British Tertiary Stratigraphy

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Chapter 9

The Lenham Beds

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INTRODUCTION

In 1854, Harris and Jones (see Prestwich, 1857b) discovered fossiliferous ferruginous sandstones within solution pipes in the surface of the Chalk escarpment between Harrietsham and Charing in Kent. They believed the deposits to be part of the Basement Bed of the London Clay. Prestwich visited the area in 1855 and described a section at Lenham Hill about 1 km north of the village of Lenham. He found the fossiliferous sandstone to be present as 'detached blocks' within the fill of the solution pipes. The sandstones are decalcified with molluscan shells preserved only as moulds. Prestwich soon noticed that certain elements of the fauna contradicted a Palaeogene age for the deposit (Prestwich, 1858). These elements included the bryozoan *Lunulites*, a large *Terebratula*, *Emarginula* and echinoid spines.

Prestwich also noticed a similarity to the fauna of the East Anglian Crags and postulated that the deposits might be equivalent in age with the Coralline Crag or possibly older. Prestwich submitted samples to Searles Wood, the leading authority on Crag molluscs at that time, who cautiously agreed that the fauna was similar to that of the Crag and supported the view that the deposit was older than the Red Crag (Prestwich, 1858).

The process of pipe formation was described by Prestwich (1855) who noted the irregular position of the cemented blocks. Prestwich recognized that the fills had originated by the slow downward warping of an originally horizontally layered sequence into a solution hollow in the surface of the Chalk and gave a reconstruction (Prestwich, 1858, fig. 4) of the former stratigraphy. The formation of the solution pipes and their infill is intimately related to the origin of the 'Clay-with-flints' deposits, which are found over large areas of the Chalk downland of south-east England (Catt and Hodgson, 1976).

By 1872, patches of sand on the surface of the Chalk had been found over a considerable length of the North Downs as far west as Netley Heath, west of Dorking (Whitaker, 1872) (Figure 9.1). Whitaker acknowledged, however, that the deposits were not necessarily all of the same age. Sediments attributed to the Lenham Beds (*sensu stricto*) are found on the surface of the Chalk escarpment of the North Downs as far east as Folkestone (Reid, 1890; Smart *et al.*, 1966) although the deposits appear to be unfossiliferous east of Charing. Most of these deposits consist of decalcified and unfossiliferous sands and sandstones preserved as discontinuous patches or as the infills of solution pipes. The patches are often only revealed as a result of ploughing

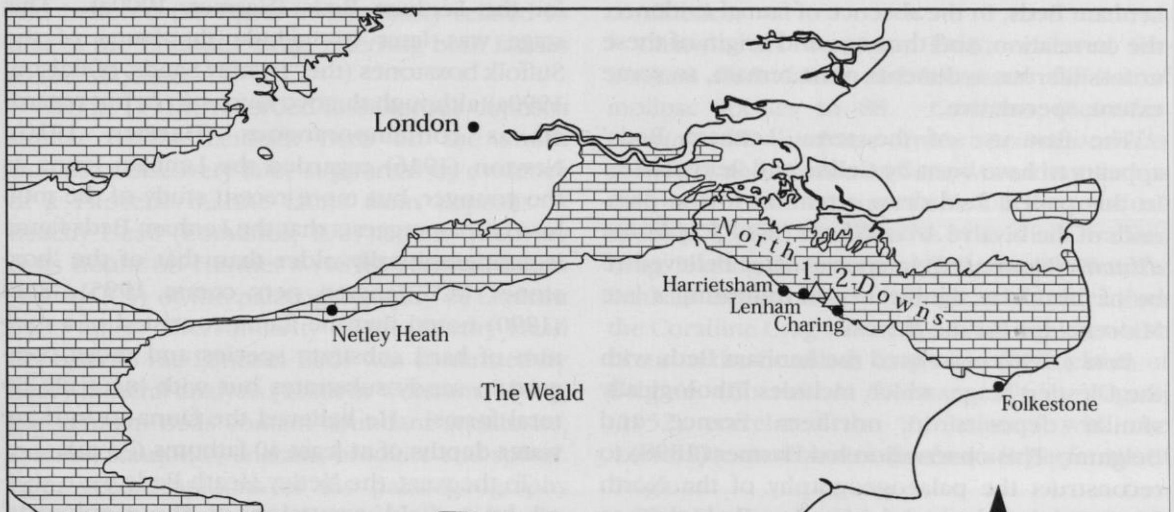

Figure 9.1 Location map for the Lenham Beds GCR sites: 1, Pivington Quarry; 2, Hart Hill Quarry.

Figure 9.2 External mould of *Scapharca diluvii* (formerly *Arca diluvii*) (British Geological Survey specimen no. GSM 49614). (Mould is 32 mm across.) (Photograph: T .Cullen.)

on the escarpment dip slope but the solution pipes are exposed as a result of former Chalk quarrying into the steep south-westward slope of the escarpment. Although attempts have been made to use sediment mineralogy to correlate these decalcified sediments with the Lenham Beds, in the absence of faunal evidence, the correlation, and thus age and origin of these unfossiliferous sediments must remain, to some extent, speculative.

The first use of the term 'Lenham Beds' appears to have been by Geikie and Reid (1886). In this paper, Reid drew attention to the presence of the bivalve *Arca diluvii* (now *Scapharca diluvii*) (Figure 9.2), a species later believed to be of particular significance in indicating a late Miocene age for the deposit.

Reid (1890) correlated the Lenham Beds with the Diestien Stage, which includes lithologically similar deposits in northern France and Belgium. This observation led Harmer (1898) to reconstruct the palaeogeography of the North Sea Basin that showed the Lenham Beds close to the southern coast of a closed embayment (Figure 9.3). Harmer noted, however (1898, p. 317), that the faunas of the Lenham Beds and Diestien, 'while presenting some resemblance, are, as to individual species, by no means identical'. In fact, *Arca diluvii*, regarded as the most diagnostic fossil of the Lenham Beds, does not even occur in the Diestien deposits (Newton, 1916). Despite this cautionary note, a correlation with the Belgian Diestien has become accepted more or less up to the present time (e.g. Curry *et al.*, 1978). A new stage, the Lenhamian or 'zone of *Arca diluvii*', was created for the Lenham Beds (Harmer, 1900a). This stage was later to include the fauna of the Suffolk boxstones (the 'Trimley Sands' of Balson, 1990a) although the two faunas were not regarded as contemporaneous (Harmer, 1910). Newton (1916) regarded the Lenham fauna as the younger, but more recent study of the mollusc faunas suggests that the Lenham Beds fauna is stratigraphically older than that of the 'boxstones' (A.W. Janssen, pers. comm. 1995). Reid (1890) noted that the fauna consisted of a mixture of hard substrate species and those common in sandy substrates but with 'no truly littoral forms'. He believed the fauna to indicate water depths of at least 40 fathoms (73 m).

To the west, the Netley Heath Beds were visited by a field excursion of the Geologists' Association (Stebbing, 1900) and fossils found for the first time. Correlation of these deposits with the Lenham Beds was based on their marine nature and similarity of elevation; the poorly preserved mollusc fauna was not diagnostic enough to correlate with certainty. Subsequent fossil finds showed a correlation of

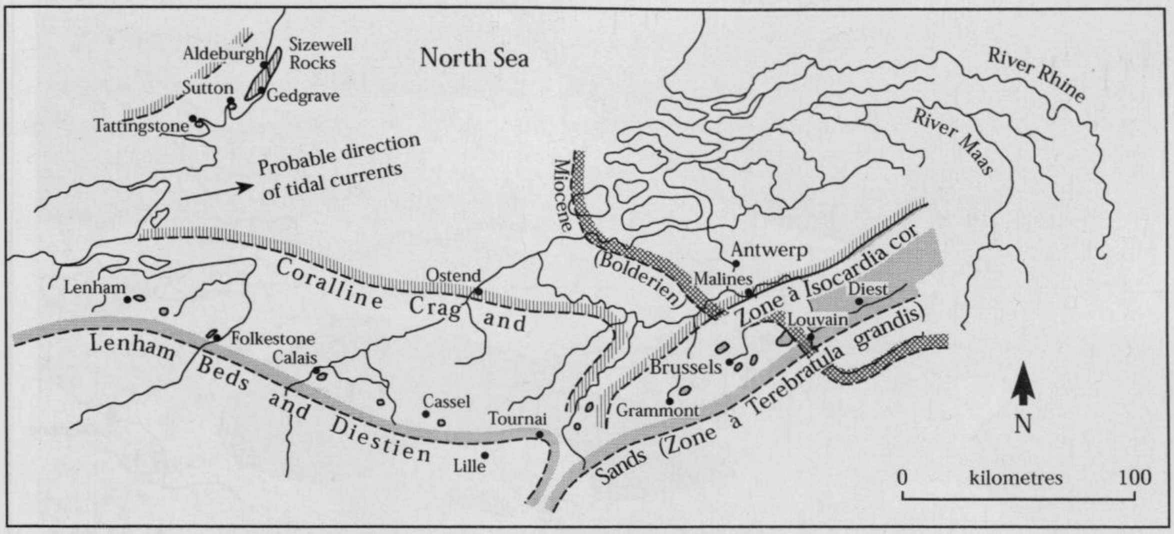

Figure 9.3 Harmer's (1898) palaeogeography of the North Sea during deposition of the Lenham Beds and Coralline Crag.

the Netley Heath Beds with the Red Crag of East Anglia to be more likely (Chatwin, 1927). It has recently been shown, however, that the ironstones that contain the fossils are not *in situ* (John and Fisher, 1984).

Newton (1916, 1917) extended the list of mollusc species from the Lenham Beds to 76 (one scaphopod, 32 gastropods and 43 bivalves) and believed the fauna to be closely related to that of the Coralline Crag, referring both faunas to the Miocene.

Abbott (1916) recorded fossiliferous deposits similar to the Lenham Beds on the South Downs, a discovery later supported by evidence of a Pliocene marine fauna from deposits at Beachy Head (Edmunds, 1927). This discovery casts doubt on Harmer's (1898) reconstruction (Figure 9.3) of the palaeogeography of Lenham Beds times. The similarity of the Beachy Head deposits to the Lenham Beds was confirmed by heavy mineral analysis (Elliot in Worssam, 1963); the Lenham Beds contain abundant andalusite, kyanite, staurolite, anatase, brookite and spinel. Later reconstructions of the palaeogeography show a 'Wealden island' surrounded by the Pliocene sea (Wooldridge and Linton, 1938) (Figure 9.4). This reconstruction implies a marine connection between the North Sea and the English Channel through the region of the modern Dover Straits which are unlikely to have been open until the middle Pleistocene (Gibbard, 1995). The model also relies on deposits such as the Netley Heath Beds being contemporaneous with the Lenham Beds. Both palaeogeographical reconstructions are therefore unsatisfactory and further work is necessary on the deposits, their relative ages and the tectonic history of the region before the palaeogeographical evolution of south-east England during the Neogene can be reconstructed with any confidence.

Chatwin (in Worssam, 1963) reviewed the Lenham Beds fauna and increased the list of mollusc species to 88. *Cardium* (*Acanthocardia*) aff. *andreae* (now *Acanthocardia andreae*) and *Nucula sulcata* were identified as the most common species. Of the mollusc species, 75 are also known from the Coralline Crag, leading Chatwin to the conclusion that the Lenham Beds are 'very little, if at all, older than the Coralline Crag'. *Arca diluvii* is not known to occur in the Coralline Crag or in the Diestien of Belgium (Chatwin in Worssam, 1963). Lagaaij (1952) correlated the 'Lenhamian' with the 'Lower Diestien' zone à *Terebratula perforata* of Belgium.

The Lenham Beds have played an important role in the debate over the uplift and denudation history of the Weald (e.g. Wooldridge and Linton, 1938, 1955; Worssam, 1963; Jones, 1980) due to their elevation of up to 680 feet (207 m) above OD (Abbott, 1916). Wooldridge and Linton (1938, 1955) postulated a late Pliocene–early Pleistocene ('Calabrian') trans-

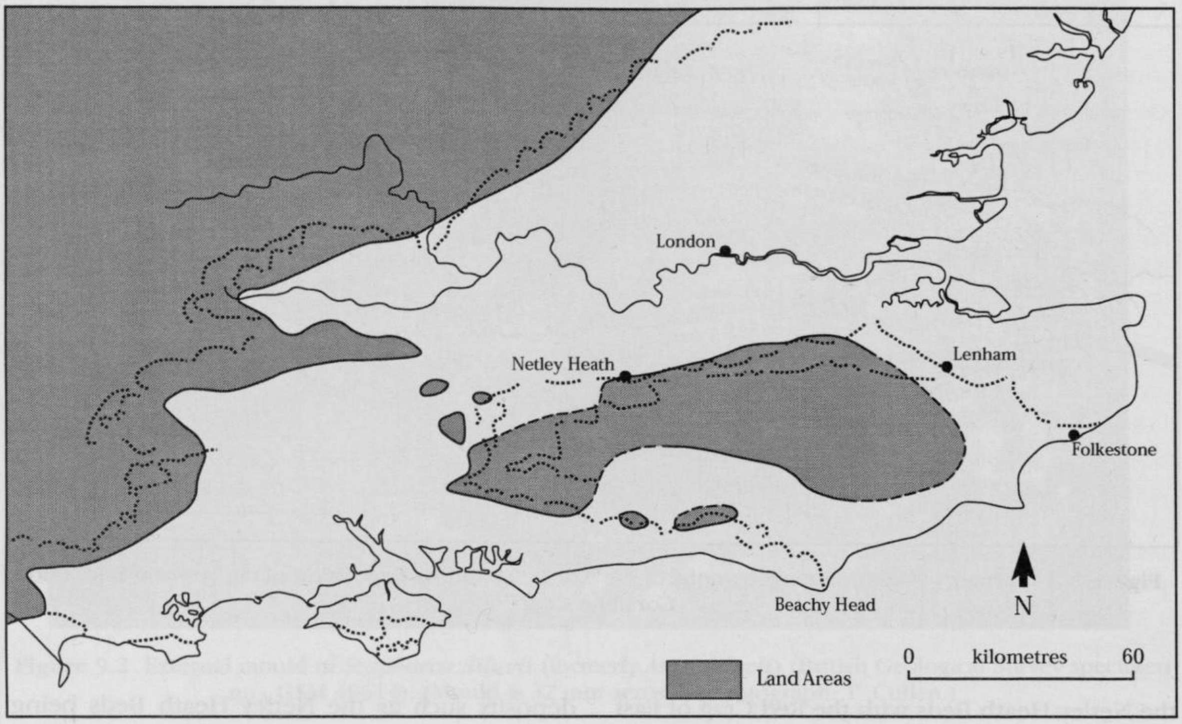

Figure 9.4 Wooldridge and Linton's (1938) palaeogeography of south-east England during deposition of the Lenham Beds.

gression which produced a widespread marine planation surface over south-east England up to an elevation of 210 m upon which marine sediments were deposited, including the Netley Heath Beds in the west and the Lenham Beds in the east. However they failed to take into account the age difference between the two deposits, possibly greater than 3 million years, and believed that they were both deposited from a single transgression that spread from east to west, depositing first the Lenham Beds and then the Netley Heath Beds. It is more likely that the Lenham Beds were deposited during a separate transgression that occurred much earlier than the transgression responsible for the deposition of the Netley Heath Beds, and that the role of Plio-Pleistocene marine erosion in forming planation surfaces (Wooldridge and Linton, 1938, 1955) has been overstated (see discussion in Catt and Hodgson, 1976).

The magnitude and timing of post-depositional tectonic uplift, particularly of the Wealden axis, and subsidence of the southern North Sea Basin, are key factors in the understanding of the Neogene evolution of south-east England. Reid's (1890) suggestion of a water depth of 40 fathoms (73 m) during deposition of the Lenham Beds would imply a sea level 280 m above present mean sea level. The Coralline Crag of Suffolk was probably deposited in water depths similar to, or less than, those of the Lenham Beds and has a maximum surface elevation of only 18 m above OD. Unless eustatic sea level was greatly different between deposition of the two deposits, this implies that the majority of the difference in elevation is due to tectonic uplift. The relative elevations of the two deposits can be explained by a regional tilt of only 0.1°. Van Voorthuysen (1954) illustrated the magnitude of uplift and subsidence in eastern England and the southern North Sea since Pliocene times with *c.* 200 m of uplift along the northern limb of the Wealden anticline and over 700 m of subsidence in the Netherlands. A 'hinge' line with no net subsidence or uplift lay in the vicinity of Ipswich and thus in the area of deposition of the Red and Coralline Crags. A more controversial explanation for the Lenham Beds location was offered by Shephard-Thorn (1975) who suggested that the sediments were glacially transported to their present position. If such a model was correct the elevation of the Lenham Beds could not be used to infer past sea levels, nor rates of tectonic uplift.

A reappraisal of the Lenham Beds fauna by Janssen (in Balson, 1990a) suggests that the

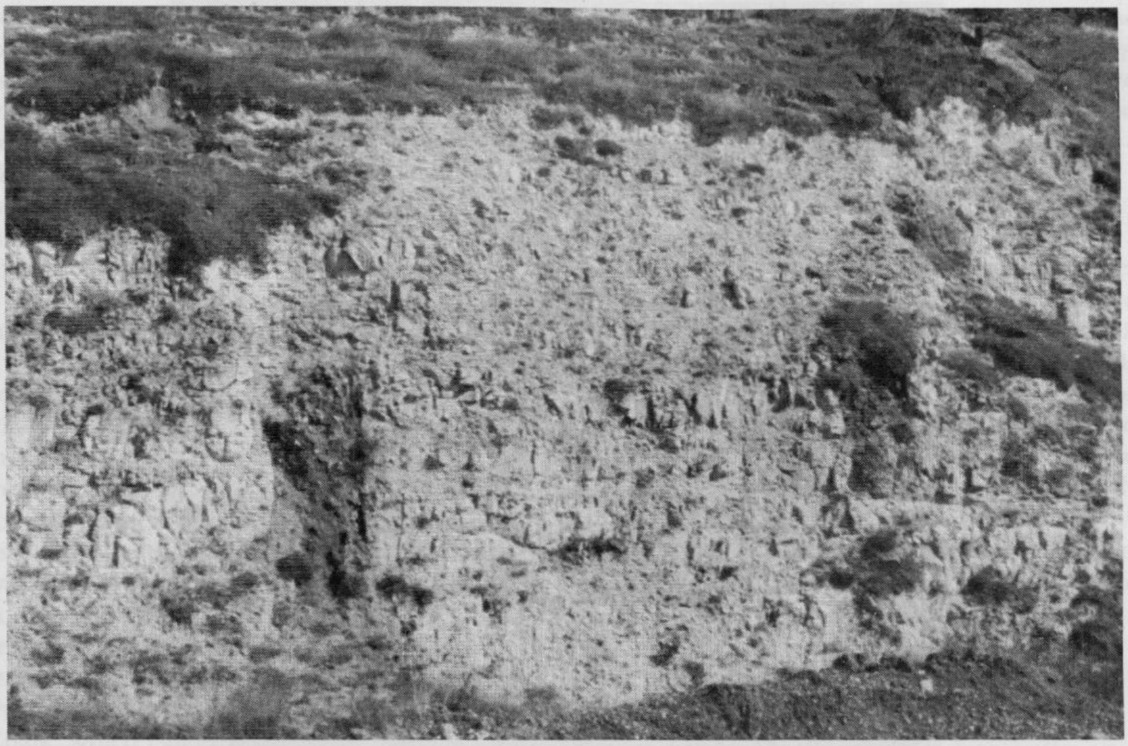

Figure 9.5 Conserved face in Pivington Quarry showing remnants of solution pipes. The photograph shows 15 m of lateral exposure. (Photograph: P. Balson.)

fauna has closer affinities with the Redonian of Brittany than with the Neogene of the North Sea Basin. This observation may have important implications to the reconstruction of the palaeogeography of Lenham Beds time and suggests that a physical barrier may have been present to the north of the North Downs rather than as a result of Wealden uplift to the south.

The Lenham Beds therefore remain controversial to the present time. Their exact age is still unknown. The environment of deposition and the mechanism by which they came to be preserved within solution pipes has still to be resolved. The resolution of these questions will shed light on the palaeogeography, environment and tectonic history of south-east England during the Neogene.

PIVINGTON QUARRY, LENHAM, KENT (TQ 915525)

Highlights

This quarry exposes solution pipes in the Chalk that contain the ferruginous fossiliferous sands of the Lenham Beds within their infills. It is one of the very few remaining places where the Lenham Beds fauna can be observed and the ferruginous sandstone blocks that contain the fossils can be seen in the context in which they were originally described. The site is close to the type locality at Lenham.

Introduction

Pivington Quarry is a disused Chalk pit cut into the hillside formed by the Chalk escarpment about 500 m north of the A20. According to Worssam (1963), the excavation of this Chalk pit commenced in 1947. However, Ordnance Survey maps show the presence of a small quarry before this time. A pit at this approximate location was mentioned by Reid (1890, p. 48). This earlier quarry probably forms the eastern end of the present quarry (TQ 916525). The quarry is presently being used as a landfill site.

Description

When the quarry was being extended in 1947, the removal of the topsoil revealed the surface of the Middle Chalk which was seen to be riddled

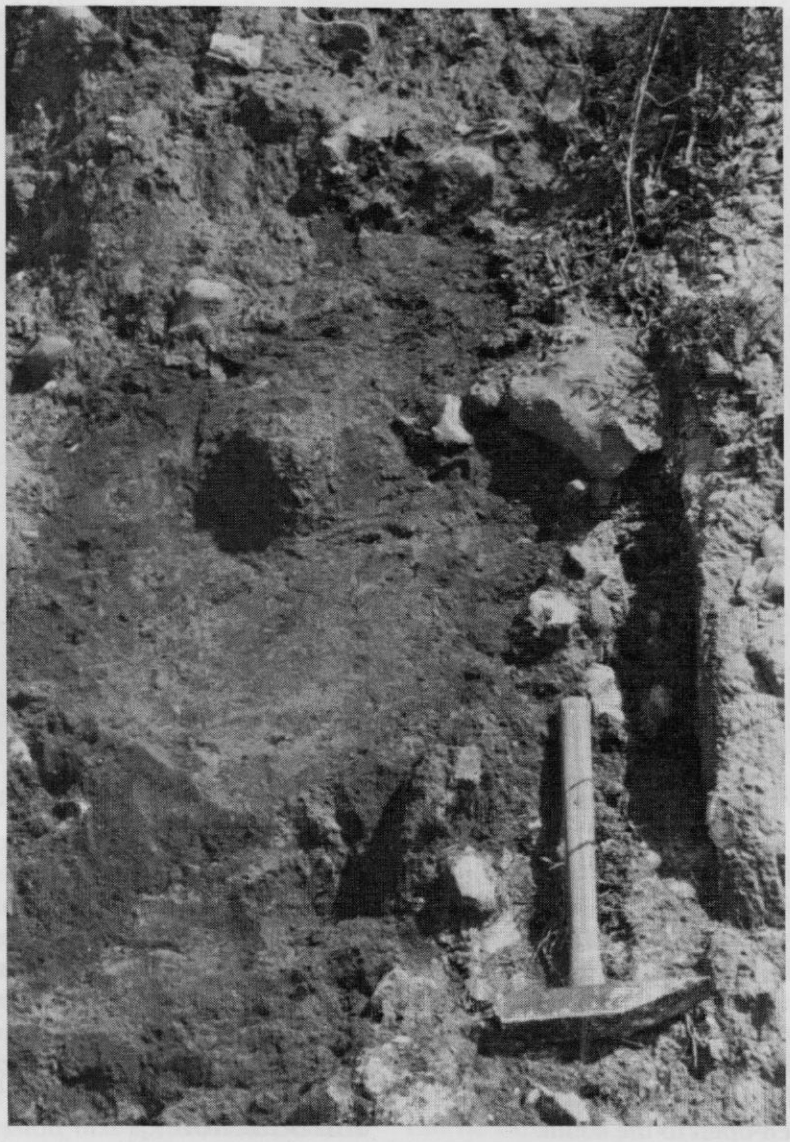

Figure 9.6 Solution pipe infill showing sharp vertical wall (right) and disturbed structure in ferruginous sands at centre of pipe infill. (Hammer shaft is 33 cm long). (Photograph: P. Balson.)

with solution pipes that were largest and most numerous towards the crest of the escarpment. Their density was estimated at 15 in a 50 yard square (45.7 m square) area. Most were roughly circular in plan and up to 15 feet (4.6 m) across (Worssam, 1963).

At the present time the quarry exposes faces of Chalk up to approximately 10 m high. Solution pipes can be seen in section on the face. The upper surface of the Chalk is obscured by vegetation on the graded slope above the quarry faces and therefore in most cases the uppermost parts of the solution pipes are absent as the plane of the face slopes away from vertical. However, part of the quarry face is being conserved from landfill tipping. The visible pipes on the conserved face (Figure 9.5) are up to 1.3 m wide and the longest could be traced vertically for over 3 m in length. At the eastern end of the quarry the partial mould of a solution pipe from which the fill has been lost is over 7 m deep and more than 4 m wide.

The pipes are lined with a dark grey silty clay 2–3 cm thick. The remainder of the fill appears chaotic with abundant subangular flints up to 100 mm diameter and Chalk granules in a silty sand matrix. In some pipes the central core of the pipe contains a disturbed deposit of orange-brown ferruginous sand (Figure 9.6). This sand is moderately sorted and dominantly fine-grained, and is occasionally cemented into irregular blocks, which have an apparent random orientation. The decalcified cemented blocks may contain poorly preserved moulds of molluscan shells.

Interpretation and evaluation

Solution pipes are common in the surface of the Chalk and indeed are found in the surface of many carbonate-rich formations including, for instance, the Pliocene Coralline Crag formation to be described later in this volume. They form as the result of dissolution caused by the downward movement of groundwater. Solution pipe contents may be dominated by the insoluble residue of the formation undergoing dissolution as in the case of the Coralline Crag. However, the pipes at Pivington Quarry are formed in Chalk, which is a relatively pure limestone with only a small lithic fraction. The thin lining of dark grey silty clay may in part represents the insoluble residue of the Chalk but may also in part be derived from the eluviation of clay from overlying deposits. The gravelly flint-rich deposits which 'overlie' this clay lining within the pipe represent a weathering deposit formed on the exposed surface of the Chalk during Tertiary times and probably related to the 'Clay-with-flints' (Catt and Hodgson, 1976). This deposit sagged into the pipe as solution took place. The ferruginous sand deposit was probably originally deposited over the flint-rich gravel and has also sagged into the pipe so that it now occupies the central core of the infill. If cementation preceded pipe formation this might help explain the occurrence of randomly orientated blocks resulting from the breakup of a formerly continuous layer.

Fossiliferous Lenham Beds appear to be restricted to the type area between Harrietsham and Charing where the cessation of Chalk quarrying means that exposures of Lenham Beds are becoming increasingly degraded. The type locality at Lenham, just over a kilometre to the west, is now much degraded such that the quarries at Pivington and Hart Hill are among the last remaining sites where fossiliferous Lenham Beds can be observed, which therefore increases the importance of these sites. The exposed solution pipes clearly show the relationship between the Chalk and the overlying residual deposits (clay-with-flints) with disturbed and contorted Lenham Beds sands occupying the central portion of the pipes.

Conclusions

Pivington Quarry is one of two remaining sites that expose solution pipes containing fossiliferous Lenham Beds sediment. As such, the site is important in that it illustrates faunal and sedimentological evidence of a marine transgression of Neogene age in north Kent. The age and elevation of the deposits are important in the reconstruction of the timing and extent of uplift of the Weald–Artois axis and consequently have implications for the determination of the time of breaching of the uplifted barrier to form the Dover Straits.

HART HILL, KENT (TQ 943506)

Highlights

The quarry at Hart Hill represents one of the few remaining localities where solution pipes in the surface of the Chalk containing fossiliferous Lenham Beds can be observed.

Introduction

This locality consists of a disused Chalk quarry

Figure 9.7 Solution pipe at Hart Hill showing 'concentric' zonation of infill. (Photograph: P. Balson, taken in 1981.)

cut into the Chalk escarpment about 500 m N of the A20. The quarry was not mentioned by Reid in his review of Lenham Beds localities in 1890, but the pit was recorded by the Ordnance Survey in 1906. The old face on the northern side of the quarry is approximately 20 m high and is densely overgrown but small sections of exposed Chalk are now visible. Several solution pipes are visible extending downwards from the upper surface of the Chalk.

The exposed solution pipes clearly show the relationship between the Chalk and the overlying residual deposits (Clay-with-flints) with disturbed and contorted Lenham Beds sands occupying the central portion of the pipes.

Description

The solution pipes visible in section at this location are up to 2 m deep and up to 3 m wide formed in the surface of the Middle Chalk. It should however be noted that the visible pipe may not be an accurate indication of its total extent because it represents the intersection of a downward-tapering cylinder with the vertical or sloping quarry face. The infills of the pipes show a conspicuous 'concentric' zonation (Figure 9.7) due to the downward 'sagging' of the overlying deposits during the slow formation of the pipe by solution of the Chalk. The pipes are lined with dark-grey silty clay overlain by gravelly sands with abundant flint pebbles. These residual deposits may be equivalent to the Clay-with-flints deposits, which are widespread on the surface of the Chalk and formed during Tertiary subaerial exposure (Catt and Hodgson, 1976). The central core of the infill consists of ferruginous sand and sandstone from which fossils have been obtained in the past and which represent the Lenham Beds deposits *sensu stricto*.

Interpretation and evaluation

Fossiliferous Lenham Beds appear to be restricted to the type area between Harrietsham and Charing where the cessation of Chalk quarrying means that exposures of Lenham Beds are becoming increasingly degraded. The type locality at Lenham, 5 km to the northwest is now much degraded such that the quarries at Pivington and Hart Hill are among the last remaining sites where fossiliferous Lenham Beds can be examined.

Conclusions

Hart Hill Quarry is an important site in that it is one of the few remaining sites that exposes solution pipes containing fossiliferous Lenham Beds sediment. The concentric zonation that results from the slow downward sagging of layered deposits into a solution pipe are seen particularly well at this locality. The presence of a fauna allows determination of the sedimentary environment and suggests the possible age of a Neogene marine transgression in north Kent. The age and elevation of the deposits are important in the reconstruction of the timing and extent of uplift of the Weald–Artois axis and consequently have implications to the determination of the time of breaching of the uplifted barrier to form the Dover Straits.