# SOUTHERHAM PIT

*OS Grid Reference: TQ426096*

## Introduction

The Southerham Pit GCR site comprises three former quarries at Lewes, in the core of the Caburn Syncline. From south to north these are Southerham Works Pit (now Cliffe Industrial Estate), Chandlers Yard and the Navigation Pit (combined into one pit during construction of the A26 Cuilfail Tunnel, Figure 3.106; Figure 3.115, p. 257). These combined sections expose a continuous composite succession in the White Chalk Subgroup through virtually all of the Turonian Stage and most of the Coniacian Stage, from the shell-rich Holywell Nodular Chalk Formation to the Seven Sisters Flint Band in the Seaford Chalk Formation. The quarries are the type sections for the Southerham and Lewes marls, the Lewes Tubular Flints, the Cuilfail Zoophycos (Flints) and the Cliffe Hardground, all of which are used for long-range correlation within and outside the Southern Province. Together with sections in the immediate vicinity, the quarries provide the composite standard sections for the Lewes Nodular Chalk Formation. The Upper Turonian to Lower Coniacian succession is thicker and more complete than anywhere else in England, and contains fossils that are apparently not present elsewhere. Many of the fossils described and illustrated by Mantell (1822, 1827), and now housed in the Natural History Museum, London, came from these quarries. This is one of only two sites in England in which granular phosphatic chalk is known to occur in the Turonian strata, the other being the nearby Glyndebourne Pit.

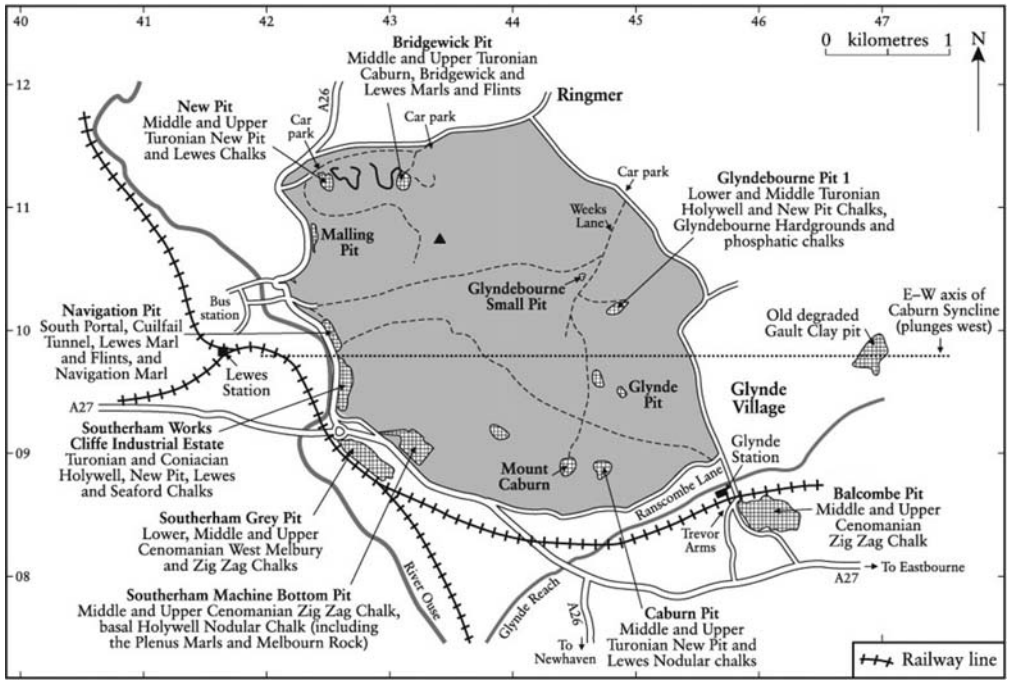


*Figure 3.106: Map of the Caburn group of chalk pits at Lewes, Sussex showing the position of the GCR sites (boldface type) in relation to correlative sections. (After Mortimore, 1997.)*

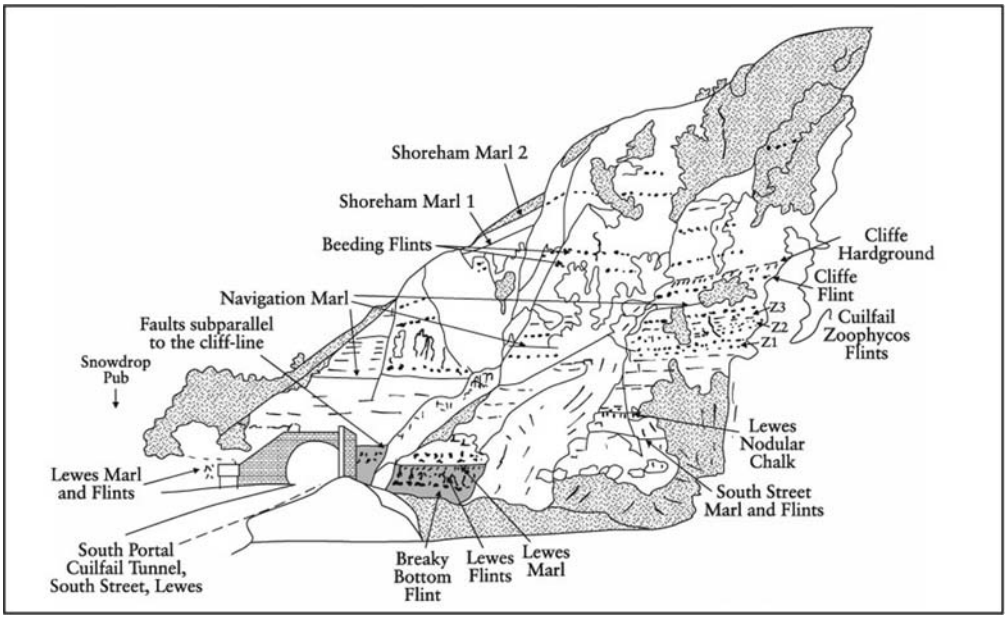


*Figure 3.115: The northern end of the Southerham Pit GCR site showing the Cuilfail Tunnel, South Portal cut in the former Navigation Pit. (After Mortimore, 1997.)*

These ‘Southerham' quarries are cut into the steep, west-facing slope of the Mount Caburn Chalk Block with the hill of Cuilfail overlooking the site from the north. This steep slope, one of the steepest natural slopes in England, was the site of a fatal avalanche in 1856. The avalanche swept off Cuilfail Hill onto a public house, which subsequently became known as ‘The Snowdrop'. Mantell (1822, Tablet II, fig. 3) and Jukes-Browne and Hill (1903, pp. 399–402, fig. 72) described the line of hills from Malling to Southerham informally as the ‘Cliff Hills'.

## Description

The three former quarries comprising the Southerham Pit GCR site expose Chalk with bedding dips of 30º north at the southern end in Southerham Works Pit, nearly horizontal below the Lewes Golf Club House in the former Chandlers Yard, and 5º –8º south at the northern end in the Navigation Pit. These angles of dip, and the plunge westwards of the strata, were first recorded and illustrated by Mantell (1822, p. 140 and Tablet VII). The quarries have been variously named depending on the occupancy. Southerham Works Pit is the most southerly and largest and was simply known as ‘the quarry at Southerham' by Mantell (1822, p. 140) and later the ‘Southerham Limekiln Quarry' (Jukes-Browne and Hill, 1904, p. 46), where lime kilns and, subsequently, the cement works, were located. It is now occupied by Cliffe Industrial Estate and exposes most of the Turonian and the Coniacian succession up to the Seven Sisters Flint Band. It includes the famous Lewes Phosphatic Chalk (Strahan, 1896; Jukes-Browne and Hill, 1904, p. 46), floored by Strahan's Hardground (Mortimore, 1986a,b). The phosphatic chalk overlies a mineralized hardground (Strahan's Hardground) which represents the lithification of a local channel. The overlying 15 m of flinty chalk are anomalous and are assumed to represent a channel-fill.

The next quarry to the north, Chandlers Yard, is named after Chandlers, a local Builders Merchants. Chandlers occupied the quarry until the Cuilfail Tunnel was constructed in 1978–1979 (Figure 3.115, p. 257). The quarry was last worked in the 19th and early 20th centuries, when a railway was used to transport chalk to the kilns in Southerham Works Quarry. Relict pieces of this railway were finally removed when the A26 was constructed south of the Cuilfail Tunnel, but its position is occupied by the slope bench in the spur of chalk dividing Southerham Works from Chandlers Yard. The most northerly of the quarries is the ‘Navigation' or ‘Snowdrop' Pit, which is named after the Navigation of the River Ouse construction project, completed in 1796, under the guidance of canal building civil engineer, William Smith. Mantell (1822, Tablet II, fig. 3 and p. 140) illustrates the position of a quarry that appears to be the Navigation Pit that he calls the ‘South Street Pit' where the strata were horizontal. Chalk was excavated from the Navigation Pit and other quarries (e.g. the Chalk Pit at Offham) for the original construction and subsequent maintenance of the revetments along

the banks of the Ouse between Lewes and Newhaven. White (1926, pl. IV) illustrated these quarries and the railway line between them.

## *Southerham Works Quarry (now Cliffe Industrial Estate) (TQ 425 095)*

The Southerham Works Quarry (formerly known as 'Eastwoods Pit' or 'Southerham Cement Works') has provided exposures for studying the stratigraphy of the Chalk since the end of the 18th century. Mantell's *The Fossils of the South Downs* (1822, Tablet VII) illustrates the extent of his 'Lower Chalk' then exposed at Southerham near the Old Lime Kilns. Parts of this old section still remained when Strahan (1896) and Dibley (1906) described the Lewes Phosphatic Chalk, but until recently it was degraded and overgrown. Since 1980, construction of the Cliffe Industrial Estate has resulted in a complete re-excavation of the whole succession from near the base of the Holywell Nodular Chalk Formation to the Beeding Beds in the upper part of the Lewes Nodular Chalk Formation, providing an outstanding section through the Turonian succession and the phosphatic chalk (Mortimore, 1986a,b; 1997). Parts of the succession were included in the descriptions by Jukes-Browne and Hill (1903, 1904) with lists of fossils and some lithological details. The first detailed logs of the stratigraphy were provided by Mortimore (1979, 1983, 1986a,b) and sketches of the exposures showing the stratigraphy are illustrated in Mortimore (1997).

### *Lithostratigraphy*

At the southern end of the quarry, the beds of the Holywell Nodular Chalk Formation dip relatively steeply north at 25° –30°. The lowest horizons that can be identified are the Holywell Marls and the griotte or flaser bedded chalks containing bands of abundant *Mytiloides* (Figure 3.114). Higher up-section are found the Gun Gardens Marls and, at the top of the formation, the Gun Gardens Main Marl, which here is associated with numerous nodules of red-weathering iron pyrites. The basal metre of the overlying New Pit Chalk Formation contains inconspicuous, small white flints, the Glyndebourne Tubular and Finger Flints, which take their name from a nearby locality, Glyndebourne Pit 1. Two normal faults filled with a weathered gouge complicate the section.

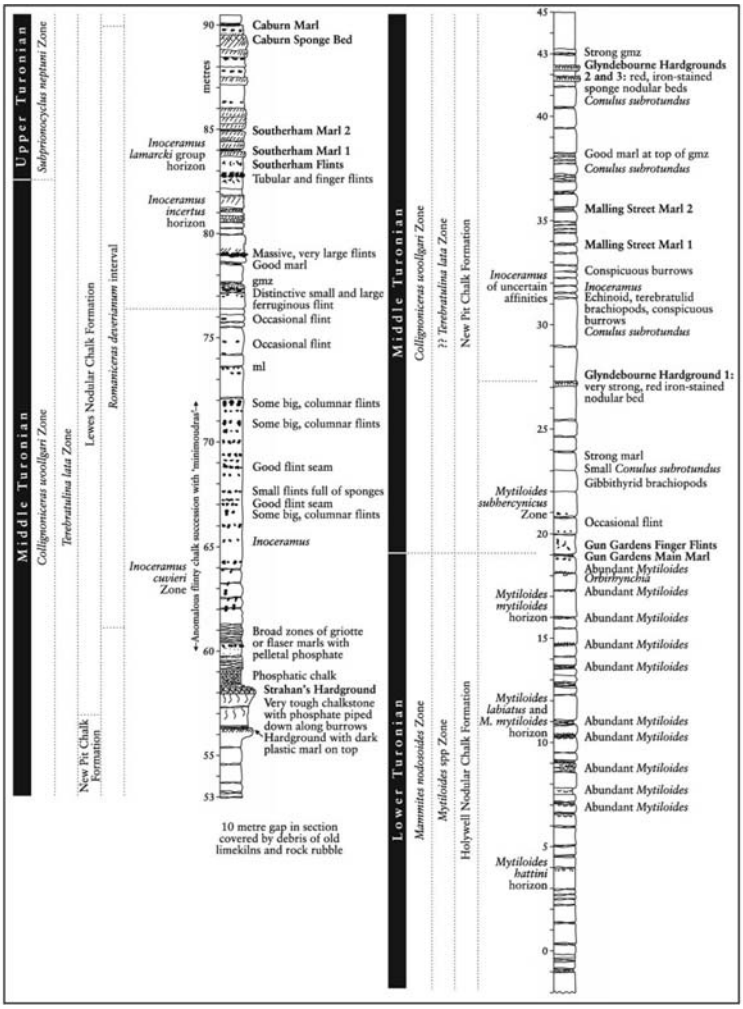


*Figure 3.114: Stratigraphy of the Turonian Holywell Nodular Chalk, New Pit Chalk and Lewes Nodular Chalk formations at Southerham Pit, Cliffe Industrial Estate (formerly known as 'Eastwoods Pit' or 'Southerham Cement Works'). (gmz = griotte (or flaser) marl zone; ml = marly laminae.)*

A strongly developed, red-orange, iron-stained nodular chalk bed in the now poorly exposed upper part of the section, where it turns eastwards towards the Malling Street Marls exposures, is the lateral equivalent of Glyndebourne Hardground 1 in the anomalous succession at Glyndebourne Pit 1. The section up to the Malling Street Marls is poor, but the two dark, plastic marls are well exposed at the south corner behind the first building (Mortimore, 1997, fig. 8). Iron-stained nodular beds, equivalent to Glyndebourne Hardgrounds 2 and 3 (Figure 3.114), are present in the succeeding face behind the first building.

The section between the Malling Street Marls and Strahan's Hardground is largely covered by scree, but the section above, up to the Cliffe Hardground, is well exposed. The lowest beds below the hardground contain a well-developed bed of nodular chalk overlain by a thick, plastic marl. Some 2 m above is the hardground originally described by Strahan (1896), and later named 'Strahan's Hardground' (Mortimore, 1986a,b). It is an intensely indurated chalkstone penetrated by an extensive *Thalassinoides* burrow system, which pipes the overlying phosphatic chalk up to 0.15 m below the heavily phosphatized surface. The walls of the burrows are glauconitized and phosphatized and the phosphatic chalk fills may include bored and mineralized pebbles of hardened chalk.

The hardground is overlain by the Lewes Phosphatic Chalk (Strahan, 1896; Figure 3.114), a complex unit *c.* 2 m thick of pelletal phosphatic chalk containing sharks teeth, with a basal lag of worn glauconitized and phosphatized pebbles. The pelletal phosphate is concentrated in the first 0.5 m. The phosphatic chalk is followed by a sparsely flinty unit comprising two flaser marls and a weakly developed marl seam, above which there is a thick interval (*c.* 10 m) of very flinty chalk, terminating in a pair of wispy marls. The beds above contain two conspicuous

bands of nodular flint, separated and overlain by thin marl seams. Some metres higher, above two closely spaced beds of indurated nodular chalk, are seen the paired Southerham Marls, for which this is the type section. The interpretation of the succession between Strahan's Hardground and the Southerham Marls presents difficulties and is discussed below.

In the succeeding section, the Caburn and Bridgewick marls are readily identifiable. Farther north in the old quarry, the Lewes Marl and Lewes Tubular Flints and the Navigation Marls can be seen on the steeply dipping south flank of the Caburn Syncline. At the northern limit of the quarry (TQ 425 098), the stratotype section of the overlying Cliffe Hardground is exposed (Figure 3.115) on the upper bench of the road cutting, where a spur formerly separated the Southerham Works Pit from Chandlers Yard. The Shoreham Marls and the Belle Tout Marls form grooves towards the top of the high, inaccessible part of the cliff, and the conspicuous Seven Sisters Flint Band can be seen just below the top.

## *Navigation Pit and Chandlers Yard (TQ 425 100) (South Portal, Cuilfail Tunnel)*

Construction of the Cuilfail Tunnel (1976–1978) has partly obscured the section formerly exposed in the Navigation Pit. As a result of the southerly dip, the entire lower Lewes Nodular Chalk succession up to the Lewes Marl was exposed during construction of the tunnel. The Navigation Pit is the stratotype section for the Lewes Marl and the Lewes Tubular Flints, as well as for the succession between the Lewes Marl and the Cliffe Hardground. The latter comprises, in ascending order, the South Street Beds, Navigation Beds and Cliffe Beds (Mortimore, 1986a) and includes several key marker horizons, notably the South Street Marl, the Lewes Nodular Chalks, the Cuilfail Zoophycos (Flints) and the Navigation Hardgrounds and Navigation Marls. The University of Brighton's South Street Research Borehole was drilled in the floor of Chandlers Yard, immediately to the south, to provide control geophysical logs. The non-standard resistivity and gamma logs obtained (Mortimore, 1986b) helped in the interpretation of the stratigraphical position of Strahan's Hardground and the overlying Lewes Phosphatic Chalk (see below) and provided information on thicknesses of the Turonian Chalk in the area. These stratigraphical studies were complemented by the logs from three rotary cored boreholes and the logging of an old well sunk through the hillside.

### *Lithostratigraphy*

The highest beds of the lower Lewes Nodular Chalk Formation (upper part of the Kingston Beds, Figure 3.116) are well exposed in the faulted section immediately south of the tunnel portal, dipping south on the northern limb of the Caburn Syncline. At the base of the section is seen a continuous layer of large flints, the Breaky Bottom Flint, which takes its name from a small section near Breaky Bottom Vineyard (TQ 405 055). The overlying succession, comprising two beds of nodular chalk, separated by non-nodular chalk, is penetrated by an inter-connecting network of spectacular branching *c.* 0.03 m diameter vertical ‘tubular' flints up to 3 m long, the Lower Lewes Tubular Flints (Figures 3.9b and 3.116). These flints are annular in cross-section, with the original burrow wall preserved as a thin layer of white chalk between an inner core and an outer layer of flint. The inner flint is frequently missing and/or weathered-out, leaving a tubular flint.

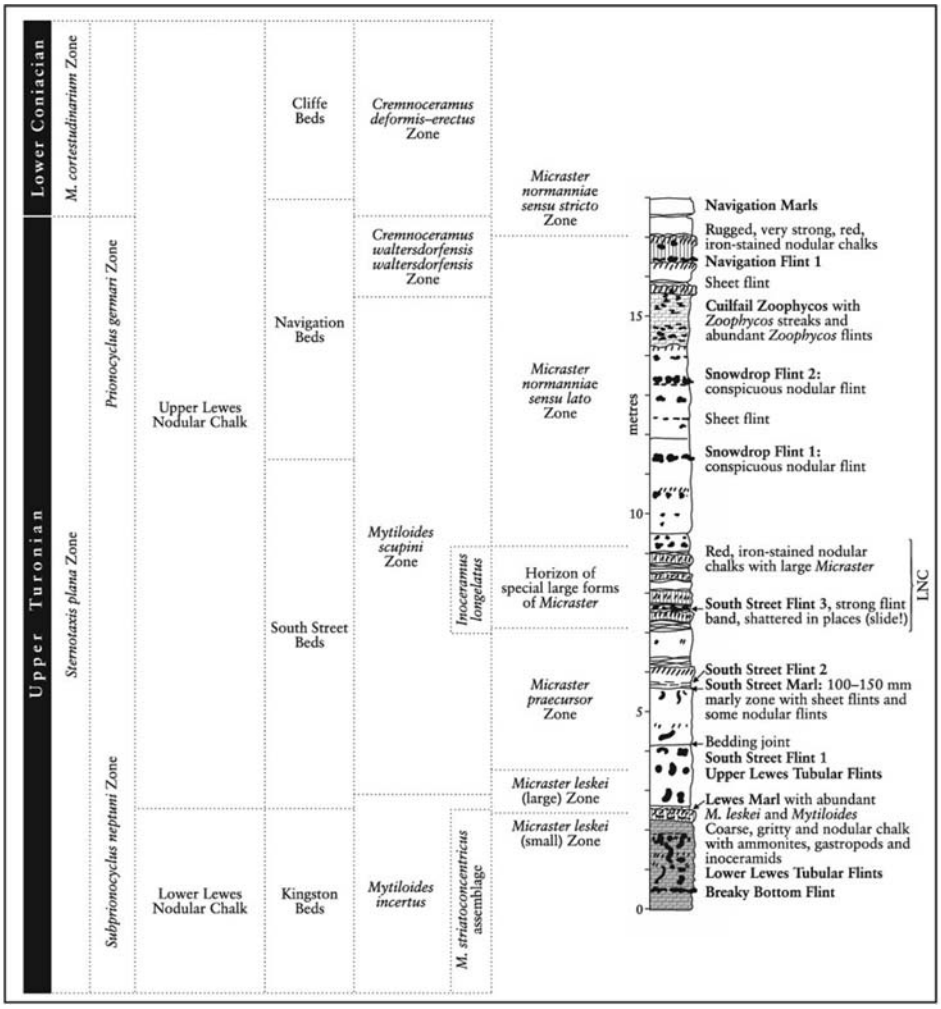


*Figure 3.116: The Southerham Navigation Pit, Lewes, Sussex, Late Turonian and the base of the Coniacian stages (inoceramid bivalve zones inferred by extrapolation from expanded successions in Germany, see Walaszczyk and Wood, (1999b)). (LNC = Lewes Nodular Chalk.)*

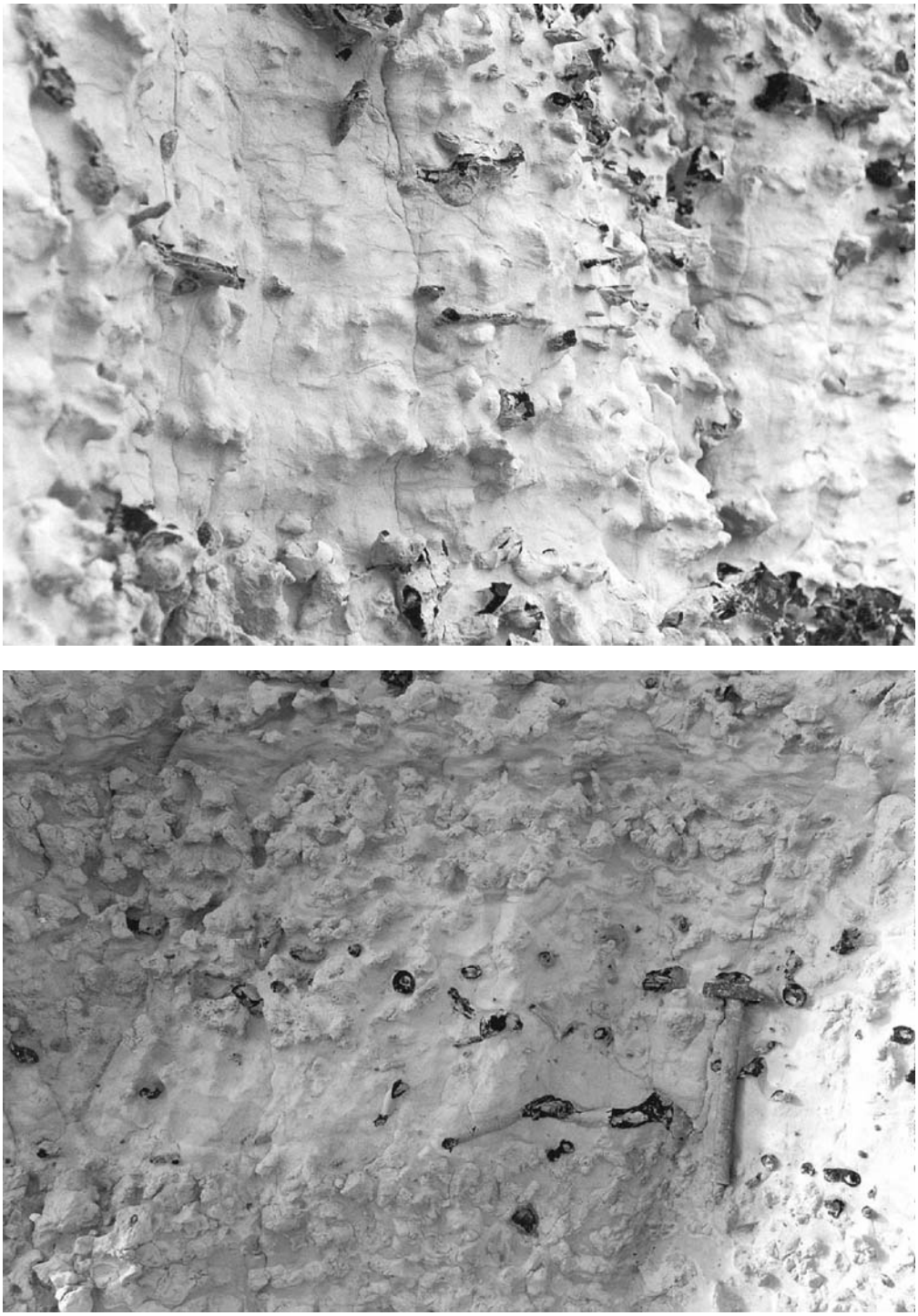

*Figure 3.9: (a, b) Basin-wide marker beds in the Upper Turonian part of the Lewes Nodular Chalk Formation present in the Hooken succession at Hooken Cliff. (Photos: R.N. Mortimore.)*

The top of the lower Lewes Nodular Chalk Formation is marked by a bed of hard, iron-stained nodular chalk, which is overlain by the Lewes Marl, 0.05–0.1 m thick (cf. Figure3.86). Although this marl is vulcanogenic (Wray, 1999), it has the 'brittle' (i.e. non-plastic texture) that is typically associated with a detrital marl and is full of mesofossil debris, mainly crinoid ossicles. It also contains many macrofossils, including inoceramid bivalves, regular echinoids and abundant *Micraster* (see below). Between 0.5 and 1 m above the Lewes Marl there are the Upper Lewes Tubular Flints, which are fatter and more dumbell-shaped than the elongate tubular flints below the marl. The South Street Marl, 2 m above the Lewes Marl, marks the base of the South Street Beds and also has a few thin elongate tubular flints below it. It is followed by beds of increasingly nodular chalk and flaser marls containing chalk pebbles (intraclasts). The nodularity culminates in the conspicuous group of iron-stained Lewes Nodular

Chalks and flaser marls.

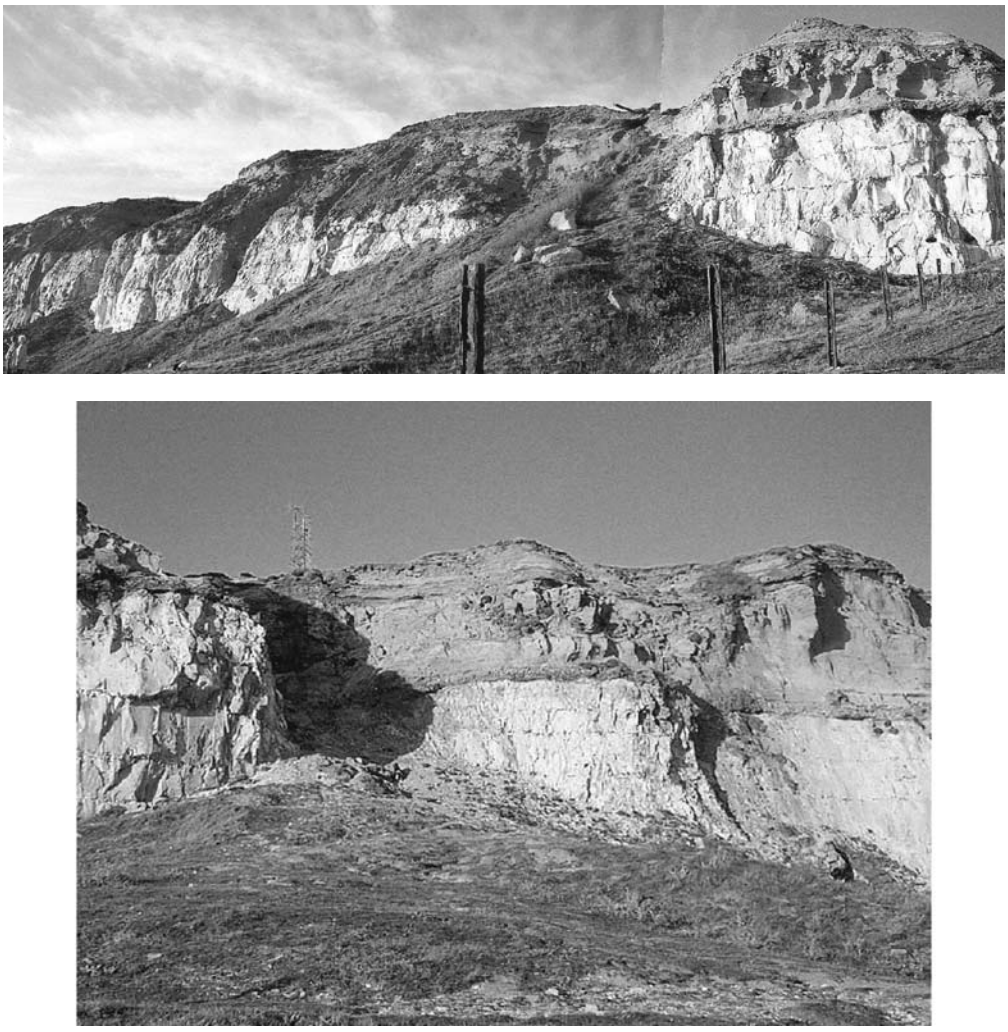

*Figure 3.86: Castle Hill, Newhaen, at the eastern end of the Newhaven to Brighton GCR Site illustrating the sub-Palaeogene unconformity (compare the flint stratigraphy with Figure 3.92). (Photomosaic: R.N. Mortimore.)*

Above this level, following two bands of ?conspicuous nodular flints (Snowdrop Flints, Figure 3.116), there is a significant change to soft chalks containing three horizons of the trace-fossil *Zoophycos*, which here (exceptionally) are silicified, forming '*Zoophycos* flints' that preserve details of the structure (Bromley and Ekdale, 1984a) (cf. Figures 3.9a and 3.10). These Cuilfail Zoophycos (Flints), named after the hill above the tunnel, are a distinctive feature of the higher part of the interval between the Lewes Nodular Chalks and the three more strongly indurated, nodular Navigation Hardgrounds. These hardgrounds are overlain by the closely spaced, paired Navigation Marls, the lower of which forms a conspicuous groove that is traceable across the lower part of the quarry face (Figures 3.115 and 3.116).

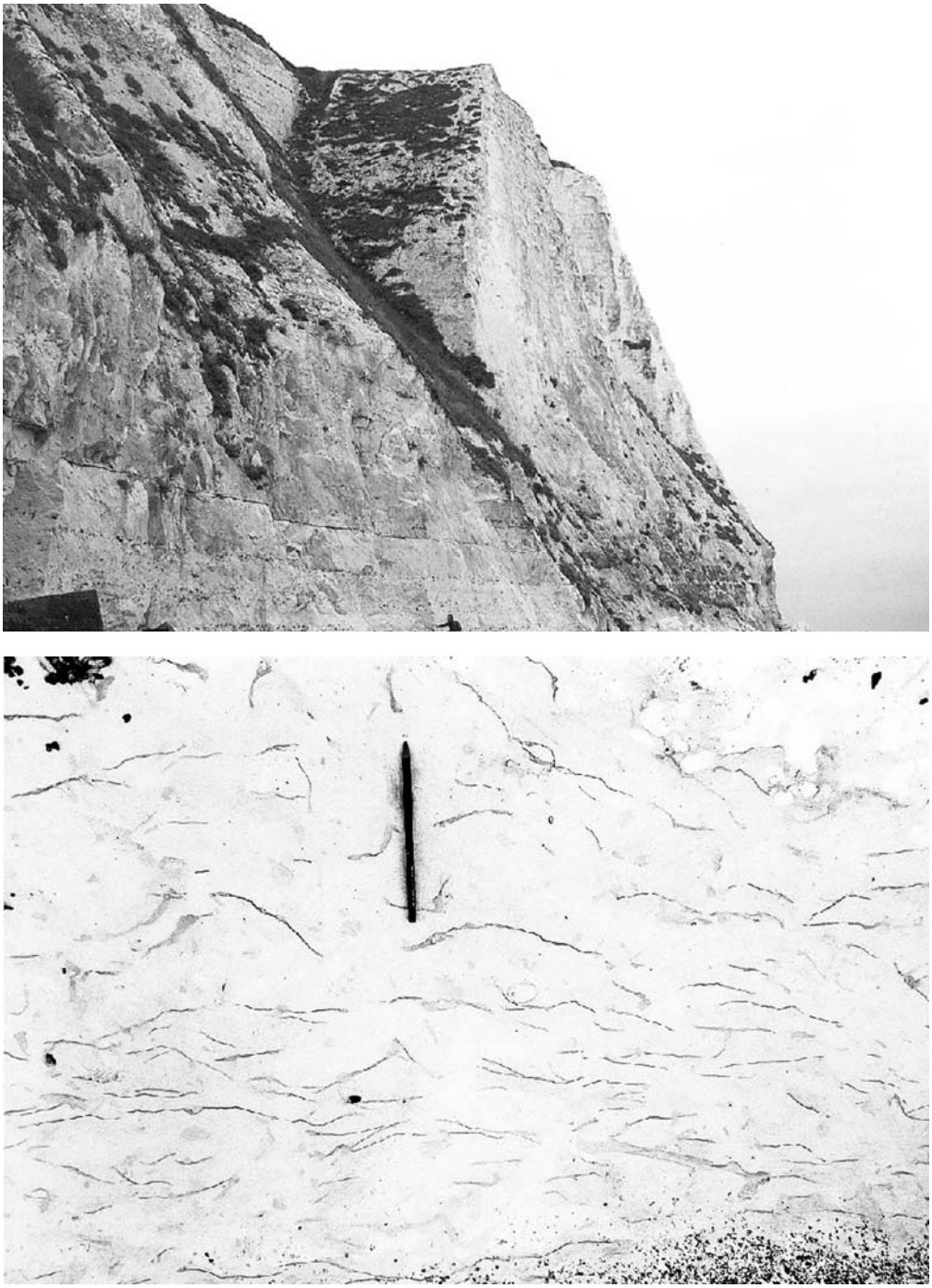

*Figure 3.10: Chalk adjacent to St Margaret's Bay, Dover. (a) South side of St Margaret's Bay beyond the South Foreland, showing the Cuilfail Zoophycos in the topmost Turonian strata. (b) North side of St Margaret's Bay, showing the topmost Lewes Nodular Chalk and basal Seaford Chalk formations. (Photos: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

### *Biostratigraphy*

In Southerham Works Pit abundant Lower Turonian *Mytiloides* have been obtained from the Holywell Nodular Chalk Formation in association with bands of *Orbirhynchia cuvieri* (d'Orbigny). There is a conspicuous change to a brachiopod–*Conulus subrotundus* assemblage above the Gun Gardens Main Marl, which marks the base of the Middle Turonian Substage (Figure 3.114). Few fossils other than *Conulus subrotundus* Mantell, large terebratulid brachiopods and nautiloids have been recorded from the interval between the Malling Street Marls and the Strahan's Hardground. Strahan's Hardground and the overlying Lewes Phosphatic Chalk is remarkably barren of fossils in contrast to many other phosphatic chalk deposits (e.g. **Boxford Chalk Pit** and **South Lodge Pit** GCR sites). Strahan (1896) recorded *Holaster planus* (i.e. *Sternotaxis plana* (Mantell)) from above the hardground. Fragments of

inoceramid bivalves indicative of *I. cuvieri* were found below the main hardground and *Terebratulina lata* R. Etheridge occurs both below and above Strahan's Hardground.

The ammonite *Lewesiceras peramplum* has been collected from between the two Southerham Marls in association with a remarkable specimen of *Holaster* cf. *subglobosus* (Leske).

In the Navigation Pit, the beds from the base of the section around the Breaky Bottom Flint up to the Navigation Marl 1 (Figure 3.116) belong to the Upper Turonian Substage. The abundance and variety of the heart-shaped urchin *Micraster* is a special feature here and in nearby chalk pits. The beds with the Lower Lewes Tubular Flints contain abundant inoceramid bivalves (*Mytiloides* spp., including *M. striatoconcentricus* (Gümbel)). Originally aragonitic shelled fossils, including the large gastropod *Bathrotomaria perspectiva* (Mantell) and heteromorph ammonites, are present in the nodular chalk horizons within the lower tubular flint belt, particularly at one horizon (Mortimore 1986a, 1997). Typical Chalk Rock rhynchonellid brachiopods, including *Orbirhynchia reedensis* (R. Etheridge), *Cretirhynchia minor* (Pettitt) and *C. cuneiformis* Pettitt, are also present in these nodular chalks below the Lewes Marl.

The Lewes Marl is remarkable for the abundance of *Micraster leskei* Desmoulins and *Mytiloides* that it contains. Some 500 specimens of *Micraster* have been collected from this marl here and in the chalk pits surrounding Lewes. The *Micraster* are predominatly the large forms of *leskei* (*leskei magna* of Drummond, in manuscript) in contrast to smaller forms typically found on the top surface of the Chalk Rock at **Charnage Down Chalk Pit** and **Kensworth Chalk Pit**. The interval above the marl containing the Upper Lewes Tubular Flints is characterized by *Micraster praecursor* (Rowe, in manuscript; Drummond, 1983).

Very large specimens of *Micraster* are found in the higher part of the South Street Beds (Figure 3.116) which is possibly the horizon of the holotype of *Micraster corbovis* (Forbes). Large, inflated specimens of *Sternotaxis placenta* (Agassiz) and *Echinocorys* occur immediately above and in the soft Cuilfail Zoophycos Chalks of the Navigation Beds.

Late Turonian *Mytiloides* are found in the South Street Beds and, with the evidence from Shoreham Cement Works, probably range up to the Navigation Hardgrounds. The topmost Turonian–Lower Coniacian inoceramid bivalve *Cremnoceramus waltersdorfensis* (Andert) has been found in the Navigation Marls and *Micraster normanniae* Bucaille enters above the Lewes Nodular Chalks. *M. normanniae* was taken in France to mark the traditional base of the stratotype Senonian, and by inference, therefore, the base of the Coniacian Stage. The presence of this fossil at Southerham led to earlier suggestions that the base of the Coniacian Stage might coincide with the base of the Navigation Beds rather than with the top of these beds (Bailey *et al.*, 1983, 1984; Mortimore and Pomerol, 1987; Pomerol *et al.*, 1987).

## Interpretation

The sections comprising the composite Southerham Pit GCR site cannot be studied in isolation, but need to be seen in the context of the other exposures around Mount Caburn and the sections at Beachy Head, Eastbourne and Upper Beeding, Shoreham (Mortimore, 1986a).

In the Lower and Middle Turonian strata, a key section in relation to Southerham Pit is Glyndebourne Pit 1 (TQ 448 102), on the northern flank of the Caburn Syncline. In the lowest part of the pit, there are exposures of Holywell Nodular Chalk Formation shell-beds containing abundant *Mytiloides* and large ammonites (*Metasigaloceras rusticum* (J. Sowerby), *Mammites nodosoides* (Schlotheim) and *Morrowites wingi* (Morrow) (Mortimore and Pomerol, 1991b, 1996). In the overlying sections, the *Filograna avita* horizon of abundant *Mytiloides* encrusted with the serpulid *Filograna avita* (J. Sowerby) provides a marker that can be traced throughout the Southern Province and the Anglo-Paris Basin (Gale, 1996), and as far north as the southern Chiltern Hills (see also Aker's Steps in the Folkestone to Kingsdown GCR site report, this volume, where the succession is condensed).

In the upper section at Glyndebourne Pit 1, the Gun Gardens Main Marl, at the top of the Holywell Nodular Chalk, is well developed. This marl is overlain by a 1 m thick bed with slender finger-flints, the Glyndebourne Tubular and Finger Flints, for which this is the type locality

(Mortimore, 1990, 1997; Mortimore and Pomerol, 1996). These flints are white externally and hence are relatively inconspicuous. The marl and the associated flints occur very widely throughout the Southern Province and Anglo-Paris Basin but have not so far been recognized in the extremely condensed sections in the Folkestone–Dover section (**Folkestone to Kingsdown** GCR site) although they are present in the North Downs Medway Pits at Halling. They mark a break from the *Mytiloides*-dominated, shelly Holywell Nodular Chalk Formation to the brachiopod-rich, smooth chalks with the echinoid *Conulus subrotundus* (Leske), that characterize the basal part of the New Pit Chalk Formation. The entry of the international marker for the base of the Middle Turonian Substage, the ammonite *Collignoniceras woollgari* (Mantell), has been located *in situ* in this section and a succession of *Mytiloides* from *M. mytiloides* (Mantell) to *M. subhercynicus* (Seitz) has been identified (Mortimore and Pomerol, 1991b, 1996). In conjunction with data from the expanded Beachy Head (Gun Gardens) section, these fossil records enable the basal Middle Turonian Chalk successions of the Southern Province to be linked to the ammonite and inoceramid bivalve standard international zonal schemes.

Of particular interest in this pit is a group of six glauconitized and phosphatized hargrounds, the Glyndebourne Hardgrounds (Mortimore, 1986a,b, 1997; Mortimore and Pomerol, 1987, 1991a,b, 1996) in the Middle Turonian Substage. Glyndebourne is the only place in England where hardgrounds associated with phosphatic chalks are known from the Middle Turonian Substage. Hardground 1 is located below the Malling Street Marls, while the remaining hardgrounds lie above these marls. The interval between Hardground 1 and the Malling Street Marls contains beds of chalk intraclast conglomerates, indicating synsedimentary erosion and channelling. In the Southerham Works Quarry (Cliffe Industrial Estate) section of the Southerham Pit GCR site, Glyndebourne Hardgrounds 1, 2 and 3 are represented by iron-stained nodular beds. Whether or not any of the higher Glyndebourne Hardgrounds (4, 5 or 6) relate to Strahan's Hardground at that locality is uncertain. Hardgrounds of a similar age, the Tilleul Hardgrounds, are present on the French Normandy coast at Tilleul (Mortimore and Pomerol, 1997, fig. 14).

At the nearby Glyndebourne Pit 2 (TQ 446 105), *Collignoniceras woollgari*, associated with *Inoceramus cuvieri* J. Sowerby, is not uncommon beneath New Pit Marl 1 (Mortimore, 1986a; Mortimore and Pomerol, 1996). This section extends the range of *C. woollgari* in the Southern Province up to a relatively high level in the New Pit Chalk Formation and additionally suggests the existence here of a standard succession in proximity to the anomalous successions in the Glyndebourne Pit containing numerous hardgrounds formed on erosional channel floors.

Glynde Pit (TQ 449 096) exposes a section from Glynde Marl 1 (for which this is the type locality) to above Southerham Marl 2. The well-developed Southerham Marl 1 here yielded the holotype and six paratypes of the unusually large lituolacean foraminifer *Labyrinthidoma southerhamensis* Hart. This species was formerly (e.g. Hart, 1982; Mortimore and Wood, 1986) referred to as *Coskinophragma* (see Hart, 1993 for discussion) and is generally inferred to indicate a deeper water environment.

Three additional chalk pits around Mount Caburn expose sections that are critical to long-range correlations within the Southern Province (and deserve to be considered for GCR status). The very large Caburn Pit (TQ 447 089) (Ranscombe Pit of Barrois (1876)) must formerly have extended from the Zig Zag Chalk Formation of the Grey Chalk Subgroup to the Lewes Marl, in the Lewes Nodular Chalk Formation of the White Chalk Subgroup. This is the type locality for the base of the Lewes Nodular Chalk Formation (Mortimore, 1986a, 1997; Bristow *et al.*, 1997). It is also the type locality for the Caburn Sponge Bed and carious flints, and for the overlying Caburn Marl. The strong development of flint in the Glynde Beds here, and in correlative localities around Mount Caburn, including the Southerham Pit, emphasizes the difference between sections in the South Downs and those in the North Downs, such as at Dover, where flints are much less well developed at this level.

The occurrence of *Micraster michelini* (Agassiz) immediately below the Caburn Marl in the Caburn pit (Mortimore, 1986a) compares with records (Stokes, 1975) of similar forms from below this marl at Langdon Stairs, Dover (**Folkestone to Kingsdown** GCR site). The Turonian zonal index ammonite, *Romaniceras deverianum* (d'Orbigny) has been collected here just above the Glynde Marls. The occurrence of the diminutive, wheel-like bryozoan, *Bicavea*

*rotaformis* Gregory, in the nodular beds immediately above the Caburn Marl (Mortimore, 1986a), establishes a key correlation with the abundance level of this species above the so-called 'Grey Marl' in the **Compton Down**, Isle of Wight GCR site (Rowe, 1908, White, 1921). This event-occurrence has not been traced farther east, since it is not represented at Dover, or in any of the correlative sections in the North Downs (Mortimore and Wood, 1986, fig. 3.3).

New Pit Depot (TQ 424 113) on Malling Hill (Figure3.106), on the north side of the Caburn Chalk Block, is the type locality of the New Pit Marls, and exposes an excellent section in the lower Lewes Nodular Chalk Formation (Figure 3.117). In this pit *Micraster corbovis* of *lata* Zone type has been obtained from the basal nodular beds of the formation and through the overlying beds to above Bridgewick Marl 2. This range can be compared with the records for *Micraster* in south-east Devon (see Hooken Cliff GCR site report, this volume). On track sections adjacent to New Pit Depot, the Middle Turonian ammonite *Romaniceras* (*Yubariceras*) *ornatissimum* (Stoliczka) was collected just below New Pit Marl 2. *Romaniceras deverianum* has been collected in the interval from below the Glynde Marls (Offham Track adjacent to 'The Chalk Pit', Offham), to 0.3 m below the Caburn Marl (Firle Pit) (Mortimore, 1986a). These in-situ records of the international indices for the Middle and Upper Turonian Substages help with correlation in chalk facies in Europe.

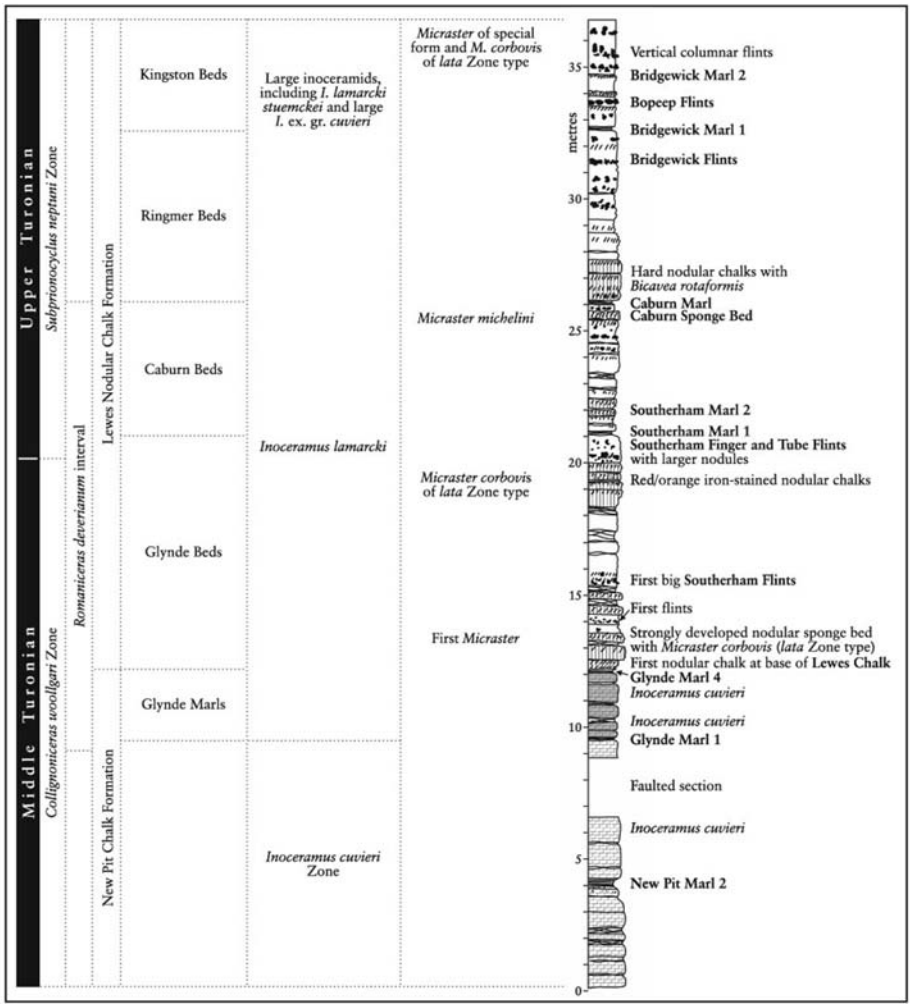


*Figure 3.117: New Pit on Malling Hill, Lewes: the type section for the New Pit Chalk Formation–Lewes Nodular Chalk Formation junction and the New Pit Marls. A link to the Southerham Pit sections and the Sussex Downs.*

Bridgewick Pit (TQ 431 113), to the east of New Pit, is an outstanding section in the lower Lewes Nodular Chalk extending up to just above the Lewes Marl. Horizons of nodular chalks in the Glynde, Caburn, Ringmer and Kingston beds preserve moulds of originally aragonitic-shelled molluscs, including ammonites, i.e. elements of the so-called *reussianum* fauna that typically characterizes the Kingston Nodular Beds and the Chalk Rock (Mortimore, 1986a). This

is a greater range of occurrences than elsewhere in the Southern Province. Bridgewick is also the type locality of the Bridgewick Marls and Bridgewick Flints.

Despite the wealth of stratigraphical information from the Lewes chalk pits, one outstanding stratigraphical anomaly remains. Dating Strahan's Hardground and the overlying Lewes Phosphatic Chalk in the Southerham Works Pit has proved very difficult. It clearly lies above a New Pit Marl seam, and below Southerham Marl 1 and the associated Southerham Flints. The only fossil data are Strahan's (1896) records of *Holaster planus* (i.e. *Sternotaxis plana* (Mantell)) and *Terebratulina lata* R. Etheridge from less than a metre above the hardground. These fossils suggest a horizon in the basal Lewes Nodular Chalk Formation, i.e. at the level where *S. plana* first becomes common.

The hardground is, however, identifiable as a positive resistivity ‘spike' in the non-standard resistivity log of the South Street Borehole in Chandlers Yard, close to the axis of the Caburn Syncline (Mortimore, 1986b, fig. 3.10). The resistivity log suggests that New Pit Marl 2 is missing, and that the marl below the hardground is probably New Pit Marl 1. Furthermore, the succession between the top of the anomalous interval of flinty chalk above the phosphatic chalk, and below the Southerham Flints, is broadly similar to the standard Glynde Beds succession in the New Pit Depot section, on the north side of the Caburn Syncline (Mortimore, 1986b, fig. 3.11). Both of these sections contain two conspicuous bands of nodular flint that, at New Pit Depot, overlie well-developed marl seams (Glynde Marls) and, at Southerham, succeed wispy marls that may represent Glynde Marls. The typically thick, dark, plastic Glynde Marl 1 appears to be absent at the latter locality.

A possible interpretation of the succession is that Strahan's Hardground represents the lithification of the floor of a channel that has cut down from the Glynde Beds, at the base of the Lewes Nodular Chalk, into the New Pit Chalk Formation (e.g. Mortimore and Pomerol, 1987, 1991a). This channel appears to have cut out both Glynde Marl 1 and New Pit Marl 2, to terminate just above New Pit Marl 1. The anomalous flinty chalk above the phosphatic chalk can be inferred to represent the channel fill. The exposure of the hardground is laterally extremely limited and consequently the original extent and geometry of the channel remain unclear. There is no evidence for Strahan's Hardground at New Pit Depot, only 3 km from the Cliffe Industrial Estate, but on the northern, less steeply inclined flank of the Caburn Syncline. The New Pit Chalk Formation–Lewes Nodular Chalk Formation boundary is represented in New Pit by a standard succession. These facts indicate that the anomalous succession is restricted to the axis of the syncline and to the steeply dipping northern flank of the Kingston Anticline.

The succession comprising Strahan's Hardground, the overlying Lewes Phosphatic Chalk and the anomalous interval of flinty chalk below the Southerham Marls has a major bearing on the interpretation of the base of the Lewes Nodular Chalk Formation and its probable correlative, the Chalk Rock of the Marlborough–Berkshire Downs (see Fognam Quarry GCR site report, this volume). The localization of the hardground and phosphatic chalks on the northern, steeply dipping limb of the Kingston Anticline, underlain by a major inversion fault-line, suggests tectonic control of sedimentation (Mortimore, 1986b; Mortimore and Pomerol, 1987, 1991a, 1997).

## Conclusions

The Southerham Pit GCR site provides a unique composite inland section through an almost complete Turonian succession. This includes the thickest, most complete and most fossiliferous, Turonian–Coniacian boundary succession in the Southern Province, which is consequently of great potential international importance. This importance is enhanced by the abundance and variety of the echinoid genus *Micraster* and the inoceramid bivalves in the Turonian and Coniacian stages. Many type and figured species are also considered to have come from the Chalk pits in the vicinity including *Micraster corbovis* and *Collignoniceras woollgari*.

The site includes the type sections for the Southerham and Lewes marls, the Lewes Tubular Flints, the Cuilfail Zoophycos, the Navigation Hardgrounds and Navigation Marls and the Cliffe Hardground, all of which are used as marker horizons for correlation within and outside the Southern Province. Other marker horizons (New Pit Marls, Glynde Marls, Caburn Marls and Bridgewick Marls) have their type sections in nearby related pits. The GCR site and these

related sites collectively provide the standard section for the Lewes Nodular Chalk Formation and for the framework of Turonian detrital marls and vulcanogenic marls. These relatively expanded sections help in the interpretation of the condensed successions in the adjoining regions.

The site is unique in the occurrence of Strahan's Hardground and the Lewes Phosphatic Chalk in the Middle Turonian succession. Solving the stratigraphy of these deposits and establishing their relationship with the Chalk Rock is a key to understanding sedimentary processes in the Chalk.

## Reference list

Bailey, H.W., Gale, A.S., Mortimore, R.N., Swiecicki, A.and Wood, C.J. (1983) The Coniacian–Maastrichtian Stages in the United Kingdom, with particular reference to southern England. Newsletters on Stratigraphy, **12**, 19–42.

Bailey, H.W., Gale, A.S., Mortimore, R.N., Swiecicki, A. and Wood, C.J. (1984) Biostratigraphical criteria for recognition of the Coniacian to Maastrichtian stage boundaries in the Chalk of north-west Europe, with particular reference to southern England. Bulletin of the Geological Society of Denmark, **33**, 31–9.

Barrois, C. (1876) Recherches sur le terrain Crétacé Supérieur de l'Angleterre et de l'Irlande, Mémoire de la Société Géologique du Nord, 232 pp.

Bristow, C.R., Mortimore, R.N. and Wood, C.J. (1997) Lithostratigraphy for mapping the Chalk of southern England. Proceedings of the Geologists' Association,**108**, 293–315.

Bromley, R.G. and Ekdale, A.A. (1984a) Trace fossil preservation in flint in the European Chalk. Journal of Paleontology, **58**, 298–311.

Dibley, G.E. (1906) Excursion to Lewes. Proceedings of the Geologists' Association,**19**, 451–3

Drummond, P.V.O. (1983) The Micraster biostratigraphy of the Senonian White Chalk of Sussex, southern England. Geologie Mediterranéenne,**X**, 177–82.

Gale, A.S. (1996) Turonian correlation and sequence stratigraphy of the Chalk in southern England. In Sequence Stratigraphy in British Geology, (eds S.P. Hesselbo and D.N. Parkinson), Geological Society of London, Special Publication, No. 103, pp. 177–95.

Hart, M.B. (1982) Turonian foraminiferal biostratigraphy of Southern England. Mémoires du Museum national d'Histoire Naturelle Nouvel Series,**49**, 203–7.

Hart, M.B. (1993) Labyrinthidoma Adams, Knight & Hodgkinson; an unusually large foraminiferal genus from the Chalk facies (Upper Cretaceous) of southern England and northern France. In Proceedings of the Fourth International Workshop on Agglutinated Foraminifera, Krakow, Poland, September 12–19, 1993, (eds M.A.Kaminski, S. Geroch and M.A. Gasinski), Grzybowski Foundation Special Publication, No. 3, pp. 123–30.

Jukes-Browne, A.J. and Hill, W. (1903) The Cretaceous Rocks of Britain, volume 2: The Lower and Middle Chalk of England, Memoir of the Geological Survey of the United Kingdom, HMSO, London, 568 pp.

Jukes-Browne, A.J. and Hill, W. (1904) The Cretaceous Rocks of Britain, volume 3: The Upper Chalk of England, Memoir of the Geological Survey of the United Kingdom, HMSO, London, 566 pp.

Mantell, G.A. (1822) The Fossils of the South Downs or Illustrations of the Geology of Sussex, Lepton Relfe, London, 327 pp.

Mantell, G.A. (1827) Illustrations of the Geology of Sussex, Lepton Relfe, London, 92 pp.

Mortimore, R.N. (1979) The relationship of stratigraphy and tectonofacies to the physical properties of the White Chalk of Sussex. PhD thesis, Brighton Polytechnic.

Mortimore, R.N. (1983). The stratigraphy and sedimentation of the Turonian–Campanian in the Southern Province of England. Zitteliana,**10**, 27–41.

Mortimore, R.N. (1986a) Stratigraphy of the Upper Cretaceous White Chalk of Sussex. Proceedings of the Geologists' Association,**97**, 97–139.

Mortimore, R.N. (1986b) Controls on Upper Cretaceous sedimentation in the South Downs with particular reference to flint distribution. In The Scientific Study of Flint and Chert, (eds G. de G. Sieveking and M.B. Hart), Cambridge University Press, Cambridge, pp. 21–42.

Mortimore, R.N. (1990) Chalk or chalk. In Chalk, (eds J.B. Burland, R.N. Mortimore, L.D. Roberts, D.L. Jones and B.O. Corbett), Thomas Telford, London, pp. 15–46.

Mortimore, R.N. (1997) The Chalk of Sussex and Kent, Geologists' Association Field Guide No. 57, Geologists' Association, London, 193 pp.

Mortimore, R.N. and Pomerol, B. (1987) Correlation of the Upper Cretaceous White Chalk (Turonian to Campanian) in the Anglo-Paris Basin. Proceedings of the Geologists' Association, **98**, 97–143.

Mortimore, R.N. and Pomerol, B. (1991a) Upper Cretaceous tectonic disruptions in a placid Chalk sequence in the Anglo-Paris Basin. Journal of the Geological Society, London,**148**, 391–404.

Mortimore, R.N. and Pomerol, B. (1991b) Stratigraphy and Eustatic Implications of Trace Fossil Events in the Upper Cretaceous Chalk of Northern Europe. Palaios, **6**, 216–31.

Mortimore, R.N. and Pomerol, B. (1996) A revision of Turonian litho- and biostratigraphy in the Anglo-Paris Basin. Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universität Hamburg, **77**, 423–41.

Mortimore, R.N. and Pomerol, B. (1997) Upper Cretaceous tectonic phases and end Cretaceous inversion in the Chalk of the Anglo-Paris Basin. Proceedings of the Geologists' Association, **108**, 231–55.

Mortimore, R.N. and Wood, C.J. (1986) The distribution of flint in the English Chalk, with particular reference to the ‘Brandon Flint Series' and the high Turonian flint maximum. In The Scientific Study of Flint and Chert, (eds G. de G. Sieveking and M.B. Hart), Cambridge University Press, Cambridge, pp. 7–20.

Pomerol, B., Bailey, H.W., Monciardini, C. and Mortimore, R.N. (1987) Lithostratigraphy and Biostratigraphy of the Lewes and Seaford Chalks: A Link across the Anglo-Paris Basin at the Turonian–Senonian boundary. Cretaceous Research, **8**, 289–304.

Rowe, A.W. (1908). The Zones of the White Chalk of the English Coast. V. The Isle of Wight. Proceedings of the Geologists' Association, **20**, 209–352.

Stokes, R.B. (1975) Royaumes et provinces faunistiques du Crétacéétablis sur la base d'une étude systématique du genre Micraster. Memoire du Museum national d'Histoire naturelle, Series C, **31**, 94 pp.

Strahan, A. (1896) On a phosphatic chalk with Holaster planus at Lewes. Quarterly Journal of the Geological Society of London, **52**, 463–473.

White, H.J.O. (1921) A Short Account of the Geology of the Isle of Wight, Memoir of the Geological Survey of Great Britain, HMSO, London, 219 pp.

White, H.J.O. (1926) The Geology of the Country near Lewes, Memoir of the Geological Survey of Great Britain (England and Wales) New Series, Sheet 319, HMSO, London, 97 pp.

Wray, D.S. (1999) Identification and long-range correlation of bentonites in Turonian–Coniacian (Upper Cretaceous) chalks of northwest Europe. Geological Magazine, **136**, 361–71.