'Barton Cliffs', Hampshire/Dorset

[SZ 200 930]–[SZ 283 915]

Highlights

The 'Barton Cliffs' site has provided a major contribution to the understanding of middle to late Eocene times in the southern British area. It includes the type sections for three formations within the Barton Group and is of international importance as the type section for the Bartonian Stage.

Introduction

This account primarily concerns sea cliffs extending from Highcliffe in the west (grid reference [SZ 200 930]) to Milford-on-Sea [SZ 283 915], but includes information derived from temporary foreshore exposures sometimes caused by storms. Geographically included are Highcliffe, Barton, Beacon and Hordle Cliffs, collectively referred to here as 'Barton Cliffs' (Figure 6.13). All beds dip eastwards at a very low angle. The oldest sediments occur at the western end of Highcliffe, whilst the youngest part of the Headon Hill Formation is exposed near Paddy's Gap to the west of Milford.

This site was also independently selected for its fossil reptile content, a more detailed account of which can be found in the GCR series volume *Fossil Reptiles of Great Britain* (Benton and Spencer, 1995).

Four formations are exposed in 'Barton Cliffs'. In ascending order, these are the Barton Clay, the Chama Sand and the Becton Sand (all part of the Barton Group) and the Headon Hill Formation (Headon Formation of Edwards and Freshney, 1987b).

'Barton Cliffs' has a vast geological literature dating from the 18th century to the present day. In part, it is a catalogue of geological discovery, but also reveals some of the mistakes and some of the controversy that arose.

Since the early 19th century, a great deal of attention has been paid to stratigraphical aspects of 'Barton Cliffs', both in terms of classification and correlation with other localities. Berger (1811) referred to the cliffs in his early attempt at a stratigraphical classification of the rocks of Hampshire and Dorset, although the first relatively detailed stratigraphical observations were those of Webster (1824) in which he attempted to correlate the freshwater beds of Alum Bay with those of Hordle Cliff. Lyell (1829) published the first attempted detailed vertical section through the Upper Barton and Lower Headon Beds of Beacon and Hordle Cliffs. He recognized the upward change from marine to freshwater faunas and correlated the beds with those in the Alum Bay/Headon Hill area. Early difficulty in correlating the mainland sections with those of the Isle of Wight is exemplified by Bowerbank's (1841) assignment of the beds at Barton to the London Clay. As an understanding of the stratigraphy developed, Prestwich (1847a) recognized the Barton Beds and Bracklesham Sands as separate formations and suggested (Prestwich, 1847b) that the Barton Beds of Hampshire correlate with part of the Bagshot Sands succession in the London Basin.

The first account of an 'upper marine formation' at the eastern end of the Hordle Cliff section was published in Wood (1846). The earliest detailed, reasonably accurate descriptions of the succession in Barton, Beacon and Hordle Cliffs were published by Wright (1851) and the Marchioness of Hastings (1848, 1852, 1853). Prestwich (1857a) reviewed the correlation of the Bracklesham and Barton Beds in England, France and Belgium.

Towards the latter part of the 19th century, a large number of papers of a stratigraphical nature were published. Judd (1880) correlated the 'Lower Headon Beds' of Hordle with those of Headon Hill, largely on faunal evidence. Gardner (1882) suggested a revised classification of the British Eocene, placing the Eocene–Oligocene boundary at the base of the Barton Beds on the grounds that cold-water faunas first appeared at this time. Fisher (1882) correlated the thin Lower Headon Limestone and 'Upper Marine Bed' of Hordle with the How Ledge Limestone and the Middle Headon Beds of the Isle of Wight.

Fisher's paper led to a furious controversy, quite disproportionate to its importance, over the stratigraphical relationship of the 'Upper Marine Bed' and, in particular, whether the section contained freshwater strata above the latter. Amongst the protagonists were Judd (1882a,b, 1883), Wood (1883a,b, 1884), Elwes (1883, 1884), Tawney and Keeping (1883) and Keeping (1883). Tawney and Keeping, and Elwes correctly asserted the absence of higher non-marine strata, as confirmed by more recent studies such as that of Edwards (1967). Perhaps unwittingly, some of the arguments were about *different* beds. Wood (1884), for example, based his dispute of Tawney and Keeping's observations on a complete misunderstanding, since he believed the controversy was about the 'Long Mead End Bed', a unit lower down the succession.

A few years later, Gardner *et al.* (1888) published an account of the complete succession of the Barton Clay and overlying Barton Sand. Burton's (1929) system of letters, with which he labelled the principal units of the Barton Beds, is still in use today. More recent work on the stratigraphy has been undertaken by Hooker (1986), Plint (1984) and Edwards and Freshney (1987b). These are referred to in more detail below.

Notwithstanding the importance of stratigraphical matters, the abundance of well-preserved fossils was without doubt the principal factor which attracted an early interest in 'Barton Cliffs' and ultimately led to its becoming a classic British Tertiary locality.

In the 18th century, a number of fossils from Barton were figured in Brander (1766). In the 19th century, many of the stratigraphical accounts also included references to or lists of fossils (e.g. Wright, 1851). Many references to specimens collected from Barton Cliffs were made in a series of memoirs documenting the British Tertiary biota published by the Palaeontographical Society in the second half of the 19th century. These publications include Forbes (1852) on the echinoids, Wood (1861) on the bivalves, Edwards and Wood (1849–1877) on cephalopods and gastropods, and Gardner and von Ettinghausen (1879–1882) on the flora.

Twentieth century work on the palaeontology includes Burton (1929) on the Bryozoa, the same author (1933) on the molluscan fossils, and the important studies of Curry (1937) on the large foraminifer *Nummulites.* Later macroinvertebrate studies include work on the brachiopods by Elliott (1954), on asteroids and ophiuroids by Rasmussen (1972), on decapod crustaceans by Quayle and Collins (1981) and by Lewis (1989) on the echinoids. Vertebrate studies include those on fish otoliths by Stinton (1975, 1977, 1978, 1980), Milner *et al.* (1982) on small amphibians and reptiles, and Halstead and Middleton (1972), Cray (1973) and Hooker (1982, 1986) on mammals.

Over many years, excursions to the Barton Cliffs sections have included those by the Geologists' Association (e.g. Burton and Curry, 1950) the Tertiary Research Group (Daniels, 1970a; Edwards, 1971c; Clasby, 1972, 1974; Hooker, 1975b; Daley, 1996) and parties attending national and international conferences (e.g. Curry, 1968; Daley, 1996). Descriptions of Barton Cliffs include that in the Geologists' Association Guide by Curry and Wisden (1958), a recent summary by Daley, (1998) and a detailed account of the succession of the Totland Bay Member of the Headon Hill Formation by Edwards and Daley (1997).

Description

Below Highcliffe Castle, the junction of the Barton Clay with the underlying Boscombe Sand is marked by a thin pebble bed. From here, a conformable, gently dipping succession extends for something over 8 km eastwards to Milford-on-Sea (Figure 6.13). Although at one time a continuous and mainly well-exposed section in readily degradable cliffs (Barton, 1970, 1973), it is now interrupted by sea defence works, where exposures are poor or non-existent (see Melville and Freshney, 1982, fig. 29; Clasby, 1971), and the Hordle Cliff section is much obscured by talus.

Lithological succession

The strata present (Figure 6.14) comprise, in ascending order, the Barton Clay Formation (somewhat over 30 m), the Chama Sand Formation (around 5.5 m) and the Becton Sand Formation (about 22 m), all part of the Barton Group of Edwards and Freshney (1987b), and the Headon Hill Formation (30 m). Above the basal pebble bed, the Barton Clay mainly comprises muds and sandy muds (Figure 6.16), the exception being the heterolithic 'High Cliff Sands and Clays'.

Above the distinctive 'Stone band' (Bed G of Burton, 1929), the succession coarsens. Sandy muds of the Chama Sand are succeeded by the clean, fine-grained sands of the Becton Sand (Figure 6.17), although the latter is split into two units here by mainly sandy clays of the Becton Bunny Member. Lithologies in the Headon Hill Formation above (Figure 6.18) are more varied than lower down the succession ((Figure 6.15); Edwards and Daley, 1997). Clastic lithologies (sands, muds and heterolithic sediments) are still predominant but some of the muds are lignitic and the sequence includes a thin, soft, brown limestone.

Stratigraphy

The long section displays what were for a long time simply called the 'Barton Beds' and, above them to the east, the 'Lower and Middle Headon Beds'. The Boscombe Sand is also exposed below Highcliffe Castle, but is best seen further to the west in Friar's Cliff, Mudeford and beyond. The stratigraphical sequence has been described on a number of occasions, but Burton's (1933) system of labelling the principal units of the 'Barton Beds' with letters is still widely used.

Tawney and Keeping (1883) divided the 'Lower Headon Beds' into 33 numbered beds, whilst the stratigraphical scheme of Edwards (1971c) split this part of the succession into eight 'divisions', each comprising a number of beds. Plint's (1984) scheme of 24 numbered beds includes Beds J, K and L of Burton and extends up into the Totland Bay Member (= 'Lower Headon Beds').

With the recognition of the need to regulate and standardize stratigraphical terminology (cf. Hedberg, 1976), new terms have been introduced at formation level and above. Edwards and Freshney (1987b) recognized three formations within the 'Barton Beds': the Barton Clay (up to and including Burton Bed G); the Chama Sand (Burton Bed H); the Becton Sand (Burton Beds I, J, K). The lithostratigraphical importance of Barton Cliffs is apparent in its choice as stratotype for all three. With the Boscombe Sand, these three formations comprise the Barton Group of Edwards and Freshney (1987b). These authors include the remainder (younger) part of the 'Barton Cliffs' section in their Headon Formation, although this part of the succession was earlier assigned to the Headon Hill Formation of Insole and Daley (1985). The formerly named 'Middle Headon Beds' of this part of the succession were renamed the Colwell Bay Member by Insole and Daley (1985) and the Lyndhurst Member by Edwards and Freshney (1987b).

Chronostratigraphy

The section is also very important chronostratigraphically as the type section for the Bartonian Stage (Mayer-Eymar, 1857). However, as Hooker (1986) has explained (see also Curry *et al.,* 1978, table 2), there are different conceptions of the Bartonian.

The 'Barton Cliffs' section is also the type locality for nannoplankton Zone NP17 (Martini, 1971), whilst more recently, nannoplankton from the section enabled Aubry (1986) to approximate the NP 16/17 boundary to Bed E of the Barton Clay. Bujak *et al.* (1980) recorded 100 species of dinoflagellate from the Barton Beds and it is significant that the first three of their 'Barton Beds Zones' (BAR-1, BAR-2, BAR-3) have Barton Cliffs as the type section. From glauconites in Burton Bed A_I (containing *N. prestwichianus*)*,* Odin *et al.* (1969) obtained a date of 42.0 ± 2 Ma BP for the basal part of the succession.

Invertebrate macrofauna

There is no doubt that palaeontologically 'Barton Cliffs' is one of the most important sites in the British Palaeogene succession. It is famous for its molluscan fauna, the quality and preservation of which is unrivalled in the Hampshire Basin. Burton (1933) listed some 480 species, many of which occur in large numbers. Wrigley produced many papers on the molluscs (see list in Cox, 1954). With those found in the overlying Headon Hill Formation, Barton Cliffs contains a wide variety of molluscan assemblages, representing marine, brackish and freshwater conditions (see also Edwards, 1967). An interesting specialist study by Gardner (1886) of *Teredo* (a mollusc, though sometimes called the 'shipworm') and bored wood, found that whilst the latter was abundant in the 'Barton Beds', it was absent in the 'Lower Headon Beds' of brackish and freshwater origin.

Microfauna and microflora

Work on the site has led to a number of micropalaeontological papers, including Murray and Wright (1974) on the foraminifera, Haskins (1968a,b,c, 1969, 1970, 1971a,b) and Keen (1972a,b, 1977) on the ostracods. Microfloral studies have included work by Costa and Downie (1976), the latter referring to the section in a review of the important dinoflagellate zone fossil *Wetzeliella.*

Macroflora

Plant macrofossils described from 'Barton Cliffs' have made important contributions to our understanding of contemporary geography and climate. The charophyte flora of Hordle Cliff was described by Reid and Groves (1921). In 1925 and 1926, Chandler published her study of the macroflora (leaves, fruits and seeds) from this locality, later (1961a) re-examining the flora and adding 27 new species. Fowler *et al.* (1973) described in-situ taxodiaceous conifer tree stumps and root systems assigned to the wood genus *Glyptostroboxylon* from the Leaf Bed. Roots (*Lacunoradix*), interpreted as those of a hydrophytic angiosperm, were described by Crane and Plint (1979) from the Mammal Bed. These roots had been preserved by a process of siderite permineralization, a hitherto unrecorded mode of fossilization that had preserved the cellular structure in great detail.

Vertebrate remains

Vertebrate remains from 'Barton Cliffs' have been useful stratigraphically and as palaeoenvironmental indicators, as well as being of innate palaeontological interest. Tropical or subtropical environments were indicated by some of the earlier discoveries. Wood (1844, 1846), who described a small mammalian skull and an almost complete crocodile skull, referred to the latter as 'the most interesting saurian relic yet discovered in Britain'. Other workers recorded crocodile and turtle remains (eg. Owen, 1848a; Seeley, 1876). In reviewing fossil crocodiles, Woodward (1885) alluded to the celebrated 'Crocodile Beds' of Hordle.

An early description of mammalian fossils from the site is that of Owen (1848a,b). More recently, extensive and detailed work has been undertaken by Hooker, who in 1972 described the first land mammal remains from the Barton Clay. Hooker (1986) recognized 53 mammalian species from the Bartonian of the Hampshire Basin, though this number includes material mainly from sections other than 'Barton Cliffs'. Selected orders from the 'Headon Beds' were studied by Cray (1973), whilst large vertebrae from the Barton Clay have been attributed to the whales *Zygorhiza* and *Basilosaurus,* the latter being a new record in Europe (Halstead and Middleton, 1972).

Sedimentology

The sediments of 'Barton Cliffs' represent a diverse suite of sedimentary environments: offshore and inshore shelf, littoral beach or barrier, lagoon, lake, river, marsh and swamp conditions. Furthermore, the succession provides an excellent opportunity to study the development of a succession of transgressions and regressions and how these have influenced sedimentological, faunal and floral character. Little work has been undertaken on the detailed sedimentology of the Barton Group but both Edwards (1967) and Plint (1984) have studied the Totland Bay Member of the Headon Hill Formation in some detail.

Sedimentary cyclicity

Hooker (1976) interpreted the succession as representing four transgressive–regressive cycles, although the youngest (represented by the Colwell Bay Member) is incomplete (Figure 6.14). The first two cycles are coarsening-upwards sequences in which highly glauconitic muds pass up through non-glauconitic muds, then sandy muds to sands. Cycle 1 (Beds A_0 to A_3) begins with a basal pebble bed representing a transgressive lag. Bed A_3 contains abraded fossils indicative of considerable reworking as regressive-phase shallowing developed.

Cycle 2 (Beds B to I) has no basal pebble bed, but there is a sharp burrowed junction and some rolled shells probably derived from Bed A_3. Glauconitic silty clays at the base represent a transgressive phase. An ultimate upwards shallowing is reflected in the highly winnowed lag of Bed G, whilst the sands with *Ophiomorpha* of Bed I (the bottom part of the Becton Sand) show no evidence of subaerial exposure and having accumulated in the middle to upper shoreface (Edwards and Freshney, 1987a, p. 66).

As proposed by Hooker (1976), Cycle 3 comprises Beds J, K and the Totland Bay Member of the overlying Headon Hill Formation. A marked break occurs at the base of Bed J (the Becton Bunny Member of Edwards and Freshney, 1987b), though it is less distinct where burrowing has occurred. The upward transition into the clean sands of Bed K may reflect the development of beach or barrier island conditions. The remainder of Cycle 3 differs from earlier cycles in the succession in that regressive facies are better represented. This part of the succession contains a variety of sediments and fossils, representing a range of brackish and freshwater conditions and comprising several minor transgressive and regressive cycles and a major palaeochannel fill. The palaeobiological significance of this part of the sequence is emphasized by a number of named beds: the 'Mammal Bed', the 'Leaf and Seed Bed', the 'Crocodile Bed', the 'Chara Bed', etc.

Cycle 4 is incomplete, comprising the transgressive phase ('Milford Marine Bed') of the Colwell Bay Member, more fully developed on the Isle of Wight. This unit is unconformable on sands overlying the 'Unio Bed' (N. Edwards, pers. comm., 1992).

Interpretation and evaluation

Although coastal protection works have obscured considerable areas of cliff, 'Barton Cliffs' continues to be the major section in the Barton Group. Its importance stratigraphically is, therefore, beyond doubt.

Stratigraphical definition and nomenclature

Over the years, different stratigraphical schemes have been used to describe the succession here. Changes in both nomenclature and the definition of unit boundaries provide an example of how the application of criteria for stratigraphical classification have changed with time, culminating in the modern application of 'Hedbergian' principles and also event stratigraphy. Even so, differences of opinion persist.

Where the bottom of the Barton Clay should now be placed is widely agreed, although previously this was not the case. The presently accepted base is marked by a pebble bed resting on the underlying Boscombe Sand. This was the base of Prestwich's (1857a) Barton Series. Burton (1933), following Fisher (1862), however, placed the bottom of the Barton Clay at the *Nummulites prestwichianus* horizon 3 m above. Curry (1958a) suggested a reversion to Prestwich's usage since 'the natural break in the succession occurs at the pebble bed' and indeed this follows the lithostratigraphical code of Hedberg (1976). Furthermore, this reversion to the pebble bed at the base precisely mirrors what has been done in Alum Bay, where what were formerly called the '(?) Upper Bracklesham Beds' (Wright and Curry 1958, p. 14) are now included in the Barton Clay.

Edwards and Freshney's (1987a) subdivision of the Barton Group into three formations follows Hedberg, as does the system of Hooker (1986) who designated two interdigitating formations the Barton Clay Formation (Beds A_0 to H (lower part) and J) and the Becton Sand Formation (Beds H (upper part), I and the pale sand component of K).

Comparison with other localities

Compared with most other localities the Barton Clay in 'Barton Cliffs' is thin. The 30+ m here compares with over 60 m in Whitecliff Bay and around 90 m in Alum Bay (cf. Daley and Insole, 1984), whilst thicknesses in excess of 90 m are found to the south of Southampton (Edwards and Freshney, 1987, fig. 32). Some 5 km west of Lymington, the succession begins to thin rapidly westwards. Together with the fact that the Hengistbury succession appears to reflect a sandy 'marginal marine' facies of the Barton Clay (see separate account), this trend appears to point to the existence of a contemporary land area not far to the west.

Both the overlying Chama Sand and the Becton Sand are thinly developed in 'Barton Cliffs' compared with many other localities. Whilst the former is 5.5 m here, it thickens to 7 m at Alum Bay and 14 m at Whitecliff Bay. The Becton Sand exhibits considerable variation in thickness. At 22 m, the thickness in 'Barton Cliffs' is greater than the 10 m near Dibden. The formation is, however, 30 m at Alum Bay and as much as 93 m in the Sandhills Borehole on the Isle of Wight (Edwards and Freshney, 1987a,b).

At around 28.5 m, the Totland Bay Member of the Headon Hill Formation is only very slightly thicker than this member at Headon Hill, but considerably thicker than the *c.* 8 m at Whitecliff Bay. Whilst the succession in 'Barton Cliffs' represents a range of brackish to freshwater environments similar to those represented by this member at other localities, the details of the successions bear little relationship to each other.

Invertebrate palaeontology

As far as the palaeontology of the sequence is concerned, it was the molluscan fauna that first attracted attention and which has proved particularly important in palaeosalinity determination, facilitating the recognition of marine, brackish and freshwater strata. The Barton Clay molluscs of this locality are, in a context of the Hampshire Basin succession, unrivalled in preservation and quality. Their high species diversity approaches that of the Bracklesham Group. Compositional differences of the various assemblages found indicate clearly that they are facies controlled. Some species are, for example, almost entirely restricted to the more sandy units (Hooker, 1986).

The microfauna, as elsewhere, has proved to be a sensitive indicator of environmental factors such as water temperature and salinity. The presence of certain foraminifera suggest a cool aspect to the fauna (Murray and Wright, 1974). Despite the considerable molluscan species diversity and the presence of such marine forms as echinoids, there is a general absence of planktonic species amongst the faunas. This points to little circulation with the open sea, and that, even during what appear to be marine phases, the water was slightly hyposaline.

Vertebrate palaeontology

The 'Barton Cliffs' section has proved to be an important vertebrate and, in particular, mammalian locality (Cray, 1973; Hooker, 1986; Collinson and Hooker, 1987). The presence of mammals in marine strata is particularly important stratigraphically, for since such fossils frequently occur in fissure fills or in non-marine or 'marginally' marine deposits, their relationships with standard marine successions are normally obscure (Hooker, 1986). The non-marine beds of the Headon Hill Formation are also important, since the lakes, marshes, etc., that they represent provided ideal sites for the preservation of terrestrial vertebrates, as in the 'Crocodile Bed'. A total of 36 species of mammal have recently been listed from the 'Mammal Bed' (Hooker, 1992).

Plant fossils

The plant fossils of 'Barton Cliffs', particularly those comprising the 'Hordle Flora' (Chandler, 1925, 1926, 1961a) from the Totland Bay Member have contributed significantly to our understanding of contemporary geography and climate. The different plant macrofossil assemblages represent a variety of environments. Fowler *et al.* (1973) suggest that open water, marsh and swamp forest communities are represented. Chandler (1964) claimed that some plants were estuarine, perhaps fully halophytic, although Fowler *et al.* (1973) were less certain that this can be substantiated. In a study of the 'Leaf Bed' flora, they pointed out that the brackish water-tolerant fern genus *Acrostichum,* which is the only possible indicator of brackish conditions present, also has extant freshwater species. Furthermore, they doubted whether the specimen of *Nipa,* another brackish water indicator, recorded from the 'Leaf Bed', actually came from that horizon.

Palaeoclimatology

From a palaeoclimatological point of view, the presence or absence of *Nipa* is important. Palynological work by Fowler (in Fowler *et al.,* 1973) suggests that this characteristically tropical palm had disappeared from the Hampshire Basin area before the deposition of the underlying Barton Group had ended. A later study (Collinson *et al.,* 1981) showed that *Nipa* pollen (*Spinizonocolpites*) did not extend higher than the Bracklesham Group. That the 'Hordle Flora' reflects a climatic change is also indicated by Collinson and Hooker's (1987) suggestion that it represents the last occurrence in the local succession of previously dominant tropical elements. Chandler (1964) had recognized the importance of temperate elements in the 'Hordle Flora' but considered them as montane-derived. Fowler *et al.* (1973) concluded that the 'Leaf Bed' assemblage is locally derived and is analogous to humid warm-temperate swamp floras, such as those of southern Florida.

Sedimentary environments

'Barton Cliffs' comprise strata representing a diverse suite of sedimentary environments from offshore shelf to lacustrine. Whilst the brackish to freshwater elements are well-represented on the Isle of Wight, the more marine strata are relatively poorly (Alum Bay) or badly exposed there (Whitecliff Bay). Only in 'Barton Cliffs' is the Barton Clay clearly exposed and the cyclic nature of the succession apparent. Broadly, the coarsening-upwards cycles represent a continuation of the transgressive/regressive pattern established during London Clay times and continued in the Bracklesham Group. Bristow *et al.* (1991) considered that the lower three cycles represented minor transgressions and regressions, the latter resulting in shoreline facies of which the most important is the Becton Sand. By the time the fourth, locally incomplete cycle, developed, however, the pattern of cyclicity showed a marked change, for in the remainder of the Hampshire Basin Palaeogene succession, transgressive sediments are poorly developed whilst those of a regressive, non-marine character predominate.

International significance and correlation

The importance of the 'Barton Cliffs' section internationally was established in the 19th century (Mayer-Eymar, 1857) when it was designated the type section for the Bartonian Stage. Pomerol (1982, table III) continued to recognize the Bartonian as a 'principal' stage of the Eocene, although as Hooker (1986) pointed out (and discussed in considerable detail), some 15 different concepts of the Bartonian have existed over the years.

Hooker (1986) also wrote in some detail about attempts made to correlate the 'Barton Cliffs' succession with that of the Paris Basin, and hence the application of the two French substages, the Auversian and the Marinesian, to the local succession.

Chateauneuf (1980, p. 290) correlated the Colwell Bay Member with the Marnes a Lucines (overlying the Marnes a *Pholadomya ludensis*) and Beds C to F of the Barton Clay with the Sables de Cresnes, using his own dinoflagellate evidence and that of Bujak *et al.* (1980). Using ostracods, Keen (1978) suggested a general correlation of the 'Barton Beds' with the Marnes *P. ludensis.* He also supported the Marnes a Lucines correlation with the Colwell Bay Member though, on the basis of charophytes, Grambast (1962) correlated the latter with the higher parts of the Marnes a *P. ludensis.* According to Hooker (1982), the widespread but short-lived trangression at the base of the latter may correlate with the equally short-lived transgression represented in 'Barton Cliffs' by Bed J. If this is the case, and bearing in mind the Marnes a *P. ludensis* are post-Marinesian (Pomerol, 1982, p. 74), the top of the Bartonian (or Marinesian) coincides with the top of Bed I. Towards the bottom of the succession, Chateauneuf (1980) considered the *N. prestwichianus* bed of the Barton Clay as Auversian on the basis of dinoflagellate correlation with a horizon high in the Sables de Beauchamp. He found Beds C to F to be Marinesian, using dinoflagellates again to correlate this part of the sequence with the Sables de Cresnes. Hence the Auversian–Marinesian boundary lies somewhere between Beds A_1 and C in 'Barton Cliffs'.

Conclusions

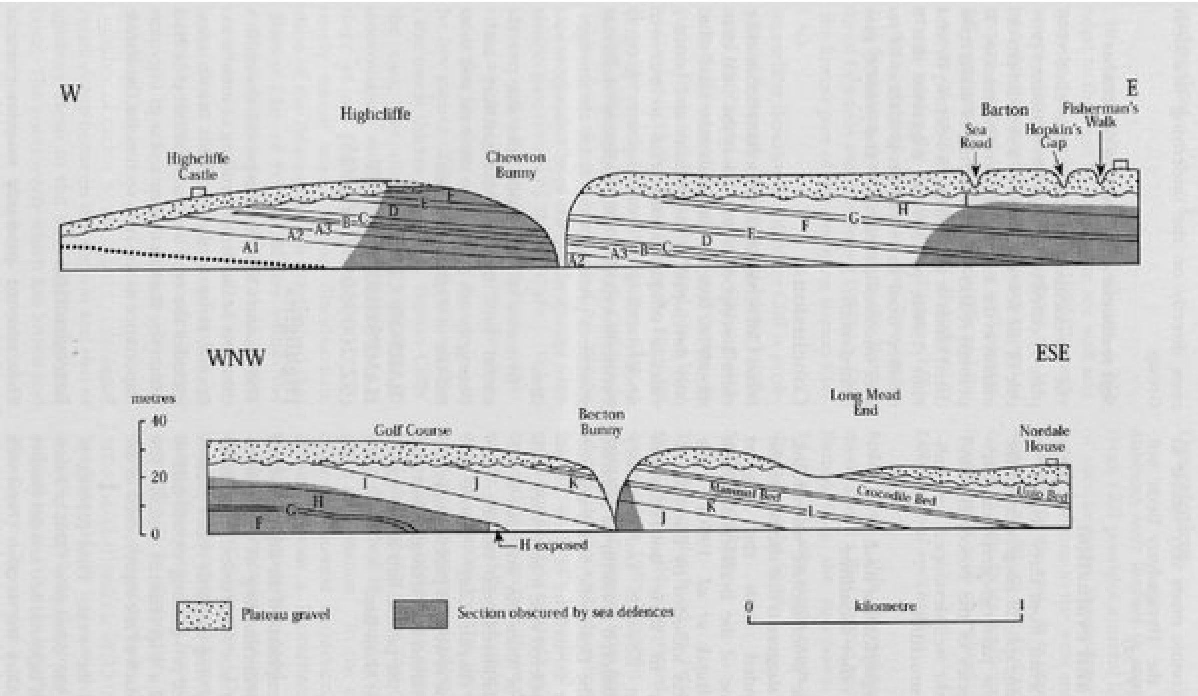
'Barton Cliffs' comprises a classic site which has been the subject of geological interest for over 200 years. Extensive research on the site since the early 19th century has made major contributions to our understanding of middle to late Eocene times.

The importance of the section lithostratigraphically is clear from its designation as type locality for the Barton Clay, the Chama Sand and the Becton Sand. Known since the middle of the 19th century as the type section for the Bartonian Stage, its chronostratigraphical impor tance was recently emphasized by its designation as the type locality for one nannoplankton and three dinoflagellate zones.

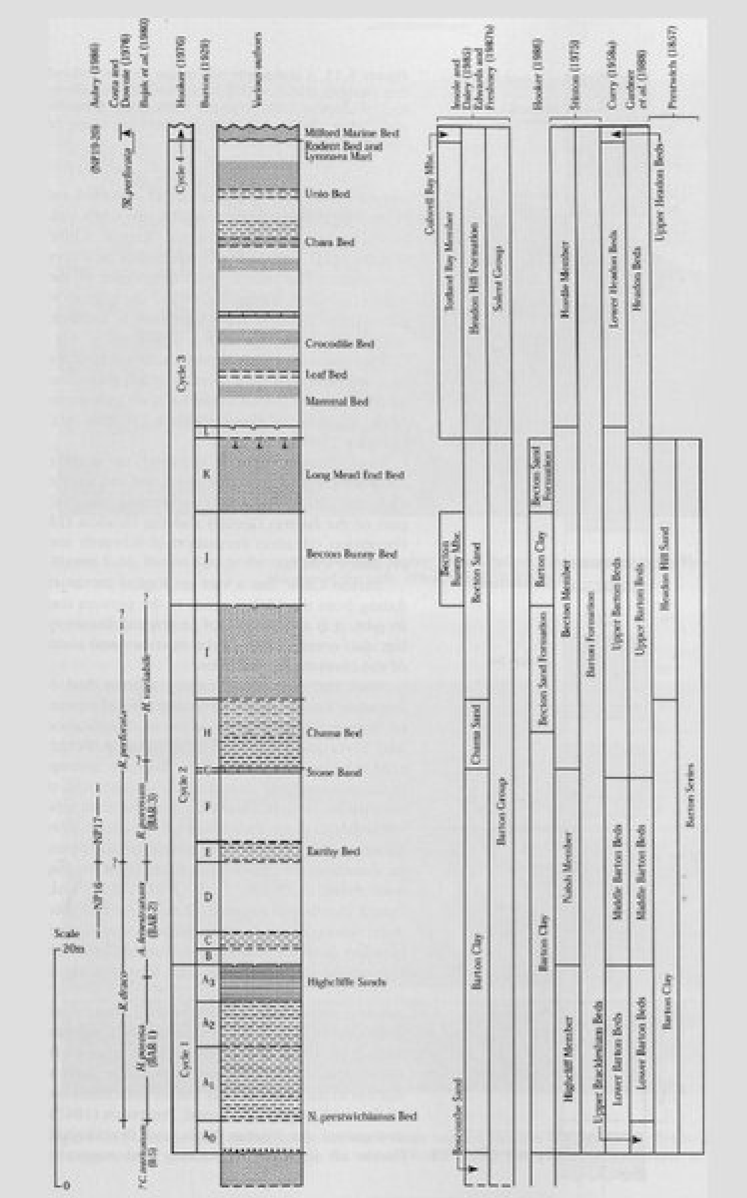
Despite its stratigraphical, and indeed sedimentological importance, the initial and lasting attraction of 'Barton Cliffs' is its fossils, their abundance, diversity and often superb preservation. The molluscan fauna of maybe as many as 600 species, many present in large numbers, is supplemented by the presence of other macroin-vertebrates such as echinoids and brachiopods, albeit uncommon but even less common elsewhere in the local Palaeogene. Rich vertebrate assemblages occur, including fish (represented particularly by otoliths), reptiles and mammals, whilst the upper part of the succession contains the important 'Hordle Flora'. Less overtly apparent, but of considerable significance, are the ostracod and foraminiferal faunas and the dinoflagellate microflora, important both from a palaeoenvironmental and stratigraphical point of view.

As the type section for the Bartonian Stage, the 'Barton Cliffs' site continues to be important internationally as well as within the context of the English Palaeogene. Its potential for research remains considerable, particularly in aspects of palaeontology such as molluscan palaeoecology.

References



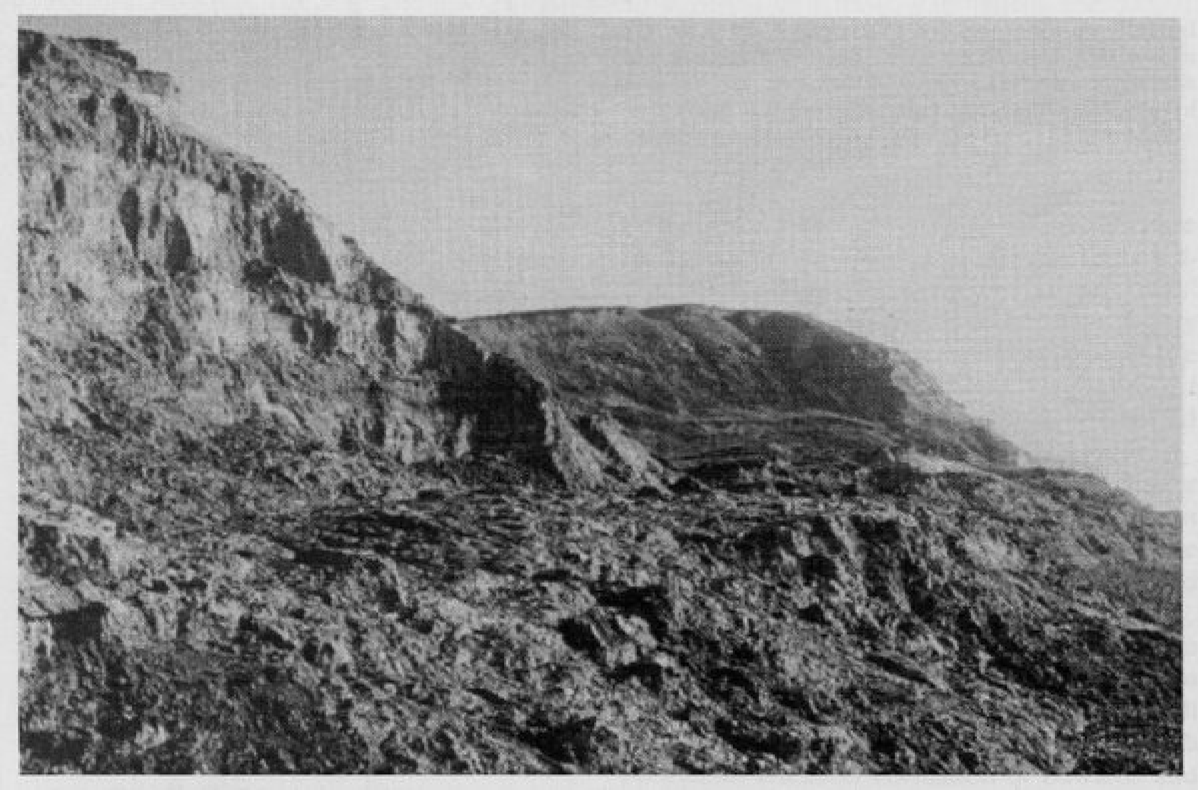
(Figure 6.13) 'Barton Cliffs': cliff profile to show the succession of the Barton Group and part of the overlying Headon Hill Formation. The shaded sections on the profile represent stabilized 'coastal protection' and contain few or no exposures (after Melville and Freshney, 1982).



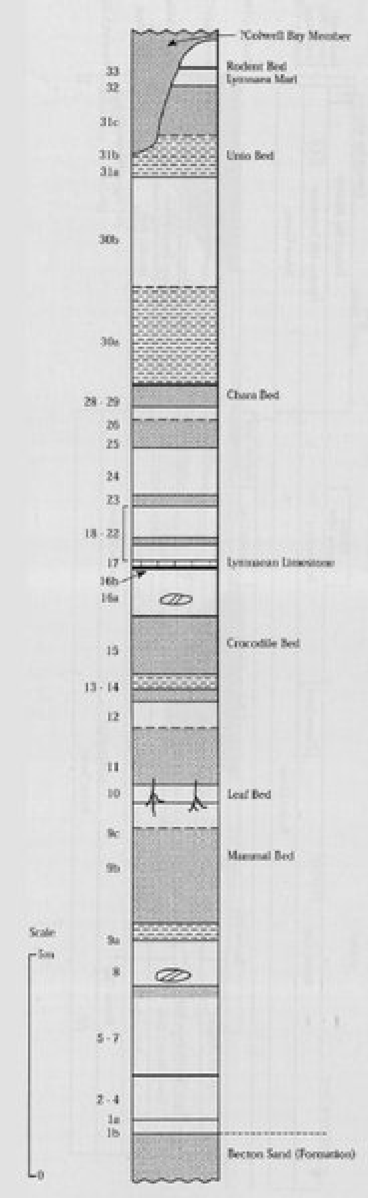
(Figure 6.14) Generalized succession of the Barton Group and Headon Hill Formation at 'Barton Cliffs', Hampshire/Dorset (after various authors). (Figure 6.15) A composite succession for the Totland Bay Member (Headon Hill Formation) at the eastern end of 'Barton Cliffs' (Hordle Cliff) (after Edwards and Daley, 1997). The bed numbers are those of Tawney and Keeping (1883).

(Figure 6.16) Barton Clay to the east of Chewton Bunny, Dorset, below a thin cover of Quaternary Gravel at the top of the cliff. (Photograph: B. Daley.)

(Figure 6.17) Becton Sand succeeded by the more thinly bedded Headon Hill Formation, below a covering of Quaternary gravel, in the section to the east of Becton Bunny, Hampshire. (Photograph: B. Daley.)



(Figure 6.18) Headon Hill Formation in Hordle Cliff, Hampshire. (Photograph: B. Daley.)



(Figure 6.15) A composite succession for the Totland Bay Member (Headon Hill Formation) at the eastern end of Barton