British Tertiary Stratigraphy

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Chapter 7

Western outliers of Dorset and Devon

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INTRODUCTION

To the west of the main outcrop of Palaeogene strata in the Hampshire Basin, there are a number of localities that represent a variety of continental facies which, with the possible exception of the Creechbarrow Limestone, lay beyond the influence of the Palaeogene sea to the east. Six have GCR status as a result of their stratigraphical importance (see Figure 7.1 for their location).

In Dorset, the outliers of gravel at Blackdown and Bincombe Down are thought to reflect alluvial fan developments associated with contemporaneous fault movement, whilst at Creechbarrow, the succession includes a unique remnant of a non-marine limestone of early late-Eocene age. In Devon, Tower Wood Quarry and Buller's Hill Quarry comprise gravels that predominantly originated as the weathering residue of the Chalk and its reworking by fluvial processes in early Palaeogene times. The Aller Sand Pit further west represents a braided stream deposit associated with the development of the economically important Bovey Tracey Basin.

The latter, together with the Petrockstowe Basin further north, reflect downwarping associated with movement on the Sticklepath–Lustleigh fault. Both contain thick sequences of Palaeogene strata of which a large proportion comprises kaolin-rich 'ball-clay'. The latter may be examined together with associated sediments in numerous working pits in both the Bovey Tracey and Petrockstowe basins, and to the east in Dorset.

BLACKDOWN, DORSET (SY 613875)

Highlights

The almost unique gravels of Blackdown suggest the former presence of alluvial fan sedimentation in Palaeogene times to the west of the Hampshire Basin. The variety of pre-Chalk pebbles found here provides insights into the provenance of the gravels. Flint and chert pebbles of local Cretaceous and Upper Jurassic provenance are thought to have been derived as a result of fault movement, uplift and erosion in Eocene times.

Introduction

The site occurs within the Blackdown Outlier (SY 613875), south-west of Dorchester and some 10 km west of the main Palaeogene outcrop of the Hampshire Basin (Figure 7.1). It comprises a series of disused gravel pits around the summit of Blackdown, with the best exposures some 100 m south of the Hardy Monument.

The Tertiary sediments of Blackdown were first noticed by Buckland (1826) who assigned

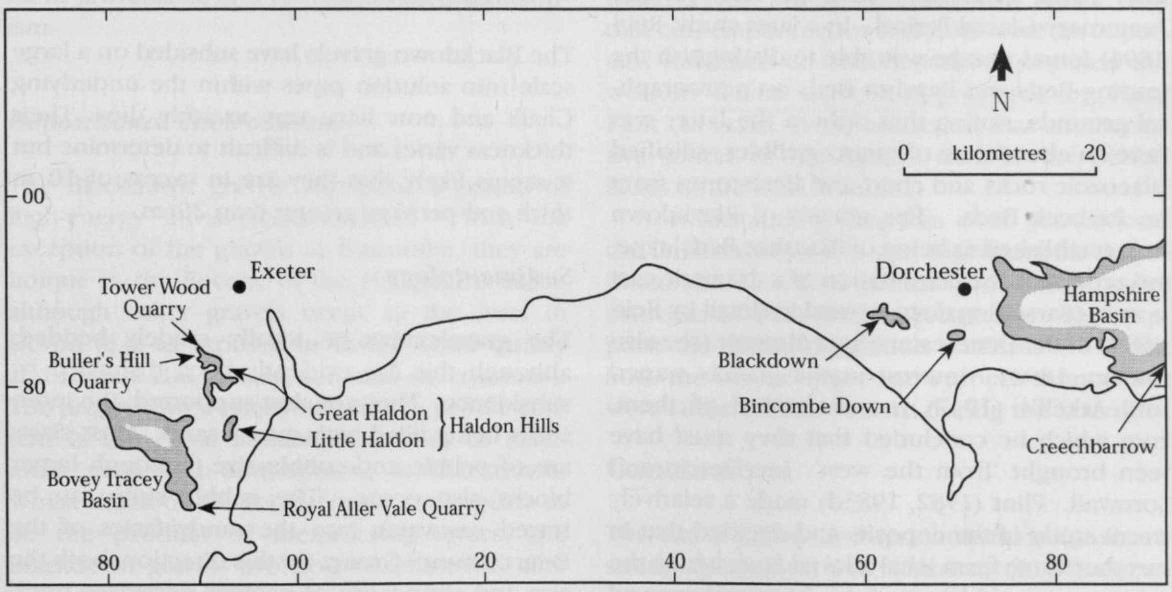

Figure 7.1 Map to show the distribution of Palaeogene outliers in Dorset and Devon.

Figure 7.2 Blackdown, Dorset. Blackdown Gravel exposed in the disused quarry to the south of Hardy's Moument. (Photograph: B. Daley.)

them to what was at the time called the Plastic Clay Formation (now the Reading Formation). In their comprehensive survey of the Weymouth District, Buckland and de la Beche (1836) described them in more detail and agreed their Reading Beds age. Prestwich (1875), on the other hand, tentatively assigned them to the Quaternary Glacial Period. In a later study, Reid (1896) found that he was able to distinguish the Reading Beds and Bagshot Beds on petrographical grounds, noting that only in the latter was there an abundance of quartz pebbles, silicified Palaeozoic rocks and chert and limestones from the Purbeck Beds. The gravels of Blackdown were established as being of 'Bagshot Beds' type, and represent the culmination of a dramatic east to west coarsening documented in detail by Reid (1899) in the Dorchester Sheet Memoir (see also Strahan, 1898). Interest in the gravels waned until Arkell's (1947) re-examination of them, from which he concluded that they must have been brought 'from the west', i.e. Devon and Cornwall. Plint (1982, 1983d) made a relatively recent study of the deposits and decided that in part they came from local alluvial fans, whilst the more exotic pebbles may have been transported by rivers from further west.

Description

The gravels at Blackdown (Figure 7.2) represent a conglomeratic facies of Bracklesham Group age and rest unconformably on the Chalk.

Lithological succession

The Blackdown gravels have subsided on a large scale into solution pipes within the underlying Chalk and now have very variable dips. Their thickness varies and is difficult to determine but it seems likely that they are in excess of 10 m thick and perhaps greater than 20 m.

Sedimentology

The gravels may be locally crudely bedded, although this has evidently been disturbed by subsidence. They are clast supported, the interstices being filled with quartz sand. Most clasts are of pebble and cobble size, although larger blocks also occur. The pebble suite can be traced eastwards into the sandy facies of the Bournemouth Group. In this direction, both the size and abundance of pebbles decreases until, by Wareham, they disappear completely.

Pebble composition

A variety of pebble types are present including 'local' and 'exotic' components. In composition, they are quite different from the thin pebble beds of the Isle of Wight, whose clasts are almost all made of flint derived from the Upper Chalk. The Blackdown Gravels also include flint (about 70% of the total pebbles) but, in addition, chert from the Upper Greensand (13%) and chert from the Purbeck Beds (2%) (Plint, 1982). As well as these 'local' cherts, there are 'exotic' pebbles including well-rounded vein quartz (14%), plus black cherts, silicified limestones and laminated siltstones (together comprising 1%). Whilst some of the 'local' clasts reach around 35 cm in diameter, the exotic pebbles seldom exceed 4 cm. Plint (1982) suggested that the exotic pebbles were derived from Palaeozoic sources, but considered that reworking from the Wealden was also possible.

Interpretation and evaluation

The unconformable contact of the gravels at Blackdown with the Chalk is palaeogeographically significant, since it reflects the westward overlap of the 'Bagshot Beds' (now part of the Poole Formation of the Bracklesham Group; see Edwards and Freshney, 1986, p. 54) across the London Clay and Reading Formation. The gravels also facilitate an understanding of both sediment provenance and contemporaneous tectonism.

Depositional environment

The Blackdown gravels represent a period of high-energy fluvial sedimentation. With the exception of the gravels at Bincombe, they are unique in the Eocene of the Hampshire Basin, although other gravels occur to the west in Devon (e.g. as exposed in Tower Wood Quarry and Bullers Hill Quarry; see later descriptions). The progressive westerly increase in pebble content of the Poole Formation reaches its maximum preserved development at Blackdown. Whilst much of the Poole Formation appears to be the product of meandering rivers, the Blackdown gravels probably originated in alluvial fans (Plint, 1982).

Provenance and contemporaneous tectonism

In composition, the Blackdown gravels are petromictic and quite different from the flint gravels of the Boscombe Sand Formation to the east (see Plint (1988b) and the review of the 'Bournemouth Cliffs' site in this volume). Their occurrence throws considerable light on the tectonic history of this part of the Palaeogene basin. The presence of the 'local' flints, Upper Greensand and Purbeck cherts implies considerable uplift and erosion. Both the Upper Greensand and the Purbeck Beds are exposed one kilometre SSW of Blackdown on the other side of the Ridgeway fault, a fault downthrowing to the north. Plint (1982) has argued that the presence of these local flint and chert pebbles are a direct result of contemporaneous fault movement. He has suggested that high gradients and torrential run-off produced fault-scarp alluvial fans.

The explanation of the exotic clasts is more problematical. They are smaller and better rounded and have evidently travelled a considerably greater distance. Plint (1982) considered that they can be traced to Palaeozoic sources in Devon, particularly from and around the Dartmoor Granite, and that they were introduced by rivers draining eastwards along the axis of the basin, the southern margin of which was strongly fault controlled. Such rivers were clearly of lower energy than those which introduced the local Mesozoic debris from the south. Isaac (1983), whilst agreeing with Plint's view that contemporaneous tectonics were an important influence on sedimentation, disputed the western fluvial derivation proposed by Plint. Plint (in Isaac, 1983) conceded that an alternative source of the exotics may be the pebbly facies of the local Wealden.

Notwithstanding disputes over provenance, the importance of the site, together with that at Bincombe Down, is primarily that it provides evidence of intra-Eocene tectonism. This supports the earlier suggestion (Phillips, 1964) that both the Isle of Wight and Purbeck monoclines were subject to movement during the Eocene.

Conclusions

This site is nationally important and is significant stratigraphically in that it demonstrates the westerly overlap of the Poole Formation across older Palaeogene strata on to the Chalk.

The petromict gravels of Blackdown are derived in part from local Mesozoic rocks and in part from older rocks present further to the west. The large size of the local clasts has been interpreted as evidence for high-energy deposition in alluvial fans. Blackdown is one of only two localities where this facies is preserved.

The presence in the Blackdown gravels of clasts of chert from rocks older than the Chalk clearly differentiates these gravels from the Palaeogene flint gravels of the central and eastern parts of the Hampshire Basin. They therefore provide evidence of considerable uplift and erosion. This is considered to have resulted from contemporaneous movement of the Ridgeway fault, the trend of which is similar to the Purbeck and Isle of Wight monoclines whose occurrence is thought to be the superficial expression of deep-seated faults. If the fault movement inferred from the Blackdown gravel suite is correct, the locality provides support to the thesis that the structural evolution of the Hampshire Basin has been controlled by mainly vertical movements of fault-bounded basement blocks.

BINCOMBE DOWN, DORSET (SY 676856)

Highlights

The gravels of this site provide information on the palaeogeography of the area to the west of the main Palaeogene depositional basin of southern Britain. Their coarseness and composition suggest high-energy fluvial conditions within alluvial fans associated with intra-Eocene movement on the Ridgeway fault.

Introduction

The site comprises overgrown disused gravel pits near the summit of Bincombe Down (grid reference SY 676856) within a small outlier south of Dorchester and some 5 km west of the main outcrop of the Hampshire Basin Palaeogene (Figure 7.1). The sediments present comprise gravels, sands and silty muds, equivalent to what were formerly called the 'Bagshot Sands' further to the east. They were later assigned to the Poole Formation of the Bournemouth Group of Edwards and Freshney (1987b), although the latter is now subsumed into the Bracklesham Group. The pebble suite is the significant feature of the site because of its implications for provenance and contemporaneous earth movements.

The Eocene sediments capping Bincombe Down were apparently first noticed in 1855 by Fisher (1896) who described vertically bedded coarse sands, clays and gravels exposed some 200 m north of the Ridgeway fault. Bincombe was figured by Prestwich (1875) in cross-sections illustrating the structure of the Weymouth district, and also by Strahan (1895) in his detailed account of tectonic disturbances in Dorset. Strahan considered that the complex geology of the area around Bincombe Village was the result of the southward overthrusting of Middle Jurassic over Upper Jurassic beds. The most important early study of the area was that of Reid (1896), who devoted particular attention to the composition of the gravels, their sources and implication for interpreting the regional structure, palaeogeography and drainage pattern. He also noted their importance (together with those of Blackdown) as sources of the Pleistocene gravels of Dorset, Hampshire and Sussex. References to the Tertiary strata at Bincombe in the Purbeck Memoir by Strahan (1898) are mainly based on Reid (1896) and Fisher (1896). Similarly, Reid reiterated much of his earlier work (1896) in his Dorchester Sheet Memoir (1899).

Later work by Arkell (1936) suggested that Strahan's explanation of the structural geology was at variance with the evidence and thus untenable. He proposed a multi-phase history of movement on the parallel and closely spaced Abbotsbury and Ridgeway faults involving southerly downthrow during the Cretaceous and northerly downthrow during the Tertiary. He argued (Arkell, 1947) that the locally derived Eocene gravels at Bincombe provided important evidence for dating the post-Cretaceous movement on the Ridgeway fault. More recent work by Plint (1982, 1983d) is considered below.

Description

The deposits comprise crudely bedded sands, gravels and silty muds. Their thickness is difficult to determine, particularly at the present time, since exposures are very poor. Fisher (1896) noted 30 m of vertically bedded sands and gravels, although strata on the northern side of the outlier are horizontal (Strahan, 1898).

Like the pebble suite at Blackdown, a variety of clast types are present. About 50% are large, poorly rounded flints, whilst a smaller proportion comprises Upper Greensand chert clasts, some up to 30 cm in diameter. Small pebbles of vein quartz are common, and were considered by Reid (1896) to have been derived from the Wealden. In addition to these principal components, there are pebbles of chert and silicified limestone of Purbeck age, 'veined grits', quartzites, radiolarian chert and red and green jasper (Reid, 1896).

Interpretation and evaluation

The importance of the Bincombe outlier is principally that it provides (with similar gravels at Blackdown) evidence of intra-Eocene syn-sedimentary movement on the Ridgeway fault.

Stratigraphical affinities

Stratigraphically, gravels such as those at Bincombe and Blackdown have been included in the Poole Formation of Edwards and Freshney (1987b). There may, however, be a case for giving them separate formation status, since they are likely to be a separately mappable unit. The Bincombe gravels can be traced eastwards into the 'Bagshot Sands' of Warmwell (SY 752881) where the underlying strata are Reading Beds and London Clay. Since the Bincombe gravels rest on the Chalk, a westward overstepping relationship is apparent.

Depositional environment and palaeogeography

Plint (1982) suggested that the texturally immature, locally derived Chalk flints, Upper Greensand and Purbeck cherts in the gravels indicate the contemporaneous exposure of such rocks to erosion and that this occurred immediately to the south of the Ridgeway fault. He suggested (Plint, 1982, 1983d) that the coarseness of these clasts may support a conclusion that alluvial fans had developed at this time adjacent to a fault scarp produced by intra-Eocene movement. The coarseness of the Bincombe gravels is in sharp contrast with their more easterly equivalents at Warmwell and Povington (SY 892824) where exotic pebbles are much smaller and comprise only a minor constituent of the sediment. Since such a clast size distribution provides an index of stream power and gradient, it seems that alluvial fan sedimentation was replaced eastwards from the Bincombe area by a less energetic fluvial regime.

Provenance

Plint (1982) concluded that in contrast with the pebbles of Mesozoic age derived by local erosion, the origin of the 'exotic' pebbles was more problematical. He postulated that they might have been introduced from parent rocks to the west by easterly flowing streams, a suggestion disputed by Isaac (1983). An alternative is that such pebbles were reworked from Mesozoic gravels such as those of the Wealden strata of Dorset or even from earlier Palaeogene sediments, possibly those from the southern, uplifted side of the Ridgeway fault.

Conclusions

The gravels at Bincombe, like those of Blackdown, provide evidence of considerable contemporaneous uplift and erosion. High-energy deposition of coarse clastics in alluvial fans adjacent to the Ridgeway fault has been inferred. With Blackdown, Bincombe provides clear evidence of intra-Eocene tectonism and is therefore an important national site.

CREECHBARROW, DORSET (SY 922824)

POTENTIAL GCR SITE

Highlights

Interest in Creechbarrow is centred on the Creechbarrow Limestone, the sole remnant of non-marine limestones of early late Eocene age in the Hampshire Basin. Its land and non-marine gastropods, together with a rich mammalian fauna, provide a prime source of information on the contemporary palaeogeography.

Introduction

The conical form and height (193 m) of Creechbarrow (grid reference SY 922824; see Figure 7.1) is a striking physical feature of the Dorset landscape (Figure 7.3). It is capped by the Creechbarrow Limestone (Creechbarrow Limestone Formation of Hooker, 1977b) which is underlain by a complex of fine to coarse clastics. Both the nature of the succession and its

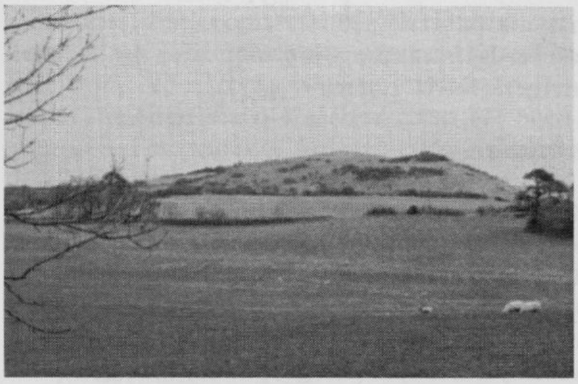

Figure 7.3 Creechbarrow, Dorset. General view from the south-west. The outcrop of the Creechbarrow Limestone Formation at the summit is marked by a light cover of grass, whilst the dark cover of bracken below occurs on the underlying sands, clays and gravels. (Photograph: B. Daley.)

relationship to the underlying Chalk have significant stratigraphical, palaeogeographical and tectonic implications.

Geological interest in Creechbarrow began at the beginning of the 20th century with the pioneer work of Hudleston (1901, 1902a,b, 1903). He was initially concerned to explain its anomalous physical features and age, but in the course of this work discovered the capping of limestone which has provided the focus of interest for subsequent work including that of recent years.

Excavation is necessary to expose the limestone and this has proceeded at intervals up to the present day. Much of the interest has centred on the fossils from the limestone and their use for dating the Creechbarrow strata and for palaeogeographical interpretation. Work by Hudleston and others (Keeping, 1910, 1912; Bury, 1934; Arkell, 1947) led to the recognition of a mainly molluscan fauna and a long-lasting debate on the age of the 'Creechbarrow Beds'.

More recently, excavations by field parties from the Natural History Museum in 1975, 1976 and 1978 have led to the discovery of a rich vertebrate fauna (see Hooker, 1977b, 1986, 1992; Hooker and Insole, 1980), whilst a modern review of the mollusca from the Creechbarrow Limestone has been undertaken by Preece (1980).

Originally the sequence was mapped by the Geological Survey as 'Bagshot Beds', whilst the disparity of the dip of these strata and the nearby Chalk led to early speculation about the age of the local folds (Arkell, 1947; see also Jones, 1981).

This site is a confirmed GCR site for its fossil mammal content, a more detailed account of which can be found in the GCR series volume *Fossil Mammals and Birds of Great Britain* (Benton *et al*., in prep).

Description

Creechbarrow is a conical hill immediately north of the Chalk ridge of the Purbeck Hills and comprises an outlier, the sole remnant of the 'Creechbarrow Beds', resting on what used to be called the 'Pipe-clay Series' (Arkell, 1947, pp. 233–41). At 194 m in height, it is higher than the summit ridge of the Chalk except for Ridgeway Hill and Nine Barrow Down, and rises above the supposed Miocene planation surface (House, 1993, p. 129).

Lithological succession

Altogether, the 'Creechbarrow Beds' are some 52–64 m thick. The youngest unit comprises 2–3 m of limestone, which rests on a sequence of clastic strata comprising brick-clays, sands, grits and bands of flint pebbles (Figure 7.4).

The present fossil mammal GCR site includes both the limestone and the immediately underlying 'Sand with bands of flints' (Arkell, 1947, p. 237) which forms the lower part of the 'Upper Creechbarrow Beds', but it is exclusively the nature of the former (the Creechbarrow Limestone) that justifies independent GCR/SSSI status on stratigraphical grounds.

Stratigraphy

The 'Lower Creechbarrow Beds' of Arkell (thought to be the equivalent of the Agglestone Grit) occur within the Poole Formation of Curry *et al*. (1978, table 1) whilst the 'Middle and Upper Creechbarrow Beds' were assigned to their Bournemouth Formation. The application of the more recent stratigraphical terminology of Edwards and Freshney (1987b), as amended by Bristow *et al*. (1991), is not totally clear, but it seems possible that the 'Creechbarrow Beds' occur across the boundary between the Poole Formation and the Branksome Sand of the former authors. The Creechbarrow Limestone of Hudleston (1902a) has recently been formally described by Hooker (1977b), to conform with Hedberg (1976), and named the Creechbarrow Limestone Formation.

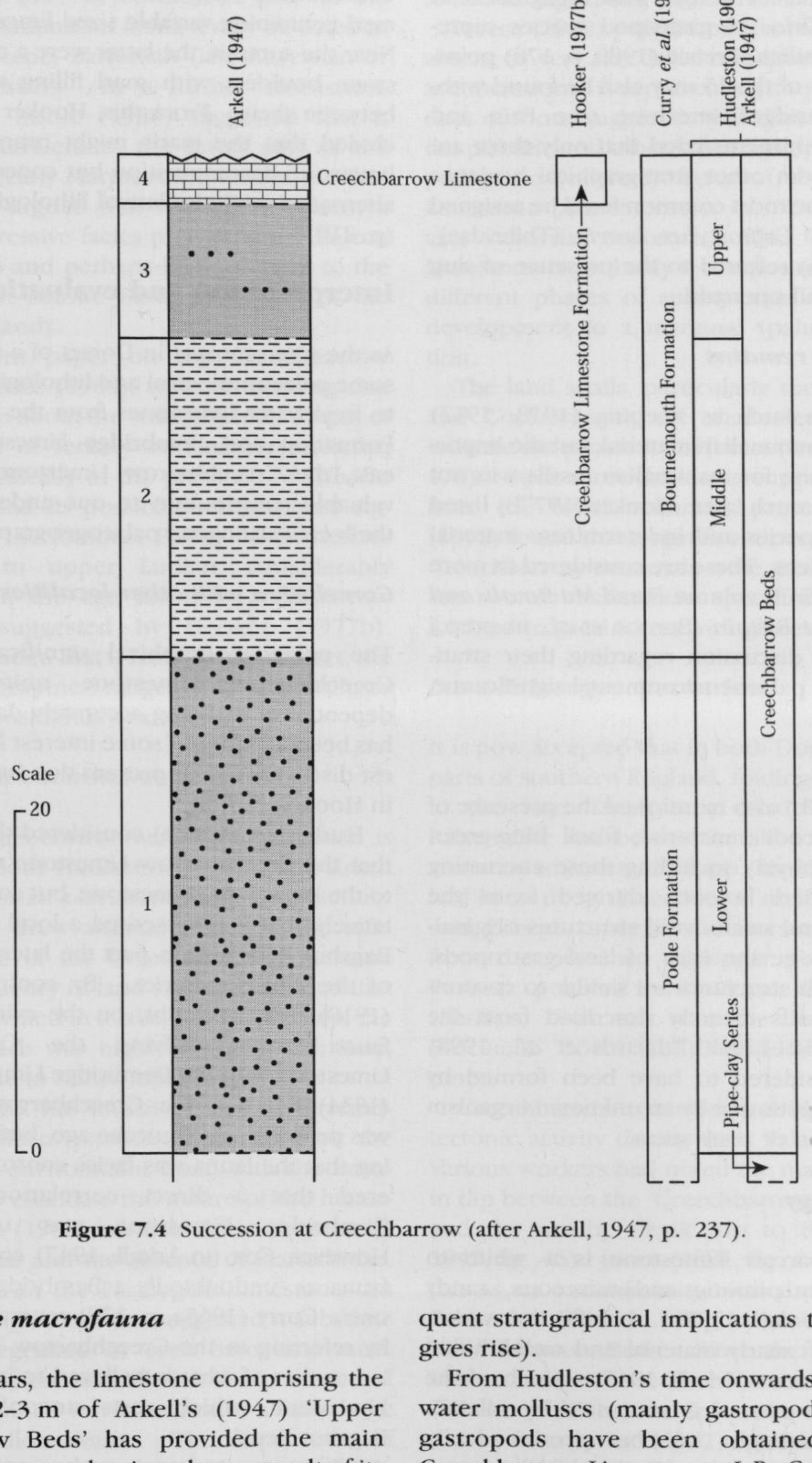

Figure 7.4 Succession at Creechbarrow (after Arkell, 1947, p. 237).

Invertebrate macrofauna

For many years, the limestone comprising the uppermost 2–3 m of Arkell's (1947) 'Upper Creechbarrow Beds' has provided the main focus of interest, predominantly as a result of its fossils (although in part too as a result of its locally unique lithological nature and the consequent stratigraphical implications to which this gives rise).

From Hudleston's time onwards, both freshwater molluscs (mainly gastropods) and land gastropods have been obtained from the Creechbarrow Limestone. L.R. Cox (in Arkell, 1947, p. 240) listed nine gastropods and the bivalve *Unio* and concluded that 'the fauna is undoubtedly a Bembridge Limestone one'. More recently, the molluscan fauna was reviewed by Preece (1980) who recognized, in addition to *Unio*, 15 gastropod species representing 12 families. Preece (1980, p. 178) pointed out that 13 of the 15 may also be found within the Bembridge Limestone (see Pain and Preece, 1968) but conceded that only three are not known from other stratigraphical horizons elsewhere. The most common fossil he assigned tentatively to *Coptostylus brevis* (Thiaridae). Hooker (1986) referred to the presence of slug plates and snail opercula.

Mammalian remains

Early workers such as Keeping (1910, 1912) found some mammalian material, but the importance of the site for mammalian fossils was not realised until much later. Hooker (1977b) listed some thirty species and indeterminate material from nine orders. These are considered in more detail in the GCR volume *Fossil Mammals and Birds of Great Britain* (Benton *et al.*, in prep.) but see later discussion regarding their stratigraphical and palaeoenvironmental significance.

Other fossils

Hooker (1977b) also mentioned the presence of fish and crocodile material, fossil blue-green algae (Cyanophyta), including those encrusting shells, silicified bryozoa derived from the Cretaceous, and small ovoid structures originally thought to be the eggs of land gastropods. However, such structures are similar to cocoon-like trace fossils recently described from the Bembridge Limestone (Edwards *et al.*, 1998) that are considered to have been formed by insects for pupation or by an unknown organism for hibernation or aestivation.

Sedimentology

The Creechbarrow Limestone is a white to cream, largely pisolitic and tufaceous, sandy limestone (Hooker, 1977b). Lithification varies, with both soft marly material and well-lithified limestone present (Arkell, 1947). Much of the shell material present is encrusted by calcium carbonate, thought to be produced by cyanophyte algae, whilst cylindrical hollows may be rhizoconcretions (Hooker, 1977b). Diagenesis has left little original shell material, with many specimens represented by internal casts. In a later account, Hooker (1986) described the Creechbarrow Limestone as comprising 'a buff marl containing variable sized limestone clasts'. Near the summit, the latter were a mass of limestone boulders with marl filling narrow gaps between them. From this, Hooker (1986) concluded that the marls might represent in-situ limestone decomposition but conceded that an alternative might be lateral lithological variation (p. 210).

Interpretation and evaluation

As the sole remnant in Dorset of a facies having some palaeontological and lithological similarity to freshwater limestones from the Headon Hill Formation and Bembridge Limestone further east, the Creechbarrow Limestone provides a valuable contribution to our understanding of the local Palaeogene palaeogeography.

Correlation with other localities

The palaeogeographical significance of the Creechbarrow Limestone quite naturally depends on its being accurately dated and this has been a matter of some interest from its earliest discovery to the present day (see discussion in Hooker, 1977b).

Hudleston (1902b) considered the possibility that the Creechbarrow Limestone might equate to the Bembridge Limestone, but concluded tentatively that it represented a local facies of the Bagshot Beds and in part the lateral equivalent of the Pipe-clay Series. By contrast, Keeping (1910) had no doubt, on the evidence of the fauna, in identifying the Creechbarrow Limestone with the Bembridge Limestone. Bury (1934) felt that the Creechbarrow Limestone was probably of Oligocene age, but, in recognizing that the fauna was facies controlled, considered that a direct correlation with the Bembridge Limestone was unwarranted. However, Cox (in Arkell, 1947) considered the fauna as 'undoubtedly a Bembridge Limestone one'. Curry (1965a, p. 170) reiterated this view by referring to the Creechbarrow Limestone as 'an outlier of what is believed to be Bembridge Limestone, which rests unconformably on Bagshot Beds'.

Within recent years, such a correlation has been disputed. Hooker (1977b) has pointed out that as the most rapidly evolving group found as fossils within the Creechbarrow Limestone, the Mammalia are the most suitable for relative dating. Hooker (1977b) considered that on the basis of the mammalian fauna it may be dated as early late–Eocene, Bartonian (late Auversian or early Marinesian). In a further discussion, Hooker and Insole (1980) suggested that it could be equivalent to the lower part of the Barton Clay (early Marinesian). Earlier, Hooker (1977b) had argued that it might represent a marginal regressive facies preceding the Barton transgression and perhaps be equivalent to the Bournemouth Marine Beds (now part of the Branksome Sand).

In a recent paper on the Creechbarrow Mollusca, Preece (1980), whilst conceding that little is known about the stratigraphical ranges of most species of Tertiary non-marine molluscs, referred specifically to the presence of *Filholia laevolonga* and its possible stratigraphical significance. In the Toulouse Basin, it characterizes the lower to upper Ludian, considerably younger than the age for the Creechbarrow Limestone suggested by Hooker (1977b). Preece concluded that if Hooker was correct, the known stratigraphical ranges of several molluscs have been considerably extended.

Depositional environment

As far as palaeoenvironmental interpretation is concerned, both Hudleston (1902a) and Arkell (1947) supported a lacustrine origin, whilst Bury (1934), who drew attention both to the tufaceous nature of the Creechbarrow Limestone and the frequency of land snails, concluded that it was 'not formed in a lake, but in a swamp, the water in which was highly charged with lime, and was liable to rather rapid evaporation'.

Recent work has enhanced our understanding, the molluscs provide information on the depositional environment itself, with the mammals used to elucidate the nature of the hinterland. Preece (1980) has referred to the scarcity of Lymnaeidae and the absence of Planorbidae, in contrast with the Palaeogene limestones on the Isle of Wight, and has suggested a substrate of poorly vegetated or even bare lime mud. Preece (1980) considered that the presence of *Unio*, with united valves, indicates a fairly large body of shallow water. The importance of *Coptostylus* (found elsewhere by Paul (1989) with the slightly brackish *Potamomya* and other rare brackish water snails) and the absence of planorbids, even less tolerant of raised salinities than Lymnaeids (Paul, 1989), might be construed as suggesting slight brackishness.

Preece (1980) pointed out that land shells are absent or very rare in lake sediments. The rhizoconcretions, if representing the former presence of roots, suggest very shallow water, whilst the pisolitic and other structures resembling the pedogenic (calcrete) facies of the Bembridge Limestone (Armenteros *et al.*, 1997) may indicate subaerial exposure. The Creechbarrow Limestone is probably a composite reflection of different phases of subaqueous and subaerial development in a marginal (palustrine) situation.

The land snails, particularly the *Clausiliidae* and *Cochlostoma*, are shade-demanding and indicate the proximity of forest (Preece, 1980, p. 178). Such a conclusion is supported by data from the fossil mammals present. Hooker (1992) found that a significant percentage of the Creechbarrow mammals were arboreal and that the overall mammalian spectrum indicated a lowland tropical forest with glades.

Intra-Palaeogene tectonism

It is now accepted that in both Dorset and other parts of southern England, folding, which began in the Late Cretaceous, continued into the Palaeogene and beyond into the Neogene (see summary in Jones, 1981, pp. 76–85). That there had been deep dissection of such structures by mid Eocene times in the Dorset area is clear from the presence of Upper Greensand and Purbeck pebbles in the local 'Bagshot Beds' (Phillips, 1964; see also site descriptions for Bincombe Down and Blackdown in this volume).

Creechbarrow contributes evidence for local tectonic activity during early Palaeogene times. Various workers had noted the marked disparity in dip between the 'Creechbarrow Beds' (10° N) and the nearby Chalk (up to 85° N) (Arkell, 1947, fig. 46). Jones (1981, fig. 4.8) interpreted this as an unconformity, with the Chalk of the Purbeck Downs originally overlain by 'Creechbarrow Beds'. Since the Creechbarrow Limestone has been dated as early late-Eocene (Hooker, 1977b), the inference which may be drawn from Jones' (1981) interpretation is that considerable folding had developed in this area by mid Eocene times.

Although changes in dip over a short distance do not unequivocally prove an unconformable relationship (cf. dip changes at the northern ends of Alum and Whitecliff Bays, Isle of Wight), Creechbarrow supplies other evidence to support the view that by early Palaeogene times both the Chalk and older Mesozoic strata were being actively eroded. Large, unworn flints found within the 'Creechbarrow Beds' by Hudleston must have been locally derived from the Chalk, whilst Hooker (1977b, p. 142) considered that the derived silicified bryozoa in the Creechbarrow Limestone are most likely from the Upper Greensand. Plint (1982) concluded that the Chalk had been exposed locally in the late Lutetian.

Conclusions

Of the 'Creechbarrow Beds', the uppermost unit, the Creechbarrow Limestone, is the most significant both stratigraphically and palaeogeographically.

The Creechbarrow Limestone at Creechbarrow is the sole remnant of a non-marine limestone of early late Eocene age in the Hampshire Basin and may represent a marginal facies equivalent to more marine strata further east. It bears some resemblance to the Bembridge Limestone and other freshwater limestones of the Isle of Wight, although there are considerable faunal differences.

The presence of terrestrial as well as non-marine gastropods, together with a rich mammalian fauna, including a significant arboreal element, suggests a possible palustrine environment adjacent to a tropical wooded hinterland.

The structural relationship between the 'Creechbarrow Beds' and the underlying Chalk, together with the presence of derived Mesozoic fossils and pebbles, supports the view that by mid Eocene times, folds and other tectonic structures which had developed in the early Palaeogene had already been considerably dissected by erosion.

TOWER WOOD QUARRY, DEVON (SX 876856)

Highlights

This is the main and type locality for the Tower Wood Gravel. This, the older of the two Haldon

Figure 7.5 Tower Wood Quarry, Great Haldon, Devon. The Tower Wood Gravel, a residual flint gravel formed by solution of the chalk *in situ*. Photograph taken in 1970, reproduced by courtesy of the British Geological Survey (BGS photograph A11556).

Gravels facies, represents an in-situ weathering residue of the Chalk which developed locally in early Palaeogene times.

Introduction

About halfway between Exeter and Torquay are the Haldon Hills (Figure 7.1), capped by gravels of predominantly Palaeogene age. Tower Wood Quarry (Figure 7.5) occurs at the extreme north-western end of Great Haldon at grid reference SX 87688567. In this small quarry, the Tower Wood Gravel Member represents the residual facies of the 'Haldon Gravels Formation'. Although not presently demonstrable in the quarry, the Tower Wood Gravel rests unconformably on the Upper Greensand (Cretaceous). Whilst the Haldon Gravels have been a subject of considerable interest to both geologists and geographers since the 19th century, the earliest reference to Tower Wood Quarry appears to be in Pickard (1949). More recent descriptions of the locality reflect the detailed study of the Haldon Gravels by Hamblin (1969, 1973a,b, 1974), whilst brief accounts are given in Edwards and Freshney (1982, p. 234) and Selwood *et al.* (1984, p. 128).

Despite a lack of earlier descriptions of Tower Wood Quarry, there is a copious literature on the Haldon Gravels (see Hamblin, 1969, 1973a). Whilst now accepted as being of predominantly Palaeogene age (Hamblin, 1973a), the latter have over the years been dated as Late Cretaceous (Clayden, 1906), equivalent to the Reading Beds (de la Beche, 1839), Bagshot Beds (Reid, 1898b) and Bournemouth Beds (Jukes-Browne, 1907), whilst Green (1941) and Ussher (1878) suggested Miocene and Pleistocene ages respectively. Hamblin (1973a) has argued that the Tower Wood Gravel is certainly pre-Bagshot and probably pre-Reading Beds in age. He conceded that the age cannot be fixed more exactly, arguing that the solution of possibly 200 m of Chalk would have taken a considerable time and may have filled the period from the Maastrichtian to the Thanetian.

Over the years, various opinions have been proposed for the origin of the Haldon Gravels. Marine deposition was suggested by Clayden (1906), Jukes-Browne (1907) and Waters (1960b); Reid (1898b) and Boswell (1923) believed that the gravels were fluvial, whilst a glacial origin was put forward by Ussher (1878). Hamblin (1973a, p. 461) suggested that this dissention reflected failure by earlier workers to perceive that the Haldon Gravels contained more than one member. De la Beche (1839) did, however, recognize that some flints were residual, 'the flints having been let down nearly in places above which they occurred in the chalk', whilst at the same time recognizing that the origin of the gravels was more complex: 'the accumulation of chalk flints … may be referable to more epochs than one', and that the flints are in places 'mixed with rounded pieces of granite, porphyry and other older rocks'.

Description

Tower Wood Quarry comprises a small section in the Tower Wood Gravel, formerly the 'Haldon Residual Gravel' of Hamblin (1969), for which the quarry is the type locality. Neither the upper nor lower boundaries of the unit have been observed here, although detailed mapping indicates that the gravels rest unconformably on the Upper Greensand (see Edwards and Freshney, 1982, fig. 9.2). Brief descriptions of the section are given in Edwards and Freshney (1982, p. 128).

Lithological succession

A 6 m thickness of flint gravel is exposed, although Edwards and Freshney (1982) suggested the presence of a further 3 m below this which is presently covered by talus. Hamblin (1973a) gave an approximate overall maximum thickness for the member in the area of 8 m.

Sedimentology

The deposit is predominantly an unstratified flint gravel, the clasts being up to 0.3 m in diameter and unabraded. They have, however, been peripherally shattered by Pleistocene frost action. Most now comprise horizontally aligned cores surrounded by small flint chips.

Hamblin (1974) pointed out that for the most part the Tower Wood Gravel has neither abraded flints nor exotic pebbles. Pickard (1949), however, referred to a basal bed with water-worn pebbles of quartz, tourmaline and shale, although Hamblin (1973a) quotes this author as having found quartz and schorl (a quartz-tourmaline rock). The pebbles occur in what Hamblin (1973a, p. 463) describes without specific reference to Tower Wood Quarry as a sandy, flint-free basal bed up to 125 mm thick. This bed was obscured at Tower Wood Quarry when Hamblin was undertaking his work and this continues to be the case at present. In 1990, only about 2 m of gravel were visible in the upper part of the east and south-east faces of the quarry (Edwards, 1991).

Elsewhere in the formation, the matrix between the flint pebbles comprises clay with very little sand. Broader studies of the clay from the Tower Wood Gravel (Hamblin, 1973a) have shown that it typically comprises well-ordered 'china clay' kaolinite, with a little disordered 'ball clay' kaolinite and illite. Some samples, however, show mixtures of well-ordered and disordered kaolinite more characteristic of the overlying Buller's Hill Gravel (Hamblin, 1973b).

Interpretation and evaluation

The Tower Wood Gravel, at its type locality Tower Wood Quarry and elsewhere, sheds light on the weathering and denudation affecting an area to the west of the Hampshire Basin in early Palaeogene times.

Gravel provenance

Despite a variety of origins for the Haldon Gravels suggested by earlier workers (see discussion of Buller's Hill Quarry), it now seems that the composition of the Tower Wood Gravel indicates its formation as a residual deposit derived from a former cover of Chalk, the nearest outlier of which is today almost 25 km to the east. It follows from the nature of the gravel (in particular its silicified fossils) that this cover included flinty Upper or Senonian Chalk. Derived fossils from the Haldon Gravels as a whole include material from as high as the *Belemnitella mucronata* Zone (Edmonds *et al.*, 1975, p. 75).

By contrast, the exotic clasts in the sandy pebble bed at the bottom of the Tower Wood Gravel may represent the basal conglomerate associated with a westerly transgressive early Chalk sea. As yet, there is no proof that any pre-Senonian (non-flint-bearing) Chalk was ever present here, but Hamblin (1973a) has suggested that this pebbly sand represents the residuum of the flint-free Lower Chalk. It remains apparent, however, that the Tower Wood Gravel (together with the remainder of the Haldon Gravels) is all that remains of a former Upper Cretaceous cover some 200–300 m in thickness.

The origin of the clay matrix is less clear than that of the flints themselves. Hamblin (1973a, 1973b) stressed that the Tower Wood Gravel was quite unlike the 'Clay with Flints' and explained this by a variety of factors, including a different climatic regime, altitude of formation and the relative position of the water table.

He believed that the well-ordered kaolinite present in a number of samples could not have been derived form the Chalk, but came from a hydrothermal kaolinite source probably in the area of the Dartmoor Granite a few miles to the west. This suggestion is supported by the presence of a granite-derived heavy mineral suite associated with the clay matrix. Since the gravel has an intact framework (i.e. closely packed clasts), it seems likely that the clay was introduced post-depositionally by downward infiltration. Where the matrix of the Tower Wood Gravel contains a mixture of well-ordered and disordered kaolinite, downward eluviation from the overlying Buller's Hill Gravel may provide an explanation (Hamblin, 1973b).

Palaeoclimatic implications

Hamblin considered that the weathering of the Chalk that gave rise to the Tower Wood Gravel had occurred under savannah conditions rather than those of tropical rain forest (cf. Chandler, 1964), arguing that kaolinite characterized savannah soils. Whilst this was disputed by Green (1974), it is compatible with the findings of Isaac (1979). He concluded that the Peak Hill Gravels of the Sidmouth area (also unabraded flints in a matrix of kaolinite) and the Tower Wood Gravels had a common origin in the lateritic weathering of the Chalk, but that the presence of silcretes in the former provided evidence for dry conditions for at least some of the time. Edwards and Freshney (1982) have suggested that the Orleigh Court Gravel of North Devon (first described by Rogers and Simpson, 1937) may be a residual deposit of probably Palaeocene age and hence comparable with the Tower Wood Gravel. However, Edmonds *et al.* (1975) suggested that the former might be a Pliocene beach deposit.

Occurrence elsewhere

That the Tower Wood Gravel (and hence the Chalk cover) originally extended further westwards is supported by the occurrence of unworn flint nodules in solution pipes in Middle Devonian limestone, exposed in the Newton Abbot Bypass, which Brunsden *et al.* (1976) considered as having a Chalk weathering residue origin comparable to the Tower Wood Gravel.

Conclusions

Tower Wood Quarry comprises the type locality for the Tower Wood Gravel and is one of very few localities where this formation may be observed. The gravel exposed in this section represents an in-situ weathering residue of the Chalk which formerly extended further west than at the present time. Its kaolinitic interclast matrix appears to have been derived from hydrochemically altered granite to the west. The section reflects the denudation of a land mass which lay to the west of what is now the Hampshire Basin. Climatically, it has been interpreted as representing savannah conditions in this area during early Palaeogene times.

BULLER'S HILL QUARRY, DEVON (SX 882846)

Highlights

This is now the best exposure of the Haldon Gravels and is the only extant site to show the Buller's Hill Gravel resting on the Tower Wood Gravel. The site demonstrates how the residual facies was in time replaced by gravels laid down in fast-flowing rivers.

Introduction

Buller's Hill Quarry (Figure 7.6) occurs at grid reference SX 882846, approximately 1 km SSE, from Tower Wood Quarry. According to Edwards and Freshney (1982), this is the best exposure of the 'Haldon Gravels'. Here the Buller's Hill Gravel is seen to rest on the Tower Wood Gravel, which in turn lies unconformably on the Upper Greensand.

A review of the earlier work on the Haldon Gravels as a whole is included in the account of Tower Wood Quarry. Buller's Hill Quarry itself has only been mentioned by name in relatively recent years. Brief descriptions occur in Edwards and Freshney (1982, p. 234) and Selwood *et al.* (1984, p. 128). There is a possibility that Kiddens Quarry, referred to by Pickard (1949), may be Buller's Hill Quarry but this is unproven.

Earlier views as to the age and origin of the Haldon Gravels have already been referred to in the introduction to the account of Tower Wood Quarry. Work by Hamblin (1969, 1973a,b, 1974) suggests a fluvial origin for the Buller's Hill Gravel. In age, the latter is probably Eocene,

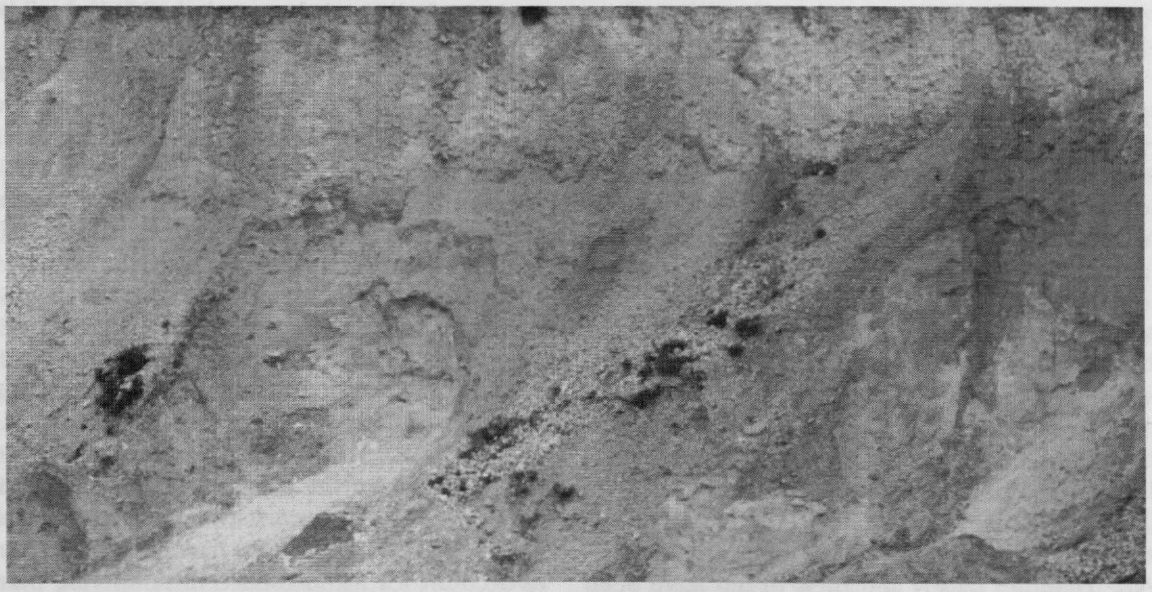

Figure 7.6 Buller's Hill Quarry, Great Haldon, Devon. 'Haldon Gravels' unconformably overlying the Upper Greensand (mainly talus-covered). Both the Tower Wood Gravel and the Buller's Hill Gravel are represented by the former although these cannot be distinguished in the photograph. Photograph taken in 1971, reproduced courtesy of the British Geological Survey (BGS photograph A11558).

and correlation with the 'Bagshot Beds' further east has been suggested.

Description

In Buller's Hill Quarry, the Buller's Hill Gravel Member (the 'Haldon Fluvial Gravel' of Hamblin, 1969) rests on the Tower Wood Gravel.

Lithological succession

The succession comprises abraded gravels of the Buller's Hill Gravel Member above the unabraded gravels of the Tower Wood Gravel Member. As at Tower Wood Quarry, the pebbles have been subjected to shattering by frost and Pleistocene cryoturbation has made the boundary between the two units difficult to define. Hamblin (1973a) has referred to large unabraded flints standing vertically in the Buller's Hill Gravel which had migrated upwards from the underlying Tower Wood Gravel.

Estimates of thickness of the two units vary. Hamblin (1973a) referred to several metres of the Buller's Hill Gravel resting on the Tower Wood Gravel, whilst Edwards and Freshney (1982) wrote of 2 m of the former resting on 7 m of the latter. As a working quarry until recently, measured thickness variation may reflect changing exposure over a period of some years.

Sedimentology

The Buller's Hill Gravel comprises abraded 'chatter-marked' flints. The pebbles are closely packed (an intact framework) with an interclast matrix of sandy clay. Hamblin's (1974) broader study of this unit has shown that a variety of exotic pebbles also occur within the gravel, including vein quartz, tourmaline rock, quartzite and thermally altered Carboniferous shale and chert. Hamblin (1973b) pointed out that the matrix is more sandy than that of the Tower Wood Gravel and that the clay present comprises more or less equal amounts of well-ordered and disordered kaolinite and a greater proportion of illite than occurs in the latter.

Interpretation and evaluation

The Haldon Gravels and their origin have been of interest to geologists since the 19th century. Their formation under marine, fluvial or glacial regimes has been suggested, with Hamblin (1973a) commenting that such a range of ideas reflects a failure to perceive the complexity of the formation.

Comparison with other localities

Buller's Hill Quarry represents one of the few extant exposures of the Haldon Gravels. Whilst it is important in that two contrasting units of the latter are present, it is now the only site where Buller's Hill Gravel may be observed. Elsewhere on Great Haldon and Little Haldon, Edwards and Freshney (1982) indicated a thickness of up to 10 m for the Buller's Hill Gravel, whilst Selwood *et al*. (1984) recognized some 21 m of gravel, probably mostly Buller's Hill Gravel, at the Haldon Plantation (SX 883854) following a seismic survey of the area.

Significance of the Buller's Hill Gravel

A proper evaluation of the Buller's Hill Gravel is vital to our understanding of the palaeogeography of the land area which lay to the west of the Hampshire Basin. Whilst Waters (1960a,b) thought that the Haldon Gravels were marine shingle, Hamblin (1973a) has shown them to be fluvial in nature. All the exotic pebbles have a westerly derivation whereas a transgressive marine gravel would probably have included exotics from the east (Purbeck or Portland, cherts for example). Hamblin also referred to the lack of 'all over' chatter marks (thought to be characteristic of marine pebbles) to support a fluvial origin. Furthermore, he considered that since kaolinite is common in fluvial sediments but rare in marine, this also supported this interpretation.

Unfortunately, and no doubt in part due to Pleistocene cryoturbation, the Buller's Hill Gravel contains no internal structures which might facilitate the interpretation of the depositional environment. Hamblin (1973a) argued that this thin tabular sheet of gravel accumulated on an essentially flat plain by sheet flooding, although this was challenged by Green (1974). What is clear is that the absence of thick, wedge-shaped, less mature rudite bodies denies the existence, at least in this area, of early Palaeogene uplands which had been postulated to account for the presence of temperate plant remains in some of the 'tropical' Eocene floras obtained from localities further to the east in the London and Hampshire basins.

Provenance

Aspects of the petrology and mineralogy of the Buller's Hill Gravel in the quarry and elsewhere shed some light on the evolving palaeogeography of the area. Whilst the exotic pebbles suggest a probable Dartmoor aureole origin, many are very well-rounded for the short distance (as little as 6 km) they have travelled from the west. It may be, therefore, that, as Hamblin (1973a) suggested, there has been some recycling of material. Possible sources of such clasts are the basal pebble bed of the former Chalk cover or later gravels derived from that source. An Upper Greensand basal conglomerate derivation is unlikely in view of the absence of Upper Greensand chert accompanying the pebbles (Hamblin, 1973a).

The sand content of the Buller's Hill Gravel resembles that of the Upper Greensand Chert Beds (Hamblin, 1973a) and could have been derived from the latter or recycled from the Tower Wood Gravel. The mixture of well-ordered kaolinite and disordered kaolinite is perhaps more revealing. Whilst the former could have been reworked from the Tower Wood Gravel, the latter probably derives from the weathering of sedimentary strata, such as the Culm, which are thought to be the source of the kaolinite within the majority of the ball clay deposits of Devon and Dorset, together with lenticular clay horizons elsewhere within the Buller's Hill Gravel.

Age and correlation

The age of the gravels of Buller's Hill Quarry is difficult to determine since no contemporaneous fossils have been recorded. What can be said with certainty is that they post-date the youngest derived fossils found, i.e. those of Campanian age. Some indication of age may be derived from comparisons with strata both to the west, and to the east. To the west, the Aller Gravel, with which the Buller's Hill Gravel has been correlated by Edwards (1973), underlies the Bovey Formation, the lowest part of which is thought to be of Eocene age (Edwards, 1976, p. 4). Hamblin (1973a) has argued that the derivation of the gravel from the west could hardly have persisted after the formation of the Bovey Basin and considers the Aller Gravel to be younger than the Bullers Hill Gravel (Hamblin, 1974).

Reid (1898b; and in Ussher, 1913) was the first to infer that the Buller's Hill Gravel be correlated with the 'Bagshot Beds' to the east. Hamblin (1973a, table 1, p. 470) supported this view by indicating that the former is equatable with the Reading Formation to Bournemouth Freshwater Beds. He quoted various examples of south-westerly derived detritus found further east, and appeared in part to base his conclusions concerning correlation on Groves' (1931) finding that whilst Dartmoor detritals are abundant in the 'Bagshot Beds', they are absent from the Bracklesham and Barton Beds. More recent heavy mineral studies by Morton (1982b), however, suggest that early inferences regarding provenance may be a little simplistic. He concluded that Cornubian detritus did not arrive in the Hampshire Basin until late Wittering Formation times, but stressed that the presence of such material reflected regressive periods whereas sediments of a transgressive nature (e.g. the Barton Group) tended to be dominated by material derived from Scotland via the 'North Sea'.

Positive support for Hamblin's (1973a) suggested correlation comes from the gravels preserved at Blackdown and Bincombe. In both cases, whilst the exotic pebbles are of sedimentary origin rather than derived from aureole rocks, it has been suggested that they might have come from Palaeozoic sources from and around the Dartmoor Granite (Plint, 1982). The latter author does, however, concede that they may have been polycyclic and derived relatively locally from rudites of Mesozoic age.

Clearly, the Tower Wood Gravel predates the Buller's Hill Gravel. Hamblin (1973a) has suggested a pre-'Bagshot-Beds', and possibly even pre-Reading Beds age for this member.

Conclusions

This site is important as it is the only remaining exposure portraying both the Tower Wood Gravel and the Buller's Hill Gravel. Furthermore, it is the type locality for the latter member.

Buller's Hill Quarry illustrates the evolution of the Haldon Gravels where those of residual nature are replaced by those of fluvial origin. The Tower Wood Gravel is the residual remains of a thick cover of Chalk, which extended formerly over this area, whilst the interclast matrix indicates a later infilling of material derived from the Dartmoor Granite and its associated hydrothermal 'china clay'. The Buller's Hill Gravel reflects the accumulation of material in a high-energy, probably braided fluvial complex, which derived material both from the granite and its aureole as well as weathered Palaeozoic sedimentary rocks. Some of the material may however have been recycled.

If the correlation with the early Eocene and possibly Palaeocene strata to the east is correct, then Buller's Hill Quarry sheds light on the western hinterland of the Palaeogene depositional basin represented now by the strata of the London and Hampshire tectonic basins further eastwards. What does seem clear is that south-western England at this time did not comprise an upland area subject to deep dissection and rapid erosion.

ALLER SAND PIT, DEVON (SX 880695)

Highlights

This site, the type locality for the Aller Gravel, gives an important insight into the local palaeogeography during early Palaeogene times. Its coarse sediments indicate the former presence of fast-flowing juvenile streams whilst the pebbles present indicate derivation from the Chalk, Palaeozoic rocks, the Dartmoor Granite and its metamorphic aureole.

Introduction

The Aller Sand Pit GCR site comprises a conserved section towards the eastern margin of a quarry complex immediately to the east of the Newton Abbot–Torquay road (A380), around map reference SX 877694. The complex includes the former Royal Aller Vale Quarry and has also been referred to as Aller Pits. This site, which has recently ceased aggregate production, is the northerly of two quarries adjacent to the village of Aller, the other being Zigzag Quarry (SX 880690).

The sediments quarried comprise cross-bedded and channelled gravels and sands with subordinate muds, and represent the formation known as the Aller Gravel, an account of which has been published by Edwards (1973). The Aller Gravel occurs along the eastern side of the Bovey Basin and around the Decoy Basin south of Newton Abbot (see sketch map in Selwood *et al.*, 1984, fig. 25). For the most part, it rests unconformably on the Upper Greensand which, although not exposed, probably occurs not far below the surface at the bottom of the conserved section.

Nineteenth century papers such as that of Woodward (1876) referred to the large number of sand and gravel pits around at that time, some of great size. Whilst the gravels of the Bovey area are broadly discussed in various early papers (De La Beche 1839; Reid, 1898b; Clayden, 1906; Jukes-Browne, 1907), there is no specific mention of the locality later called the Royal Aller Vale Quarry or Aller Pits. Reid (1913) referred to old gravel pits in Milber Down, but the earliest specific mention of the site appears to be by Pickard (1949), whose Aller A and B quarries coincide with the position of the former Royal Aller Vale Quarry. Vachell (1963), who first introduced the name Aller Gravel, referred to typical exposures of this unit being found in the gravel pits at Aller. A very brief description of the quarry is given in Edwards and Freshney (1982), whilst that in Selwood *et al.* (1984) is a little more detailed and includes references to both sedimentological features and gravel composition, together with a photograph (plate 16) illustrating the characteristic lenticular nature of the gravels. There is no separate published description of the conserved face comprising the Aller Sand Pit GCR site.

Description

Together with the gravels preserved in the Haldon Hills, the nature of the Aller Gravel sheds considerable light both on the earliest Palaeogene environment of this part of England and, from pebble provenance, the geological character of the area from which it was derived. Whilst there are a number of mainly overgrown, relatively shallow Aller Gravel pits in the area (see Selwood *et al.*, 1984, p. 129), the former Royal Aller Vale Quarry was designated the type area (sic) for the formation (see Edwards and Freshney, 1982, p. 234). The current type locality is the Aller Sand Pit GCR site (Figure 7.7).

Lithological succession

Information derived from the quarry complex to the west of the site indicates a succession dipping westwards at between 4° and 10°, comprising a lenticular-bedded sequence of abraded

Figure 7.7 The Aller Gravel in the conserved section of the former Royal Aller Vale Quarry now known as Aller Sand Pit, showing alternating gravels and sands. (Photograph: B. Daley, taken in November 1997.)

gravels and sands with subordinate silts and clays. From time to time, from 25 to 30 m of the formation have been exposed. The quarry complex was around 0.2 km^2 in size in the late 1980s. By November 1997, this had partially been backfilled although exposures of the Aller Gravel still existed at this time in addition to the GCR site itself.

The present Aller Sand Pit GCR site comprises a face some 80 m in length and 5–8 m high. The succession comprises a complex of alternating cobble to granule gravels and very coarse to gravelly sands. The gravels are clast-supported but poorly sorted with a sandy matrix (Figure 7.8). A small number of pebbles are of boulder size (>256 mm). Most pebbles are well-rounded but a minority are more angular. In the inaccessible upper part of the section, the pebbles appear to be more angular. The sands and granule gravels are moderately sorted.

Stratification is lenticular with units bounded by undulose to planar surfaces. The bases of the gravel units are often but not always sharp. Bedding within the coarser gravels is obscure, except where they contain sandy lenses. The sands and granule gravels are internally lenticular-bedded.

Detrital mineralogy and petrology

Both the nature of the heavy mineral suite and the pebble composition provide considerable insight into the source of the Aller Gravel. Scrivener and Beer (1971) found cassiterite in the heavy mineral suite from the quarry, in addition to large quantities of tourmaline, lesser chlorite, zircon and topaz, and a little iron oxide, ilmenite, garnet, epidote and rutile. Cassiterite is confined to the sandy lithologies and only those which are ill-sorted. Interestingly, these authors suggested the likely occurrence of high-grade cassiterite concentrate within the formation, although stanniferous gravels have, in fact, long been recognized in the South West Peninsula and were mined by the Romans (Edmonds *et al.*, 1975, pp. 85–6).

Whilst moderately abraded flint pebbles predominate, pebbles of vein quartz, tourmaline

Figure 7.8 Badly sorted, poorly bedded gravel unit within the Aller Sand Pit section. The larger pebbles are predominantly flints. The small, dark pebbles comprise chert and various exotic lithologies. (Photograph: B. Daley, taken in November 1997.)

and schorl rock are also abundant and those of Greensand chert fairly common. Other pebbles present include Palaeozoic rocks, especially Lower Carboniferous cherts, Upper Carboniferous sandstone, dolerite, hornfels and other metamorphic aureole rocks (Edwards, 1973; Edwards and Freshney, 1982; Selwood *et al.*, 1984). Such pebbles indicate a northerly or north-westerly source.

Interpretation and evaluation

According to Scrivener and Beer (1971), the thickness of the Aller Gravel varies from around 10 m in the most northerly outcrop to 38 m to the east of Newton Abbot. Whilst the maximum thickness was not exposed in the Royal Aller Vale Quarry, the latter has been, with the Zigzag Quarry nearby, the best and most revealing Aller

Gravel pit of the large number which previously existed in the Bovey area. The present GCR site indicates the general nature of the formation but probably does not fully represent all the elements of the up to 30 m thick, laterally variable succession described from the Royal Aller Vale Quarry by Edwards and Freshney (1982, p. 234).

Sedimentology

The dominantly boulder to granule gravel and gravelly to coarse sand, together with the frequent erosion surfaces, channel structures and cross-bedding found in the present site and the adjacent quarry complex, demonstrate the very high energy and probable braided stream origin of these sediments. The lenticular geometry and marked lateral and vertical variation characteristic of braided stream sedimentation is particularly well developed. The presence of fine-grained lenses (cf. Selwood *et al.*, 1984, plate 16), although not a feature of the conserved section, indicates periodic channel abandonment.

Provenance

In terms of provenance and the nature of the source area, the Aller Sand Pit GCR site and the former Royal Aller Vale Quarry provide useful information. The predominance of flint confirms the former westerly extension of the Chalk cover, although polycyclic derivation from an earlier gravel or gravels remains a possibility. The presence of aureole rock pebbles indicates clearly that the Cretaceous cover had been breached, whilst the presence of cassiterite, a relatively high-temperature ore mineral (see Edmonds *et al.*, 1975, p. 92), implies a source in or close to the Dartmoor Granite itself. Again, however, the polycyclic derivation of the exotic pebbles cannot be ruled out.

The altitude of such a source land cannot be determined with any degree of certainty, although the association of pebbly braided streams with the upstream, juvenile reaches of rivers suggests some topographic relief.

Relationship of the Aller and Haldon Gravels

Good exposures, such as those of the Royal Aller Vale Quarry, have contributed to discussion on the stratigraphical relationship between the Aller Gravel and the gravels of Haldon to the north. De la Beche (1839) was the earliest writer to discuss the stratigraphical position of the Aller Gravel. Clayden (1906) considered that the latter gravels dipped 'as if they formed the floor of the Bovey deposit', and had in mind a direct correlation with the Haldon Gravels. Reid (1913) rejected the correlation of the Aller and Haldon gravels, since he considered the former was a marginal facies of the 'lacustrine' Bovey Formation and in part derived from the Haldon Gravel sheet. Vachell (1963) concurred with this derivation but thought that the Aller Gravel overlaid the Bovey Beds. The latter relationship had been earlier suggested by Woodward (1876) and subsequently by Reid (1898b).

Edwards (1973, 1976) had favoured a direct correlation between the Aller Gravel and the Buller's Hill Gravel of the Haldon area, dating from the interval preceding the subsidence of the Bovey Basin, and arguing that they were lithologically similar, a mere 2 km apart and the remnants of a single sheet whose westerly dip reflected the subsidence associated with the formation of the Bovey Basin. Small outliers of Aller Gravel north of Kingsteignton and at Connybear Brake (SX 891693), at greater heights than the main outcrop, perhaps add support to the suggested formerly continuous gravel sheet.

Hamblin (1969, 1974) rejected this correlation and concluded that the Aller Gravels were younger. Amongst his arguments were that, in terms of sedimentary structures, the two gravels were quite different. Certainly the lenticular and other larger scale sedimentary structures in the Royal Aller Vale Quarry contrast markedly with the structureless gravels in the Buller's Hill Quarry. He argued that the petrological similarities were only to be expected, since fluvial gravels formed in this region at any time during the Eocene would likely have a broadly similar composition. He did, however, also point out that differences included the greater presence of sand, silt and clay in the Aller Gravel and its greater variety of exotic pebbles. It is, of course, possible for lateral variation to occur within a single stratigraphical unit for a number of reasons. Scrivener and Beer (1971) pointed out that in two quarries in the Aller Gravel at Sands Copse, further north (SX 866759 and SX 871752), there was more coarse detritus than in the Aller Vale Quarry and a lack of the lensoid stratigraphy typifying the gravels developed in the Aller Valley. In terms of post-depositional lateral variation, it has been argued that the contrast in sedimentary structure development between the Royal Aller Vale Quarry gravels and those at Buller's Hill Quarry may reflect marked periglacial (cryogenic) modification at the latter locality.

Both Reid (1898b) and Jukes-Browne (1907) considered that the Aller Gravel was older than the Bovey Formation and recent work broadly confirms this view. Edwards (1973), for example, refers to the Institute of Geological Sciences (now the British Geological Survey) 'Higher Sandygate' (SX 86727507) borehole near Kingsteignton where typical pink-mottled clays of the lower part of the Bovey Formation are underlain by flint gravels of the Aller type. Here, along the eastern side of the main basin, the Aller Gravel predates the Abbrook Clay and Sand (Edwards, 1973, p. 18), but its relationship to the concealed pre-Abbrook beds in the centre of the basin is not yet known. Earlier interpretations that the Aller Gravel was younger than the Bovey Formation may in part reflect the fact that the former is in places reworked to rest on the latter.

No clear indication exists as to whether the gravels in the Aller area are the downwarped remnants of gravels such as those of Haldon, which accumulated on a laterally extensive Tertiary erosion surface such as that discussed by Waters (1960a,b) or whether the Aller Gravel is younger and developed coevally with the initiation of the Bovey Basin. What is clear, is that since the lower part of the Bovey Formation is considered as Eocene (Edwards and Freshney, 1982, p. 218), the underlying Aller Gravel must be at least of this age.

Conclusions

Aller Sand Pit is the type locality for the Aller Gravel of probable Eocene age. It comprises a conserved face within the former Royal Aller Vale Quarry which for many years provided a thicker exposed succession than at most of the other pits in this formation, of which the majority are now overgrown.

Aller Sand Pit comprises a small section from the former large quarry complex, which, over the years, has provided valuable data to facilitate the interpretation of Eocene times in this area. The nature of the pebbles found confirms the former presence of a cover of flint-bearing Upper Cretaceous Chalk, whilst exotic pebbles and the heavy mineral suite found implies a source area including both non-metamorphosed Palaeozoic rocks, aureole rocks and probably the Dartmoor Granite itself. The Aller Sand Pit GCR site section supports the interpretation of the formation as the product of juvenile, braided streams.