WILMINGTON QUARRY

OS Grid Reference: SY209997

Introduction

The entrance to the Wilmington Quarry ('White Hart Sandpit') is situated opposite the White Hart Inn, Wilmington (Figure 3.25). The quarry was worked for calcareous sands and calcarenites (Wilmington Sand), which had become largely decalcified. The sands occur beneath a thin capping of Beer Head Limestone Formation and basal White Chalk Subgroup (Holywell Nodular Chalk Formation) and, on the southern and western sides of the quarry, Clay-with-flints. In the south-west corner, where the Clay-with-flints is at its thickest, it infills deep, wide dissolution pipes separated by isolated pillars of Wilmington Sand calcarenites overlain by the Chalk. The sand workings consisted of a number of small, hand-dug pits at the time of Jukes-Browne's (1898) visit, but these subsequently became amalgamated and the workings now cover about 5 hectares (Figure 3.25). They were dug to a depth of 12 to 15 m, but are now mostly backfilled and only the upper part of the succession has been exposed in recent years.

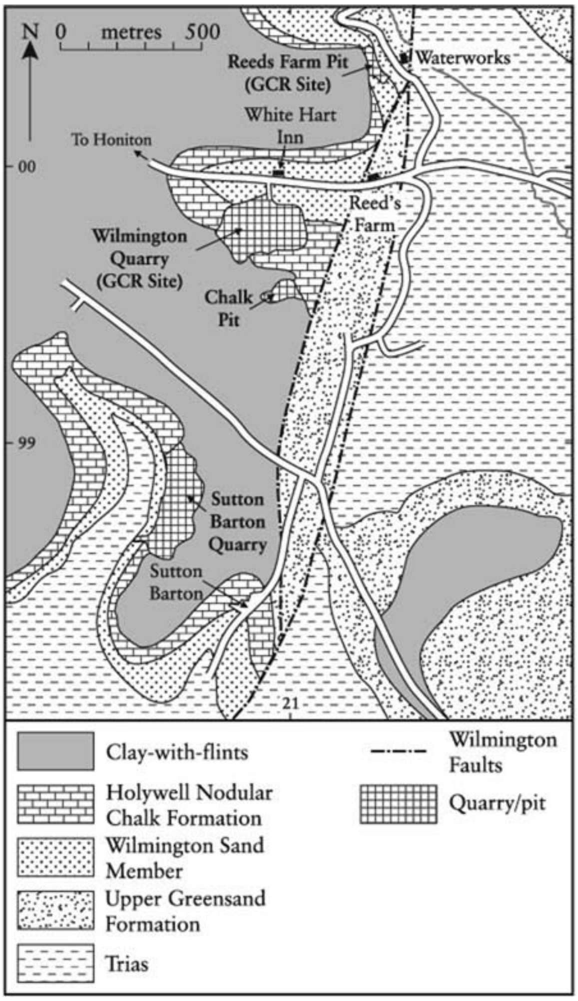

Figure 3.25: Geological setting of Wilmington Quarry, Reeds Farm Pit and adjacent sections, south-east Devon.

Wilmington Quarry has yielded over 300 fossil species, one of the most diverse Cenomanian faunas recorded anywhere in the Anglo-Paris Basin. The site is especially rich in fossil brachiopods, bivalves, echinoderms and crabs, and includes many species that are unknown elsewhere in Britain. Fossil crabs are rare in the Upper Cretaceous Series in Britain except in the sandy Cenomanian deposits of Devon. Of the 28 recorded species, 24 are present at

Wilmington. The echinoderms recorded by Smith *et al*. (1988) comprise 36 species of echinoid, 10 of which had not previously been recorded in Britain, 18 species of asteroid and 7 species of crinoid. This richness in fossils is partly explained by the geological setting of the site within the structurally controlled 'Hooken–Wilmington Trough' (Figures 3.19 and 3.21), within which the arenaceous facies of the Cenomanian and the Lower Turonian Beer Stone is developed. It exposes a key section that complements that of **Hooken Cliff** (see GCR site report, this volume). The quarry provides the best remaining inland exposures of the Lower Cenomanian Wilmington Sand facies of the Hooken Member (Bed A2) of the Beer Head Limestone Formation. It is also the most northerly exposure of the Beer Stone.

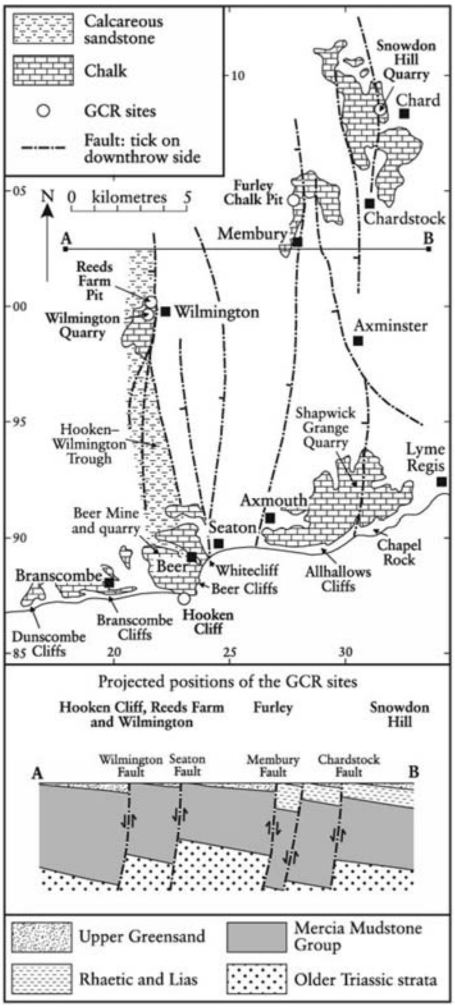

Figure 3.19: Geological sketch map and section showing the position of the Upper Cretaceous GCR sites in relation to outcrop and structure.

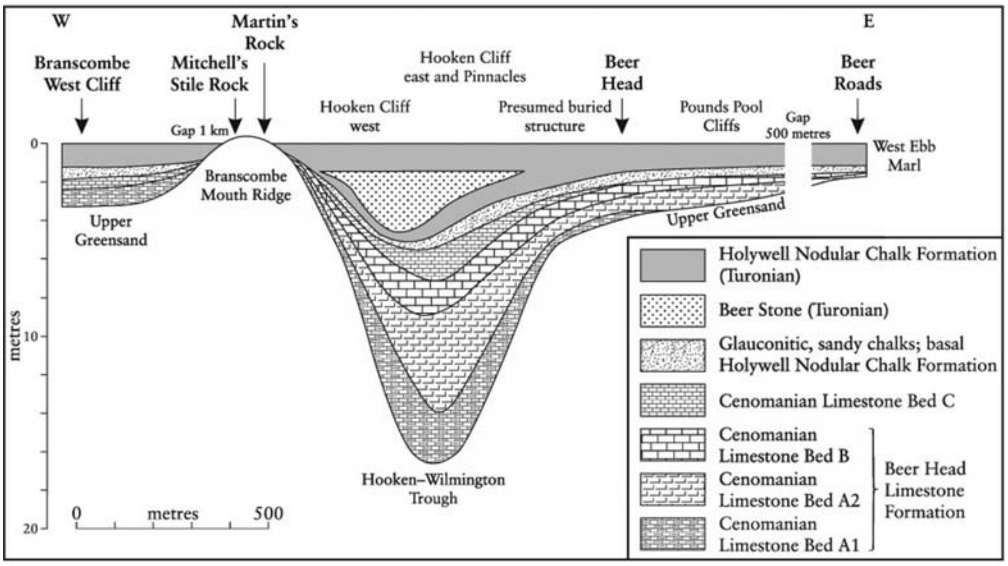

Figure 3.21: Schematic and simplified view of lateral variation in the Cenomanian and Early Turonian deposits of Hooken Cliffs and adjacent areas. The datum is the West Ebb Marl.

Description

Wilmington Quarry was worked for building sand from the early part of the 19th Century until 1993. The section was first recorded by Fitton (1836, p. 234), who noted that 'a stone called 'Grizzle' by the quarry-men is dug ... about 5 feet (1.5 m) in thickness ... it contains green particles and does not burn to lime'. Jukes-Browne (1898) recorded a diverse Cenomanian fauna from the Wilmington Sand that he subsequently correlated with that of Bed A2 of the 'arenaceous beds' or Zone of *Ammonites mantelli* of the coastal sections (Jukes-Browne and Hill, 1903, p. 129). The unusual lithologies and the highly fossiliferous nature of the Wilmington section attracted numerous later researchers, who have made it one of the most studied and best-documented Cenomanian successions in the Southern Province. The more important works include Jukes-Browne and Hill's (1903) and Smith's (1957b) descriptions of the stratigraphy as a whole, Kennedy's (1970, 1971) and Wright and Kennedy's (1981, 1984) descriptions of the lithostratigraphy and the ammonite sequence, and Smith *et al.*'s (1988) description and analysis of the echinoderm faunas. Hart (1983) described the foraminiferal biostratigraphy and used it to correlate the succession with that in the Grey Chalk Subgroup succession at Folkestone (see Folkestone to Kingsdown GCR site report, this volume). Figures of sections showing lateral variations within the quarry are given by Kennedy (1970, fig. 18), Jarvis and Tocher (1987, fig. 6) and by Smith *et al.* (1988, fig. 3).

Jukes-Browne (1898) described over 30 ft (9 m) of Wilmington Sand with loose blocks of 'Grizzle' in the overlying soil. An attempt to dig below the floor of the quarry was stopped when a dense, calcareous-cemented bed of pebbly sandstone, presumed to be a Chalk Basement Bed, was encountered. The quarry workers said that this bed had previously been exposed in an excavation in the village where it had been 15 ft (4.5 m) thick (Jukes-Browne, 1898). Subsequent descriptions by Smith (1957b), Smith and Drummond (1962), Kennedy (1970), Jarvis and Tocher (1987), Hart (1983) and Smith *et al.* (1988), all of whom saw the full thickness of the Wilmington Sand, showed the basal pebble bed (i.e. Basement Bed) to be less than 1 m thick.

In contrast to the Wilmington Sand, the Little Beach Member of the Beer Head Limestone Formation, and the overlying basal White Subgroup strata (Holywell Nodular Chalk Formation) show marked variations in lithology; several authors have drawn attention to and have illustrated this feature. The highest bed seen in the quarry at present is the deeply weathered gritty Beer Stone, crowded with tiny echinoderm prisms. Previously, several metres of shell-rich chalk were locally preserved above this stone. Jukes-Browne (1898) recorded the stone in another quarry (now backfilled) adjacent to Wilmington Quarry. This had reputedly supplied the stone for Widworthy Court, which overlooks Wilmington Quarry. A petrologically identical stone was formerly worked at Sutton Barton Quarry to the south of Wilmington Quarry (Figure 3.25), under the name 'Sutton Stone' (Jukes-Browne, 1898).

Lithostratigraphy

The lithologies present in the Cretaceous succession at Wilmington Quarry (Figure3.26 and Table 3.1) below a capping of Clay-with-flints, comprise, in descending order:

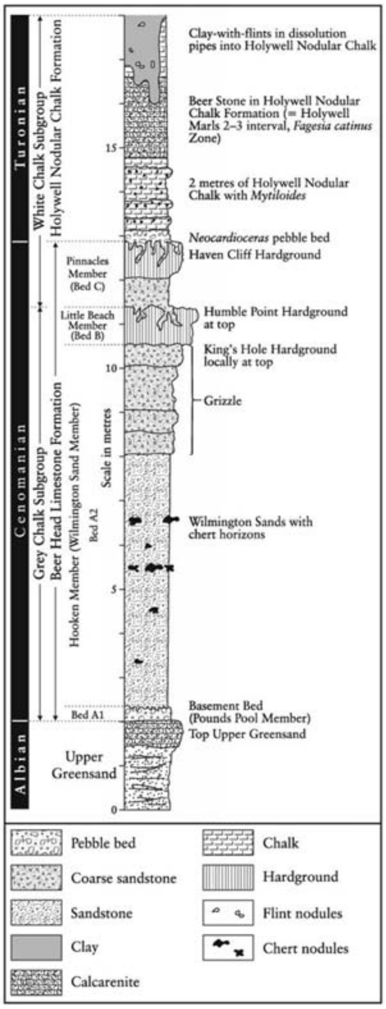

Figure 3.26: The Cretaceous succession at Wilmington Quarry, south-east Devon.

Upper Greensand Formation (up to 2 m): Sandy, glauconitic calcarenite and calcareous sandstone with a densely cemented and mineralized top surface.

'Basement Bed' (0.2 to 0.3 m): Pebbles and cobbles of green-coated calcareous sandstone and calcarenite, and hard and soft phosphatic pebbles, set in a glauconitic sandy limestone matrix.

Wilmington Sand (4 to 14 m): Decalcified calcareous sand and sandy calcarenite, coarse-grained at the base. Fine- and medium-grained beds alternate with medium- and coarse-grained beds, all with granules and small pebbles. There are several horizons of laterally impersistent and partially silicified thalassinoid burrow systems. Shallow trough cross-bedding is present at several levels and there are traces of rotted pyritic horizons.

'Grizzle' (mostly 2.5 to 3.5 m): Highly fossiliferous sand with a chalky matrix; with patchy cementation producing hard nodules and patches in a loose sand matrix. Large shells (inoceramid bivalves) are concentrated in the basal 0.5 m. The lowest 0.8 to 1.0 m is much less calcareous. The percentage content of quartz grains decreases upward and there is a concomitant increase in the chalky matrix (up to 35%) and degree of nodularity. The top is marked by a bed of green-stained sandstone pebbles.

Little Beach Member (Bed B) (= Wilmington Limestone of Smith *et al*., 1988): This varies laterally from a hard quartzose bioclastic limestone in the northern part of the quarry to a highly bioturbated mixture of quartz sand, glauconite and chalky mud; locally calcareously cemented to dense calcarenite/calcareous sandstone. In the upper 0.3 m there is a concentration of phosphatized and glauconitized nodules. The top surface is glauconite-impregnated and penetrated by a ramifying *Thalassinoides* burrow system, which is also green-stained. The burrows pipe down glauconitic calcareous sands and small phosphate clasts from the overlying Pinnacles Member. The surface and the burrow walls are coated with a shiny chocolate-brown veneer of phosphate. There is a rich fauna of encrusting organisms, which is also phosphatized. This complex surface corresponds to the Humble Point Hardground (Jarvis and Woodroof, 1984) at the top of the member in the coastal exposures.

The Little Beach Member thins and disappears laterally, resulting in the Pinnacles Member coming to rest directly on the top mineralized surface of the 'Grizzle' (Figure 3.27).

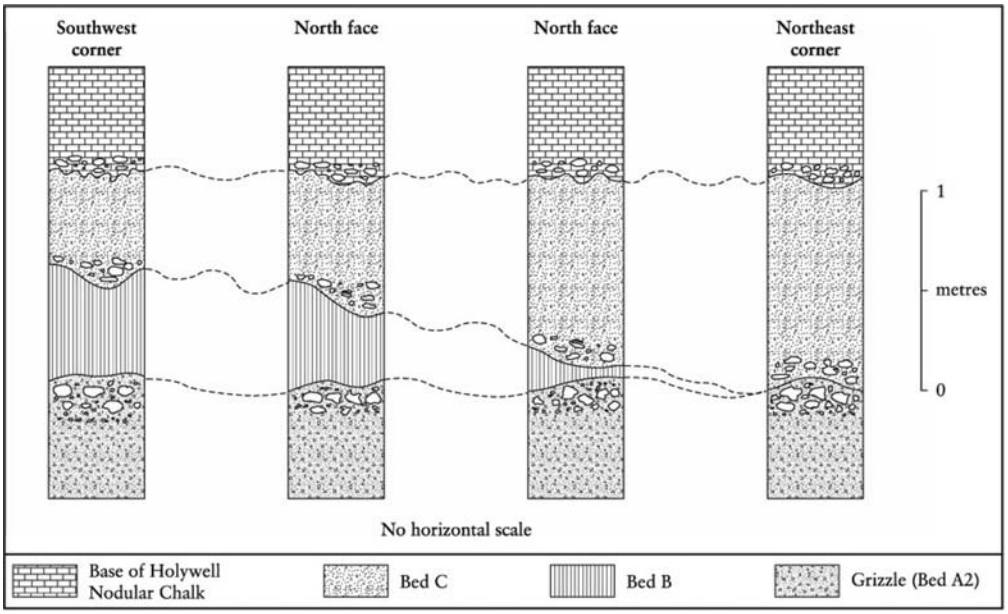

Figure 3.27: Lateral variations in the Cenomanian Limestone equivalent (see Table 3.1) in the Wilmington Quarry GCR site (White Hart Sandpit) illustrating the reason for the near absence of Bed B in parts of the exposure.

Pinnacles Member (Bed C): The Little Beach Member is overlain in this section by a laterally extremely variable unit of glauconitic sediments. All of the descriptions of this unit differ significantly.

Wright and Kennedy (1981) recorded a basal conglomerate of unlithified phosphate clasts overlain by 0.6 m of soft quartzose glauconitic bioturbated chalk with scattered phosphates and small quartz pebbles. This graded up into 0.8 m of intensely hard splintery and nodular quartzose and glauconitic chalk. The unit ended in a hardground with green-coated pebbles in and welded to the surface, which was penetrated by a ramifying *Thalassinoides* burrow system. This description is similar to that of Kennedy (1970), but differs in that he did not report the higher unit of quartzose chalk.

Smith *et al*. (1988), on the other hand, reported that the Humble Point Hardground was overlain by 0.2 to 0.23 m of glauconitic sand (with a basal phosphate pebble conglomerate). This sand thinned westwards to a point where it was represented merely by a thin veneer capping the Little Beach Member and infilling fissures and burrows. These sections were mainly in the north-east corner of the quarry.

The present section in the south-west corner of the quarry, where there are residual pillars of Cretaceous rock surrounded by solution hollows, resembles that originally described by

Kennedy (1970). The Pinnacles Member consists of up to 0.9 m of white and greyish white, porcellanous, nodular, highly bioturbated, glauconitic limestone. At the base, resting on the glauconitized and phosphatized hardground at the top of the Little Beach Member, there is locally a pebble bed with green-coated limestone and phosphate pebbles. The top of the unit is glauconitized, forming the Haven Cliff Hardground of coastal sections, and is penetrated by a *Thalassinoides* burrow system filled with sandy glauconitic chalk piped down. This hardground is intensely glauconitized and indurated in nearly inaccessible sections in the present north-east corner of the quarry.

The Haven Cliff Hardground is overlain by up to 2 m of gritty, glauconitic chalk, with common phosphatic pebbles and green-coated limestone pebbles in the basal 0.2 m (the Haven Cliff *Neocardioceras* Pebble-Bed of coastal sections).

Beer Stone Member (up to 2 m): Comprises deeply weathered, bioturbated, very sparsely shelly gritty chalk composed largely of sand-grade echinoderm prisms.

The Beer Stone Member is overlain by up to 3 m of deeply weathered, slightly marly, gritty chalk with common inoceramid bivalve debris as well as whole and fragmentary shells.

Biostratigraphy

The 'Basement Bed' has yielded far fewer stratigraphically diagnostic ammonites than at the **Reeds Farm Pit** (see GCR site report, this volume), but the presence of common specimens of the coralline sponge *Acanthochaetetes ramulosus* (Michelin) and trigoniid bivalves at both localities suggests that they are of the same *Neostlingoceras carcitanense* ammonite Subzone age. Wright and Kennedy (1996) recorded from here the rare ammonite species *Baskaniceras deshayesitoides* Wright and Kennedy, which is also known from **Reeds Farm Pit**.

The Wilmington Sand and 'Grizzle' contain an unusually abundant, diverse and exotic fauna that is especially rich in bivalves, brachiopods, echinoderms and crabs. The bulk of the sands are decalcified, to a greater or lesser degree, and the better-preserved specimens have almost all come from the 'Grizzle', mostly from the more calcareous patches. The 'Grizzle' is, in any case, much more fossiliferous than the underlying sands.

The relatively poorly preserved indigenous ammonite fauna of the 'Grizzle' includes *Acompsoceras inconstans* (Schlüter), *Hyphoplites curvatus arausionensis* (Hébert and Munier-Chalmas), *H. falcatus* (Mantell), *Hypoturrilites gravesianus* (d'Orbigny), *H. tuberculatus* Bosc, *Mantelliceras cantianum* Spath, *M. dixoni* Spath, *M. lymense* (Mantell), *M. mantelli* (J. Sowerby), *Mariella lewesiensis* (Spath), *Schloenbachia varians* (J. Sowerby) and *Turrilites scheuchzerianus* Bosc.

The 'Grizzle' contains an abundance of (typically bivalved) *Inoceramus* ex gr. *virgatus* Schlüter (*I. conicus* Guéranger in Kennedy, 1970), as well as other calcitic bivalves and brachiopods. Some of the latter are a bluish-purple in colour and display beekite rings on their surfaces, indicating that they are partially or wholly silicified (Holdaway and Clayton, 1982). In addition to small oysters (*Amphidonte* sp.), the commonest silicified fossils are large pectinacean bivalves, notably the highly spinose *Merklinia aspera* (Lamarck), and the large, coarsely-ribbed rhynchonellid brachiopod *Cyclothyris difformis* (Valenciennes, in Lamarck); the former is sometimes – the latter typically – found with both valves together. With careful application of dilute acid it is possible to free the silicified shells completely from the calcareous matrix of the sands and, in the case of the *Cyclothyris*, to separate the two valves sufficiently to reveal the brachial apparatus.

The rich brachiopod fauna also includes *Arcuatothyris arcuata* (Roemer), *Arenaciarcula beaumonti* (d'Archiac), *Burrirhynchia devoniana* Owen, *Dereta pectita* (J. Sowerby), *Grasirhynchia grasiana* (d'Orbigny), *Kingena arenosa* (d'Archiac), *Orbirhynchia wilmingtonensis* Owen, *Ovatathyris ovata* (J. Sowerby), *Rectithyris wrightorum* Owen, and *Terebrirostra lyra* (J. Sowerby). Some of these are robustly ornamented forms that characterize coarse-grained sediments and are absent from the Cenomanian chalks of other parts of England. The holotypes and paratypes of *B. devoniana* and *O. wilmingtonensis*, and the only known specimen (holotype) of *R. wrightorum* (Owen, 1988) came from here.

The Wilmington Sand is particularly rich in echinoderms. Smith *et al*. (1988) recorded 37 species of echinoid, 18 of asteroid and 7 of crinoid. No new species of echinoid were described, but ten species had not previously been reported from Britain. The fauna is extraordinarily diverse, and comprises both ‘regular' and ‘irregular' taxa, much of it very well preserved. The commonest species are *Discoides subuculus* (Leske), *Rostrogalerus rostratus* (Desor), *Catopygus columbarius* (Lamarck) and *Holaster nodulosus* (Goldfuss). The long-ranging *C. columbarius* is extremely common in the basal part of the ‘Grizzle' and *Holaster bischoffi* Renevier (previously recorded as *H. altus*) is restricted to the upper part. The asteroids occur only as isolated ossicles throughout. The crinoids in the Wilmington Sand range from the Basement Bed into the Cenomanian Limestone but appear to be concentrated below the ‘Grizzle'. The comatulid genus *Glenotremites*, occurs as isolated cups; the commonest crinoid, *Isocrinus? undulatus*, was described as a new species by Paul and Donovan (in Smith *et al*., 1988) on the basis of lengths of stem.

The Wilmington Sand, especially the ‘Grizzle', is renowned for its rich fossil crab fauna, this quarry being one of the most prolific sources of Cretaceous crabs in Britain. Of the 24 taxa recorded from here, seven were described as new by Wright and Collins (1972), one new genus appropriately being given the name *Wilmingtonia*. The new species described from the ‘Grizzle' are *Notopocorystes ornatus*, *Paranecrocarcinus biscissus*, *P. digitatus*, *P. foersteri*, *Pithonoton cenomanense*, *Wilmingtonia satyrica* and *Xanthosia fossa*. Three species, *Plagiophthalmus oviformis* Bell, *Diaulax oweni* (Bell) and *Necrocarcinus labeschei* (Deslongchamps) are relatively common, the remainder are rare. The holotype of *Plagiophthalmus*? *nodulosus* Wright and Collins came from the overlying Cenomanian Limestone (see Table 3.1).

The fauna of the Little Beach Member is sparse, and echinoids, mostly *Conulus castanea* (Brongniart) and *Holaster subglobosus* (Leske), and crustacean debris are the only common fossils. Wright and Kennedy (1987, pl. 49, fig. 5) illustrated a well-preserved, incomplete specimen of *Acanthoceras rhotomagense* (Brongniart) from here.

The phosphatized *Calycoceras* (*Proeucalycoceras*) *guerangeri* Zone ammonite fauna from the base of the Pinnacles Member (Bed C) recorded from here includes *Calycoceras* (*C.*) *naviculare* (Mantell), *C.* (*Newboldiceras*) *hippocastanum* (J. de C. Sowerby), *C.* (*Proeucalycoceras*) *picteti* Wright and Kennedy, *Eucalycoceras pentagonum* (Jukes-Browne), *E. rowei* (Spath), *Euomphaloceras euomphalum* (Sharpe), *Forbesiceras bicarinatum* Szasz, *Lotzeites aberrans* (Kossmat), *Neostlingoceras virdenense* Cobban, Hook and Kennedy, *Protacanthoceras bunburianum* (Sharpe), *P. proteus proteus* Wright and Kennedy, *P. proteus baylissi* Wright and Kennedy, *P. proteus vascoceratoides* Wright and Kennedy (holotype), *P. tuberculatum devonense* Wright and Kennedy (a paratype), *Scaphites equalis, Schloenbachia lymense* Spath, *Sciponoceras baculoides* (Mantell), *Thomelites sornayi* (Thomel) and *Worthoceras compressum* Wright and Kennedy (holotype). *C.* (*Calycoceras*) *naviculare*, *C.* (*Newboldiceras*) *hippocastanum*, *E. euomphalum* and *P. bunburianum* are particularly characteristic of this derived *Calycoceras guerangeri* Zone assemblage.

The indigenous fauna of the lower part of the Pinnacles Member includes the belemnite *Praeactinocamax plenus* (Blainville) and the rhynchonellid brachiopod *Orbirhynchia wiesti* (Quenstedt), as in the coastal sections, indicating that it belongs to the *Metoicoceras geslinianum* Zone. The higher, nodular part of the member has yielded *Euomphaloceras euomphalum.* The puzzling record of *ollignoniceras* (Wright and Kennedy, 1981, fig. 5; pl. 8, fig. 17) may refer to another genus. The Haven Cliff Hardground contains *Sciponoceras* sp. and common spines of the regular echinoid *Hirudocidaris hirudo* (Sorignet). The overlying glauconitized pebble-fossils include *Sciponoceras bohemicum anterius* Wright and Kennedy and *Neocardioceras* sp., belonging to the terminal Cenomanian *Neocardioceras juddii* ammonite Zone; the surrounding quartzose glauconitic chalk contains indigenous *Watinoceras devonense* Wright and Kennedy, the zonal index fossil of the basal Turonian ammonite zone.

The indigenous fauna of the Holywell Nodular Chalk Formation includes the echinoids *Cardiaster truncatus* (Goldfuss) (*Cardiaster pygmaeus* in the older literature), *Cardiotaxis cretacea* (Sorignet), *Conulus subrotundus* (Mantell), *Camerogalerus minimus* (Desor) (*Discoidea dixoni*), *Hemiaster nasutulus* (Sorignet), *Prionocidaris granulostriata* (Desor) and common specimens of the inoceramid bivalve *Mytiloides labiatus* (Schlotheim). The overlying beds of the Holywell Nodular Chalk are deeply weathered and the fossils are mostly poorly preserved. A specimen of the ammonite *Spathites* (*Jeanrogericeras*) cf. *subconciliatus* (Choffat) from here was figured by Wright and Kennedy (1981, pl. 22, fig. 3).

Interpretation

All the published lithological descriptions of the Wilmington Sand are in broad agreement, but even within the confines of the quarry, thicknesses from 6 to 14 m have been recorded. Kennedy (1970) measured 12 to 14 m, Jarvis and Tocher (1987) recorded 6.2 m and Smith *et al*. (1988) recorded about 8 m. The latter two measurements were made in the eastern face, closest to the fault (Wilmington Fault) that bounds the Wilmington outlier to the east whereas Jukes-Browne's (1898: 9+ m) and Kennedy's measurements were probably made in what is now the western part. The differences in thickness record rapid lateral variations related to the proximity of the fault or one of its splays. The Wilmington Sand at the **Reeds Farm Pit**, which is even closer to the fault, is only 4 to 5 m thick (see GCR site report, this volume). It should be noted that, although the Wilmington Sand is thicker here when traced away from the Wilmington Fault, the overlying Little Beach (Bed B) and Pinnacles members (Bed C) are thin in comparison with the developments of these members in the **Hooken Cliff** sections.

The development of the thick arenaceous (Wilmington Sand) facies of the Lower Cenomanian sandy Beer Head Formation limestones, and of the lenticular Beer Stone (locally called 'Sutton Stone') in the lower part of the Holywell Nodular Chalk Formation, is of critical importance in structural terms. It allows the key postulation of an approximately north–south aligned 'Hooken–Wilmington Trough', extending from Hooken Cliff, through the Beer Stone quarries and nearby sections such as Bovey Lane Quarry (Figure 3.17), to the sections in the fault-controlled Wilmington outlier. This outlier is delimited to the east by a major fault (Wilmington Fault), which seismic reflection surveys show to have a westerly downthrow of more than 0.3 m in the Trias close to Wilmington. As noted above, the Cenomanian sediments thicken significantly westwards away from the fault, and the structural situation is broadly similar to that described from the **Hooken Cliff** GCR site between the Beer Head and Beer Stone adit sections. Because of the loss of Cretaceous strata beneath the Clay-with-flints cover to the west of Wilmington, there is no clear evidence for the existence of the other side of the trough. However, to the south of Sutton Barton there are several eastward-downthrowing displacements of the Upper Greensand scarp, which, extended to the north, would allow the inference of a western structural limit to the Wilmington outlier (Figure 3.19).

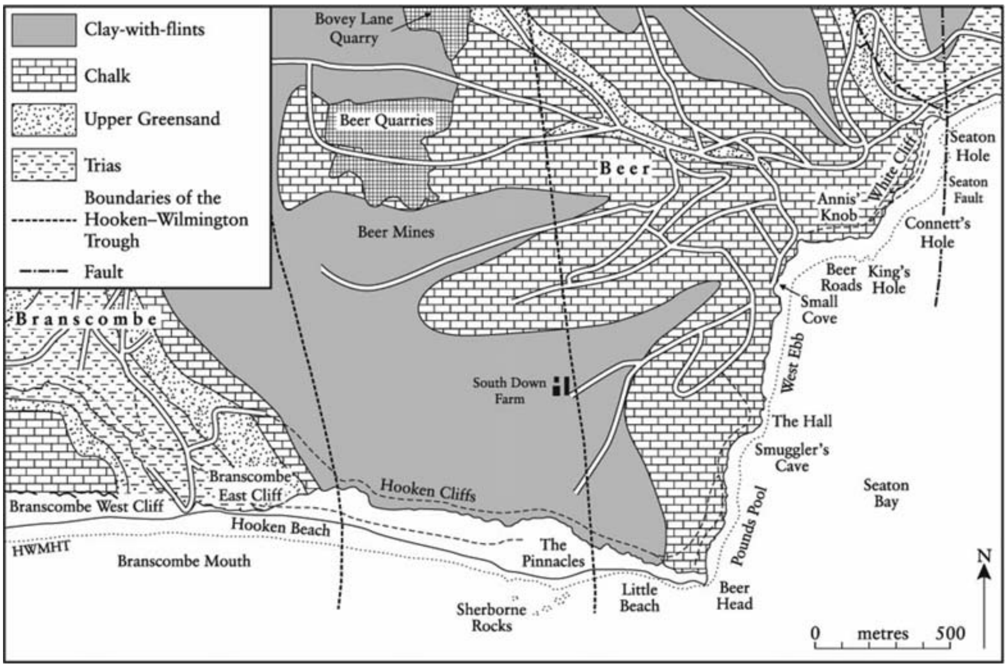

Figure 3.17: The Hooken Cliff GCR site in relation to nearby sections and the local geology.

The presence of *Acanthochaetetes ramulosus* in the 'Basement Bed' suggests correlation with the Pounds Pool Member of the Beer Head Limestone, and the lithological similarity to the richly fossiliferous 'Basement Bed' of the nearby **Reeds Farm Pit** suggests a *carcitanense* Subzone age. This interpretation is contrary to that presented by Jarvis and Tocher (1987, fig. 6) and by Smith *et al*. (1988, fig. 5), who correlate the 'Grizzle' with the Hooken Member, and place the underlying sands in the Pounds Pool Member. In the interpretation given here, the convolute top of the Wilmington Hardground of Jarvis and Tocher (= the Basement Bed) could well equate with the (locally developed) Weston Hardground (Jarvis and Woodroof, 1984) at the top of the Pounds Pool Member on the coast. Our interpretion is supported by the occurrence of *Inoceramus virgatus* at the base of the Wilmington Sand at the **Reeds Farm Pit,** indicative of the *Mantelliceras dixoni* Zone.

The coarse grain-size of the sands and their sedimentary (cross-bedding) features suggest rapid deposition, and the whole of the Wilmington Sand above the 'Basement Bed' is probably of a similar age. The presence of lines of cherts indicates that the sediments were formerly much more calcareous. The association of *Mantelliceras dixoni* with an abundance of the bivalve *Inoceramus* ex gr. *virgatus* places the 'Grizzle' in the *Mantelliceras dixoni* Zone and suggests correlation with the Hooken Member (Bed A2). This is supported by the abundance in the 'Grizzle' of *Merklinia aspera*, which is common at the top of the arenaceous Hooken Member at **Hooken Cliff**. The ocurrence of *I*. ex gr. *virgatus* suggests correlation with the *I. virgatus*-acme that characterizes the lower third of the *dixoni* Zone in the 'Chalk Marl' facies of the Grey Chalk Subgroup, for example at **Southerham Grey Pit**, Lewes (see GCR site report, this volume), and at Folkestone (see Folkestone to Kingsdown GCR site report, this volume). They typically occur as bivalved specimens in both successions and, in both cases, in relatively calcareous sediments. The abundance of the rhynchonellid brachiopod *Orbirhynchia wilmingtonensis* in the 'Grizzle' suggests possible correlation with the *O. mantelliana* band that immediately follows the *I. virgatus*-acme. However, the presence in the 'Grizzle' of *Acompsoceras inconstans* and *Turrilites scheuchzerianus* additionally indicates the highest of the three ammonite assemblages recognized in the *dixoni* Zone by Gale (1996), the *Mesoturrilites boerssumensis* Subzone of Kaplan *et al*. (1998).

Conclusions

Wilmington Quarry (White Hart Sandpit) has exposed, from time to time, the greatest thickness of the unusual Cenomanian deposits within the Hooken–Wilmington Trough. The ? sections have yielded an abundant and exceptionally diverse fauna of ammonites, echinoids and crustaceans, many of which have only been recorded from east Devon, and some of which are unique to Wilmington Quarry.

Reference list

Fitton, W.H. (1836) Observations on the strata between the Chalk and the Oxford Oolite in the South-East of England. Transactions of the Geological Society of London, 2nd Series, **4**, 103–324.

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. (1983) Planktonic Foraminifera from the Cenomanian of the Wilmington quarries (S.E. Devon). Proceedings of the Ussher Society, **5**, 406–10.

Holdaway, H.K. and Clayton, C.J. (1982) Preservation of shell microstructure in silicified brachiopods from the Upper Cretaceous Wilmington Sands of Devon. Geological Magazine, **119**, 371–82.

Jarvis, I. and Tocher, B.A. (1987) Field Meeting: the Cretaceous of SE Devon, 14–16 March, 1986. Proceedings of the Geologists' Association, **98**, 51–66.

Jarvis, I. and Woodroof, P.B. (1984) Stratigraphy of the Cenomanian and basal Turonian (Upper Cretaceous) betweeen Branscombe and Seaton, SE Devon, England. Proceedings of the Geologists' Association, **95**, 193–215.

Jukes-Browne, A.J. (1898) On an outlier of Cenomanian and Turonian (equivalent to Lower and Middle Chalk) near Honiton, with a note on Holaster altus Agassiz. Quarterly Journal of the

Geological Society of London, **54**, 239–50.

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.

Kaplan, U., Kennedy, W.J., Lehmann, J. and Marcinowski, R. (1998) Stratigraphie und Ammonitenfaunen des westfälischen Cenoman. Geologie und Paläontologie in Westfalen,**51**, 236 pp.

Kennedy, W.J. (1970) A correlation of the uppermost Albian and the Cenomanian of South-West England. Proceedings of the Geologists' Association,**81**, 613–77.

Owen, E.F. (1988) Cenomanian brachiopods from the Lower Chalk of Britain and northern Europe. *Bulletin of the British Museum (Natural History). Geology Series*, **44**.

Smith, W.E. (1957b) Summer Field Meeting in South Devon and Dorset. Proceedings of the Geologists' Association, **68**, 136–52.

Smith, W.E. and Drummond, P.V.O. (1962) Easter Field Meeting: The Upper Albian and Cenomanian Deposits of Wessex. Proceedings of the Geologists' Association,**73**, 335–52.

Smith, A.B., Paul, C.R.C., Gale, A.S. and Donovan, S.K. (1988) Cenomanian and Lower Turonian echinoderms from Wilmington, south-east Devon, England. Bulletin of the British Museum (Natural History). Geology Series, **42**, 245 pp.

Wright, C.W. and Collins, J.S.H. (1972) British Cretaceous Crabs, Monograph of the Palaeontographical Society, London, 114 pp.

Wright, C.W and Kennedy, W.J. (1981) The Ammonoidea of the Plenus Marls and the Middle Chalk, Monograph of the Palaeontographical Society, London, 148 pp.

Wright, C.W. and Kennedy, W.J. (1987) The Ammonoidea of the Lower Chalk: Part 2, Monograph of the Palaeontographical Society, London, pp 127–218.

Wright, C. W. and Kennedy, W. J. (1996) The Ammonoidea of the Lower Chalk: Part 5, Monograph of the Palaeontographical Society, London, pp. 320–403.