Hooken Cliff, South-East Devon

[SY 210 881]–[SY 227 878]

Introduction

The Hooken Cliff GCR site includes the Hooken Cliffs, Beer Head and Branscombe East Cliff. The vertical cliffs of Beer Head and the great Hooken Cliffs landslip (Figure 3.16), (Figure 3.17), (Figure 3.18) expose the most complete Upper Cretaceous succession in south-east Devon. These are also the westernmost exposures of Chalk in England and illustrate what happens to the Upper Cretaceous sediments as they approach the basin margin. At the base of the succession, the earliest (Cenomanian) deposits are highly condensed sandy limestones about 5 m thick, compared with more than 80 m for the same interval in the main basin in Sussex and Kent. Despite this condensation there is a remarkable preservation of fossils, particularly ammonites, that aids correlation with the main basin to the east, with Europe and with North America. As the seas deepened and chalks formed, key basinal lithological markers such as the Turonian marl seams and flint bands can be recognized and the main basin lithostratigraphy can be applied. These chalk units form the main high cliffs at Beer Head.

Within a relatively small outcrop, Hooken Cliff illustrates extraordinary lateral changes in sedimentation, which include onlapping of higher Turonian beds over earlier ones onto the Albian Upper Greensand. The Cenomanian deposits pass from thin sandy limestone facies, on the margins of the site, to calcarenitic (Wilmington Sand') facies in the centre of the site. This lateral variation, which is also seen in the lenticular development of a calcarenitic freestone (Beer Stone) near the base of the Lower Turonian Holywell Nodular Chalk Formation, is attributable to the site traversing a narrow, north-south, fault-bounded depositional trough ('Hooken–Wilmington trough', (Figure 3.17) and (Figure 3.19), which controlled sedimentation. A combination of tectonic fault control and sea-level rise is used to explain the sedimentary variations.

The site and, particularly, the sections immediately to the west, are famous for the rich Lower Turonian echinoid faunas in the Holywell Nodular Chalk Formation.

Description

Hooken Cliff comprises several components (see (Figure 3.20)):

1. The continuous cliff section landward of the landslip, from Branscombe East Cliff to Hooken Cliffs, including the Beer Stone adit.
2. Slipped masses from these cliffs in the landslip area including, from west to east, Mitchell's Stile Rock, Martin's Rock, and the three Pinnacles.
3. The cliff section east of the landslip area extending from Little Beach to Beer Head, and fallen blocks therefrom. This was described by Rowe (1903, p. 20): 'there is no section on the English coast which gives so much zonal detail, or tells the story of zonal succession in so convincing and graphic a manner'.
4. High-level slipped masses at and near Beer Head, which preserve the highest Chalk: these include the so-called 'Belay Buttress' and a karstic collapse structure.

The beds dip gradually eastwards at 4°, bringing Upper Cretaceous strata from near the top of the cliff in Branscombe East Cliff down to sea level at Beer Head.

Between the Beer and Branscombe valleys the Chalk caps a ridge of high ground known as South Down (Figure 3.17) and (Figure 3.20). Prior to 1790, this ridge terminated in a line of Upper Greensand and Chalk cliffs up to 150 m high, but in March 1790 failure along a thin bed of sandy clay at the base of the Upper Greensand caused a mass 1300 m long, and up to 250 m wide, to subside seawards. Dawson *et al.* (1840) provided the following graphic description, based on local accounts.

… in the middle of the night, a tract of from seven to ten acres, ranging along the brow of a steep cliff immediately overhanging the sea, suddenly sank down from 200 to 260 feet, presenting a striking group of shattered pinnacles and columns of chalk entangled with the sunken fragments of the fields thus torn away from their native site; the remains of hedges still traversed these fragments, and a stile was seen undis turbed on the summit of one of the subsided columnar masses. The subsided mass pressed forward into the sea… fishermen relate that points on which they had laid their crab-pots beneath the water, and over which they had sailed the night before… were raised… on a reef at a height of fifteen feet in the air'.

No-one witnessed the event, but fishermen out at sea were alarmed by the noise of it. The fields, hedges and the stile have long since gone, but the pinnacles of remarkably undisturbed Upper Greensand and Chalk remain, rising above a sea of tangled vegetation that now separates them from the Hooken Cliffs in the back face of the landslip.

De la Beche (1826) was the first to describe the Upper Cretaceous succession of the coast sections including the Hooken. He noted the anomalous nature of the oldest Chalk and recorded the presence of 'chalk with quartz grains' underlain by up to 3 ft (*c.* 1 m) of a richly fossiliferous 'compact pebbly basal bed'. This was succeeded by 'chalk without flints' overlain by 'chalk with flints'. Meyer (1874) was, however, the first to describe the stratigraphy of the Chalk of Hooken Cliff. Barrois (1876) was then the first to recognize the presence of the Paris Basin macrofossil assemblage zones of *Rhynchonella cuvieri, Terebratulina gracilis* and *Holaster planus* (Turonian), and *Micraster cortestudinarium* (Coniacian). Jukes-Browne and Hill (1903, 1904) and, particularly, Rowe (1903) described the stratigraphy and fauna of the traditional Middle and Upper Chalk successions of the coastal and inland quarry sections in considerable detail.

Jukes-Browne and Hill (1903; Jukes-Browne 1896, 1903) gave detailed descriptions of the Cenomanian sediments at Hooken Cliff. They termed these collectively the 'arenaceous beds', or 'Zone of *Ammonites mantelli',* and subdivided the succession into two distinct beds, which they designated A and B, in ascending order. In the sections west of Branscombe, i.e. west of the site, they noted (1903) that the lower part of Bed A (Al) was characterized by the common occurrence of what they took to be a giant coral-like bryozoan, *Ceriopora ramulosa* (Michelin), which was absent from the higher part (A2) of the same bed. The bed overlying Bed B (Bed C), which they described as chalk and excluded from the arenaceous beds, was particularly well developed at Humble Point, between Lyme Regis and Axmouth. They inferred that Bed C, which was represented by glauconitic sands in Hooken Cliff; correlated with the Plenus Marls of areas to the east, and emphasized the considerable hiatus between Beds B and C (Figure 3.4).

Smith (1957a) gave formal formation status to the previously (e.g. Rowe, 1903) informally named 'Cenomanian Limestone'. At first he accepted the subdivisions Al, A2, B and C, but he later (1965) renamed Bed C the 'Orbirhynchia Bed' because he considered that it was of Turonian rather than Cenomanian age, and excluded it from the Cenomanian Limestone. In a series of papers, following and adding to the earlier work by Jukes-Browne (1898) and Jukes-Browne and Hill (1903), he described the lateral variation of the Cenomanian deposits between Sidmouth and Lyme Regis. Two of these papers (Smith, 1957a, 1961) are of particular relevance to the Hooken Cliff GCR site.

Jarvis and Woodroof (1984) renamed Smith's original 'Cenomanian Limestone Formation' the 'Beer Head Limestone Formation' and gave formal member status to the four subdivisions (A1, A2, B and C), which were then in general usage (see (Figure 3.21)). In ascending order, these became the 'Pounds Pool Sandy Limestone Member', 'Hooken Nodular Limestone Member', 'Little Beach Bioclastic Limestone Member' and 'Pinnacles Glauconitic Limestone Member'. With the exception of the Pounds Pool Member, the type section of which lies to the north of the site, these members are named after the Hooken Cliff GCR site and localities within it. They named the hardground surfaces at the upper boundaries of these members the Weston, King's Hole, Humble Point and Haven Cliff Neocardioceras hardgrounds respectively. All of these names derive from localities outside the GCR site. They also named the hardground at the top of the Upper Greensand the 'Small Cove Hardground' from a coastal feature near Beer. Robaszynski *et al.* (1998) correlated the sedimentary breaks that these hardground surfaces represent with sequence boundaries in the Cenomanian deposits of northern France, and demonstrated that they lay at consistent stratigraphical levels throughout the north-west part of the Anglo-Paris Basin.

Rowe (1903) provided superb annotated photographs to illustrate the positions of key marker bands in the Chalk at Beer Head (Rowe, 1903, pl. IX); the Pinnacles and the eastern part of Hooken Cliff (pl. X); and the central and western part of

Hooken Cliff (pl. XI). These marker horizons were, in ascending order: 'the first flint line dividing the R.c. and T.g.' (*Rhynchonella cuvieri* and *Terebratulina gracilis* zones); two conspicuous marl-rich bands (the '2-ft band' and the '4-ft band') in the *gracilis* Zone; and a 'marl seam dividing T.g. and H.p.' (*Holaster planus* Zone). In the highest part of the succession, he recognized a 'strong double flint line'; a 'strong nodular flint line in the *Holaster planus* Zone'; a 'thin tabular band dividing the *planus* Zone from the *Micraster cortestudinarium* Zone'; and a 'marl seam within the *cortestudinarium* Zone'. His zonation of these sections has proved to be remarkably accurate.

More recent descriptions of all or part of the south-east Devon successions include those of the Turonian Stage by Jarvis and Woodroof (1984) and Jarvis and Tocher (1987). Jarvis and Woodroof (1984) placed the Chalk overlying the Cenomanian strata into the Seaton Chalk Formation, which they subdivided into the Connett's Hole Member (nodular and shell-detrital chalk, with flints at the top) and the Beer Roads Member (marly chalks with flints). The higher part of the Turonian and basal Coniacian succession exposed in Pinhay Cliffs and in the Annis' Knob block at Beer was later (Jarvis and Tocher, 1987) placed in the St Margaret's Bay Member, which had been established by Robinson (1986) for the approximate equivalent in the North Downs of the Lewes Nodular Chalk Formation.

Jarvis *et al.* (1988a) documented in detail the foraminiferal and dinoflagellate cyst biostratigraphy and the stable isotope stratigraphy across the Cenomanian–Turonian boundary succession at the Beer Stone adit section. Their study complemented previous work on the foraminifera of the Pinnacles section by Carter and Hart (1977a).

Hooken Cliff is particularly famous for the remarkable thinning of the thick Cenomanian arenaceous deposits (Wilmington Sand facies of the Cenomanian Limestone) and the cutting out of the basal Turonian (Holywell Nodular Chalk Formation) chalks westward from the centre of the site onto a positive structure, and the progressive onlap in the same direction of flinty Turonian Chalk (New Pit Chalk Formation) (Figure 3.21) and (Figure 3.22). This thinning and overstep, first illustrated by Whitaker (1871), and subsequently described by Rowe (1903), Jukes-Browne and Hill (1903, fig. 80) and Smith (1961, fig. 4b), is further discussed below.

Lithostratigraphy

The site exposes an almost complete section through the Upper Greensand Formation, overlain by up to 80 m of Upper Cretaceous deposits that extend in a continuous succession from the base of the Cenomanian sediments (Cenomanian Limestone Formation) up to a horizon low in the Seaford Chalk Formation of the White Chalk Stibgroup. The extensive cliff sections, and their continuation in Branscombe and Salcombe cliffs to the west, and in Beer Cliffs to the east (Figure 3.16), (Figure 3.18) and (Figure 3.20), (Figure 3.21), (Figure 3.22), (Figure 3.23), (Figure 3.24), enable the lateral variations to be studied in detail. The exposures within the site provide a transect through the thick Albian to Turonian succession developed in the 'Hooken–Wilmington Trough'.

In this book we use the local lithostratigraphical scheme introduced for the Cenomanian Stage by Jarvis and Woodroof (1984), treating the thicker arenaceous developments of Bed A (Pounds Pool and Hooken members) as the arenaceous or 'Wilmington Sand' facies. We choose to use the member names, rather than the traditional beds A1–C in order to reflect the sedimentological complexity of these units. However, we consider that the Pinnacles Member (Bed C) should be regarded as the basal bed of the White Chalk Subgroup, rather than as the terminal member of the Beer Head Limestone Formation (see (Figure 3.23)). This follows the observations of Wright *et al.* (1984) who stated that Bed C is simply Chalk Basement Bed. In fact, at some localities, for example White Cliff and Haven Cliff, the lithology of Bed C was described by Wright and Kennedy (1981) as quartzose chalk. Except in the centre of Hooken Cliff, the Pinnacles Member is largely co-extensive with the Plenus Marls Member of the Holywell Nodular Chalk Formation, and its base can effectively be regarded as the sub-Plenus erosion surface. However, in view of its totally different lithological character we adopt for this basal unit of the White Chalk Subgroup in south-east Devon the existing name 'Pinnacles Member'. For reasons explained below, we choose to apply the standard lithostratigraphical classification of the lower part of the White Chalk Subgroup into Holywell Nodular Chalk, New Pit Chalk and Lewes Nodular Chalk formations (Rawson *et al.,* 2001), rather than accept the local lithostratigraphical nomenclature introduced by Jarvis and Woodroof (1984), and further modified by Jarvis and Tocher (1987) and Tocher and Jarvis (1987). The highest preserved Chalk belongs to the Seaford Chalk Formation.

Grey Chalk Subgroup: Beer Head Limestone Formation (Cenomanian Limestone Beds A and B and the Wilmington Sand facies)

At the base of the Upper Cretaceous succession, the richly fossiliferous Cenomanian Limestone is exposed at the eastern end of the site at Beer Head (Figure 3.23). It can be traced westwards into a much thicker succession of sandy limestones, calcarenites and calcareous sandstones (Wilmington Sand facies and transitional lithologies) over a distance of a few hundred metres at Little Beach. The Cenomanian Limestone facies reappears at the western end of the site.

The type section for Meyer's (1874) beds 10, 11, 12 and 13 and for the Beer Head Limestone Formation lies within the site, where the succession is thickest and most arenaceous, adjacent to the Beer Stone adit. The descriptions below illustrate the principal features of the end members of the laterally variable succession. The full thickness of the limestone facies of the Beer Head Limestone is perfectly exposed at the foot of Beer Head [SY 227 879], where the following descriptions apply.

The Pounds Pool Member (Bed A1)

The Pounds Pool Member (Bed A1) is the basal unit of the Beer Head Limestone. It rests on the Small Cove Hardground at the top of the Upper Greensand and terminates at the top surface of the Weston Hardground. The member has a basal metre of yellow-brown, very coarse, calcareous sandstone with 50% rounded quartz grains, accessory tourmaline and feldspar. This part of the member is commonly decalcified to weather out as a notch and it contains ripped up blocks of Upper Greensand hardground at the base. These coarse sands are overlain by pale brown, sandy bioclastic limestones containing 35% subangular to rounded quartz grains and *c.* 30% bioclasts. The sandy limestones become more shelly and weakly nodular upwards, and terminate either in a locally developed mineralized hardground (the Weston Hardground), or in a weakly glauconitized and limonite stained surface producing a weak parting penetrated by a *Thalassinoides* burrow system. This basal unit of the formation contains common coralline sponges, *Acanthochaetetes ramulosus* (Michelin) (the *'Ceriopora ramulosa'* of the old literature).

The Hooken Member (Bed A2)

The Hooken Member (Bed A2) is up to 5 m thick at the adit, thinning to 0.9 m at Beer Head. It rests on the underlying Pounds Pool Member and terminates in the well-developed King's Hole Hardground. The basal part is a grey nodular shell-detrital limestone characteristically rubbly, with intraclasts on scour surfaces in thicker sections. Pebble-grade nodules and intraclasts are often cemented together to form larger 100–150 mm complex nodules. Nodules become reworked and weakly glauconitized and/or limonite stained as the member thins towards Beer Head. The unit contains about 30% bioclasts and many large silicified shell fragments. The terminal-intraclastic King's Hole Hardground contains a closely spaced succession of phosphatized surfaces, of which the top one is the most strongly phosphatized and near planar.

The Little Beach Member (Bed B)

The Little Beach Member (Bed B) is about 1.75 m thick at the adit, and slightly thicker at Little Beach. It contains a complex stratigraphy with a basal heavily mineralized convolute hardground at Beer Head (a cavernous hardground). Elsewhere this hardground is replaced by white pebbles and contains many *Holaster subglobosus* (Leske) in sandy biomicrites. These beds are overlain by light grey biomicrites with 30% bioclasts penetrated by a *Thalassinoides* burrow system with a fill of glauconitic sand from the base of the overlying member, giving rise to a distinctive honeycomb appearance.

The Wilmington Sand facies (Bed A equivalent) at Hooken Cliff comprises gritty; shell-rich, fine- and medium-grained calcareous sandstones and calcarenites with patchy calcareous cement giving rise to nodular textures similar to the Wilmington 'Grizzle' (see Wilmington Quarry GCR site report, this volume). These pass down into softer (decalcified?) calcarenites and calcareous sands with mostly comminuted shells and common oyster fragments up to 0.05 m across. The base is irregular and rests on the mineralized surface of the Upper Greensand calcarenite (i.e. the Small Cove Hardground).

White Chalk Subgroup

The White Chalk Subgroup at Hooken Cliff includes the Pinnacles Member (Bed C of the traditional Cenomanian Limestone succession) and all of the overlying Chalk (Figure 3.9), (Figure 3.11), (Figure 3.23) and (Figure 3.24).

The Pinnacles Member is 2.3 m thick at the adit, thinning to less less than 0.1 m at Little Beach (Figure 3.20). The basal few centimetres contain 40% quartz sand and 15–20% glauconite in a biomicrite matrix. The succession continues with white nodules, a limonitic nodule hardground with phosphatized surface that in turn is overlain by friable sandy glauconitic limestones. As the member thins towards Beer Head, the limonitic nodule hardground converges with the Humble Point Hardground and, at Beer Head itself; the member is represented only by the massively indurated terminal Haven Cliff Hardground.

The Pinnacles Member is thicker and more complex in the centre of Hooken Cliff than elsewhere in the region (see 'Interpretation' below).

Above the Pinnacles Member is an unbroken succession of Lower Turonian to Middle Coniacian chalks (Holywell Nodular Chalk, New Pit Chalk, Lewes Nodular Chalk and Seaford Chalk formations). The most westerly lower New Pit Chalk Formation is preserved on top of the cliffs at Salcombe Regis (Figure 3.1). The Chalk successions in the eastern (more accessible) parts of Hooken Cliff and Beer Head are illustrated in (Figure 3.9), (Figure 3.11), (Figure 3.16), (Figure 3.23) and (Figure 3.24). When traced westwards through Hooken Cliff into Branscombe East Cliff (Figure 3.17), the oldest beds (Holywell Nodular Chalk Formation) are cut out, as younger strata (New Pit Chalk Formation) onlap the structural high ('Branscombe Mouth Ridge' of the literature) that here forms the western boundary of the southern end of the Hooken–Wilmington Trough (Figure 3.21) and (Figure 3.22). A low easterly dip causes the higher part of the succession to be cut out in the same direction by the erosion surface at the base of the overlying Clay-with-flints. The stratigraphically highest Chalk at Hooken Cliff (Seaford Chalk Formation), is preserved within a large karstic (solution) collapse feature above Beer Head (Figure 3.16).

Holywell Nodular Chalk Formation

Holywell Nodular Chalk Formation: This formation also shows rapid lateral facies variations within the Hooken–Wilmington Trough. It comprises a series of nodular beds described in detail by Jarvis and Woodroof (1984). In the lower part of the formation, a variably developed marly bed, the West Ebb Marl, provides an important marker horizon for correlation (Figure 3.21), (Figure 3.22), (Figure 3.23), (Figure 3.24).

The lower part of the Holywell Nodular Chalk Formation, below the West Ebb Marl, displays a marked thickening towards the centre of the site owing to the development of the lenticular Beer Stone (Figure 3.21) and (Figure 3.22). This is a grey, fine-grained calcarenite, up to 3 m thick, composed largely of fragmented echinoderm (micro-crinoid) plates which sparkle in the sun. It is virtually the only true 'freestone' in the British Chalk, for although it contains some patches with bioturbation and a few fossils, it is largely homogeneous in grain-size and texture. The stone has been worked almost continuously since Roman times, and has been used in the cathedrals at Exeter, Winchester and Norwich, and in many churches and houses in east Devon. The conspicuous adit, high in the cliff in the centre of the site, marks the position of a former working for Beer Stone.

The Holywell Nodular Chalk Formation within the site is capped by a prominent iron-stained massive hardground, the Branscombe Hardground ((Figure 3.24); Jarvis and Woodroof 1984), for which this site is the type locality (Tocher and Jarvis, 1987). The hardground here marks a major break in sedimentation, and a sudden change from nodular, non-flinty chalks to the smooth-textured, manly chalks with numerous flint-rich bands that characterize the local equivalent of the New Pit Chalk Formation, the 'Beer Roads Member' of Jarvis and Woodroof (1984). However, this hardground rests on a relatively low level in the Holywell Nodular Chalk Formation, with much of the higher part of the formation being absent here.

New Pit Chalk Formation

New Pit Chalk Formation: From a distance (Figure 3.24), the New Pit Chalk Formation looks exactly like the smoother chalk, seamed with marl, that is characteristic of it in the main basin. Close to, this chalk is seen to contain many flint bands. At the Pinnacles, these flints are often small, finger- and *Zoophycos*-like at the base (reminiscent of the Glyndebourne Flints (see Southerham Pit GCR site report, this volume)), while others have a columnar arrangement. Within the New Pit Chalk at Hooken Cliff are several conspicuous marker bands, seen particularly well on photographs (Figure 3.16), (Figure 3.18), (Figure 3.23) and (Figure 3.24). These include the marl-rich '2-ft' and '4-ft' bands identified by Rowe (1903) (and also recognized by Meyer, 1874 and by Jukes-Browne and Hill, 1903), which weather-out as conspicuous grooves that can be traced almost continuously in the cliffs from Beer to Beer Head and through part of Hooken Cliff The '2-ft' band (= New Pit Marl 1) progressively oversteps the lower part of the New Pit Chalk Formation and the underlying Holywell Nodular Chalk Formation westwards within the site, and comes to rest at Mitchell's Stile Rock on the merged Branscombe and Haven Cliff hardgrounds and the underlying Pounds Pool Member of the Beer Head Limestone (Figure 3.22) and (Figure 3.24). At this point, the composite succession above the Pounds Pool Member up to the Haven Cliff Hardground, and from the Haven Cliff Hardground up to the Branscombe Hardground, has been cut out. Farther to the west, Turonian chalk actually rests on the Upper Greensand.

The so-called '4-ft band' (= New Pit Marl 2) is actually about 3.5 m thick in the central part of the site; the base of the bed can be recognized immediately beneath the Clay-with-flints as far west as Branscombe East Cliff (Figure 3.22). The highest bed of the New Pit Chalk, the Glynde or Dowlands Marl (Rowe's 'marl seam at the base of the *Holaster planus* Zone'), can also be traced as a conspicuous groove high in the cliff; marking the approximate base of nodular chalk. Over much of the section it forms the lower limit of karstic (solution) action at the base of the Clay-with-flints. All of these marl seams were also formerly seen in inland quarry sections west of Beer (Jukes-Browne and Hill, 1903, 1904).

The conspicuous marker beds in the New Pit Chalk Formation are considered to be correlatives of the main basin markers, specifically the New Pit and Glynde marls.

Lewes Nodular Chalk Formation

Lewes Nodular Chalk Formation: This formation enters above the Dowlands (Glynde) Marl and is composed of nodular and very nodular chalks and chalkstones with numerous hardgrounds and flint-rich beds (some with very large flints), as well as several thin, but laterally persistent marl seams that enable the Hooken Cliff succession to be correlated with the sections at Allhallows [SY 312 906] and Chapel Rock [SY 291 899], west of Lyme Regis (Figure 3.19). These marl seams also corrrespond to basin-wide marker beds including the Southerham, Caburn, Lewes and Navigation marls ((Figure 2.9), Chapter 2). The Lewes Nodular Chalk Formation at Hooken Cliff is capped by a strongly mineralized hardground, the Chapel Rock Hardground (Jarvis and Tocher, 1987). This hardground marks a major lithological change from nodular chalks to the soft white chalks of the overlying Seaford Chalk Formation with many horizons of medium-sized flints, thick tabular flints and, in the stratigraphically highest preserved beds, paramoudra flints.

Biostratigraphy

The Upper Cretaceous succession of the site extends from the basal Cenomanian *Neostlingoceras carcitanense* Subzone of the ammonite *Mantelliceras mantelli* Zone up to the lower part of the traditional *Micraster coranguinum* Zone (Middle Coniacian), the equivalent of the *Volviceramus koeneni* and V. *involutus* zones of the inoceramid bivalve zonal scheme. Equivalents of the traditional *Mytiloides* spp., *Terebratulina lata, Sternotaxis plana* and *Micraster cortestudinarium* zones can also be recognized.

The Cenomanian strata ((Figure 3.4); (Figure 2.8), Chapter 2) of the coastal sections contain a diverse and commonly well-preserved fauna, which is well represented in museum and other collections. Most of this material has been systematically collected using the traditional subdivision into beds A1, A2, B and C. In-situ sections (Figure 3.19) of the condensed Cenomanian succession, east of Hooken Cliff, at Whitecliff (Seaton) [SY 235 895], Shapwick Grange Quarry (Uplyme) [SY 312 918] and in fallen blocks below the Undercliff Landslip (notably below Haven Cliff, [SY 262 896]) and at Humble Point [SY 307 899] have yielded an extraordinarily diverse ammonite fauna that forms the basis for the current zonation. The Cenomanian deposits exposed at the eastern end of Hooken Cliff have yielded few of these species, largely because of its tough, unweathered state and its relative inaccessibility. The lithological correlation is, however,

sufficiently clear to suggest that the same zones and sub-zones are present.

The Pounds Pool Member (Bed A1) at Hooken Cliff has yielded ammonites including *Mantelliceras cantianum* Spath, *M.* spp., *Mariella cenomanensis* (Schlüter) and *Schloenbachia* spp. (Kennedy, 1970), some of which show signs of intraformational reworking (Wright *et al.,* 1984). The small rhynchonellid brachiopod *Cyclothyris schloenbachi* (Davidson), terebratulid brachiopods, fragmentary oysters and pectinacean bivalves, several species of echinoid, including *Catopygus columbarius* (Lamarck) and *Holaster* spp., and crustacean remains are locally common. The Pounds Pool Member has also been known as the 'Ceriopora Limestone' because of the abundance in it, particularly towards the base, of broken, rolled and bored fragments of the coralline sponge *Acanthochaetetes ramulosus,* which was formerly regarded as a giant bryozoan, and referred to the genus *Ceriopora* (see Hart and Johnson, 1984). This sponge also occurs in the Basement Bed of the Wilmington Sand at Wilmington Quarry and Reeds Farm Pit (see GCR site reports, this volume). At the latter locality, the bed contains a rich basal Lower Cenomanian *Neostlingoceras carcitanense* Subzone ammonite fauna.

In the Hooken Member (Bed A2), the diverse ammonite fauna includes species of *Hyphoplites, Hypoturrilites, Mantelliceras* and *Schloenbachia,* and was assigned (Wright *et al.,* 1984) to the *Mantelliceras saxbii* Subzone of the *Mantelliceras mantelli* Zone; locally the overlying *M. dixoni* Zone was also represented. Apart from a record (Wright and Kennedy, 1987) of a specimen of the zonal index ammonite from the Cenomanian Limestone ('precise horizon unknown') of the Hooken Landslip, there is no evidence for the *Sharpeiceras schlueteri* Subzone. The Hooken Member is sedimentologically complex and some of the apparently well-preserved ammonites are reworked limestone pebble fossils incorporated in a limestone matrix. The occurrence of the inoceramid bivalve *Inoceramus virgatus Schlüter* (recorded by Jukes-Browne and Hill (1903) from Hooken Cliff as *I. striatus*) and *Mantelliceras dixoni* Spath at many localities clearly points to the fauna belonging largely to the *dixoni* Zone (see (Figure 3.4)). The higher part of the member at Hooken Cliff is characterized by the large, highly ornate pectinacean bivalve *Merklinia aspera* (Lamarck) (the *Pecten asper* of earlier literature).

In the Little Beach Member (Bed B), phosphatic and limestone pebbles at the base contain a phosphatized ammonite assemblage derived from the Middle Cenomanian *Turrilites costatus* Subzone of the *Acanthoceras rhotomagense* Zone, including *Acanthoceras rhotomagense* (Brongniart), *Calycoceras* (*Newboldiceras*) *asiaticum asiaticum* (Jimbo) and *Turrilites costatus* Lamarck (A.S. Gale, pers. comet., 2000). There is also some evidence from localities east of Beer for reworked *dixoni* Zone ammonites, including *Hyphoplites, Mantelliceras* ex gr. *dixoni* Spath, *M. lymense* (Mantell) and *Schloenbachia* (Kennedy, 1970). As noted by Wright *et al.* (1984), it is difficult in some cases to distinguish between material from the top of Bed A2 and that from the base of Bed B, particularly where the boundary between the two units is ill-defined. Between the Hooken Member and Little Beach Member there is a major hiatus comprising the higher part of the *dixoni* Zone, the basal Middle Cenomanian *Cunningtoniceras inerme* Zone and the sediment of the *costatus* Subzone. The abundance of the echinoid *Holaster subglobosus,* together with smaller numbers of *Conulus castanea* (Brongniart), above the pebble bed at the base of the Little Beach Member at Hooken Cliff is indicative of the *Turrilites acutus* Subzone. The higher part of the member here has yielded to Professor Gale rare indigenous examples of the zonal index fossil, *Acanthoceras jukesbrownei* (Spath), together with *Calycoceras* (*Newboldiceras*) *tunetanum* (Pervinquiere) and *C.* (*N.*) *planecostum* (Kossmat), indicating that the sediment itself is of *jukesbrownei* Zone age. This interpretation of the ammonite biostratigraphy of this member corrects that presented by Robaszynski *et al.* (1998).

At the base of the Pinnacles Member the rich phosphatized ammonite assemblage has been largely derived from the *Calycoceras guerangeri* Zone, with a few of the more strongly phosphatized specimens coming from the underlying *Acanthoceras jukesbrownei* Zone. Knowledge of this assemblage is mainly based on extensive collections made from fallen blocks, particularly at Humble Point, that have split open along this surface; and also from Wilmington Quarry (see GCR site report, this volume) and Shapwick Grange Quarry. Some of these *guerangeri* zonal elements, for example *Thomelites sornayi* (Thomel) and the zonal index fossil itself, have been collected *in situ* in chalk facies 3 to 4 m and 7 to 8 m below the Plenus Marls Member at Ballard Cliff, Dorset (see Handfast Point to Ballard Point GCR site report, this volume) and Beachy Head, Eastbourne (see (Figure 3.112), p. 251) respectively (Wright and Kennedy, 1996). Wright and Kennedy (1987) recorded four specimens of *Protacanthoceras tuberculatum devonense* Wright and Kennedy from the Hooken Cliff GCR site. The main mass of the Pinnacles Member contains a glauconitized Upper Cenomanian *Metoicoceras geslinianum* Zone ammonite fauna. This includes *Euomphaloceras septemseriatum* (Cragin), *M.*

geslinianum (d'Orbigny), *Pseudocalycoceras angolaense* Spath, *Sciponoceras gracile* (Shumard) and *Tarrantoceras (Sumitomoceras) cautisalbae* Wright and Kennedy, together with non-glauconitized elements including *Allocrioceras annulatum* (Shumard), the belemnite *Praeactinocamax plenus* (Blainville), the rhynchonellid brachiopods *Orbirhynchia multicostata* Pettitt and *O. wiesti* (Quenstedt) and the echinoid *Camerogalerus cylindricus* (Lamarck). In the Hooken Cliff GCR site, *Praeactinocamax plenus* and *Orbirhynchia wiesti* are well represented, but there seem to be no published ammonite records. Uniquely at this site, the Pinnacles Member succession is thicker and more complex, and may possibly include a pre-*geslinianum* Zone, i.e. a *guerangeri* Zone component, in the lower part of the bed (see below). At Shapwick Grange Quarry, the highest part of the Pinnacles Member contains an exotic Tethyan ammonite assemblage that includes *Puzosia odiensis* Kossmat, *Kamerunoceras* aff. *puebloense* (Cobban and Scott), *Nigericeras* cf. *gignouxi* Schneegans, *Thomasites gongilensis lautus* (Barber) and *T. gongilensis tectiformis* (Barber).

The Haven Cliff Hardground, at the top of the Pinnacles Member, contains moulds of ammonites belonging to the terminal Cenomanian *Neocardioceras juddii* Zone assemblage, including the zonal index fossil and *Sciponoceras* sp., as well as spines of the regular echinoid *Hirudocidaris hirudo* (Sorignet). At Haven Cliff, these fossils, together with *Thomelites serotinus* Wright and Kennedy and the inoceramid bivalve *Mytiloides hattini* Elder, are concentrated as glauconitized pebbles on the surface of the hardground, forming the so-called '*Neocardioceras* Pebble-Bed'.

In comparison with the Cenomanian deposits, the basal Turonian Chalk successions are sparsely fossiliferous. With the exception of relatively common *Watinoceras devonense* and *Mammites nodosoides* (Schlotheim), immediately above the Haven Cliff Hardground and in the lower part of the Holywell Nodular Chalk Formation respectively, ammonites are rare. *Lewesiceras peramplum* (Mantell), *Metasigaloceras rusticum* (J. Sowerby), *Morrowites wingi reveliereoides* Wright and Kennedy and *M. wingi wingi* (Morrow) have been recorded from low in the Holywell Nodular Chalk Formation of the coast sections adjacent to the site, and the same level at Haven Cliff has yielded *Fagesia catinus* (Mantell), *Kamerunoceras turoniense* (d'Orbigny), and the only known British record of *Lecointriceras fleuriausianum* (d'Orbigny). These last three species are typically Tethyan in their distribution and also occur in the type Turonian section of Touraine.

The Holywell Nodular Chalk Formation at Hooken Cliff contains a rich fauna of (predominantly small) echinoids, notably *Camerogalerus minimus* (Desor) (*Discoidea dixoni* Forbes of the older literature), *Hemiaster nasutulus* Sorignet (*H. minimus* Agassiz), *Cardiaster truncatus (Goldfuss) (C. pygmaeus), Cardiotaxis cretacea* (Sorignet), *Conulus castanea, Hirudocidaris hirudo* and *Tylocidaris sorigneti* (Desor). Rowe (1903, p. 2) commented that 'This coast affords a scope for the study of Echinoderma which alone would render any section famous.', and noted (p. 33) that he had collected 30 specimens of *Conulus castanea* (13 from a single block) at Hooken Beach. *Micraster* also appears at this level, which is unusually low compared with its first occurrence elsewhere in the Southern Province. Immediately west of Branscombe Mouth, just outside the site limits, the echinoid assemblage in the equivalent beds is dominated by abundant spines and tests of *Hirudocidaris hirudo* and *Tylocidaris sorigneti,* together with ossicles of the asteroid *Metopaster cornutus* Sladen.

Apart from echinoids, inoceramid bivalves are the most common fossils in the Holywell Nodular Chalk Formation. They include *Mytiloides labiatus* (Schlotheim) and *M. mytiloides* (Mantell), indicative of the Lower Turonian '*Mytiloides* spp.' Zone or *Mammites nodosoides* ammonite Zone. The occurrence of *Mytiloides* shells encrusted by the serpulid *Filograna avita* (J. Sowerby) ('*Filograna avita* event'), first observed here and in Dorset by Rowe (1901, 1903), and found in the middle part of the Holywell Nodular Chalk Formation (*M. nodosoides* Zone) throughout the Southern Province and the Anglo-Paris Basin, has been identified in the very condensed succession above the West Ebb Marl at West Ebb, north of Beer Head (Gale, 1996, fig. 4). In the Hooken Cliff sections, the erosive Branscombe Hardground has presumably cut out this key marker horizon (cf. Jams and WoodrocA 1984, fig. 4). *Terebratulina lata* R. Etheridge, the zonal index fossil of the *T. lata* Zone, which elsewhere in the Southern Province enters in the lower part of the New Pit Chalk Formation, appears in the thick Lower Turonian succession at Beer at the level of the 'first flint-line' (Rowe, 1903), i.e. at the base of the higher (flinty) part of the Holywell Nodular Chalk Formation. The inoceramid bivalves at this level appear to belong to the *M. subhercynicus (Seitz*)-*hercynicus* (Petrascheck) group and these are also common at the base of the New Pit Chalk Formation (see Glyndebourne Pit description in the Southerham Pit GCR site report, this volume).

Terebratulina lata is common throughout the New Pit Chalk Formation and is reported (Rowe, 1903) to be larger here than elsewhere. Other common macrofaunal elements (for a full list see Rowe, 1903) are *Micraster corbovis* Forbes of *lata* Zone type, and the inoceramid bivalves *Inoceramus cuvieri* J. Sowerby and *I. lamarcki* Parkinson.

The Lewes Nodular Chalk Formation of Hooken Cliff is richly fossiliferous; echinoderms, brachiopods and bivalves are abundant at many levels. The fauna is similar to that of the type area, comprising echinoids (abundant *Micraster* spp., including *M. corbovis* Forbes, *M. leskei* Desmoulins and *M. normanniae* Bucaille, *Sternotaxis plana* (Mantell)), inoceramid bivalves (common thick-shelled *Inoceramus* spp. in the lower and middle parts and *Cremnoceramus,* indicative of the Coniacian, in the highest part, above the Annis' Knob Flint), common *Orbirhynchia* and terebratulid brachiopods.

The lower part of the Seaford Chalk Formation is well exposed at the eastern end of the site, but in sections that are mostly deeply weathered and difficult to access. The only common fossils are large shell pieces, many being several centimetres across, of the inoceramid bivalve genera *Platyceramus* and *Volviceramus.*

Micropalaeontology

The foraminiferal biostratigraphy of the Cenomanian–Turonian succession at the Pinnacles was described by Carter and Hart (1977a) and that of the nearby Beer Stone adit section by Jarvis *et al.* (1988a).

By extrapolation from the Beer Roads section (Hart and Weaver, 1977; Hart, 1997, fig. 2), the condensed Holywell Nodular Chalk Formation of the Hooken Cliff GCR site belongs to the *Helvetoglobotruncana helvetica* Interval Zone of the planktonic foraminifer zonal scheme, with the basal beds, i.e. up to just above the West Ebb Marl, falling in the *Hedbergella archaeocretacea* Partial Range Zone. The overlying *Marginotruncana sigali* Interval Zone extends from the base of the New Pit Chalk Formation up to a horizon *c.* 2 m above the '4-ft band'. The overlying succession belongs in part to the *Marginotruncana pseudolinneiana* Interval Zone ((Figure 2.41), Chapter 2). The giant agglutinating foraminifer, *Labyrinthidoma southerhamensis* Hart (recorded by Rowe (1903) as *Haplophragmium,* and usually cited as '*Coskinophragma'* sp. (see Hart, 1993)), occurs in large numbers in several thin bands, mostly marl seams, over a similar stratigraphical range to that in the New Pit Chalk Formation of the type area around Lewes, Sussex, but enters here in the higher (flinty) part of the Holywell Nodular Chalk Formation. The tests of this microfossil are larger in Devon than elsewhere. At Hooken Cliff; *Labyrinthidoma* is first seen at the base of the New Pit Chalk Formation. By extrapolation from the Annis' Knob section, Beer (Bailey, 1975; Hart and Weaver, 1977; Hart, 1997), the highest preserved Lewes Nodular Chalk Formation at Beer Head (*Sternotaxis plana* and *Micraster cortestudinarium* macrofossil zones) belongs to the *Marginotruncana coronata* and overlying *Whiteinella baltica* interval zones ((Figure 2.41), Chapter 2).

The dinoflagellate cyst biostratigraphy of the Holywell Nodular and New Pit Chalk formations at Hooken Cliff, Beer Roads cliffs and Beer Quarry, has been documented by Tocher and Jarvis (1987).

Interpretation

The 'Cenomanian Limestone' (see (Figure 3.21) and (Figure 3.23))), can be traced eastwards, as a continuous hard bed at the foot of the cliffs, for 2 km from Beer Head to Beer Roads. At the latter locality, it consists of a highly condensed, splintery limestone that is only 0.4 to 0.6 m thick and contains several coalescing hardground surfaces. Eastwards from Beer to its most easterly known occurrence near Lyme Regis, the Beer Head Limestone remains highly condensed and less than 1 m thick. It can also be traced westwards from Hooken Cliff in discontinuous cliff sections and fallen bocks, as far as Salcombe Regis (Figure 3.1).

Inland, the full thickness of the arenaceous facies of the Cenomanian succession was formerly exposed in Bovey Lane Quarry [SY 217 899], 2 km north of the site; the upper part is exposed from time to time in the floor of the nearby working Beer quarries (Figure 3.17). The published records (Smith, 1961; Smith and Drummond, 1962) of the faunal and lithological succession at Bovey Lane Quarry provide a useful link between the successions at Hooken Cliff and Wilmington Quarry (see GCR site report, this volume).

The Pinnacles Member (Bed C) succession is thicker and more complex in the centre of the Hooken Cliff GCR site than elsewhere in the region. The lower part of the member includes two accumulations of white nodules and phosphatized intraclasts in a glauconitic sand matrix. Towards the top of the member there is a phosphatized and limonitized hardground (the informally named 'limonitic nodule hardground' of Jarvis and Woodroof 1984), overlain by a concentration of phosphatized intraclasts including fossils. The occurrence of unphosphatized specimens of the

eponymous belemnite of the Plenus Marls, *Praeactinocamax plenus,* at this level suggests that the hardground probably correlates with the erosion surface at the top of Bed 3 of the standard Plenus Marls succession of Jefferies (1963). However, carbon stable isotope (Jarvis *et al.,* 1988a, fig. 4) and microfaunal (foraminiferal) data point to a significant hiatus at this level, involving the equivalent of the lower part (Jefferies' beds 1–3) of the Plenus Marls and the top few metres of the underlying Zig Zag Chalk Formation. It is therefore probable that the terminal Bed 3 erosion surface is superimposed directly on the sub-Plenus erosion surface. The lower (glauconitic) part of the Pinnacles Member was considered by Jarvis *et al.* (1988a) to pre-date the (*geslinianum* Zone) Plenus Marls, i.e. to be of *Calycoceras guerangeri* Zone age, but this interpretation is controversial.

Towards Beer Head, following the Jarvis *et al.* (1988a) interpretation, the superimposed Bed 3 and sub-Plenus erosion surfaces converge to rest on the Humble Point Hardground at the top of the Little Beach Member. This hardground and the accumulation of phosphatized fossils that is associated with, and overlies it, may represent a sequence boundary that has recently been identified in the Upper Cenomanian succession (equivalent of the *guerangeri* Zone) of northern Spain (Wiese and Wilmsen, 1999). It may also equate with the Eastbourne Sponge Bed at Beachy Head in Sussex (see (Figure 3.112), p. 251). Where the member is thin, the basal glauconitic sand is preserved only in the fills of the burrows that penetrate the Little Beach Member. The higher part of the Pinnacles Member also thins in this direction, so that the member is eventually represented merely by a thin composite bed comprising the Haven Cliff Hardground and the subjacent nodular chalk (Jarvis and Woodroof, 1984, fig. 2).

The thicker, more arenaceous sequences at the Hooken Cliff and Wilmington Quarry GCR sites, and at intermediate sites, lie within a 'Hooken–Wilmington' depositional trough (Figure 3.17), (Figure 3.19) and (Figure 3.21), which is bounded by deep-seated faults that strongly influenced sedimentation in the Cenomanian and Turonian ages. The dominant structure consists of a series of approximately north–south faults, which are closely related to the boundaries of the Cretaceous outliers (Figure 3.19). Local thickening of the Cenomanian strata into the Hooken–Wilmington Trough (Figure 3.21) is associated with a change from the margins, where limestones with mineralized surfaces are present, to calcarenites (Wilmington Sand facies) in the centre of the trough. In the lower part of the Lower Turonian Holywell Nodular Chalk Formation, the calcarenitic Beer Stone, is developed only in the same structural feature. The trough extends northwards, through the area to the west of Beer with the Beer Stone quarries and the Bovey Lane Quarry, to the Wilmington outlier; its eastern boundary, in particular, parallels the Wilmington Fault, with its downthrow to the west. At Wilmington Quarry and Reeds Farm Pit (see GCR site reports, this volume), the Hooken Member is represented by the highly fossiliferous Wilmington Sand; nearby, the Beer Stone was formerly quarried as the 'Sutton Stone'. The Beer Stone is generally inferred to equate with the similarly bioclastic (microcrinoid debris) sediment of the bed between Holywell Marls 2 and 3 of the expanded Southern Province sections. The latter bed belongs to the *Fagesia catinus* ammonite Zone (Gale, 1996).

The stratotype Branscombe Hardground, as seen in and immediately adjacent to the Hooken Cliff GCR site only, actually represents a convergence of all the hardgrounds from the higher (flinty) part of the Holywell Nodular Chalk Formation onto a hardground overlain by marly chalk, to form a single massively indurated hardground (see Jarvis and Woodroof, 1984, figs 4–6). Those authors also show that this hardground further converges with the two highest gimonitic hardgrounds' in the non-flinty lower part of the Holywell Nodular Chalk Formation above the West Ebb Marl. Some 9 m of sediment at Beer Roads are represented by a hiatus at the surface of the Branscombe Hardground (Tocher and Jarvis, 1987). The flinty part of the Holywell Nodular Chalk Formation, which is best developed and thickest in the sections immediately east of Beer, has cut out completely in the Pounds Pool cliffs, to the north of Beer Head, and is not represented at all at Hooken Cliff (see (Figure 3.22)). It follows that Rowe's 'first flint line' at the base of the *gracilis* (i.e. *lata*) Zone in the site is not equivalent to his 'first flint line' in the cliffs east of Beer, since these flints are located in the basal New Pit Chalk Formation and Holywell Nodular Chalk Formation respectively.

The New Pit Chalk Formation is more flinty in Devon than elsewhere in southern England, which led Jarvis and Woodroof (1984) to introduce the term 'Beer Roads Flinty Chalk Member'. However, the flints apart, the gross lithologies of the member are not dissimilar to those of the type sections in Sussex. In view of the fact that it was recently decided (Rawson *et al.,* 2001) to accept lateral lithological variations within the standard lithostratigraphical framework of formations, there is no need to retain the new name. The same argument applies in the case of the Connett's Hole Nodular Chalk Member (Jarvis and Woodroof, 1984), which differs from the standard Holywell Nodular Chalk Formation

only in the fact that the higher part is flinty. Even this difference is not particularly significant, for the Holywell Nodular Chalk Formation contains flints towards the top on the Dorset coast, and is markedly flinty in the northern Chiltern Hills. The introduction, by those authors, of the new term 'Seaton Chalk Formation' for an interval that essentially comprises the Holywell Nodular and New Pit Chalk formations of the standard scheme (Rawson *et* al., 2001), is likewise not followed here.

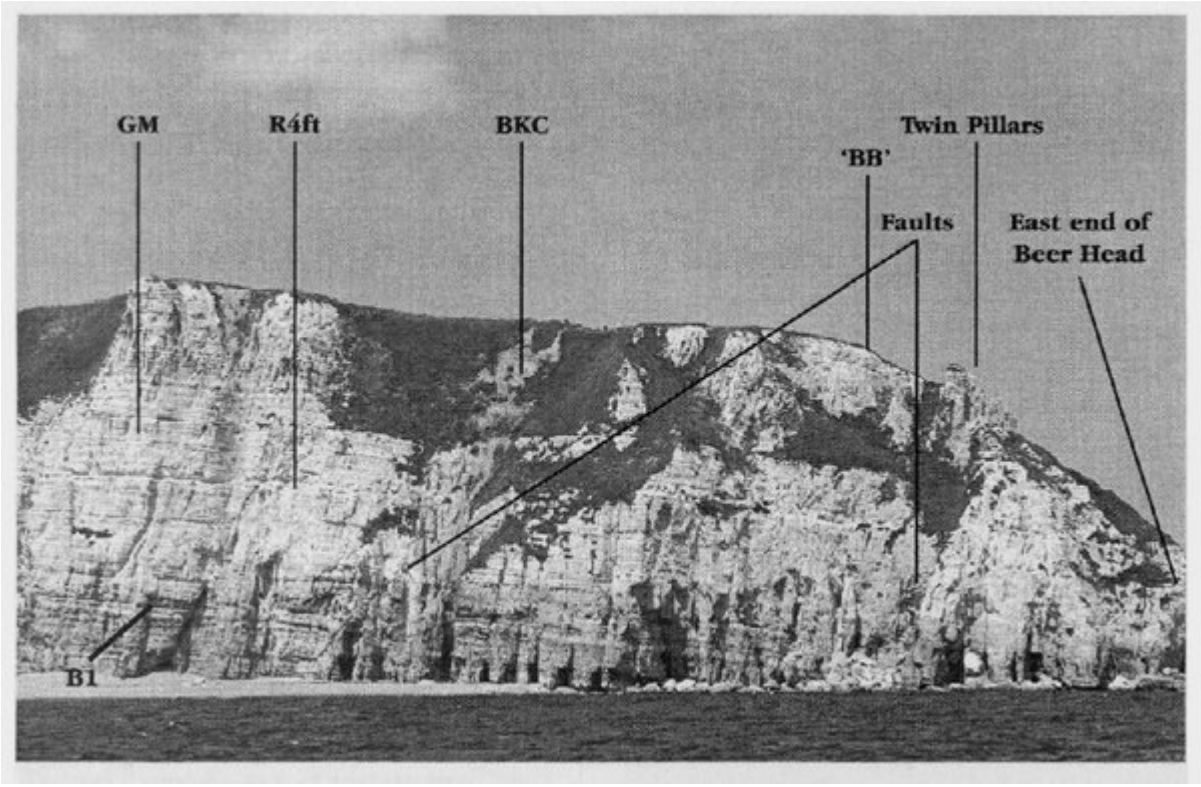
Subsequent work has largely confirmed the correctness of Rowe's (1903) zonation of the Chalk in and adjacent to the Hooken Cliff GCR site. The 'first flint line' lies just above the Branscombe Hardground, which marks the base of the modern *Terebratulina lata* Zone, and the 'marl seam' (Dowlands Marl = Glynde Marl after the section in the Dowlands Landslip between Axmouth and Lyme Regis) marks (albeit somewhat below) the approximate base of the *Sternotaxis plans* Zone. This marl seam is also close to a rapid upward change from the smooth-textured marly chalks of the New Pit Chalk Formation to the nodular chalks of the Lewes Nodular Chalk Formation.

The Chalk successions at Hooken Cliff can be matched in detail with those to the east in Beer Cliffs, Allhallows Cliffs and at Chapel Rock. There are, however, significant local lithological variations, especially in the Holywell Nodular Chalk and the New Pit Chalk formations, that are probably due to penecontemporaneous fault activity.

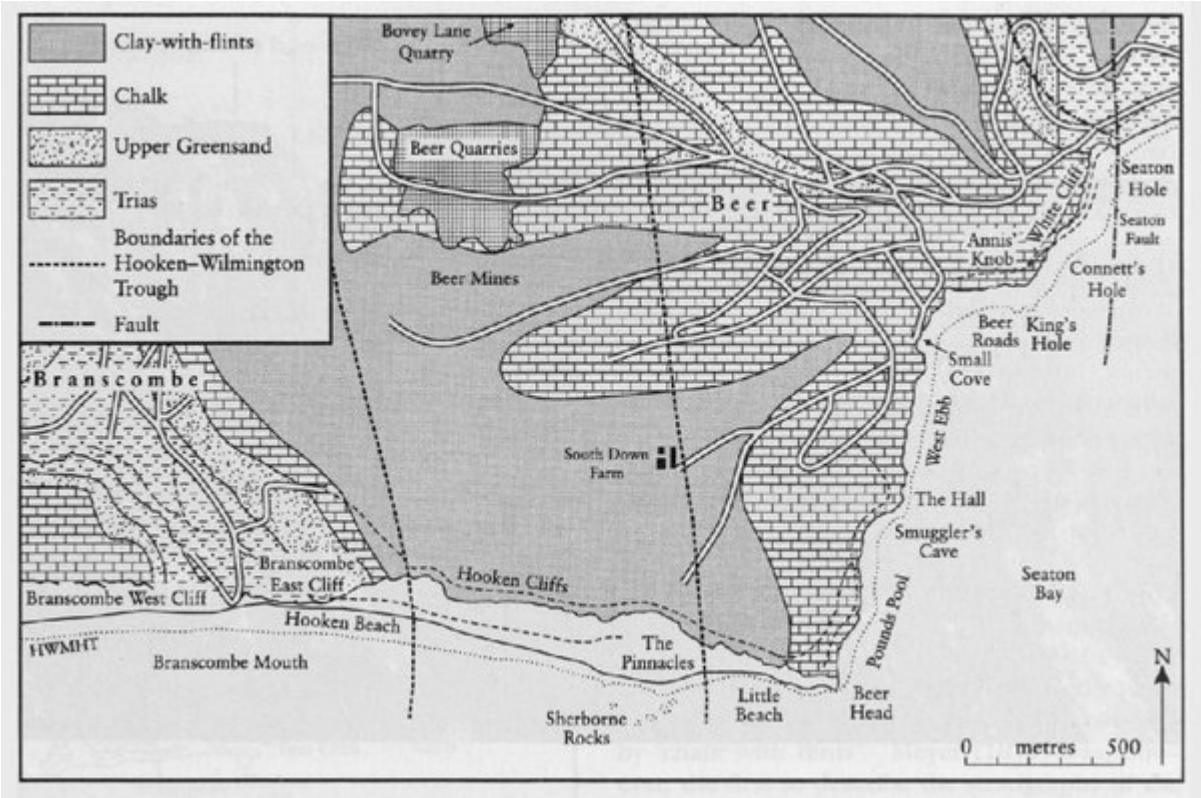
Conclusions

The extensive exposures in the Hooken Cliff GCR site, including Hooken Cliffs, Branscombe East Cliff, Beer Head and the Pinnacles, provide continuous exposures through some of the most unusual facies variations in the Cenomanian and Lower Turonian strata that can be observed anywhere in the Southern Province. The site includes the stratotype section for the arenaceous limestones and sands comprising the Cenomanian deposits of Devon. The westward thinning of these Cenomanian arenaceous sediments, and the overlying Lower Turonian chalks, onto a structural high, and their progressive onlap by Middle Turonian (New Pit Chalk Formation) flinty chalks, is unique in Britain. The preservation in a karstic collapse structure of an Upper Turonian and Coniacian Chalk succession, extending up to the lower part of the Seaford Chalk Formation, indicates the former extension of these beds to the west of the exposures in the landslip between Lyme Regis and Seaton. The rich echinoid faunas in the Lower Turonian Holywell Nodular Chalk Formation are of critical importance in evolutionary studies, notably the classic example of the heart-urchin *Micraster.*

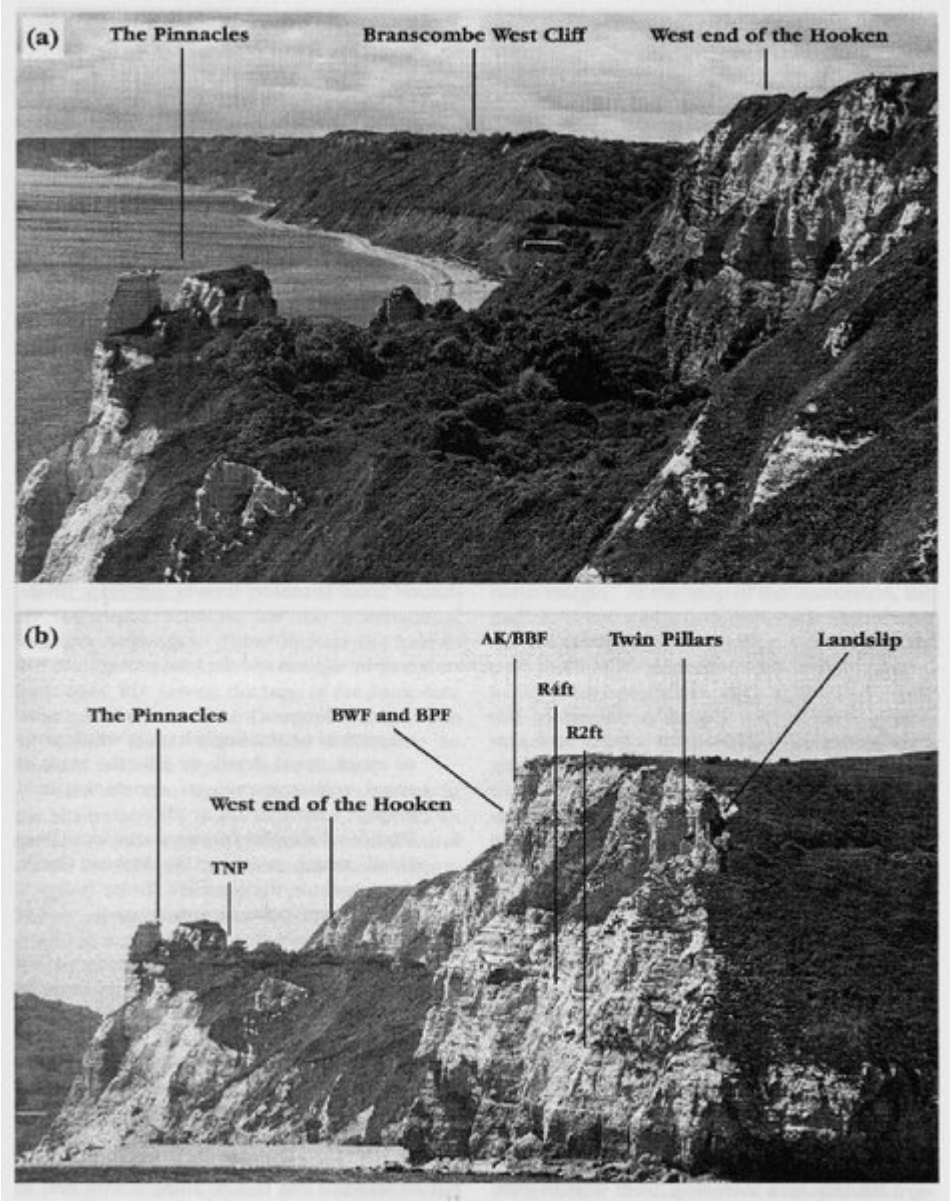
References



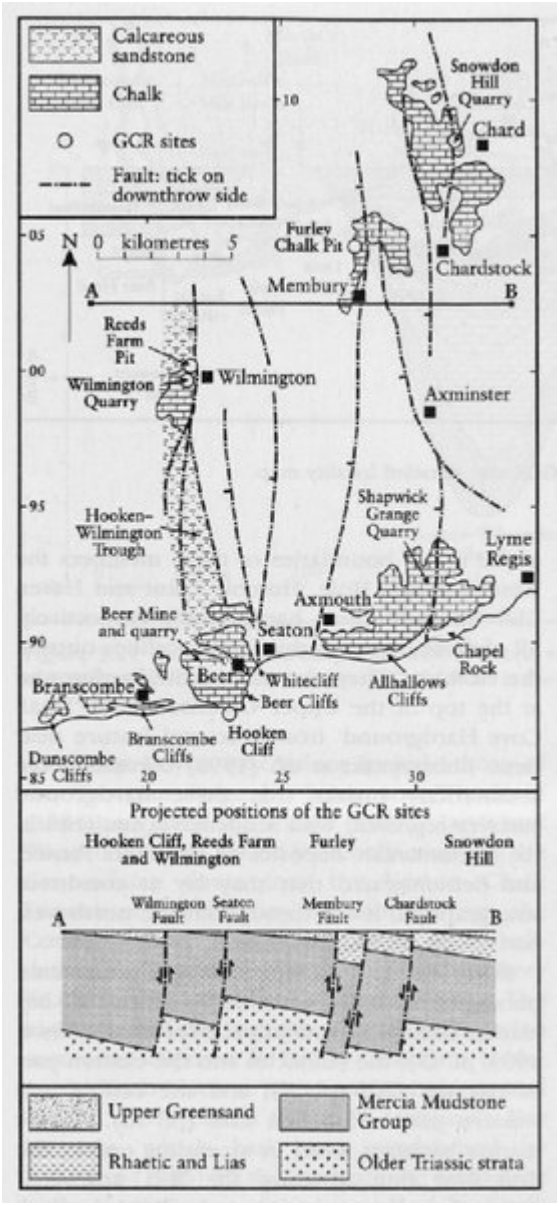
(Figure 3.16) Beer Head at the east end of the Hooken Cliff site, south-east Devon, showing the base of the Upper Cretaceous strata resting on the Albian Upper Greensand. Note the bedding dip of 4° to the south-east and the joint pattern along which caves have formed. (B1 = Boundary between Albian (Lower Cretaceous) and Cenomanian (Upper Cretaceous); 'BB' = 'Belay Buttress'; BKC = base of Karst collapse; GM = Glynde Marl (Dowlands Marl and base of Lewes Nodular Chalk); R4ft = Rowe's 4-ft band.) (Photo: R.N. Mortimore.)



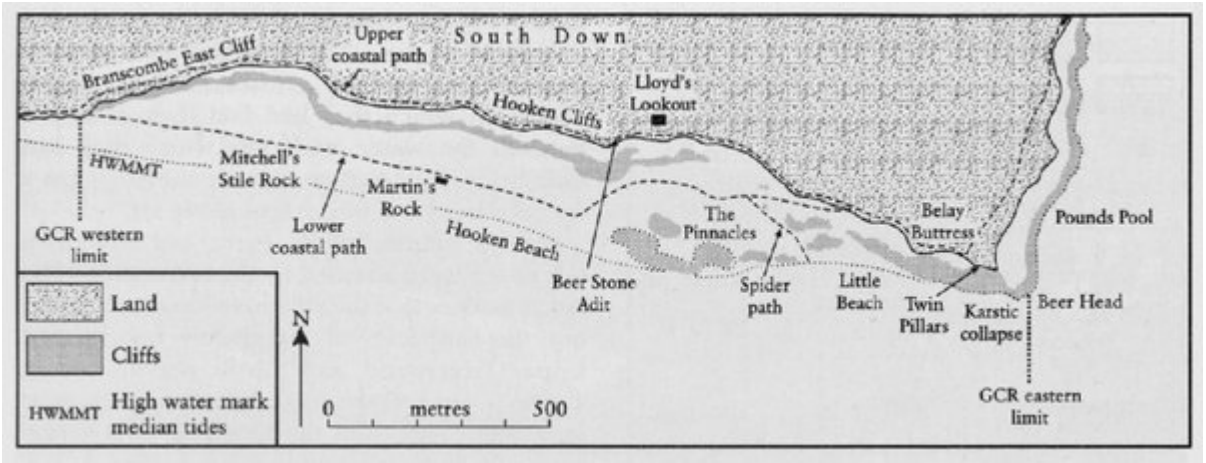
(Figure 3.17) The Hooken Cliff GCR site in relation to nearby sections and the local geology.



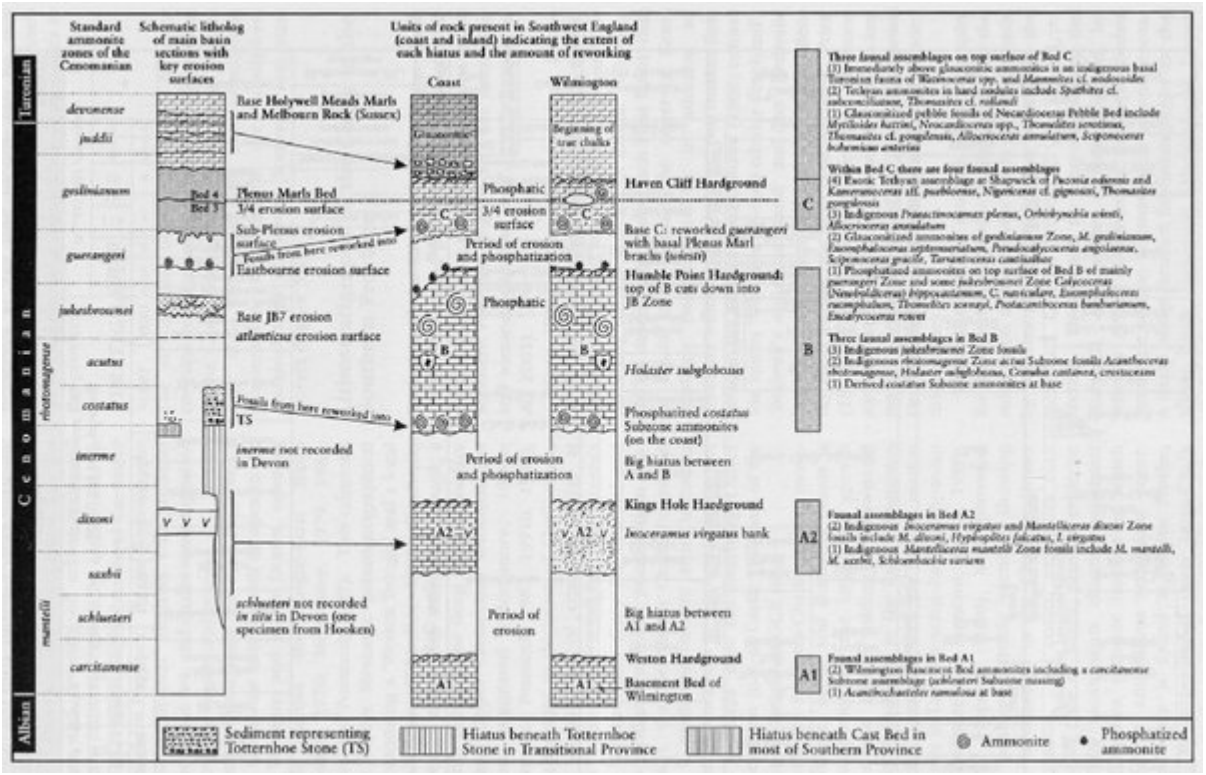
(Figure 3.18) (a) Beer Head looking west; the west end of the Hooken Cliff GCR site shows the overstep of Chalk onto Upper Greensand. (b) Hooken Landslip looking north-west. The Twin Pillars are composed of Annis' Knob Flint, Lewes Flint, Lewes Marl, Cuilfail Zoophycos and Navigation Marl; the Landslip displays the stratigraphically highest chalk on the Devon coast with Platyceramus/Volviceramus and the Seven Sisters Flint Band. (AK/BBF = Annis' Knob/Breaky Bottom Flint; BWF and BPF = Bridgewick Flints and Bopeep Flints; R2ft = Rowe's 2-ft band; R4ft = Rowe's 4-ft band; TNP = Turonian New Pit Chalk section in landslip with abundant spiky flints.) (Photos: R.N. Mortimore.)



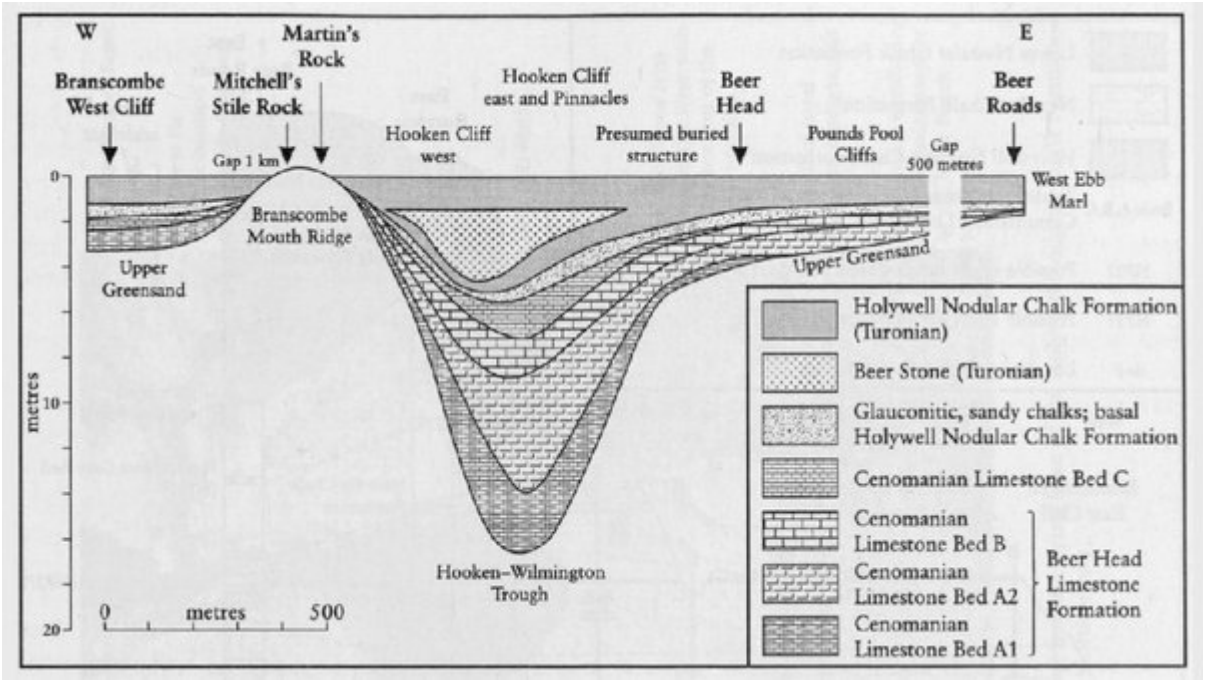
(Figure 3.19) Geological sketch map and section showing the position of the Upper Cretaceous GCR sites in relation to outcrop and structure.



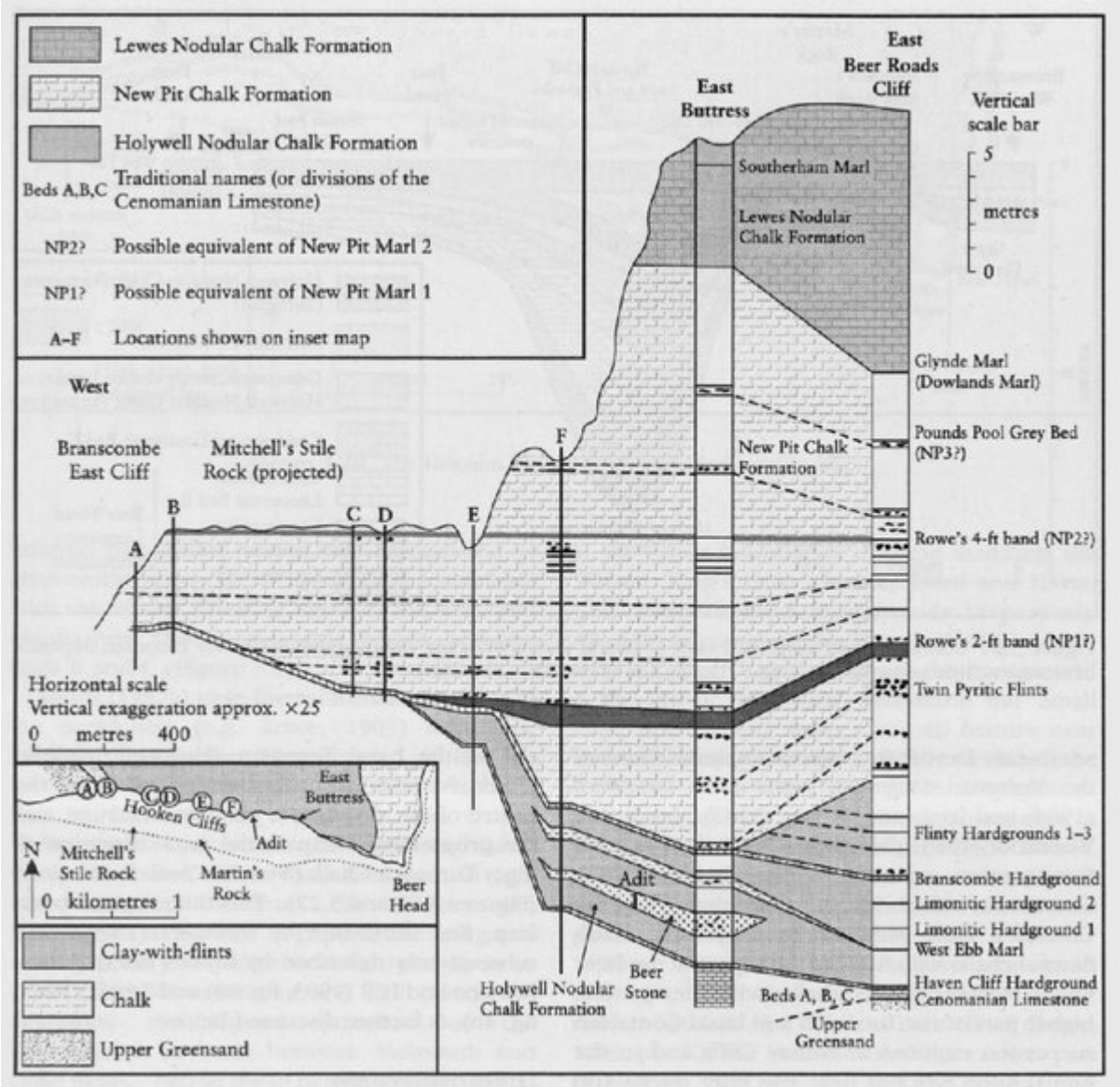
(Figure 3.20) The Hooken Cliff GCR site, detailed locality map.



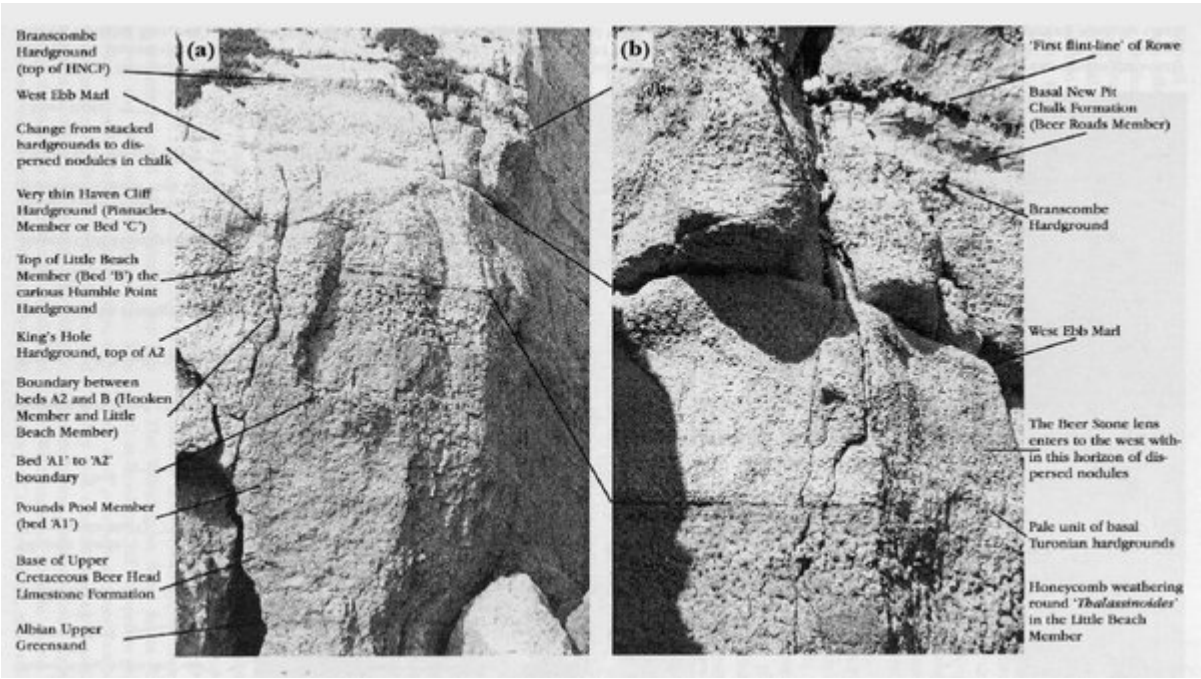
(Figure 3.4) Schematic relationship between the Cenomanian deposits of the thicker successions in Sussex and Kent and the condensed Cenomanian Limestone (A, B, C). Because of tectonics the age of the Chalk Basement Bed is different in different places.



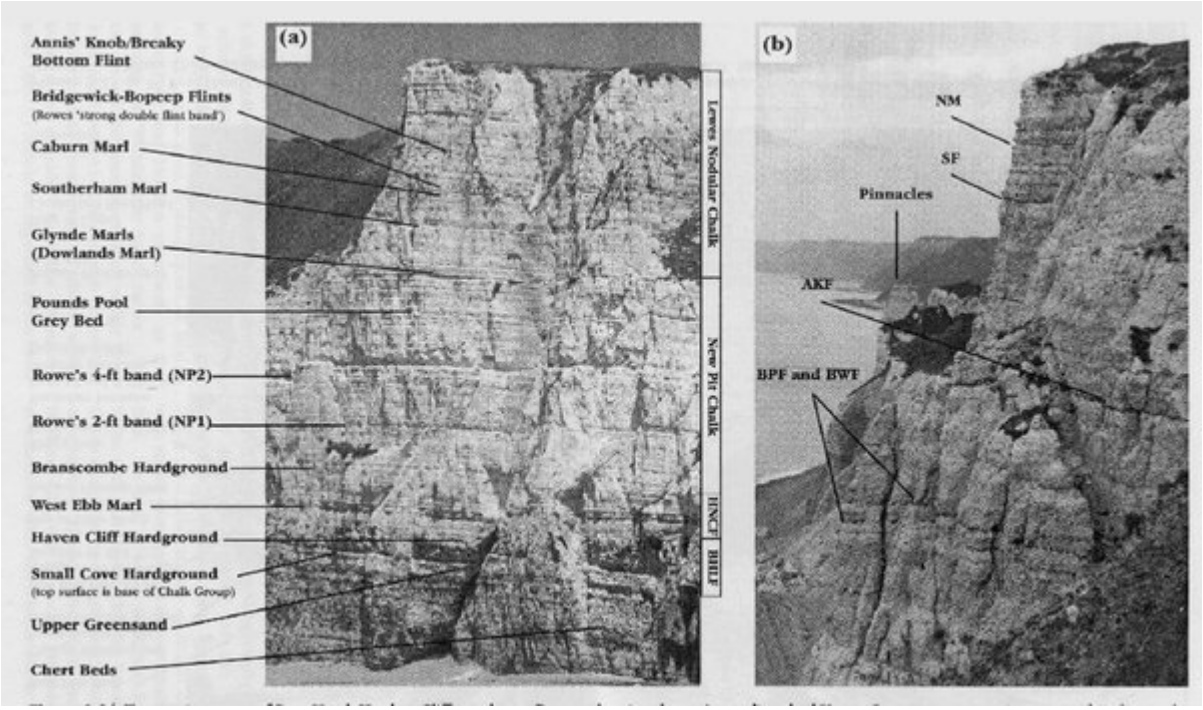
(Figure 3.21) Schematic and simplified view of lateral variation in the Cenomanian and Early Turonian deposits of Hooken Cliffs and adjacent areas. The datum is the West Ebb Marl.



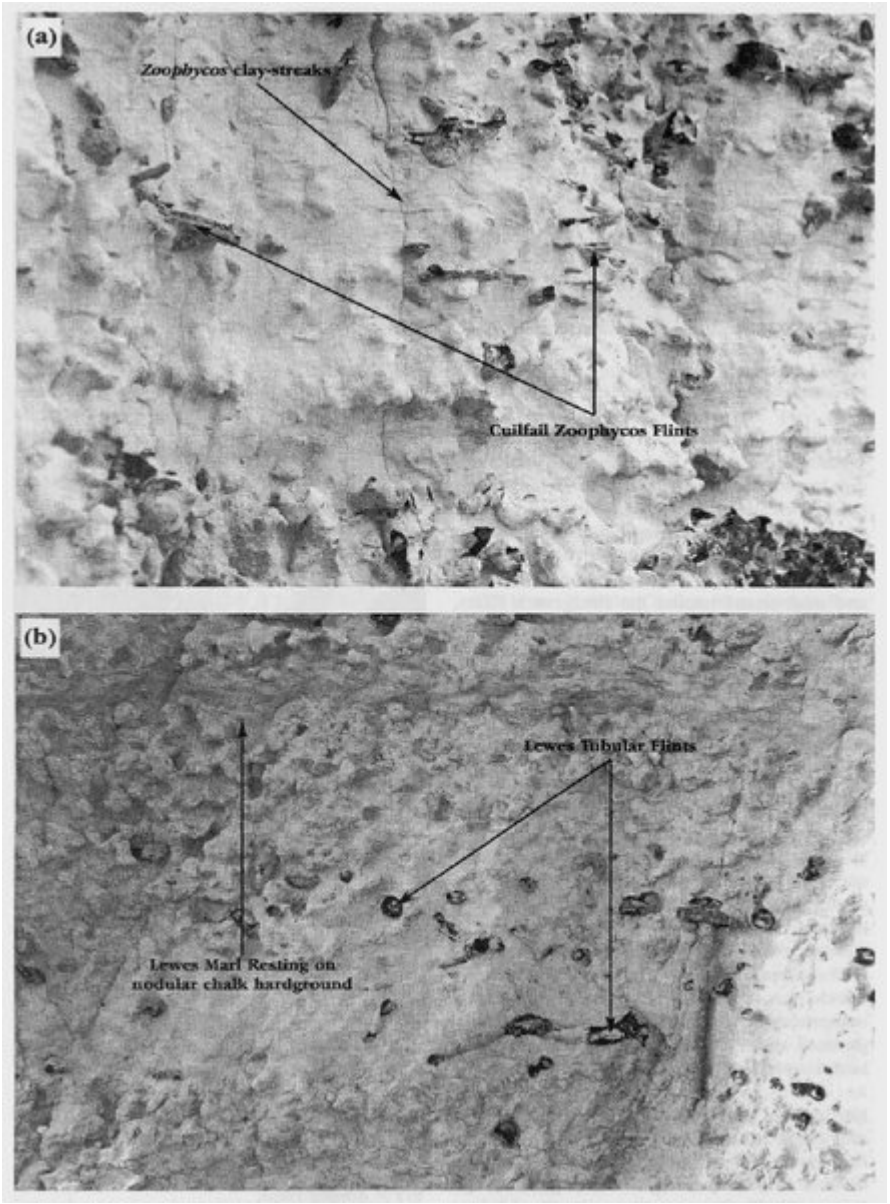
(Figure 3.22) Overstep of the Upper Cretaceous Chalk (New Pit Chalk Formation) onto the Albian Upper Greensand. Lateral variation shows the Beer Stone as a lensoid sedimentary body within the Hooken–Wilmington Trough and the complete loss of the Holywell Chalk and lower New Pit Chalk traced westwards within the Hooken Cliff GCR site.



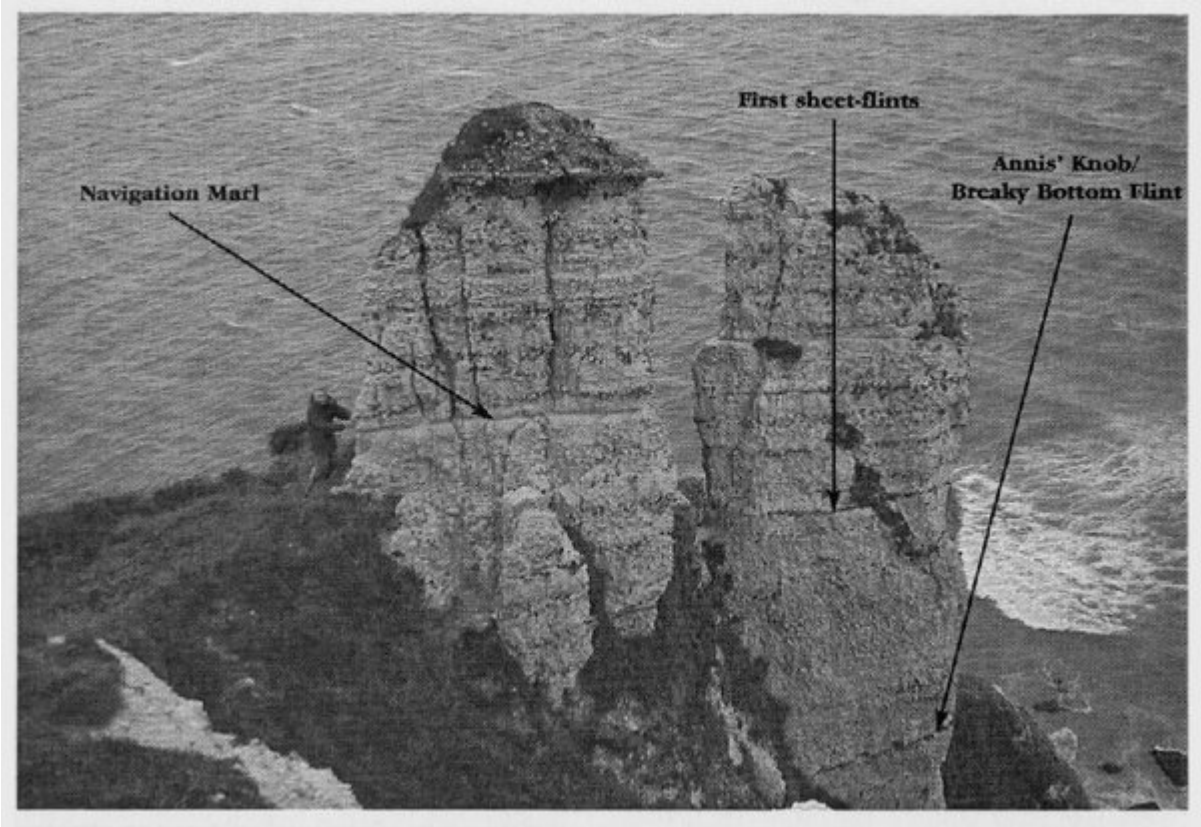
(Figure 3.23) (a, b) Beer Head Limestone Formation (Cenomanian Limestone), Grey Chalk Subgroup, and overlying base of the Holywell Nodular Chalk Formation (HNCF) and White Chalk Subgroup at Beer Head, Hooken Cliff, south-east Devon. (Photos: R.N. Mortimore.)



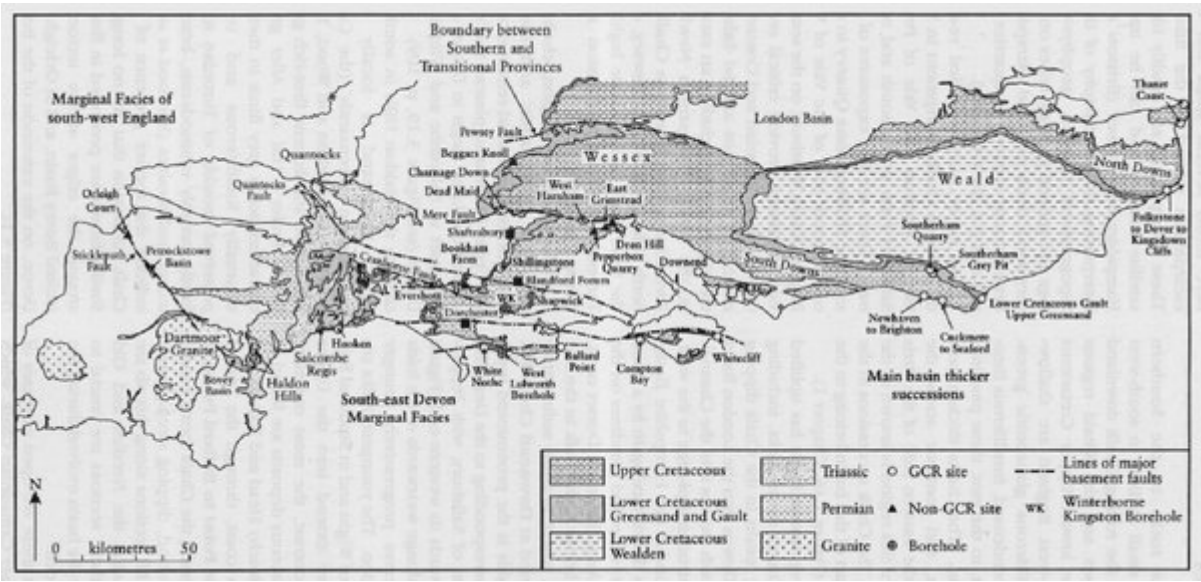
(Figure 3.24) Two sections west of Beer Head, Hooken Cliff, south-east Devon, showing the entire undisturbed Upper Cretaceous succession exposed in the southeast Devon faulted outliers. (a) West side of Beer Head above Little Beach. (b) Section on 'Belay Bluff' above Beer Head. (AKF = Annis' Knob Flint (Rowe's 'strong nodular flint line'); BHLF = Beer Head Limestone Formation; BPF and BWF = Bopeep Flints and Bridgewick Flints; HNCF= Holywell Nodular Chalk Formation; NM = Navigation Marl, (Rowe's 'marl in M.c.t.'); NP1, NP2= New Pit Marls 1 and 2; SF = sheet-flint (Rowe's 'Tabular at Base M.c.t.').) (Photos: R.N. Mortimore.)



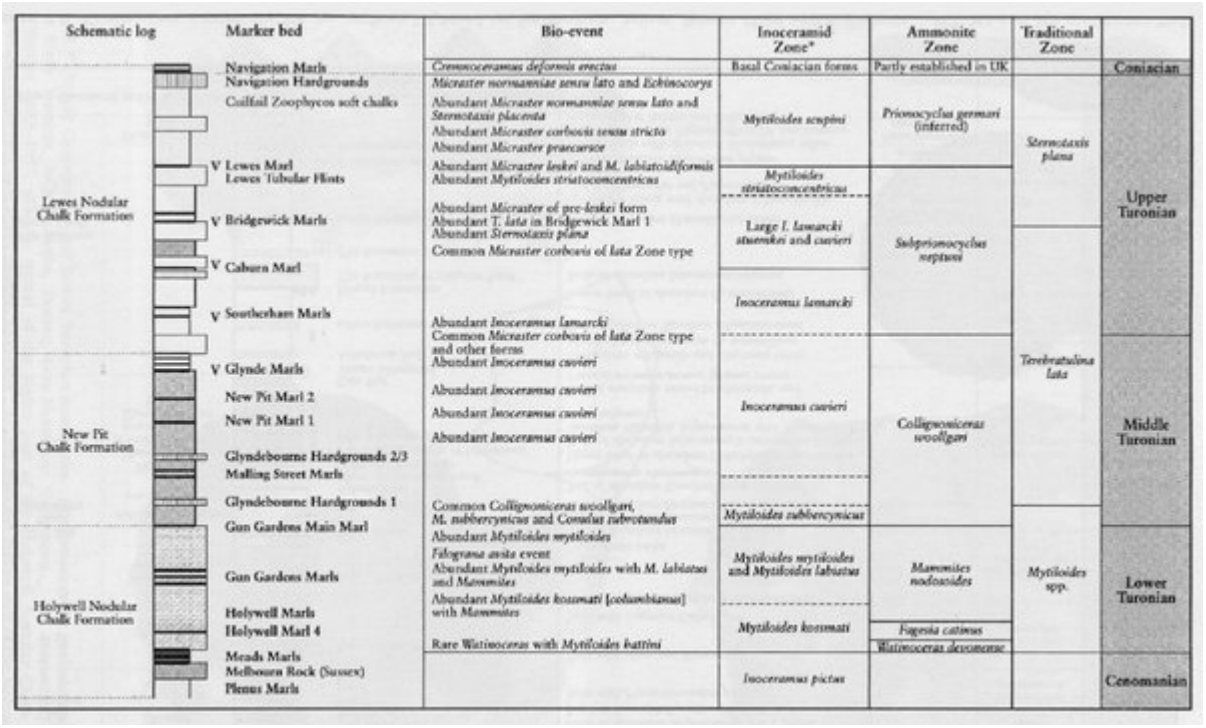
(Figure 3.9) (a, b) Basin-wide marker beds in the Upper Turonian part of the Lewes Nodular Chalk Formation present in the Hooken succession at Hooken Cliff. (Photos: R.N. Mortimore.)



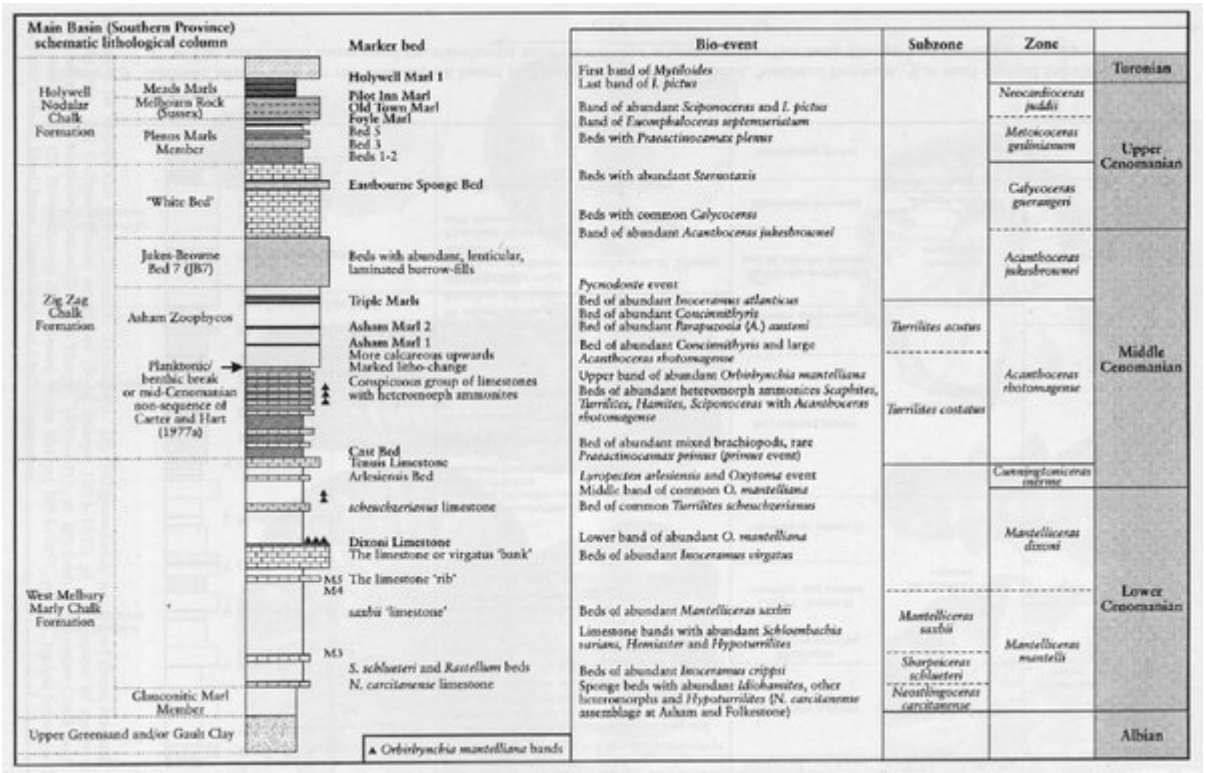
(Figure 3.11) Hooken Cliff and the Twin Pillars at Beer Head; pinnacles of Lewes Nodular Chalk Formation exposing the succession from below the Annis' Knob Flint, through the Lewes Marl and Navigation Marl to a horizon around the Hope Gap Hardground equivalent. The first sheet-flints were used by Rowe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



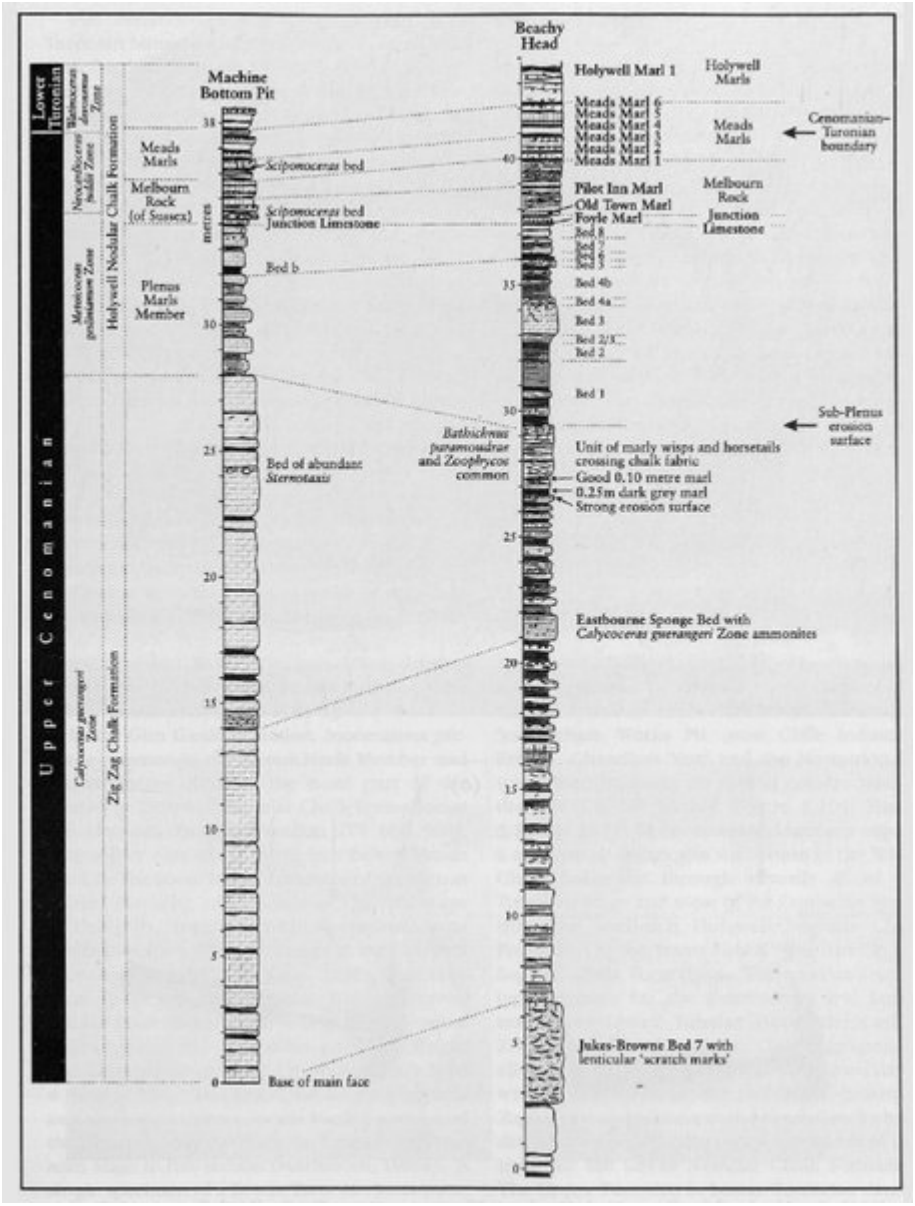
(Figure 3.1) Southern Province GCR localities in relation to the Upper Cretaceous outcrop and major tectonic lineaments. For south-east Devon GCR sites, see also (Figure 3.19), p. 109.



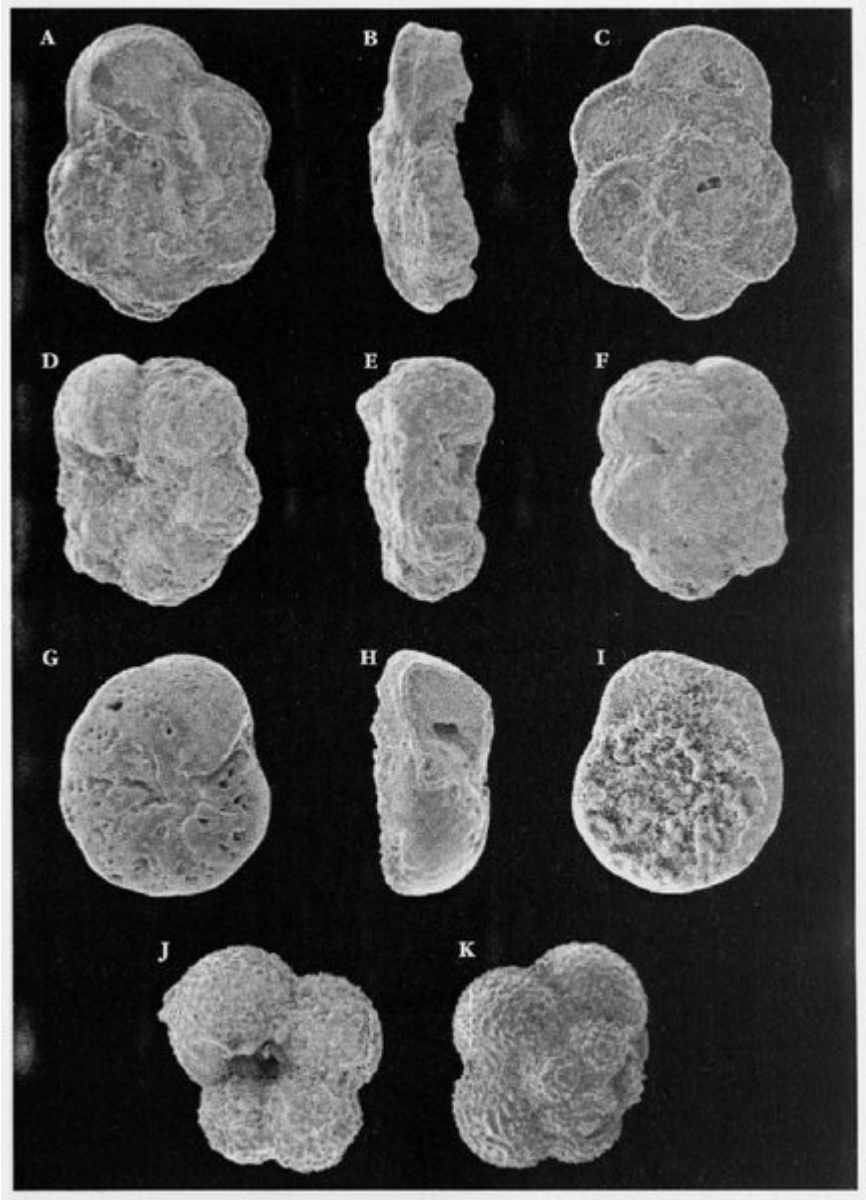
(Figure 2.9) Turonian stratigraphy for the onshore UK based on Lewes Pits and Beachy Head, Southern Province. V = marl derived from volcanic ash. (= The inoceramid zones used are transferred from the current scheme used in Northern Europe and are under review.)*



(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 3.112) The Machine Bottom Pit (part of the Southerham Grey Pit GCR site) correlated with Beachy Head, near Eastbourne, showing the very different lithologies of the two sites.



(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.