Bournemouth Cliffs, Dorset

[SZ 057 891]–[SZ 138 913]

Highlights

The various 'Bournemouth Cliffs' sections provide the best exposures to facilitate understanding of the western margins of the marine basin that existed in the southern British area in early Bracklesham and Barton times. Fluvial, estuarine and shallow marine conditions are represented by the Branksome Sand and Boscombe Sand whose type sections occur within the site. The succession includes flint conglomerates in the Boscombe Sand that comprise the thickest pebble beds of the British Palaeogene succession.

Introduction

Between Canford Cliffs to the west (grid reference [SZ 057 891]) and just west of Southbourne in the east [SZ 138 913], sediments of Eocene age are exposed in a number of intermittent cliff sections, originally grouped by the NCC for the purposes of conservation into two GCR sites: 'Western Bournemouth Cliffs' to the west of Bournemouth Pier [SZ 089 907]; and 'Eastern Bournemouth Cliffs' to the east. However, since this is geologically arbitrary, the sections of Poole, Bournemouth, Boscombe and Southbourne are here considered together as 'Bournemouth Cliffs'.

A cliff profile for Bournemouth Cliffs (from Bristow *et al.,* 1991) is given in (Figure 6.5), although following cliff stabilization over a period of many years, exposures are limited. The strata present in the gently eastward-dipping succession comprise two formations, the Branksome Sand and the overlying Boscombe Sand, the former including two informal units, the Bournemouth Freshwater Beds and the Bournemouth Marine Beds.

The sediments exposed in the cliffs between Christchurch Harbour in the east and Poole Harbour in the west were first mentioned by Lyell (1827). He produced no detailed descriptions but commented on the abundance of fine sands and laminated clays with indistinct vegetable remains. He assigned all the strata present to the 'Plastic Clay Formation' which he believed underlay the 'London Clay' (what we now know as the Barton Group). He considered that the strata were horizontal and all formed from the same beds, whereas Prestwich (1849a), who examined the section in more detail, recognized that, by contrast, there were complex lateral facies variations.

The major late 19th century work on the section was that of Gardner (1877, 1879a,b,c; 1882). His 1877 paper was a general description of the section, whilst in his 1879b paper, he correlated the Bournemouth Beds (Gardner, 1879a) with the Bracklesham Beds to the east. Gardner's work on the stratigraphy of Poole Bay culminated with definitive accounts of the 'Bournemouth Beds' in which he distinguished the Bournemouth Marine Beds (1879c) and the Bournemouth Freshwater Beds (Gardner, 1882), together overlain by the Boscombe Sand. Fossil plants, first noticed by Brodie (1842) and later by Wanklyn (1869), provided a strongly palaeobotanical emphasis in certain of Gardner's papers (Gardner 1877, 1879a,b; Gardner and von Ettinghausen, 1879).

Following Gardner's work, little more was published until a visit by the Geologists' Association led by Ord (1910), who subsequently redescribed the section (1913), illustrating his paper with photographs which provide a valuable record of exposures at the beginning of the 20th century. Quite a comprehensive review of the section also appears in the Bournemouth Sheet Memoir (White, 1917).

Until recently, little further geological work was done on the section except on fossil plants. Early 20th century studies of these were undertaken by Bandulska (1923a,b; 1928), whilst later, Chandler (1963b) published her important monograph on plants found at this locality and further eastwards near Mudeford.

The IGS publication *The Hampshire Basin and adjoining areas* (Melville and Freshney, 1982) figured Gardner's (1882) cliff profile of the section, although it is misleading as far as present-day exposures are concerned. More recent work has

led to the publication of a more up-to-date geological cliff profile (Daley and Crewdson, 1987; Plint, 1988b; Bristow *et al.,* 1991).

In recent years, Plint (1980, 1983a,b, 1988b) has studied the sedimentology and palaeoenvironments of 'Bournemouth Cliffs' in the context of wider research into the Eocene geology of the Hampshire Basin. Microfloral studies undertak en by Costa *et al.* (1976) attempted to correlate the sequence with other Palaeogene sections. Bristow *et al.* (1991) provides an excellent account of the cliffs in a regional context.

Description

There are eight major present-day exposures. Four occur within the 'Western Bournemouth Cliffs' GCR site:

1. Canford Cliffs

2. Branksome Dene Chine

3. Alum Chine to Middle Chine

4. Durley Chine.

The remainder comprise part of the 'Eastern Bournemouth Cliffs' GCR site and are:

5. East Cliff Zig-zag to Toft Zig-zag

6. West of Boscombe Pier

7. Manor Zig-zag

8. Portman Ravine to Southbourne.

The significance of the 'Bournemouth Cliffs' section is that the succession is quite different from those of equivalent age towards the eastern end of the Hampshire Basin. The sediments here represent the western margins of the Eocene sea, this being emphasized in 'Bournemouth Cliffs' by the, in part, lateral juxtaposition of coeval marine and non-marine strata.

Lithological succession

Two formations are represented in Bournemouth Cliffs: the Branksome Sand, overlain by the Boscombe Sand. Whilst Bristow *et al.* (1991) stated that the former has a thickness in the Bournemouth area of 70 m, it is difficult to determine its thickness in Bournemouth Cliffs in the shallow-dipping and intermittently exposed sections. A 22 m section occurs just to the east of Bournemouth Pier but this represents only a small part of the whole. The Branksome Sand comprises a variety of elastic lithotypes. At the western end of Bournemouth Cliffs, mainly medium to coarse-grained sands with subsidiary mud-clast conglomerates and 'pipe clays' (kaolinitic 'ball clays') are interbedded with and enclose lenticular, laminated mudstone bodies. To the east of Bournemouth Pier the latter are associated with finer grained sands.

The Boscombe Sand has a regional thickness of between 20 and 27 m (Bristow *et al.* (1991) but considerably less than this is exposed in the cliff sections. It first appears towards the top of the cliff just to the east of Durley Chine (Figure 6.5); it thickens generally eastwards, whence it descends the cliff to reach shore level at the eastern end of the section. The formation mainly comprises clean sands but in places contains flint conglomerates forming lenticular bodies.

Stratigraphy

Recognition that the Bournemouth sequence is lithologically distinct, led Edwards and Freshney (1987b) to establish the Bournemouth Group. Subsequently, this has been superseded by assigning these sediments to the Bracklesham Group (see discussion in Bristow *et al.,* 1991). Its local upper formation, the Branksome Sand, has the section of cliffs from

Boscombe Pier [SZ 112 911] westwards to Poole as its stratotype. The cliffs between Boscombe Pier and Hengistbury Head are the stratotype for the overlying Boscombe Sand, the lowest formation of the Barton Group (Edwards and Freshney, 1987b).

Biostratigraphy

From a study of the dinoflagellate flora from the Bournemouth Marine Beds, Costa *et al.* (1976) concluded that at least the upper part of this unit could be assigned to the uppermost of Eaton's (1971a,b; 1976) 'Bracklesham Zones' (his *A. undulates D. craterum* Zone) known now as the *Cyclonephelium intricatum* Zone (Bujak *et al.,* 1980).

Sedimentology and palaeontology

The sedimentological and palaeogeographical significance of the site has recently been emphasized by the work of Plint (1980, 1983a,b, 1988b), who has described a variety of facies ranging from those of fluvial origin in the central and more westerly exposures to those of estuarine and shallow marine nature further eastwards (Figure 6.6).

Plint (1983b) described the fluvial beds in detail and recognized nine facies (reduced to four in Hint, 1988b), representing a range of environments from high-energy, active to abandoned river channels. The former are particularly well-represented by the predominantly sandy sediments of Canford Cliffs and the upper part of the section to the east of Branksome Dene Chine (Plint, 1983b; (Figure 6.7)). Mud-clast conglomerates are present within the sandy facies, as are lenticular bodies of 'pipe clay'. Altogether, Plint (1983a) recognized seven fining-upwards cycles in the fluvial Branksome Sand, increased to eight by Bristow *et al.* (1991) by an additional one at the base (see (Figure 6.5)).

Spectacular channel plugs comprising thinly laminated fine-grained sands, silts and clay are exemplified by that at the base of the cliff immediately east of Branksome Dene Chine (see Plint 1983b, fig. 7; (Figure 6.8)). That some of these fills reflect rapid abandonment (neck cut-offs) is shown where such sediments rest on the channel sands with a sharp contact, such as may be seen just west of Middle Chine. Some of the muds are carbonaceous, whilst plant debris may also occur. Fruits and seeds were found by Chandler (1963b, p.10) in the channel plug near Branksome Dene Chine. Marine dinoflagellates have also been recorded in some of these channel plugs (Bristow *et al.,* 1991).

A particularly striking and palaeogeographically significant section occurs between East Cliff Zig-zag and Toft Zig-zag. Towards the base of the cliff just eastwards of the chairlift, the lateral junction of the Bournemouth Freshwater Beds and the Bournemouth Marine Beds may be observed, although the former also extend below the latter for some distance further east. The junction is complex, and slump, ball and pillow, and water-escape structures are notable features, which Plint (1983a) interpreted as resulting from the gravity-induced deformation of an estuarine channel margin.

A few hundred metres east of the chairlift, thinly-bedded and laminated silty muds and fine sand, with a primary depositional dip of about 5°, have been interpreted as estuarine channel plugs by Plint (1983a, pp. 637–8). Plant debris is common and in-situ roots occur at two levels. Chandler (1963b, p. 14) listed a small number of fossil plants from this locality. Neither Ord (1913) nor Plint (1988b) could find the 'mixed' marine, brackish and freshwater molluscan fauna recorded here by Gardner (1879c).

Between Bournemouth and Boscombe, the Boscombe Sands is exposed intermittently towards the upper part of the cliffs, the base of the formation dipping eastwards to reach shore level near Southbourne. The unit mainly comprises well-sorted sands. More westerly exposures and those higher up further to the east are characterized by bidirectional cross-stratification, whilst the lower part of the formation towards the east is characterized by sands with planar lamination. Plint (1983a, 1988b) interpreted the former as indicative of an estuarine tidal channel situation, whilst the latter represents beach and upper shoreface conditions.

Just east of Manor Zig-zag, the Boscombe Sand includes an excellent exposure of lenticular pebble beds interbedded with pale sands, which Prestwich (1849a) described as forming, 'for its limited extent, the most important conglomerate bed in the English Tertiaries' (Figure 6.9). The pebble beds are clast supported and contain well-rounded and relatively well-sorted flint pebbles up to 20 cm in diameter. Flint (1983a, p. 633) suggested that the conglomerates represent beach

pebbles transported into the mouth of an estuary by longshore drift.

Interpretation and evaluation

The importance of 'Bournemouth Cliffs' is that it is the only existing exposed section at which evidence for the western limits of the late Bracklesham to early Barton sea may be found. Uniquely, the junction of marine and non-marine sediments can be observed rather than just inferred as is normally the case where palaeogeographical 'boundaries' are concerned.

Dating and correlation

From a study of the dinoflagellates, Costa *et al.* (1976) were able to correlate the 'Bournemouth Cliff' sediments with the better known sections on the Isle of Wight. Costa *et al.* (1976) considered that the Bournemouth Marine Beds and the overlying Boscombe Sand together might be equivalent to Prestwich Beds 25–28 in Alum Bay. In concurring with this view, Edwards and Freshney (1987b, fig. 2) specifically matched the Boscombe Sand with Bed 28 in Alum Bay. Figure 3 of Costa *et al.* (1976) implies a correlation of the Bournemouth Marine Beds with Bed 27 of Alum Bay. Plint (1988b), by contrast, suggested a correlation with Bed 24, although the dinoflagellate assemblages of the latter considerably pre-date those found in the Bournemouth Marine Beds (Costa *et* at, 1976, p. 282).

Stratigraphical definition and nomenclature

Lithologically, the difference between the 'Bournemouth Cliffs' sediments and those further east has long been recognized. This has led to the use of a number of nomenclatural systems for these strata, which in part have recognized their distinctiveness and yet have sought a correlation of the section with those elsewhere.

The subdivision by Gardner (1879c, 1882) into Bournemouth Freshwater Beds, Bournemouth Marine Beds and Boscombe Sand was used for many years, but has given the British Geological Survey a few problems (see Edwards and Freshney, 1987b, p. 54). White (1917), for example, found it impossible to map the first of these and the underlying 'Lower Bagshot Series' separately, and grouped them as 'Bagshot Beds'. Whilst the Bournemouth Marine Beds were allocated to the Bracklesham Beds, even that distinction is unmappable away from the coast.

The grouping together of Gardner's three units into the Bournemouth Formation by Curry *et al.* (1978) was rejected by King (1981, p. 13) as invalid due to inadequate definition. Plint (1983a) included these units within his Bracklesham Formation, but, as Edwards and Freshney (1987b, p. 46) pointed out, his use of the term was chronostratigraphical and hence lithostratigraphically invalid.

Plint (1988b) has, however, in turn questioned the value of grouping the Bournemouth Freshwater Beds and the Bournemouth Marine Beds by these authors into a single unit, the Branksome Sand. Whilst conceding that this may be justified from the point of view of mapping, he implies that doing so plays down the sedimentological differences vital in determining palaeoenvironments. Giving these two units formal member status was not suggested by Bristow *et al.* (1991), and it is evident from recent work that neither are unequivocally freshwater and marine as was once thought.

Palaeoclimatology

Palaeontologically and palaeoclimatically, 'Bournemouth Cliffs' is of considerable importance. Although devoid of animal fossils, excepting the old record of Gardner (1879c), it is a major locality for fossil plants (Chandler, 1963b). Apart from the small macroflora described by Crane (1977) from Prestwich 'Bed' 24 in Alum Bay, the Bournemouth macroflora is the only one known at this stratigraphical level in the Hampshire Basin. Apart from its innate palaeontological importance, it is significant palaeoclimatologically. Chandler (1964, pp. 68–9) had little doubt of its tropical nature, although changes in the microflora elsewhere at this level indicate gradual climatic cooling (Collinson *et al.,* 1981).

Depositional environment and palaeogeography

Only in recent years, particularly through the work of Plint, has the sedimentological and palaeogeographical importance of the 'Bournemouth Cliffs' sequence been realized. The 'fluvial' sediments of the Bournemouth Freshwater Beds represent a wide variety of environments. Plint (1988b) interpreted the various constituent facies as representing meandering rivers in which channels, levees, channel plugs and flood basins were identifiable. The channel plug facies are some of the best examples of their type in the British stratigraphical column. Whether the fluvial facies is that of a meandering river is open to some doubt. The lack of laterally continuous overbank muds and the generally lenticular geometry of much of the sequence indicates that it may have a braided stream origin. Recently, Bristow *et al.* (1991, p. 57) have pointed out that since some of the mud units contain sparse marine dinoflagellate cyst assemblages, these deposits cannot be solely fluvial since there must have been some access to the sea.

Together, the deposits of the Bournemouth Marine Beds and much of the Boscombe Sand provide one of the best examples of estuarine facies in the British stratigraphical succession. Much of the former comprises heterolithic, but essentially muddy, sediments (facies G of Plint, 1988b, p. 132 or Cycle G in fig. 33) which accumulated in tidal areas of variable salinity (cf. Gardner, 1879b, c) and which, from the amount of plant debris present, was adjacent to rivers draining a well-vegetated hinterland. The section some 250 m west of Toft Zig-zag is a particularly fine example of low-angle, depositionally inclined stratification. Although referred to as an estuarine channel plug by Plint (1983a, p. 638), it may be considered as a very fine example of sedimentation of a laterally accreting point bar of a sluggish, muddy estuarine channel system. The shallowness of the water at times is indicated by rooted horizons (?palaeosols), presumably representing tidal (?salt) marshes, whilst thin, graded beds may represent fluctuating tidal activity or fluvial discharge. To a certain extent these sediments resemble those forming the channel plugs in the Bournemouth Freshwater Beds; both reflect muddy channel sedimentation.

The onset of the Boscombe Sand represents a transgression (T4 transgression of Plint, 1983a), with its clean, bi-directionally cross-bedded sandstones providing a fine example of deposition in a tidal channel complex, although the lower part of the succession towards the eastern end of 'Bournemouth Cliffs' is thought to represent beach and upper shoreface sedimentation (Plint, 1988b).

Pebble provenance and tectonism

The flint conglomerates developed within the Boscombe Sand represent a unique occurrence in the Palaeogene succession, since although thin flint pebble beds occur above transgressive surfaces at a number of horizons in the Palaeogene of the Hampshire Basin, there is no other instance of flint conglomerate reaching a thickness of up to 14 m (Plint, 1988b, p. 132). In composition, they are different from the petromictic conglomerates present at Bincombe and Blackdown; hence a fluvial derivation from the west seems unlikely. Clearly they indicate a source which is either exposed Upper Chalk or an earlier gravel derived from the latter. Plint (1988b, p. 132) suggested that the pebbles had probably been transported by longshore drift into an estuarine environment to accumulate in channels or in a shoreface situation whilst Bristow *et al.* (1991, p. 69) proposed a storm beach origin.

Some of the flint pebbles from these conglomerates provide vital information about the evolution and uplift of major tectonic structures during Tertiary times. Curry (1986) found that a few pebbles that had 'decayed' contained foraminifera unknown from the Chalk of the English mainland, but characteristic of late Maastrichtian levels in continental Europe. He concluded that the nearest source of such material was to the south over 50 km away near the 'Central Channel Structure' (Smith and Curry, 1975). The implication of this conclusion is that local derivation of the Boscombe Sand conglomerates by longshore drift does not adequately explain the presence of such pebbles. More significantly, the Maastrichtian pebbles in the Boscombe Sand travelled from the south across the Purbeck–Isle of Wight line, which, if active at that time, would have acted as a barrier to such movement. Curry (1986) therefore concluded that, at least at that time, the eastern half of the Purbeck–Isle of Wight structural line was quiescent or had not been initiated.

Conclusions

'Bournemouth Cliffs' provide a great deal of information to facilitate our understanding of sedimentation in the more westerly part of the Hampshire Basin.

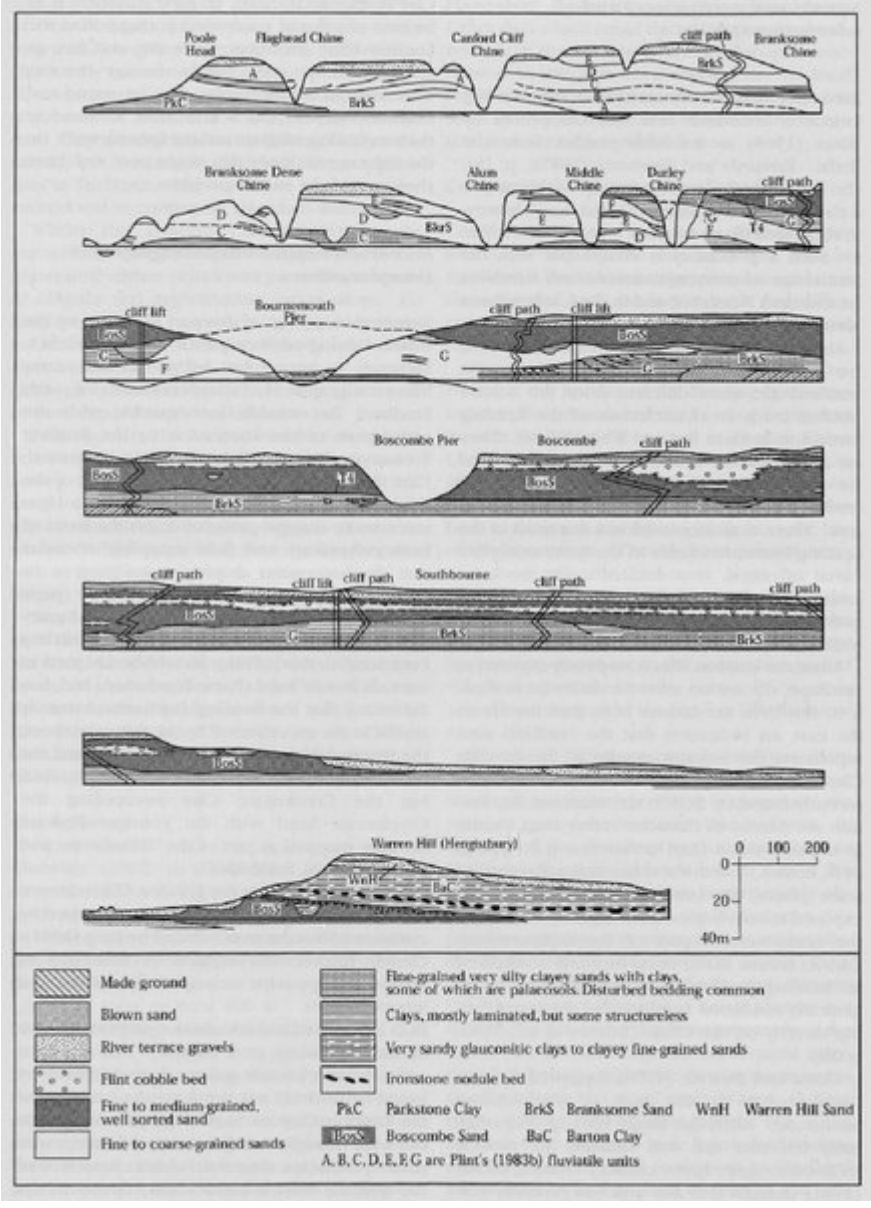
Although apparently devoid of animal fossils, the sections contain a diverse macroflora. This site is important as it contains the only well-preserved flora at this stratigraphical level in the Hampshire Basin sequence. It perhaps represents the youngest of the 'tropical' floras of the Hampshire and London Basin successions.

'Bournemouth Cliffs' contain sediments representing a wide range of environments including fluvial, estuarine and shallow marine. Fluvial sediments are particularly well-developed towards the western end of the site, although the rivers they represent were close to the sea. Amongst the various facies present are superb examples of channel plug sedimentation. More easterly localities include sections in the Bournemouth Marine Beds and Boscombe Sand which are thought to provide some of the best examples of estuarine sedimentation in Britain.

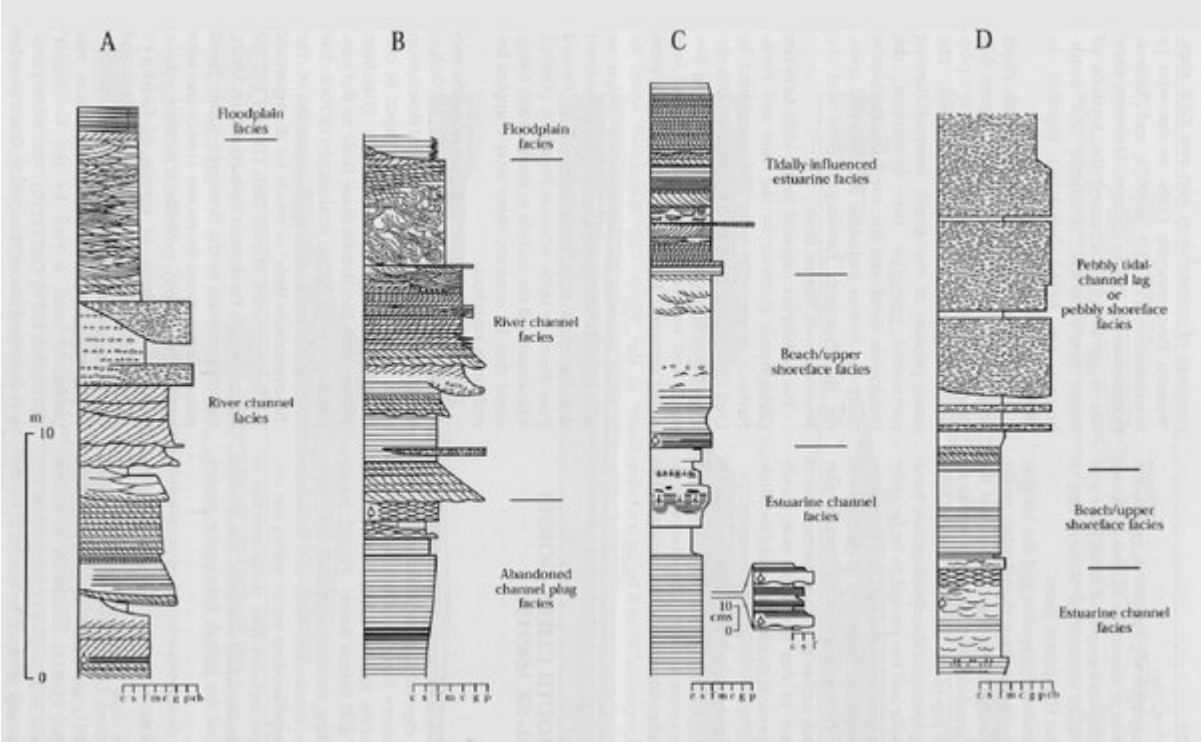
The presence of thick flint conglomerates in the Boscombe Sand is exceptional in the local Tertiary. Pebbles probably derived from Maast-rictian Chalk exposed well to the south in the central part of the English Channel indicate that no local barrier reflecting movement along the eastern half of the Purbeck–Isle of Wight tectonic line existed at that time.

The designation of the Bournemouth Group (although now superceded) recognized that at this stratigraphical level, the sequence towards the western end of the Hampshire Basin is different from the essentially coeval Bracklesham Group found further to the east. The importance of 'Bournemouth Cliffs' is apparent from its being the stratotype for both the Branksome Sand, locally the uppermost formation of the Bracklesham Group, and also the overlying Boscombe Sand. It provides a vital stratigraphical link between the marine strata of more easterly localities such as those on the Isle of Wight and the thick fluvial sediments of the Wareham Basin to the west.

References

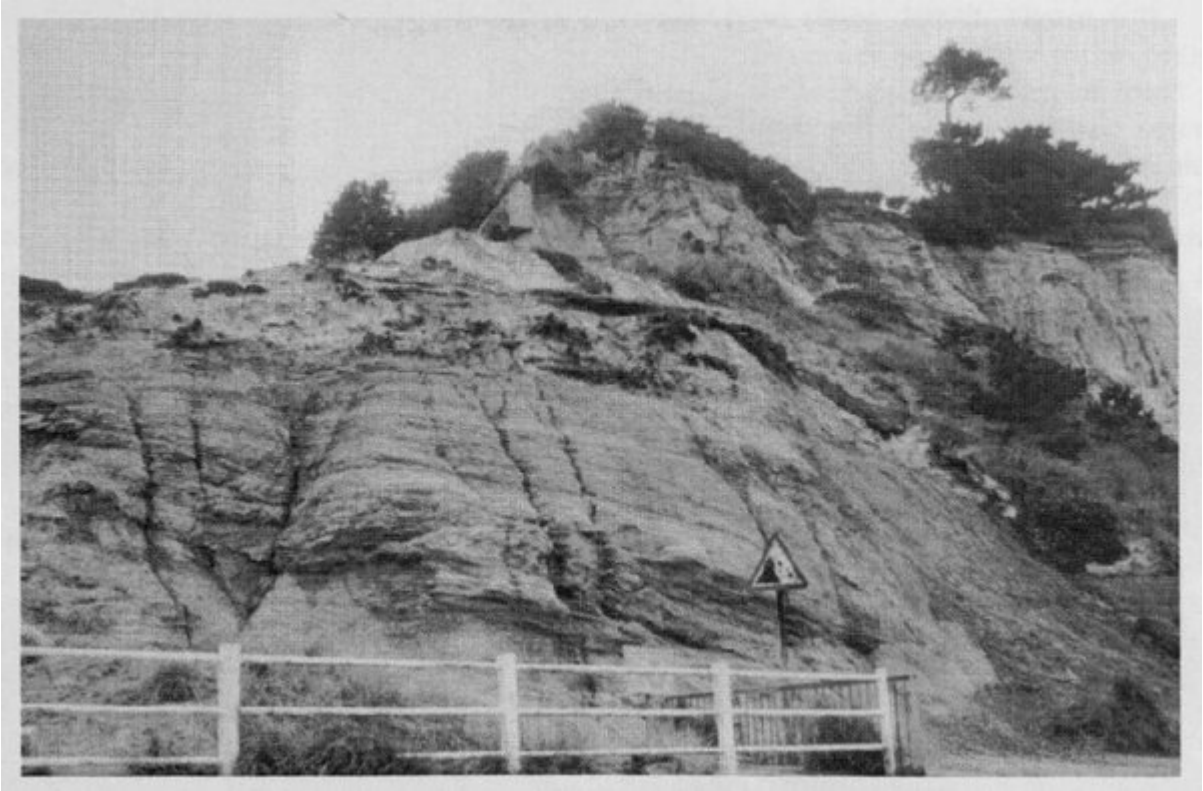


(Figure 6.5) Bournemouth Cliffs and Hengistbury Head (Warren Hill), Dorset: cliff profile (from Bristow et al.,



(Figure 6.6) Representative vertical sections from Bournemouth Cliffs: (A) fluvial channel facies, with overbank floodplain facies at the top (Canford Cliffs); (B) fluvial facies, with the lower third channel plug fades (east of Alum Chine); (C) estuarine channel facies (Bournemouth Marine Beds) overlain by beach/upper shoreface facies, followed by tidally-influenced estuarine fades (both Boscombe Sand) (200 m west of Toft Zig-zag); (D) pebbly tidal channel lag or pebbly shoreface facies (Boscombe Sand) in upper part (east of Manor Zig-zag). Clay=c; silt=s; fine/medium/coarse sand=f, m, c; gravel=g; pebbles=p; cobbles=cb. (After Plint, 1988b.)

(Figure 6.7) Canford Cliffs, Poole, Dorset. The Branksome Sand (overlain by thin Quaternary gravel), viewed from the west. (Photograph: B. Daley.)



(Figure 6.8) Branksome Dene Chine, Poole, Dorset. Laminated channel plug facies in the Branksome Sand, exposed immediately to the east of the chine. (Photograph: B. Daley.)

(Figure 6.9) Boscombe, Dorset. Pebble bed in the Boscombe Sand, overlain by Quaternary gravel (brown), exposed immediately east of Fisherman's Walk Zig-zag. (Photograph: B. Daley.)