Herne Bay

([TR 217 691]–[TR 205 687])

Highlights

At Herne Bay in Kent an almost continuous sequence through the Palaeocene and Lower Eocene strata is exposed along the foreshore and cliff outcrop, and fossil fishes have been found in most units in the pre-London Clay Tertiaries and basal London Clay Formation. The 'Beltinge Fish Bed' (Woolwich Bottom Bed) which occurs near the base of the section, has yielded an exceptionally rich fossil fish fauna, with three species that only occur at this locality.

Introduction

Cliff and foreshore exposures extending from the east side of Herne Bay town north-eastwards to Reculver Point [TR 224 693] give a continuous section from the Upper Thanet Formation to the London Clay. It is considered to be one of the best Lower Eocene fish-bearing localities in the British Isles and has yielded abundant material from nearly all levels in the sequence. The Beltinge Fish Bed (of the Woolwich Bottom Bed) near the base of the section is particularly important, as it yields well-preserved chimaeroid toothplates of at least seven species, three of which are known only from Herne Bay, in conjunction with a diverse shark fauna. Other important fish-bearing horizons occur within the Thanet Formation, the Oldhaven Formation and the basal beds of the London Clay. The sequence at Herne Bay has in all yielded 17 species of selachians, eight holocephalians and over 30 bony fish species based upon scattered teeth, bones and teleost otoliths.

The Herne Bay section has been described many times over the past 140 years, including the classic early works by Prestwich (1850, 1852, 1854a) and Whitaker (1866, 1872). Recent descriptions include that by Ward (1978a) on the pre-London Clay strata and by King (1981) on the London Clay itself, and a general account of the geology is provided in the memoir for the Faversham sheet (Holmes, 1981). Herne Bay is included in the Geologists' Association Guide No. 30B (Pitcher *et al.,* 1967). The site was selected as an SSSI for Tertiary stratigraphy, as it is designated the co-stratotype (with Pegwell Bay, Kent; [TR 3498 6429] for the Thanetian Stage of the Palaeocene by Pomerol (1982), and is described by Daley (*in* Daley and Balson, 1999). The site is also the type locality for King's (1981) definitions of the Oldhaven Formation, and Herne Bay Member of this formation. The fish fossils have been recorded by Gurr (1963), Ward (1975, 1978a) and Gamble (1979). As an important Tertiary fish and stratigraphical site, Herne Bay used to be one of the most visited sites in the pre-London Clay Tertiaries and was the venue for several fieldtrips by the Geologists' Association (Brown, 1936; Gamble, 1968; Hutchinson, 1968) and the Tertiary Research Group (e.g. Rundle, 1970). However, in the past 20 years this activity has declined as coastal defence schemes have left the cliff sections poorly exposed.

Description

The section between Herne Bay town and Reculver village comprises a series of Palaeogene beds which dip gently towards the west. The oldest strata present, the 'Lower London Tertiaries', is made up of the upper part of the Thanet Formation and the overlying 'Woolwich Beds' of Ellison's (1983, p. 312) Woolwich and Reading Formation. These are succeeded unconformably by the Thames Group (King, 1981), i.e. the Oldhaven Beds of the Blackheath and Oldhaven Formation and the London Clay Formation (Figure 14.4). However, the London Clay succession at Herne Bay is now poorly exposed along the cliff sections, although King (1981) referred to cliff exposures of this unit as up to 30 m in thickness and the thickest preservation of the London Clay in Kent (Daley *in* Daley and Balson, 1999).

Relatively few workers have studied the section from a detailed lithostratigraphical and sedimentary facies viewpoint, and in most cases, have only done so as part of broader regional studies (e.g. Hester, 1965; King, 1981; Ellison, 1983; Ellison *et al.,* 1994). The section in descending succession below is a composite made from several reports along the whole length of the cliffs between Reculver and Herne Bay, it has been summarized from the early works of Prestwich (1850,

1852, 1854) and Whitaker (1872), and the later sections produced by the British Geological Survey (Holmes, 1981):

	Thickness (m)
[Foreshore exposure at [TR 201 686]: Holmes, 1981, p. 48]	
London Clay Formation, Division B	
a. Pale, bluish grey shaley clay, roughly laminated	—
Grey or faintly mauve sandy clay with lignite, iron pyrite, pyritized wood and selenite concentrated at the base; locally interbedded with sand:	0.23–0.46
London Clay Formation, Basement Bed	
b. Coarse-grained glauconitic sand, locally ferruginous with a few black flint pebbles, lignite, pyrite, pyritized wood and selenite; and many fish teeth, associated with casts of the molluscs *Natica* and *Cardium.* The base of the bed is gently undulating	up to 0.15
Finely bedded glauconitic sand interbedded with shale towards the base, forming lenticular masses; few small flint pebbles	0–0.46
[Cliffs 1400 m west of ruined church at Rcculvcr, [TR 214 690]; Holmes, 1981, p. 41; a–b, London Clay as above; with 0.6 m of basal beds]	
Blackheath and Oldhaven Formation, Oldhaven Beds	
c. Fine-grained, pale, cross-bedded sand with lines of larger grains, including much glauconite, and selenite. A 0.10 m thick ferruginous lens with many shells and casts, and a few pebbles; locally interbedded with long lenticular masses of brownish clay; the whole forming a soft sandrock	5.33
d. Ochreous sandy, brown loam	0.15
Sandy pebble bed, with large and small black pebbles, and fish debris. Developed locally as shelly units (e.g. 320 m west of Bishopstone ravine or Oldhaven Gap [[TR 204 687]]); the whole unit	0–0.46
[Cliff section 550 m westward of the ruined Reculver church, [TR 214 690]; Holmes, 1981, pp. 29, 37]	
Woolwich and Reading Formation, Woolwich Beds	
e. Pale greenish grey sand, with uniform and even glauconitic grains; with top few centimetres coarser-grained	2.1
f. More clayey sand, grey with ochreous mottling	2.4
Woolwich and Reading Formation, Woolwich Bottom Bed	
g. Pale grey sand, mostly coarser with dark grains and a few small pebbles and fish teeth; dark grey sand with pyritic nodules locally marking the base. Known hereabouts as the 'Behinge Fish Bed'	0.6–2.7
Grey glauconitic sand, locally ferruginous, with lignite and casts of shells; locally there is an abundance of silicified nodules containing *Corbula*	0.5–1.0
The divisions of the Woolwich Beds arc very indistinct, as is the separation of these from the underlying Thanet Formation	
h. **Thanet Formation, Reculver Silts Member**	

Fine sand, slightly clayey, brownish grey at top, and with very few flint pebbles. For most part a very pale greenish grey	3.7
Layer of concretionary blocks ('doggers') of calcareous indurated sandstone	0.3
Pale grey sandstone with abundant shells	2.6
Layer of calcareous sandstone doggers	0.3
Bedded, clayey buff sand with many shells seen to	0.9

Prestwich (1852, p. 263) reported the Chalk beneath sands 'at a depth of about 70 feet [21 m], in a deep well at Reculver'.

The lenticular and locally discontinuous nature of some of the beds, and the general poor quality of the section, were discussed by Holmes (1981) and in the GCR volume report on the Tertiary deposits of Herne Bay (Daley *in* Daley and Balson, 1999). The latter author also recorded the biostratigraphy and mineralogy of the units exposed along the coast at Herne Bay, including the chronostratigraphical scheme based upon microfossils and employed successfully by Costa *et al.* (1976) at this locality, the magnetostratigraphical work carried out by Townsend and Hailwood (1985) and the radiometric ages given by Odin *et al.* (1978), Odin and Curry (1985) and Fitch *et al.* (1978) for glauconite-bearing units within the succession.

Fauna

Fish fossils have been recovered from most levels in the sequence (Ward, 1980; Holmes, 1981) and are listed below bed by bed, otolith taxa are not included (Figure 14.5):

Thant Formation, Reculver Silts Member (Units A–G of Ward, 1979)

Chondrichthyes: Elasmobranchii: Neoselachii: Squalomorphii

Squalus orpiensis (Winkler, 1874)

S. minor Leriche, 1902

Chondrichthyes: Elasmobranchii: Neoselachii: Squatinomorphii

Squatina prima (Winkler, 1874)

Chondrichthycs: Elasmobranchii: Ncosclachii: Galeomorphii

Heterodontus lerichei Casier, 1943

Hypotodus robustus (Leriche, 1921)

'*Lamna*' *inflata* Leriche, 1936

Palaeogaleus vincenti (Leriche, 1902)

Palaeohypotodus rutoti (Winkler, 1874)

Otodus obliquus Agassiz 1836–1843

Synodontaspis striatus (Winkler, 1874)

S. teretidens (White, 1931)

Chondrichthyes: Holocephali: Chimaeriformes

Callorhinchus newtoni Ward, 1973

Osteichthyes: Actinopterygii: Neopterygii: Euteleosti

Ardiodus marriotti White, 1931

Woolwich Formation Bottom Bed, 'Beltinge Fish Bed'

Chondrichthyes: Elasmobranchii: Neoselachii: Squalomorphii

Notidanodon loozi (Vincent, 1876)

Squalus orpiensis (Winkler, 1874)

S. minor Leriche, 1902

Chondrichthyes: Elasmobranchii: Neoselachii: Squatinomorphii

Squatina prima (Winkler, 1874)

Chondrichthyes: Elasmobranchii: Neoselachii: Galeomorphii

Galeorhinus gomphorhiza Arambourg, 1952

Heterodontus lerichei Casier, 1943

Hypotodus robustus (Leriche, 1921)

'*Lamna*' *inflata* Leriche, 1936

Otodus obliquus Agassiz, 1836

Palaeogaleus vincenti (Leriche, 1902)

Palaeohypotodus rutoti Winkler, 1874)

Scyliorhinus gilberti Casier, 1946

Synechodus eocaenus Leriche, 1902

Synodontaspis striatus (Winkler, 1874)

S. teretidens (White, 1931)

S. hopei (Agassiz, 1843)

Chondrichthyes: Elasmobranchii: Neoselachii: Batomorphii

'*Hypolophus*' *sylvestris* White, 1931

Myliobatis dixoni Agassiz, 1843

Myliobatis sp.

Chondrichthyes: Holocephali: Chimaeriformes

Callorhinchus regulbiensis Gurr, 1963

Chimaera eophantasma Ward, 1973

Edaphodon bucklandi Agassiz, 1843

E. minor Ward, 1973

Elasmodus hunteri Egerton, 1843

Ischyodus dolloi Leriche, 1902

Osteichthyes: Actinopterygii: Neopterygii: Halecostomi

Pycnodus sp.

Osteichthyes: Actinopterygii: Neopterygii: Euteleosti

Ardoides marriotti White, 1931

Egertonia sp.

Oldhaven Beds

Chondrichthyes: Elasmobranchii: Neoselachii: Squatinomorphii

Squatina prima (Winkler, 1874)

Chondrichthyes: Elasmobranchii: Neoselachii: Galeomorphii

Otodus obliquus Agassiz, 1836

Palaeohypotodus rutoti (Winkler, 1874)

Synodontaspis macrotus (Agassiz, 1843)

S. teretidens (White, 1931)

S. hopei (Agassiz, 1843)

Chondrichthyes: Elasmobranchii: Neoselachii: Batomorphii

Hypolophodon ('*Hypolophus*)*sylvestris* (White, 1931)

Chondrichthyes: Holocephali: Chimaeriformes

Amylodon eocenica (Woodward and White, 1930)

Undifferentiated osteichthyan bones, teeth, scales and vertebrae

London Clay Formation, Basement Bed

Chondrichthyes: Elasmobranchii: Neoselachii: Squatinomorphii

Squatina prima (Winlder, 1874)

Chondrichthyes: Elasmobranchii: Neoselachii: Galeomorphii

Otodus obliquus Agassiz, 1836

Palaeohypotodus rutoti (Winkler, 1874)

Synodontaspis macrotus (Agassiz, 1843)

S. teretidens (White, 1931)

S. hopei (Agassiz, 1843)

Chondrichthyes: Elasmobranchii: Neoselachii: Batomorphii

Hypolophodon ('*Hypolophus*')*sylvestris* (White, 1931)

Chondrichthyes: Holocephali: Chimaeriformes

Amylodon eocenica (Woodward and White, 1930)

London Clay Formation, Division B

Chondrichthyes: Elasmobranchii: Neoselachii: Squalomorphii

Notorhynchus serratissimus (Agassiz, 1844)

Isistius trituratus (Winkler, 1874)

Chondrichthyes: Elasmobranchii: Neoselachii: Galeomorphii

Carcharias hopei (Agassiz, 1843) (includes species labelled as *Hypotodus robustus* (Leriche, 1921) and *H. verticalis* (Agassiz, 1843))

Isurolamna affinis (Casier, 1946)

Jaekelotodus trigonalis (Jaekel, 1895)

'*Lamna*' *lerichei* Casier, 1946

Palaeohypotodus rutoti (Winkler, 1874)

Synodontaspis macrotus (Agassiz, 1843)

S. teretidens (White, 1931)

S. hopei (Agassiz, 1843)

Chondrichthyes: Holocephali: Chimaeriformes

Elasmodus hunteri Egerton, 1843

Osteichthyes: Actinopterygii: Neopterygii: Euteleostei

Ardiodus marriotti White, 1931

Cylindracanthus rectus (Dixon, 1850)

Interpretation

Several models for the deposition of the Thanet Formation at Herne Bay have been attempted, because of the rich fossil assemblage recovered from these beds. Although the depositional environment seems to have been within shallow

marine conditions, with a maximum sea depth of about 50 m (Curry, 1965), the evidence is somewhat equivocal regarding climatic implications. For instance, Wrigley (1949) found both warm- and cold-water species of molluscs, and concluded that the evidence pointed to a subtropical regime, which seems to be compatible with the subtropical and tropical fish fauna (White, 1931) and Curry's (1965) reference to calcareous algae occurring in the highest beds of the Thanet Formation near Bishopstone Glen.

The beds of the Woolwich Formation are extremely thin at Herne Bay, in comparison to exposures in other parts of the London Basin, suggesting that uplift and erosion of a thicker sequence took place in the eastern part of the basin before the deposition of the overlying Thames Group. The glauconitic sands of the Woolwich Bottom Bed may represent a littoral deposit in a barrier sand complex and are suggestive of a transgressive sand sheet that extended across much of southern England (Ellison, 1983). The overlying Woolwich Formation is considered to be lagoonal or fully marine.

The mineralogy of some units in the Herne Bay section, has revealed early Palaeogene sediment provenance details (see Blondeau and Pomerol, 1968; Weir and Catt, 1968; Morton, 1982) and evidence of ash falls from contemporary volcanism within the Oldhaven Formation (Knox, 1979). Recent studies of palaeomagnetic and mineralogical data from the Oldhaven Formation by Townsend and Hailwood (1985) show this unit is laterally equivalent to the basal London Clay in Norfolk, and represents deposition in a nearshore environment within the initial London Clay Formation transgression. The variations in faunal composition between the Oldhaven Formation and overlying London Clay at Herne Bay (referred to by King, 1981) are now known to be a reflection of the differences in depositional environments (Knox *et al.,* 1983).

Fish material has been found throughout the sequence at Herne Bay and is in all beds dominated by the abundance of small sharks teeth (Cooper, 1977; (Figure 14.5)). The sand sharks *Synodontaspis striatus* and *S. teretidens* are common in the sandy uppermost horizons of the Thanet Formation at Herne Bay, whilst the dogfishes *Squalus minor* and *Palaeogaleus vincenti* occur in the more argillaceous facies (Ward, 1980). The species *Hypotodus verticalis* (Agassiz, 1843) and *H. robustus* Leriche, 1921 reported in the Herne Bay fauna have recently been synonomized with the sand shark *Carcharias hopei* (Agassiz, 1843) by Ward (1988).

All the Thanet Formation elasmobranch species range up into the Bottom Beds at Herne Bay and are accompanied by a large influx of new species including the sharks *Synechodus eocaenus, Notidanodon loozi* and *Scyliorhinus gilberti,* and the ray *Hypolophodon* ('*Hypolophus*') *sylvestris.* The particularly rich fish-bearing horizon in the Basal Beds at Herne Bay has been termed the Beltinge Fish Bed by Ward (1978a) and is the only deposit of this age in Britain to have yielded this assemblage.

The faunas of the remaining pre-London Clay Tertiaries and the London Clay Division A are restricted, and dominated by the coastal species *Synodontaspis striatus, S. teretidens* (both sand sharks), the monkfish *Squatina prima* and the ray *Hypolophodon* ('*Hypolophus*) *sylvestris*'. They yield only two new species: the shark ' *Scyliorhinus*' *biauriculatus* and the giant stingray *Dasyatis wochadunensis,* which are not recorded at Herne Bay (Ward, 1980).

The various faunal communities identified within the British Palaeogene include many molluscan species, and it is clear that in the wide variety of depositional environments present, organic productivity was generally very high (Taylor, *in* McKerrow, 1978). Vertebrates figure in all but the marine sand communities. The teleosts and the elasmobranchs were clearly at the apex or high on the trophic pyramid, and appear to be adapted to a wide range of feeding habits. Predation upon benthic invertebrates by both kinds of fish would have been an important ecological factor, but feeding on planktonic and nektonic prey was probably even more conspicuous amongst these vertebrates.

Comparison with other localities

The cliff section at Herne Bay exposes one of the oldest successions in the British Tertiary and yields some of the earliest Tertiary fish (Ward, 1980). The overgrown cliff section at Pegwell Bay, Kent [TR 3498 6429], also has an important microshark and teleost otolith assemblage, in a shelly unit within the Basal Bed Member of the Thanet Formation (Stinton, 1965a, p. 395; Ward, 1977, 1980). The overlying Pegwell Marl Member and Reculver Silt Member have both yielded sporadic microshark material, in association with indeterminate chimaeroid and teleost remains (Ward,

1977). Although shark remains are still relatively uncommon in the Thanet Formation at Herne Bay compared with later Tertiary fish sites, it is possible that intensive sampling will yield some of the rarer selachians listed by Herman (1973) from the slightly younger deposits at Orp-de-Grand, Belgium.

The Beltinge Fish Bed is only exposed at Herne Bay, and yields a unique assemblage of selachians and holocephalians. Components of this fauna are found in Belgian Tertiary deposits, such as the Sables and Graviers de Dormaal (Casier, 1967). However, although the Dormaal mammal fauna can be correlated with those from the Suffolk Pebble Bed (equivalent to or slightly younger than the Woolwich and Reading Formation; Hooker, 1980), the fish teeth are poorly preserved and clearly derived. The fish remains clearly come from a different deposit than the mammal teeth, but Ward (1980) considered it impossible to differentiate which fauna was the older, as the same shark faunas persisted up to the lower part of the Argile d'Yprcs (approximately equivalent to the London Clay) in Belgium.

The Woolwich Shell Beds in eastern Kent commonly yield isolated shark teeth and other fish remains, and localities include Upnor (q.v.) and Swanscombe quarries ([TQ 59 73]; Stamp and Priest, 1920; Brown and Priest, 1924). Farther west, the contemporary Reading Beds also yield fish remains.

The London Clay fish fauna at Herne Bay is fairly unremarkable in diversity and preservation, in comparison to the assemblages taken from the younger London Clay of Sheppey (q.v.) and the Hampshire Basin (see below).

Conclusion

The almost complete section through the Lower London Tertiaries and basal beds of the London Clay on the cliffs and foreshore at Herne Bay, has provided fish remains from almost all horizons. Those from the Thanet Formation are amongst the oldest British Tertiary fish remains, and the 'Beltinge Fish Bed' (Woolwich Bottom Bed) yields an exceptionally rich fossil fish fauna from which the site derives its conservation value.

References

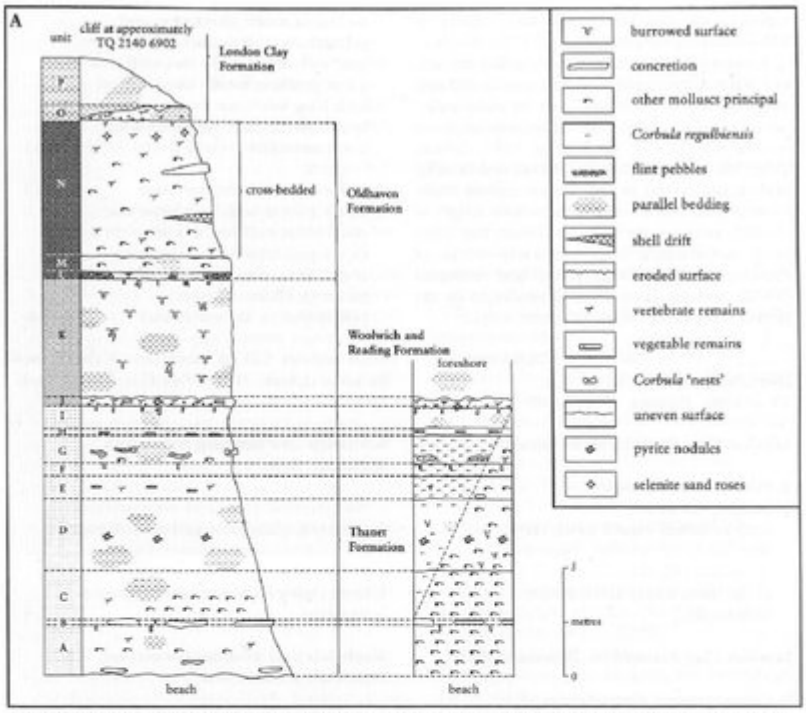
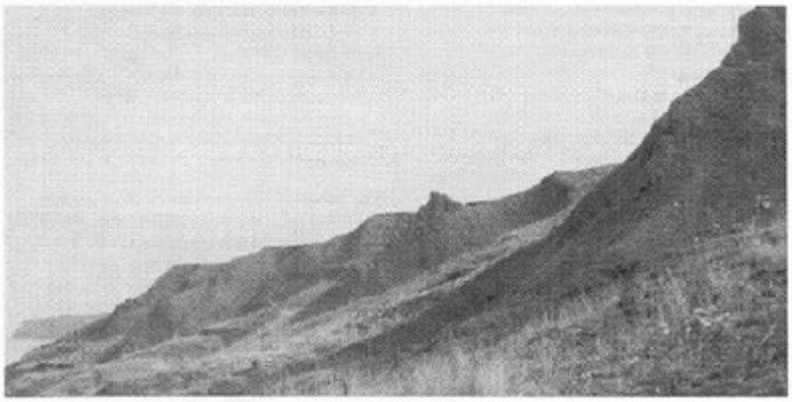
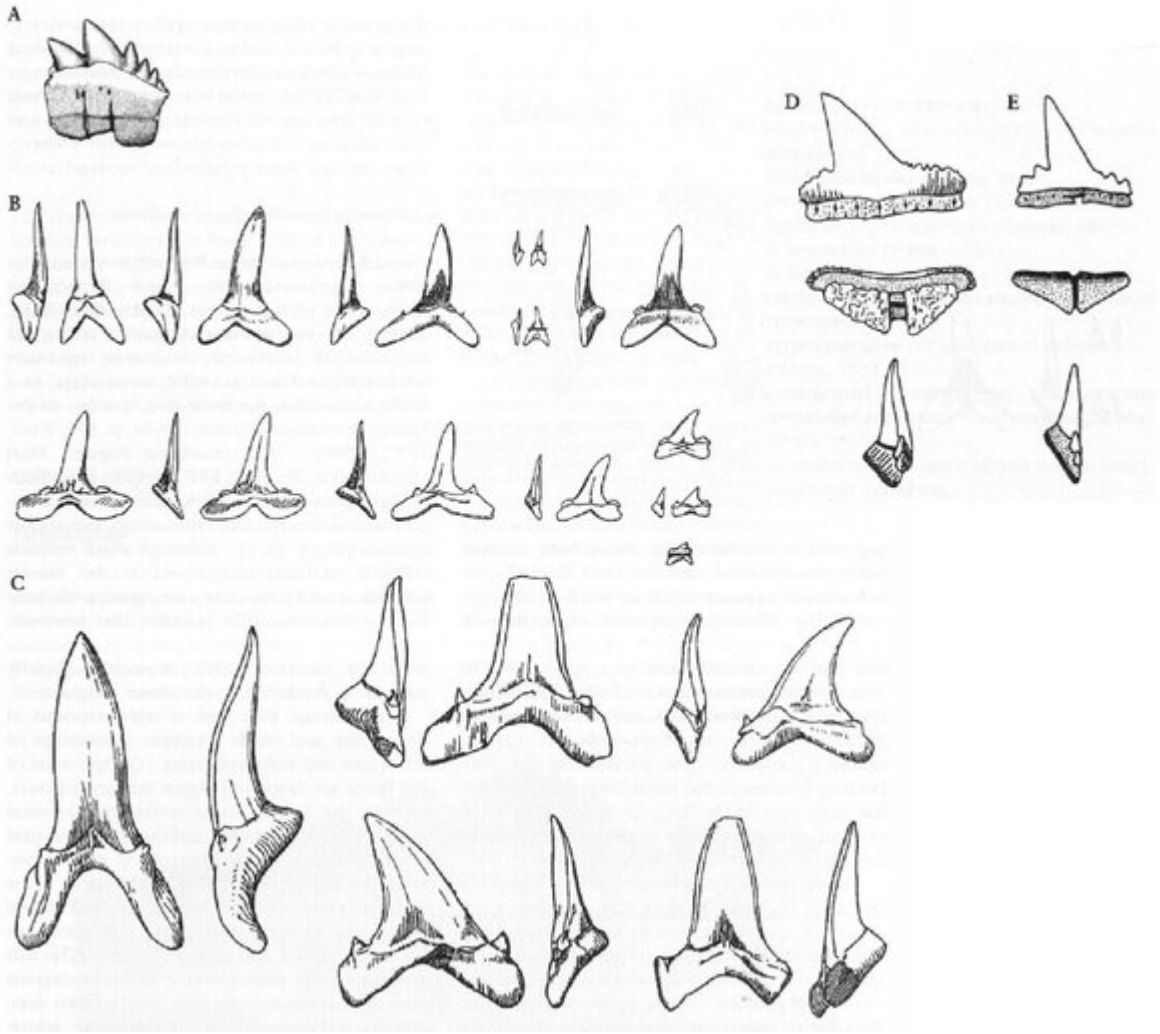


Figure 14.4 (A) Sedimentary log of a generalized vertical section of the Palaeocene and Lower Eocene in the Herne Bay Cliffs and foreshore (after Ward, 1978a). (B) London Clay exposed in Beltinge Cliff, Herne Bay, view to the west from Bishopstone Glen (photo: BGS no. A7933; Crown copyright reserved).



(Figure 14.4) (A) Sedimentary log of a generalized vertical section of the Palaeocene and Lower Eocene in the Herne Bay Cliffs and foreshore (after Ward, 1978a). (B) London Clay exposed in Beltinge Cliff, Herne Bay, view to the west from Bishopstone Glen (photo: BGS no. A7933; Crown copyright reserved).



(Figure 14.5) Fossil fishes from Herne Bay, Upnor and Abbey Wood. (A) Notidanodon sp., lingual view of lower anterior tooth, x 0.65, Herne Bay (from Cappetta, 1987); (B) elasmobranch teeth from Abbey Wood, Odontaspis (Synodontaspis) macrota (Agassiz) x 1.3; (C) O. striata (Winkler) (after White, 1931) x 2. (Continued on page 496.)Fossil fishes from Herne Bay, Upnor and Abbey Wood. (D) Palaeogaleus vincenti (Hooker and Ward) x 1; (E) Galeorhinus lefevrei Gunn, x 0.1 (after Cappetta, 1987).