, 1989, 1995; Gale, in Jenkyns *et al.,* 1994; Paul *et al.,* 1994; Mitchell and Carr, 1998).

The basal Middle Cenomanian index ammonite, *Cunningtoniceras inerme* (Pervinquiere) enters slightly below the middle of the three *Orbirhynchia mantelliana* bands (Gale, 1995). The dark marl below the lower of the two prominent limestones in this section is extremely fossiliferous. It is named the Arlesiensis Bed after the restricted occurrence in it of the small pectinacean bivalve *Lyropecten* (*Aequipecten*) *arlesiensis* (Woods) together with a diverse fauna including serpulids, a flood occurrence of the small bivalve *Oxytoma seminudum* Dames and the inoceramid bivalve *Inoceramus schoendorfi* Heinz. The second of the Middle Cenomanian zonal index ammonites, *Acanthoceras rhotomagense* (Brongniart), enters in the higher of the two prominent limestones. This latter limestone is the correlative of the Tenuis Limestone of

Southerham Grey Pit.

The Cast Bed of Price (1877) contains an abundant, diverse assemblage of small brachiopods, including *Grasirhynchia grasiana* (d'Orbigny), *G. martini* (Mantell), *Kingena concinna* Owen and *Modestella geinitzi* (Schloenbach), the latter being restricted to this bed. The associated fossils include sporadic small corals, (*Micrabacia coronula* (Goldfuss)), the smooth pectinacian bivalve *Entolium orbiculare* (J. Sowerby) and a second flood abundance of *Oxytoma seminudum.* A key element of the fauna is the belemnite *Praeactinocamax primus;* rare occurrences (three specimens) from here compare with two finds at Southerham Grey Pit (Paul *et al.,* 1994) and provide evidence for the *primus* event of European event stratigraphy (Ernst *et al.,* 1983; Christensen, 1990, (Figure 2.8), Chapter 2).

The range of *Orbirhynchia mantelliana* (J. de C. Sowerby) in the upper of the three bands is greater here than elsewhere (Gale, 1990). Above this upper band of *O. mantelliana* there is a succession of nine, more or less equally developed, 0.12–0.2 m thick, conspicuous limestone bands. The lowermost two limestones are formed from discontinuous concentrations of sponges. On the upper surface of the eighth band the small coral *Micrabacia coronula* is again abundant: this is the *Micrabacia* Band (Band 11 of Kennedy, 1969). The terebratulid brachiopod *Concinnithyris subundata* (J. Sowerby) is also abundant throughout this interval and above the *Micrabacia* band. The occurrence of this brachiopod provides a useful marker throughout the Southern and Transitional provinces.

An integrated biostratigraphical study of the Cenomanian–Turonian boundary succession (with particular reference to the Plenus Marls Member) on the Abbot's Cliff path using nannofossils, foraminifera, ostracods, dinoflagellates within a stable isotope stratigraphical framework was undertaken by Jarvis *et al.* (1988b). A quantitative study of nannofossil changes across the Plenus Marls was carried out by Lamolda *et al.* (1994). These studies relate to mass extinctions and the recovery of faunas and floras across the OAE II.

Turonian Stage

The extremely condensed Lower Turonian Holywell Nodular Chalk succession is particularly important as a source of ammonites that can be used for international correlation. The Holywell Marl 2/3 interval contains *Fagesia catinus* (Mantell) and *Lewesiceras peramplum* (Mantell) indicating the presence of the *Fagesia catinus* Zone in Britain. The sediment of this interval is composed of comminuted debris from the microcrinoid genus *Roveacrinus,* constituting the lower of two microcrinoid events in the Turonian succession. A specimen of *Pseudaspidoceras* cf. *footeanum* (Stoliczka), the only one known from Britain, found loose on the beach here and illustrated by Wright and Kennedy (1981, pl. 21, fig. 3), came from this horizon.

The higher part of the Holywell Nodular Chalk Formation is a grit bed, characterized by abundant bivalve shell debris. *Mytiloides* shells encrusted by the serpulid *Filograna avita* (J. Sowerby), are found at the at the top of the maximum abundance of *Mytiloides* shell detritus, constituting the *Filograna avita* event.

An ammonite bed in the upper part of the Holywell Nodular Chalk Formation, a few couplets above the *Filograna avita* event, has yielded specimens of the large ammonites *Mammites nodosoides* (Schlotheim), *Morrowites wingi* (Morrow) and *Metasigaloceras rusticum* (J. Sowerby). Thus, even in this highly condensed succession it is possible to recognize some of the key biostratigraphical marker horizons in the Lower Turonian succession. The limestone immediately overlying the Gun Gardens Main Marl (the 'Lulworth Marl' of Gale, 1996) is composed of *Roveacrinus* debris and constitutes the higher of the two microcrinoid events.

The Aker's Steps section is used as the standard reference section for the foraminiferal biostratigraphy of the Turonian Stage in the UK. Unfortunately, the published logs (Hart, 1982, figs 1, 2; Hart *et al.,* 1989), which are based on an unpublished PhD thesis (M. Owen, 1970), are seriously incorrect and hence difficult to interpret. Because of failure to take account of a fault in the middle of the section, some 3 m of strata are repeated in the New Pit Marl 2-Glynde Marls interval. Nevertheless, some of the key planktonic foraminiferal events can be interpreted with a degree of confidence. *Marginotruncana sigali* (Reichel) enters at the Mailing Street Marl 1 (Round Down Marl of Robinson (1986)) and ranges up to a level within the Glynde Marls. *M. pseudolinneiana* Pessagno ((Figure 2.41), Chapter 2) enters 3 m above New Pit Marl 2, and *M. coronata* (Boni) in the Glynde Marls–Southerham Marl 1 interval, *c.* 4 m above the Lydden Spout Flint.

These entry levels define the bases of the *sigali* (UKP6), *pseudolinneiana* (UKP7) and *coronata* (UKP8) planktonic foraminiferal zones respectively.

Inoceramid bivalves of the *Inoceramus lamarcki* Parkinson group are common in the nodular sponge beds below Southerham Marl 1 in Langdon Bay. This is the type locality for the European inoceramid zonal index fossil *I. lamarcki sensu stricto.* The holotype (now in the Natural History Museum, London) was collected (Parkinson, 1819) from a flint below the Southerham Marls, probably from the big nodular Southerham Flints. The ammonite *Subprionocyclus hitchinensis* (Billinghurst) was found here in the Southerham Marl 1–Marl 2 interval (Gale, 1996). *Micraster corbovis* Forbes of *lata* Zone type (Stokes, 1975), thin-shelled *Sternotaxis plana* (Mantell) and terebratulid brachiopods are also present above and below the Southerham marls. The surface beneath the Caburn Marl has yielded *Micraster michelini* (Agassiz), the same level as the Caburn Pit examples in Sussex (Mortimore, 1986a). So far, unlike in Sussex, no specimens of the international zonal index ammonite, *Romaniceras deverianum* (d'Orbigny) have been collected at this level at Dover.

The boundary between the conventional *Terebratulina lata* Zone and the *Sternotaxis* (formerly *Holaster*) *plana* Zone was taken by Jukes-Browne and Hill (1903, 1904) at the base of the Basal Complex of nodular chalks, marl seams and large flints. This level corresponds to the lowest Bridgewick Flint Band in the Ringmer Beds of Sussex. In the Bridgewick Flints echinoids are common, including *Micraster michelini, M. corbovis* of *lata* Zone type and *S. plana.* Rowe (1900), on the other hand, took the base of his *Holaster planus* Zone at Bridgewick Marl 1, which is the horizon of the last occurrence of *Terebratulina lata* R. Etheridge (it is abundant in this marl seam). The Basal Complex above this level is characterized by common specimens of the rhynchonellid brachiopod *Orbirhynchia dispansa* Pettitt and the regular echinoid *Gauthieria radiata* (Sorignet). The rhynchonellid brachiopod genus *Cretirhynchia* enters above Bridgewick Marl 3.

Each of the nodular chalks of the Dover Chalk Rock contains a specific Upper Turonian ammonite and inoceramid bivalve assemblage. The bottom nodular layer contains a low diversity assemblage comprising the inoceramid bivalves *Inoceramus perplexus* Whitfield and *Mytiloides costellatus* (Woods), together with *Subprionocyclus hitchinensis* and *Yezoites bladenensis* (Schlüter), but without *Hyphantoceras reussianum* (d'Orbigny). This is the 'allocrioceratid and collignoniceratid ammonite fauna' of the *Hyphantoceras* Event complex of northern Germany (Kaplan and Kennedy, 1996). Nodular beds 2 and 3 contain the higher diversity, 'nostoceratid ammonite fauna' (Kaplan and Kennedy, 1996), including *Hyphantoceras reussianum, Eubostrychoceras saxonicum* (Schlüter) and *Scaphites geinitzii* d'Orbigny, but not *Subprionocyclus.* These beds also contain many small bivalves and gastropods and typical Chalk Rock brachiopods including *Orbirhynchia reedensis* (R. Etheridge), *Cretirhynchia cuneiformis* Pettitt, *C. minor* Pettitt and *Gibbithyris subrotunda* (J. Sowerby). The beds with the characteristic Lewes Tubular Flints contain the echinoid *Micraster leskei* Desmoulins as well as the inoceramid bivalves *Mytiloides striatoconcentricus* (GUmbel) and *M. incertus* (Jimbo), marking the position of the 'desmoceratid ammonite fauna' of the German succession, but without the characteristic ammonites. Each of these assemblages enables correlation to the expanded Sussex sections and to the more condensed Chalk Rock sections of the Chiltern Hills (see Kensworth Quarry GCR site report, this volume) and Marlborough Downs (see Fogn.arn Quarry GCR site report, this volume). Dover is the one place in England where the succession of distinct ammonite faunas found in the German 'Scaphiten-Schichten' can be demonstrated.

Beds above the Chalk Rock contain *Micraster* that are already more advanced than the *M. praecursor sensu* Drummond assemblages of Sussex, indicating further condensation here. The soft chalks of the Cuilfail Zoophycos contain large, inflated specimens of the thin-tested echinoid *Sternotaxis placenta* (Agassiz) associated with *Micraster normanniae* Bucaille. Within these highest beds below the Navigation Hardground, Rowe (1900) took his boundary of the *S. plan* and *Micraster cortestudinarium* zones.

Coniacian Stage

The boundary between the Turonian and Coniacian stages is currently taken along the top surface of the Navigation Hardground. A juvenile ammonite, questionably identified as *Forresteria petrocoriensis,* was found inside a broken echinoid -on this surface at Langdon Stairs (Gale and Woodroof, 1981). The only unequivocal record of the biostratigraphically significant (Turonian–Coniacian boundary transition) thin-shelled bivalve *Didymotis* from the Southern Province was from soft chalk within the Navigation Hardground complex at the South Foreland. The basal index taxon for the Coniacian Stage, the inoceramid bivalve *Cremnoceramus deformis erectus* (Meek) occurs together with *C. waltersdorfensis* (Andert) in a shell-rich bed 0.7 m above the Navigation Marls at East Cliff Dover. This compares with the occurrence of these species in the lower Navigation Marl at Upper Beeding Quarry, Shoreham Cement Works, Sussex. The small rhynchonellid brachiopod *Cretirhymbia subplicata* (Mantell) is particularly common between the Cliffe and Hope Gap hardgrounds. The Hope Gap Hardground is well cemented and contains moulds of small, originally aragonite-shelled, bivalves and gastropods. Large, poorly preserved, unidentified ammonites occur in this hardground at the South Foreland.

The beds above the Hope Gap Hardground contain larger inoceramid bivalves (*Cremnoceramus* spp.) and large specimens of the inoceramid zonal index fossil *C. crassus crassus* (Petrascheck) are a particular feature of the interval from the Light Point Hardground to the Beachy Head Sponge Beds. *Micraster decipiens* (Bayle) (i.e. *M. cortestudinarium* (Goldfuss)) occurs in several bands: on the Hope Gap Hardground, in the Beeding Hardgrounds and in the Light Point Hardground. Large specimens of *Micraster turonensis* (Bayle) characterize the Beachy Head Sponge Beds. The boundary between the traditional *Micraster cortestudinarium* and *M. coranguinum* zones was taken by Rowe (1900) at a sponge bed above Shoreham Marl 2 on Langdon Stairs (Figure 3.124), but lower down, at a sponge bed below Shoreham Marl 1 at St Margaret's Bay.

The basal Middle Coniacian zonal index inoceramid bivalve, *Volviceramus koeneni* (Müller), has been collected from the calcarenite 2.7 m above Shoreham Marl 2 at East Cliff (Figure 3.124). The lowest specimens of *Platyceramus mantelli* were also noted at this horizon. Abundant shell fragments of *Platyceramus* ((Figure 2.20), Chapter 2) are characteristic throughout the Belle Tout Beds and up to the Cuckmere Flints. These shells are abundant in the Belle Tout Marls. There are also several bands of *Volviceramus* ex gr. *involutus* (J. de C. Sowerby) in these beds ((Figure 3.124); (Figure 2.20), Chapter 2). The Seven Sisters Flint Band has the same association of *Platyceramus* and *Volviceramus* below, in and above as in the Cuckmere to Seaford site, Birling Gap and Tarring Neville Quarry. The echinoid *Conulus raulini* (d'Orbigny) occurs in the Belle Tout Beds in the Kent sections, but has not been found in Sussex.

The successive, closely-spaced entry datums of the benthic foraminifera *Stensioeina granulata granulata* (Olbertz) ((Figure 2.41), Chapter 2), *S. exsculpta exsculpta* (Reuss) ((Figure 2.42), Chapter 2) and *Loxostomum eleyi* (Cushman) in the lower half of the Belle Tout Beds (Figure 3.124) mark, respectively, the bases of the UKB12 and UKB13 benthic foraminiferal zones and a bio-horizon within the UKB13 Zone (see Hart *et al.,* 1989; Bailey *et al.,* 1983).

Interpretation

The Folkestone–Dover section is usually considered to be the standard section for the Cenomanian Stage in the UK. The most complete Lower Cenomanian succession in England is present here, but the *Mantelliceras saxbii* flood-event seen at Southerham Grey Pit, Sussex, is missing either because of erosion or to non-preservation. The marker horizon M4, the erosion surface at the base of the *M. dixoni* Zone, passes laterally into phosphates in Sussex (Eastbourne) and the Isle of Wight (i.e. it becomes a much more developed erosion surface compared to the burrowed surface at Folkestone). The highly fossiliferous limestone of couplet B24 of Gale (1995) at Southerham Grey Pit (the possible equivalent of Bed h of Kennedy, 1969) is barely cemented and inconspicuous at Folkestone. Consequently the rich and well-preserved three-dimensional ammonite and inoceramid fauna is not represented in the Folkestone sections.

The White Bed at the top of the Grey Chalk Subgroup is more homogeneous, less obviously rhythmically bedded and thinner compared to its development at Southerham Grey Pit and at Beachy Head. This is probably due to its position on the margin of the Anglo-Brabant Massif ((Figure 1.8), Chapter 1) compared to the more basinal Sussex sections.

In the Turonian strata, the highly condensed nature of the Holywell Nodular Chalk Formation has resulted in the loss of numerous marker beds. The marl seams of the expanded succession are represented here merely by thin, marl-coated wavy surfaces. This condensation continues across the Anglo-Brabant Massif into the southern Chiltern Hills. Despite this condensation, the presence of some regional markers such as the *Filograna avita* event (Gale, 1996), has allowed a correlation to be established in the upper part of the shell-detrital layers. The *Filograna avita* event is found throughout the Southern Province and in the southern Chiltern Hills, where it has been traced as far north as Pitstone Quarry. There are fewer ammonite horizons in the Lower Turonian Holywell Nodular Chalk Formation at Dover compared with Sussex.

Because of the extreme condensation of the basal beds of the Holywell Nodular Chalk Formation (equivalent of the Melbourn Rock of Sussex) the rich *Neocardioceras juddii* Zone ammonite assemblage of the expanded Eastbourne sections is represented only by occurrences of *Sciponoceras.*

The extreme condensation at Dover continues into the base of the New Pit Chalk Formation, which here is still nodular but does not contain the shell detritus of the Holywell Nodular Chalk Formation below. The Glyndebourne Flints are missing in the Aker's Steps section but are present elsewhere in the North Downs (e.g. Halling Pit, Mortimore, 1990). Some of the nodular beds may represent the Glyndebourne Hardgrounds of Sussex (see Southerham Pit GCR site report, this volume).

The Dover–Kingsdown section of the Folkestone to Kingsdown GCR site is a link in the New Pit Chalk and Lewes Nodular Chalk formations between the main basinal sections of Sussex and Hampshire and the Transitional Province sections such as Fognam Quarry, Kensworth Quarry and the sections in East Anglia, including Grimes Graves, near Brandon. It is critical to the development of a lithostratigraphy for the Transitional Province. This is particularly the case with the Chalk Rock because the nodular 'Dover Chalk Rock' succession is intermediate between the highly condensed Chalk Rock *sensu stricto* of Fognam Quarry and Charnage Down Chalk Pit and the expanded Kingston Beds of Sussex.

The interval between the top of the 'Dover Chalk Rock' and the Navigation Hardgrounds is also condensed compared with that in the Southerham Pit, Lewes. There are more species of *Micraster* at Lewes, and current evidence suggests that there are also more Late Turonian inoceramid bivalves in this expanded section. However, the only basal Coniacian ammonite to be found so far in the Chalk of the UK came from the Navigation Hardground at Langdon Stairs.

The Aker's Steps section has provided a detailed isotope stratigraphy for the Turonian Stage of the Southern Province, the upward continuation being taken from the Langdon Bay–Langdon Stairs composite section (see Jenkyns *et al.,* 1994, figs 3, 4 for the δ^{13}C and δ^{18}O curves respectively). The remainder of the stable isotope stratigraphy up to the top of the preserved Chalk on Thanet was based on the cliff sections south of Kingsdown and in the Isle of Thanet.

The Turonian δ^{13}C curve from the Dover sections has been extensively used for long-range correlation to reference sections in Lower Saxony and Saxony (Germany) and to the cliffs near Santander in northern Spain. In all of these sections, several δ^{13}C positive 'spikes' serve as correlative marker horizons (Voigt and Hilbrecht, 1997, figs 6, 7). These have been given numbers in relation to the point on the curve with the minimum δ^{13}C value (the datum or zero — see Wiese, 1999, figs 4, 5). The most prominent of the four 'spikes' below the datum (–4 or the Pewsey event) is inferred (Gale, 1996) to correlate with the Pewsey Hardground in the bottom hardground suite of the stratotypic Chalk Rock (see Fognam Quarry GCR site report, this volume). At Dover, this peak falls low in the Lewes Nodular Chalk Formation, *c.* 4 m above the Lydden Spout Flint and immediately below the entry of the planktonic foraminifer *Marginotruncana coronata* at the base of the UKP8 planktonic foraminiferal Zone. The inception of this species may relate to a transgressive episode. Peaks –3, –2 and –1 (in ascending order) correspond respectively to the Southerham Flints below Southerham Marl 1; to a level *c.* 1 m above the Southerham Marls; and to the Caburn Flints below the Caburn Marl. This latter level, which yields the Upper Turonian zonal index ammonite, *Romaniceras deverianum,* in both the Southern and Transitional provinces, can be equated, using stable isotope stratigraphy, with the *costellatusi plana* event of European event stratigraphy and the provisional marker for the base of the Upper Turonian Substage. However, the entry of *Subprionocyclus bitchinensis* at Dover between the Southerham Marls, and the lowest ocurrence of *S. neptuni* (Geinitz) a short distance beneath the inferred equivalent of Southerham Marl 1 at Fognam Quarry, suggests that the base of the Upper Turonian Substage in the UK should be shifted significantly downwards (see also Appendix, this volume).

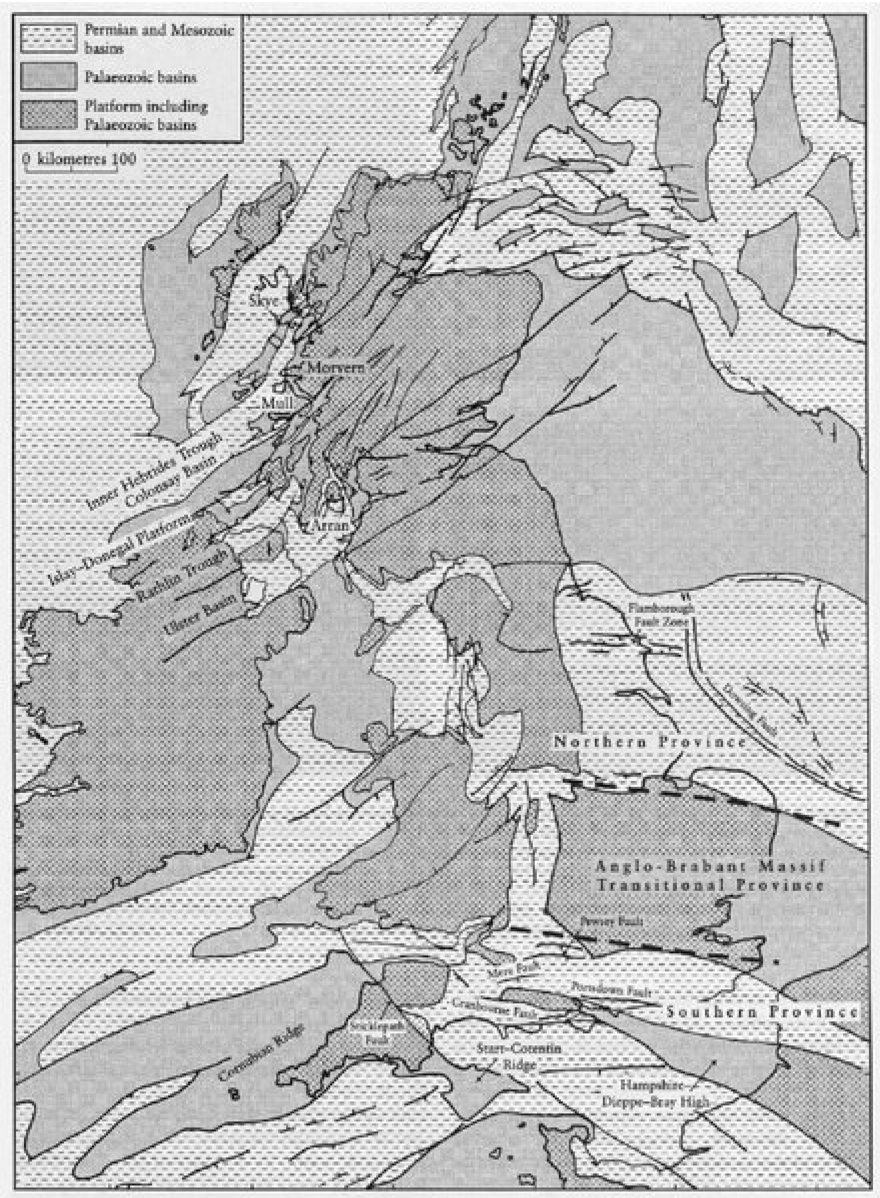
Conclusions

The Folkestone to Kingsdown Upper Cretaceous Chalk cliffs are ideally situated on the northern flanks of the Southern Province, providing a link to the Transitional Province and on into the North Sea and German sections. Detailed correlations have also been made with northern France. These cliffs provide the standard reference section for the Cenomanian Stage of the Southern Province. The Albian–Cenomanian boundary is better developed here than elsewhere in the Southern Province, with an expanded, lithologically differentiated and fossiliferous Glauconitic Marl Member at the base of the Chalk Group. This is also the best section in Europe of the *Mantelliceras schlueteri* ammonite

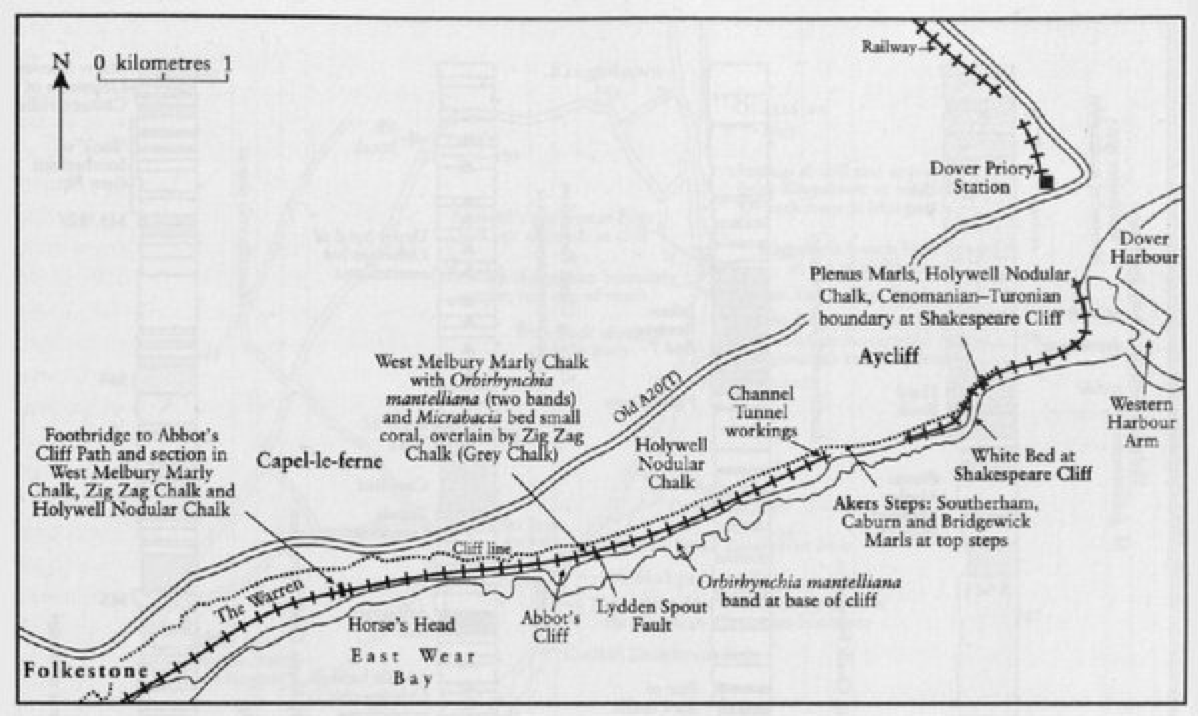
Subzone. It is one of the standard reference sections, with Southerham Grey Pit and Compton Bay, for the marl–limestone couplet cyclostratigraphy of the Cenomanian Stage. The sections illustrate the stratigraphical and sedimentological impacts of condensation in the 'Melbourn Rock' (Holywell Nodular Chalk Formation) and Chalk Rock. Many type specimens of Upper Cretaceous macrofossils come from these cliffs. It is only in the 'Dover Chalk Rock' that it is possible to demonstrate the succession of Upper Turonian ammonite faunas known from expanded sections in Germany. The rich inoceramid bivalve faunas enable correlation between the traditional macrofossil zones and the standard inoceramid zonal scheme. The site also includes several of the reference sections for the microfossil (foraminiferal) zonal scheme of the UK.

Together with the Sussex sections, the Folkestone to Kingsdown cliffs provide standard reference sections for the trace element and rare earth geochemistry of the Turonian marl seams. Closely spaced chalk samples collected from this and the Thanet Coast GCR site were used to establish the lowest part of the continuous stable isotope curve for the Cenomanian–Upper Santonian interval in the Southern Province.

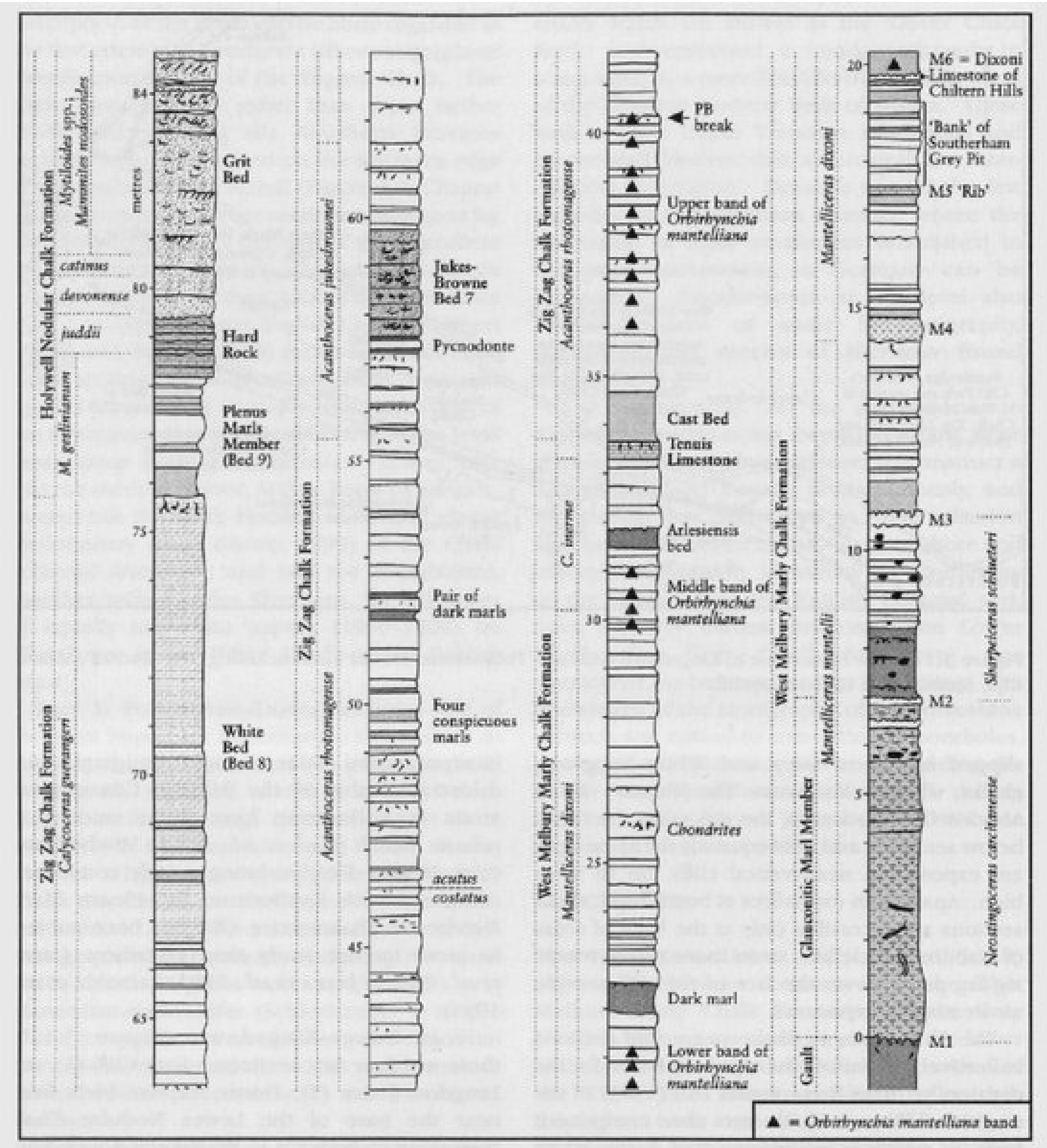
[References](#)



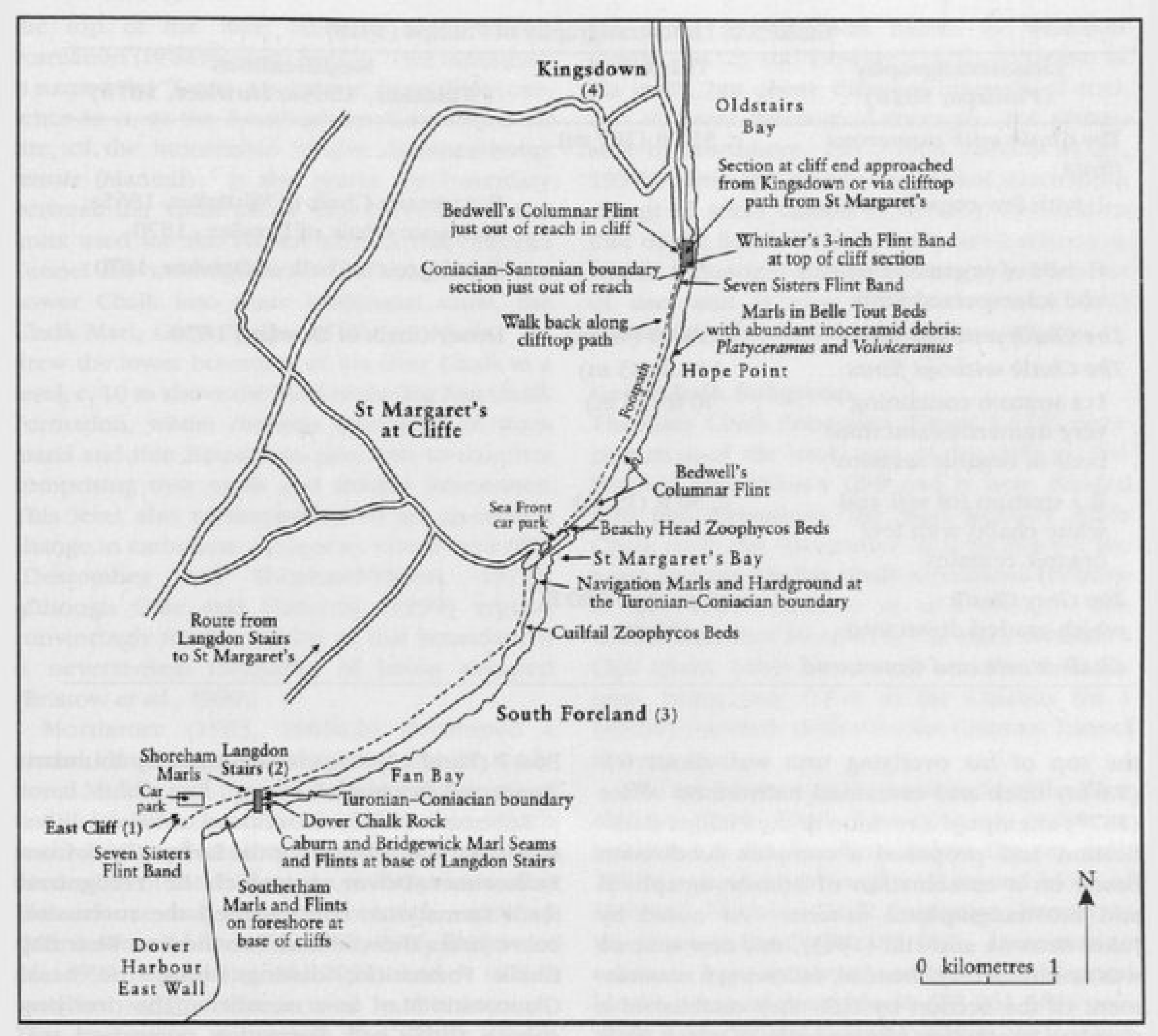
(Figure 1.8) Broad structural features affecting sedimentation of the Upper Cretaceous deposits in the British Isles. (Based on British Geological Survey 1:1 000 000 maps of the Geology of the UK, Ireland and Continental Shelf; North and South Sheets.)



(Figure 3.118) The Folkestone to Kingsdown GCR site; Folkestone–Dover cliffs including 'The Warren', Abbot's Cliff, Shakespeare Cliff and Aycliff.



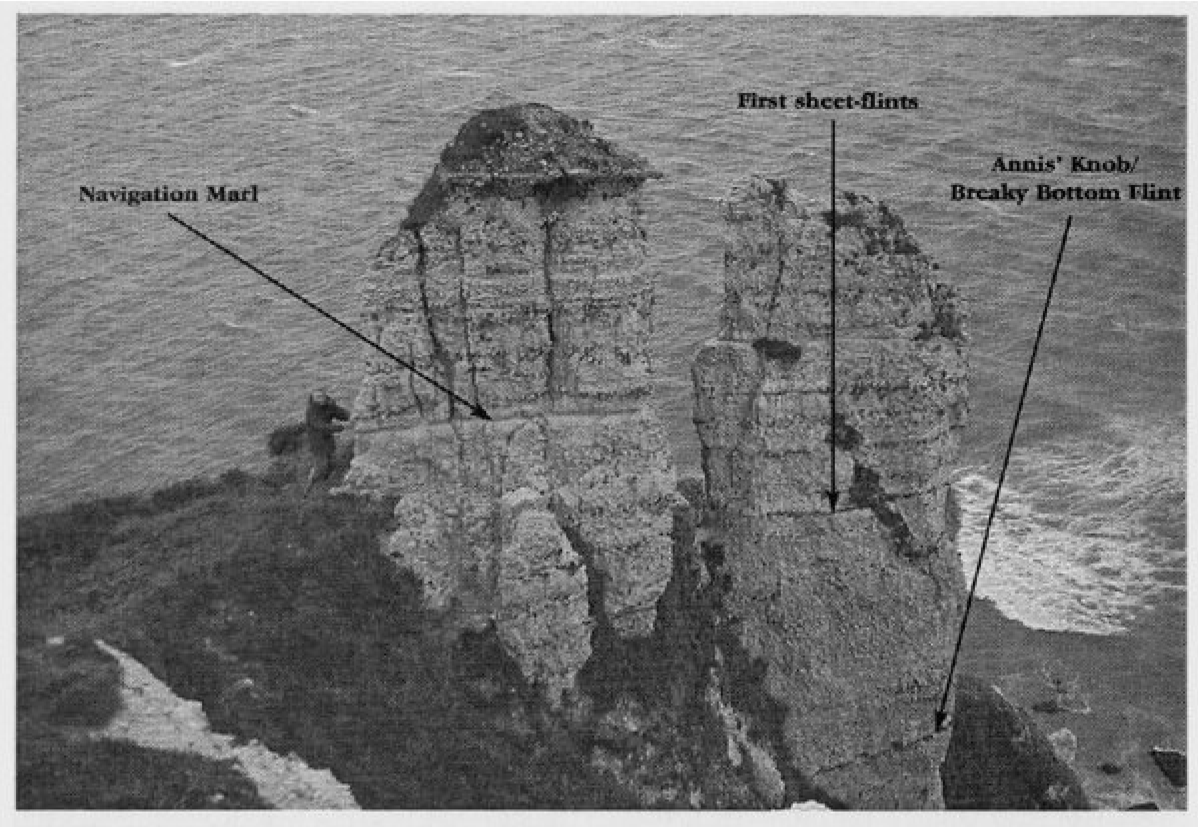
(Figure 3.119) The Grey Chalk Subgroup type section at Folkestone, Abbot's Cliff, showing key litho- and biostratigraphy. (Modified from Gale in Jenkyns et al., 1994: and Mortimore, 1997.) The black symbols in the schlueteri Subzone represent spongiferous nodules.



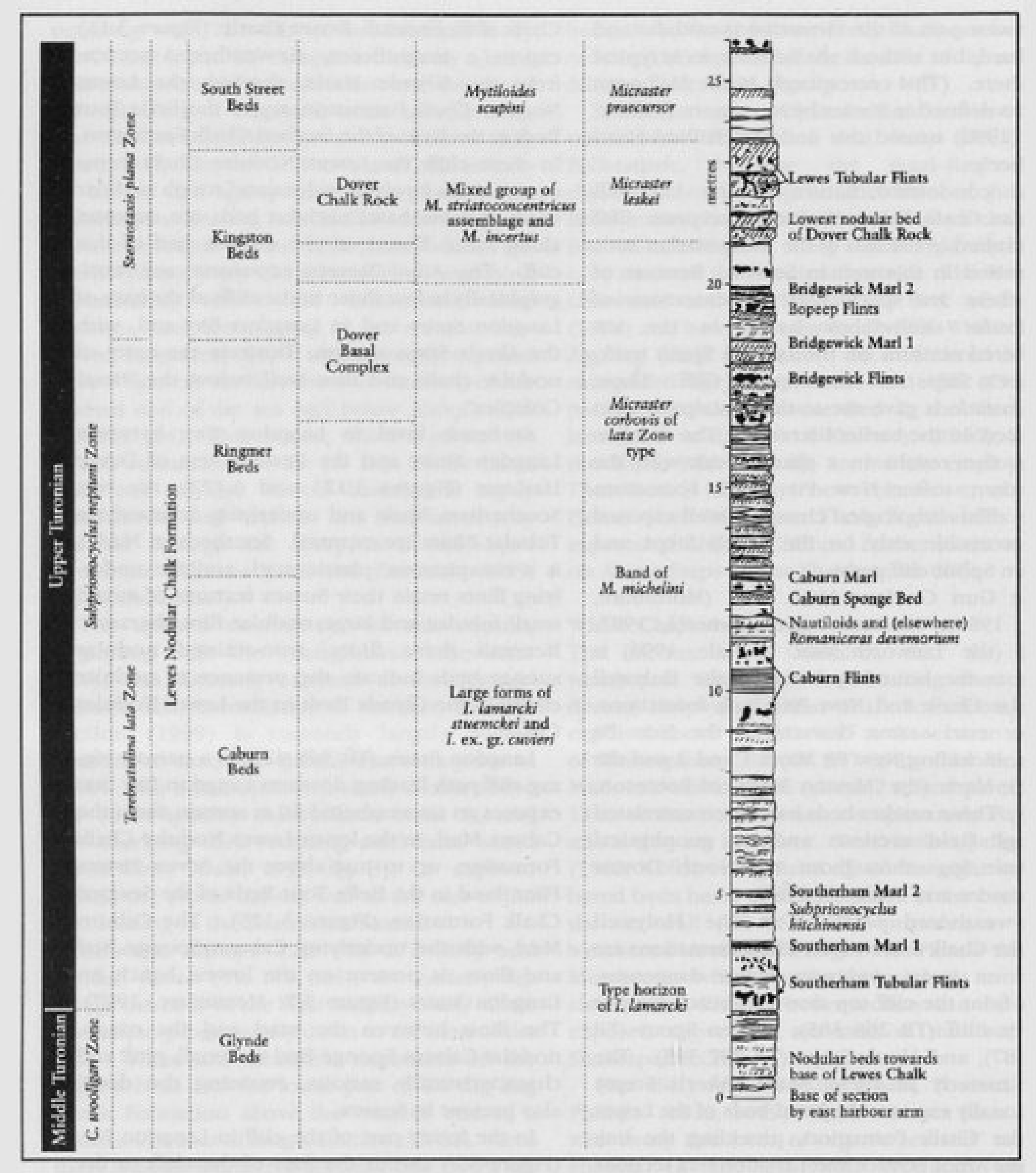
(Figure 3.120) The Folkestone to Kingsdown GCR site from Langdon Cliffs to Kingsdown. For a description of localities (1)–(4) see text.

Lithostratigraphy (Phillips, 1818)	Thickness	Modifications (Whitaker, 1865a, Dowker, 1870)
The Chalk with numerous flints	*c.* 350 ft (107 m)	
I with few organic remains		Broadstairs Chalk of Whitaker, 1865a; Ramsgate Chalk of Dowker, 1870
II bed of organic remains and interspersed flints		St Margaret's Chalk of Dowker, 1870
The Chalk with few flints	*c.* 130 ft (40 m)	Dover Chalk of Dowker, 1870
The Chalk without flints	140 ft (43 m)	
I a stratum containing very numerous and thin beds of organic remains	90 ft (27 m)	
II a stratum (of soft and white chalk) with few organic remains	*c.* 50 ft (15 m)	
The Grey Chalk which graded down into *Chalk Marle and Greensand*	not less than 200 ft (61 m)	

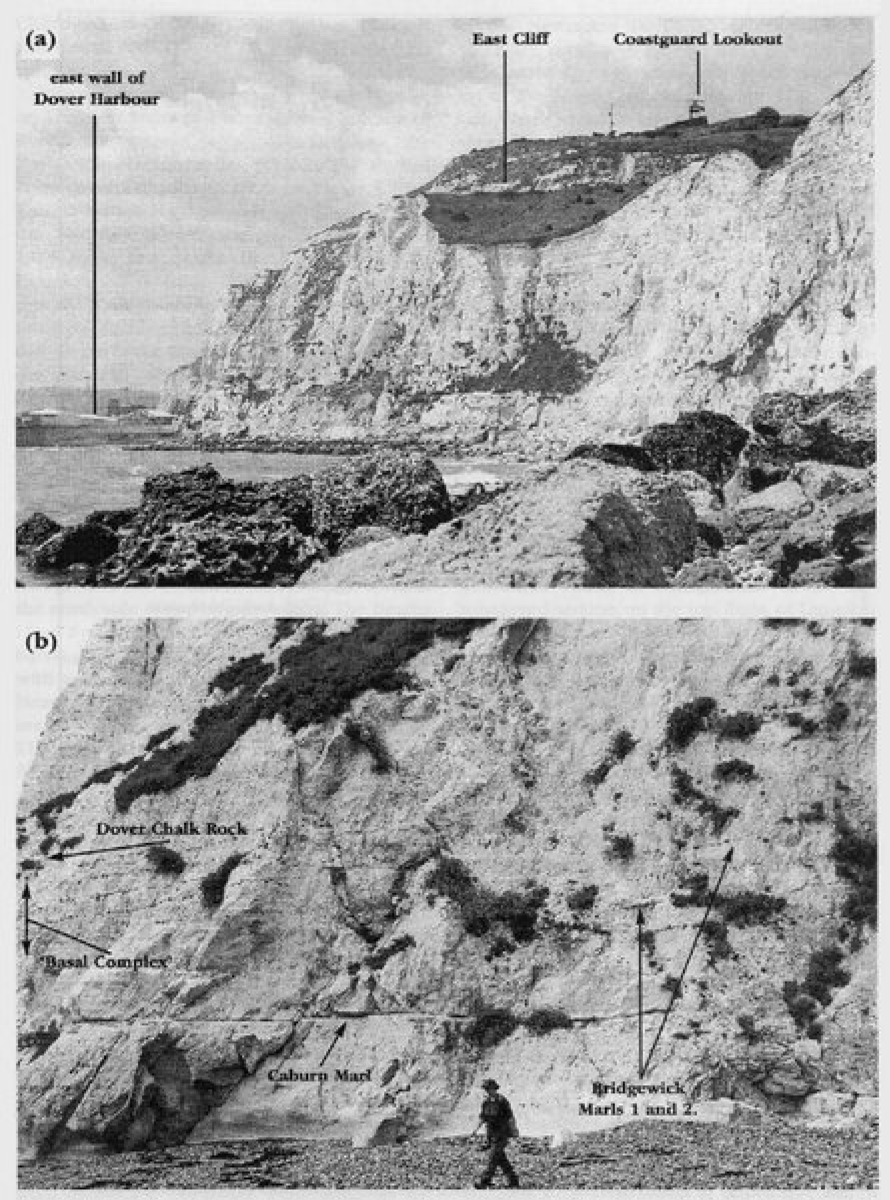
(Table 3.2) Lithostratigraphy of Phillips (1818).



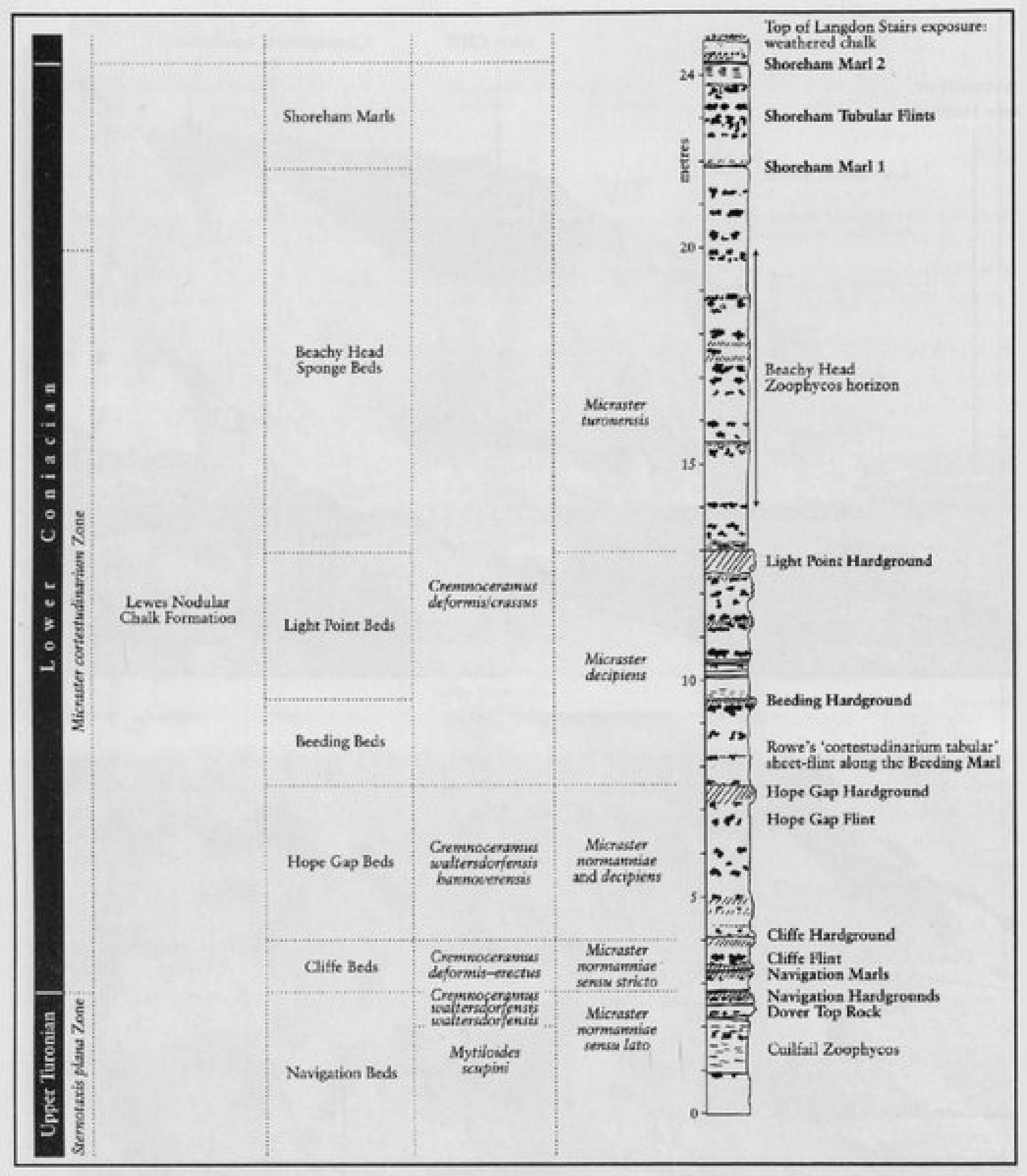
(Figure 3.11) Hooken Cliff and the Twin Pillars at Beer Head; pinnacles of Lewes Nodular Chalk Formation exposing the succession from below the Annis' Knob Flint, through the Lewes Marl and Navigation Marl to a horizon around the Hope Gap Hardground equivalent. The first sheet-flints were used by Rowe (1903) for correlation. (Photo: R.N. Mortimore.)



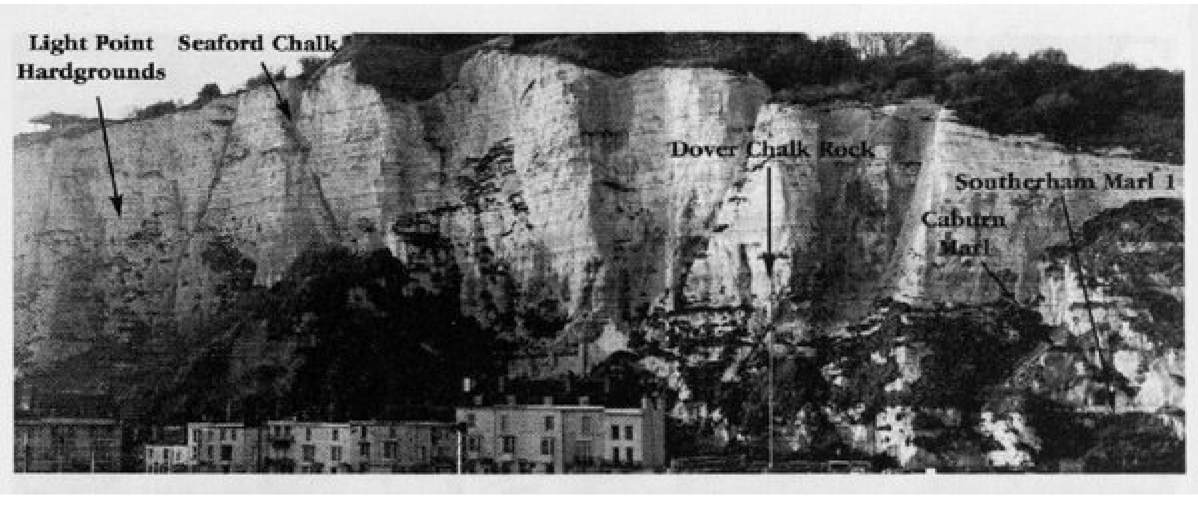
(Figure 3.121) The lowest sections on Landon Stairs including the Dover Chalk Rock and Basal Complex. (Based on Mortimore, 1997.)



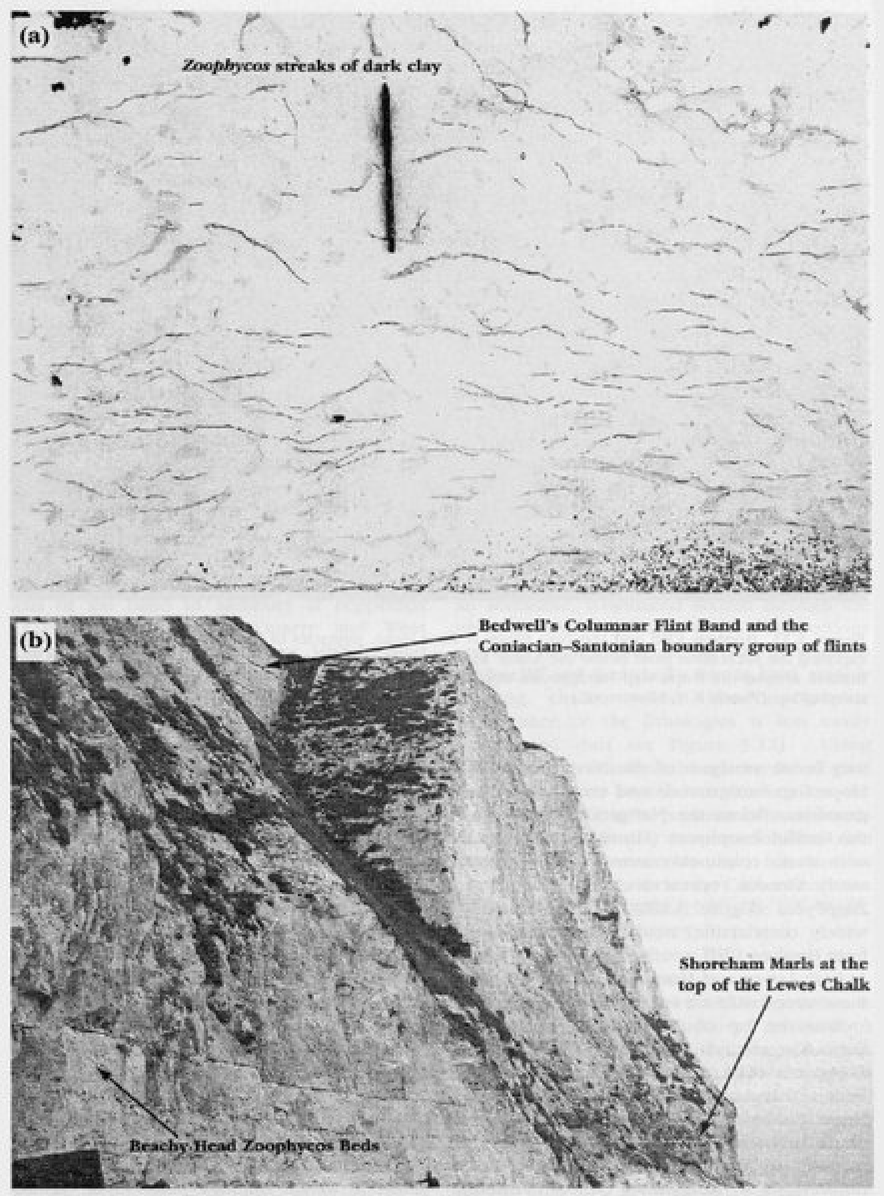
(Figure 3.122) East Cliff Dover. (a) Looking west from Fan Bay across Langdon Bay to the east wall of Dover Harbour. (b) Lower part of the Lewes Nodular Chalk Formation in Fan Bay (scale given by Dr Silke Voigt). (Photos: R.N. Mortimore.)



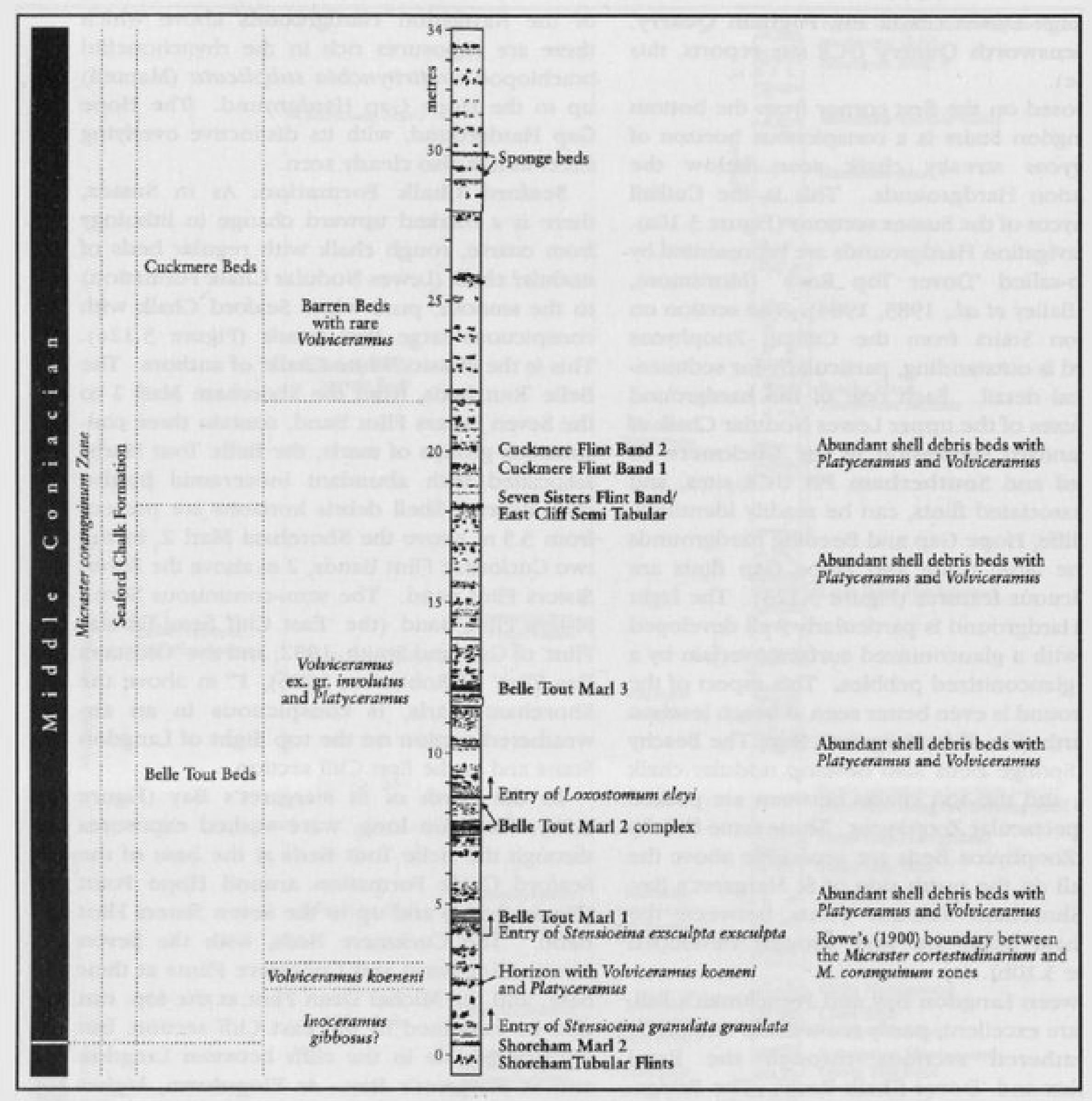
(Figure 3.123) The upper sections on the Langdon Stairs exposure, Dover showing the Dover Top Rock and upper Lewes Nodular Chalk Formation. Inoceramid bivalve zones are inferred from expanded sections in Germany and are subject to review



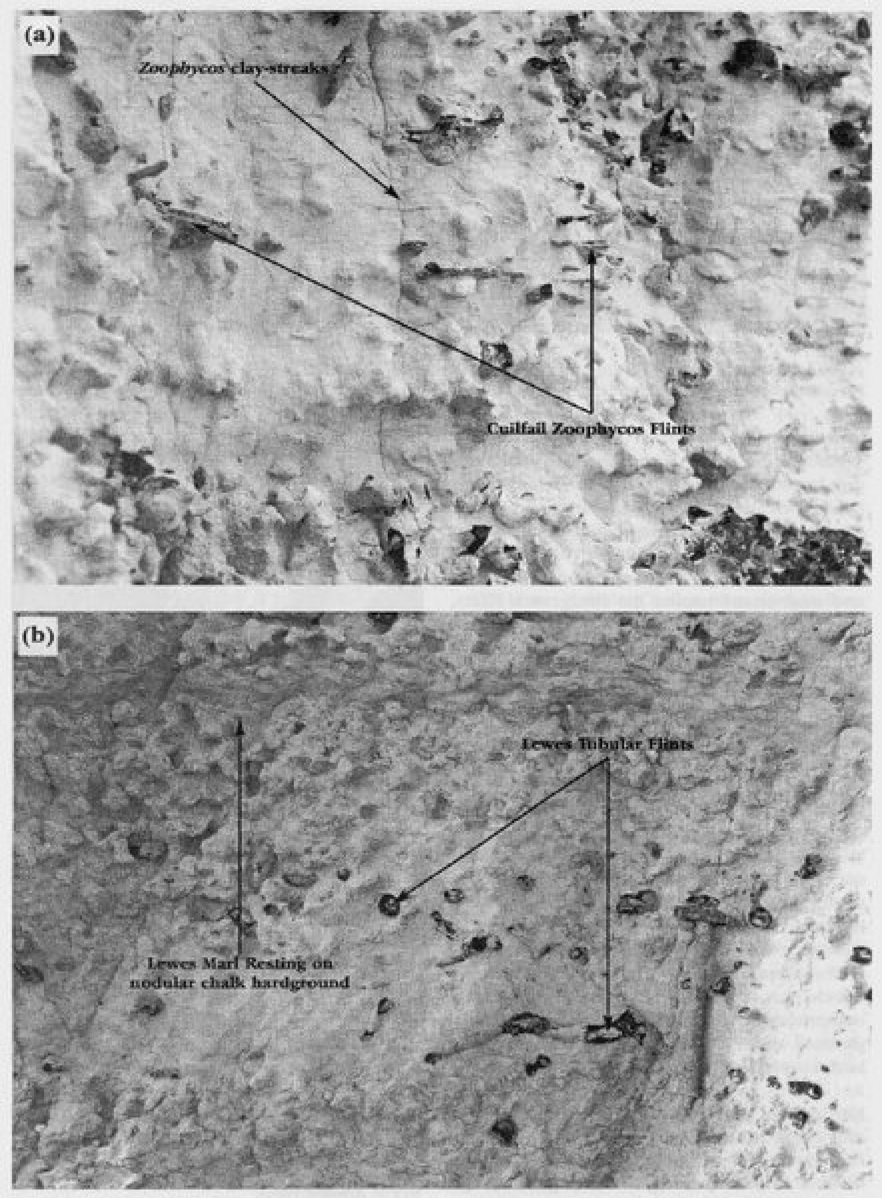
(Figure 3.7) Part of the Chalk cliffs at Dover above Athol Terrace exposing the entire Lewes Nodular Chalk Formation and the basal Seaford Chalk Formation. (Photomosaic: R.N. Mortimore.)



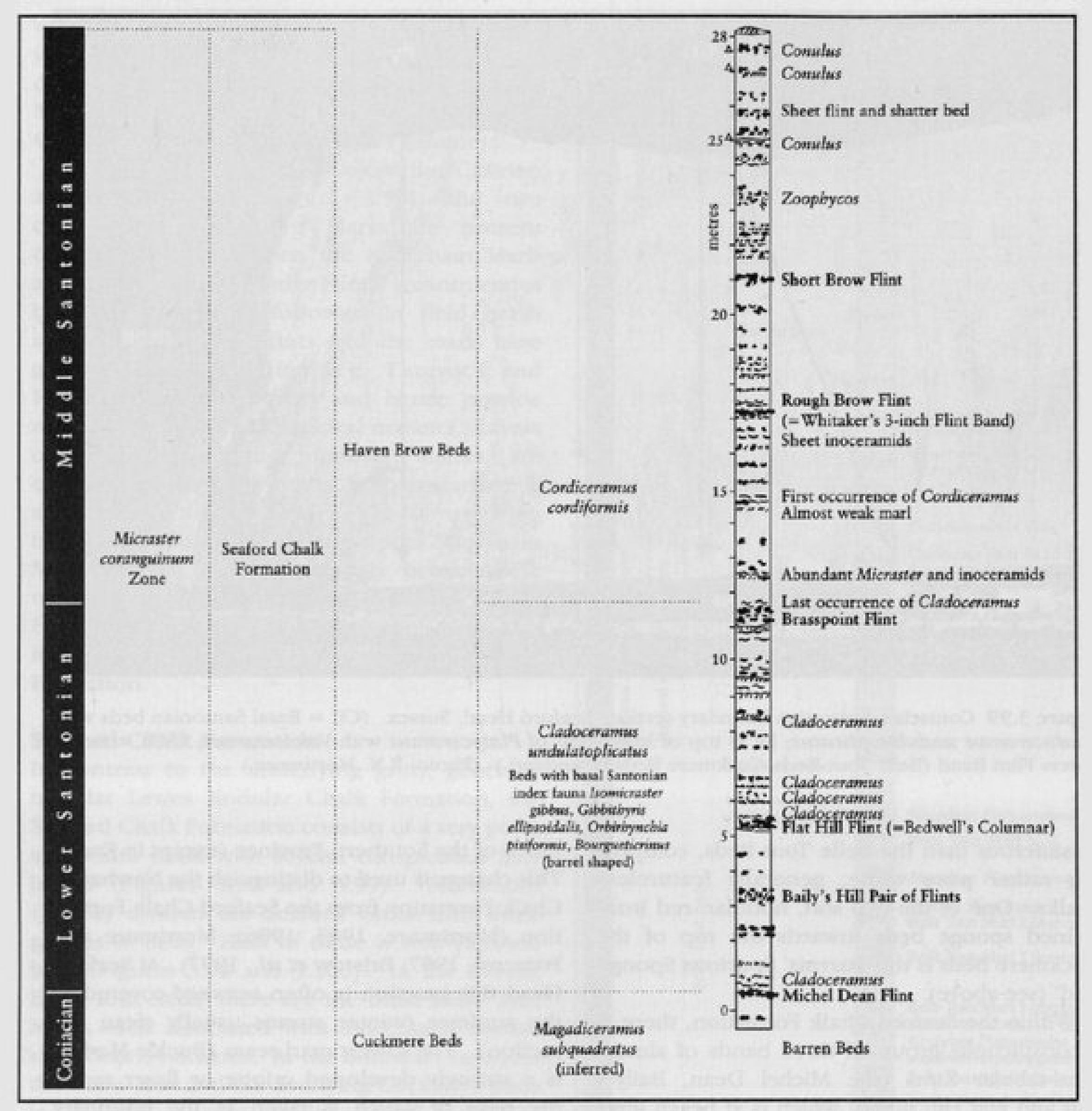
(Figure 3.10) Chalk adjacent to St Margaret's Bay, Dover. (a) South side of St Margaret's Bay beyond the South Foreland, showing the Cuilfail Zoophycos in the topmost Turonian strata. (b) North side of St Margaret's Bay, showing the topmost Lewes Nodular Chalk and basal Seaford Chalk formations. (Photos: R.N. Mortimore.)



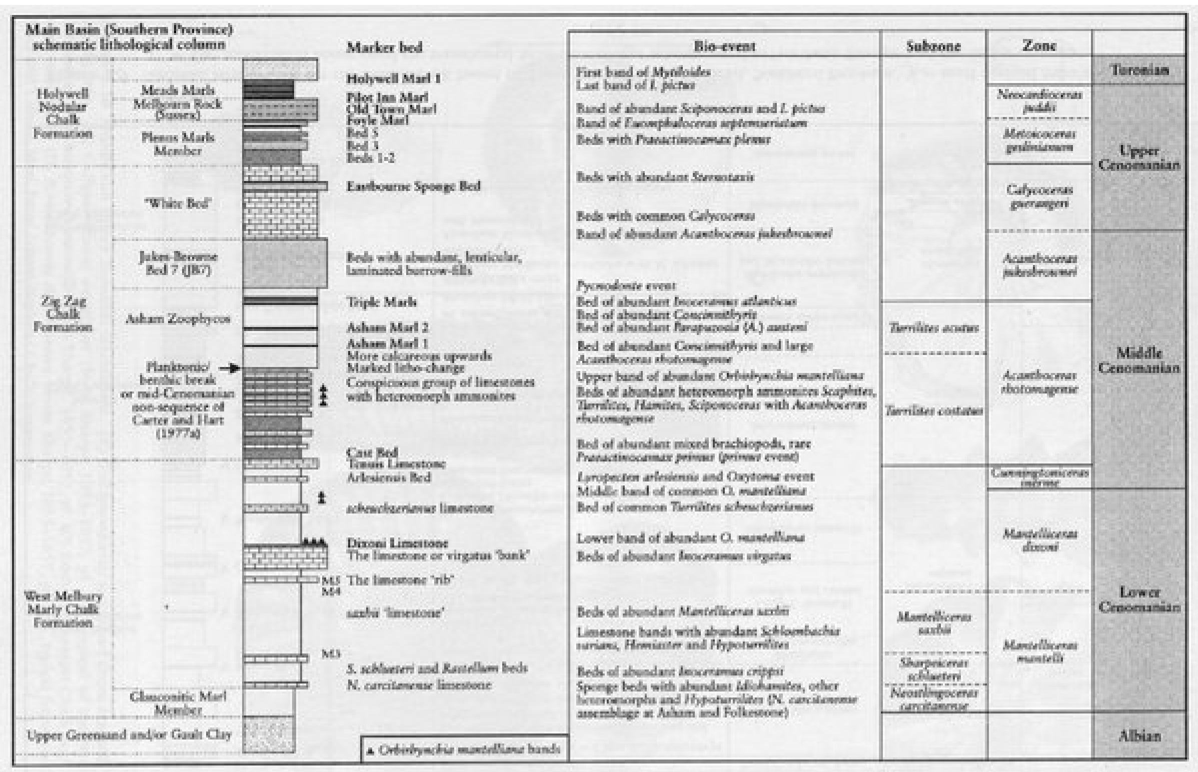
(Figure 3.124) Seaford Chalk Formation on Langdon Stairs, Langdon Cliff and East Cliff, Dover, showing key marker beds.



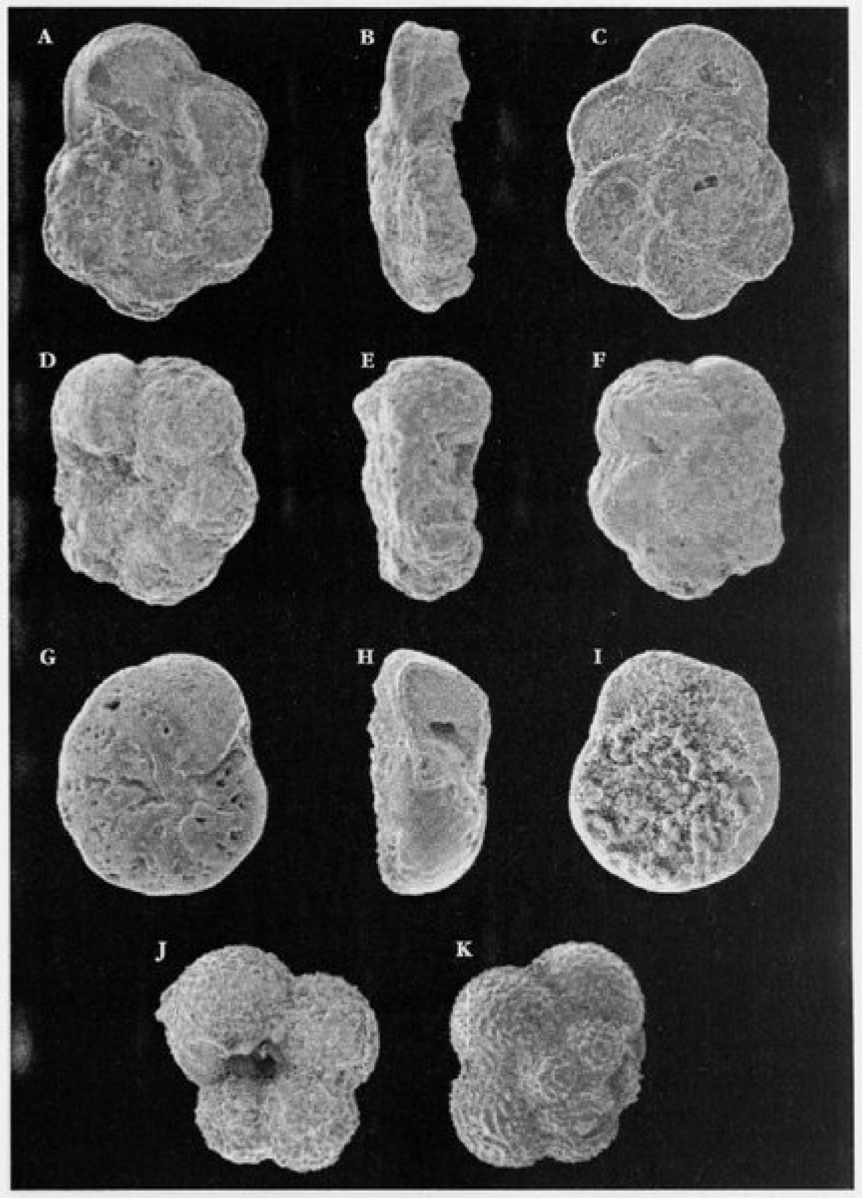
(Figure 3.9) (a, b) Basin-wide marker beds in the Upper Turonian part of the Lewes Nodular Chalk Formation present in the Hooken succession at Hooken Cliff. (Photos: R.N. Mortimore.)



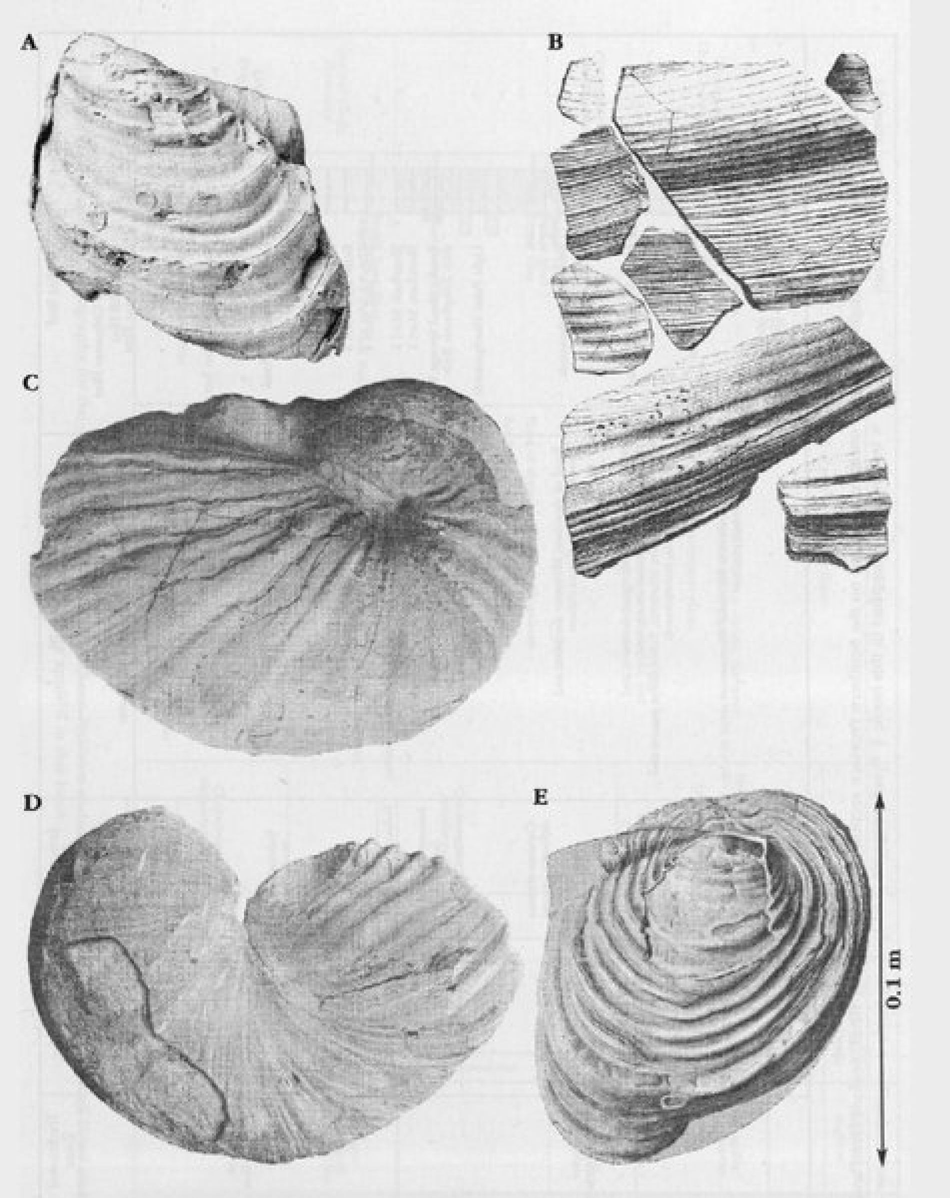
(Figure 3.100) Seaford Head: the Coniacian–Santonian boundary and the higher part of the Seaford Chalk Formation.



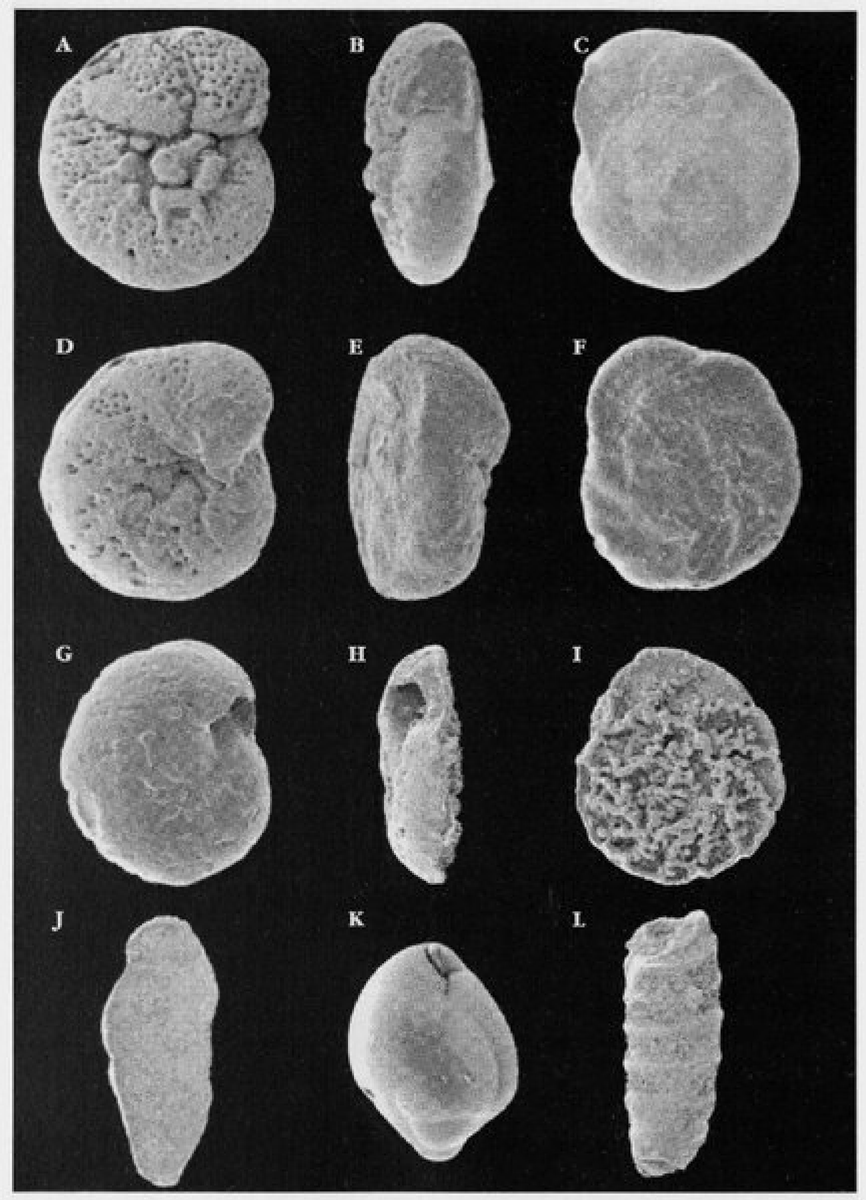
(Figure 2.8) Cenomanian stratigraphy for the onshore UK based on Southerham, Asham, Beachy Head and Folkestone. M2, M4 and M5 are Marker Beds of Gale (1995).



(Figure 2.41) Turonian and Coniacian foraminifera. SEM images of Turonian and Coniacian foraminifera. (A–C) Marginotruncana pseudolinneiana (Pessagno) (× 150) (planktonic), from New Pit, Lewes, East Sussex, (New Pit Chalk Formation), Middle Turonian Collignoniceras woollgari Zone. Range: Turonian to Santonian. Remarks: key zonal form in Europe, entry marks a planktonic foraminiferal zone in the Turonian. (D–F) Helvetoglobotruncana helvetica (Bolli) (× 150) (typical Tethyan planktonic), from New Pit, Lewes, East Sussex, (New Pit Chalk Formation), Middle Turonian Collignoniceras woollgari Zone. Range: Lower to Middle Turonian. Remarks: key entry zonal index fossil. (G–I) Stensioeina granulata granulata (Olbertz) (× 150) (benthic), from Seaford Head (Cuckmere to Seaford GCR site) East Sussex (Seaford Chalk Formation), Middle Coniacian Micraster coranguinum Zone. Range: base of Middle Coniacian to Middle Santonian. Remarks: key marker at base of Seaford Chalk Formation (Bailey et al., 1983, 1984). O, K) Whiteinella baltica (Douglas and Rankin) (× 150) (planktonic), from Euston, Suffolk, M coranguinum Zone. Range: Base of Coniacian to Upper Santonian.



(Figure 2.20) Lower and Middle Coniacian inoceramid bivalves. (A) Cremnoceramus crassus crassus typical of Beeding to Light Point beds, Lewes Nodular Chalk (from Walaszczyk and Wood, 1999b, pl. 17, fig. 2). (B) Fragments of Platyceramus sp. shell typical of the Belle Tout Beds, Seaford Chalk Formation (from De Mercy, 1877). (C–E) Volviceramus aff. involutus; (C, D) typical of Belle Tout Beds, Seaford Chalk Formation (from Woods, 1912, text-figs 93, 90); (E) typical cap valve in Belle Tout Beds, Seaford Chalk Formation, common 1.8–2 m below the Seven Sisters Flint Band (from Woods, 1912, text-fig. 94). Scale bar applies to all specimens.



(Figure 2.42) Santonian foraminifera. SEM images of Santonian foraminifera. (A–C) Gavelinella cristata (Goel) (× 100) (benthic), from Ipswich, Suffolk, Lower Campanian. Range: Upper Santonian to Lower Campanian. Remarks: entry is approximately coincident with base of Uintacrinus socialis Zone (Bailey et al., 1983). (D–F) Stensioeina granulata polonica (Witwicka) (× 150) (benthic), from Euston, Suffolk (Seaford Chalk Formation), Upper Coniacian M coranguinum Zone. Range: entry in Upper Coniacian. Remarks: zonal index in UKB scheme (Bailey et al., 1983). (G-I) Stensioeina exsculpta exsculpta (Reuss) (× 150) (benthic), from Euston, Suffolk (Seaford Chalk Formation), Upper Coniacian M. coranguinum Zone. Range: Benthic Foraminiferal Zone in the Middle and Upper Coniacian. Remarks: ranges from just above the Shoreham Marls to the Flat Hill Flint, Seaford Chalk Formation. (1) Loxostomum eleyi (Cushman) (× 150) (benthic), from Ipswich, Suffolk, Lower Campanian. Range: Santonian to Upper Campanian. (K) Praebulimina reussi (Morrow) (× 150) (benthic), from Ipswich, Suffolk, Lower Campanian. Range: Santonian to Upper Campanian. (L) Vaginulinopsis scalariformis (Porthault) (× 50) (benthic), from Euston, Suffolk, Seaford Chalk Formation M coranguinum Zone. Range: Middle Coniacian and Lower Santonian.