# Chapter 5 Northern Province, England

## Introduction

At Hunstanton, on the eastern shores of the Wash, a marked change takes place in the Chalk successions representing the Upper Cretaceous Series in England, emphasized by the conspicuous red chalk at the base of the cliffs in contrast to the white cliffs of the south coast. Northwards from the Wash, the Upper Cretaceous Chalk forms the treeless rolling hills of the Lincolnshire and Yorkshire Wolds, where it is exposed in large working quarries. In East Yorkshire, the Chalk forms forbidding and inaccessible sea cliffs, inhabited only by kittiwakes and fulmars. In plough, along the base of the Wolds escarpment, is the conspicuous brick-red Hunstanton Red Chalk Formation, a unit not present in the Southern Province or Transitional Province, but one which is a vital marker bed in North Sea boreholes. There are major lithological and sedimentological differences between the Northern Province and areas south of the Wash. Not only is the Chalk red at the base in this province, but chalk sediment begins in the Upper Albian succession, rather than at the base of the Cenomanian. The Cenomanian succession is conspicuously thinner, there is no Plenus Marls Member or Melbourn Rock, the higher part of this interval being replaced by the Black Band. Regular flint bands occur lower, at the base of the equivalent of the New Pit Chalk Formation of the Southern Province, and there are huge thicknesses of marly Upper Santonian–Lower Campanian Flamborough Chalk Formation (an expanded Newhaven Chalk Formation) without flint. The Chalk succession of the Northern Province (Figure 5.1) and (Figure 5.2) is, therefore, sufficiently different from that in southern England that it requires a separate lithostratigraphical classification (Figure 5.3).

As in the Southern and Transitional provinces, the Chalk Group is divided into the Grey Chalk and White Chalk subgroups. Within these subgroups, the Northern Province Chalk comprises four mappable formations, the Ferriby Chalk, Welton Chalk, Burnham Chalk and Flamborough Chalk formations, in ascending order. The Ferriby Chalk Formation has virtually the same lower and upper boundaries as the Grey Chalk Subgroup. Above the Ferriby Chalk Formation, only the Holywell Nodular Chalk Formation and the lithological change at its top to the white, smooth chalks of the equivalent of the New Pit Chalk Formation, are recognizable. However, the equivalent of the Holywell Nodular Chalk is extremely condensed, and the immediately overlying chalk contains conspicuous flints. The latter are much more strongly developed than the approximately correlative Glyndebourne Flints of the Southern Province; the only other areas in the UK where flints are so strongly developed at the base of the equivalent of the New Pit Chalk are in the northern Chiltern Hills and in south-east Devon.

There are also major faunal differences throughout the succession compared with regions south of the Wash. In contrast, there is a strong similarity both lithostratigraphically and faunally to the limestone and chalk successions of northern Germany. Sections in the Cenomanian succession in the two areas are virtually interchangeable. The main bio-events and lithofacies changes can be correlated readily. The continuous Cenomanian to Lower Campanian succession exposed in the sea cliffs and inland sections is of fundamental importance in the understanding and interpretation of the immediately adjacent offshore succession in the North Sea.

Apart from these litho- and biostratigraphical differences, the bedding is much more clearly defined, and much of the succession is very thin bedded. Nodular chalks are only weakly developed, and are restricted to particular horizons, while strongly glauconitized and phosphatized hardgrounds, such as the Chalk Rock, are not found, with the exception of parts of the Cenomanian succession and the channel floor hardground in the basal Coniacian strata. The flints at Willerby Quarry, Hull, are typically grey, predominantly tabular, poorly delimited from the chalk, and relatively inconspicuous, in contrast to the generally black nodular flints of the south. All of these features are commonly, if controversially, attributed to deposition in a deeper-water environment. The chalk is pervasively indurated north of Louth, Lincolnshire, as a result of overgrowth cements and the way calcite crystals interlock (Mimran, 1978; Mortimore and Fielding, 1990). Concomitant with this greater hardness, sub-horizontal, hard-rock stylolites are a marked feature of the northern chalk.

The hardening is variously interpreted as resulting from deep burial, the effect of superincumbent ice during the last glaciations, and even mild regional hydrothermal metamorphism connected with the Whin Sill and other igneous intrusions (Scholle, 1974). Mimran (1978) concluded that the hardening of the Yorkshire Chalk took place after the end of the Cretaceous Period through the introduction of carbonate from an external source at some time between the Palaeocene and the Eocene epochs. Part of the explanation for the hardening must, however, be due to differences in the original sediment, and even to different depositional situations, for relatively softer chalks are found intercalated between the hard chalks, and hard chalks may pass laterally into soft chalks. In addition, the lower part of the succession in Lincolnshire becomes less hard and, at the same time, more fossiliferous, as it progressively thickens southwards. The idea that up to 50% of the Yorkshire Chalk at Flamborough Head may have been lost by dissolution is not supported by the litho- and biostratigraphical evidence (see GCR site report, this volume).

## Tectonic structure and sedimentological setting

The Chalk of the Northern Province belongs to three main structural units that shifted their positions over time. Throughout the Mesozoic Era, the area of present-day Lincolnshire constituted a slowly subsiding platform, known as the 'East Midlands Shelf' (see (Figure 1.15), Chapter 1). To the north, the Market Weighton Axis acted as an intermittently positive area. Jurassic and Lower Cretaceous strata thinned towards this structure, and became eroded over it. Recent work has shown that, just as in the case of north Norfolk, the presence of an inferred buried granite at or about the position of the Market Weighton structure, and also offshore, to the east (Donato and Megson, 1990; Donato, 1993), may have exerted some control on chalk sedimentation, but probably did not contribute to the pervasive hardening. This structural control continued until at least the end of the Cenomanian Age, since the Hunstanton Red Chalk Formation and Ferriby Chalk Formation exhibit reduced thicknesses in this area. The markedly reduced thicknesses of the Welton Chalk-and basal Burnham Chalk successions at Burdale and Newbald Wold (Wood and Smith, 1978, fig. 5; Whitham, 1991, fig. 6), to the north and south of the axis of this structure respectively, may relate to continuing structural control, or the thinning may conform to the pattern of generally smaller thicknesses that is found in the western part of the Wolds. Higher Burnham Chalk successions (Upper Turonian–Lower Coniacian in age) over the structure actually show no evidence of thinning and are, if anything, significantly expanded and less indurated. On the other hand, borehole evidence suggests that the subcrop Burnham Chalk under Holderness may actually be significantly thinner than elsewhere. Around Hornsea, uncored commercial wells proved a total 510 m of Chalk, of which the top 70 m were flint-bearing (Sumbler, 1996).

On the northern margin of the Market Weighton Axis, an east–west zone of faulting at the edge of the Yorkshire Wolds (the Howardian–Flamborough Fault Zone), extending eastwards offshore into the North Sea, formed the limit of the more rapidly subsiding Cleveland Basin, in which thick Lower Cretaceous successions accumulated, for example at Speeton Cliff (see Flamborough Head GCR site report, this volume). The Market Weighton Axis thus represented a hinge between a more rapidly subsiding area to the north, and a gently subsiding area to the south. The Flamborough Fault Zone effectively delimits the Flamborough Head promontory and finds its surface expression in narrow east–west zones of intense deformation crossing the Wolds (e.g. Foxholes Pit, [TA 012 735]), and intersecting the Chalk of the Yorkshire coast sea cliffs at two points (Staple Nook and Selwicks Bay). The faults were initiated in early Mesozoic times and bound a halfgraben with thick Lower Cretaceous sediments (Kirby and Swallow, 1987); they were then reactivated in Late Cretaceous or Early Tertiary times.

The Chalk in Lincolnshire displays a general dip of less than 1° to the ENE. The highest chalk seen at outcrop (the Lower Coniacian Barrow Flints) lies low in the Burnham Chalk, and the subcrop succession extends only as high as the lower part (Santonian) of the Flamborough Chalk. In the Yorkshire Wolds, the Chalk is folded into a gentle broad syncline, plunging south-east. In the Flamborough Head area, dips are generally of the order of 50–10° to the south, but locally attain 20°. The entire Upper Cretaceous succession, with the exception of the highest beds of the Flamborough Chalk, is exposed in the sea cliffs of Flamborough Head, between Speeton Cliff and Sewerby Steps. The highest Chalk seen at outcrop (Lower Campanian Flamborough Chalk) is found in quarries on the top of the Wolds inland from Bridlington. Beneath Holderness, and also on the east side of Lincolnshire, the Chalk disappears beneath a cover of Pleistocene (Devensian) and alluvial sediments.

## Stratigraphy

It was recognized by 19th century workers (e.g. Blake, 1878) that, in striking contrast to the situation in southern England, where much of the traditional Middle Chalk and the entire Upper Chalk comprised chalk with flints, the flinty chalk in Yorkshire, which began at or near the base of the Middle Chalk and extended up into the equivalent of the lower part of the Upper Chalk, was overlain by a thick succession of chalk that was totally devoid of flint. Within the flinty chalk, Barrois (1876), followed by Blake (1878) and Hill (1888), recognized several different units characterized by particular types of flint. Mortimer (1878) came to the remarkable conclusions that these flinty units graded laterally into the flintless chalk and that the characteristically tabular flints formed by replacing sheets of fucoids (seaweed). Not only was the equivalent of the Lower Chalk seen to be much thinner, harder, and overall much less fossiliferous than in the south, but it overlay highly fossiliferous red-coloured marls and limestones (the Red Chalk). Fossil evidence showed that these red marls were equivalent to the Gault, but they could not logically be separated lithostratigraphically from the Chalk proper. Finally, although hard shelly chalks approximately equivalent to the Melbourn Rock at the base of the Middle Chalk in southern England could be identified, the underlying Belemnite (later Plenus) Marls appeared to be represented here by a thin (*c.* 0.1 m) bituminous black shale full of fish remains, which was termed by Rowe (1904), the 'Black Band', only 15 ft (4.3 m) above which the first flints were found.

Early classifications took the base of the Middle Chalk variously either at the Black Band and/or the base of the inferred equivalent of the immediately overlying Melbourn Rock; or else at the onset of flint. Although the [British] Geological Survey geologists formally took the base at the Black Band, it was clearly stated in the memoirs that they used the first flints for mapping purposes. The base of the Upper Chalk was taken originally at the lower limit of flintless chalk, but later (Jukes-Browne and Hill, 1903, 1904), at the onset of tabular flints. Whilst it was appreciated that the latter criterion had some stratigraphical significance, it was applied inconsistently in the field. This is because the earlier workers (notably Rowe, 1904) were not in a position to know that conspicuous, continuous semi-tabular flints, such as the Deepdale Flint, are actually developed well below the onset of regular tabular flints.

In the course of geological mapping in north Lincolnshire by the British Geological Survey, starting in the late 1960s, it became apparent that the 'Chalk with Flints' of the 19th century surveyors could be consistently subdivided into two units. These two units were characterized by nodular burrow-form flints and tabular flints respectively. Massive, closely spaced, feature-forming (and, hence, mappable) tabular flints at the base of the higher unit corresponded to the Basal Complex at the base of the traditional Upper Chalk of the North Downs, and the coast section at Dover. A rapid field survey of the Chalk outcrop of Yorkshire by the British Geological Survey in 1974 revealed that these lithological units were recognizable and, to a greater or lesser extent, also mappable. In the structurally complex northern part of the Wolds the contact originally mapped between the flinty chalk and the succeeding flintless chalk was found to be tectonic rather than sedimentary. Wood and Smith (1978) consequently established this stratigraphy on a formal basis, subdividing the Chalk of the Northern Province into four mappable formations.

## Lithostratigraphy

### Ferriby Chalk Formation

The Ferriby Chalk Formation (typically 20–30 m thick), named after the stratotype section at Middlegate Quarry (Rugby plc), South Ferriby, north Lincolnshire, originally comprised the traditional Red Chalk and the equivalent of the Lower Chalk. The upper limit is taken at the erosion surface below the thin unit (Variegated Beds of Wood and Mortimore, 1995) that includes the Black Band. This surface is interpreted as being equivalent to the sub-Plenus erosion surface of southern England.

The basal (Red Chalk) component of this formation was controversially separated by the British Geological Survey (Wood and Smith, 1978) as the 'Hunstanton Chalk Member', named after the stratotype section at Hunstanton Cliffs, Norfolk (see GCR site report, this volume) rather than, as other workers recommended at the time (see discussion in Wood and Smith, 1978), treated as an independent mappable formation. 'Hunstanton Red Chalk Formation' is now used as the preferred stratigraphical term. The re-defined 'Ferriby Chalk Formation' has virtually the same lower and upper limits as the traditional Lower Chalk of the Southern Province, although the lithologies are significantly different from those of the south. The re-defined Ferriby Chalk Formation also correlates with the Hidra Formation (Lou and Knox,

1994) of Southern North Sea Basin stratigraphy ((Figure 1.17), Chapter 1). Because in some places the upper part of the Hunstanton Red Chalk Formation is of Cenomanian age (e.g. Speeton Cliff) it falls within the Upper Cretaceous Series and is, therefore, included here.

### Welton Chalk Formation

The Welton Chalk Formation (typically 44–53 m thick) is named after the stratotype section in the Welton Wold Quarry (Melton Bottom Chalk Pit GCR site) (operated by the Omnia Croxton and Garry quarry company), south Yorkshire, and is characterized by generally massive-bedded chalk with marl seams at intervals, and nodular, burrow-form flints. The base is taken at the erosion surface below the Black Band. Overlying the erosion surface is a thin unit, typically about 0.5 m thick, of limestones and siltstones, overlain by green and khaki marls, which includes the Black Band. These sediments were later collectively named the 'Variegated Beds' (Wood and Mortimore, 1995). The 3 to 4 m interval between the Black Band and the first flints comprises impure, greyish-green, shell-detrital chalks, which are lithologically identical to the chalks of the Holywell Nodular Chalk Formation of the Southern and Transitional provinces. These shelly chalks terminate in a closely spaced group of three dark marl seams within 0.25 m (the Chalk Hill Marls). Above this, there is a conspicuous abrupt lithological change to white, flinty chalks.

The Welton Chalk Formation extends from the base of the Upper Cenomanian *Metoicoceras geslinianum* Zone to the top of the Upper Turonian *Terebratulina lata* Zone of the traditional scheme. The faunas are of generally low diversity, comprising brachiopods, inoceramid bivalves and echinoids. Except in the basal (Lower Turonian) beds, ammonites are extremely rare, presumably due to their low preservation potential.

The Welton Chalk Formation approximately equates with the Herring Formation of Southern North Sea Basin stratigraphy (Lott and Knox, 1994), the base of which is also marked by the Black Band.

### Burnham Chalk Formation

The (composite) Burnham Chalk Formation (inferred to be 130–150 m thick) is based on a large number of sections in both north Lincolnshire and Yorkshire. It is named after the basal boundary stratotype at the Burnham Lodge Quarry [TA 0685 1720], near the hamlet of Burnham, north Lincolnshire (Figure 5.1) and (Figure 5.2).

The onset of nodularity, which marks the base of the Lewes Nodular Chalk Formation in the Southern Province, cannot be recognized in the Northern Province. However, the approximately equivalent horizon can be located by recognizing the correlation with the immediately underlying Glynde Marls, which here correlate to the Barton Marls; this boundary cannot be mapped. In fact, the next higher mappable level in the Northern Province above the base of the Welton Chalk Formation (the base of the Burnham Chalk Formation), is taken at the entry of large tabular flints (Figure 5.4). This is the level formerly mapped as the base of the traditional Upper Chalk in the North Downs, i.e. at the Basal Complex of closely spaced marl seams and large flints, and its East Anglian correlative, the 'Brandon Flint Series'. There is, likewise, no obvious lithological change at the horizon equivalent to the base of the Seaford Chalk Formation, which falls within the Burnham Chalk Formation, although the equivalent of the Belle Tout Beds can be recognized without difficulty.

The Burnham Chalk Formation is relatively thin bedded, and is much more flinty overall than the underlying Welton Chalk, although towards the top the flints become thin and inconspicuous, as well as being irregularly and only very sparsely developed. Marl seams are present throughout. Tabular and semi-tabular flints predominate over nodular burrow-form flints, and the huge vertical flints known as paramoudras are found at two levels. In some parts of the succession many of the flints are markedly carious, leading to the expression 'intermingled chalk and flints' (e.g. Jukes-Browne and Hill, 1903, 1904).

The Burnham Chalk Formation approximately equates with the Lamplugh Formation and the lower part of the Jukes Formation of the Southern North Sea Basin stratigraphy (Lott and Knox, 1994; and see (Figure 1.17), Chapter 1).

### Flamborough Chalk Formation

The onset of persistent (and relatively closely spaced) marl seams, which marks the base of the Newhaven Chalk Formation of the Southern Province occurs much lower in the Northern Province, at the base of the Flamborough Chalk Formation, and within the higher part of the equivalent of the Seaford Chalk Formation. The Flamborough Chalk Formation (260–280 m thick, on the basis of logs of uncored deep commercial wells drilled through the Chalk subcrop beneath Devensian sediments under Holderness) is named after Flamborough Head, and is characterized by flintless, relatively marly chalk with numerous marl seams. It is not possible at present to identify the Burnham-Flamborough boundary on a faunal basis. However, since the base of the *Uintacrinus socialis* Zone lies 70 m above the High Stacks Flint (at the top of the Burnham Chalk Formation; see Flamborough Head GCR site report, this volume), it is clear that the higher part of the equivalent of the *Micraster coranguinum* Zone is enormously expanded here compared to its development in southern England. The base of the offshore Jukes Formation (Lott and Knox, 1994) approximates to the base of the Santonian Stage, which is situated only a short distance below the base of the Flamborough Chalk.

A detailed graphic section through the entire Flamborough Chalk Formation was given by Whitham (1993); the Upper Santonian and basal Campanian succession was subsequently revised by Mitchell (1994, 1995b).

### Rowe Formation

The logs of the Holderness wells (Sumbler, 1996) show that the flintless chalk is overlain by up to 70 m of flinty chalk. This latter unit has been recognized in offshore wells, where it has been given the name 'Rowe Formation' (Lou and Knox, 1994). However, nannofossil evidence indicates (Bailey, pers. comm., 1999) that the base of the offshore Rowe Formation appears to be approximately coincident with the Campanian–Maastrichtian boundary as recognized in the glacio-tectonic successions in north Norfolk at Sidestrand (see Overstrand to Trimingham Cliffs GCR site report, this volume) and not, as suggested by Lott and Knox (1994) with the base of the *Belemnitella mucronata* Zone. The up-section change, in the subcrop, from flintless Flamborough Chalk to flinty chalk may correspond to the change in the subcrop in the Southern Province at the boundary between the Newhaven Chalk and Culver Chalk formations. Unfortunately there are no reliable biostratigraphical data to confirm this interpretation.

## Biostratigraphy

The biostratigraphy of the Chalk of the Northern Province exhibits greater similarities to that of contemporaneous successions in northern Germany than to the basinal chalks of the Southern Province and Anglo-Paris Basin.

### Cenomanian Stage

The Cenomanian strata of the Northern Province were formerly traditionally divided by means of echinoids into a lower Zone of *Holaster subglobosus* and a higher Zone of *Holaster trecensis.* This contrasted with the parallel zonal scheme for southern England, which recognized a lower *Schloenbachia varians* Zone, succeeded by a *Holaster subglobosus* Zone. However, both schemes were based on misconceptions of the range and occurrence of *H. subglobosus:* on the one hand, the small *Holaster (H. bischoffi* Renevier) in the Lower Cenomanian deposits of the Northern Province were incorrectly attributed to *H. subglobosus* (Leske) and, on the other, in neither province does *H. subglobosus* range above the Nettleton Stone, or its equivalent (Jukes-Browne Bed 7). The Cenomanian strata of the Northern Province are relatively poorly fossiliferous, particularly in respect of ammonites. However, they can be successfully correlated with the more fossiliferous equivalents in northern Germany, and with the successions in the Southern Province by means of bio-events. On this basis, it is possible to infer the positions of the ammonite zonal boundaries, even though the zonal index fossils themselves are largely absent.

The Albian–Cenomanian boundary and, hence, the base of the Upper Cretaceous Series, falls near the top of the expanded Hunstanton Red Chalk Formation in the basinal succession developed at Speeton Cliff in the Cleveland Basin. Full biostratigraphical data, and details of the stable isotope correlation that allows the base of the Cenomanian Stage to be exactly located in this succession are given under the description of this section (see Flamborough Head GCR site report, this volume). It is only in the platform successions, for example Melton Bottom Chalk Pit, Middlegate Quarry, South Ferriby and Hunstanton Cliffs, where there is a hiatus at the boundary, involving both upper Albian and basal

Cenomanian strata. In these cases, the base of the Upper Cretaceous succession (i.e. the base of the Cenomanian Stage) is taken at the thin dark marl beneath the Paradoxica Bed, and thus approximately at the base of the restricted Ferriby Chalk/Lower Chalk Formation.

The Cenomanian–Turonian boundary falls in or just above the 'Black Band' in the Northern Province. Wood and Mortimore (1995) described this variable succession of extremely condensed thin limestones and silts, within which there may be one or more black bands and marl seams, as the 'Variegated Beds' (Figure 5.5). The type locality is Melton Ross Quarry, Lincolnshire, where the Variegated Beds contained at least two black bands. Beds immediately below the Black Band proper can be correlated with the Plenus Marls Member of the Southern Province (*Metoicoceras geslinianum* ammonite Zone) at least up to and including Jefferies' Bed 4. The Black Band itself may equate with the basal part of the Sussex Melbourn Rock–Meads Marls of the Southern Province. The Cenomanian–Turonian boundary falls between the Black Band and the terminal green clay of the Variegated Beds (see Wood and Mortimore, 1995). It is, therefore, incorrect to treat the Variegated Beds as the correlative of the Plenus Marls, as has been done by Whitham (1991) and by Jeans *et al.* (1991). The equivalent of the Black Band is, rather, to be sought in the lower part of the thick terminal Cenomanian (*Neocardioceras juddii* Zone)–basal Turonian (*Mytiloides* spp. Zone) black shales that overlie the so-called 'Plenus Limestone' in basinal successions in northern Germany (cf. Ernst *et al.,* 1984; Hilbrecht and Dahmer, 1994; Wood and Ernst, 1998). The Black Band also equates with the (Lower Turonian) Black Band at the base of the Herring Formation of Southern North Sea Basin stratigraphy.

### Turonian Stage

The limits and diagnostic faunas of the traditional *Mytiloides* spp., *Terebratulina lata* and *Sternotaxis plana* zones of the Turonian Stage of southern England can be recognized without difficulty. However, the echinoid genus *Infulaster,* which is virtually absent from the Southern Province, is a characteristic and common faunal element throughout the higher part of the *lata* Zone and the entire *plana* Zone.

As yet there is no unequivocal evidence for the existence of the *Fagesia catinus* Zone in the Northern Province. However, the Lower Turonian *Mammites nodosoides* (ammonite) Zone is widely represented by *Mammites nodosoides* (Schlotheim) and *Morrowites wingi* (Morrow) (see Melton Bottom Chalk Pit GCR site report, this volume). *Mytiloides labiatus* (Schlotheim) and *M. mytiloides* (Mantel), are also found throughout the province, indicative of the *Mytiloides* spp. Zone (*Inoceramus labiatus* Zone of earlier zonal schemes).

The basal Middle Turonian zonal marker fossils *Collignoniceras woollgari* and *M. subhercynicus* have not been recorded in the Northern Province. Proxies for this boundary, the brachiopods *Concinnithyris* and *Terebratulina lata,* are recorded a short distance below the Grasby Marl (see Melton Bottom Chalk Pit GCR site report, this volume) in the Welton Chalk Formation.

Inoceramid bivalves of the *Inoceramus lamarcki* Parkinson and *I. cuvieri* J. Sowerby complex (*I. brongniarti* in the earlier literature on this area) first become conspicuous above the Grasby Marl, and are abundant in the interval between Barton Marls 2 and 3. The latter acme-occurrence corresponds in northern Germany to the *lamarcki/cuvieri* event 2, above tuff $T_c$ (cf. Ernst *et al.,* 1998, figs 6.1, 6.2), the equivalent of Barton Marl 1. *Sternotaxis plana* (Mantell) first appears below Barton Marl 3, and in the Ferruginous Flint, a short distance above. A thin bed midway between this flint and the Melton Ross Marl, containing specimens of *Inoceramus lamarcki sensu stricto,* corresponds approximately to the type horizon of this biostratigraphically important species, at Langdon Bay near Dover. Apart from a relative abundance of the zonal index fossil, *Terebratulina lata* R. Etheridge, between, and for some distance above, the paired Deepdale Marls, little is known about the biostratigraphy of the highest part of the Welton Chalk.

The basal Upper Turonian ammonite zonal index species *Subprionocyclus neptuni* (Geinitz) is represented by a single find from below Deepdale Marl 1, a horizon inferred to be the equivalent of the basal Upper Turonian *costellatus/plana* event of northern Germany. The rich *neptuni* Zone ammonite fauna of the Chalk Rock is represented only by rare, poorly preserved specimens from the equivalent of the Kingston nodular beds (*S. plana* Zone), including the rare species *Pseudojacobites farmeryi* (Crick) (cf. Kennedy and Kaplan, 1995a).

The *Sternotaxis plana* Zone (Upper Turonian) is located at the base of the Burnham Chalk Formation. In the very condensed section at Newbald Wold Pit, Whitham (1991) recorded a remarkable concentration of echinoids, including primitive *Echinocorys, Infulaster* spp., common *Sternotaxis plana* (Mantel) and a single specimen of *Micraster michelini* (Agassiz), in and just above a bed of marly, nodular flaser-chalk at the base of the Burnham Chalk Formation. Wood (1992) noted that the association of *M. michelini* and common *S. planes* supported the correlation with the basal beds of the *S. plana* Zone of Dover, i.e. the Bridgewick Flints.

The Chalk Rock *reussianum* fauna of southern England is represented in the north by extremely rare, poorly preserved ammonites, including *Allocrioceras angustum* (J. de C. Sowerby), *Hyphantoceras reussianum* (d'Orbigny), *Lewesiceras mantelli* Wright and Wright and *Pseudojacobites farmeryi.* These ammonites come mainly from unspecified levels in the interval between the Wootton Marls and the Ulceby Marl, although Whitham (1991) recorded the eponymous *H. reussianum* from immediately beneath the Wootton Marls, and large, smooth ammonites occur in the bed beneath the Ulceby Marl at several localities. *P. farmeryi,* which belongs to the highest of the three ammonite faunas described from the contemporaneous 'Scaphitenschichten' of northern Germany (Kaplan and Kennedy, 1996), is extremely rare in the Chalk Rock, and was originally described on the basis of a single, extremely distorted specimen (Crick, 1910b; Kennedy and Kaplan, 1995a, p1. 4) from a Northern Province locality, the Boswell Farm Pit [TF 279 906] north of Louth. This same interval at Boswell Farm is highly fossiliferous, yielding a rich and well-preserved echinoid fauna, including common specimens of the large, thin-tested, primitive *Micraster corbovis* Forbes and subordinate, smaller *Micraster leskei* Desmoulins, which are typically Northern, and Southern, Province forms respectively.

The Ulceby Oyster Bed, in which small pycnodonteine oysters are abundant, marks a significant faunal change, with the entry of a diverse brachiopod fauna of Chalk Rock type, for example *Cretirhynchia cuneiforrnis* Pettit and *Gibbithyris subrotunda* (J. Sowerby), together with 'advanced' *Micraster* of the *bucailli* group. Immediately beneath this bed there is a sponge bed characterized by the typically Northern Province sponge species, *Cystispongia bursa* Quenstedt (Wood, 1992; Wiese and Wood, 2001). The Ulceby Oyster Bed is inferred to equate with the echinoid-rich *Micraster* Marl of northern Germany (Wiese and Kroger, 1998), both being beds situated a short distance above a vulcanogenic clay, the Ulceby Marl and Tuff $T_F$ respectively (Wray and Wood, 1998).

### Coniacian Stage

The Turonian–Coniacian boundary is present at the Enthorpe Railway Cutting GCR site and falls somewhere in the interval containing the three Kiplingcotes Marls. The biostratigraphy of the remainder of the Coniacian Stage was documented by Whitham (1991) and Wood (1992). A feature of particular note in the lower part of the Northern Province equivalent of the *Micraster cortestudinarium* Zone is the co-occurrence of *Micraster normanniae* and *M. corbovis,* together with a diverse *Cremnoceramus* assemblage, including *C. crassus inconstans* (Woods) and C. *c. crassus* (Petrascheck). In the higher part of the zone, the Southern Province zonal index species is also absent, being replaced here by the characteristically Northern Province *Micraster* of the *bucailli* group. Here, a lower *Cremnoceramus crassus–Inoceramus annulatus* Goldfuss assemblage is succeeded by a monospecific *I. annulatus* assemblage, a faunal change which has so far not been recognized in the Southern Province, but which has been recently identified in northern Germany (Walaszczyk and Wood, 1999c).

In the *M. cortestudinarium* Zone, echinoids are common, but the Northern Province form *Micraster bucailli* Parent replaces the Southern Province *M. cortestudinarium* (Goldfuss) and *M. decipiens* (Bayle) forms. The zone could be readily subdivided by means of echinoids, and the European Lower Coniacian inoceramid bivalve zones (Walaszczyk and Wood, 1999a,b) can also be identified. The rarity of *Micraster* in the equivalent of the *Micraster coranguinum* Zone (with the exception of the lower beds) has led to the introduction of a local Zone of *Hagenowia rostratus.* This zone, introduced by Rowe (1904), is based on a misconception that the common *Hagenowia* (actually *H. anterior* Ernst and Schulz) in the Flamborough Chalk, ranged throughout the interval in question. There is no suitable Northern Province zonal index species for this zone. However, the basal beds can be assigned to the European *Volviceramus koeneni* and V. *involutus* inoceramid bivalve zones, followed by a local zone characterized by *Inoceramus digitatus* J. de C. Sowerby.

The basal beds of the equivalent of the *Micraster coranguinum* Zone yield rich mixed *Platyceramus–Volviceramus* inoceramid bivalve faunas, as in southern England. The basal Middle Coniacian inoceramid zonal index species, V.

*koeneni* (Mailer), which is uncommon in the south, occurs in a shell-bed close to the base of the zone. Noteworthy occurrences at this level are *Inoceramus gibbosus* Schlüter, which is common in the *koeneni* Zone in Germany, but has not so far been recorded from the Southern Province; and a single specimen of the extremely rare belemnite *Actinocamax bohemicus* Stolley (Christensen, 1982) from the now backfilled Little Weighton Quarry. The succeeding zonal index fossil, V. *involutus* (J. de C. Sowerby), is found in proximity to a giant flint, the Eppleworth Flint, above which *Platyceramus* dominates the inoceramid bivalve assemblage. This faunal change parallels that found in the Southern Province at and above the level of the Seven Sisters Flint.

The beds below the Middleton Marl at Middleton-on-the-Wolds Quarry [SE 942 501], and in the Killingholme boreholes in Lincolnshire, contain specimens of the very large inoceramid bivalve *Inoceramus digitatus* J. de C. Sowerby, which has a thick, tyically purple-coloured, strongly corrugated shell, with radiating ribs and a massive hinge. This fossil was originally described from a flint internal mould found in gravels in Essex, and is not known from the correlative level in southern England. Siliceous sponges, three-dimensionally preserved in limonite, are also common in these beds. In the higher part of the section, above the *marl, Volviceramus* re-appears, perhaps indicating the lower part of the Upper Coniacian succession of the European scheme.

### Santonian Stage

By comparison with the Southern Province, the basal Santonian echinoids such as *Micraster coranguinum sensu stricto, M. gibbus,* and *Conulus albogalerus* are very rare or absent in the Northern Province. Even the stage boundary index inoceramid bivalve *Cladoceramus undulatoplicatus* (Roemer) is difficult to find. *C. undulatoplicatus,* found in only two horizons at Selvvicks Bay (see Flamborough Head GCR site report, this volume), allows recognition of the basal Santonian Zone. *Cladoceramus* is also recorded about 12 m above the Middleton Marl in the Killingholme Borehole NIREX BH 37 (Berridge and Pattison, 1994, fig. 19). Other index fossils of the Lower Santonian Substage in the Northern Province found about 1 m above the higher *Cladoceramus* horizon are the echinoid *Infulaster infulasteroides* (Wright and Wright), together with terebratulid brachiopods (*Gibbithyris*) and inoceramid bivalves that are possibly *Sphenoceramus cardissoides* (Goldfuss). The occurrence of *Cordiceramus cordiformis* in inoceramid bivalve rich, fossiliferous chalk over about 4 m suggests a correlation with the *Cordiceramus*-acme in the Middle Santonian strata of northern Germany (Ernst and Schulz, 1974), and indicates a possible upper limit to the Lower Santonian succession in the Northern Province. In terms of the Southern Province, this would fall in the higher part of the *Micraster coranguinum* Zone.

The entire equivalent of the *coranguinum* Zone, which spans the terminal Burnham Chalk and the basal Flamborough Chalk, was placed by Rowe (1904) in the local zone of *Infulaster rostratus.* This was based on the misunderstanding that, in view of the rarity of the Southern Province zonal index fossil, the flood occurrences in the Flamborough Chalk of *Hagenowia anterior* (mistakenly identified by him and later workers as *Infulaster* (now *Hagenowia) rostratus(a)*) could be used to characterize both the flinty (Burnham) and flint-less (Flamborough) parts of the zone.

The *Uintacrinus socialis* and *Marsupites testudinarius* zones are well developed here, although their original limits (Rowe, 1904) have been revised (Whitham, 1993; Mitchell, 1994, 1995b) on the basis of bed-by-bed collecting.

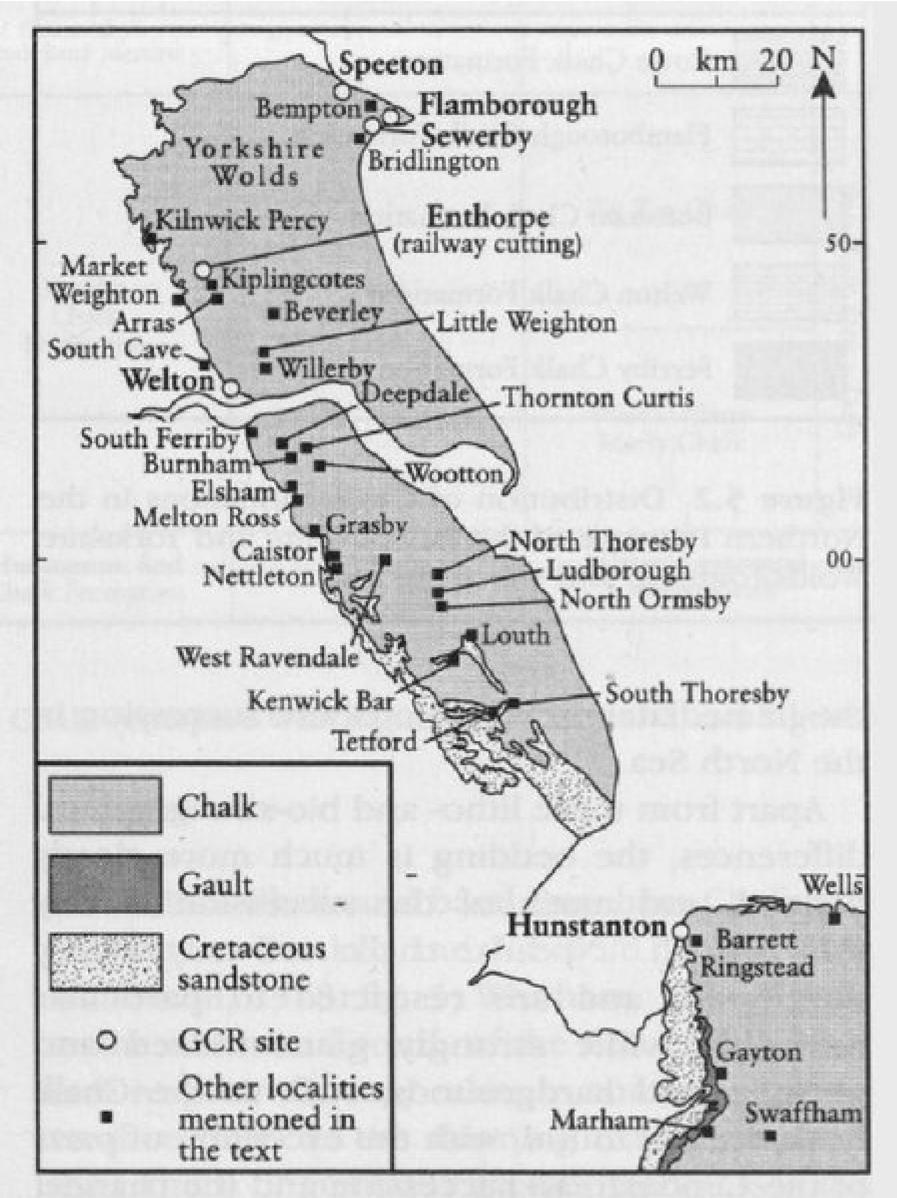
### Campanian Stage

The beds between the upper limit of *Marsupites* and the top of the section by Sewerby Steps, including the famous Flamborough Sponge Beds, were assigned by Rowe (1904) to the local zone of *Inoceramus* (now *Sphenoceramus*) *lingua* ((Figure 2.25), Chapter 2), which replaced the Zone of *Actinocamax quadratus* then applied in the Southern Province. Mitchell (1995b) separated the basal beds of Rowe's *lingua* Zone as an independent zone of *Uintacrinus anglicus,* on the basis of recognizing two discrete minor floods of the eponymous crinoid. The *S. lingua* Zone is characterized by *S. patootensiformis* Seitz ((Figure 2.25), Chapter 2) and *S. angustus* Beyenburg and is commonly assigned to the *S. patootensiformis* inoceramid Zone ((Figure 2.27), Chapter 2).

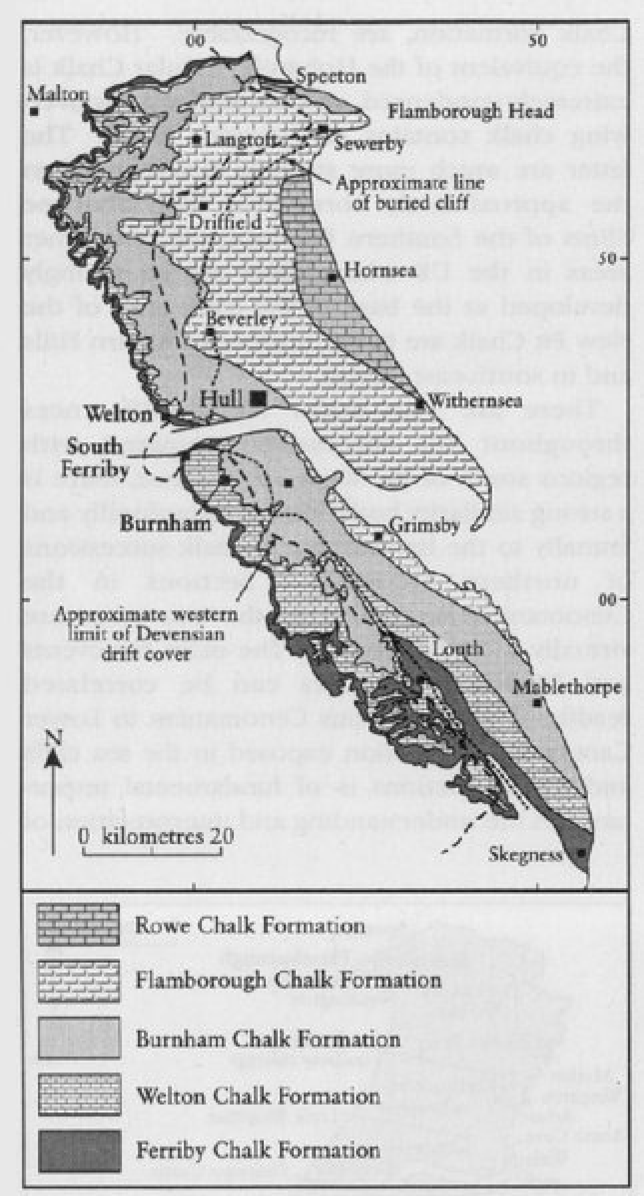
At Sewerby Steps, the occurrence of the heteromorph ammonite *Scaphites binodosus* Roemer, was taken by Whitham (1993) to mark the base of the *Discoscaphites binodosus* Subzone (Wright and Wright, 1942) of the *lingua* Zone. On the basis of the ammonite and inoceramid bivalve faunas, there is no evidence that the currently exposed coastal and inland

Chalk in Yorkshire extends any higher than the lower part of the equivalent of the *Offaster pilula* Zone of southern England. However, faunas recorded from now vanished pits by Wright and Wright (1942) and by Whitham (1993), including *Micraster schroederi* and the belemnite *Belemnitella,* are significantly different from those of the extant quarries, and may indicate a higher horizon, but still within the *Offaster pilula* Zone. None of the typical *Echinocorys* of the *Offaster pilula* Zone of the Southern Province has been found in Yorkshire and it is not, therefore, possible to apply the Southern Province zonal and subzonal scheme to the Northern Province.

[References](#)



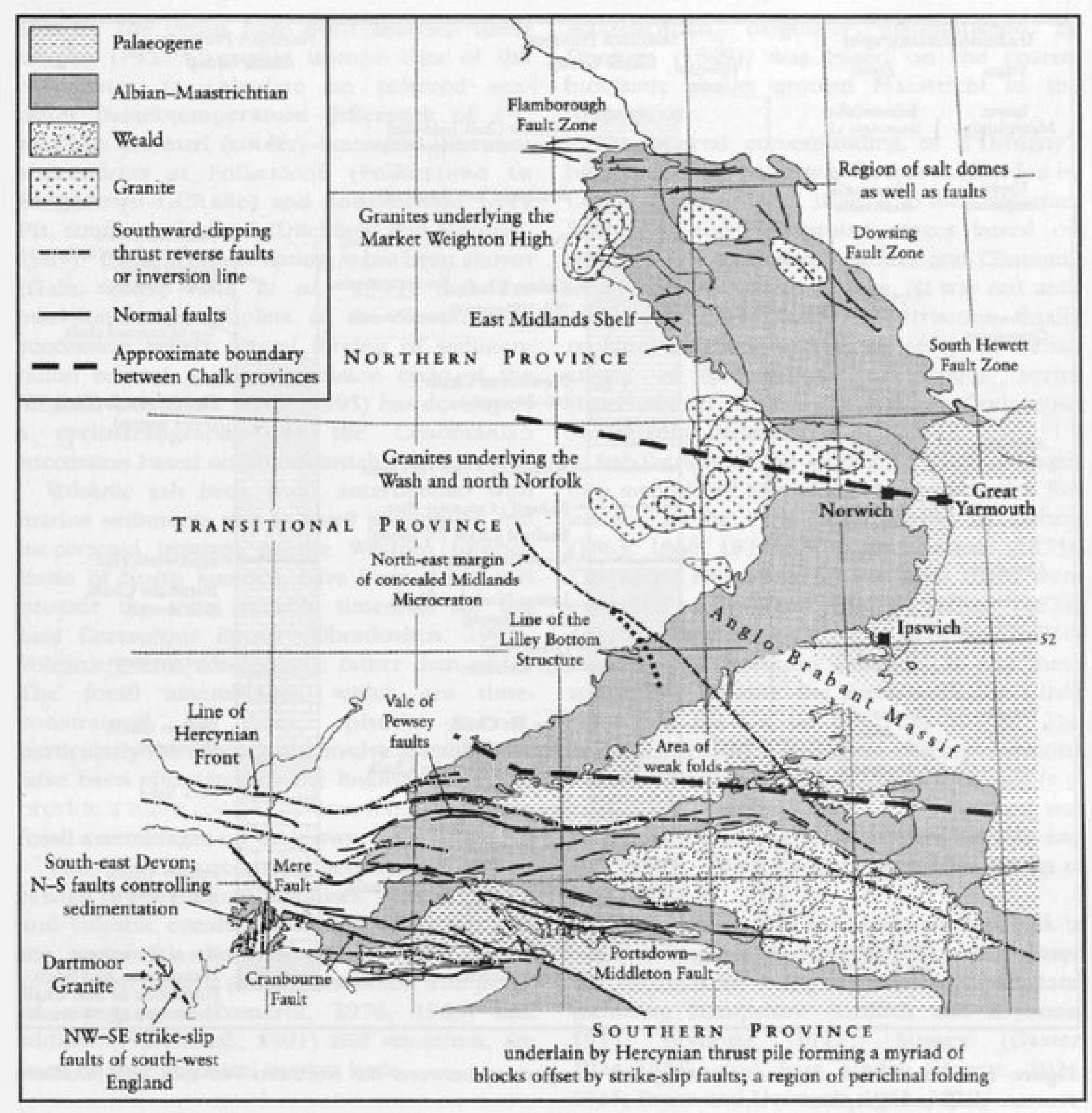

*(Figure 5.1) Location of GCR sites and other sites mentioned in the text in the Northern Chalk Province of England.*



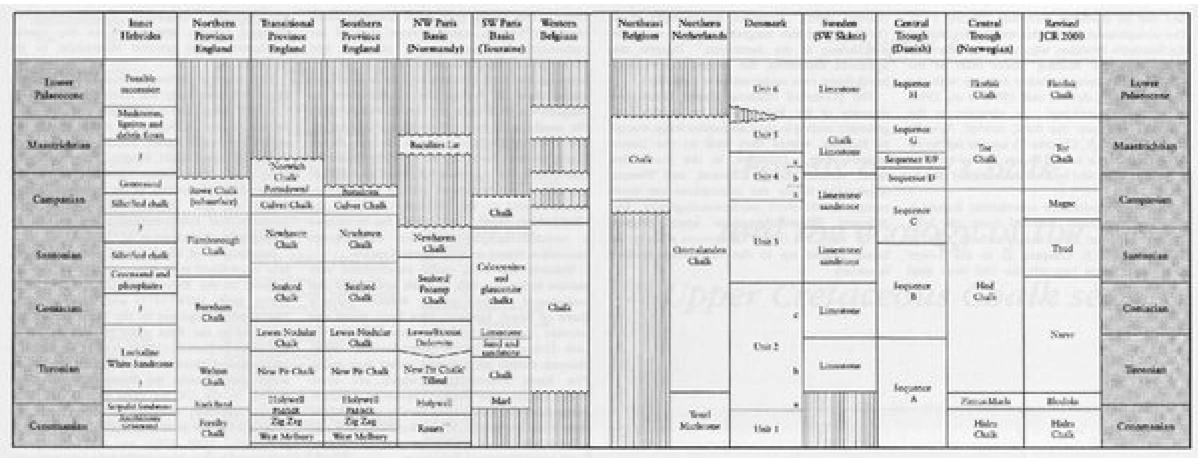

*(Figure 5.2) Distribution of Chalk formations in the Northern Province of the Lincolnshire and Yorkshire Wolds (outcrop and subcrop).*

| Stage | Biozones | | Lithostratigraphy | | | |
|---|---|---|---|---|---|---|
| | North | South | North | | South (Chalk Formations) | |
| Campanian | *Belemnitella mucronata* | | ? Rowe Formation | ? Flinty Chalk | Portsdown | |
| | ? | *Gonioteuthis quadrata* | ? | ? | Culver Chalk | White Chalk Subgroup |
| | *Sphenoceramus lingua* | *Offaster pilula* | Flamborough Chalk Formation | Chalk without flints | Newhaven Chalk | |
| | *Uintacrinus anglicus* | | | | | |
| Santonian | *Marsupites testudinarius* | | | | | |
| | *Uintacrinus socialis* | | | | | |
| | *Hagenowia rostrata* | *Micraster coranguinum* | | | Seaford Chalk | |
| Coniacian | *Micraster cortestudinarium* | | Burnham Chalk Formation | Chalk with flints | Lewes Nodular Chalk | |
| Turonian | *Sternotaxis plana* | *P. germari* | | | | |
| | | *S. neptuni* | | | | |
| | *Terebratulina lata* | *Collignoniceras woollgari* | Welton Chalk Formation | | New Pit Chalk | |
| | *Mytiloides* spp. | *M. nodosoides* | | Chalk without flints | Holywell Nodular Chalk | |
| | | *F. catinus* | | | | |
| | | *W. devonense* | | | | |
| Cenomanian | *Sciponoceras gracile* | *Neocardioceras juddii* | | | | |
| | | *Metoicoceras geslinianum* | Plenus Marls Black Band Member | | | |
| | *Holaster trecensis* | *Calycoceras guerangeri* | Ferriby Chalk Formation | Chalk without flints | Zig Zag Chalk | Grey Chalk Subgroup |
| | *Holaster subglobosus* | *Acanthoceras jukesbrownei* | | | | |
| | | *Acanthoceras rhotomagense* | | | | |
| | | *C. inerme* | | | | |
| | | *Mantelliceras dixoni* | | | West Melbury Marly Chalk | |
| | | *Mantelliceras mantelli* | | | | |
| Albian | | | Hunstanton Red Chalk Formation | Red Chalk | Upper Greensand and/or Gault | |

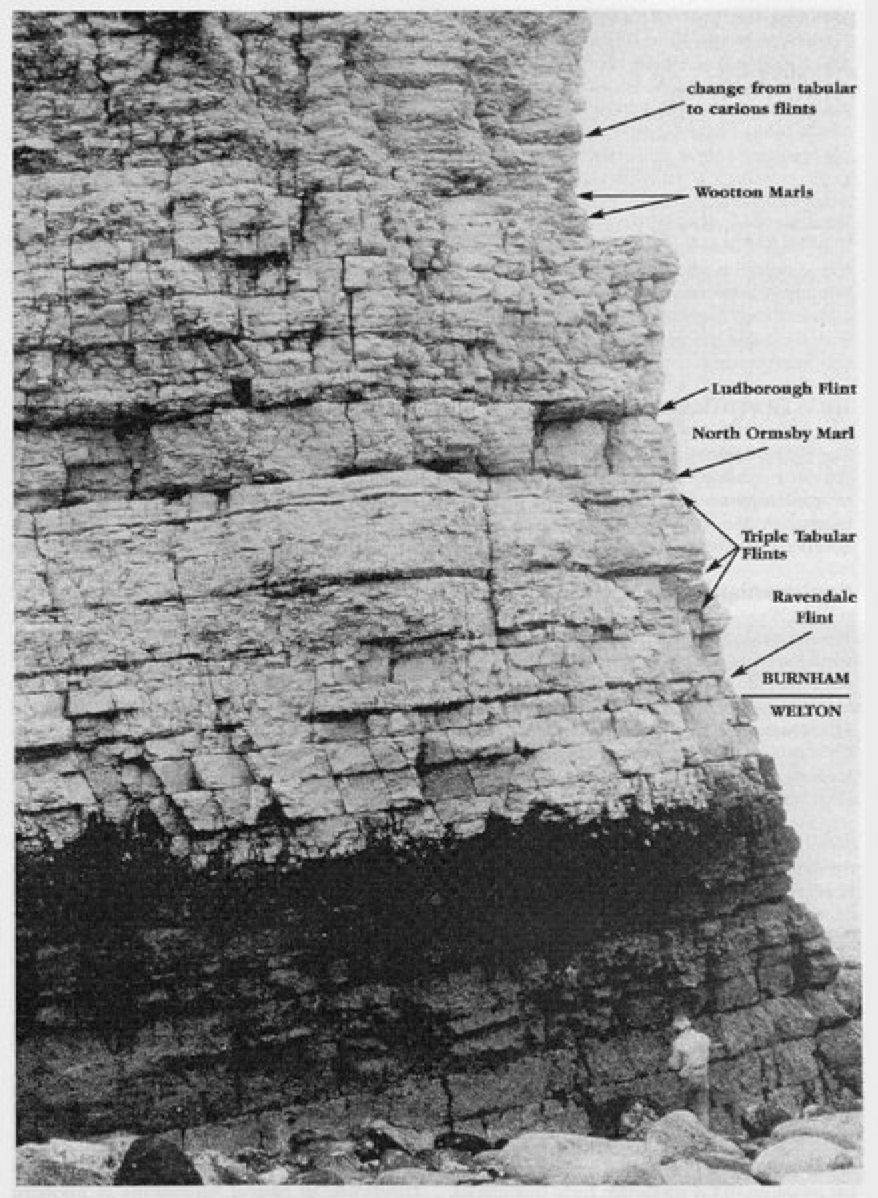
*(Figure 5.3) The stratigraphy of the Northern Province Chalk (compare with (Figure 1.5), Chapter 1 and Figures 2.8, 2.9, 2.21, 2.22 and 2.27, Chapter 2).*



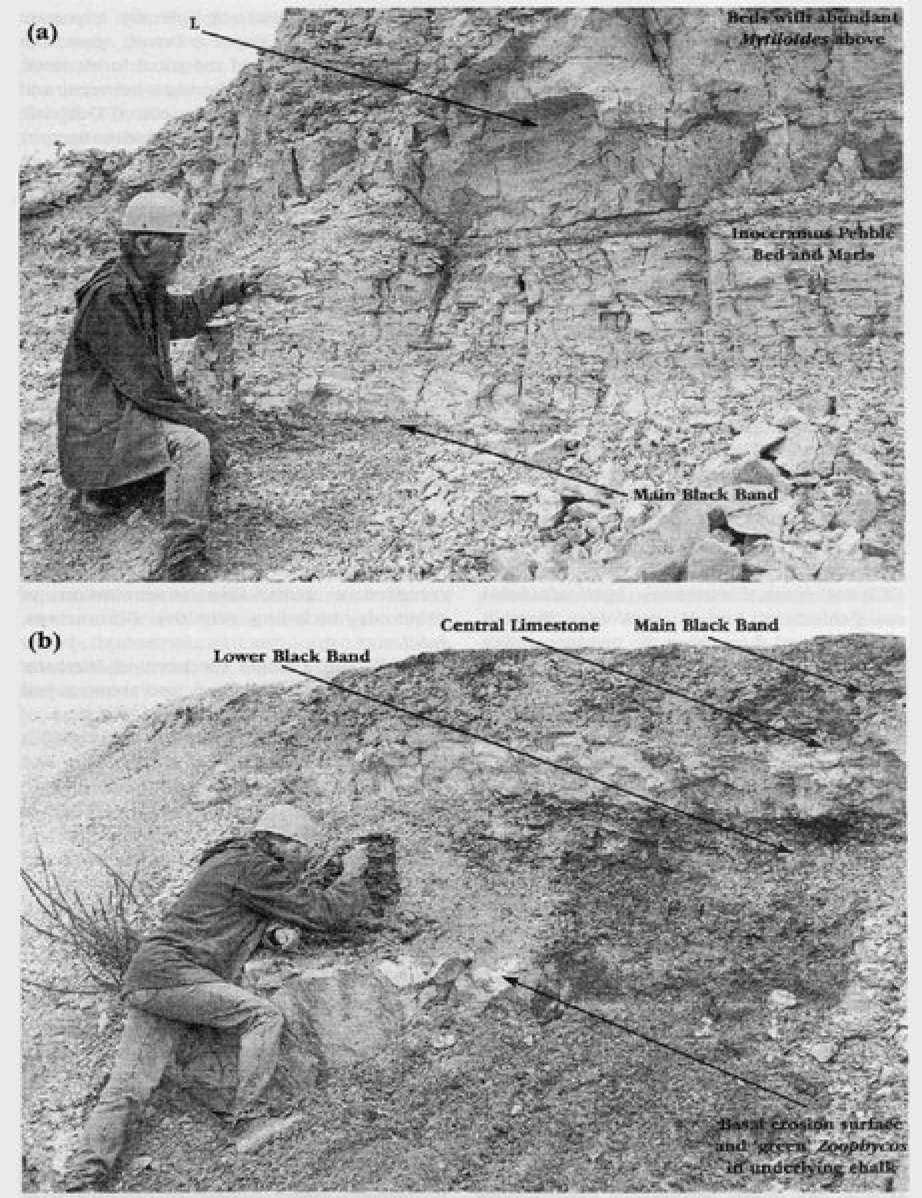

(Figure 1.15) Simplified structural map showing the main features affecting sedimentation of the Upper Cretaceous deposits of England.



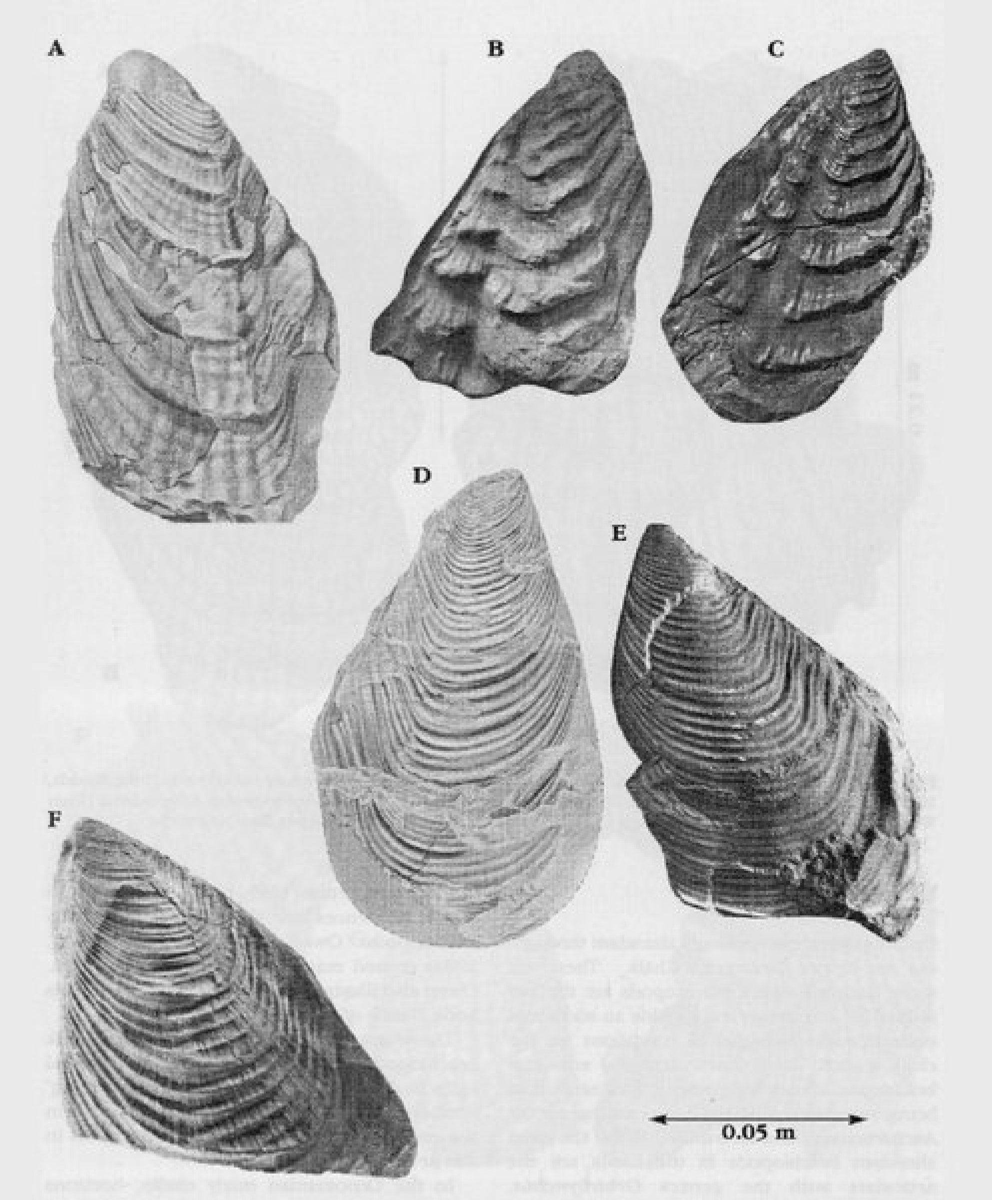

(Figure 1.17) Schematic and simplified stratigraphy of the Chalk and related carbonates in north-west Europe.



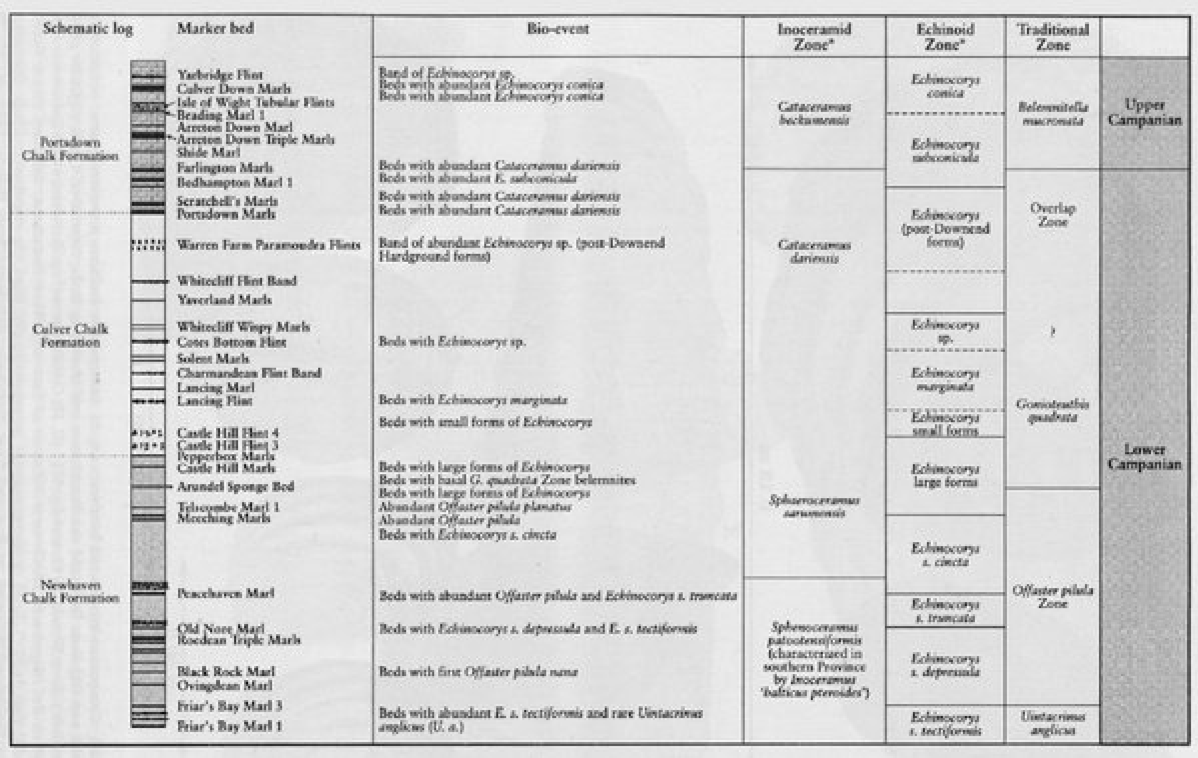

*(Figure 5.4) Key marker beds at the Welton-Burnham Chalk boundary, North Landing, Flamborough Head GCR site, Yorkshire. (Photo: C.J. Wood.)*




*(Figure 5.5) The Black Band of the Northern Province at the base of the White Chalk Subgroup and the Welton Chalk Formation. (a) The top of the Black Band to the twin marls (Inoceramus Pebble Bed) in Bigby Quarry Lincolnshire. Note the mould of a very large ammonite (Lewesiceras, labelled 'L'). (b) The Black Band succession of Variegated Beds in Melton Ross Quarry Lincolnshire. (Photos: R.N. Mortimore.)*




*(Figure 2.25) Lower Santonian and Lower Campanian inoceramid bivalves. (A) Sphenoceramus pathti (from Woods, 1912, text-fig. 57), Northern Province, Yorkshire coast, Santonian Micraster coranguinum Zone. (B, C) Sphenoceramus pathti pachti (from Seitz, 1965). (D, E) Sphenoceramus lingua; (D) typical of the upper Flamborough Chalk Formation, Lower Campanian, Northern Province (from Woods, 1912, text-fig. 54); (E) typical of the upper Flamborough Chalk Formation, Lower Campanian (from Seitz, 1965). (F) Sphenoceramus patootensiformis typical of the Lower Campanian, Northern Province (from Seitz, 1965). Scale bar applies to all specimens.*




*(Figure 2.27) Campanian stratigraphy for the onshore UK based on the Southern Province sections at Seaford Head, Portsdown and the Isle of Wight. (* = informal zones applied in this book.)*