Bouldnor and Hamstead Cliffs and foreshore, Isle of Wight

[SZ 375 902]–[SZ 405 920]

Highlights

This is the only site with a more or less complete succession of the Bouldnor Formation and the only place where the Hamstead and Cranmore Members are exposed. These are the youngest rocks of the local Palaeogene succession, with the site the sole extant exposure of Oligocene age in the Hampshire Basin. It is one of the best localities for the study of low-energy, freshwater and brackish elastic environments and has well-preserved plant macrofossils and macroinvertebrates, particularly gastropods.

Introduction

Bouldnor Cliff and its north-easterly continuation in Hamstead Cliff extends for about 3.2 km as far as Hamstead Ledge. The south-western limit of the site is around map reference [SZ 375 902] and the north-eastern limit at [SZ 405 920]. It is of considerable stratigraphical and palaeoenvironmental significance, although due to the badly slipped and well-vegetated nature of the cliff section, exposures are intermittent. Except for a very restricted occurrence near Gurnard Ledge, it is the only site where the Hamstead and Cranmore Members of the Bouldnor Formation are exposed and provides the last preserved record of Palaeogene sedimentation in the Hampshire Basin.

This site was also independently selected for its fossil plant content, a more detailed account of which can be found in the GCR series volume *Mesoozoic to Tertiary Palaeobotany of Great Britain* (Cleal and Thomas, in prep.), and its fossil insect content which will be discussed in a future GCR volume.

The section comprises a complete sequence of the Bouldnor Formation, consisting of muds with variable fossil content which have been assigned to three members: the Bembridge Marls Member, the Hamstead Member and the Cranmore Member. The first is seen west of the poor exposures of the underlying Bembridge Limestone forming Hamstead Ledge at the north-eastern end of the section ([SZ 403 920]; (Figure 5.36)). Although the cliff exposures are intermittent here, the whole of this member is exposed on the foreshore at low water, equinoctial spring tides (Figure 5.37). The Hamstead Member is exposed here, in part along the foreshore and in scattered cliff sections, and the Cranmore Member at the cliff top near the end of Cranmore Avenue ([SZ 386 906]; (Figure 5.38)), below a capping of Quaternary Gravel. Limited foreshore exposures also occur at the southwestern end of the section, towards Yarmouth.

The early descriptions of the cliff section by Forbes (1853) and Bristow *et al.* (1889) remain the most comprehensive due to the very considerable deterioration in exposure which has taken place since the 19th century. No detailed succession of the Hamstead and Cranmore Members has been published since that of Bristow *et al.* (see summary in White, 1921). Daley (1969, 1972c) has redescribed the Bembridge Marls Member, the whole of which is exposed on the foreshore at low water (see also Daley and Edwards, 1974). Brief descriptions of the section as a whole occur in Curry *et al.* (1972) and Daley and Insole (1984); whilst recently the importance of the section has been comprehensively reviewed by Daley (1999, pp. 49–55)..

Recent palaeontological work on the section includes that of Daley (1972b) on macroinvertebrates, Keen (1972a) on the ostracods, Murray and Wright (1974) on the foraminifera, and Ford (1967) and Bosma (1974) on the mammals. Microfloral studies include Machin (1971) on pollen and spores, and Costa and Downie (1976) and Liengjaren *et al.* (1980) on the dinoflagellates. Collinson (1983b) provided details of the stratigraphical distribution of plant beds within the Bembridge Marls Member.

Description

Whilst the site extends laterally for 3.2 km, exposures are intermittent. No complete sequence has ever been measured and there are parts of the succession for which no published description exists.

Lithological succession

Apart from the poorly exposed Bembridge Limestone at the base, the section is entirely within the Bouldnor Formation. It is difficult to determine its thickness but for the site as a whole a composite estimate is almost 110 m. Individual member thicknesses are as follows: the Bembridge Marls Member: 21.5 m; the Hamstead Member: approximately 78 m; and the Cranmore Member: about 9.2 m preserved (Figure 5.39). Above the thin shell bed with *Ostrea* which caps the Bembridge Limestone at Hamstead Ledge, the Bouldnor Formation is predominantly black, grey and green more or less fossiliferous muds and muddy silts, other lithologies being uncommon. There is no representative here of the 'Insect Limestone' which occurs close to the base of the Bembridge Marls Member (Figure 5.40) at all the other major localities where this member is found. Horizons with rough or hackly concretionary ironstone nodules and one continuous ironstone band occur in the lower part of the formation.

Stratigraphy

Forbes (1853, 1856) split the sequence here into the Bembridge Marls and overlying Hamstead Beds, the boundary between them being the carbonaceous mud or so-called 'Black Band' at the base of the latter (see White, 1921, p. 129). These two stratigraphical units were retained by Bristow (1862) and Bristow *et al.* (1889), although in both cases, doubts were expressed as to whether the separation of the two was justified. The complete sequence is, after all, both here and elsewhere, argillaceous throughout.

Hence, following Hedberg (1976), the similarity of the strata above and below the 'Black Band' denies separate formation status for the Bembridge Marls and Hamstead Beds of the traditional nomenclature scheme. This was recognized by Curry *et al.* (1978) who united both of these units into a single Hamstead Formation, although without a formal definition of its characteristics.

Insole and Daley (1985), in proposing new lithostratigraphical nomenclature, designated the site as the type area for the Bouldnor Formation, a new term used instead of the Hamstead Formation of Curry *et al.* (1978) to avoid nomenclature confusion. The foreshore and cliffs between Hamstead Ledge and Bouldnor were defined as the type area both for the formation and the Hamstead Member (formerly the Lower Hamstead Beds of Bristow *et al.* (1889) and equivalent to the Lower and Middle Hamstead Beds of Keen (1972a)). The stratotype for the Cranmore Member (formerly the Upper Hamstead Beds of Bristow *et al.,* 1889) is the uppermost part of Bouldnor Cliff.

Palaeontology

The Bouldnor and Hamstead site is particularly important palaeontologically, firstly because nowhere else in Britain are rocks of this age and facies preserved (see below) and secondly because it provides an opportunity for the palaeoecologist to study a variety of animal and plant communities from brackish to freshwater environments.

The study of macroinvertebrate assemblages undertaken by Daley (1972b) relied heavily on data derived from this site. A variety of brackish and freshwater assemblages in the Bembridge Marls Member are especially well developed here. In the foreshore exposures, shell preservation is particularly good compared with that frequently encountered elsewhere.

Macroflora

Plant macrofossil assemblages described by Collinson (1983b) from the foreshore exposures west of Hamstead Ledge provide a major contribution to our knowledge of aquatic and marginal aquatic floras of this age and shed considerable light on the conditions under which the lower part of the Bouldnor Formation was deposited. She recognized nine plant macrofossil-bearing horizons; eight are in the Bembridge Marls Member, the ninth being the 'Black Band' at the base of the overlying Hamstead Member. These contain abundant fruits, seeds, fern sporangia, megaspores of the water fern *Azolla* and, less commonly, leaves. She also described one new genus and three new species from the locality (see also

Collinson, 1980a). The fern sporangia, discussed in more detail elsewhere by Collinson (1978b) occur in all the plant-bearing horizons of the Bembridge Marls Member. They are assigned to the present-day genus *Acrostichum,* characteristic of modern mangrove floras, but extending into freshwater marshes.

At some levels in the Hamstead Member, coniferous leafy shoots and cones of *Sequoiadendron* and *Pinus* are quite abundant and some large logs are common (Collinson and Hooker, 1987). These genera are not part of the swamp flora and Chandler (1978) considered that they might have been derived from some distance. Their abundance does, however, suggest a more proximal hinterland (cf. Schneider, 1992, figs 2 and 3).

More recently, Collinson (1992, pp. 441–2) has discussed the fossil plant remains from this site in the context of floristic changes around the Eocene/Oligocene boundary in western and central Europe.

Vertebrate remains

A particularly significant feature of the Hamstead Member is the presence of vertebrate material, with the larger fossils found mostly not *in situ* but on the foreshore or in foreshore exposures of slumped material. As well as fish, crocodiles, turtles, frogs and lizards, a variety of mammalian fossils have been found. Amongst mammalian genera listed by Ford (1967) are *Entelodon* (pig-like animal), *Bothriodon* and *Brachyodus* (grazers), *Caenotherium* (small and deer-like) and a few carnivores, the largest being *Hyaenodon.* The presence of the insectivore *Butselia biveri is* referred to in Butler (1972). The rodent fauna has recently been described by Bosma (1974) whilst fossil birds found in the vicinity of Bouldnor Cliff were described by Harrison and

Walker (1979). Hooker (1987, 1989) listed the mammalian fossils from this site and later dicussed them (Hooker, 1992) in a paper on palaeocommunities. Collinson (1992, fig. 22.1) indicated the position of two 'Mammal levels' (MP) of Brunet *et al.* (1987) in the succession: MP20 below the 'Black Band' and MP21 between the Nematura Band' and the 'White Band'.

Microfauna

Microfaunal studies of the site include research on the foraminifera of the Cranmore Member by Murray and Wright (1974) and the ostracods by Keen (1968, 1971, 1972a). The foraminiferal fauna, though mainly indicative of hyposaline conditions, suggests that open marine conditions existed at the time represented by the upper part of the 'Cerithium Beds'.

The Cranmore Member contains the youngest Palaeogene ostracod fauna in the British Isles. Ten species of polyhaline marine ostracod are present; eight are unique to this horizon, whilst one occurs in the Hamstead Member and another as low as the Bembridge Limestone (Keen, 1972a, p. 313). Ostracods are common at some horizons in the Bembridge Marls Member and thin, lensoid ostracod limestones have been found in one bed described by Daley (1969; see also Daley and Edwards, 1974, p. 286). Keen (1977) referred to low-salinity brackish ostracod faunas in the Tembridge Oyster Bed' at the base of the member but gave no detail of ostracod faunas from higher up the succession.

Microflora

Microfloral research on the Bouldnor and Hamstead section includes work on pollen and spores by Machin (1971) and on dinoflagellates by Costa and Downie (1976) and Liengjaren *et al.* (1980). Machin noted a significant, though not sudden, change coinciding with the Bembridge Marls/Hamstead boundary. Above this horizon, most of the forms increasing or coming in for the first time are more characteristically north temperate. Some subtropical genera, by contrast, disappear from the local flora, e.g. the palm *Thrinax.* Costa and Downie (1976), whilst referring to the presence of the dinoflagellate zone fossil *Wetzeliella gochtii* in the Cranmore Member, implied that the base of the zone may be lower in the succession, good dinoflagellate zone fossils being absent between this member and the considerably older Colwell Bay Member. In a more detailed paper, Liengjaren *et al.* (1980) described a number of assemblages, which at this locality coincide with three transgressive events: that of the Tembridge Oyster Bed', that associated with the *Nematura* 'Band' in the Hamstead Member and that of the Cranmore Member. The assemblages from the last of these led Liengjaren *et al.* (1980) to imply a very pronounced break in the dinocyst succession between this unit and the preceding strata.

Nannofossils are rare, but Martini (1972) tentatively assigned material found in the Corbula bed (sic) of the Cranmore Member to Nannoplankton Zone 23 (NP23).

Sedimentology

Sedimentological work has only been undertaken on the Bembridge Marls Member (Daley, 1969, 1973a; Daley and Edwards, 1974). Low-energy conditions are implied by its argillaceous character, with varve-like lamination reflecting vertical sedimentation. Periods of higher energy are reflected by often laterally continuous coquinas and also gutter structures. Roots and mudcracked horizons testify to the shallowness of the water. An association of these sediments with a variety of brackish and freshwater faunas (Daley, 1972) suggests the former presence of sluggish lagoons or estuaries, the upper reaches of which were sufficiently river-influenced and isolated from the sea to have experienced near-or truly freshwater conditions.

Interpretation and evaluation

The essentially uniformly argillaceous nature of the Bouldnor Formation is clearly apparent at this site. The lithological similarity of the strata above and below the 'Black Band' demonstrates the validity of replacing the separate Bembridge Marls and Hamstead Beds with a single Bouldnor Formation.

It is unfortunate that the cliff exposures are generally poor and it seems possible that the sections exposed may be inferior to those available to 19th century geologists. The lack of good cliff exposures above the lower part of the Hamstead Member is particularly adverse, since there are no foreshore exposures above this stratigraphical level. However, since the site is the only available exposure in south-eastern England of rocks of this age, its importance remains considerable.

Comparison with other localities

Stratigraphically, the site is unique, since it is the only locality where the whole of the Bouldnor Formation is exposed. The Cranmore Member only occurs here. It is also the only site where reasonable exposures of the Hamstead Member occur, for although much of the subcrop of northern Wight comprises this member, brickyards such as those mentioned in White (1921) were infilled many years ago and the only other coastal site near Gurnard Ledge has poor, currently obscured exposures of the 'Black Band' and the strata immediately above.

The Bembridge Marls Member is not unique to this site, but it is one of two sites where the complete succession may be examined; with its excellent foreshore exposures, it is better than the other rather overgrown section near Gurnard Ledge in Thorness Bay. Although thinner than the incomplete sequence in Whitecliff Bay, it resembles the equivalent in Thorness Bay, both in thickness and lithology. Significant differences are, however, the very thin development of oyster-bearing rock at the base (a thin 'cap' to the Bembridge Limestone rather than anything that could seriously be called the 'Tembridge Oyster Bed') and that of the absence of the 'Insect Limestone'.

Palaeontology and palaeoclimatology

The importance of the site palaeontologically has already been referred to. As well as having a variety of well-preserved macroinvertebrate, fresh to brackish water assemblages, its plant fossils have shed much light on our understanding of contemporaneous aquatic and marginal aquatic floras. Collinson's (1983b) study of these floras, almost exclusively from this site, must rank as one of the most important pieces of research on the British Palaeogene flora in recent years. Machin's (1971) work on the microflora was palaeoclimatologically revealing. She concluded that there is evidence of a climatic shift towards cooler conditions than the sub-tropical/warm temperate conditions that she had postulated for earlier, post-Bartonian times. It is interesting that Buchardt (1978) found that oxygen isotope temperatures obtained from Palaeogene shell material showed a sharp drop at the commencement of the Oligocene. Such a cooling appears also to be compatible with the findings of Collinson and Hooker (1987). They concluded that by the beginning of Oligocene times, dense forests of tropical aspect had given way to a more open environment with only scattered trees, whilst Hamstead mammalian faunas show a decrease in arborescent forms and an increase in large ground mammals,

especially herbivores with a high fibre diet!

Dating and correlation

Curry *et al.* (1978, table 2) gave an early to middle Oligocene age to the Bouldnor Formation. In fact, correlation with Oligocene strata in other areas of north-western Europe depends to a very considerable extent on material from this site, which was selected by Curry and Hailwood (1986) to typify the English succession spanning the Eocene/Oligocene boundary.

Such workers as Keen (1972a) have stressed the differences between the fossil assemblages of this formation and the older Palaeogene strata of the Hampshire Basin. From his work on the ostracods, Keen considered that this reflected the arrival of a new fauna heralding the Rupelian transgression, which was such a major event over much of north-western Europe (see also Sub-group Lithostratigraphy and Maps, 1980). With this in mind, he placed both the Hamstead and Cranmore Members in the so-called 'Sannoisian Facies' at the base of the Rupelian (Keen, 1971). Cavelier (1964) had earlier established a convincing case for correlating the 'Hamstead Beds' (Hamstead and Cranmore Members) with the Sannoisian of the Paris Basin, which he had placed at the base of the Oligocene. Keen (1972a) placed the Eocene/ Oligocene boundary at this site 'somewhere' within the Bembridge Marls Member.

Martini's (1972) tentative assignment of the Cranmore Member to Nannoplankton Zone 23 (NP 23) was based on material from a weathered sample and more recent work indicates that the strata are probably somewhat older. Costa and Downie (1976) assigned this member to the *Wetzeliella gochtii* dinoflagellate Zone, which is also recorded from the Rupel Clay in Belgium.

From their work on dinoflagellates at this site, Liengjaren *et al.* (1980) correlated the Cranmore Member with the Calcaire de Sannois and the lower part of the Marnes a Huitres in the Paris Basin. Dinoflagellate assemblages characterizing the overlying Sables de Fontainbleau are, however, not present here. Liengjaren *et al.* (1980) found that the assemblages from the vicinity of the *Nematura* Band show marked similarities to those of the Argil& Verte de Romainville at the base of the Stampian, which has been considered as the Eocene/Oligocene boundary. With this correlation as evidence, they have suggested that the base of the Oligiocene could conveniently be taken as the bottom of the Hamstead Member, some 9 m below the *Nematura* Band (but see Hooker (1992, p. 508) for further discussion and a suggestion that the boundary could be a significant distance below the Nematura Band).

Some attempt has also been made to use the mammalian fossils from lower down the succession for correlation purposes. The presence of *Bothriodon* and *Entelodon* has led to correlation with the Calcaire de Brie in the Paris Basin (Melville and Freshney, 1982), whilst Bosma (1974) suggested a close resemblance of the Hamstead Member mammalian fauna to that from the Horizon of Hoogbutsel in Belgium (base of Upper Tongrian in age) (see also Hooker, 1987).

Depositional environment and palaeogeographical context

The Bouldnor and Hamstead site completes the record of Palaeogene sedimentation in southeastern England. The pattern of transgression and regression that characterized the whole of the Palaeogene succession is still apparent, although this site demonstrates that the uppermost part of the sequence is essentially non-marine in character. Conditions of deposition are quiet throughout, representing a sluggish fluvial/estuarine/lagoonal complex with salinities varying from brackish to freshwater. Fine sediments are ubiquitous, almost certainly indicating a total lack of local or hinterland tectonism and rejuvenation. Horizontal, sometimes graded laminae represent vertical accretion in essentially still water, whilst gutter structures and laminae with thin organic debris lags and sometimes parallel-orientated gastropod shells indicate periodic lateral water flow. Some of the more laterally extensive shell bands may represent storm events.

Sometimes the water was very shallow, as implied by the presence of desiccation cracks in the brackish water sediments in the lower part of the Bembridge Marls Member and the presence of in-situ rootlets, and in some cases larger roots, higher up the succession. Collinson

(1983b) suggested that the plant-rich horizons were laid down in depths of 0.3 to 3.0 m. There is evidence from a variety of criteria that some areas were subaerially exposed. Collinson (1990) referred to the existence of 'tree islands' and the mammalian fauna of the Hamstead Member indicates a woodland/bushland habitat (Hooker, 1992). Possibly, the red-mottled horizons in the Hamstead Member originated in contemporaneous weathering.

Whilst there is evidence from a number of horizons that salinity fluctuated, there are three horizons in particular that represent some degree of transgression. Immediately above the base of the formation the shelly layer with oysters overlying the Bembridge Limestone is the distal (and relatively low salinity) expression of the 'Bembridge Oyster Bed' best seen in Whitecliff Bay. The second occurs at the level of the 'Nematura Band' where a restricted fauna indicates that salinities remained brackish. The third comprises the Cranmore Member at the top of the formation. A concensus, based on evidence from the molluscs, foraminiferids, ostracods and dinoflagellates is that this unit represents a time of fluctuating salinities but that conditions were sometimes fully marine. The 'Corbula Beds', in particular, contain a number of wholly marine elements and such workers as Liengjaren *et al.* (1980) believed that assemblages at this level represent the beginning of a major transgression.

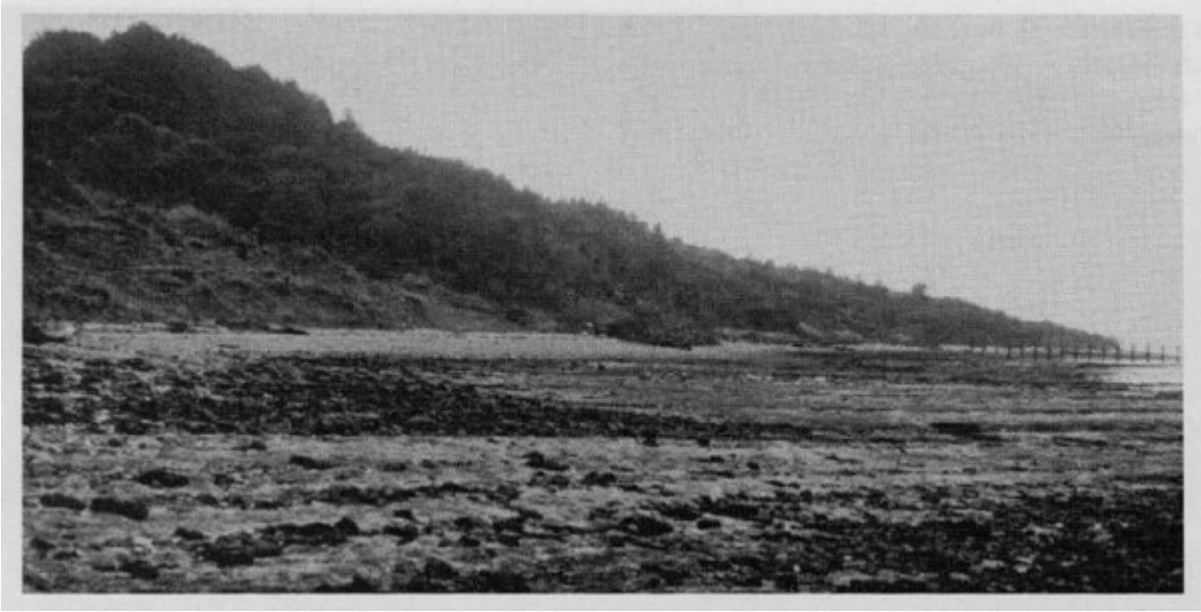
Conclusions

Although the succession is incompletely exposed, the site is of international importance. It is unique, since it is the only locality at which the whole vertical extent of the Bouldnor Formation is exposed. It provides an opportunity to study environments transitional from brackish to freshwater, together with their sediments and associated fossils. A muddy succession throughout represents deposition in a sluggish fluvial/estuary/lagoonal complex occasionally subject to marine inundation (transgression). The site is valuable as a source of information on brackish to freshwater molluscan faunas. It has an important macroflora (particularly water plants) and a variety of vertebrate fossils, including mammals and birds, have been found. The site is uniquely important for correlating the British succession with that of continental Europe.

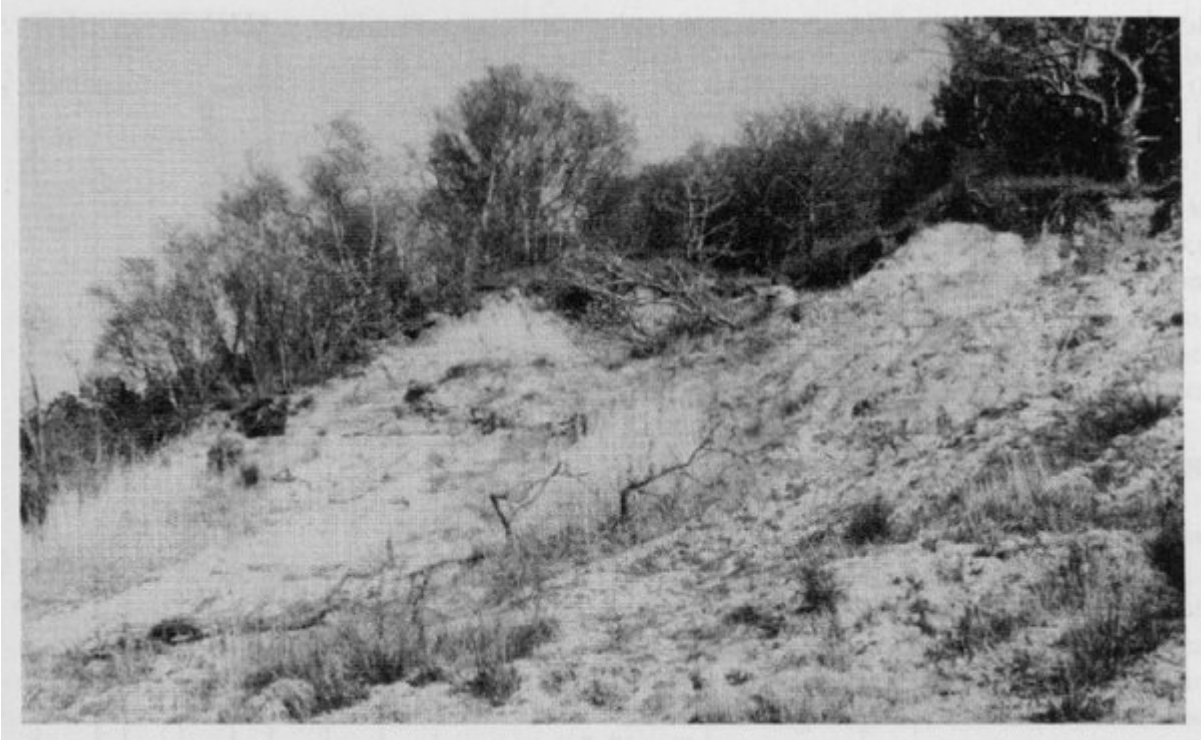
Ostracods, nannoplankton, dinoflagellates and mammals from the younger part of the formation have been used for this purpose. The upper part of the succession is certainly of Oligocene age, with the Eocene/Oligocene boundary within the formation, either within the Bembridge Marls Member or at the base of the overlying Hamstead Member.

References

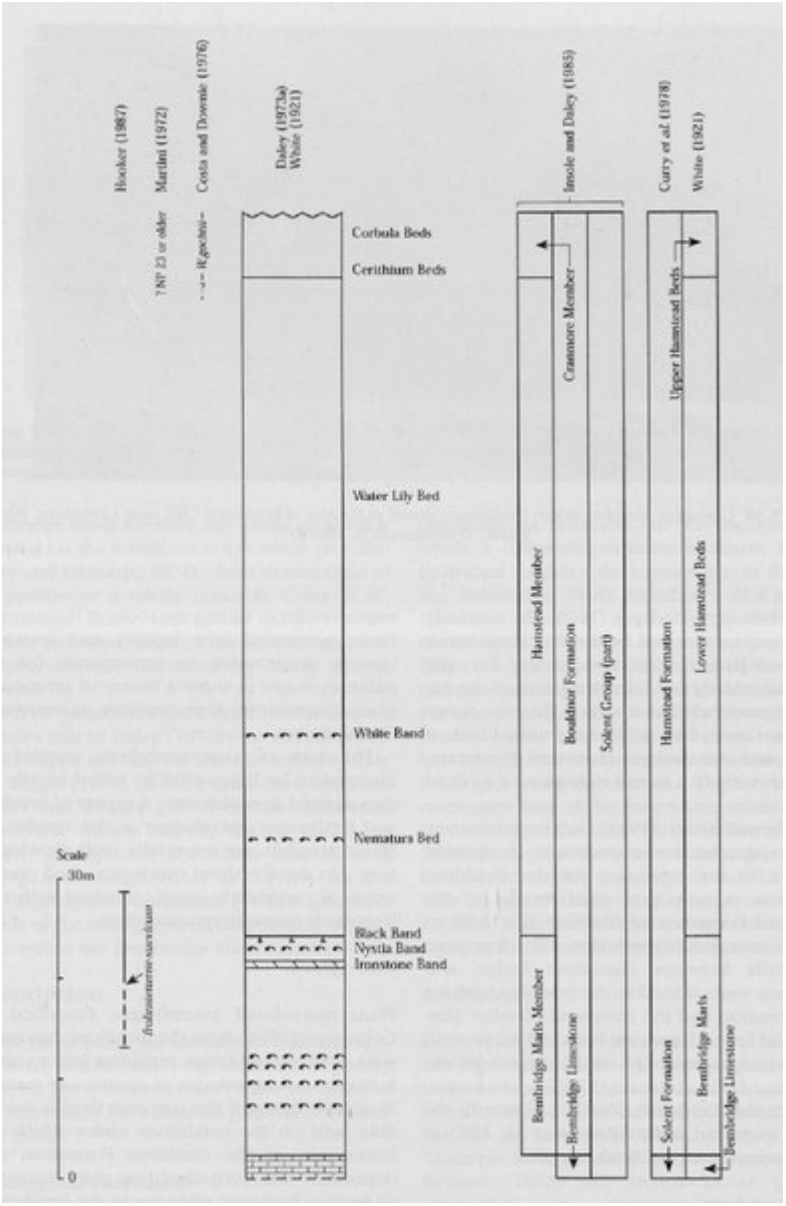
(Figure 5.36) Hamstead Cliffs, Isle of Wight. Cliff and foreshore exposures of the Bembridge Marls Member (Bouldnor Formation), the lighter bands in the cliff representing shell concentrate horizons. (Photograph: B. Daley.)



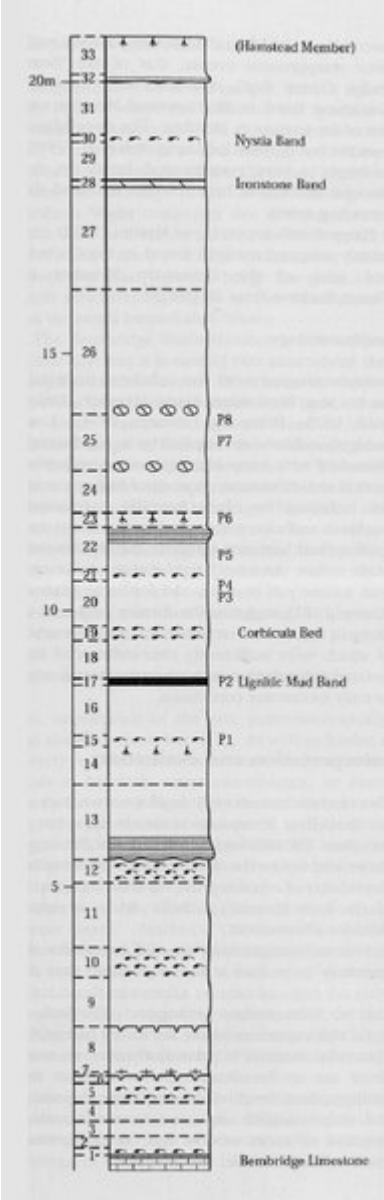
(Figure 5.37) View of Hamstead foreshore at low water, equinoctial spring tides. Foreshore exposures provide a continuous section through the whole of the Bembridge Marls Member and the lowest part of the overlying Hamstead Member. (Photograph: B. Daley.)



(Figure 5.38) Cranmore Member below Quaternary gravel at the top of Bouldnor Cliff, near Cranmore, Isle of Wight. (Photograph: B. Daley.)



(Figure 5.39) I.ithostratigraphical succession of the Bouldnor Formation in Bouldnor and Hamstead Cliffs, Isle of Wight, based on the section from Cranmore north-eastwards to Hamstead Ledge (after Daley, 1973a; White, 1921 and other authors). The frohnstettense-suevicum Zone (Hooker, 1987) is a mammal concurrent range zone.



(Figure 5.40) Bembridge Marls Member (Bouldnor Formation) succession at Hamstead Ledge, Isle of Wight (after Daley, 1973a), with 'plant beds' (P1 to P9) after Collinson (1983b).