THANET COAST

OS Grid Reference: TR296696–TR399675

Introduction

The Thanet Coast GCR site (Figure 3.125) comprises several separate cliff sections, covering 21 km between Cliffs End in Pegwell Bay on the south coast; along the east coast through Ramsgate, Broadstairs and Kingsgate; and along the north coast from Margate westward to Grenham Bay.

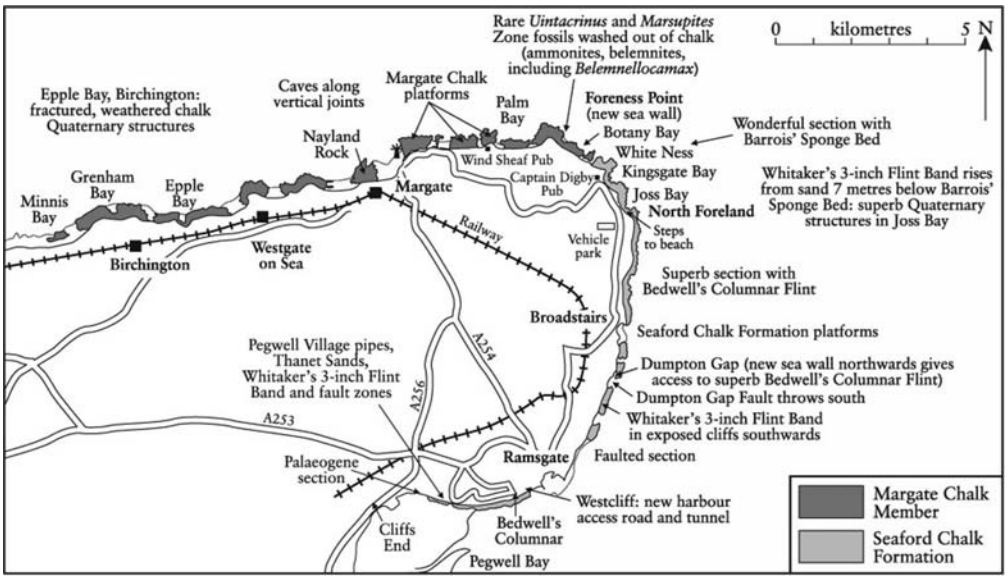

Figure 3.125: The Thanet Coast Upper Cretaceous Chalk GCR site showing key features.

The Isle of Thanet is the type locality for three of the most conspicuous marker beds in the White Chalk Subgroup of the Southern Province: Bedwell's Columnar Flint Band, Whitaker's 3-inch Flint Band and the Barrois' Sponge Bed. It is also the type area for the Margate Chalk Member. Thanet is famous for the excellent preservation in very soft chalks of fossil echinoderms and (towards the higher part of the succession) for the relative abundance of giant ammonites. Compared with other sites in the Southern Province, there is also an unusual abundance of belemnites in the Santonian succession, including several records of *Belemnellocamax grossouvrei* (Janet), which is extremely rare elsewhere in the UK.

Sea walls have been constructed around much of the coast, at Dumpton Gap, Broadstairs, Joss Bay and Foreness Point; and also along the greater part of the north coast, reducing in particular the exposure of Margate Chalk in the *Uintacrinus socialis*, *Marsupites testudinarius* and *Uintacrinus anglicus* zones. Extension of Ramsgate Harbour by land reclamation east into Pegwell Bay has also reduced the exposure of the Seaford Chalk Formation (*Micraster coranguinum* Zone), but the section on the undercliff road is still just workable. On the other hand, the building of the relatively new undersea walls has resulted in significantly less cliff erosion and has provided access to parts of the succession that were formerly difficult to study. For example, Bedwell's Columnar Flint Band is now within reach along the top of the sea wall northwards from Dumpton Gap.

Description

The Chalk of the Thanet Coast (Figures 3.125 and 3.126) is cut entirely in the Seaford Chalk Formation and overlying Margate Chalk Member (Newhaven Chalk Formation) of the White Chalk Subgroup (Bristow *et al.*, 1997; Rawson *et al.*, 2001). Whitaker (1865a, 1872) placed all the Chalk of Thanet in two lithological units. The Broadstairs Chalk, at the base, included the beds described by Phillips (1818, 1819) as 'Chalk with many flints and few organic remains'

(i.e. the upper half of the Lewes Nodular Chalk Formation and all of the Seaford Chalk Formation). Above this were beds with few flints, which he called 'Margate Chalk'.Dowker (1870) also followed this division of the Chalk of Thanet, but termed Whitaker's 'Broadstairs Chalk' the 'Ramsgate Chalk'. The [British] Geological Survey (Jukes-Browne and Hill, 1904) did not accept this lithostratigraphical scheme, which to them was of local application only, and used instead Upper Chalk divided (biostratigraphically) into macrofossil assemblage zones. Robinson (1986) provided detailed graphic stratigraphical logs of the Thanet succession, and used the lithological concepts of Mortimore (1983, 1986a) to define a Broadstairs Chalk Member with exactly the same lower limit as that of the Seaford Chalk Formation. He also accepted the traditional concept of the Margate Chalk. In the new classification, the variously defined 'Broadstairs Chalk' is replaced by the Seaford Chalk Formation (Mortimore, 1983, 1986a; Bristow *et al*., 1997) and the 'Margate Chalk' is retained (Bristow *et al*., 1997) but now with member status as part of the Newhaven Chalk Formation.

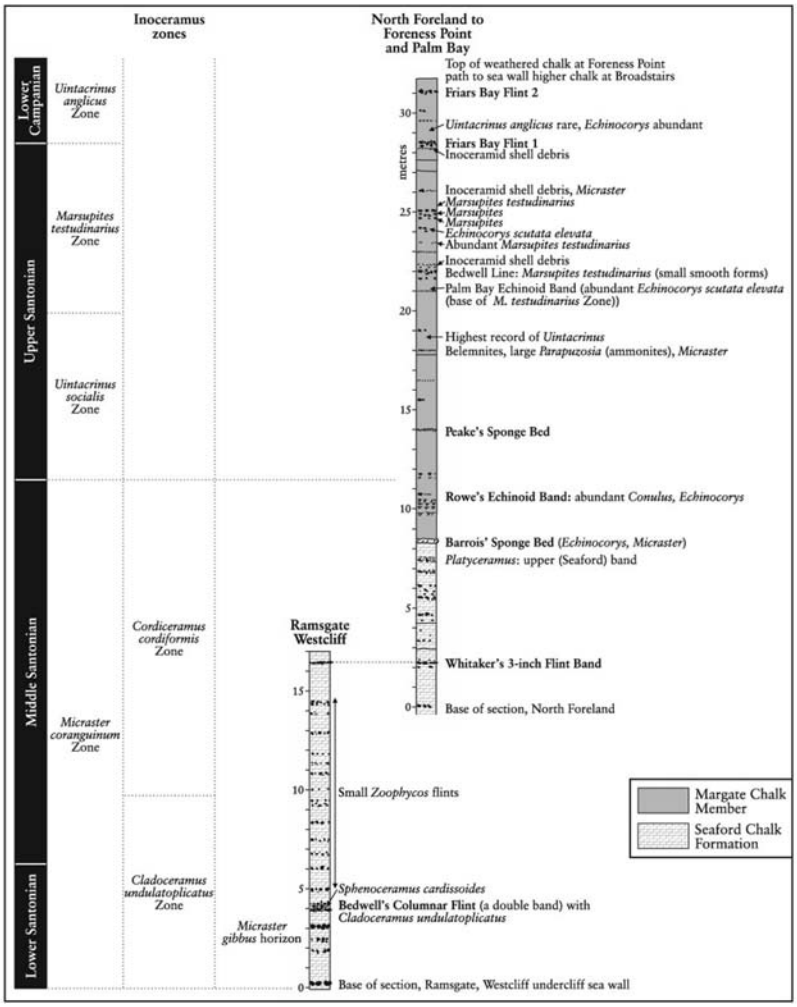

Figure 3.126: The Chalk succession around the Thanet Coast of north-east Kent. The upper limit of the Cladoceramus undulatoplicatus Zone is uncertain.

Two conspicuous flint bands (in the Broadstairs or Ramsgate Chalk) were identified by Whitaker (1865a, 1872), Dowker (1870) and Bedwell (1874) as useful stratigraphical markers in the cliffs of the Thanet Coast. Bedwell (1874) also recognized a higher flint band, in the Margate Chalk. These flints were later named by Rowe (1900): the 'Bedwell Columnar Flint Band' (Figures 3.126 and 3.127), the 'Whitaker's 3-inch Flint Band' and the 'Bedwell Line', in ascending order. Barrois (1876) additionally identified a well-developed 'sponge bed' that he could trace from Joss Bay to White Ness, at the boundary between his *Micraster coranguinum* and *Marsupites* zones. Rowe (1900) named this the 'Barrois' Sponge Bed' after its discoverer.

Figure 3.127: (a) The cliffs at Joss Bay, showing Whitakers 3-inch Flint Band (W3) and strongly cryoturbated chalk and flint. (b) Giant flint columns emanating from Bedwell's Columnar Flint Band, South Portal, Ramsgate Harbour Tunnel (arrowed). (Photos: R.N. Mortimore.)

Skeletal longitudinal sections of the cliffs showing the position of these key markers were published by Sherborn (in Rowe, 1900, Section 3, p. 368) and in the British Geological Survey Dover and Ramsgate Sheet Memoir (Shephard-Thorn, 1988, fig. 12). The memoir also includes descriptions of the geology of the area, a map (fig. 11) to show the distribution of the Chalk zones in Thanet, and an analysis of the geological structure, showing faults and folds. Further details are to be found in the Geologists' Association Guide to the Chalk of the region (Mortimore, 1997), and the stratigraphy of the Chalk (using the Robinson scheme) was also published by Gale (in Jenkyns *et al.*, 1994, fig. 13c) as part of a composite stratigraphy of the Chalk of the Kent coast sections.

A continuing dip northwards from the Dover–Deal section would take the Chalk well below Thanet, but it is brought to the surface again by the Thanet Anticline (e.g.Shephard-Thorn, 1988). Structure contours show that this is a periclinal and asymmetrical structure, with the steepest dips for the Chalk on the south side of the anticline, along the north coast of Pegwell Bay. Here the Chalk dips south into the Richborough Syncline beneath the Palaeogene deposits. The Thanet Chalk is regularly faulted and the faults are frequently associated with intense jointing with a dominant trend between 310º and 330º.

Lithostratigraphy

Seaford Chalk Formation is present along the south coast in Pegwell Bay, at Ramsgate and Broadstairs, and extends as far north as White Ness, Kingsgate. The cliffs and foreshore in Botany Bay, at Foreness Point, in Palm Bay and along the north coast from Margate westwards to Grenham Bay are cut entirely in the Margate Chalk Member. Both of these units are made of very soft, pure white chalk.

Seaford Chalk Formation

The lowest Chalk exposed on Thanet is found at the western end of the Western Undercliff, Ramsgate (Figures 3.127–3.129). Flints on the wave-cut platform here probably correlate with the Michel Dean and Baily's Hill flints of Seaford Head, Sussex. The cliff section includes Bedwell's Columnar Flint Band (Figure 3.127), which in places consists of a double band of scattered nodular flints with several large paramoudra columns. Paramoudra flints are more common in this band in the coast section north of Dumpton Gap, and also occur in association with the underlying flint bands.

Figure 3.127: (a) The cliffs at Joss Bay, showing Whitakers 3-inch Flint Band (W3) and strongly cryoturbated chalk and flint. (b) Giant flint columns emanating from Bedwell's Columnar Flint Band, South Portal, Ramsgate Harbour Tunnel (arrowed). (Photos: R.N. Mortimore.)

Between Bedwell's Columnar Flint Band and the next conspicuous marker above, Whitaker's 3-inch Flint Band (Figure 3.127), are some 12 m of chalk with 13 flint bands, most of which consist of small *Zoophycos* finger-flints. In contrast to the discontinuous nodules of the Columnar Flint Band, Whitaker's 3-inch Flint Band is typically a solid tabular band, comprising an overgrown horizontal *Thalassinoides* flint. The interval from this flint to Barrois' Sponge Bed consists of 6 m of chalk with bands of discontinuous nodular flint. Barrois' Sponge Bed is a conspicuous iron-stained nodular bed, 0.2–0.3 m thick, with a weakly developed, pale green, glauconitized top surface. It forms a small reef on the wave-cut platform at White Ness.

Margate Chalk Member of the Newhaven Chalk Formation

Barrois' Sponge Bed marks a significant change in lithology: the underlying Chalk contains regular flint bands, while the Chalk above appears flintless. This was the criteria originally chosen by Whitaker (1865a) to distinguish the Margate Chalk from the Broadstairs Chalk below. In the cliffs around White Ness it is difficult to identify any marker beds, the chalk appearing homogeneous and pure white. Close inspection reveals a horizon 2 m above Barrois' Sponge Bed, comprising an inconspicuous group of four weakly developed, iron-stained sponge beds, above which there are sporadic occurrences of nodular flints. This horizon was named by Robinson (1986) ‘Rowe's Echinoid Bed' (Figure 3.126). Three metres higher there is a weakly indurated, discontinuous and inconspicuous sponge bed that was originally described by Peake (1967), and is generally known as ‘Peake's Sponge Bed' (Figure 3.126).

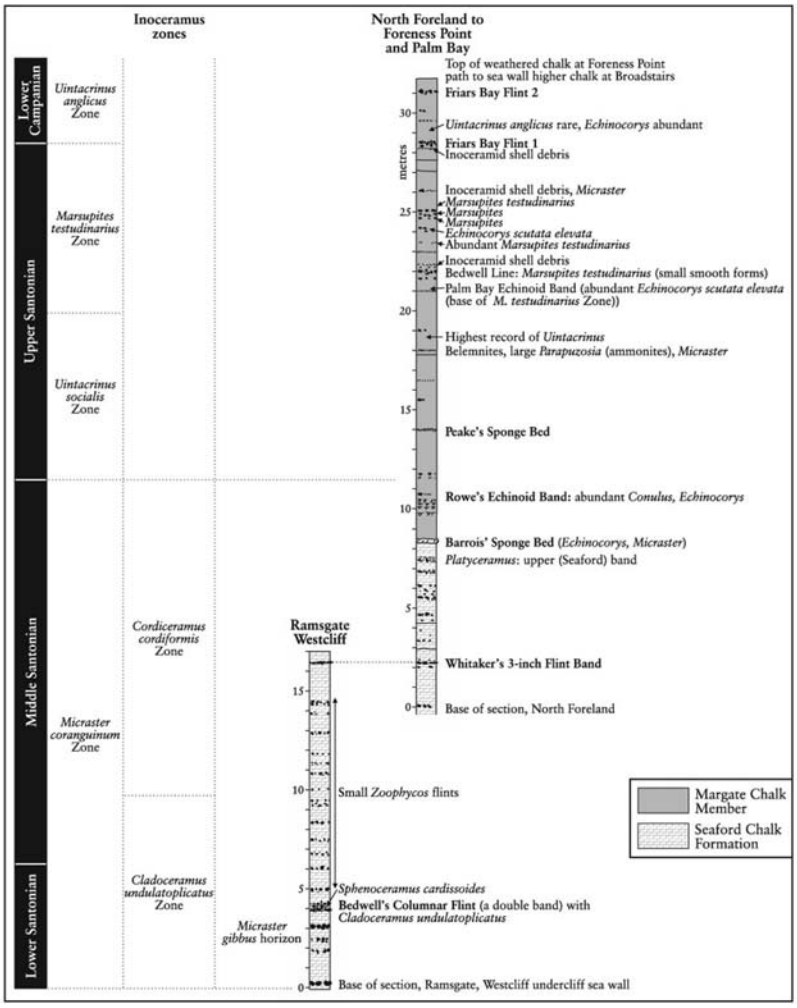

Figure 3.126: The Chalk succession around the Thanet Coast of north-east Kent. The upper limit of the Cladoceramus undulatoplicatus Zone is uncertain.

For 8 m above Peake's Sponge Bed the chalk is particularly homogeneous, with only the occasional ‘clot' of nodular flints to break the monotony. A continuous flint band then enters the section, comprising scattered nodules in a 0.5 m wide zone of flint. This is the Bedwell Line (Bedwell, 1874; Rowe, 1900). Between two and three metres above the Bedwell Line there is another scattered flint nodule band. These two flint bands are exposed at the base of the cliff at Foreness Point (Figures 3.125 and 3.126). The section in the gully leading down to the beach past Margate Headworks (Figure 3.130) here includes two additional flint bands, which are the highest in the Margate coast sections.

Figure 3.130: East side of Margate Headworks showing the cliffs of Botany Bay and the critical Chalk exposures in the Uintacrinus socialis and Marsupites testudinarius zones. (Photomosaic: R.N. Mortimore.)

North-east of St Peter's Church, Broadstairs, Shephard-Thorn (1988) recorded the highest Margate Chalk on Thanet in a small, partly backfilled pit (TR 384 686), but its lithology is poorly known. Here, the Chalk is overlain, as in Pegwell Bay, by the Palaeogene Thanet Formation

The Margate Chalk is truncated by the Palaeogene erosion surface in Pegwell Bay, but this surface is not exposed in the Thanet Coast section proper. On the eastern headland of Epple Bay, a few nodular flints, preserving strongly developed trace fossils typical of the basal Newhaven Chalk Formation, can be seen in the Chalk wave-cut platform at low tide. The Chalk in the cliffs is virtually flintless, but a single sheet-flint is present towards the top of the cliffs on the eastern headland of Epple Bay and continues east towards Westgate on Sea. The Chalk is regularly and closely jointed, with the dominant trend between 310º and 330º, as it is on the south Thanet Coast at Pegwell Bay. A similar frequency and style of faulting is also present.

Biostratigraphy

The Chalk of the Isle of Thanet spans the higher part of the *Micraster coranguinum* Zone (highest Upper Coniacian, Lower and Middle Santonian substages), the *Uintacrinus socialis* and *Marsupites testudinarius* crinoid zones (Upper Santonian Substage), the *Uintacrinus anglicus* Zone and the lowest beds of the *Offaster pilula* Zone (Lower Campanian Substage). The cliffs are primarily cut in Santonian chalks, with just a few metres of basal Campanian strata preserved in the core of a minor syncline at Foreness Point, and also inland at Broadstairs. Key papers on the macrofossils are those by Rowe (1900), Gale and Smith (1982) and Bailey *et al*. (1983, 1984). The foraminiferal biostratigraphy, including new benthic foraminiferal biozones developed here and based on the genera *Stensioeina* and *Bolivinoides* (Figure 1.5, Chapter 1), was documented by Bailey *et al*. (1983, 1984) and is also incorporated in skeletal sections in *The Stratigraphical Index of Fossil Foraminifera* (Hart *et al*., 1989).

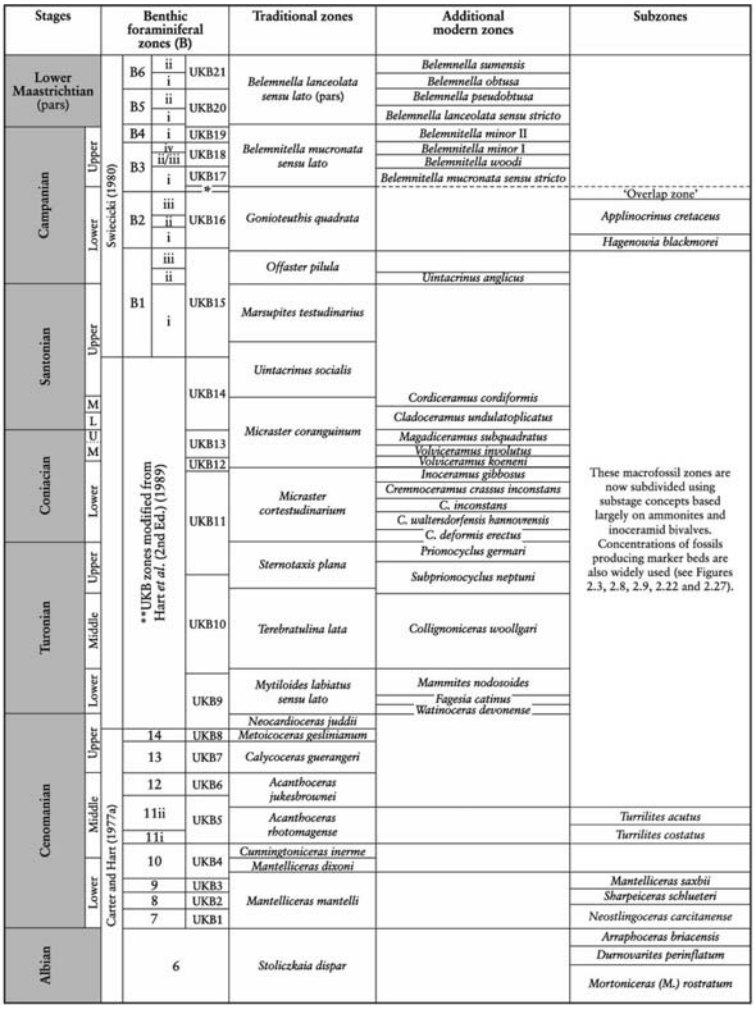

Figure 1.5: Zones of the Upper Cretaceous Chalk. (= Gap in UKB scheme; ** = UKB zonal scheme modified for this book.)*

Santonian Stage

In Thanet, the lowest occurrences of the basal marker taxon for the Santonian Stage, the inoceramid bivalve *Cladoceramus undulatoplicatus* (Roemer), are found in two concentrations below, and immediately above, a conspicuous flint band that is the probable correlative of the Michel Dean Flint of Seaford Head. This composite occurrence constitutes the 'Pegwell Inoceramid Band' of Robinson (1986), for which the type locality is the West Cliff Promenade, Ramsgate (TR 376 642). Robinson (1986) actually recorded scattered occurrences of *Cladoceramus* for up to 0.3 m beneath the lower concentration. The distinctively corrugated, pinkish-purple shells of *Cladoceramus* at this level were earlier erroneously identified as *Inoceramus digitatus* J. de C. Sowerby, a species that characterizes a high level in the Upper Coniacian strata of the Northern Province, and the occurrence was accordingly named the 'Inoceramus digitatus Band' (Bailey *et al.*, 1983, fig. 2). Subsequent work showed that the inoceramid bivalves at this horizon and those that characterize the basal part of Bedwell's Columnar Flint Band cannot be distinguished, and that they are both *Cladoceramus.* For this reason, Bailey *et al.* (1984) recognized instead a lower and and an upper *Cladoceramus* event.

In the *c.* 5 m interval between the two *Cladoceramus* events, Bailey *et al.* (1983) identified a level of major faunal turnover, with the entry of a new, high-diversity fauna, coincident with a flint which they named the 'Chartham Flint', after a locality (TR 105 559), south-west of Canterbury. The development of flint in this interval in the North Downs sections is extremely variable (cf. Robinson, 1986, fig. 22) and it is not always possible to identify the Chartham Flint unequivocally. The new fauna, which enters the succession in Thanet only 2 m above the base of the Santonian Stage, is characterized by the first appearance of the benthic foraminifer *Stensioeina granulata polonica* Witwicka, marking the base of the UKB14 Zone, and by the entry of the terebratulid brachiopod *Gibbithyris ellipsoidalis* Sahni, the inoceramid bivalve

Cordiceramus cordiformis (J. Sowerby), the echinoid *Conulus albogalerus* (Leske) and the ammonite aptychus *Spinaptychus* cf. *spinosus* Cox. Other elements of this fauna include the small rhynchonellid brachiopod *Orbirhynchia pisiformis* Pettitt and the echinoids *Cardiotaxis aequituberculatus* (Cotteau), *Micraster gibbus* (Lamarck) and thin-tested *Sternotaxis* sp., as well as barrel-shaped columnal ossicles of the crinoid *Bourgueticrinus*. The occurrence of *Spinaptychus* is of particular interest, since this aptychus has been found in Zululand in association with *Texanites* (Kennedy and Klinger, 1972). Although poorly preserved chalk moulds of texanitid ammonites are known from this level at Cliffe in north Kent (Spath, 1926), there are no records from Thanet. The inferred occurrence of *Texanites* here fits well with records of this genus in association with *Cladoceramus* in Germany.

This fauna can be collected from the wave-cut platform below the first sea-worn cliff exposures at the west end of the Western Undercliff Wall, Ramsgate, where Bedwell's Columnar Flint Band, with abundant *Cladoceramus undulatoplicatus* at the base, is present just above beach level. It is also to be found where the basal Santonian beds are brought into the foot of the cliff again by faulting, in the cliffs and foreshore of the long, northward dipping section to the north of Dumpton Gap. This is the type locality for the giant agglutinating foraminifer *Labyrinthidoma dumptonensis* Adams, Knight and Hodgkinson, a species that appears to range from the base of the Santonian to *c*. 3 m above Whitaker's 3-inch Flint Band (Adams *et al*., 1973; Hart, 1993).

There is a minor concentration of *Cordiceramus cordiformis* below the remarkable flood occurrence of *Cladoceramus undulatoplicatus* at the base of Bedwell's Columnar Flint Band. The long-ranging Santonian inoceramid bivalve, *Sphenoceramus cardissoides* (Goldfuss), the thin-tested echinoid *Hagenowia rostrata* (Forbes) and extremely rare belemnites (*Gonioteuthis praewestfalica* Ernst and Schulz or early *G. westfalica* (Schlüter)) have been collected from just above the base of the Columnar Flint at the foot of the cliff at North Foreland.

There are several minor concentrations of *Cladoceramus* above the second *Cladoceramus* event at the base of the Columnar Flint. The last occurrence of *C. undulatoplicatus* is provisionally taken as the boundary between the Lower and Middle Santonian substages (Lamolda and Hancock, 1996): this is located in Thanet in a *Cladoceramus*/*Platyceramus* shell-bed situated several metres above the Columnar Flint.

The richly fossiliferous beds between the Columnar Flint and the Whitaker's 3-inch Flint Band contain distinctive forms of *Echinocorys*, relatively rounded *Conulus* (which tend to occur concentrated at particular horizons) and *Micraster coranguinum* (Leske). Other common elements of the fauna include several species of small simple corals (*'Parasmilia'*), numerous bivalves, including *Spondylus spinosus* (J. Sowerby) and the inoceramid bivalves *Platyceramus* sp. and *Cordiceramus cordiformis*, regular echinoids (predominantly isolated spines), for example *Phymosoma koenigi* (Mantell), *Temnocidaris sceptrifera* (Mantell), *Tylocidaris clavigera* (Mantell) and asteroids, including *Metopaster parkinsoni* (Forbes) and *M. uncatus* (Forbes). There is an acme-ocurrence of the thin-tested echinoid *Infulaster infulasteroides* (Wright and Wright) 2–4 m beneath the 3-inch flint (Gale and Smith, 1982, fig. 1).

Whitaker's 3-inch Flint Band is accessible on top of the short stretch of sea wall beneath the Pegwell Bay Hotel, and also at the head of Joss Bay. At the former locality, late forms of the inoceramid bivalve *Platyceramus*, as well as *Sphenoceramus* sp. and *Cordiceramus cordiformis*, are associated with an acme of the echinoid *Conulus.* The 3-inch Flint Band is a major biostratigraphical boundary. Specimens of *Micraster coranguinum* from above the flint show an anterior prolongation of the labrum that is not seen in specimens from lower beds. The benthic foraminifer *Cibicides beaumontianus* (d'Orbigny) first enters in strength just above the flint, together with *C. ribbingi* Brotzen, marking the base of the *C.* ex gr. *beaumontianus* Assemblage Biozone of Bailey *et al*. (1983). The last (sporadic) occurrence of the benthic species *Gavelinella arnagerensis* Solakius (*Lingulogavelinella* cf. *vombensis* (Brotzen) in the earlier literature, for example Bailey *et al*., 1983, 1984) is located *c*. 2 m above the flint, close to the upper limit of the giant agglutinating form *Labyrinthidoma dumptonensis*. The upper limit of *G. arnagerensis* was used in the interpretation of boreholes for the site investigation for the Thames Barrage (Carter and Hart, 1977b).

A minor surface *c*. 2 m beneath Barrois' Sponge Bed marks the entry of the small, spindle-

shaped belemnite *Actinocamax verus* Miller and the highest record of the terebratulid brachiopod genus *Gibbithyris* in Thanet. This horizon also yields rare specimens of the belemnite *Gonioteuthis westfalica* and a distinctive small form of *Echinocorys*, which is reminiscent of (but not so elevated as) the *E. scutata elevata* Griffith and Brydone that occurs at the base of the *Marsupites testudinarius* Zone. It is noteworthy that elsewhere in the Southern Province there is a virtual absence of terebratulid brachiopods from this level up to the highest beds of the *Gonioteuthis quadrata* Zone. Thick-shelled *Platyceramus* sp. are common in the interval between this surface and the Barrois' Sponge Bed.

Barrois' Sponge Bed was formerly taken (e.g. White, 1928) as the boundary between the *Micraster coranguinum* and *Uintacrinus socialis* zones, but this latter datum is now taken *c.* 3 m higher, at the entry of the zonal index crinoid (Figure 3.126). Barrois' Sponge Bed itself contains the large vertical-sided 'tea-cosy' form of *Echinocorys*, both in and resting on its surface, as well as unusual large forms of *Micraster*. The latter include *Micraster gibbus* and *M.* sp. close to the eastern European and German form *Micraster rogalae* Nowak. These echinoids can be readily collected from the wave-cut reef at the foot of White Ness.

The *c.* 2 m unit of coarse-grained, shell-detrital chalk with small scours and closely spaced minor iron-stained sponge beds ('Rowe's Echinoid Bed') that overlies Barrois Sponge Bed is very fossiliferous. It takes its name from the abundance of acutely pyramidal *Conulus albogalerus* and other echinoids such as *Echinocorys* and *Micraster*. The *Conulus* tend to occur in concentrations with the tests in juxtaposition, notably near the base of the cliff at White Ness. It is also a bed characterized by sporadic belemnites (*Actinocamax verus* and *Gonioteuthis* sp.: either *G. westfalica* or *G. westfalicagranulata* (Stolley)) and the large rhynchonellid brachiopod *Cretirhynchia plicatilis* (J. Sowerby), which appears to be restricted to this level.

There is a significant increase in benthic foraminiferal diversity a short distance below the base of the *Uintacrinus* Zone in the Thanet section, marked by the entry of *Reussella szajnochae praecursor* de Klasz and Knipscheer immediately followed by that of *Gavelinella stelligera* (Marie) and *G. cristata* (Goel). The last occurrence of *Stensioeina granulata polonica* is just below the entry of *Uintacrinus.* The first occurrence of *Stensioeina granulata perfecta* Koch, marking the base of the *perfecta* Biozone (Bailey *et al.*, 1983), is near the base of the *socialis* Zone. The inception of *Bolivinoides strigillatus* (Chapman), marking the base of the UKB15 zone, is at or close to the last occurrence of *Uintacrinus,* based on a revision downwards of this latter datum compared with that previously published by Bailey *et al.* (1983, fig. 2). All of these bio-events, which were first recognized in the Thanet cliffs, are critical to long-range correlation within the UK and with successions in northern Europe, as well as offshore, in the southern North Sea Basin (cf. Hart *et al.*, 1989, fig. 8.9).

The *Uintacrinus socialis* Zone contains sporadic accumulations of calyx plates and arm ossicles of the zonal index crinoid, but the commonest fossil is the belemnite *Actinocamax verus*. Inland sections, such as at Sayer's Woodyard, Ramsgate, have yielded the distinctive flat-topped form of *Echinocorys* that characterizes this zone but these, partly as a result of the activities of fossil collectors, are difficult to find in the coast sections Gale and Smith (1982, fig. 1) recorded an acme-ocurrence of the thin-tested echinoid *Hagenowia anterior* Ernst and Schulz in the middle of the zone. The wave-cut platform in the beds below the Bedwell Line contains specimens of the giant ammonite *Parapuzosia* (*P.*) *leptophylla* (Sharpe) and belemnites (*Actinocamax verus* and sporadic *Gonioteuthis*; see Bailey *et al.*, 1983). Bedwell (1874) drew attention to the fact that the giant ammonites were concentrated in several levels of abundance below a datum flint (the Bedwell Line), notably near the top, and just above the base, of the interval now placed in the *socialis* Zone. Several specimens of the rare belemnite *Belemnellocamax grossouvrei* collected loose from the wave-cut platform are inferred to have come from the top beds of the *Uintacrinus socialis* Zone. The upper limit of *Uintacrinus* is 3.5 m beneath the Bedwell Line. There is a small (1.2 m) gap here between the last *Uintacrinus* and the first *Marsupites*. Unfortunately, construction of a sea wall around Foreness Point, and in Palm Bay, has partly obscured some of the best sections of the boundary between the two crinoid zones.

The Bedwell Line (Figure 3.126) is associated with another fossil turnover, the entry of the zonal index crinoid *Marsupites*, at a minor indurated surface, 2.3 m below the flint, followed by the occurrence of abundant specimens of the distinctively shaped echinoid *Echinocorys scutata*

elevata (resembling an old-fashioned policeman's helmet in cross-section) in a sponge bed ('Palm Bay Echinoid Band' of Robinson (1986)), immediately below the flint. There is a second acme-occurrence of *Hagenowia anterior* just above the Bedwell Line. The *Marsupites* calyx plates exhibit the same successive changes in ornament from small smooth plates, through large strongly ornamented plates, to small ornamented plates, that are seen in the expanded successions of the zone elsewhere, for example in the air-weathered faces of the Black Rock path, east of Brighton (**Newhaven to Brighton** GCR site, this volume). The two distinct types of calyx plates, i.e. the lower form, with a simple fold in each edge of the plate; and the higher form with crinkled edges, can also be recognized here. The acme-ocurrence of strongly ornamented calyx plates in Thanet is associated with relatively common specimens of the belemnite *Gonioteuthis granulata* (Blainville). This association is seen particularly well in the air-weathered section above the sea wall at Foreness Point.

Campanian Stage

The youngest beds of chalk are exposed beside the access path to the sea wall at Foreness Point. The base of the stage is marked by the last occurrence of *Marsupites* and the first occurrence, within the *Gonioteuthis* evolutionary lineage, of the belemnite *G. granulataquadrata* (Stolley) (Hancock and Gale, 1996). The extinction level of *Marsupites* in the marl-free Margate Chalk Member of Thanet occurs in an inoceramid bivalve shell-debris bed beneath the lower of two conspicuous flints that are presumed to correlate with the two Friars Bay Flints of the marl-rich Newhaven Chalk in Sussex at Seaford Head, Seaford, and Friars Bay, Newhaven; at these latter localities the top of this debris band is coincident with Friars Bay Marl 1.

The arm ossicles and the distinctive fluted calyx plates of the basal Campanian zonal index crinoid, *Uintacrinus anglicus* Rasmussen, occur here rarely between Friars Bay Flints 1 and 2 (Figure 3.126; Mortimore, 1997, fig. 66), constituting the basal Lower Campanian *Uintacrinus anglicus* Zone. Better specimens (British Geological Survey collections) were found in Chalk excavated from graves at St Peters Church, Ramsgate. This crinoid has a short total range in the Southern Province and also (Mitchell, 1995b) in the Northern Province in the **Flamborough Head** GCR site. The correlation at this level between the Kent and Sussex successions is supported by the abundance of *Echinocorys scutata tectiformis* Griffith and Brydone above Friars Bay Flint 1 at Foreness Point, and at a similar level in Sussex. The successive entry of the benthic foraminifer *Bolivinoides culverensis* Barr, and the last occurrence of the planktonic foraminifer *Globigerinelloides rowei* (Barr), two events that are critical to long-range correlation (Bailey *et al*., 1983, fig. 2; Hart *et al*., 1989, fig. 8.9), are at or just above the upper limit of *Uintacrinus anglicus*, in the higher part of the interval between the Friars Bay Flints.

The highest Chalk in the Isle of Thanet and the North Downs is in the basal beds of the *Offaster pilula* Zone. Up to 6 m of *Offaster pilula* Zone chalk, overlain by the Thanet Beds Formation, was proved in the partially backfilled pit that formerly exposed the *Marsupites testudinarius* Zone, north of St Peter's Church, Broadstairs (TA 384 686). The discovery of the zonal index fossil here proved, as many had suspected, that *O. pilula* Zone chalk does actually occur on Thanet.

Interpretation

The north-east Kent coastal sections expose the highest chalk in the North Downs in the Santonian and the very base of the Campanian stages, divided into two lithological units, the Seaford Chalk Formation and the overlying Margate Chalk Member. By contrast with the same levels in the coeval Newhaven Chalk Formation at Seaford Head (**Cuckmere to Seaford** GCR site) and Black Rock (**Newhaven to Brighton** GCR site), there is a conspicuous absence of marl seams in the Margate Chalk, and no, or reduced numbers, of flint bands. Those flint bands that do occur are, therefore, more conspicuous. A similarity between the two areas lies in the fact that the equivalent in Thanet of the Friars Bay Flints of Sussex are likewise well-developed, rounded flints. These contrast with the flints below, which are peppered with the trace fossil *Chondrites*. Flint *form* is surprisingly consistent in the basin, an observation that contradicts the views expressed by Whitaker (1872) and Rowe (1900–1908), who considered flints to be only of extremely local use in correlation. In one respect, however, the loss of some flint bands

on Thanet has had the advantage of emphasizing the remaining beds. This is true of three key marker flint beds: Bedwell's Columnar Flint Band, Whitaker's 3-inch Flint Band and the Bedwell Line, which stand out in Kent, but form two of several very conspicuous bands in Sussex and elsewhere.

Barrois' Sponge Bed (or its correlative) is a hardground that is a key marker bed throughout much of the Southern Province. However, it is developed only over structural highs, and is absent from the intervening, thicker successions. This implies the differentiation of the depositional area into a submarine 'swell and basin' topography at this time. It represents a lithified erosion surface located at various levels in the *Micraster coranguinum* Zone, depending on the extent of downcutting. It is relatively weakly indurated in Thanet, and not represented at all at Canterbury. Barrois' Sponge Bed forms the intensely indurated, glauconitized and phosphatized floor of the Chislehurst caves in south London, and is particularly well-developed at the West Clandon Quarry, east of Guildford (TQ 038 508) (where it was called the 'Clandon Hardground' by Robinson, 1986). It is inferred to equate with the Taplow Lower Hardground at the **South Lodge Pit**, Taplow; with the Whitway Rock (Hawkins, 1918) of the Kingsclere area; with the Boxford Paired Hardgrounds of the **Boxford Chalk Pit**, where it rests on a level in the (Middle Coniacian) beds with *Volviceramus involutus* (J. de C. Sowerby); and with the hardground in the North Barn Pit near Dorchester, Dorset.

There are several biostratigraphical differences between Thanet and Sussex in the distribution and/or abundance of the belemnites, brachiopods and crinoids (Mortimore, 1979, 1986a, 1997). The Chalk of Thanet has long been famous for the rich diversity of fossils contained in soft, white chalk, enhancing the quality of preservation and ease of extraction. Echinoids, particularly *Micraster* (Rowe, 1899, 1900), *Echinocorys* and *Conulus*, as well as the fragile *Hagenowia* (Gale and Smith, 1982) and cidarids are common in the higher (Santonian) part of the *M. coranguinum* Zone. In the *Uintacrinus socialis* and *Marsupites testudinarius* zones belemnites are much commoner than in Sussex, where they are exceptionally rare. In contrast, the rhynchonellid brachiopod *Cretirhynchia exsculpta* Pettitt, which is common in the crinoid zones in Sussex, has not been found in Kent.

The relative abundance and diversity of belemnites, compared with their rarity in the more basinal Sussex successions, has been critical for correlation of this part of the Chalk with the standard belemnite zonal scheme for the European Boreal Cretaceous (e.g.Christensen, 1997). The soft chalks also contain more microbrachiopods (Johansen and Surlyk, 1990). Detailed study of the microfossil and nannofossil biostratigraphy (seeCuckmere to Seaford GCR site report, this volume) has shown how the ranges of many index species are condensed in Thanet compared to Sussex, implying significant loss of section. It is for this reason that the Seaford Head section, which is more complete in terms of both litho- and biostratigraphy than the Thanet section, has been selected as a candidate Global boundary Stratotype Section and Point (GSSP) for the Santonian Stage.

Despite the missing stratigraphy on Thanet compared to the more basinal Sussex sections, this coastline provides a standard for the successions developed over the Anglo-Brabant Massif in the Transitional Province. Margate Chalk with little flint is present in Essex and Suffolk, and has been proved in cored boreholes at Layer de la Hay and Ipswich. Flinty equivalents of the Margate Chalk Member come in westwards, so that the same levels west of the Medway at Pinden, Pepperbox Hill and in pits around Croydon, Surrey and on the Leatherhead–Dorking sections of the M25 are packed with numerous good flint seams. These lateral changes in lithology, which have not been fully appreciated before, aid in the interpretation of Santonian–Campanian palaeogeography.

Conclusions

The Isle of Thanet is the type locality for three of the most conspicuous marker beds in the White Chalk Subgroup of the Southern Province: Bedwell's Columnar Flint Band, Whitaker's 3-inch Flint Band and the Barrois' Sponge Bed. It is also the type area for the Margate Chalk Member of the Newhaven Chalk Formation. Thanet is famous for the excellent preservation in very soft chalks of fossil echinoderms and (towards the higher part of the succession) for the relative abundance of giant ammonites. Compared with other sites in the Southern Province, there is also an unusual abundance of belemnites in the Santonian succession, including

several records of *Belemnellocamax grossouvrei*, which is extremely rare elsewhere in the UK. The belemnites and inoceramid bivalves from here enable correlation between the traditional macrofossil zones and the standard northern European zones. It is a key section for the microfossil (foraminiferal) zonal scheme of the Santonian Stage and it has provided one of the standard stable isotope curves.

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