J.N.C.C.

Fossil Fishes of Great Britain

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JOINT NATURE CONSERVATION COMMITTEE

Chapter 13

British Cretaceous fossil fishes sites

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INTRODUCTION: PALAEOGEOGRAPHY AND STRATIGRAPHY

The Cretaceous System in Britain (Figures 13.1 and 13.2) is represented by two broad phases of deposition which relate to palaeogeography. Earth movements during the Late Jurassic uplifted most of north-west Europe to form land. In the British region, there were initially two main basins of deposition, in the East Anglia–North Sea area, and in the Weald and northern France. Facies of the Early Cretaceous were deposited subaerially or in relatively shallow-water marine and freshwater environments, represented by lagoonal, fluvial and lacustrine sediments of the Purbeck and Wealden, and by shallow-marine shelf facies of the Lower Greensand, Gault and Upper Greensand. Following a major transgression in Mid-Cretaceous times, seas flooded most of the British area, leaving small patches of land only in the mountainous areas of North Wales, eastern Ireland, southern Scotland, and the Scottish Highlands. Late Cretaceous history in Britain is dominated by the predominantly coccolith limestone facies of the Chalk.

The Cretaceous has been zoned primarily on the basis of ammonites and belemnites, but the relative, or complete, absence of these fossils from much of the sequence gives a poorer overall macrofossil stratigraphical resolution than for the Jurassic. Even in the marine Late Cretaceous Chalk facies, selective preservation, probably because of sea-floor dissolution, has limited the ammonites to discrete horizons (Kennedy, 1969), and schemes of correlation have involved the use of inoceramids, belemnites, brachiopods and echinoderms. Micropalaeontological dating, especially with foraminiferans, is used in the absence of macrofossils (Figure 13.2).

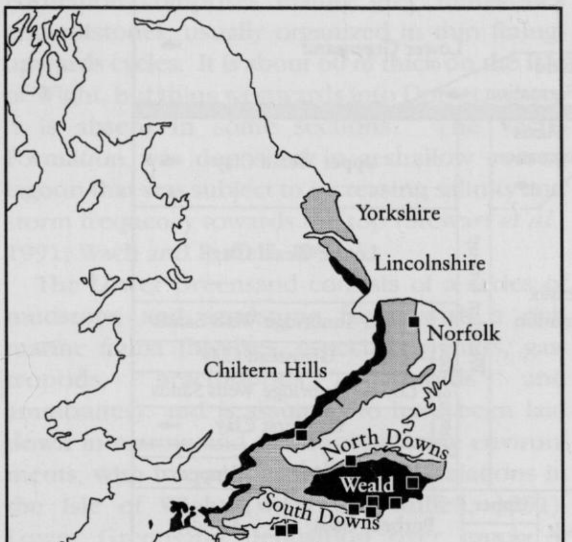

Figure 13.1 Map of outcrop of Cretaceous with GCR fish sites indicated (from Benton and Spencer, 1995).

ENVIRONMENTS

Late Jurassic to Early Cretaceous earth movements led to the development of regressive facies over much of northern Europe and England, and in Britain the base of the Cretaceous System falls in the non-marine Purbeck Beds and within the Norfolk–Lincolnshire marine sequence (Allen and Wimbledon, 1991). The succeeding Wealden Group consists of lagoonal, fluvial and lacustrine deposits which crop out over an extensive area of Sussex, Surrey and Kent (the Weald area) and on the Isle of Wight and in Dorset–Wessex area. The Wealden of the Weald sub-basin (Berriasian–Barremian) falls into two divisions: the lower sand-dominated Hastings Beds and the upper Weald Clay.

The Hastings Beds consist of predominantly sandy, but often argillaceous, deposits which reach a maximum thickness of *c.* 400 m in the centre of the Weald; three major cycles of sedimentation can be identified (= Ashdown Beds + Wadhurst Clay, Lower Tunbridge Wells Sand + Grinstead Clay and, less well developed, Upper Tunbridge Wells Sand). The base of each cycle commences with clays and mudstones, which gradually coarsen upwards into cross-bedded sandstones. The uppermost beds may include pockets and lenses of bone-rich gravel, passing upwards into cross-laminated siltstones with the horsetail *Equisetites*. A return to argillaceous rocks forms the base of the following cycle. These sediments have been interpreted as deltaic, but the work of P. Allen (1976, 1981a) indicates that they were deposited in lagoonal to lacustrine mudplain environments in which salinity was controlled by the rate of surface freshwater runoff. Soil horizons, dinosaur footprints (Norman, 1987) and the common remains

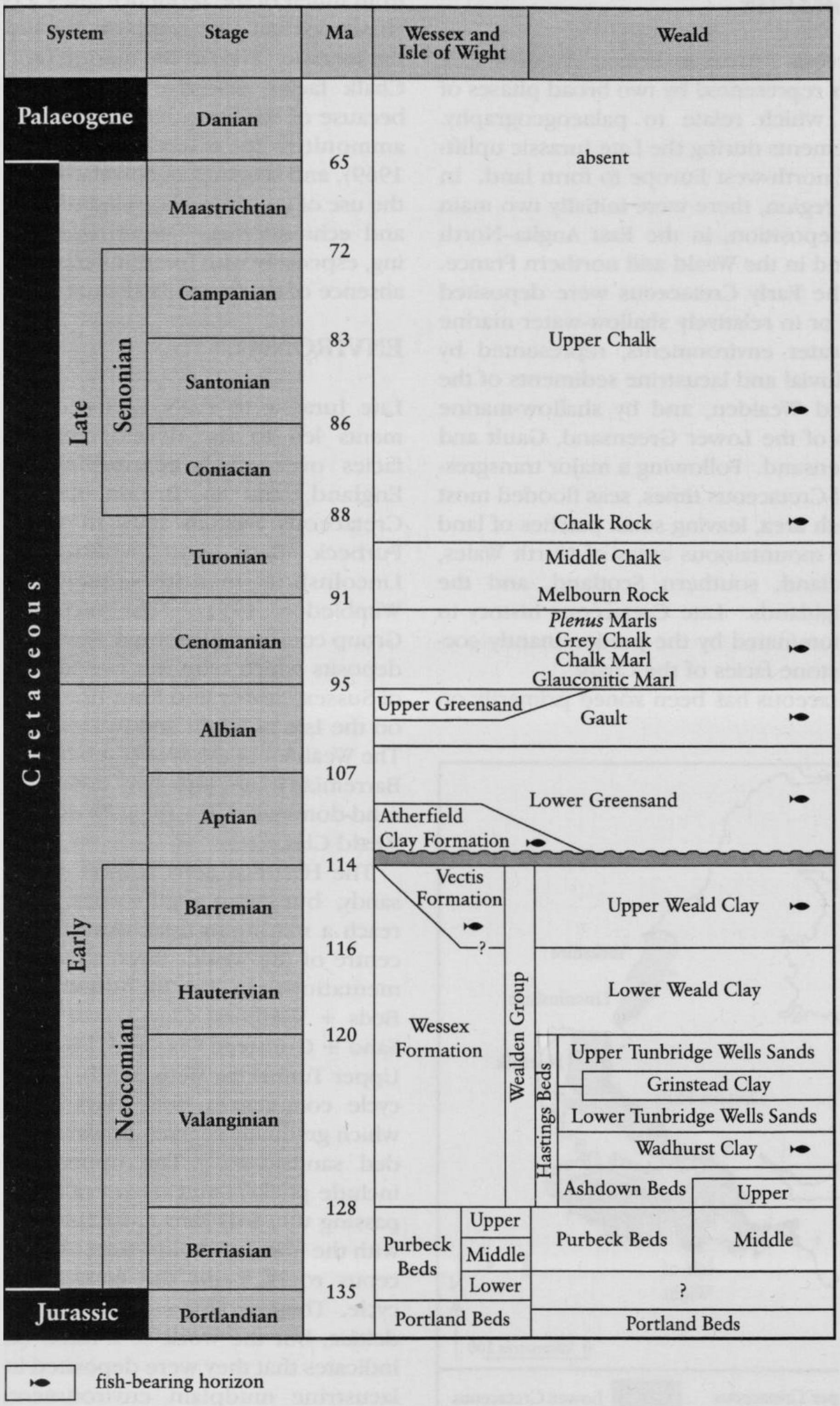

Figure 13.2 Cretaceous stratigraphy (from Benton and Spencer, 1995).

of in-situ horsetail roots and stems are testimony to the maintenance of shallow-water conditions of deposition throughout.

The Weald Clay, above the Hastings Beds, with a maximum thickness of 450 m, was deposited almost exclusively in mudplain environments, with occasional localized influxes of coarser sediment (P. Allen, 1976, 1981a). The incoming of typically marine fossils toward the top of the Weald Clay (e.g. echinoderms and oysters) documents the initial phases of the main Cretaceous transgression and subsequent deposition of the Lower Greensand across southern and eastern England during the Aptian and Albian stages.

The Wealden Group (Berriasian–Aptian; Kerth and Hailwood, 1988) in the Wessex sub-basin comprises the Wessex Formation (formerly Wealden Marls) and the overlying Vectis Formation (formerly Wealden Shales). The Wessex Formation is a sequence of alternations of mainly red, mudstones with subordinate sandstones. The unit thins from about 530 m below the Isle of Wight to 70 m in Dorset. Sedimentological and palaeoecological evidence indicates that the Wessex Formation was deposited on an alluvial plain crossed by a perennial meandering river system (Daley and Stewart, 1979; Stewart, 1981a, 1981b, 1983). The Vectis Formation comprises mainly grey mudstones and siltstones, usually organized in thin fining-upwards cycles. It is about 60 m thick on the Isle of Wight, but thins westwards into Dorset, where it is absent in some sections. The Vectis Formation was deposited in a shallow coastal lagoon that was subject to increasing salinity and storm frequency towards the top (Stewart *et al.*, 1991; Wach and Ruffell, 1991).

The Lower Greensand consists of a series of mudstone and sandstone facies with a rich marine fauna (bivalves, especially oysters, gastropods, brachiopods, echinoids and ammonites), and is assumed to have been laid down in marine and nearshore marine environments, with frequent estuarine intercalations in the Isle of Wight (Wach and Ruffell, 1991). Lower Greensand deposition over much of southern and south-eastern England was terminated by a further transgression which, during the early Albian, led to widespread development of basinal marine mudstone facies (the Gault Clay Formation). These argillaceous deposits are commonly highly condensed, and phosphatic nodule horizons may be present. Westwards, the facies passes laterally into the Upper Greensand Formation, a variable, often bioturbated deposit of glauconitic sands. This unit contains abundant marine fossils, such as bivalves (especially oysters) and serpulid worms. In Cambridgeshire, Albian fossils are reworked into the Cenomanian Cambridge Greensand. Farther north (from Norfolk into the North Sea) the Gault passes laterally into the condensed carbonate sequences of the Carstone and Red Chalk, or Hunstanton Red Rock (Hunstanton Formation).

Transgression, initiated in the Aptian, continued until the close of the Cretaceous and brought changes which led to massive developments of coccolith ooze interbedded with marls that now form the Chalk. The base of the Chalk is marked by a condensed marly deposit, known as the 'basement bed', which contains abundant quartz, glauconite and reworked phosphatized fossils. Above this, the Chalk sedimentation is characterized by rhythmically alternating chalky limestones and interbedded marls. Sedimentation was only interrupted during the Turonian, when a strongly regressive phase led to deposition of 'nodular chalk' with some associated hardgrounds.

The Late Cretaceous sea submerged much of the denuded European craton, so that there was very little terrigenous input during Chalk deposition. The soft limestones and marls of the Chalk are intensely bioturbated and represent deposition within warm clear water, at depths of 100–600 m (Hancock, 1975). Normal marine salinities are indicated by the presence of echinoderms, brachiopods and cephalopods, but substrate conditions were probably very soft, inhibiting a proper benthic community. Over submerged massifs, the chalk facies thins, and stratigraphical gaps are present. In these regions, condensed hardground horizons (for example the 'Chalk Rock') can form and these are characterized by encrusting organisms, phosphatized fossils and glauconite. The European Chalk contains abundant flint nodules which formed from the dissolution and reprecipitation of biogenic silica (e.g. sponge spicules) during early diagenesis (Sieveking and Hart, 1986).

The end of the Cretaceous (late Maastrichtian) saw a substantial marine regression in Britain and much of Europe. This coincided with a major phase of extinction of many groups of invertebrates and vertebrates; among marine invertebrates, the ammonoids, belemnites, inoceramids and rudists became extinct.

FISH FAUNAS

Cretaceous fish faunas chart an important watershed in the history of the bony fishes, as the archaic, dominantly non-teleost, neopterygian faunas typical of the early Mesozoic were replaced by the teleosts, which are the dominant group of bony fishes in late Cretaceous, Tertiary and modern aquatic environments. The evolution of the fishes during the long Cretaceous period was typified by the expansion of the higher bony fishes towards the end of that time (Stinton, 1973). They appear to have diversified in form, habit and mode of life, and to have become abundant in most of the seas and oceans. Important marine groups such as the herrings (clupeomorphs) and mackerel (gadiiforms) were established, and in the later half of the period some very large predatory forms were present. In contrast, the primitive actinopterygians fishes did not reach the end of Cretaceous time in such numbers as they had at the beginning of the period. They included such successful types as the Pholidophoridae (a Triassic and Jurassic group from which the teleosts may have sprung), *Aspidorhynchus* (amiids) and the ancient gars, but their overall numbers were declining. The Chondrostei too were in decline. The coelacanths and freshwater lungfishes were not common, but survived throughout the period. The coelacanths were relatively few. Until 1938 they were thought to have died out at the end of the Cretaceous, but were then found in deep water off the coast of East Africa. Cretaceous lungfishes, like the Jurassic species, belong only to the Ceratodidae, an extant freshwater family.

Teleost evolution included the development from the Jurassic pholidophorids and the slightly more advanced Leptolepidae of five major groups: the Osteoglossomorpha, Elopomorpha, Clupeomorpha and the Euteleostei, which survive to the present day, and the now extinct, but prominent, Cretaceous Ichthyodectidae (Patterson and Rosen, 1977). Most were marine. All the Late Jurassic and Early Cretaceous fossils regarded as predecessors of the modern teleost groups were very similar in overall morphology (e.g. the Leptolepidae). The Osteoglossomorpha are cosmopolitan in the fossil record and are now freshwater predators in southern continents and North America, and include the largest extant freshwater fish, e.g. *Arapaima* (*c.* 5 m long) from Brazil. The other cohorts and subcohorts have throughout the Cenozoic followed the euteleosts in diversification and adaptation to new habitats. Their development is discussed below.

Amongst the chondrichthyans there were very few innovations, but the Wealden (Lower Cretaceous) shark fauna of southern Britain is unusual in being predominantly freshwater in habitat and containing only hybodonts. It has been suggested that the hybodonts escaped competition with more advanced neoselachian sharks by entering fresh water. Some of the more specialized Wealden hybodonts seem to have given rise to the Upper Cretaceous hybodonts and ptychodonts, which are marine forms. The palatal crushing teeth of the ptychodont *Ptychodus* were once so common in the British Lower Chalk that they were known as 'fossil slugs' by quarrymen.

Amphibians have never been recorded from the Cretaceous succession in Britain.

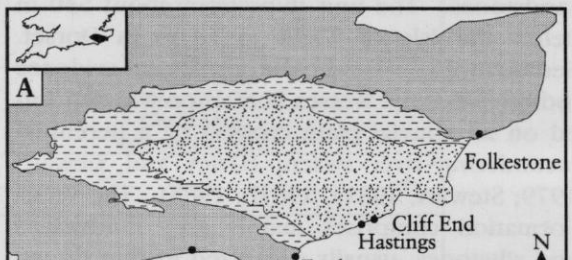

Figure 13.3 (A) Map of the Lower Cretaceous Hastings Formation (Beds) and Weald Clay Formation of the Weald area of southeast England (after Cook, 1995); (B) geological map of Isle of Wight.

EARLY CRETACEOUS: WEALDEN GROUP (BERRIASIAN–BARREMIAN)

The lagoonal, lacustrine and fluvial deposits of the Wealden Group of the Weald and the Isle of Wight are famed for their freshwater fish beds (Figure 13.3). The Brook–Atherfield section on the south-west coast of the Isle of Wight exceeds the contemporaneous vertebrate-rich sediments of Mongolia and the USA both in the abundance and variety of the material.

The Wealden of the Weald (Berriasian –Barremian) is well known for its fossil fishes, and specimens have come from many localities, most of which are inland extractive sites (clay pits) and are no longer accessible. Fish material is known from all Wealden formations, but occurs most frequently in the Hastings Beds. The succeeding Weald Clay has yielded fewer fish remains, although scattered scales and teeth are common in many horizons. The Bexhill–Hastings region has produced three-dimensional specimens of *Lepidotes* and hybodont sharks preserved in ironstone noules.

FISH SITES

Specific localities in the Wealden of the Weald include:

WEST SUSSEX: Longbrook Brickworks (TQ 117188; fishes; Wells Collection); Henfield Brickworks (TQ 220143; *Hybodus basanus*, *H. brevicostatus* (holotype), *H. parvidens*, *Hylaeobatis ornata*, *Lissodus breve breve*, *L. striatum* (holotype), *Coelodus mantelli*, *Lepidotes mantelli*, *Pachythrissops* sp., '*Clupavus*' sp., *Caturus tenuidens*; Patterson, 1966; Tilgate Forest (TQ 2735, exact localities uncertain; *Coelodus mantelli*, *Lepidotes mantelli*, '*Asteracanthus granulosus*' (= ?*Hybodus ensis* (Patterson, 1966)), '*Acrodus hirudo*' (= ?*Hylaeobatis problematica*), *Hybodus brevicostatus*, '*Hybodus striatulus*', '*H. elongatus*', '*H. subcannus*', '*H. sulcatus*', '*Oxyrhina paradoxa*' [= ?*Sphenodus*]; Topley, 1875); Cuckfield (TQ 300256, now largely infilled; *Lepidotes mantelli*; White, 1924, p. 9); Keymer Tileworks (TQ 325189; microvertebrates, including *Lepidotes* spp., and indeterminate fish remains; Cook, 1995); Wivelsfield (TQ 3420; various localities with fossil fishes; Young and Lake, 1988, p. 23); Philpotts Quarry (TQ 355322; articulated specimens of *Pachythrissops* sp.; Allen, 1976, p. 401); Homeland, Ashurstwood (TQ 419363; *Lissodus breve breve*, *L. breve crenulatum*; Patterson, 1966).

EAST SUSSEX: Bexhill–Cooden Beach (TQ 715062–TQ 750070; *Hybodus basanus*, *Hybodus* sp., *Hylaeobatis ornata*, batoid, *Lepidotes mantelli*, *Coelodus* sp., *Caturus (Callopterus) latidens* Woodward, 1918 (holotype), *Neorhombolepis valdensis* Woodward, 1895 (holotype); Woodward, 1895a, 1918; Patterson, 1966; Lake and Shephard-Thorn, 1987); Hastings (TQ 831095–TQ 853105; various localities along the foreshore; 11 species, see site report; White, 1928; Allen, 1949, 1960; Clemens, 1963; Patterson, 1966); West Marina Quarry, St Leonards-on-Sea (TQ 7808; *Lepidotes* spp., *Hybodus parvidens*, *Hybodus* spp.; Allen, 1947, 1949); Castle Farm, Mountfield (TQ 7320; *Hybodus* spp., *Lepidotes* spp.; Allen, 1949); Black Horse Quarry, Telham (TQ 769142; *Lepidotes* sp., *Coelodus* sp., *Hybodus* sp., coprolites; Topley, 1875; White, 1928; Lake and Shephard-Thorn, 1987); Telham Farm Quarry, Telham (*Lepidotes* spp., *Hybodus* spp.; Topley, 1875, pp. 63–4, White, 1928); Crowhurst stone pit, Rackwell Wood (TQ 764124; *Hyleaobatis ornata*, *Lepidotes mantelli*; Sweeting, 1925; Patterson, 1966); Baldslow (TQ 8013; *Lepidotes fittoni*; White, 1928; Allen, 1949); Hare Farm Lane, Brede (TQ 832184; *Lepidotes* spp., *Hybodus parvidens*, *Hybodus* spp.; Allen, 1949); Stubb Lane, Brede (TQ 833187; *Lepidotes* spp., *Hybodus parvidens*, *Hybodus* spp.; Allen, 1947, 1949); Brede (TQ 8218; Telham Bone Bed (Wadhurst Clay) outcrops at several localities around the town; *Hybodus* spp., *Lepidotes* spp.; Allen, 1949); Ludley Hill, Beckley (TQ 8521; *Hybodus* spp.; Allen, 1947, 1949); Peasmarsh, Waterwall Wood (TQ 8621; *Hybodus* spp., *Lepidotes* spp.; Allen, 1949); Knellstone, Udimore (TQ 8819; *Hybodus* spp., *Lepidotes* spp.; Allen, 1949); Paddockhurst Park, Turner's Hill (TQ 3435); *Hybodus ensis*, *H. parvidens*, *H. brevicostatus*, *Lissodus breve breve* (holotype), *L. breve crenulatum* (holotype), '*Lonchidion*' *rhizion*, *Lepidotes* spp.; Patterson, 1966).

KENT: Tighe (Teigh) Farm, Stone (TQ 936266; *Hybodus ensis*, *H. parvidens*, *Lissodus breve breve*, '*Lonchidion*' *rhizion*, *Lepidotes* spp.; Allen, 1949, Patterson, 1966, Lillegraven *et al.*, 1979, p. 27); Stone Hole Quarry, Stone (TQ 9428; *Hybodus* spp., *Lepidotes* spp.; Allen, 1949); Sevenoaks, Kent (TQ 2555; *Hylaeobatis ornata*; Patterson, 1966).

SURREY: Bookhurst (TQ 0739; *Hybodus brevicostatus*; Patterson, 1966); Cranleigh (TQ 0539; whole *Lepidotes* sp.; Allen, 1976, p. 421); Clockhouse Brickworks (TQ 175386; indeterminate fish scales, fin spines, bones and teeth (including *Hybodus* spp. and *Lepidotes* spp.), egg cases (*Spirangium jugleri* Schrimper: ?hybodont shark), teleost scales, and coprolites; Jarzembowski, 1991); Auclaye Brickworks (TQ 170388; indeterminate fish scales, bones (including *Lepidotes* spp.) and egg cases (*Spirangium jugleri* Schrimper: ?hybodont shark); Jarzembowski, 1991); Smokejacks Brickworks, Ockley (TQ 113373; fish fragments (including *Lepidotes* spp. and *Hybodus* spp.) and egg cases (*Spirangium jugleri* Schrimper: ?hybodont shark); Jarzembowski, 1991); Meadvale, Redhill (TQ 2750; *Hylaeobatis ornata*; Patterson, 1966).

In the Isle of Wight the Wealden beds are represented by predominantly argillaceous facies of the Wealden Marls and Wealden Shales (Wessex and Vectis Formations), which are best seen in the coast sections between Brook and Atherfield Point in the south-west (see site report) and at Yaverland, near Sandown (SZ 613850) in the south-east. Isolated fish remains occur in most horizons within these sections.

In Europe, comparable Wealden fossil fish faunas are known from the Bernissart coal mines, Belgium (Norman, 1980), France (Buffetaut and Leloeuff, 1991), Hannover, Germany and North America (Cloverly Formation, Wyoming; Ostrom, 1970; Morrison Formation, Wyoming; Dodson *et al.*, 1980).

Of the classic early Cretaceous fish sites in the Wealden of southern Britain, two sites were selected for inclusion within the GCR, one in the Hastings Beds of East Sussex and the other in the Wealden of the Isle of Wight:

1. Hastings, East Sussex (TQ 831095–TQ 887129). Early Cretaceous (Berriasian–Valanginian), Hastings Beds (Ashdown Beds).
2. Brook–Atherfield Point, Isle of Wight (SZ 375842–SZ 452788). Early Cretaceous (Barremian–Early Aptian), Wessex and Vectis Formations.

HASTINGS (TQ 831095–TQ 887129) (POTENTIAL GCR SITE)

Highlights

The Early Cretaceous sandstones and shales that crop out along the East Sussex coast and foreshore east of Hastings have been famous for 100 years for specimens of fossil selachians and bony fishes. More recent discoveries include rare microvertebrate remains concentrated in the Cliff End Bone Bed, one of the richest bone accumulations in the Weald.

Introduction

The Hastings Beds (Early Cretaceous: Valanginian; Figure 13.3A) of the south Weald contain fossil fishes, reptiles and their footprints (Benton and Spencer, 1995) sporadically throughout the sequence. Hastings is the type locality for the hybodont shark *Hybodus parvidens* Woodward, 1889, and two species of the pycnodont fish *Coelodus*, recovered from the Wadhurst Clay beds. A primitive actinopterygian (possibly *Coccolepis*) has been recovered from the Wadhurst Clay at Hastings. This species was one of the last of the early actinopterygians species to evolve.

In the Hastings area, vertebrate-rich levels also occur within the thin sandstones and conglomeratic horizons. One such accumulation, the Cliff End Bone Bed, is particularly well known and the faunal assemblage, which includes abundant fish remains in association with rarer reptilian and mammalian material, has formed the basis of several reports on Wealden palaeoecology and taphonomy (e.g. Allen, 1949; Cook, 1995). The hybodont, '*Lonchidium*' *rhizion* (Patterson, 1966), was described from the Cliff End Bone Bed. At the type locality at Cliff End (TQ 887129; Figure 13.4) some 7 km north-east of Hastings, the bone-bearing level occurs at the top of the cliff and is not easily accessible. However, the coast is subject to continuous erosion, and slabs of the bone bed are frequently recovered from beach gravel at the foot of the cliff, following major storms and rock falls. Parts of the section are obscured by landslips and coastal erosion, but access to the beach is fairly good.

The stratigraphy of the Wealden of Hastings has been described by several authors (e.g. Beckles, 1856; Topley, 1875; White, 1928; Allen,

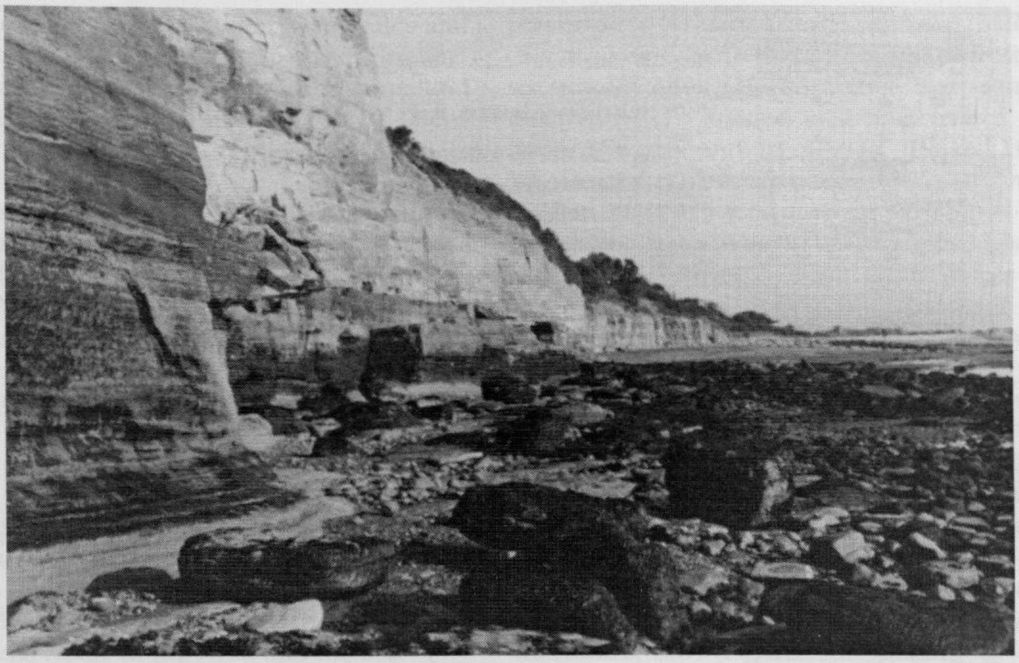

Figure 13.4 Cliff End, Hastings, exposing Wealden sediments. Looking to the east. (Photo: S.J. Metcalf.)

1976; Lake and Shephard-Thorn, 1987). The palaeoecological implications of the Cliff End Bone Bed have been described by Allen (1949, 1967), Clemens and Lees (1971) and Cook (1995).

Description

The geology of the coastal cliff sections around Hastings (Figure 13.4) has been described by Allen (1962), Stewart (1981b) and Lake and Shephard-Thorn (1987). The general succcession in the cliffs is presented below, and the position of the bone bed indicated, based on sections in Lake and Shephard-Thorn (1987; pp. 67–9):

	Thickness (m)
Hastings Beds	up to 50
Tunbridge Wells Sand	
Fine grained, yellowish sandstones and silts with impersistent seams of mottled silty clay	
Wadhurst Clay	50–57
Grey-green calcareous shales interlaminated with thin siltstones.	
Also: calcareous sandstone bed (Tilgate Stone), sandstone channel fills, soils and near the base	
Cliff End Bone Bed	
Cliff End Sandstone	
Top Ashdown Pebble Bed	10
Ashdown Beds	180–200
The upper 30–50 m are chiefly sandstone, while the strata below are dominantly massive mottled sphaerosiderite sandstone beds	
Near the base:	
Lee Ness Sandstone	1–2

Most of the fish finds have been made from the Wadhurst Clay at Hastings, East Cliff and Cliff End. However, some remains, including specimens of *Lepidotes* spp. and *Hybodus* spp., have also been found in the underlying Ashdown Beds exposed in the cliffs at East Cliff, Hastings, Cliff End and Fairlight Cove (White, 1928). The Wadhurst Clay comprises a thick succession of clays, with interbeds of siltstone, sandstone, shelly limestone and thin conglomerates. The sequence becomes more arenaceous around Hastings and the coastal sections in this region are characterized by the thick and prominent Cliff End Sandstone, capped by the Cliff End Pebble Bed conglomerate. The Cliff End Bone Bed is laterally impersistent along the coastal section and may be equivalent to the pebble bed (Figure 13.5). In the type locality the bone bed occurs some 2.5 m above the Cliff End Sandstone, within the vegetated and landslipped upper part of the cliffs (Figure 13.4; Allen, 1967; Lake and Shephard-Thorn, 1987).

Vertebrate material is generally common

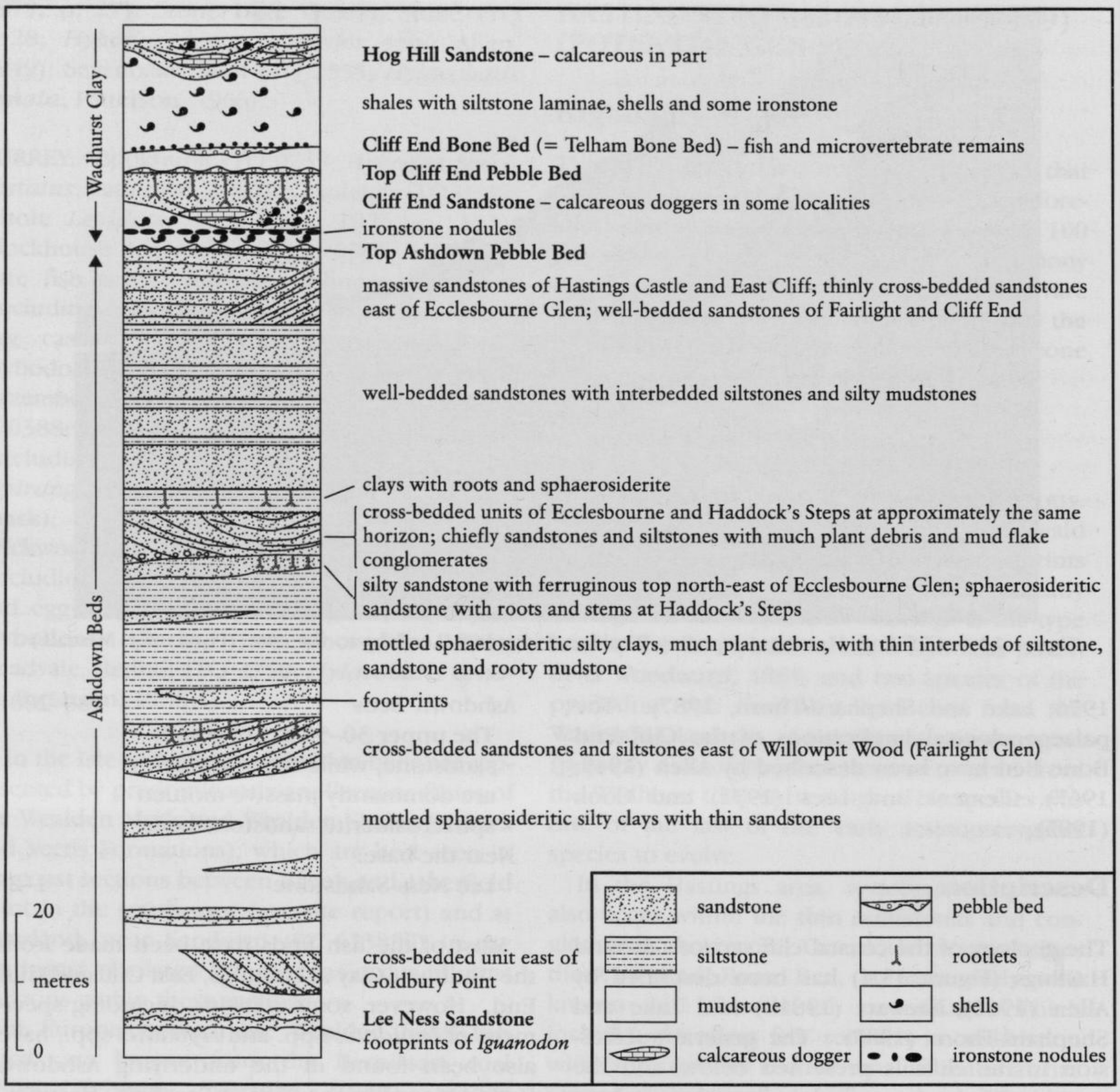

Figure 13.5 Stratigraphical log of Cliff End section, near Hastings (after Lake *et al.*, 1987).

throughout the Wadhurst Clay sequence, but specific bone beds are confined to east Sussex and parts of Kent (Allen, 1949). Two types of bone-rich accumulations are recognized in the Wadhurst Clay (Allen, 1949): the first are lenticular units of muddy sandstone (e.g. Brede Bone Bed); the other typically poorly sorted, cross-bedded conglomerates and pebbly sandstones, to which the Cliff End accumulation belongs. The Cliff End Bone Bed has been noted in inland sections, around Hastings, Rye and Guestling (White, 1928), and is thought to correspond with the Telham Bone Bed horizon exposed near Battle (e.g. Topley, 1875; Lake and Shephard-Thorn, 1987). Allen (1949) regarded the bone bed as a correlatable event horizon, restricted to the most eastern part of East Sussex and neighbouring parts of Kent, and lying on top of the 'Tilgate Stone' horizon (Lake and Shephard-Thorn, 1987, p. 28).

The Cliff End Bone Bed is a pale grey, coarse quartzose sandstone with a calcareous cement, about 0.2 m thick in its type locality. The unit is poorly sorted and contains sub-angular to well-rounded pebbles (up to 2 mm in diameter). Approximately 97% of the clasts are quartz. The remainder are sandstone pebbles and ferruginous claystone nodules, vertebrate debris and fossilized wood (Cook, 1995). Vertebrate material has been recovered by acid separation techniques and includes actinopterygian scales and teeth, shark teeth, along with rarer reptilian remains and mammalian teeth. The fauna and sampling methods are reviewed by Clemens (1963), Clemens and Lees (1971) and Cook (1995).

Dissociated vertebrate remains are scattered throughout the fossiliferous unit and all specimens show some fragmentation (Cook, 1995). Much of the material is heavily abraded and the bone bed is thought to have accumulated under a high-energy flow regime, and represents a winnowed channel lag deposit (Cook, 1995).

Fauna

The Hastings fish fauna (Figure 13.6) has been reviewed by Woodward (1915–1919), and the sharks in particular have received a more detailed study by Patterson (1966). Most of the specimens reside in the NHM and the SM.

Chondrichthyes: Elasmobranchii: Euselachii: Hybodontoidea
- *Hybodus ensis* Woodward, 1911
- *H. basanus* Egerton, 1845
- *H. parvidens* Woodward, 1889
- *H. brevicostatus* Patterson, 1966
- *Hybodus* sp.
- *Hylaeobatis ornata* (Woodward, 1889)
- '*Lonchidion*' *rhizion* (Patterson, 1966) *nomen dubium*
- *Lissodus breve breve* Patterson, 1966
- *L. (L.) heterodon* Patterson, 1966

Osteichthyes: Actinopterygii: Neopterygii
- *Coccolepis* sp.

Osteichthyes: Actinopterygii: Neopterygii: Halecostomi
- *Lepidotes mantelli* Agassiz, 1833–1837
- *Coelodus mantelli* (Agassiz, 1839–1844)
- *C. hirudo* (Agassiz, 1839)

Interpretation

The palaeoenvironment of the Wadhurst Clay has been interpreted as pro-deltaic or lagoonal (Lake and Shephard-Thorn, 1987). The deposition of the Wealden of the Weald had formerly been interpreted as largely deltaic (e.g. Allen, 1959, 1962; Taylor, 1963), but P. Allen (1976, 1981a) revised his former theory in favour of a model in which the normal Wealden environment was a variable-salinity mudplain, periodically transformed into a sandy braidplain by powerful overloaded streams, the salinity changes being controlled by the rate of freshwater runoff. Allen (1981a) argued that many of the rivers were braided in their proximal portions, whereas Stewart (1981a, 1981b, 1983) emphasized evidence for meandering streams.

Allen (1976) interpreted the Wadhurst Clay pebble bed facies in terms of reworking of fluvial lags by non-marine transgressions across the low-lying Wealden floodplain. The Cliff End Bone Bed was interpreted as a high-energy lag deposit by Allen (1949) and Cook (1995), in which the vertebrate elements suffered several cycles of reworking and transportation.

The fish fauna from the Hastings district is largely represented by isolated skeletal elements and teeth of hybodont sharks and holostean-grade bony fish. The hybodonts are represented by at least four species of *Hybodus*, and Hastings is the type locality for one of these, *H. parvidens* Woodward, 1889 (Figure 13.6). This species was diagnosed from isolated teeth, and the holotype is from the Wadhurst Clay of Hastings. Teeth of a small freshwater hybodont shark found in the accumulation were assigned to the genus *Lonchidion* by Patterson (1966). Species pertaining to *Lonchidion* have recently been reassigned to the Mesozoic taxon, *Lissodus*, by Duffin (1985), but the specific determinations of Patterson (*L. breve* and *L. heterodon*) still stand. *Lissodus* is known only from isolated teeth, cephalic spines and fin spines, and is represented in the Wealden of Hastings by three species (Figure 13.6A,B). The strongly heterodont dentition comprises low-crowned, unicuspid or tricuspid teeth of a crushing or grinding type (Patterson, 1966). However, the type and associated specimens of '*Lonchidion*' *rhizion* Patterson, 1966, which were recovered from the Cliff End Bone Bed at Cliff End, lack enameloid and several authors have disputed the validity of the species (e.g. Herman, 1977, p. 42; Duffin, 1985, p. 112). Both Herman (1977) and Duffin (1985) concluded that the specimens comprising '*Lonchidion*' *rhizion* are not teeth, but hybodontoid dermal denticles. As *Lonchidion* has been synomized with *Lissodus*, Duffin (1985, p. 113) suggested that they might represent the dermal denticles of a species of that genus. The last hybodont shark in the Hastings fish fauna is the ptychodont shark, *Hylaeobatis ornata* (Woodward, 1889a), diagnosed from material from the Brook–Atherfield Point section (q.v.) in the Wealden of the Isle of Wight.

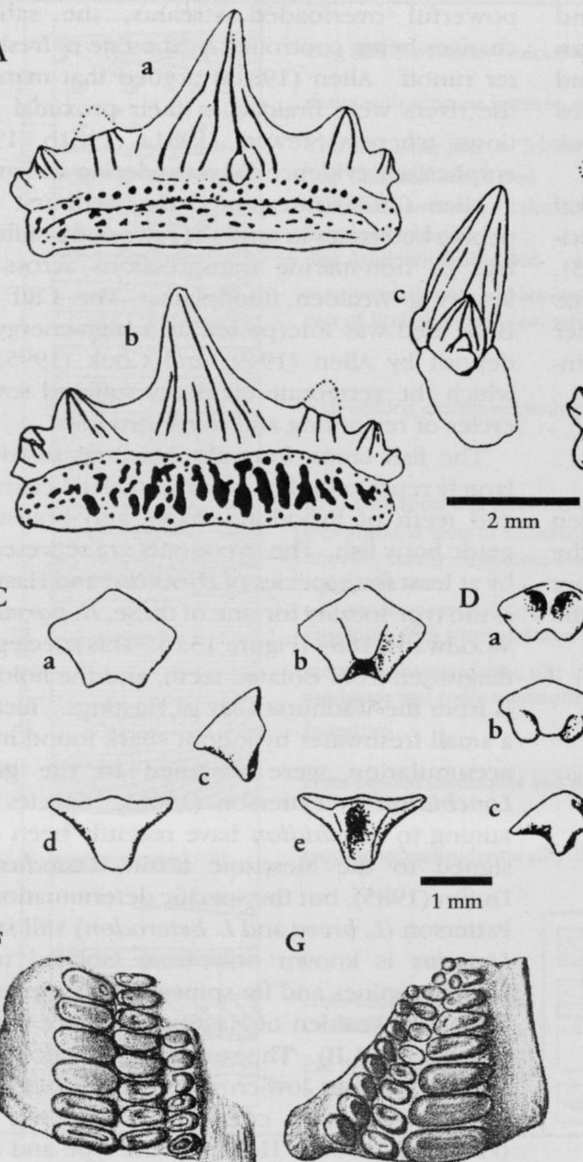

Figure 13.6 Wealden fossil fish: (A), (B) *Hybodus parvidens* Woodward anterior and posterior teeth in (a) labial, (b) lingual and (c) medial view, NHM P 46930 31; (C)–(E) *Lissodus rhizion* 'teeth' in (a) lingual, (b) labial, (c) medial, (d) occlusal and (e) basal view: (D) the holotype NHM P 47144 (from Patterson, 1966); (F) *Coelodus mantelli* Agassiz, oral view of the right splenial bone with teeth, × 1, Wealdon, Hastings; (G) *Coelodus mantelli* left splenial, × 1, Wealdon, Hastings. Figures from Woodward (1889–1901) © The Natural History Museum, London.

The bony fish assemblage is largely composed of halecostomids, including teeth and scales of the ubiquitous *Lepidotes mantelli* Agassiz, 1833–1837, and type material of two species of the pycnodont *Coelodus*. *Coelodus mantelli* (Agassiz, 1839–1844) is represented by dentition and jaws and *C. hirudo* (Agassiz, 1839–1844) by isolated teeth, from the Wadhurst Clay of the Hastings area (Woodward, 1915–19). The crushing dentition of the former species is a common find in the Wealden of Sussex, comprising five rows of teeth on the vomer and three rows on the splenial, representing a moderate-sized form.

An imperfect maxilla, possibly representing that of a species of *Coccolepis*, one of the last known members of the primitive actinopterygians first encountered in the Scottish Upper

Devonian and Carboniferous localities, has been recovered from the Wadhurst Clay succession at Hastings (Woodward, 1915–19).

Comparison with other localities

The Cliff End Bone Bed is exposed (Lake and Shephard-Thorn, 1987) near the steps from the Undercliff to Watchbell Street, Rye (TQ 91952018), and formerly in a brickpit near Baldslow (TQ 810133). Bone beds with a similar fish fauna and which may be equivalent to the Cliff End Bone Bed are seen at Reyson's Farm, near Brede (TQ 832192; Allen, 1949), Stubb Lane, Brede (TQ 82121853; Lake and Shephard-Thorn, 1987), Hare Lane, Brede (TQ 83141844; Benton and Spencer, 1995), and West Ascent, St Leonards (TQ 79820885; Lake and Shephard-Thorn, 1987), where they are known as the 'Brede Bone Bed'. The Brede Bone Bed is also exposed at Ludley Hill, Beckley (TQ 8521), and possibly also at Oxenbridge Hill, Iden (?TQ 9225; Allen, 1949). The Telham Bone Bed is also apparently equivalent to the Cliff End Bone Bed, and has yielded a similar fauna. This bone-rich horizon is exposed in small inland quarries, including the Black Horse Quarry, Telham (TQ 769142; Benton and Spencer, 1995), Rackwell Wood, Crowhurst (TQ 764124; Sweeting, 1925; White, 1928; Lake and Shephard-Thorn, 1987), Maplehurst Wood (TQ 81001307; Lake and Shephard-Thorn, 1987), Baldslow (TQ 8013; Allen, 1949), Brede (several exposures around TQ 8320; Allen, 1949), Peamarsh (TQ 8621; Allen, 1949), Udimore (TQ 8819; Allen, 1949), Stone Hole Quarry, Stone (TQ 9428; Allen, 1949), and Tighe (Teigh) Farm (TQ 936266; Allen, 1949).

Many nearly complete fossil fish specimens were recovered from the foreshore and beach along the coast between Bexhill-on-Sea and Cooden, East Sussex (TQ 715062–TQ 750070), in the 19th century by S.H. Beckles, and form a major part of the Wealden fish collection in the Natural History Museum (Beckles Collection). Some of these finds were erroneously ascribed to the Wadhurst Clay of Hastings (e.g. Woodward, 1895a, 1915–19; White, 1928), and these include the type specimens of the caturid halecomorphs *Caturus (Callopterus) latidens* and *Neorhombolepis valdensis*. The incorrect locality information seems to have been perpetuated by Beckles himself, who wished to keep the true provenance of his specimens a secret (D. Ward, pers. comm., 1995). In recent years several uncrushed specimens of *Lepidotes* and hybodont shark species have been recovered. The fossils occur as isolated bones, scales, spines and teeth, and as near-complete fish or parts of fish in ironstone nodules within the Weald Clay, which crops out in a narrow coastal strip at Cooden. However, in the past ten years the foreshore between Bexhill and Cooden has been subjected to extensive coastal protection schemes that have limited the usefulness of the lower section. More finds can be made after cliff falls and the site has SSSI status for fossil reptiles (Benton and Spencer, 1995).

Conclusion

The Hastings succession is the only extensive coastal setting in the non-marine strata of the Hastings Beds undergoing active erosion, and therefore has considerable potential for future finds. The conservation value of the site is derived from the wealth of fossil fishes obtained from the section over the last 100 years, including two type specimens of hybodont sharks and two of the pycnodont *Coelodus*. One of the last basal actinopterygians, *Coccolepis*, has also been recovered from these beds. The fish debris rich horizons – such as the Cliff End Bone Bed – may yield new microvertebrates.

BROOK–ATHERFIELD POINT (SZ 375842–SZ 452788) (POTENTIAL GCR SITE)

Highlights

The Brook–Atherfield Point section on the Isle of Wight has yielded several type specimens of hybodont shark and is type locality for the aspidorhynchid *Belonostomus hooleyi* and the teleost *Pachythrissops vectensis*. The Compton Bay–Atherfield section is also well documented for the provenance of finds made.

Introduction

The Wealden Group of the south-west coast of the Isle of Wight (Figure 13.7) is world famous for rich vertebrate faunas. It has yielded abundant material in the past (Reid and Strahan, 1889) and good finds are made frequently because of continuing coastal erosion. The overlying Atherfield Clay Formation of the Lower

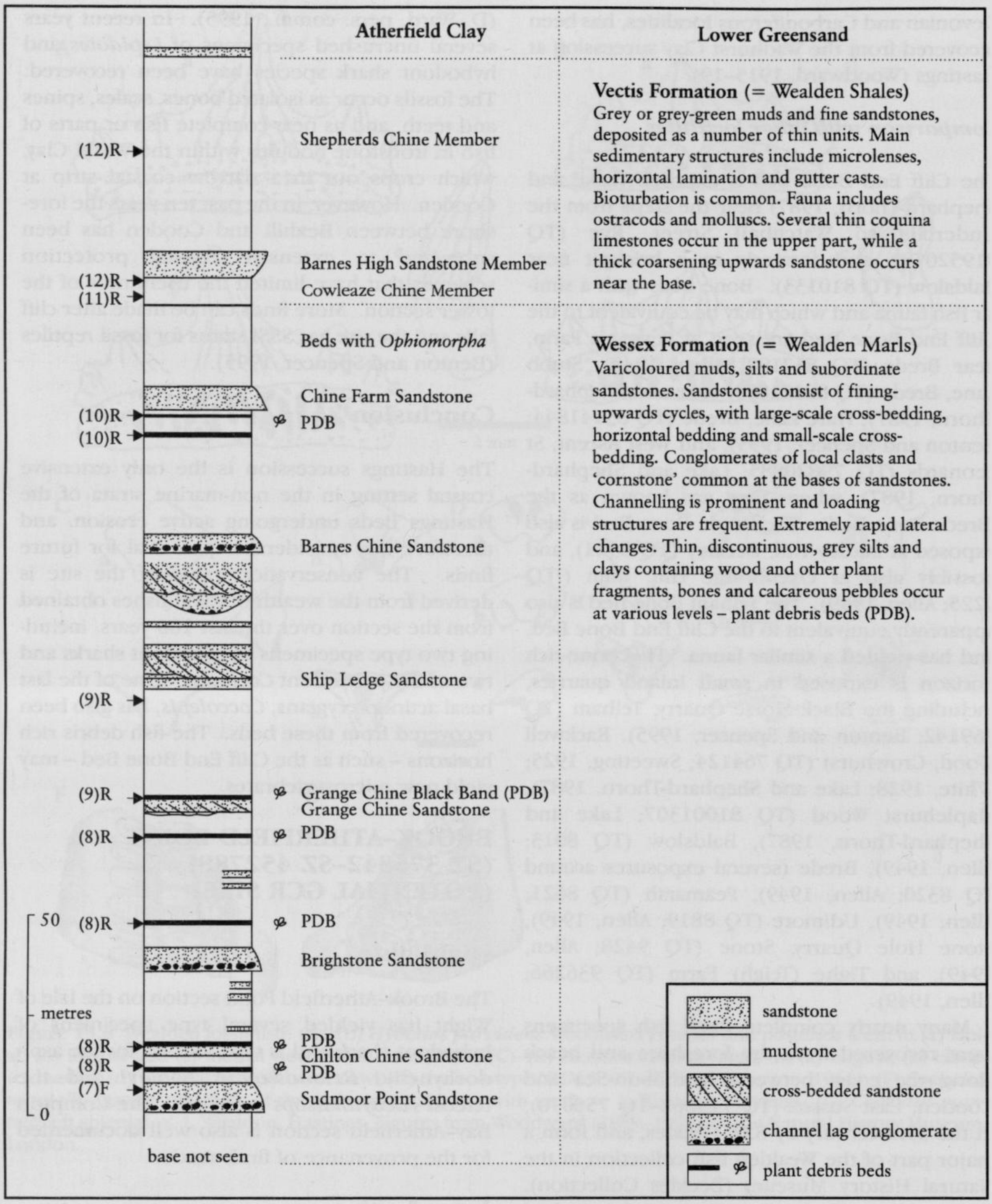

Figure 13.7 Brook–Atherfield Point section with locality details (after Benton and Spencer, 1995).

Greensand has also yielded abundant fish remains.

The section between Compton Bay and Atherfield Point has been described by White (1921, pp. 5–15), Daley and Stewart (1979), Stewart (1981b), Simpson (1985), Stewart *et al.* (1991) and Wach and Ruffell (1991). The exposed portions are dated as mostly Barremian, but may reach Early Aptian (Kerth and Hailwood, 1988; Hughes and McDougall, 1990; Allen and Wimbledon, 1991). The section is best known for its dinosaur fossils and has been designated an SSSI for fossil reptiles (Benton and Spencer, 1995).

Description

The Wealden Group along the Brook–Atherfield section (Figures 13.7 and 13.8) is exposed in the core of the Brighstone anticline, the hinge of which is difficult to locate, but lies within Brook Bay. The Wealden Group and Atherfield Clay Formation (part) are to be seen at both ends of the section, and the oldest beds are in the Brook Chine area. The section, on the southern limb of the anticline, is summarized from White (1921) with refinements from Simpson (1985), and formation and member names from Stewart (1978), Daley and Stewart (1979), Simpson (1985) and Wach and Ruffell (1991).

	Thickness (m)
Lower Greensand	
Atherfield Clay Formation (= Atherfield Group)	
Chale Clay Member (= Atherfield Clay; beds 3–6 of Simpson, 1985, p. 27, fig. 4): pale bluish grey silty clay with numerous small round or irregular clay–ironstone nodules, some forming discrete bands. Highly fossiliferous, containing small fish teeth, pyritized wood and bivalves	19
Perna Beds Member: Upper Sandstone (bed 2 of Simpson, 1985, p. 27, fig. 4). Hard, coarse-grained, greenish calcareous sandstone in which marine fossils (bivalves, brachiopods, corals, rare ammonites, burrows and fish teeth) occur	0.54
Lower Clay and Atherfield Bone Bed (bed 1 of Simpson 1985, p. 27, fig. 4): grey-brown, passing into dark blue, sandy clay with many bivalves (including *Panopea*, *Aetostreon* and *Mulletia*), echinoids, brachiopods, but no indigenous ammonites. At the base is a thin layer (10–100 mm) of coarse quartz grit, bone fragments, fish teeth, phosphate nodules, rolled Jurassic ammonites and reptile remains (Atherfield Bone Bed)	0.85
– – – – – – disconformity – – – – – –	
Wealden Beds	
Vectis Formation (= Wealden Shales)	
Shepherd's Chine Member: grey or grey-green muds and fine sandstones, deposited as a number of thin cyclic units; impersistent ironstone lenses; several thin coquina limestones, and other beds with ostracods, plants and fishes	45
Barnes High Sandstone Member (= Sandstone of Cowleaze Chine and Barnes High of White, 1921): Massive, cross-bedded, yellow sandstone, with bands of *Filosina*,over-lying thin-bedded sandstone with shale	7
Cowleaze Chine Member: blue shales containing bivalves, overlying white sand and clay	8
Wessex Formation (= Wealden Marls)	
Beds with *Ophiomorpha*: at the very top, red sand with bones (*Hypsilophodon* Bed, 1 m); then reddish-brown mudstones, laminated in places, with mudcracks, calcareous nodules, burrows and rootlets, interbedded with medium-grained, cross-laminated sandstones; includes, about the middle, a new fossiliferous bed	14
Chine Farm Sandstone: white and yellow sand, with fragments and large trunks of carbonized wood ('lignite')	3
Clays/marls: pale-blue and purple clays, with two plant debris beds near the top (9 m), overlying 'hard green bed, containing lignite and bones' (0.7 m), followed by deep-red marls (2 m) and purple and mottled marls (10 m)	22
Barnes Chine Sandstone: sandstone with clayey beds	4
Deep-red marls, purple below	9
Pebbly sandstone: channel fill	1
Clays, marls and sands: green and white clays with purple and red marl and white, sandy interbeds	20
Ship Ledge Sandstone: fine, white sandstone	1
Mottled marls	8+
Grange Chine Black Band (Black Band of Brixton Chine of White, 1921, p. 14): plant debris bed with bivalves and bones	0.8
White, sandy marl (1 m) overlying 'mottled red marls of Brixton (= Grange) Chine, with a plant debris bed near the middle' (29 m). The Grange Chine Sandstone occurs to the west of Grange Chine near the top	30
Marls and sandstones: green sandy bed with bones (0.7 m), overlying red and white sandstones interbedded with marl and a (0.1 m) bed of fragmented bone and pebble bed at the base (5 m), overlying mottled marls (15 m)	30
(?) Brighstone Sandstone: pebbly band with carbonized wood and pebbles of sandstone (top of east bank of Chilton Chine)	0.7
Chilton Chine Sandstone: cross-bedded sand-	

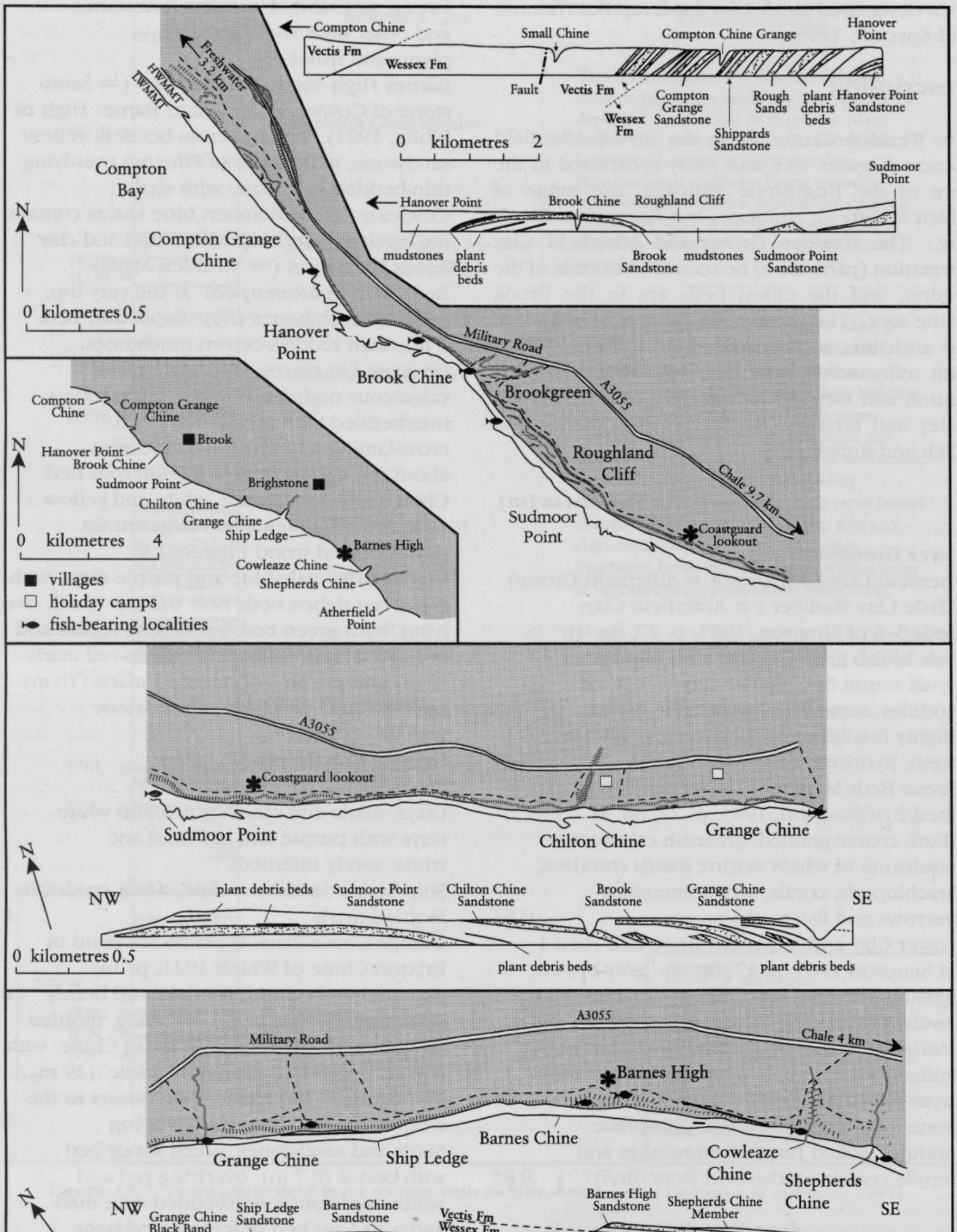

Figure 13.8 Location map, Brook–Atherfield area (from Benton and Spencer, 1995).

stone (near the bottom of Chilton Chine) 4
Marls and sandstones: mottled marls, purple marls with white calcareous concretions, and red marls passing down into cross-bedded white sandstone and marl; plant debris beds near base 13
Sudmoor Point Sandstone: massive sandstone with irregular bands of bone; 0.2–0.6 m of gravel at base, with bones; '*Iguanodon*' footprints near the top 6
Deep red and purple marls seen to 6

Unlike most other British fossil fish localities, there is much information about provenance of finds made in the Compton Bay–Atherfield section. The data given below are from White (1921). Unusually, there has always been a tradition among collectors of recording the locations of fossil vertebrate finds with a degree of precision rarely encountered elsewhere in Britain. Nearly all the specimens have a label such as 'Brook Bay' or 'Cowleaze Chine', which restricts the provenance to a particular part of the stratigraphical column, and further collector information such as 'at beach level' or 'in a 6 ft thick sandstone' is sometimes sufficient to identify the exact horizon.

The fossil localities given below are arranged in descending stratigraphical order.

Atherfield Clay Formation

1. Crackers Member at Atherfield has yielded teeth of the galeomorph shark '*Lamna*' spp. and the type specimen of the pycnodont *Gyrodus atherfieldensis* (H.J.O. White, 1921; Simpson, 1985).
2. Chale Clay Member at Atherfield has yielded small derived teeth of the Wealden sharks *Hybodus basanus* and *Lissodus breve breve* (Simpson, 1985).
3. Perna Bed at Atherfield has yielded small derived teeth of the Wealden sharks *Hybodus basanus* and *Lissodus breve breve* (Simpson, 1985).
4. Lower Clay and Atherfield Bone Bed near Atherfield Point has yielded many species of shark including '*Lamna*' spp., *Plicatolamna*, '*Sphenonchus*', *Squatina*, *Scapanorhynchus* sp. nov. Simpson, 1985, and indeterminate fish vertebrae (White, 1921; Simpson, 1985). Derived Wealden and older forms are also present , e.g. *Lissodus breve breve*, *L. breve pustulatum*, *L. striatum*, *Hylaeobatis ornata*, *Hybodus basanus*, *H. brevicostatus*, *Synechodus*, *Polyacrodus*, *Heterodontus*, *Arthrodon intermedius*, *Lepidotes* spp., ?*Caturus* (Simpson, 1985). The same bed at Redcliff, near Sandown, has yielded a similar fauna (Simpson, 1985).

Vectis Formation

Macrofossils in the Vectis Formation are mainly concentrated in locally fossiliferous horizons, such as shelly partings, coquinas and the erosional scours of parallel laminated storm deposits (Stewart *et al.*, 1991, p. 125). They consist of abundant bivalves, gastropods, ostracods, plant fossils and fragmentary fish remains. Fish debris tends to be concentrated at the base of these accumulations.

1. Vectis Formation at Atherfield Point yielded the type specimens of *Hybodus basanus* and *Pachythrissops vectensis*, associated with *Hylaeobatis ornata*, *Hybodus brevicostatus*, *Coelodus multidens* and other indeterminate fish remains (Egerton, 1845; Mantell, 1854; Woodward, 1915–1919; Patterson, 1966).
2. Vectis Formation of Brook Bay has yielded *Hybodus basanus* and teeth of *Hylaeobatis ornatas* (Mantell, 1854; Bristow *et al.*, 1889; Patterson, 1966).
3. Vectis Formation of Compton Grange Chine or Shippard's Chine include teeth of *Hybodus brevicostatus* (Patterson, 1966).
4. Vectis Formation of Brixton has yielded the type specimen of *Hylaeobatis ornata* (Patterson, 1966).
5. Plant debris bed at SZ 377840, about 200 m west of Hanover Point (= locality IV.2 of Daley and Insole, 1984, p. 6; bed CH12 of Stewart, 1978). Buffetaut and Ford (1979) reported the discovery of crocodilian teeth (*Bernissartia*) and other vertebrate remains including several thousand fish teeth, including several undiagnosed species of shark and bony fish (mainly *Lepidotes*: Buffetaut and Ford, 1979, p. 905) in a marly clay horizon beneath a fossil tree trunk in the cliff face. They stated that the tree trunk occurred 'at beach level in the second of the three 'lignitic bands' depicted by White (1921, fig. 1, p. 12).' White (1921) illustrated three lignitic bands, none of which is anywhere near the site mentioned by Buffetaut and Ford (1979). The map reference is probably correct since the

latter authors state that the site was 'midway between Compton Grange Chine and Hanover Point', and thus in the Wessex Formation, and probably in the region of White's (1921, p. 9) 16 ft (5 m) 'White Sandstone (east of Compton Grange Chine)' or the 'variegated marl' (30 ft, 9 m) below.

6. Shepherds Chine Member 'one foot below the base of the Lower Greensand' (Bristow *et al.*, 1889, p. 14) at Cowleaze or Shepherds Chine has yielded abundant fish remains, including teeth of the shark *Hybodus brevicostatus* (Patterson, 1966).

Wessex Formation

Though the bulk of the Wessex Formation marls is unfossiliferous, locally persistent fossiliferous bands have yielded large pieces of fossilized wood, coniferous fruits, ferns, freshwater molluscs (*Vivaparus* and *Unio*), water-worn bones of reptiles and abundant fragments of fishes (White, 1921).

1. Wessex Formation at Atherfield Point included *Hybodus basanus*.
2. Wessex Formation at Brook Bay and Brook Point has yielded *Hybodus basanus*, *Lepidotes mantelli* and *Coelodus multidens* (Bristow *et al.*, 1889; Woodward, 1895a, 1916–1919).
3. Wessex Formation of Sedmore has yielded *Lepidotes mantelli* (Mantell, 1854; Bristow *et al.*, 1889).
4. In a bed known as the 'Pine Raft' within the shales between the *Hypsilophodon* Bed and the massive sandstone which comes in at the top of the cliff at Barnes High, and runs through Cowleaze Chine (White, 1921) at Hanover Point, numerous vertebrate remains including fin spines, scales and teeth referable to *Hybodus*, *Lepidotes mantelli* and *Coelodus* occur (Mantell, 1846; White, 1921, p. 15).
5. White (1921, p. 13) mentioned a 'lignite bed' with bones 12 m above the Barnes Chine Sandstone, which is 'seen in the top of Barnes Chine' and reaches beach level to the east of Barnes High. A second plant bed, a few metres higher, has also yielded bones. Recent finds have been made in the top bed of the Wealden Marls, a 14 m thick bed of red and mottled mudstones underlain by massive white and yellow sandstones. Buffetaut and Hutt (1980) reported a crocodilian, *Vectisuchus*, from the base of the bed at Barnes High in association with a microvertebrate fauna, which included *Lepidotes* teeth and scales, freshwater molluscs and other reptile remains.

The preservation of the fish remains from the Compton Bay–Atherfield section is variable. There appear to be two modes of preservation: well-mineralized (pyrites, baryte, etc.) black bones in organic facies, such as the plant debris beds and Vectis Formation shales; and poorly mineralized pale-coloured bones, found in overbank muds and channels.

Fauna

The fish fauna of the Isle of Wight (Figure 13.9) has been described by Woodward (1890, 1895a, 1916–1919), and Patterson (1966). Large numbers of fossil fish from various sites in the Brook–Atherfield section are preserved in British museums, in particular the NHM and BGS(GSM).

Chondrichthyes: Elasmobranchii: Euselachii: Hybodontoidea

Hybodus basanus Egerton, 1845
H. brevicostatus Patterson, 1966
Hybodus sp.
Hylaeobatis (Acrodus) ornatas (Woodward, 1889)
Lissodus rhizion (Patterson, 1966)
L. breve breve (Patterson, 1966)
L. breve pustulatum (Patterson, 1966)
L. striatum (Patterson, 1966)
Polyacrodus sp.
'*Sphenonchus*' sp.

Chondrichthyes: Elasmobranchii: Neoselachii: Galeomorphii

Heterodontus sp.
'*Lamna*' spp.
'*Odontaspis*' sp.
?*Plicatolamna* sp.
Scapanorhynchus sp. nov. Simpson, 1985
Synechodus sp.

Chondrichthyes: Elasmobranchii: Neoselachii: Squatinomorphii

Squatina sp.

Osteichthyes: Actinopterygii: Neopterygii: Halecostomi

Arthrodon intermedius Woodward, 1893
Lepidotes mantelli Agassiz, 1833–1837
Coelodus mantelli (Agassiz, 1839–1844)

C. multidens Woodward, 1918
Gyrodus atherfieldensis White, 1927
Osteichthyes: Actinopterygii: Neopterygii: Halecomorphi
?*Caturus* sp.
Osteichthyes: Actinopterygii: Neopterygii: Teleostei
Belonostomus hooleyi Woodward, 1916–1919
Pachythrissops vectensis Woodward, 1890

Interpretation

Stewart *et al.* (1991) interpreted the Wealden Group on the west coast of the Isle of Wight as a sequence that records a shift from terrestrial deposition to fully marine. The lower unit, the Wessex Formation, is a fluviatile or coastal plain unit, the Vectis Formation above was deposited in a shallow lagoon and was temporarily emergent, and the overlying Atherfield Clay Formation is marine. Climatic conditions were seasonal, with wet and dry seasons in warm-temperate subtropical latitudes (Stewart, 1981b). The Wessex Formation contains numerous coarse sandstones deposited in channels, as well as overbank mudstones (marls), and a number of thin plant debris beds (carbonized wood with dinosaur and crocodilian bones, fish remains, plant cones and, occasionally, bivalve shells) represent reworked terrestrial fossils from flood events (Daley and Stewart, 1979).

The Vectis Formation was divided by Stewart *et al.* (1991) into four facies, fine sandstones, heterolithic sand/ silt and mudstones, parallel-laminated mudstones and black mudstones, which occur cyclically through the sequence. The cyclicity may relate to advance and retreat of deltaic sand bodies into the lagoon, of which the Barnes High Sandstone Member may be a major example. Mollusc and ostracod associations give measures of salinity. Salinity and the frequency of storms increase towards the top of the Vectis Formation, and the sequence is terminated by the Atherfield Clay Formation, representing the major Aptian marine transgression (Stewart *et al.*, 1991).

The Wealden fish fauna recovered from the Brook–Atherfield section comprises a mixed freshwater and brackish-water shark and bony fish assemblage (Figure 13.9). Hybodont sharks are again common and include the type specimen of *Hybodus basanus* Egerton, 1845 from the Vectis Formation (Wealden Shales) at Atherfield Point. This species is known from about 20 skulls, plus the dentition, fin spines and fragments of the postcranial skeleton, and is one of the best-known hybodonts of the Wealden (Patterson, 1966: Figure 13.9E,F). Based on this material, descriptions of the cranial morphology and dentition of the species have been given by Maisey (1983) and Patterson (1966). Complete skulls of this form have also been found at Pevensey Bay, Sussex.

The ptychodont shark *Hylaeobatis ornata* (Woodward) was described from material from the Vectis Formation at Brighstone (Brixton) Bay (Patterson, 1966). Ptychodonts are Cretaceous hybodonts which lacked fin and cephalic spines, and possessed elongate jaws with a specialized dentition of flattened, crushing teeth confined to the broad symphysial region. The teeth were arranged in up to nine paired files and one unpaired file at the front in each jaw, and decrease in size and complexity of ornamentation posteriorly (Patterson, 1966). This form has also been found in Vectis Formation of Atherfield Point, and along the coast at Yaverland and Sandown (Patterson, 1966).

Halecostomids are represented in the Vectis and Wessex Formations between Atherfield and Brook by abundant scales, teeth and isolated bone material of the ubiquitous Wealden fishes *Lepidotes mantelli* Agassiz and *Coelodus mantelli* (Agassiz). These are associated with a further species of the pycnodont *C. multidens* Woodward (Figure 13.9B), which form has also been recovered from Sevenoaks, Kent and Battle, Sussex (Woodward, 1918).

Also found in the Atherfield–Brook section are scales and incomplete fishes of the long-snouted aspidorhynchid *Belonostomus hooleyi* Woodward. The scales and skull roof of the fish were heavily ornamented in a series of irregular ridges, grooves and low tubercles.

Pachythrissops (*vectensis*) Woodward is a primitive teleost (Figure 13.9C) only known from the British Wealden (although the genus also is found in the English and Bavarian Purbeck sections; Woodward, 1919a) and seems to have been a rather large fish, attaining over 1 m.

The Atherfield Clay Formation of the Atherfield–Brook area has produced a derived Wealden assemblage of small reworked fish teeth, scales and worn bones, and several Lower Greensand and Gault species of fish. These

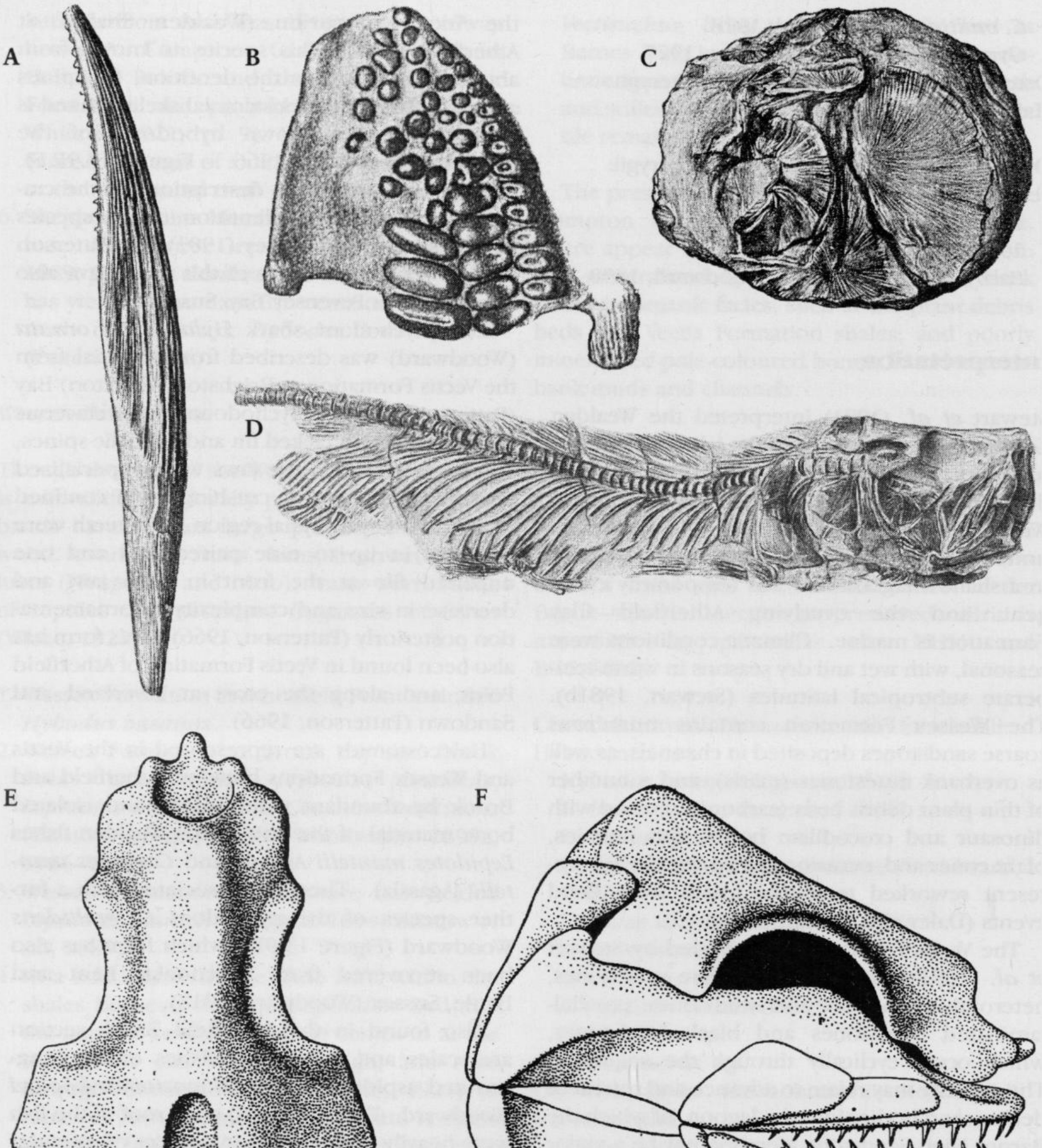

Figure 13.9 Wealden fossil fishes from Brook–Atherfield and other localities (after Woodward, 1917): (A) *Hybodus ensis* Agassiz, fin spine, × 0.5; (B) *Coelodus multidens* Woodward, right splenial with teeth, × 1.0; (C), (D) *Pachythrissops vectensis* Woodward: (C) crushed parts of right opercular region, × 0.5; (D) right lateral view of skull and axial skeleton, × 0.25; (E), (F) *Hybodus basanus* Egerton, restoration of the cranium in dorsal view and right lateral view of the skull with jaws, about half natural size. Figures from Woodward © The Natural History Museum, London.

include galeomorph (*'Lamna'* spp., *Plicatolamna* and *Scapanorhynchus* sp. nov.) and squatinomorph (*Squatina* sp.) neoselachians (Simpson, 1985). These are in association with indeterminate bony fish remains, and the pycnodont *Gyrodus atherfieldensis* White, known from the Crackers Member of the Atherfield Clay Formation at Atherfield Point. Except for the odd fragments and isolated teeth, *G. atherfieldensis* is the first pycnodont species to be described from Aptian age beds of southern England. It is distinguishable from most other species of *Gyrodus* by the smoothness and arrangement of teeth on the vomer.

Comparison with other localities

The nearest comparable Wealden locality to the Compton–Atherfield section is the coast at Yaverland, near Sandown (SZ 613850) on the south-east coast of the Isle of Wight. Here a similar section is exposed, yielding the type specimen of the hybodont subspecies *Lonchidion breve pustulatum* Patterson, from the Perna Bed, Atherfield Clay Formation, in association with further fish (*Lepidotes*, *Lissodus breve breve* and *Hylaeobatis ornata*) and reptile remains (Patterson, 1966; Benton and Spencer, 1995). Yaverland is an SSSI for fossil reptiles (Benton and Spencer, 1995). The exposed Isle of Wight Wealden is largely, or wholly, Barremian in age (mid-Early Cretaceous), whereas vertebrate localities in the Wealden of the Weald are generally Valanginian (earliest Early Cretaceous). The exception in the Weald is Smokejacks Pit, Ockley (TQ 113372), which is in the Weald Clay (Hauterivian–Barremian) in age. The vertebrates include *Lepidotes*, actinopterygian fish scales, hybodont shark teeth and reptile remains.

Conclusion

The Wealden and Lower Greensand series between Brook Bay and Atherfield Point on the Isle of Wight is one of the richest Lower Cretaceous sources for fossil fishes in Britain, hence its conservation value. The section has produced type specimens of the hybodonts *Hybodus basanus* and *Hylaeobatis ornata*, the holosteans *Gyrodus atherfieldensis* and *Coelodus multidens* and the teleosts *Belonostomus hooleyi* and *Pachythrissops vectensis*. The coastal exposures are continuously eroding and there is potential for significant future finds.

EARLY ('MID-') CRETACEOUS (APTIAN–ALBIAN)

The Aptian and Albian stages in Britain are important for their fish faunas, and significant finds have come from the Speeton Clay (Berriasian–Albian), Lower Greensand (Aptian–Early Albian), Gault Clay (Albian), Upper Greensand (Late Albian), 'Red Chalk' (Hunstanton Formation: Albian–Cenomanian), and from the areally-restricted Cambridge Greensand.

The low cliffs and foreshore between Reighton Gap and Speeton Beck in Speeton Bay, North Yorkshire (Figure 13.10; TA 143764–TA 152756) expose a discontinuous section through the Kimmeridge Clay (Upper Jurassic), the Speeton Clay Formation, the Hunstanton Formation and the Chalk (Upper Cretaceous). All the beds of the Speeton Clay have yielded sporadic fish material (Phillips, 1829; C. Underwood, pers. comm., 1996), although the lower part of the section is much disturbed by cryogenic folding and the upper part (Beds A and B) poorly exposed due to slippage. However, the section (and its fauna) is the best and most complete development of marine Lower Cretaceous in the British Isles (Neale, 1974; Rawson and Wright, 1992).

The Cambridge Greensand is a remanié deposit of early Cenomanian age, containing vertebrate remains reworked from the uppermost Albian (*dispar* Zone; Cookson and Hughes, 1964; Casey, *in* Edmonds and Dinham, 1965; Rawson *et al.*, 1978, pp. 38, 50). The vertebrate fossils are associated with abundant phosphatic material derived from the Gault, and were collected from former phosphate workings located along a SW–NE line from Whaddon (TL 3447) to Swaffham Fen (TL 5667). There are now few extant localities of the Cambridge Greensand: it may be seen at Barrington (TL 3949) and Arlesey (TL 185350; Benton and Spencer, 1995).

Fish remains in the Lower and Upper Greensand are usually fragmentary and sparse. Reworked Jurassic and Wealden fish material is also found in the Lower Greensand of southern Britain, and include taxa such as *Hybodus basanus*, *H. obtusus*, *H. subcarinatus*, *Hylaeobatis ornata* and *Synechodus tenuis* (Casey, *in* Edmonds and Dinham, 1965). Non-derived Mid-Cretaceous material includes forms

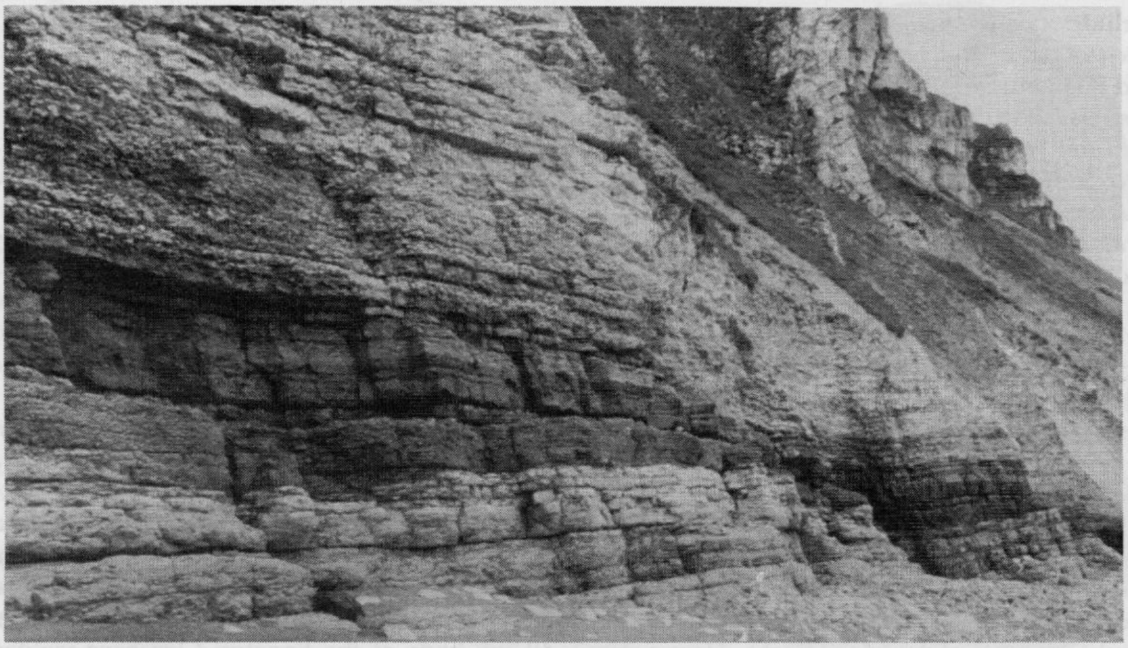

Figure 13.10 Speeton Cliffs, North Yorkshire, looking north-north-west. The Red Chalk lies near the base of the Lower Chalk and crops out in the foreshore below the beach in the foreground. Cliffs of Middle Chalk in the middle distance show small landslips. Fossil fish remains have been found in both of these formations. (Photo: BGS no. A5467, Crown Copyright reserved.)

such as *Heterodontus sulcatus*, *Cretolamna appendiculata*, *Cretoxyrhina mantelli*, *Scapanorhynchus subulatus*, *S. raphiodon*, *Scapanorhynchus* sp., *Ischyodus thurmanni*, *Edaphodon*, *Sphaerodus neocomiensis*, *Gyrodus atherfieldensis* and *Apateodus* sp. (Casey, *in* Edmonds and Dinham, 1965).

The Gault Clay has yielded abundant and well-preserved remains, particularly from the cliff sections of Folkestone (q.v.). The Gault Clay can be split into two divisions: the Lower and Upper Gault; fish remains have been found in both divisions, but they are much more numerous in the Upper Gault Clay (Jukes-Browne and Hill, 1900). The Gault Clay has a good fish fauna, isolated teeth and vertebral discs of elasmobranchs being the most common find. Most of these belong to *Cretolamna appendiculata*, although other abundant taxa are several species of *Hybodus*, *Synechodus* and *Acrodus laevis*, *Cretoxyrhina mantelli*, *Leptostyrax macrorhiza*, *Heterodontus canaliculatus*, *Squalicorax pristodontus*, *Notidanodon lanceolatus* and *Scapanorhynchus subulatus* (Jukes-Browne and Hill, 1900; Smart *et al.*, 1966), and also *Squatina* sp. Chimaeroid dental plates (*Ischyodus thurmanni*, *Edaphodon sedgwicki* and *E. laminosus*) are also common, as are teeth, scales and bones of the bony fish, e.g. *Xiphactinus gaultinus*, *Coelodus ellipticus*, *Enchodus lewesiensis*, *Pachyrhizodus salmoneus*, *Anomoeodus cretaceus*, *Apateodus glyphodus*, *Syllaemus anglicus* and *Protosphyraena ferox* (Jukes-Browne and Hill, 1900; Smart *et al.*, 1966). Most of these forms range up into the Late Cretaceous Chalk succession of Great Britain.

Aptian and Albian deposits from western Europe have also yielded similar fish faunas. A Gault fauna, similar to that at Folkestone, but lacking hexanchids, is known in northern France and in the Aptian of southern France.

FISH SITES

Aptian–Albian strata have yielded abundant fossil fish remains from dozens of localities from Dorset to Yorkshire. The majority of these finds are only isolated debris, and many sites now have only low potential for future finds. The fossil fish sites are listed below by county from the south-west to the north-east:

DORSET: Worbarrow Cove (Upper Greensand; SZ 871797; *Cretolamna appendiculata*; Jukes-Browne and Hill, 1900); Punfield Cove, Swanage

(Punfield Marine Band, Lower Greensand and in the 'Pebble Bed', Atherfield Clay Formation; SZ 032798; *Lepidotes*, pycnodonts, '*Lamna*', other fish debris; Arkell, 1947c); Corfe siding ('Basal Pebble Bed', Atherfield Clay Formation; SZ 970807; *Lepidotes*, pycnodonts, '*Lamna*', other fish debris; Arkell, 1947c); Okeford-Fitzpaine brickyard (Lower Greensand and 'Ironstone' Bed, Lower Gault Clay; ST 801101; many fish teeth, scales and bones, including *Cretolamna appendiculata*, *Synechodus*; Jukes-Browne and Hill, 1900; White, 1923); Cerne Abbas–Minterne quarries (Upper Greensand phosphate bed; various localities around SU 662035; *Ptychodus decurrens*, *Cretolamna appendiculata*; Jukes-Browne and Hill, 1900).

WILTSHIRE: Vale of Warminster ('Warminster Beds', 'Lower Sands', 'Chert Beds' and 'Rye Hill Sands'), Upper Greensand; various localities including Maiden Bradley Quarry, ST 8039, Rye Hill Farm Quarry, ST 847404, Shute Farm Quarry, ST 844411, Stourton, ST 7733, Penselwood, ST 7631; *Ptychodus decurrens*, *Scapanorhynchus subulatus*, *Squalicorax falcatus*, *Cretolamna appendiculata*, *Leptostyrax macrorhiza*, *Cretoxyrhina mantelli*, *Edaphodon crassus*, *Anomoeodus angustus*, *Coelodus cretacous*, *Coelodus* sp., *Enchodus lewesiensis*, *Plethodus expansus*, *Protosphyraena ferox*; Jukes-Browne and Hill, 1900); Seend, Devizes (Ferruginous Sands ('Devizes Beds'), Upper Greensand; ST 610980; *Cretolamna appendiculata*, '*Oxyrhina*' sp., *Protosphyraena ferox*, *Lepidotes maximus* (= Sphaerodus *neocomiensis*); Keeping, 1883; Jukes-Browne and Hill, 1900; Casey, *in* Edmonds and Dinham, 1965).

HAMPSHIRE: Alton railway cutting, Petersfield (Gault Clay; SU 7132; '*Lamna*' sp.; Jukes-Browne and Hill, 1900, p. 111); Binsted, Froyle, East Worldham, Selbourne ('Malmstone', Upper Greensand; various localities of uncertain position; *Enchodus*, *Protosphyraena ferox*, *Cretolamna appendiculata*; Jukes-Browne and Hill, 1900, p. 121).

BERKSHIRE: Farringdon (Lower Greensand; SU 2895; *Asteracanthus*, *Hybodus*, *Strophodus*, *Ischyodus*, *Gyrodus*, *Pycnodus*, *Lepidotes maximus* (= Sphaerodus *neocomiensis* and *S*. sp.; Keeping, 1883).

ISLE OF WIGHT: Bonchurch (Lower Gault Clay; SZ 360860; fish remains; Jukes-Browne and Hill, 1900); Compton Bay (Lower Gault Clay; SZ 3685; fish remains; Jukes-Browne and Hill, 1900); Luccombe and Shanklin quarries (Upper Greensand, sands and ragstones; various localities around SZ 580801; '*Lamna*', *Gyrodus*, etc.; Jukes-Browne and Hill, 1900).

SURREY: Godalming (Hythe Beds and Sandgate Beds (basal pebble beds), Lower Greensand; SU 9643; *Lepidotes*, *Hybodus*, *Gyrodus*, *Acrodus* and other reworked fish remains; Topley, 1875; Keeping, 1883; Casey, *in* Edmonds and Dinham, 1965).

SUSSEX: Eastbourne (Upper Gault Clay; TQ 5802; *Squalicorax pristodontus*, *Scapanorhynchus subulatus*; Jukes-Browne and Hill, 1900, p. 121); Hopton Wood cement works, Small Dole (Gault Clay; TQ 211126; D. Ward, pers. comm., 1995).

KENT: Iguanodon Quarry, Maidstone (TQ 746558; *Hybodus complanatus*, *Heterodontus sulcatus*, *Synechodus tenuis* (holotype specimen), *Ischyodus thurmanni*; Bensted, 1860; Casey, *in* Edmonds and Dinham, 1965, p. 539); Hythe (Hythe Beds, Lower Greensand; TR 163352; *Heterodontus sulcatus*, *Ischyodus agassizi*; Topley, 1875); Folkstone (Lower and Upper Gault Clay; TR 2235; 30 species; see site report); Dover Colliery shafts (Atherfield Clay Formation; derived Wealden fishes, including *Lepidotes* spp., *Hybodus* spp.; Casey, *in* Edmonds and Dinham, 1965).

BUCKINGHAMSHIRE: Marshall Farm quarries, Bishopstone (Lower Gault Clay; SP 8010; *Leptostyrax macrorhiza*, *Cretolamna appendiculata*, *Ischyodus* sp., *Protosphyraena ferox*; Jukes-Browne and Hill, 1900, p. 278); Puttenham Pit ('Malmstone', Upper Greensand; SO 9247; *Cretolamna appendiculata*, *Protosphyraena ferox*; Jukes-Browne and Hill, 1900, p. 282); Long Crendon Pit ('Shenley Limestone', Gault–Lower Greensand junction beds; SP 6909; fish remains indet.; Lamplugh, 1922, p. 41); Brickhill (Lower Greensand; SP 9131, ?exact locality; *Asteracanthus*, *Sphenonchus*, *Edaphodon* (derived Jurassic species), *Macromesodon* '*couloni*' and *Lepidotes maximus* (= *Sphaerodus neocomiensis*; *Sphaerodus gigas*); Keeping, 1883).

BEDFORDSHIRE: Arnold's Pit, Billington Crossing (Gault–Lower Greensand (Woburn Sands) junction beds; SP 933240; *Notorhynchus aptiensis*; Smart, 1995); Leighton Buzzard pits ('Shenley Limestone', Gault–Lower Greensand (Woburn Sands) junction beds; various sand pits around SP 9328, including Chamberlain Barn Pit (SP 929265), Shenley Hill, Mundays Hill (SP 936279); *Notorhynchus aptiensis*; *Cretolamna appendiculata*, *Scapanorhynchus subulatus*, *S. raphiodon*, *Apateodus* Lamplugh, 1922; Casey, *in* Edmonds and Dinham, 1965; D.Ward, pers. comm., 1995; Smart, 1995); Potton (Lower Greensand; TL 2249; *Asteracanthus*, *Strophodus*, *Hybodus*, *Sphenonchus*, chimaeroid material, *Gyrodus* and *Pycnodus* (derived Jurassic species), *Lepidotes maximus* (= *Sphaerodus neocomiensis*) and *Ischyodus townsendi*; Keeping, 1883).

CAMBRIDGESHIRE: Upware, Commissioner's Pit (Lower Greensand; TL 539708; mixed fauna of derived Jurassic and Cretaceous forms *Acrodus*, *Asteracanthus*, *Hybodus*, '*Sphenonchus*', *Strophodus*, *Cretoxyrhina*, *Ischyodus townsendi*, other chimaeroid material, *Macromesodon couloni*, *Gyrodus*, *Lepidotes maximus* (= Sphaerodus *neocomiensis*, *S. gigas*); Keeping, 1883); Barnwell brickpit (Upper Gault Clay; exact site now uncertain; *Ptychodus* fin spine, *Cimolichthys striatus*; Jukes-Browne and Hill, 1900).

NORFOLK: West Dereham brickpits (Gault Clay; TL 6500; *Odontaspis gracilis* (= ?*Carcharias amonensis*), pycnodonts, *Cimolichthys striatus*, indeterminate beryciform actinopterygian ('*Beryx*'); Jukes-Browne and Hill, 1900); Hunstanton (Hunstanton Formation ('Red Chalk') undifferentiated fish and shark material; Woodward, 1894).

NORTH LINCOLNSHIRE: South Ferriby brickpit (Hunstanton Formation ('Red Chalk'); SE 9820; *Hexanchus* sp., *Notorhynchus aptiensis*, *Synechodus* spp., *Paraorthacodus* sp., ?*Sphenodus* sp., *Heterodontus* sp., *Protosqualus sigei*, indeterminate squalids, ?*Protolamna* sp., ?*Cretolamna* sp., *Cretoxyrhina* sp., *Archaeolamna* sp., ?*Anomotodon* sp., *Scapanorhynchus* sp., indeterminate lamnids, *Scyliorhinus* sp., *Pteroscillium* sp., *Cederstroemia* sp., indeterminate orectolobidiformes, *Squatirhina* sp., indeterminate bony fish material, may include *Protosphyraena* sp.; C. Underwood, pers. comm., 1996).

YORKSHIRE: Speeton Cliffs (Reighton Gap to Speeton Gap) (Speeton Clay Formation and the Huntstanton Formation ('Red Chalk'); TA 143764–TA 152756; *Hexanchus* sp., *Notorhynchus aptiensis* , *Notidanodon lanceolatus*, *Synechodus dubriensis*, *S.* sp., *Paraorthacodus recurvus*, ?*Spenodus* sp., *Squatina* spp., *Heterodontus* sp., *Protosqualus sigei*, *Squalus* sp., indeterminate squalids, ?*Protolamna* sp., *Palaeobrachaelurus*, *Cretolamna woodwardi*, *Cretoxyrhina mantelli*, ?*Arhaeolamna* sp., *Anomotodon principalis*, *Scapanorhyncus praeraphidon*, indeterminate odontaspid, *Scyliorhinus destombesi*, *Scy*. sp., *Pteroscylium* sp., indeterminate scyliorhind, *Orectoloboides parvulus*, *Cederstroemia* sp., *Chiloscilium* sp., *Pararhincodon* sp., indeterminate orectolobiformes, *Squatirhina thiesi*, *Squ*. sp., otoliths; Phillips, 1829; Pictet, 1865; Neale, 1974; Rawson and Wright, 1992; C. Underwood, pers. comm., 1996.)

Only East Wear Bay, Folkestone, Kent, is selected as a 'Middle' Cretaceous (Aptian–Albian) GCR site.

EAST WEAR BAY (TR 243366) (POTENTIAL GCR SITE)

Highlights

East Wear Bay, Folkestone in Kent is the most productive British Gault Clay fish site.

Introduction

The Lower Greensand and Gault Clay which crop out along the coast east of Folkestone, Kent, have been known as a good source of fossil vertebrates for 150 years. It is one of the most productive 'mid'-Cretaceous fish sites in the country, yielding scattered shark and bony fish material throughout the succession, although they are especially concentrated in the upper beds. The section is currently well exposed, with new portions revealed by marine erosion and land-slipping. The site continues to yield fish material as the clays can be bulk processed for microvertebrate remains.

Isolated teeth and vertebral discs of sharks are the most common finds, with those of the shark

Cretolamna appendiculata being the majority. At least ten species of elasmobranchs, three species of chimaeroid and five species of bony fish are common in the Gault at Folkstone. Coprolites are also frequently recovered, as are teleost otoliths from sieved residues. Vertebrate material in the Gault Clay at Folkestone is relatively well preserved, with delicate processes intact, and whole and partial fish specimens relatively common. Burrows attributed to terebelloid worms are commonly lined with fish scales (Smart *et al*., 1966, p. 112).

The Gault section has been described by many authors, such as De Rance (1868), Price (1875), Topley (1875), Jukes-Browne and Hill (1900), Smart *et al*. (1966) and Owen (1971, 1975).

Description

The Gault section is best seen just east of Copt Point. To the west, towards Folkestone Harbour, the underlying Folkestone Beds and Sandgate Beds of the Lower Greensand crop out, and to the north, on the shore of East Wear Bay, the Gault is broken up by landslips. The section at Copt Point (from Price, 1875, Jukes-Browne and Hill, 1900, p. 71) is as follows:

		Thickness (m)
Upper Gault		
XIII.	Pale grey and buff-coloured marl	7.3
XII.	Dark glauconitic sand	1.0
XI.	Pale bluish grey, marly clay	10.8
X.	Grey marly clay	5.1
IX.	Hard marly clay	2.8
Lower Gault		
VIII.	Junction bed	0.2
VII.	Dark-grey clay	1.9
VI.	Mottled grey clay	0.3
V.	Mottled clay	0.5
IV.	Light-grey clay	0.1
III.	Light buff-coloured clay	1.4
II.	Very dark clay	1.3
I.	Dark clay and glauconitic sand with nodules at base	3.1
Ia.	Yellowish sand with phosphatic nodules	1.9

These lithological divisions of the 30–35 m thick section are readily determined in the field, and Owen (1971, 1975) gives more detailed logs. An ammonite biostratigraphy exists (Jukes-Browne and Hill, 1900; Spath, 1923–1943; Smart *et al*. 1966; Owen, 1971) and the section is dated as Mid–Late Albian (*dentatus* to *dispar* Zones). There is a clear break between the Lower and Upper Gault here, between beds VIII and IX. Invertebrates such as molluscs and crustaceans are common throughout.

Fossil fishes have been found throughout the whole section but most of the museum specimens and described fossils were not localized to a horizon. Jukes-Browne and Hill (1900, p. 79) recorded that the 'Bones of Chelonians and fish, and the eggs of a species of Crocodilian' were found in horizon X.

Fauna

Fossil fishes from the Gault of Folkestone are preserved in several museums, including the NHM, BGS(GSM), CAMSM and OUM.

Chondrichthyes: Elasmobranchii: Euselachii: Hybodontoidea
Acrodus levis Woodward, 1887
Chondrichthyes: Elasmobranchii: Neoselachii: Squalomorphii
Hexanchus sp.
Notidanodon (Notidanus) lanceolatus (Woodward, 1886)
Notorhynchus sp.
Protosqualus sigei Cappetta, 1977
Chondrichthyes: Elasmobranchii: Neoselachii: Galeomorphii
'*Brachaelurus*' sp.
Carcharias sp.
Cretolamna (Lamna) appendiculata (Agassiz, 1843)
Cretoxyrhina (Isurus) mantelli (Agassiz, 1843)
Heterodontus (Cestracion) canaliculatus (Egerton, *in* Dixon, 1850)
Leptostyrax (Lamna) macrorhiza (Cope, 1875)
Orectoloboides sp.
Paranomotodon sp.
Paraorthacodus sp.
'*Scapanorhynchus*' *subulatus* Agassiz, 1843
'*Scyliorhinus*' sp.
Squalicorax (Corax) pristodontus (Agassiz, 1843)
Synechodus spp.
Chondrichthyes: Elasmobranchii: Neoselachii: Batomorphii
Squatirhina sp.

Chondrichthyes: Holocephali: Chimaeriformes
Ischyodus thurmanni Pictet and Campiche, 1858
Edephodon sedgwicki Newton, 1878
E. laminosus Newton, 1878
Osteichthyes: Actinopterygii: Neopterygii: Teleostei
Protosphyraena ferox Leidy, 1857
Apsopelix (Syllaemus) anglicus (Dixon, 1850)
Xiphactinus (Portheus) gaultinus (Newton, 1877)
Spratticeps gaultinus Patterson, 1970
Osteichthyes: Actinopterygii: Neopterygii: Euteleostei
Pachyrhizodus (Thrissopater) salmoneus (Günther)
Apateodus glyphodus Blake, 1842
Osteichthyes: Actinopterygii: Neopterygii: Elopomorpha
?Casierius gaultinus Estes, 1969
Plethodus expansus Dixon, 1850

Interpretation

The Gault is a low-energy basinal mud unit. The environment of deposition is interpreted as 'a fairly shallow muddy-bottomed sea' (Smart *et al.*, 1966). It forms part of the major Mid-Cretaceous marine transgression over much of north-west Europe, which began with deposition of the coarse sands of the Lower Greensand (Aptian), followed by deepening of the basin in the early Albian. The Lower Greensand progressively overstepped older Mesozoic deposits, and the Gault Clay Formation was the first unit completely to cover the Palaeozoic London Platform (Owen, 1971).

The fish fauna contains many genera that range throughout the Cretaceous, and in particular those which are similar to genera from the Upper Cretaceous Chalk localities of Southerham (q.v.) and Blue Bell Hill (q.v.). For example, the species of the sharks *Cretolamna*, *Cretoxyrhina*, *Heterodontus*, *Leptostyrax*, *Paranomotodon*, *Squalicorax* and *Synechodus*, the chimaeroids *Ischyodus* and *Edaphodon*, the halecomorph actinopterygian *Protosphyraena ferox* and the teleosts *Apsopelix*, *Pachyrhizodus*, *Xiphactinus* and *Apateodus* are well represented in the British Chalk succession and are described in detail below. However, some species such as the hexanchid shark *Notidanodon (Notidanus) lanceolatus*, the teleosts *Apateodus glyphodus*, *Xiphactinus (Portheus) gaultinus* and *Pachyrhizodus (Thrissopater) salmoneus* are only found in the Albian succession.

The Grey Chalk (Cenomanian) succession at Folkestone has also yielded scattered fish remains, including the type specimen of the semionotid *Lepidotes ?pustulatus*, described from numerous isolated large flank scales.

Comparisons with other localities

The low cliffs and foreshore between Reighton Gap and Speeton Beck in Speeton Bay (TA 134753–TA 152756) expose a discontinuous section through the Kimmeridge Clay (Upper Jurassic), the Speeton Clay Formation (Berriasian–Albian), the Hunstanton Formation ('Red Chalk': Albian–Cenomanian) and the Chalk (Upper Cretaceous), and the section represents the best and most complete development of marine Lower Cretaceous in the British Isles (Phillips, 1829; Neale, 1974; Rawson and Wright, 1992). All the beds of the Speeton Clay Formation have yielded sporadic fish material, including a diverse microshark fauna (C. Underwood, pers. comm., 1996). Speeton Clay Beds D2 and D4 (basal Hauterivian) have yielded *Palaeobrachaelurus*, *Synechodus*, lamniformes and have also yielded similar shark material, with *Notorhynchus* especially common (Cappetta, 1975).

The overlying Red Chalk or Hunstanton Formation (Albian–Cenomanian) is well exposed at Speeton (thickness up to 25 m) and the alternating red marls and limestones have yielded a diverse microshark fauna, including synechodontiformes (*Synechodus* sp., *Paraorthacodus* sp. and possibly a species of *Spenodus*), the hexanchid *Notorhynchus aptiensis*, squatiniformes (*Squatina* spp.), the heterodontid *Heterodontus ?canaliculatus*, squaliformes (*Protosqualus* sp., ?*Squalus* sp. and indeterminate material), lamniformes (*Cretolamna woodwardi*, *Cretoxyrhina mantelli*, *Anomotodon* sp., possible species of *Protolamna* and *Archaeolamna*, *Scapanorhynchus* sp. and indeterminate material), carchariniformes (*Scyliorhinus* sp., *Pteroscillium* sp. and indeterminate material), orectolobiformes (*Orectoloboides* sp., *Cederstroemia* sp., indeterminate hemiscillids and *Pararhincodon* sp.),

Northern Province: Lithological unit	Northern Province: Zone	Stage	Southern Province: Zone	Southern Province: Lithological unit	
		Maastrichtian		Sussex White Chalk Formation	Portsdown Member 30 m
Flamborough Chalk Formation 300 m+	higher zones beneath drift	Campanian	*mucronata*[a]		
			quadrata[a]		Culver Member 115 m+
	lingua[b]		*pilula*[d]		Newhaven Member 75 m
	testudinarius[e]		*testudinarius*[e]		
	socialis[e]	Santonian	*socialis*[e]		
Burnham Chalk Formation 150 m	*rostrata*[d]		*coranguinum*[d]		Seaford Member 90 m
	cortestudinarium[d]	Coniacian	*cortestudinarium*[d]		Lewes Member 90 m
	planus[d]		*planus*[d]		
Welton Chalk Formation 53 m	*lata*[f]	Turonian	*lata*[f]		Ranscombe Member 85 m
	labiatus[b]		*labiatus*[b]		
Ferriby Chalk Formation 28 m	*geslinianum*[c]	Upper Cenomanian	*geslinianum*[c]	*Plenus* Marls Formation	
	trecensis[d]		*naviculare*[c]	Abbotts Cliff Chalk Formation 22 m	
	subglobosus[d]	Middle Cenomanian	*rhotomangense*[c]	East Wear Bay Formation 58 m	
		Lower Cenomanian	*mantelli*[c]		

Figure 13.11 The Upper Cretaceous Chalk Group succession, northern and southern provinces (Wood and Smith, 1978; Owen, 1975). Correlation is provisional because of uncertainties in the biostratigraphical scales: a, belemnite; b, bivalve, c, ammonite; d, echinoid; e, crinoid; f, brachiopod.

and the ray *Squatirhina* sp., which can be collected by bulk sampling and acid preparation of the sediments (C. Underwood, pers. comm., 1996). Otoliths and small, undiagnostic fragmentary bony fish material have also been reported, and may include specimens attributable to *Protosphyraena*. The section is prone to slippage and erosion, so that new outcrops and the foreshore exposures are revealed by the frequent storms. The cliffs and shore are fairly easily accessible from the path down to the shore at Reighton Gap and Speeton. Underwood (pers. comm., 1996) has also noted a similar fauna from the Red Chalk (Upper Albian) of South Ferriby brickpit, North Lincolnshire (SE 9820. Neither of these assemblages have yielded the hybodont sharks and chimaeroids common within the Gault at Folkestone, Kent (TR 2235), and large lamniforme teeth are also rare in contrast to Folkestone. However, *Notorhynchus* is much more common at Speeton and South Ferriby (C. Underwood, pers. comm., 1996).

Aptian and Albian deposits from mainland western Europe have also yielded similar fish faunas. These include those of Perle du Rhône, St. Croix, Pierre Jaune, Neuchâtel and Landeron, Switzerland (Pictet and Campiche, 1858a, 1858b, 1860), and Auxerre (Aube) and Alais (Gard), France (Keeping, 1883).

Conclusion

The section at East Wear Bay, Folkestone, is Britain's best Gault fish site. It has yielded one of the finest mid-Cretaceous fish faunas in the world. This international importance and the continuing yield of specimens establishes the site's high conservation value.

LATE CRETACEOUS: THE CHALK

The Late Cretaceous Chalk facies (Figure 13.11) of Britain (Cenomanian–Maastrichtian) have produced abundant fossil fish material from many British localities. Apart from areas such as the Welsh landmass and parts of Scotland, the Chalk seas covered most of the British Isles. The present outcrop stretches from south Devon through the English Midlands and South Downs to Norfolk, Lincolnshire and Yorkshire. The lithological and faunal differences between the Chalk of Lincolnshire and Yorkshire and that from southern England have led to the establishment of two provinces ('Northern' and 'Southern') for the English Chalk succession (Mortimer, 1878; Wood and Smith, 1978; Figure 13.11).

Although the Chalk sequence in the British Isles is fairly uniform in sedimentary character, enough variation exists for a lithostratigraphical classification. The Chalk has traditionally been split into three informal lithological groupings, the 'Lower', 'Middle' and 'Upper' Chalk based on the presence of certain marker bands, such as glauconitic marls, hardground horizons and flints. This broad lithostratigraphical tripartite division of the Chalk was recognized as early as 1822 by John Phillips (*in* Conybeare and Phillips, 1822) and has been used subsequently by many authors. However, by far the most satisfactory subdivision of the Chalk is by zone fossils, for example echinoids or nannofossils. Jukes-Browne and Hill (1903, 1904) provided a classic review of the stratigraphy of the British Chalk, and their work has been revised by Kennedy (1969), Rawson *et al.* (1978) and Wright and Kennedy (1984). Figure 13.11 shows the lithological and biostratigraphical subdivisions of the Chalk (after Owen, 1975).

Chalk fishes are commonly represented by fragmentary specimens, but whole uncrushed fish are also known from several localities in the 'Lower' and 'Middle' Chalk. They were first noticed in the 'Lower' and 'Middle' Chalk succession of the South Downs (Sussex and Kent) in the early part of the 19th century by Gidean Mantell, who subsequently made a large collection of fossil fishes there (Mantell, 1822). The writings of Mantell and Louis Agassiz (1833–1845) aroused the interest in south-east England of several local collectors, which led to a series of papers in the mid- and late 19th century on the Chalk and its fossils. Important references of that time include Dixon (1850), Barrois (1876), Newton (*in* Dixon, 1878), Jukes-Browne and Hill (1903, 1904) and culminating in the monograph of Chalk fishes by A.S. Woodward (1902–1912). Although more recent reviews of the certain elements of the fish fauna have been completed and several taxa renamed or redescribed, Woodward's monograph is still the most complete account of Chalk fishes. A more recent summary was completed by the Palaeontological Association (Longbottom and Patterson, 1987) and this includes the modern classification and terminology.

Fish remains are widely distributed in the Chalk, but apart from microvertebrate remains recovered from acid digestion of the soft limestone, they are quite rare at outcrop. Most of the large collections of partial and complete fish specimens were made in the 19th century when the Chalk was worked by hand at many pits throughout the country; today only fragmentary remains are usually found. The Lower Chalk and in particular the old ***subglobosus*** Zone (equivalent to the Upper Cenomanian; Figure 13.11) is of special interest for the number of vertebrate fossils it has yielded. Fifty-five named species of fish are recorded by Woodward (1902–1912) from the Lower Chalk. The Middle Chalk is also remarkably rich in fossil fish remains and Woodward (1902–1912) recorded 23 species from these rocks. Fish material has been recovered from the Upper Chalk, but is much rarer than in the underlying strata. Several large collections of fossil fishes made in the South Downs area are housed in the BMB, NHM, BGS(GSM), CAMSM and MAIDM. In contrast, fish remains are very rare in the northern Chalk province above the Hunstanton Formation, although marl bands have yielded sporadic finds. The Middle Cenomanian 'primus event' marl exposed at Speeton contains specimens of *Notorhynchus aptiensis*, scyliorhinids and *Squatina*, and small scyliorhinid and orectolebid teeth have also been recovered from the Black Band in the Upper Cenomanian Chalk at South Ferriby (C. Underwood, pers. comm., 1996). These assemblages are more similar in composition to those of the Early Cretaceous in these parts though, and bear little resemblance to those of the southern province, with its abundant anacoraxid sharks, large lamnid sharks, the hybodont *Ptychodus* and abundant holostean and teleost remains.

The Cenomanian and Santonian successions of Lebanon have yielded extremely important fish faunas, in which whole fish specimens have been recovered. These include sharks, rays and bony fish material comparable to that of the British Chalk.

FISH SITES

Fish material has been recovered from at least 100 Chalk localities spread throughout the whole outcrop (based on literature references and museum specimens). However, most of these sites have only yielded fragmentary remains of one or two fish species, and thus only the more significant ones are listed below by county from the south-west to north-east, with zones indicated, where known (taken mainly from Jukes-Browne and Hill, 1903; 1904; Woodward, 1902–1912):

WILTSHIRE: Porton Railway Cutting (Upper Chalk, *coranguinum* Zone; SU 1936; six species); Harnham Quarries (Upper Chalk, *quadrata* Zone; ?SU 1428; 18 species); Highfield (Upper Chalk, *marsupites* Zone; ?SU 0038; 13 species); Witherington Railway Cutting (Upper Chalk, *coranguinum* Zone; six species); Whaddon Railway Cutting (Upper Chalk, *quadrata* Zone; SU 1926; 11 species).

HAMPSHIRE: Bar End Pit (Lower Chalk, '*H. subglobosus*' Zone; ten species); Hursley Pits (Upper Chalk, *quadrata* Zone; SU 4225; seven species); Stoke Hill (Middle Chalk, *lata* Zone; SU 4051; seven species); Winchester (Middle Chalk, *labiatus* and *lata* Zones and Upper Chalk, *coranguinum* Zone; SU 4830; 14 species).

BERKSHIRE: Boxford Chalk Pit (Upper Chalk, Turonian–Santonian; SU 431719; 12 species, see report).

SUSSEX: Amberley Station Quarry (Lower Chalk, Chalk Marl, *dixoni* Zone and Middle Chalk, *labiatus* and *lata* Zones; TQ 027118; 15 species, including the type specimen of *Lophiostomus dixoni* Egerton, 1852); Beachy Head (Middle and Upper Chalk, Turonian; TV 5866; 17 species); Clayton Limeworks and Railway Tunnel (Lower Chalk, Cenomanian; TQ 2913; 12 species, including the type specimens of *Berycopsis elegans* Dixon, 1850, *Plethodus oblongus* Dixon, 1850 and *Squatina cranei* Woodward, 1888); Eastbourne coastal outcrop (Lower Chalk, Chlorite and Chalk Marls, *mantelli* and *dixoni Zones*; TV 6192; 13 species); Glynde Station Quarry (Lower Chalk, Chalk Marl, *dixoni* Zone and Middle Chalk, *labiatus* and *lata* Zones; TQ 460085; 30 species, including type specimens: *Anomoeodus willetti* Woodward, 1893, *Dercetis latiscutatus* Woodward, 1903, *Edaphodon reedi* Newton, 1878, *Enchelurus anglicus* Woodward, 1901, *Protelops anglicus* Woodward, 1888); Houghton (Middle Chalk, *labiatus* and *lata* Zones; ?TQ 014110; ten species, including type specimens: *Anomoeodus augustus* (Agassiz, 1837–1844), *Plicatolamna (Oxyrhina) crassidens* (Dixon, 1850), *Urenchelys anglicus* Woodward, 1901); Southerham (Machine Bottom) (Lower Chalk, Chalk Marl, *dixoni* Zone and Middle Chalk, Melbourn Rock, *labiatus* and *lata* Zones; TQ 432091; 53 species, including 33 type specimens, see report); Southerham Grey Pit (Lower Chalk, Chalk Marl and Grey Chalk, *dixoni* and *rhotomagense* Zones; TQ 427090; 14 species, see report); Southerham (Lime Kiln Quarries) (Middle Chalk, 'Strahan's Hardground': Ranscombe Member, ?*labiatus* Zone; TQ 426096; nine species, see report).

SURREY: South Croydon (Upper Chalk, *coranguinum* Zone; 12 species); Halling (Upper Chalk, *coranguinum* Zone; TQ 7063; 12 species).

KENT: Folkestone (Lower Chalk, Chloritic Marl and Chalk Marl, *mantelli* and *dixoni* Zones; TR 243812; 11 species, including type specimen: ?'*Lepidotes*' *pustulatus* Woodward, 1895a); Dover (Middle and Upper Chalk, *labiatus–socialis* Zones; TR 3141; 26 species, including type specimens: *Ichthyodectes elegans* Newton, 1877, *Saurodon intermedius* (Newton, 1878), *Scyliorhinus (Scyllium) dubium* (Woodward, 1889), *Synechodus dubriensis* (Mackie, 1863)); Gravesend (Upper Chalk, *coranguinum* Zone; ?TQ 6474; ten species including type specimen: *Pholidophorus disjectus*); Halling (Lower and Middle Chalk, '*H. subglobosus*' and *labiatus* Zones; TQ 7064, various quarries; 17 species including type specimens: *Coelodus fimbriatus* Woodward, 1888, *Neorhombolepis excelsus* Woodward, 1888); Cuxton (Lower and Middle Chalk, '*H. subglobosus*' and *labiatus* Zones; ?TQ 7066; 12 species); Blue Bell Hill, Burham (Lower Chalk–Upper Chalk, Cenomanian–Turonian; TQ 738617; 58 species, including 13 type specimens, see report); Chatham (Upper Chalk, *plana* and *cortestudinarium* Zones; ?TQ 7604; nine species).

BEDFORDSHIRE: Totternhoe Chalk Pit (Lower Chalk, Totternhoe Stone, *rhotomagense* and *jukesbrowni* Zones; SP 982222; 19 species, see report).

HERTFORDSHIRE: Arlesey Quarry, Hitchin (Lower Chalk, Totternhoe Stone, *rhotomagense* and *jukesbrowni* Zones; TL 1936; seven species); Hitchin Station Quarry (Middle Chalk, *labiatus* and *lata* Zones; TL 1929; five species).

CAMBRIDGESHIRE: Cherry Hinton (Lower Chalk, Totternhoe Stone, *rhotomagense* and *jukesbrowni* Zones and Upper Chalk, Chalk Rock, *plana* Zone; TL 483557, TL 485558; 15 species, including type specimen: *Pachyrhizodus subulidens* (Owen, 1842)).

NORFOLK: Hunstanton Cliffs (Lower Chalk, Totternhoe Stone *rhotomagense* and *jukesbrowni* Zones and Upper Chalk, Norwich Chalk, *mucronata* Zone (TF 672413); seven species, including type specimen: *Plicatolamna (Lamna) arcuata* (Woodward, 1894)).

Six sites are selected as GCR sites on the basis of their important Cretaceous fish faunas:

1. Blue Bell Hill Pits, Burham, Kent (TQ 738617). Late Cretaceous (Cenomanian–Turonian), Lower Chalk–Upper Chalk.
2. Totternhoe (Chalk Pit), Totternhoe, Bedfordshire (SP 982222). Late Cretaceous (Cenomanian), Lower Chalk (Totternhoe Stone).
3. Southerham (Machine Bottom Pit), Southerham, Lewes, East Sussex (TQ 432091). Late Cretaceous (Cenomanian –Turonian), Lower Chalk (Chalk Marl, Grey Chalk and *Plenus* Marl) and Middle Chalk (Melbourn Rock).
4. Southerham Grey Pit, Southerham, Lewes, East Sussex (TQ 427090). Late Cretaceous (Cenomanian), Lower Chalk (Chalk Marl and Grey Chalk).
5. Southerham (Lime Kiln Quarries), Southerham, Lewes, East Sussex (TQ 426096). Late Cretaceous (Turonian –Coniacian), Middle Chalk ('Strahan's Hardground': Ranscombe Member).
6. Boxford Chalk Pit, Berkshire (SU 431719). Late Cretaceous (Turonian– Santonian) Upper Chalk.

BLUE BELL HILL PITS (TQ 738617)

Highlights

The Blue Bell Hill Pits, Burham, in Kent are one of Britain's richest Chalk (Late Cretaceous) fish sites (Figure 13.12). During active quarrying production the pits on Blue Bell Hill produced remains of over 60 species of fish from the Lower and Middle Chalk succession. Much of the fossil fish material is well preserved, frequently without significant crushing or distortion. Articulated material and delicate cranial remains have been recovered from the Burham pits and description of these specimens has formed the basis for several monographs on Chalk fishes.

Introduction

The two Culand Pits on Blue Bell Hill near Burham, the Lower Pit (TQ 737613) and the Upper Pit (Figure 13.12; TQ 739619), have yielded some of the most important fossil fishes from the British Chalk. The material is extremely well preserved, in many cases with little distortion or disarticulation. The fauna includes 13 type specimens and several other taxa which are rare elsewhere. The type and only specimen of the galeomorph shark *Cantioscyllium decipiens* Woodward, 1899 was recovered from Blue Bell Hill in the late 19th century. This specimen is a well-preserved, incomplete skeleton that shows not only articulated jaws and vertebral column, but also an associated braincase, which is rarely preserved in sharks. The quarries are still accessible, although no longer worked. Further finds could be made with excavation.

Lower Culand Pit is in the Lower Chalk (Cenomanian) and Upper Culand Pit is in the Middle and Upper Chalk (Turonian; Figure 13.11). Jukes-Browne and Hill (1903) gave a sketch section that makes this clear. Further details of the quarries are given in papers by Dibley (1900, 1904, 1907, 1918, Dibley and Spath, 1926) and by Dines *et al*. (1954). Kennedy (1969) gave a section, with details of the ammonites, for the Lower Chalk. The fish finds have been described by Dixon (1850), Woodward (1888b, 1902–1912) and Woodward and Sherborn (1890).

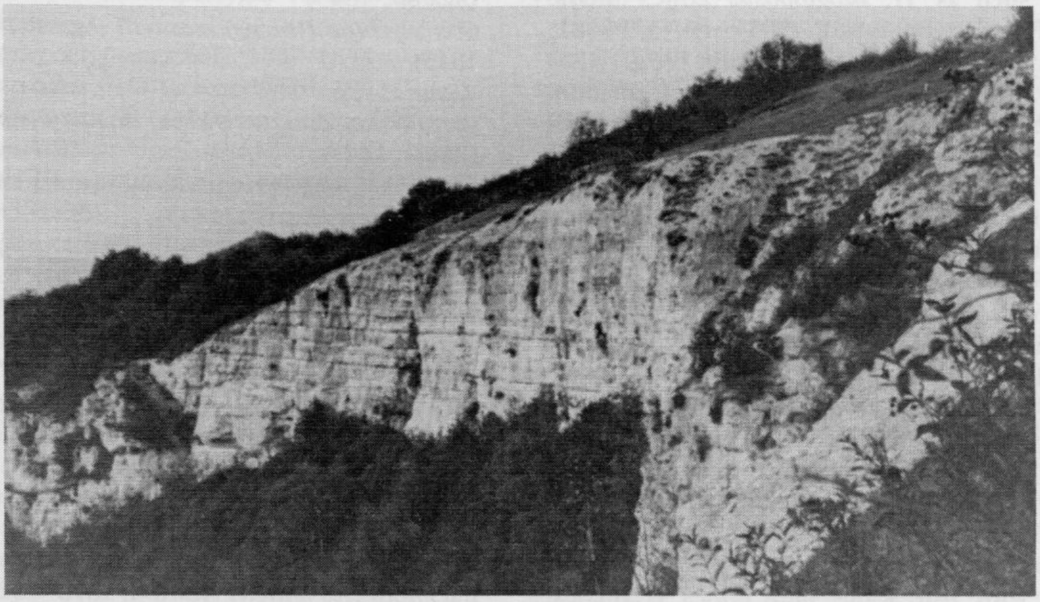

Figure 13.12 Photograph of Blue Bell Hill upper chalk pit: north-east face (photo: S.J. Metcalf).

Description

The pit faces on Blue Bell Hill form a prominent feature in the landscape, as they are cut into the North Downs. The pits probably display one of the best and most complete inland sections of the Chalk in southern England. There are two main pits on Blue Bell Hill, known as the Culand pits, and a combined section of the Chalk in the two quarries, summarized from Jukes-Browne and Hill (1903) and Dines *et al.* (1954) is:

	Thickness (m)
Upper Culand Pit	
Soil	0.3
Upper Chalk/*planus* Zone	
Very rough, rubbly hard crystalline chalk	6.1
Rough, lumpy chalk	4.9
Layer of flints	0.2
Massively bedded chalk	1.5
Layer of flints	0.2
Rough, hard, lumpy chalk	1.1
Layer of flints	0.2
Rather rough and lumpy chalk	0.9
Rather rough, hard chalk with scattered flints	0.9
	15.8
Middle Chalk (*lata* and *labiatus* Zones)	
Firm, soft, lumpy chalk	1.2
Firm, white, smooth chalk	7.6–9.1
Massive homogeneous white chalk	35.7
	c. 46.1
Lower Culand Pit	
Middle Chalk and Melbourn Rock	9.1
Lower Chalk	
Plenus Marls (Belemnite Marls; *gracile* Zone)	
Yellowish grey laminated marl	0.3–0.4
Pale yellowish grey marly chalk	1.8
Grey Chalk and *mantelliana* Band (*naviculare* and *rhotomagense* Zones)	
Beds 6, 7 and 8. Firm white chalk passing gradually down into grey chalk	*c.* 25 m
Bed 5. Grey marly chalk	*c.* 5 m

The fossil fish specimens seem to have been derived from several horizons in the Chalk succession exposed at Blue Bell Hill, but the labels of many of the museum specimens do not provide detailed stratigraphical information. Some museum specimens are labelled 'Lower Chalk' (e.g. NHM P.3977) or 'Middle Chalk' (e.g. NHM

1703, 4034) and some are even labelled to zonal level, such as '*H. subglobosus* Zone, Middle Chalk' (e.g. NHM 49014, 49054, 49073, P.5681) or '*S. plana* Zone, Upper Chalk' (e.g. NHM P.111), but others lack horizon information. Hence it is impossible to gain an impression of the vertical distribution of fish finds through the Chalk in the Blue Bell Hill pits. It is most probable that much of the vertebrate material came from the Lower Chalk of the Lower Pit, as the Middle and Upper Chalk are much less vertebrate rich.

The fossil fishes are generally well preserved and fine detail may be seen. Individual specimens may be largely articulated or broken up. Often only isolated teeth and vertebrae of larger forms are found. The Lower Chalk (*rhotomagense* Zone) of the large southern pit shows numerous small crustacean or worm burrows (*Terebella lewesiensis*) which are commonly lined with fish scales and bones (Hancock, 1958). In the past these burrows have been mistaken for complete fish specimens (e.g. Mantell, 1822), as the elongate tube looks vaguely like the skeleton of an eel-like fish (Longbottom and Patterson, 1987). The Chalk succession of Blue Bell Hill has also yielded a rich invertebrate fauna, housed in the NHM and BGS(GSM), and documented by Dibley (1900, 1922) and Dines *et al.* (1954).

Fauna

The abundant remains from the Blue Bell Hill Pits are preserved in the NHM, CAMSM, and MAIDM. These are generally labelled 'Burham' or 'Blue Bell Hill'. The following list has been derived from Woodward (1902–1912):

Chondrichthyes: Elasmobranchii: Euselachii: Hybodontoidea
- *Ptychodus decurrens* Agassiz, 1835–1839
- *P. latissimus* Agassiz, 1835–1843
- *P. mammillaris* Agassiz, 1835–1839
- *P. polygyrus* Agassiz, 1835–1839
- *P. polygyrus* var. *marginalis* Agassiz, 1835–1839

Chondrichthyes: Elasmobranchii: Neoselachii: Squalomorphii
- *Hexanchus (Notidanus) microdon* (Agassiz, 1843)

Chondrichthyes: Elasmobranchii: Neoselachii: Galeomorphii
- *Cantiosyllium decipiens* Woodward, 1889
- *Cretolamna (Lamna) appendiculata* (Agassiz, 1843)
- *Cretoxyrhina (Isurus) mantelli* (Agassiz, 1843)
- '*Lamna*' spp.
- *Paranomotodon (Oxyrhina) angustidens* (Reuss, 1843)
- *Scapanorhynchus rhapiodon* (Agassiz, 1844)
- *S. subulatus* (Agassiz, 1843)
- *Scyliorhinus antiquus* (= *Scyllium antiquum* Agassiz, 1843)
- *Squalicorax (Corax) falcatus* (Agassiz, 1843)
- *Synechodus (Hybodus) dubrisiensis* (Mackie, 1863)

Chondrichthyes: Holocephali: Chimaeriformes
- *Edaphodon (Ischyodus) agassizi* (Buckland, 1835–1836)
- *Edaphodon (I.) mantelli* (Buckland, 1835–1836)
- *E.* sp. (fin spines)
- *Elasmodectes willetti* Newton, 1878
- *Ischyodus thurmanni* Pictat and Campiche, 1858
- *I. incisus* Newton, 1878

Osteichthyes: Actinopterygii: Neopterygii: Halecomorphi
- *Neorhombolepis ?punctatus* Woodward, 1895
- *Tomognathus mordax* Dixon, 1850

Osteichthyes: Actinopterygii: Neopterygii: Teleostei
- *Apsopelix (Syllaemus) anglicus* (Dixon, 1850)
- *Belonostomus cinctus* Agassiz, 1837–1844
- *Dinelops ornatus* Woodward, 1901
- *Enchelurus anglicans* Woodward, 1902–1911
- *Ichthyodectes (Hypsodon) minor* (Egerton, 1850)
- *I. tenuidens* Woodward, 1901
- *Ichthyodectes* sp.
- *Osmeroides latifrons* Woodward, 1902–11
- *O. levis* Woodward, 1895
- *Pachyrhizodus basalis* Dixon, 1850
- *P. dibleyi* Woodward, 1901
- *P. (Acrodontosaurus) gardneri* (Mason, 1869) (= *P. basalis* Forey, 1977)
- *P. (Raphiosaurus) sublidens* (Owen, 1842)
- *Plethodus expansus* Dixon, 1850
- *P. oblongus* Dixon, 1850
- *P. pentagon* Woodward, 1899
- *Protosphyraena ferox* Leidy, 1857
- *P. (Saurocephalus) minor* (Agassiz, 1837–1844)
- *Xiphactinus (Portheus) mantelli* (Newton, 1877)

parasphenoid dentition of elopiform fish
Osteichthyes: Actinopterygii: Neopterygii: Euteleostei
Aulolepis typus Agassiz, 1837–1844
Apateodus striatus Woodward, 1901
Caproberyx (B.) superbus (Dixon, 1850)
Cimolichthys levesiensis Leidy, 1857
Ctenothrissa (Beryx) microcephala (Agassiz, 1835–1838)
C. (B.) radians (Agassiz, 1835–1838)
Enchodus (Esox) lewesiensis (Mantell, 1822)
Eurypholis pulchellus Woodward, 1901
Halec (Pomognathus) eupterygius (Dixon, 1850)
Hoplopteryx (Beryx) lewesiensis (Mantell, 1822)
H. simus Woodward, 1902
Homonoicthys dorsalis Dixon, 1850
H. rotundus Woodward, 1902–1911
Platycormus (Berycopsis) elegans Dixon, 1850
Sardinoides illustrans Woodward, 1902–1911
Osteichthyes: Sarcopterygii: Actinistia
Macropoma mantelli Agassiz, 1835–1844
M. praecursor Woodward, 1909
Macropoma sp. (coprolites)

Interpretation

The fishes of the Chalk at Burham were reviewed by Woodward between 1902 and 1912. As well as the fish fauna (Figure 13.13), the chalk pits at Blue Bell Hill have yielded a reptile fauna of international importance: see the GCR volume on fossil reptiles (Benton and Spencer, 1995). The reptile assemblage is of mainly marine forms including turtles, plesiosaurs and mosasaurs, but also contains three type specimens of the piscivorous pterosaur *Ornithocheirus*.

The specialized hybodont *Ptychodus* is represented in the Blue Bell Hill shark fauna by four species, all of which have been found elsewhere in the Chalk. All are based on isolated quadrate teeth or, in the case of *P. decurrens* Agassiz, 1835–1839, on partial dentition. The fauna also contains abundant advanced selachians, including a representative of the the six- or seven-gilled hexanchid squalomorphs or cow-sharks. *Hexanchus (Notidanus) microdon* (Agassiz, 1843) is an extinct form, known only from the isolated occurrences of its multicuspid, comb-like, lower teeth in the English Chalk. This is a relatively small species of *Hexanchus*, with teeth only about 12 mm in width (Longbottom and Patterson, 1987).

Galeomorph sharks, well represented in the Blue Bell Hill fish assemblages, include two type specimens. The orectolobid *Cantiosyllium decipiens* Woodward, 1889 is probably the most important fossil fish to have been recovered from the Culand pits (Figure 13.13A), as the monospecific genus is only known from the type specimen (a crushed but partially complete skeleton) and a few scattered teeth from the Turonian of South Dakota, USA (Cappetta, 1973), and in the Cenomanian–Turonian of Northern France (Herman, 1977). The second type at Burham is that of the dogfish *Scyliorhinus antiquus* (Agassiz 1843), which is based on a skeleton that exhibits parts of the head cartilages, the jaws and some anterior vertebrae (Figure 13.13 (B–D); Woodward, 1902–1912). Usually only the tiny (2.5 mm wide) teeth of this genus are found within acid residues (Longbottom and Patterson, 1987).

More common elements of the galeomorph shark component of the Burham fauna are the large piercing teeth of Lamniformes. These include the cretoxyrhinids, *Cretolamna appendiculata* (Agassiz) and *Cretoxyrhina mantelli* (Agassiz), the mitsukurhinids *Scapanorhynchus raphiodon* (Agassiz) and *Sc. subulatus* (Agassiz), the alopiid *Paranomotodon angustidens* (Reuss), and the anacoracid *Squalicorax falcatus* (Agassiz). The teeth of these predatory sharks are common in all Chalk facies (Longbottom and Patterson, 1987), where they probably competed with the aquatic reptiles for the top carnivore niche in the pelagic environment. Teeth of the small enigmatic palaeospinacid shark *Synechodus dubrisiensis* (Mackie) have also been recovered by acid digestion of the Lower Chalk at Burham.

Chimaeroids are well represented in the Blue Bell Hill pits, although elsewhere in the Chalk, holocephalian remains are rare and fragmentary (Newton). Those from Burham include two species of the typical Cretaceous and early Tertiary genus *Edaphodon* (based on tooth plates) and a fin spine of the same taxon, and the small, rare genus *Elasmodectes willetti* Newton, 1878 which is known from only four localities in the English Chalk (Woodward, 1902–1912, and see the Southerham (Machine Bottom Pit) report). The Jurassic genus *Ischyodus* is represented in the Burham fauna by the Gault species *I. thurmanni* Pictet and

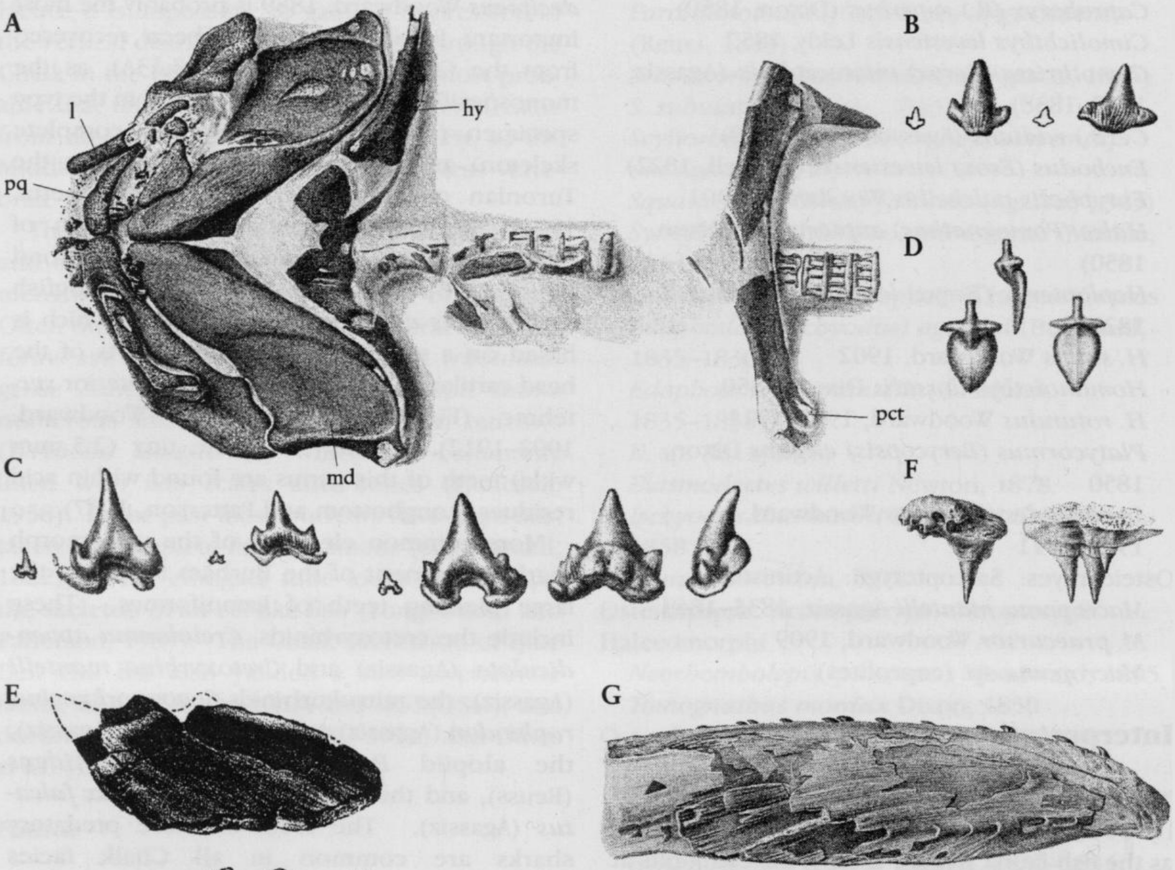

Figure 13.13 Fossil fishes from Burham Blue Bell Hill Pits (all from Woodwood, 1895a): (A) *Cantioscyllium decipiens* Woodward, anterior part of the skeleton; hy, hyoid arch; md, mandible; pct, pectoral arch; pq, palato-quadrate, × 0.75; (B), (C) *Scyliorhinus antiquus* (= *Scyllium antiquum*) Agassiz, teeth in labial and lingual views, × 4.0 and × 0.5 respectively; (D) *Scylliorhinus antiquus* (= *Scyllium antiquum*) Agassiz, dermal denticles, *c.* × 10; (E) *Ischyodus incisus* Newton, left mandibular dental plate; outer, inner and upper views, × 1.5; (F), (G) *Pachyrhizodus basalis* Dixon; (F) part of the right premaxilla with teeth, × 1; (G) right dentary in lower and inner aspects, × 0.25; (H) *Pachyrhizodus dibleyi* Woodward, left maxilla in outer view , × 0.3.

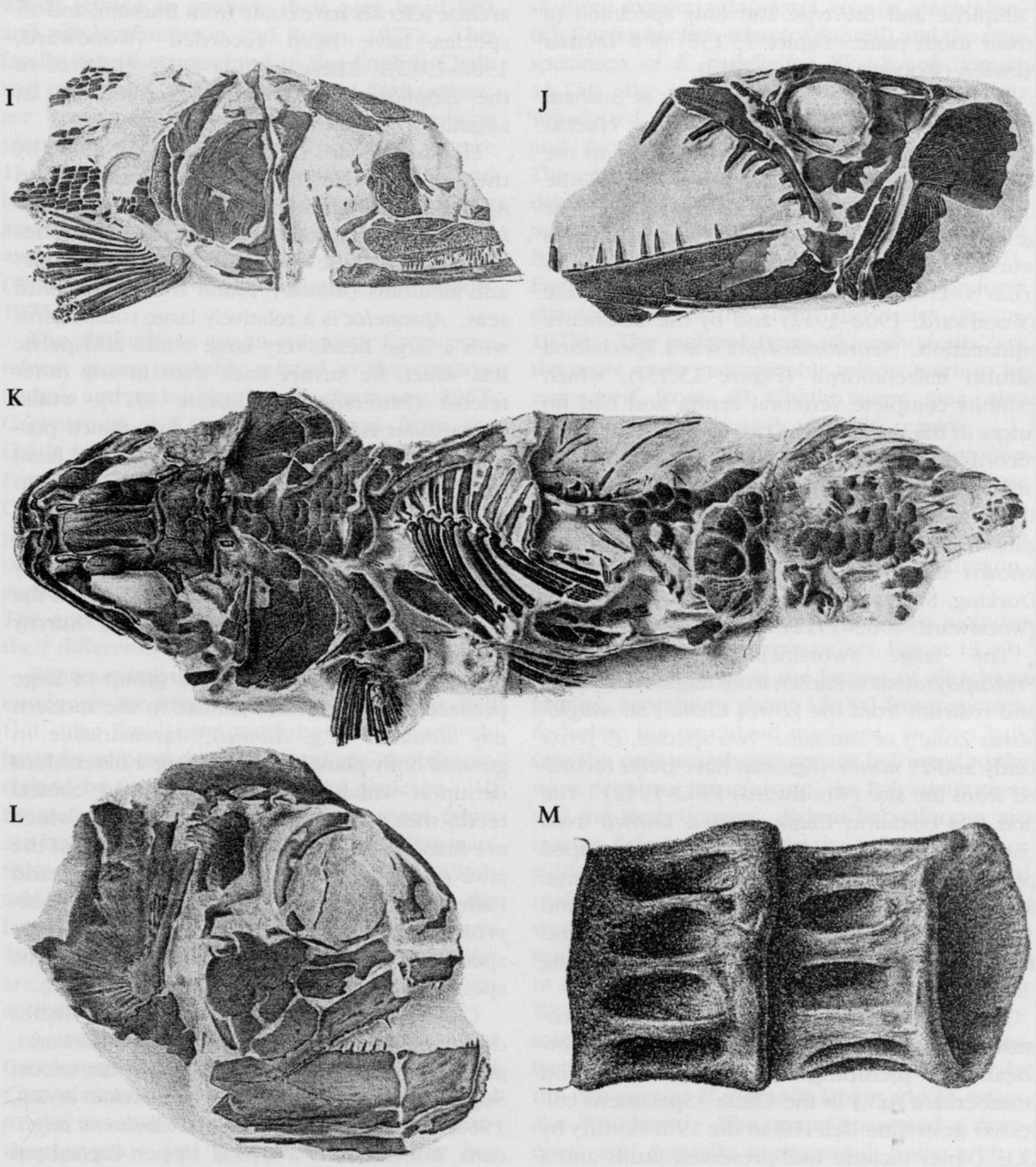

Figure 13.13 – *contd*. Fossil fishes from Burham Blue Bell Hill Pits (all from Woodwood, 1895a): (I) *Neorhombolepis excelsus* Woodward (from Kent), imperfect head and anterior abdominal region (*N. punctatus*) Woodward, (known from scales in Burnham area), × 0.6; (J) *Enchodus pulchellus* Woodward, holotype (NHM P.1703) left-hand side of the head and opercular area, , × 0.9; (K) *Sardinioides illustrans* Woodward, holotype (NHM P.3977) imperfect crushed specimen in ventral view , × 0.6; (L) *Ichthyodectes tenuidens* Woodward, right side of head and jaw,× 1; (M) *Ichthyodectes* sp., two vertebral centra, × 1.

Campiche and the type and only specimen (a lower tooth plate: Figure 13.13E) of *I. incisus* Newton (Woodward, 1902–1912).

Bony fish remains from the Chalk at Burham include neopterygians. *Belonostomus cinctus* Agassiz is one of the last representatives of the aspidorhynchid fishes that ranged from the Upper Jurassic to the Upper Palaeocene. The genus has been found in Cretaceous formations worldwide, and is characterized by the long rostrum overhanging an equally long mandible (Woodward, 1902–1912) and by the distinctive squamation. *Neorhombolepis* was a specialized caturid halecomorph (Figure 13.13I), which exhibits complete vertebral centra and had no fulcra in the paired fins. Two species have been recorded from the Lower Chalk of Kent, the second, *Neorhombolepis punctatus* Woodward, 1895, being based upon isolated but distinct ganoid scales from Burham. *N. punctatus* is also known from the '*H. subglobosus*' Zone of Dorking, Surrey and Louth, North Lincolnshire (Woodward, 1902–1912).

The large swordfish-like pachycormid *Protosphyraena* is known from fragmentary jaws and rostrum from the Lower Chalk ('*H. subglobosus* Zone') of Burham. Two species, *P. ferox* Leidy and *P. minor* (Agassiz) have been recorded from the site (Woodward, 1902–1912). The first is a common Chalk species, known from partial skulls and the characteristic sickle-shaped pectoral fins. *Protosphyraena ferox* was a large fish (the rostrum reaches 0.3 m in length) and has been noted in most Cenomanian and Turonian Chalk localities and in the underlying Cambridge Greensand (Cenomanian).

Tomognathus mordax Dixon is a halecomorph neopterygian known from only a few localities, including Blue Bell Hill and Southerham (q.v.) in the Chalk. Specimens collected from Blue Bell Hill in the 19th century by G.E. Dibley include well-preserved skulls and a partially complete skeleton, which suggest that *Tomognathus* was long-bodied, with a feebly ossified endoskeleton, large pectoral fins and a triangular caudal fin. The head was short and laterally compressed, with a very large eye and strongly curved, slender teeth. In general morphology, *Tomognathus* resembles the modern stomiiform teleosts, predators which inhabit a deep-sea niche.

Teleosts and euteleost bony fish are well represented in the Chalk fauna from Blue Bell Hill (Figure 13.13). Six type specimens of the more archiac teleosts have come from Burham, and 15 species have been recorded (Woodward, 1902–1912). These include representatives of the Elopiformes, the Icththyodectiformes, an anguilliform and the enigmatic plethodonts.

Elopiformes are represented in the fauna by the type specimens of the crossognathid *Apsopelix anglicus* (Dixon) and *Osmeroides levis* Woodward, both fusiform elopiform fishes that resemble the modern tarpon (*Megalops*) and albuloids (*Albula*), found today in tropical seas. *Apsopelix* is a relatively large robust form with a large head, very large scales and pelvic fins which lie farther back than in any other teleost (Patterson and Rosen, 1977), whilst *Osmeroides* is a much smaller fish, which possessed a tubular, non-laterally compressed head and body (Forey, 1973a). *Dinelops* is similar to the Upper Cretaceous 'pseudotarpon' genera *Notelops* and *Protelops*, recovered from Brazil and the former Czechoslovakia respectively (Forey, 1973a, 1973b); it is known only from the Lower Chalk of Kent and Dorking, Surrey (Woodward, 1902–1912).

The pachyrhizodontids are a group of large predaceous elopiformes similar to the modern day albuloids (e.g. *Albula*), unremarkable in general body-plan, but possessing a heterodont dentition which includes robust and conical teeth, with a characteristic swollen base, which are fused to and surrounded by the bone of the jaws (Woodward, 1902–1911; Longbottom and Patterson, 1987). Two type specimens of *Pachyrhizodus* are recorded from Burham, the type species *P. basalis* Dixon and the more robust species *P. dibleyi* Woodward (Figure 13.13H).

Closely related to the elopiform fishes described above, are the eels or Anguilliformes, and the two orders are united within the teleost Superorder Elopomorpha (Greenwood *et al.*, 1966; Forey, 1973a, 1973b). *Enchelurus anglicans* Woodward is a typical Upper Cretaceous anguilliform that differs from modern and Tertiary eels in possessing distinct tail and pelvic fins.

The Ichthyodectiformes are an extinct order of Mesozic teleost fishes, a sister group of the extant osteoglossomorphs (Greenwood *et al.*, 1966, 1973; Patterson and Rosen, 1977), and similar in general appearence to the living clupeiform *Cheirocentrus* (Woodward, 1902–1912; Bardack, 1965). The icthyodectids possess a large triangular supraoccipital crest, fused parietals, and were large (up to 2 m long) teleosts, which tended to swallow their prey head first and whole (Patterson and Rosen, 1977). This family is well represented in the English Chalk and two genera, *Ichthyodectes* and *Xiphactinus*, are known from Burham, including the type specimen of *I. tenuidens* Woodward (Figure 13.13L, M). Both had long fusiform bodies and large heads with an upward-pointing lower jaw and slightly protruding upper jaw, both lined with sharp hollow teeth set in deep sockets (Woodward, 1902–1912; Bardack, 1965; Nelson, 1973).

The plethodonts are an enigmatic Cretaceous teleost group probably related to the crossognathids and pachyrhizodontids (Patterson, 1967; Greenwood, 1973), which ranged from the Gault to the Upper Chalk, and of which *Plethodus* is the only genus recorded from the Chalk (Longbottom and Patterson, 1987). The plethodonts had a crushing dentition consisting of two opposing plates with smooth grinding surfaces formed from the fusion of small teeth. The species of *Plethodus* are characterized by their differently shaped tooth plates.

Representatives of the higher teleosts or euteleosts are found in the Chalk at Blue Bell Hill. The Euteleostei are fishes that primitively have an adipose dorsal fin, and are also characterized by features of the caudal skeleton. All those forms represented in the Burham fauna are highly advanced eutelosts or 'neoteleostean' fishes as defined by Rosen and Patterson (1969) and Rosen (1973). The neoteleosts are the largest group of living bony fishes (Rosen, 1973), and hence those of the Chalk succession are extremely important in defining basal characteristics of the group.

Among the neoteleosts, the extinct Cretaceous ctenothrissiform fishes *Aulolepis* and *Ctenothrissa* of Patterson (1964, 1968) are allied to the two major neoteleost groups, the acanthopterygians and paracanthopterygians, but seem to form their sister-group (Rosen, 1973).

The Chalk euteleosts also include several taxa referrable to the aulopiforms (Rosen, 1973). The Chalk aulopiforms are commonly referred to the informal grouping 'enchodonts' by many authors (Woodward, 1902–1912; Goody, 1969; Longbottom and Patterson, 1987) and were predatory fishes with characteristic fangs, probably with a lifestyle similar to that of extant deep-sea predators like the lancet-fish, *Alepocephalus* (Longbottom and Patterson, 1987). 'Enchodonts' at Burham include representatives of three extinct aulopiform groups, enchodontids *Enchodus lewesiensis* (Mantell) and the type specimen of *E. pulchellus* Woodward (Figure 13.13J), the cimolichthyid *Apateodus striatus* Woodward, and *Cimolichthys lewesiensis* Leidy, and the halecoid *Halec eupterygius* (Dixon). The general morphology of the 'enchodonts' is displayed in the type specimen of *Eurypholis pulchellus*, an imperfect head recovered from Burham and described by Woodward (1901). *Enchodus* shows some advanced aulopiform characteristics in the snout and scales (Rosen, 1973). The isolated fangs of 'enchodonts' are the more easily recognizable teleost teeth to be recovered from all Chalk facies (see also Southerham (Machine Bottom Pit) report).

The sardinoidid myctophiform *Sardinoides illustrans* Woodward is known from the type specimen (an almost complete fish: Figure 13.13K) and a skull from the ?Lower Chalk of Burham (Woodward, 1902–1911; Patterson, 1964).

The Burham neoteleost fauna also includes several acanthopterygian taxa (see Figure 13.19). The Acanthopterygii is the largest of all teleost groups, containing about 15 000 living species, including the perch and mackerel. In the Chalk seas the only acanthopterygians belonged to the most primitive living group, the Polymixiiformes and the Beryciformes. Extant beryciformes are marine fishes and include the holocentroids or soldier-fishes, which commonly inhabit coral reefs, and the trachithyoids, which are deep-water oceanic fishes. The latter group is represented in the Blue Bell Hill fauna by two species of *Hoplopteryx*, including the type of *H. simus* Woodward, and two of *Homonotichthys*, a polymixiid. However, *Homonotichthys* is a less perfectly known genus, being represented only by the two species *H. dorsalis* Dixon and *H. rotundus* Woodward. The genus possessed a deepened and laterally compressed body, with a much extended dorsal fin and consipicuous lateral line of ridged scales (Woodward, 1902–1912). Both species are known from the Lower Chalk of Kent and *H. dorsalis* ranges well into the highest zones (*quadrata* and *mucronata* Zones) of the Upper Chalk (Woodward, 1902–1912).

The second beryciform group represented in the Burham fish collections are the polymixiids, by the species *Berycopsis elegans* (Dixon). Several good specimens of *Berycopsis elegans* have been found in the Cenomanian and

Turonian Chalk sequence of Sussex and Kent. *B. elegans* possessed a deepened and laterally compressed trunk, small mouth with minute teeth and a large eye. The dorsal and anal fins are much extended and oppose one another upon the ventral and dorsal surfaces (Woodward, 1902–1912).

Two species of the Cretaceous coelacanth *Macropoma* complete the fish fauna from the Blue Bell Hill. *Macropoma mantelli* (Agassiz) is known from several complete specimens from the Turonian of Southerham (q.v.) and several horizons in the Middle and Upper Chalk succession of Kent, Sussex and Surrey (Woodward, 1902–1911). *Macropoma praecursor* Woodward is a much smaller species named from isolated bones from the '*S. varians*' Zone of Folkestone, Kent and the '*H. subglobosus*' Zone of Burham. Coprolites found in the Chalk are traditionally assigned to the coelacanth genus, although Woodward (1902–1911) pointed out that they might equally be from sharks or chimaeroids. Some spiral coprolites might not be fossil faeces but petrified intestinal contents, known as enterospirae. Longbottom and Patterson (1987) remarked that all primitive fishes, selachians, chimaeroids and non-teleost bony fishes, possess a spiral valve, and hence, the Chalk coprolites or enterospirae could have been derived from any of these fossil groups. However, no enterospirae have ever been found preserved *in situ* within more complete specimens of *Macropoma*, so it is likely that these may have been derived from sharks (Longbottom and Patterson, 1987).

Comparison with other localities

Most of the genera from the Blue Bell Hill pits have also been found in other Chalk quarries in southern England, with only the pits of the Lewes area, namely Southerham (Machine Bottom Pit; q.v.) and Southerham Grey Pit (q.v.), attaining a similar diversity. Similar Late Cretaceous marine faunas are known from the Chalk of Belgium, France, Sweden and from North America (Texas, Mississippi, Alabama, New Jersey, Kansas, etc.).

Conclusion

The Blue Bell Hill pits at Burham have yielded the most extensive fauna of Chalk fishes in Britain. This is the best British Chalk fish site with potential for new finds and is a key Late Cretaceous site of international importance, hence its conservation value.

TOTTERNHOE (CHALK QUARRY; SP 982222)

Highlights

The Totternhoe Stone is an important phosphatic and fish-bearing horizon that can be traced across much of the Lower Chalk outcrop in southern England. At Totternhoe Chalk Quarry in Bedfordshire, the unit has yielded an abundant, but fragmentary fish fauna consisting largely of teeth, concentrated within the winnowed basal limestone.

Introduction

The Chalk Quarry at Totternhoe is the only locality where the famous Totternhoe Stone is well exposed. The Totternhoe Stone (Lower Chalk: Cenomanian) is a massive gritty limestone, with a basal concentration of phosphatized nodules, which forms a well-known and distinct lithological marker band in the Lower Chalk across much of the central English Chalk outcrop. It has traditionally been used as a boundary for the base of the Middle Cenomanian (*A. rhotomagense* Zone) Grey Chalk succession (Figure 13.14).

It is best developed in parts of Bedfordshire, Hertfordshire and Cambridgeshire, where it attains thicknesses of up to 6 m and was formerly mined as an attractive and hard-wearing building stone (Jukes-Browne and Hill, 1903). At outcrop the hard Totternhoe Stone usually forms a slight rise above the low escarpment of the denuded Chalk Marl (Lower Cenomanian: *M. dixoni* and *M. mantelli* Zones).

At Totternhoe the Stone forms a spur of the Dunstable plateau. The large quarries in the northern part of the hill above Totternhoe are now disused and overgrown, but access to these sections can be gained through the working chalk quarry and cement works situated directly to the north of Lower End, Totternhoe. A small exploratory pit in the floor of the chalk quarry has been retained as an SSSI and is maintained as a source of Totternhoe Stone for architectural restoration projects (Page, 1993). The phosphate-rich basal lag accumulation is exposed in the excavation and it is this horizon that has

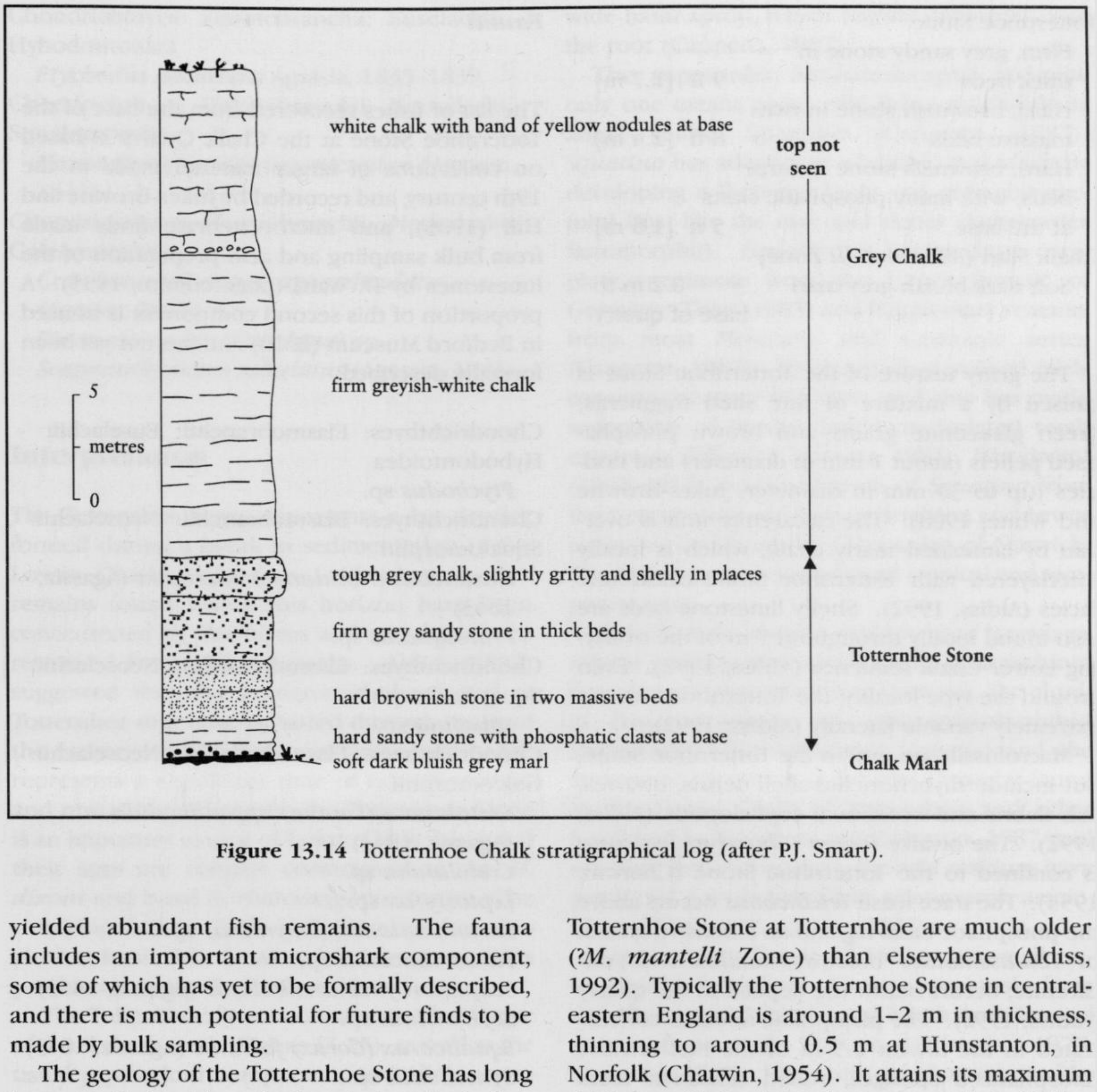

Figure 13.14 Totternhoe Chalk stratigraphical log (after P.J. Smart).

yielded abundant fish remains. The fauna includes an important microshark component, some of which has yet to be formally described, and there is much potential for future finds to be made by bulk sampling.

The geology of the Totternhoe Stone has long been studied, with early descriptions including Jukes-Browne (1889), Jukes-Browne and Hill (1903), Jukes-Browne and White (1908) and Hopkinson (1889). More recent reports on the stratigraphy of the site include British Geological Survey technical reports by Aldiss (1992) and Wood (1992). The fishes are listed in Jukes-Browne and Hill (1903).

Description

The Totternhoe Stone is a massive gritty calcarenite, with a discontinuous lag of phosphatic nodules. Although the Totternhoe Chalk Quarry is regarded as the type section of the rock, its development there is not typical (Aldiss, 1992). The beds of Chalk Marl immediately below the Totternhoe Stone at Totternhoe are much older (?*M. mantelli* Zone) than elsewhere (Aldiss, 1992). Typically the Totternhoe Stone in central-eastern England is around 1–2 m in thickness, thinning to around 0.5 m at Hunstanton, in Norfolk (Chatwin, 1954). It attains its maximum thickness (5–6 m) in the type section (Aldiss, 1992). A section in the northern part of the Chalk quarries at Totternhoe was described by Jukes-Browne and Hill (1903) and is given here with few modifications from recent accounts by Aldiss (1992) and Page (1993):

	Thickness
Grey Chalk (top not seen: *A. rhotomagense* Zone)	
White chalk, with thin band of yellow nodules at base	20–25 ft [6–7.5 m]
Firm greyish-white chalk	35–40 ft [11–12 m]
Tough grey chalk, slightly gritty and shelly in places	5 [1.5 m]

Totternhoe Stone		
Firm, grey sandy stone in thick beds	9 ft	[2.7 m]
Hard, brownish stone in two massive beds	8 ft	[2.4 m]
Hard, brownish stone in three beds, with many phosphatic clasts at the base	5 ft	[1.5 m]
Chalk Marl (?*M. mantelli* Zone)		
Soft dark bluish grey marl		0.2 m to base of quarry

The gritty texture of the Totternhoe Stone is caused by a mixture of fine shell fragments, green glauconite grains and brown phosphatised pellets (about 1 mm in diameter) and nodules (up to 30 mm in diameter; Jukes-Browne and White, 1908). The calcarenite unit is overlain by laminated marly chalk, which is locally interlayered with Totternhoe Stone calcarenite facies (Aldiss, 1992). Shelly limestone beds are also found locally throughout 7 m of the overlying Lower Chalk sequence (Aldiss, 1992). Even around the type locality, the Totternhoe Stone is extremely variable laterally (Aldiss, 1992).

Macrofossils are rare in the Totternhoe Stone, but include rhynchonellid shell debris, bivalves, fish debris and occasional cephalopods (Aldiss, 1992). The bivalve *Pecten (Chamlys) fissicosta* is confined to the Totternhoe Stone (Chatwin, 1954). The trace fossil *Teichichnus* occurs above the phosphatic basal lag and an extensive system of *Thalassinoides* burrows, infilled with calcarenite, occurs below the deposit in the quarry (Aldiss, 1992). The phosphatic nodules concentrated in the lowest 0.5 m of the bed enclose phosphatized sponges, rolled selachian teeth and other vertebrate debris. Some of the nodules have been bored and encrusted with serpulids and oysters (Aldiss, 1992). The Totternhoe Stone becomes slightly more pyritous towards the uppermost 0.4 m of the unit (Aldiss, 1992).

The vertebrate fauna mainly comprises isolated teeth, bones and coprolites, although Jukes-Browne (1903) recorded partial specimens of the coelacanth *Macropoma*. Most of the larger vertebrate remains are concentrated in the basal lag and much of the fish material is abraded and encrusted. The Totternhoe Stone is clearly a reworked, winnowed deposit, developed during a hiatus in Chalk sedimentation above a burrowed and encrusted hardground surface formed within the underlying Chalk Marl.

Fauna

The list of fishes recovered from the base of the Totternhoe Stone at the Chalk Quarry is based on collections of larger material made in the 19th century, and recorded by Jukes-Browne and Hill (1903), and microvertebrate finds made from bulk sampling and acid preparation of the limestones by D. Ward (pers. comm., 1995). A proportion of this second component is housed in Bedford Museum (BMB) and has not yet been formally described.

Chondrichthyes: Elasmobranchii: Euselachii: Hybodontoidea
Ptychodus sp.
Chondrichthyes: Elasmobranchii: Neoselachii: Squalomorphii
Hexanchus (Notidanus) microdon (Agassiz, 1843)
Protosqualus sp.
Chondrichthyes: Elasmobranchii: Neoselachii: Squatinomorphii
Squatina sp.
Chondrichthyes: Elasmobranchii: Neoselachii: Galeomorphii
Cretolamna (Lamna) appendiculata (Agassiz, 1843)
Cretolamna sp.
Leptostyrax sp.
Paranomotodon (Oxyrhina) sp.
Paraorthacodus sp.
Scapanorhynchus subulatus (Agassiz, 1843)
Scyliorhinus sp.
Squalicorax (Corax) falcatus (Agassiz, 1843)
Synechodus sp.
Synodontaspis (Carcharias) striatula (Dalinkevicius, 1935)
Chondrichthyes: Elasmobranchii: Neoselachii: Batomorphii
Squatirhina sp.
Turonibatis cappettai Landemaine, 1991
Osteichthyes: Actinopterygii: Neopterygii: Euteleostei
Cimolichthys striatus
Osteichthyes: Sarcopterygii: Actinistia
Macropoma sp.

Fish remains have also been recovered from the Lower Chalk succession above the Totternhoe Stone at Totternhoe Stone Quarry and these were listed by Jukes-Browne and Hill (1903):

Chondrichthyes: Elasmobranchii: Euselachii: Hybodontoidea

Ptychodus decurrens Agassiz, 1835–1839

Chondrichthyes: Elasmobranchii: Neoselachii: Squalomorphii

Hexanchus (Notidanus) microdon (Agassiz, 1843)

Chondrichthyes: Elasmobranchii: Neoselachii: Galeomorphii

Cretolamna (Lamna) appendiculata (Agassiz, 1843)

Paranomotodon (Oxyrhina) sp.

Scapanorhynchus subulatus (Agassiz, 1843)

Interpretation

The Totternhoe Stone represents a lag deposit formed during a break in sedimentation in the Lower Chalk succession. Clearly, any fish remains found within this horizon have been concentrated by this hiatus and may have been reworked from older deposits. Aldiss (1992) suggested that the hardground developed at Totternhoe may have persisted through much of the Lower and Middle Cenomanian and hence represents a significant time of non-deposition and reworking. However, the Totternhoe Stone is an important source of Lower Chalk fishes and their ages are roughly constrained to the *M. dixoni* and basal *A. rhotomagense* Zones. The overlying Lower Chalk at Totternhoe has also yielded fossil fish remains, but is not nearly as productive as the Totternhoe Stone.

The Totternhoe Stone contains an abundance of small shark teeth (Figure 13.15), as well as the usual ptychodont component, including representatives of the squalomorph, squatinomorph, galeomorph and batomorph neoselachians. The squalomorphs are represented by two small species (Figure 13.15), *Hexanchus microdon* (Agassiz) and *Protosqualus* sp. (Figure 13.15). The comb-like teeth of *H. microdon* have been recovered from other Chalk localities, such as Blue Bell Hill (q.v.), but is a fairly rare Chalk fossil (Longbottom and Patterson, 1987). The teeth of *Protosqualus* are extremely tiny (less than 3 mm in width) and are usually found in rocks of a Lower Cretaceous age (Cappetta, 1987), although possible *Protosqualus* teeth have been described from the Upper Cretaceous of Lithuania (Dalinkevicius, 1935). They typically possess a short cusp that leans towards the rear of the tooth and a smooth cutting edge, and a wide basal apron, which slightly protrudes over the root (Cappetta, 1987).

The superorder Squatinomorphii contains only one extant genus, the living monk-fish or angel shark, *Squatina* (Cappetta, 1987). *Squatina* has adapted to a benthic way of life by developing a flattened body and enlarged pectoral fins, like the rays and skates (Superorder Batomorphii). *Squatina* is known from complete specimens from the Upper Jurassic of Germany (Thies, 1983) and fragmentary remains from most Mesozoic and Cenozoic series (Cappetta, 1987). Its dentition remained fairly conservative over this time, and this has made separation of species based on isolated teeth extremely difficult (Cappetta, 1987). Woodward (1902–1912) described teeth of *Squatina* from the Cenomanian of Clayton, Brighton and Lewes in Sussex and from the Campanian of Norwich. The living genus is found in all tropical and temperate seas.

As well as the usual complement of large lamniform piercing teeth, such as the cretoxyrhinid *Cretolamna appendiculata* (Agassiz), the alopiid *Paranomotodon* sp., the mitsukurhinid *Scapanorhynchus subulatus* (Agassiz) and the anacoracid *Squalicorax falcatus* (Agassiz) found in the Lower Chalk of Totternhoe and other localities (Longbottom and Patterson, 1987, and see Blue Bell Hill report), the acid residues have produced a more complete galeomorph assemblage (Ward, pers. comm., 1995).

Leptostyrax (Figure 13.15B) was a small cretoxyrhinid lamniform, known previously from the Albian and Coniacian of North America and parts of western Europe (Herman, 1977; Cappetta, 1987). The teeth are characterized by a large central cusp, with prominent cutting edge flanked by two or four smaller cusps (Cappetta, 1987; Figure 13.15B). *Synodontaspis striatula* (Dalinkevicius) is a odontaspid lamniform shark with large tearing-type teeth (up to 40 mm in height; Glückman, 1964a; Figure 13.15C), indicating a fish perhaps 4 m long. *Synodontaspis*, or *Carcharias* as it is also known, is an extant genus, which is widespread in the warm temperate and tropical waters of the Mediterranean, Atlantic, Indian and western Pacific oceans (Cappetta, 1987).

The galeomorph assemblage also includes a representative of the Carcharhiniformes, the extant scyliorhinid or dogfish, *Scyliorhinus*, whose tiny teeth (less than 8 mm in height) are common from the Middle Jurassic upwards (S.

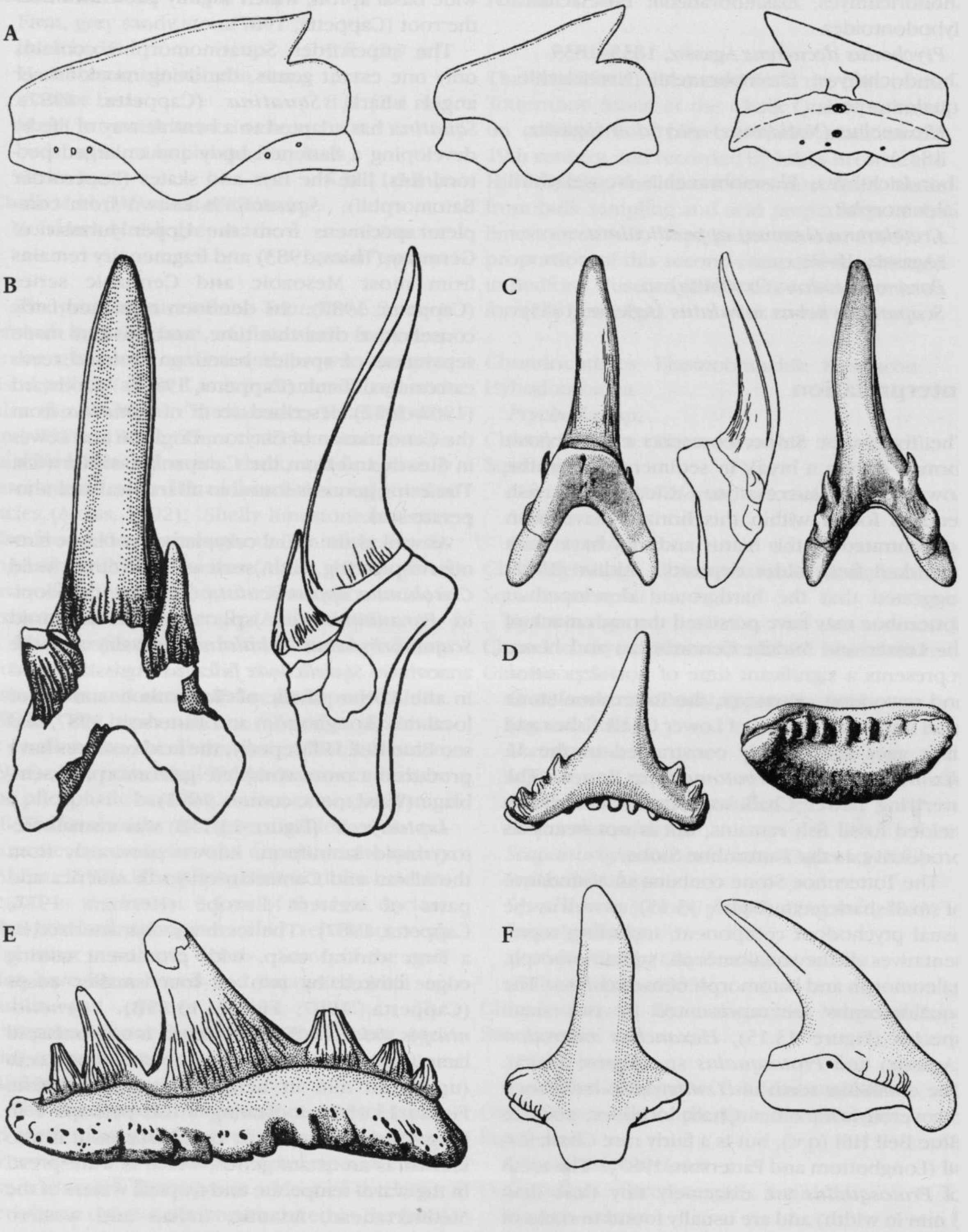

Figure 13.15 Fossil chondrichthyan teeth genera from the Chalk at Totternhoe (after Cappetta, 1987). (A) *Protosqualus* sp., × 24; (B) *Leptostyrax* sp., × 1.25 in distal view; (C) *Synodontaspis* (*Carcharias*) *striatula*, × 2 in distal view; (D) *Synechodus* sp. × 5; (E) *Paraorthacodus* sp., × 4; (F) *Squatirhina* sp., × 10, in labial and distal views.

Metcalf and C. Underwood, pers.comm.). Woodward (1899b, 1902–1911) described two scylio-rhinids, *S. dubius*, from the Lower Chalk of Dover, Kent, and *S. antiquus* (Agassiz) from the Turonian Chalk of Blue Bell Hill (q.v.).

Teeth of the small enigmatic palaeospinacid sharks, *Synechodus* and *Paraorthacodus*, have also been recovered from acid digestion of the Totternhoe Stone (Figure 13.15D,E). *Synechodus* is a fairly common component of the Lower Chalk fauna, and is known from fragmentary skeletal remains of two species, *S. dubrisensis* (Mackie) of Dover and *S. nitidus* Woodward from Snodland and Wouldham, Kent, as well as isolated teeth recovered from acid residues at many localities (Woodward, 1902–1912). *Paraorthacodus* has similar, but typically larger, teeth (up to 20 mm in height), these can usually be distinguished by details in dental morphology (Cappetta, 1987).

Completing the elasmobranch fauna at Totternhoe are the two batoids *Squatirhina* sp. and *Turonibatis cappettai* Landemaine (Ward, pers. comm., 1995). *Squatirhina* is a Cretaceous ray of uncertain taxonomic position (Cappetta, 1987), which possessed small mesio-distally compressed teeth, up to 5 mm in height (Figure 13.15F). Previous authors have assigned the genus to an intermediate position between the squatinids and orectolobids or scyliorhinds and rhinobatids (Casier, 1947), or within the orectolobids (Estes, 1964; Herman, 1977). However, Cappetta (1987) states that the genus is almost certainly an enigmatic rhinobatoid.

The Totternhoe Stone assemblage is completed by the barbed teeth of the 'enchodont' euteleost *Cimolichthes*, and coprolites dubiously assigned to the coelacanth *Macropoma* (Jukes-Browne and Hill, 1903).

Comparison with other localities

The Totternhoe Stone of neighbouring counties has also yielded an extensive vertebrate assemblage. The Arlesey Quarries, Hitchin (TL 1936), yielded whole specimens of the euteleosts *Ctenothrissa* and *Dercetis elongatus*, as well as isolated selachian teeth and bones of the coelacanth *Macropoma* (Jukes-Browne and Hill, 1903), fish remains were also recovered in the nearby Hitchin Station Quarry (TL 1929; Jukes-Browne and Hill, 1903). The Totternhoe Stone at Cherry Hinton, Cambridge (TL 483557, TL 485558), was also extremely fossiliferous with eight species of fish recorded by Jukes-Browne and Hill (1903). A similar fauna was recovered from the same horizon at Hunstanton cliffs in Norfolk. However, apart from the coastal section, all the other exposures no longer exist.

Conclusion

The conservation value of the site is derived from the phosphatic pebble bed exposed at the base of the Totternhoe Stone, which is one of the richest sources of Upper Cretaceous microshark remains, some of which have yet to be formally described. The site has great potential for new finds.

SOUTHERHAM (MACHINE BOTTOM PIT; TQ 43200905) (POTENTIAL GCR SITE)

Highlights

The Machine Bottom Pit at Southerham in Sussex is a site of special historic interest, being the locality from which most of the large 19th century collections of Chalk fossil fishes were made by famous gentleman scholars, such as Gideon Mantell and Frank Dixon. The collections include 28 type specimens (many more or less complete specimens) and still form the basis for much Upper Cretaceous fish taxonomy.

Introduction

The chalk pits around the East Sussex town of Lewes (Figure 13.16) have long been famous for their abundant and diverse fossil fish assemblages. In the 19th and early 20th centuries much material was collected from the disused Machine Bottom Pit (or 'Grey Pit' as it is known in some of the earlier literature, e.g. Jukes-Browne and Hill, 1903) in the Chalk Marl and Grey Chalk of the Lower Chalk (Cenomanian) succession. The Lewes region (Figure 13.16) has yielded some of the best fossil fish specimens and most representative faunas from the Chalk, and the collections are rivalled only by those from the Blue Bell Hill pits (q.v.) in Kent. Individual species are in many cases represented by large numbers of specimens and many of these are in a beautiful articulated state of preservation.

Most of the complete fish specimens

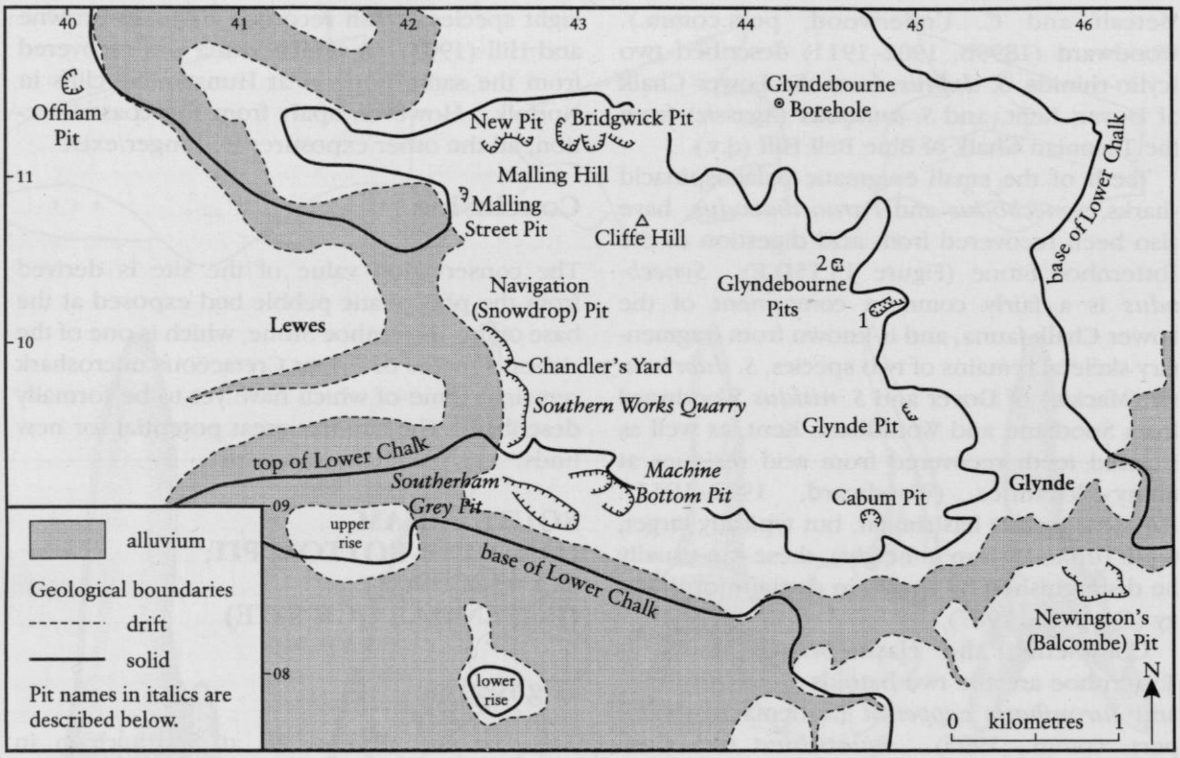

Figure 13.16 Map of chalk pits around the Mt Caburn area, Lewes (after Lake *et al.*, 1987).

described from the English Chalk were recovered in the 19th century and nowhere was fossil collecting more fashionable than in the Cretaceous succession of the South Downs. Both Gideon Mantell and Frank Dixon made extensive collections in the Chalk of Sussex, and many of their fish specimens are from the Lower and Middle Chalk around Lewes (Mantell, 1822; Dixon, 1850; Jukes-Browne and Hill, 1903). The Lewes fish collections have been the subject of much scientific description, including the work of Agassiz in the early 19th century and Smith Woodward's monographic work on Chalk fishes (1902–1912). They are the source of at least 28 type specimens.

The Lower and Middle Chalk succession in the Machine Bottom Pit was described by Barrois (1876), Jukes-Browne and Hill (1903), White (1926), Gaster (1951), Kennedy (1969) and Lake *et al.* (1987). The pit is now disused and largely overgrown, and the higher beds of the section (*Plenus* Marls and Melbourn Rock), exposed high up in the north-east face, are inaccessible (Lake *et al.*, 1987). Yet re-excavation of the lower beds is possible and could yield more specimens.

Description

The confusion over the naming of the Machine Bottom Pit at Southerham arose because prior to White's recording of the section there in 1926, the pit was known as the 'Grey Pit'. When White (1926) made his observations the pit was disused. Later the pit was reopened and greatly enlarged, until final closure in the 1970s and was given its new name (Lake *et al.*, 1987). The new Southerham Grey Pit (q.v.) is situated about 200 m to the west of the older pit.

The Machine Bottom Pit exposes approximately 30 m of Lower Chalk and the lowest beds of the Middle Chalk (Figure 13.17). The section is now largely overgrown, but was recorded in 1973 by Lake *et al* (1987) as:

	Thickness (m)
Middle Chalk	
Ranscombe Griotte Chalk Member	
Melbourn Rock: creamish white, hard, nodular chalk with marl partings; some of the nodular beds are markedly iron-stained	0.9
Lower Chalk	
Plenus Marls: pale grey, very marly chalk	

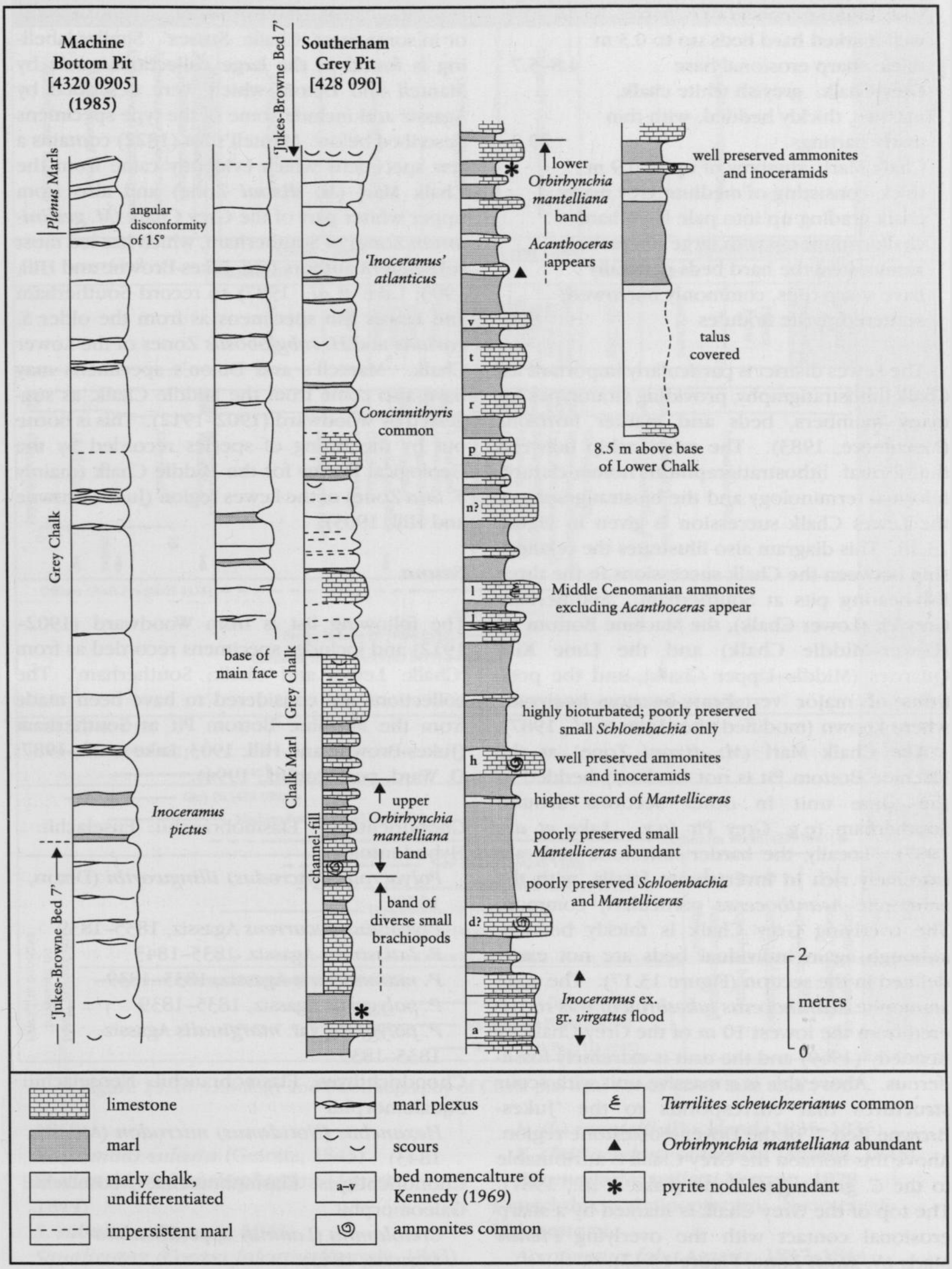

Figure 13.17 Chalk sections in the Machine Bottom Pit and Southerham Grey Pit (after Lake *et al.*, 1987).

with slight greenish tinge; two well-marked hard beds up to 0.3 m thick; sharp erosional base	4.8–5.7
Grey Chalk: greyish white chalk, massive, thickly bedded, with thin marly partings	29.2
Chalk Marl: rhythms of up to 0.9 m thick, consisting of medium grey marly chalk grading up into pale fawn hard chalk commonly with large uncrushed ammonites; the hard beds generally have sharp tops, commonly burrowed; scattered pyrite nodules	9.1

The Lewes district is particularly important for Chalk lithostratigraphy, providing stratotypes for many members, beds and marker horizons (Mortimore, 1983). The relationship between the formal lithostratigraphical nomenclature, informal terminology and the biostratigraphy of the Lewes Chalk succession is given in Figure 13.18. This diagram also illustrates the relationship between the Chalk successions in the three fish-bearing pits at Southerham: Southerham Grey Pit (Lower Chalk), the Machine Bottom Pit (Lower–Middle Chalk) and the Lime Kiln Quarries (Middle–Upper Chalk); and the positions of major vertebrate-bearing horizons, where known (modified after Lake *et al.*, 1987).

The Chalk Marl (*M. dixoni* Zone) at the Machine Bottom Pit is not as clearly bedded as the same unit in other sections around Southerham (e.g. Grey Pit (q.v.; Lake *et al.*, 1987). Locally, the harder limestone beds are extremely rich in invertebrate fossils, with the ammonite *Acanthoceras* particularly common. The overlying Grey Chalk is thickly bedded, although again individual beds are not easily defined in the section (Figure 13.17). The zone ammonite *Acanthoceras jukesbrowni* was recovered from the lowest 10 m of the Grey Chalk by Kennedy (1969) and the unit is extremely fossiliferous. Above this is a massive unit with scour structures that corresponds to the 'Jukes-Browne Bed 7' of the Dover–Folkestone region. Above this horizon the Grey Chalk is attributable to the *C. guerangeri* Zone (Lake *et al.*, 1987). The top of the Grey Chalk is marked by a sharp erosional contact with the overlying *Plenus* Marls (*N. juddi* Zone; Figure 13.17).

The rich collections made at the Southerham chalk pits in the 19th century are preserved in the BMB, NHM and CAMSM. However, the earlier workers generally labelled their material as from the 'Chalk: Southerham', 'Chalk: Lewes' or in some cases 'Chalk: Sussex'. Similar labelling is found in the large collections made by Mantell and Dixon, which were described by Agassiz and include some of the type specimens described below. Mantell's list (1822) contains a few specimens which evidently came from the Chalk Marl (*M. dixoni* Zone) and also from upper whiter part of the Grey Chalk (*M. geslinianum* Zone) of Southerham, which has led most subsequent authors (e.g. Jukes-Browne and Hill, 1903; Lake *et al.*, 1987) to record Southerham and Lewes fish specimens as from the older *S. varians* and *H. subglobosus* Zones of the Lower Chalk. Mantell's and Dixon's specimens may have also come from the Middle Chalk, as suggested by Woodward (1902–1912). This is borne out by the listing of species recorded by the Geological Survey for the Middle Chalk (mainly *T. lata* Zone) of the Lewes region (Jukes-Browne and Hill, 1903).

Fauna

The following list is from Woodward (1902–1912) and includes specimens recorded as from 'Chalk: Lewes' and 'Chalk: Southerham'. The collections are considered to have been made from the Machine Bottom Pit at Southerham (Jukes-Browne and Hill, 1903; Lake *et al.*, 1987; D. Ward, pers. comm., 1994).

Chondrichthyes: Elasmobranchii: Euselachii: Hybodontoidea
- *Polyacrodus (Acrodus) illingworthi* (Dixon, 1850)
- *Ptychodus decurrens* Agassiz, 1835–1839
- *P. latissimus* Agassiz, 1835–1843
- *P. mammillaris* Agassiz, 1835–1839
- *P. polygyrus* Agassiz, 1835–1839
- *P. polygyrus* var. *marginalis* Agassiz, 1835–1839

Chondrichthyes: Elasmobranchii: Neoselachii: Squalomorphii
- *Hexanchus (Notidanus) microdon* (Agassiz, 1843)

Chondrichthyes: Elasmobranchii: Neoselachii: Galeomorphii
- *Cretolamna (Lamna) appendiculata* (Agassiz, 1843)
- *C. (Isurus) mantelli* (Agassiz, 1843)
- *C. Woodwardi* (Herman, 1975)
- '*Lamna*' spp.
- *Plicatolamna (Oxyrhina) crassidens* (Dixon,

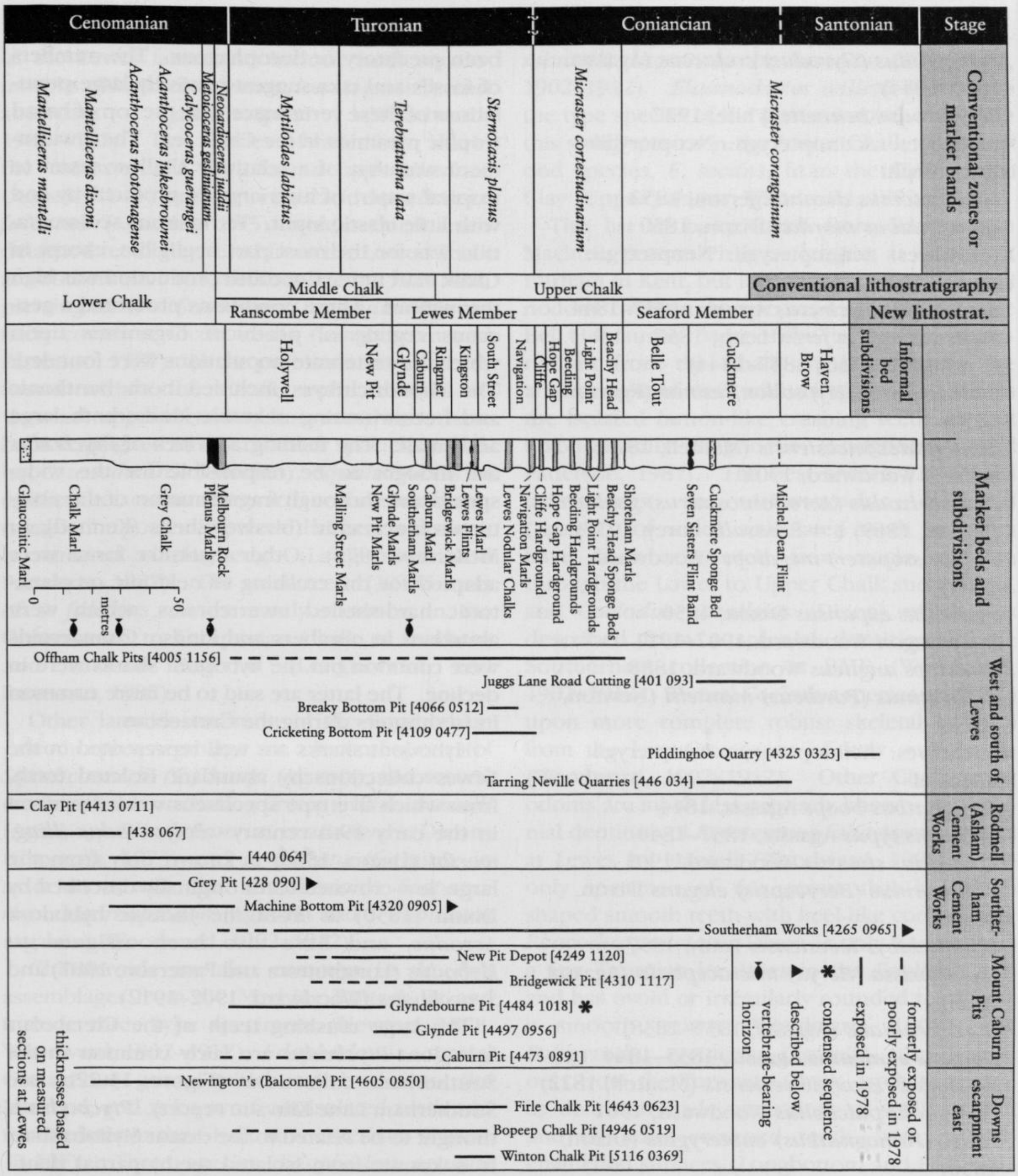

Figure 13.18 Lithology and biostratigraphy of Chalk pits near Lewes (after Lake *et al.*, 1987).

1850)
P. (Lamna) sulcata (Geinitz, 1843)
Scapanorhynchus rhaphiodon (Agassiz, 1844)
S. subulatus (Agassiz, 1843)
Squalicorax (Corax) falcatus (Agassiz, 1843)
S. (C.) kaupi (Agassiz, 1843)

Chondrichthyes: Holocephali: Chimaeriformes
Edaphodon (Ischyodus) agassizi (Buckland, 1835–1836)
E. (I.) mantelli (Buckland, 1835–1836)
E. (Psittacodon) sedgwicki (Agassiz, 1843)
Elasmodectes willetti Newton, 1878

Osteichthyes: Actinopterygii: Neopterygii: Halecostomi
Acrotemnus faba Agassiz, 1837–1844
Anomoedus (Gyrodus) angustus (Agassiz, 1837–1844)
Coelodus (Pycnodus) parallelus (Dixon, 1850)

Phacodus punctatus Dixon, 1850
Polygyrodus (Gyrodus) cretaceus (Agassiz, 1839–1844)
Polygyrodus bennetti White, 1927
Osteichthyes: Actinopterygii: Neopterygii: Halecomorphi
Lophiostomus dixoni Egerton, 1852
Tomognathus mordax Dixon, 1850
Osteichthyes: Actinopterygii: Neopterygii: Teleostei
Belonostomus cinctus Agassiz, 1837–1844
Protosphyraena ferox Leidy, 1857
P. minor (Agassiz, 1837–1844)
Ichthyodectes (Hypsodon) minor (Egerton, 1850)
Osmeroides lewesiensis (Mantell, 1822)
O. levis Woodward, 1901
Pachyrhizodus (Acrodontosaurus) gardneri (Mason, 1869) (= P. *basalis* Forey, 1977)
P. (Thrissopater) megalops (Woodward, 1901)
Plethodus expansus Dixon, 1850
P. pentagon Woodward, 1902–1911
Protelops anglicus Woodward, 1888
Xiphactinus (Portheus) mantelli (Newton, 1877)
Osteichthyes: Actinopterygii: Neopterygii: Euteleostei
Acrognathus boops Agassiz, 1844
Aulolepis typus Agassiz, 1837–1844
Apateodus striatus Woodward, 1901
Platycormus (Berycopsis) elegans Dixon, 1850
Cimolichthys levesiensis Leidy, 1857
Ctenothrissa (Beryx) microcephala (Agassiz, 1838)
C. (B.) radians (Agassiz, 1835–1838)
Dercetis elongatus Agassiz, 1835–1844
Enchodus (Esox) lewesiensis (Mantell, 1822)
Eurypholis pulchellus Woodward, 1901
Halec (Pomognathus) eupterygius (Dixon, 1850)
Hoplopteryx (Beryx) lewesiensis (Mantell, 1822)
H. (B.) superbus (Dixon, 1850)
H. simus Woodward, 1902–1911
Osteichthyes: Sarcopterygii: Actinistia
Macropoma mantelli Agassiz, 1835–1844
Macropoma sp. (coprolites)

Interpretation

The Southerham Chalk Pits reveal a flourishing assemblage of both chondrichthyans and osteichthyes, almost all of which appear to have been predatory or durophagous. The numbers of fossils and taxa suggest relatively large populations of these vertebrates near the top of broad trophic pyramids in the Chalk sea. The environment was that of a relatively shallow warm to tropical water, of high organic productivity and with little clastic input. Terrigenous sedimentation was for the most part negligible, except in Chalk Marl time. Coccolith production was high throughout. These conditions promoted a generous regime of producer organisms upon which the vertebrate populations were founded. The chondrichthyes included both benthonic and free-swimming nektonic kinds, both large and small. The feeding activities of *Ptychodus* are thought to be responsible for the widespread and thorough fragmentation of the ubiquitous inoceramid (bivalve) shells (Kennedy, *in* McKerrow, 1978). Other shark-like forms were adapted for the crushing of nektonic or planktonic hard-shelled invertebrates, which were abundant in numbers and kinds. Chimaeroids were common but the hybodont sharks were in decline. The latter are said to be more common in freshwaters during the Cretaceous.

Hybodont sharks are well represented in the Lewes collections by abundant isolated teeth, from which five type specimens were described in the early 19th century. *Polyacrodus illingworthi* (Dixon, 1850) is known only from the large, low-crowned teeth originally described by Dixon (1850) as from the Jurassic hybodont *Acrodus*, and have also been assigned to *Hybodus* (Longbottom and Patterson, 1987) and *Synechodus* (Woodward, 1902–1912).

The large crushing teeth of the Cretaceous hybodont *Ptychodus* are fairly common in the Southerham collections (Figure 13.22b, see Southerham Lime Kiln site report). *Ptychodus* is thought to be related to the extant Myliobatidae. It is known from isolated teeth, partial dentitions and the partially calcified vertebrae, although the species named from Southerham are based only upon teeth (Woodward, 1902–1912). The four species of *Ptychodus* from Southerham have been named upon minor differences in the shape, ornamentation and size of their teeth (Woodward, 1902–1912; Longbottom and Patterson *in* Owen and Smith, 1987). Most of the forms in the Southerham fauna possessed wide crushing teeth capable of grinding thick-shelled benthic molluscs (Cappetta, 1987).

Neoselachian sharks are also well represented in the Lewes fauna and include both squalomorphs (*Hexanchus microdon* (Agassiz)) and abundant galeomorphs (Woodward, 1902–1912). Two species of lamniform shark, the cretoxyrhinid *Cretolamna appendiculata* (Agassiz, 1843), and the anacoracid *Squalicorax falcatus* (Agassiz, 1843) were named from detached teeth recovered from the Lower Chalk at Southerham. The medium-sized (15–25 mm) piercing teeth of *Cretolamna appendiculata* are fairly common Chalk fossils (Longbottom and Patterson, 1987). In the past most lamnid teeth found within the Chalk were referred to '*Lamna*' *appendiculata*, but many now have been reassigned to several other species, including *C. woodwardi* (Herman). *Squalicorax* is an extinct Cretaceous anacoracid or thresher shark, notable for possessing teeth that bear a distinctly serrated cutting edge (Longbottom and Patterson, 1987). The small teeth (12–15 mm) of *S. falcatus* are extremely common in the Cenomanian to Campanian Chalk of southern and eastern England (Longbottom and Patterson, 1987).

Other lamnids common in the Southerham galeomorph assemblage are a second species of *Squalicorax*, *S. (C.) kaupi* (Agassiz), and several cretoxyrhinids, including *Cretoxyrhina mantelli* (Agassiz), *Plicatolamna crassidens* (Dixon) (Cappetta, 1975) and *P. sulcata* (Geinitz), in association with the mitsukurinids *Scapanorhynchus rhapiodon* (Agassiz) and *S. subulatus* (Agassiz) (Woodward, 1902–1912).

Chimaeroids are also common in the fish assemblages from the Machine Bottom Pit and include three type specimens (Newton, 1878; Woodward, 1902–1912). *Edaphodon* is a typical Cretaceous genus which survived into the Miocene, and is known from isolated teeth and tooth plates in the Chalk at Southerham (Figure 13.19F). Three species, *Edaphodon agassizi* (Buckland), *E. mantelli* (Buckland) and *Edaphodon sedgwicki* (Agassiz), have been found there (Woodward, 1902–1912). *E. sedgwicki* is known from the Lower and Middle Cretaceous successions of eastern and southern England, as well as ranging up into the Turonian Chalk. It is the largest species (with mandibular plates reaching lengths of up to 0.2 m; Woodward, 1902–1912). *Edaphodon mantelli* and *E. agassizi* are much smaller species described from the '*H. subglobosus*' Zone of the Cenomanian at Southerham. These species are known from other Lower Chalk localities, and *E. mantelli* ranges into the Turonian (Woodward, 1902–1912). *Elasmodectes willetti* Newton is the type species of the genus, known only from this small species in the Lower Chalk and a second species, *E. secans*, from the Kimmeridge Clay (Upper Jurassic; Woodward, 1892d).

The list of bony fishes from Southerham Machine Bottom Pit is as lengthy as that from Burham in Kent, but importantly contains a pycnodont component not known from the Blue Bell Hill faunas. Most of the five species of pycnodont from the Chalk are based upon the arrangement of teeth within fragmentary jaws, as the isolated button-like crushing teeth are not taxonomically diagnostic (Longbottom and Patterson, 1987). The best known Cretaceous pycnodonts are *Anomoeodus angustus* (Agassiz), of which articulated teeth and jaws have been recovered from rocks ranging through the Lower to Upper Chalk successions, and *Coelodus parallelus* (Dixon) which was described from a splenial dentition in the Southerham collection at BMB (Woodward, 1902–1912). Several *Coelodus* species are based upon more complete robust skeletal material from the Late Cretaceous of Italy and Austria (Woodward, 1902–1912). Other Chalk pycnodonts are much less precisely known: the splenial dentition of *Acrotemnus faba* Agassiz found at Lewes by Mantell (Woodward, 1908) is the only specimen of this genus that has bean-shaped smooth teeth with keel-like coronal tips. *Phacodus punctatus* Dixon is only known from a few Turonian localities in the English Chalk and has ovoid or irregularly rounded teeth with a smooth crown (Woodward, 1908); and *Polygyrodus cretaceus* (Agassiz), also known only from the Turonian Chalk, is characterized by dentition made up entirely of small circular and conically crowned teeth, with roughly enamelled surfaces (Longbottom and Patterson, 1987). The Southerham pycnodont species *P. bennetti* White, 1927 was described from an imperfect vomerine dentition.

The halecomorph neopterygian component of the Southerham bony fish fauna is much the same as that from the Blue Bell Hill pits (q.v.) at Burham, and includes the type specimen of the large aspidorhynchid *Belonostomus cinctus* Agassiz, 1837–1844, rostrum fragments the two species of the swordfish-like pachycormid *Protosphyraena*, and remains of the rare *Tomognathus mordax* Dixon (Woodward, 1908;

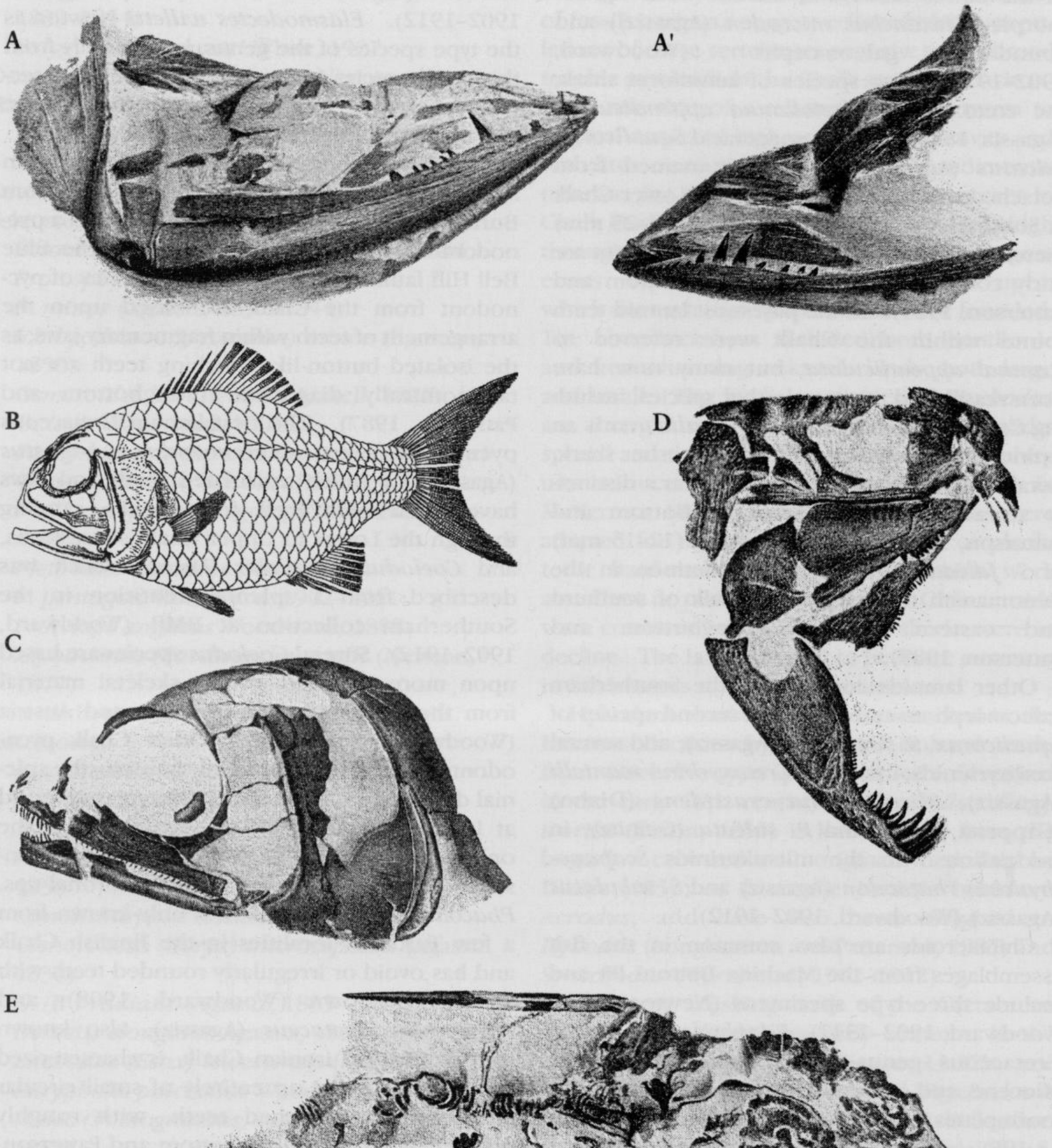

Figure 13.19 Fossil fishes from the Chalk of the Lewes area (after Woodward, 1895b). All distorted head and jaw parts; (A), (A') *Apateodus striatus* Woodward, distorted head, right and left lateral views, both are *c.* × 1.0; (B) *Hoplopteryx lewesiensis* Woodward, restoration × 0.5; (C) *Thrissopater megalops* Woodward, head with left pectoral arch , × 0.6; (D) *Tomognathus mordax* Dixon, imperfect skull and left mandible, × 1; (E) *Elasmodectes willetti* Newton, right side of head and part of trunk , × 0.8.

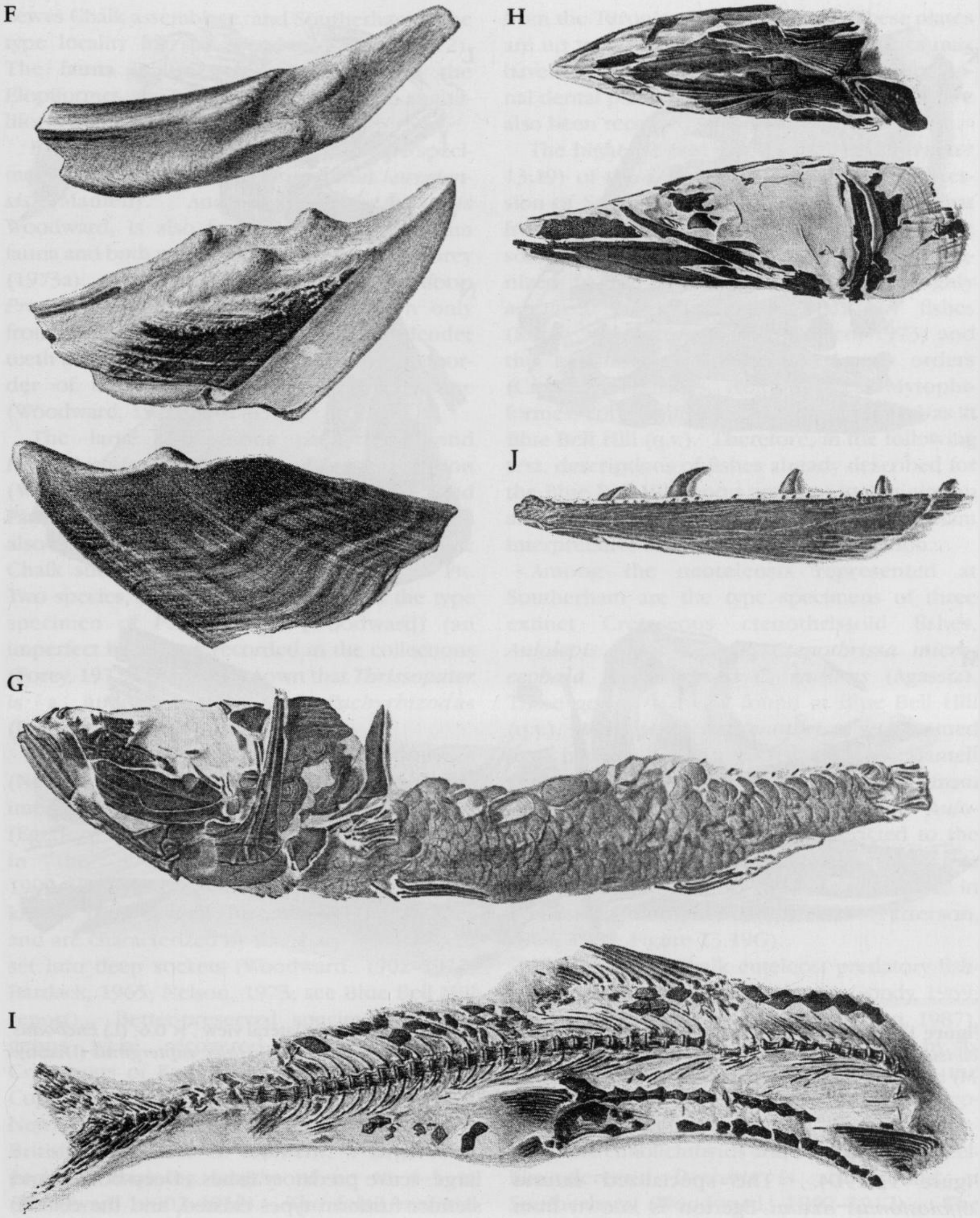

Figure 13.19 – *contd*. (F) *Edaphodon agassizi* (Buckland), left mandibular dental plate in labial, lingual and upper views, × 1; (G) *Aulolepis typus* Agassiz, incomplete head and trunk in left lateral view, × 3; (H)–(J) *Cimolichthys lewesiensis* Leidy: (H) head and opercular region in dorsal and left lateral views × 0.35, (I) damaged trunk and tail parts × 0.35, (J) labial aspect of left dentary × 0.9.

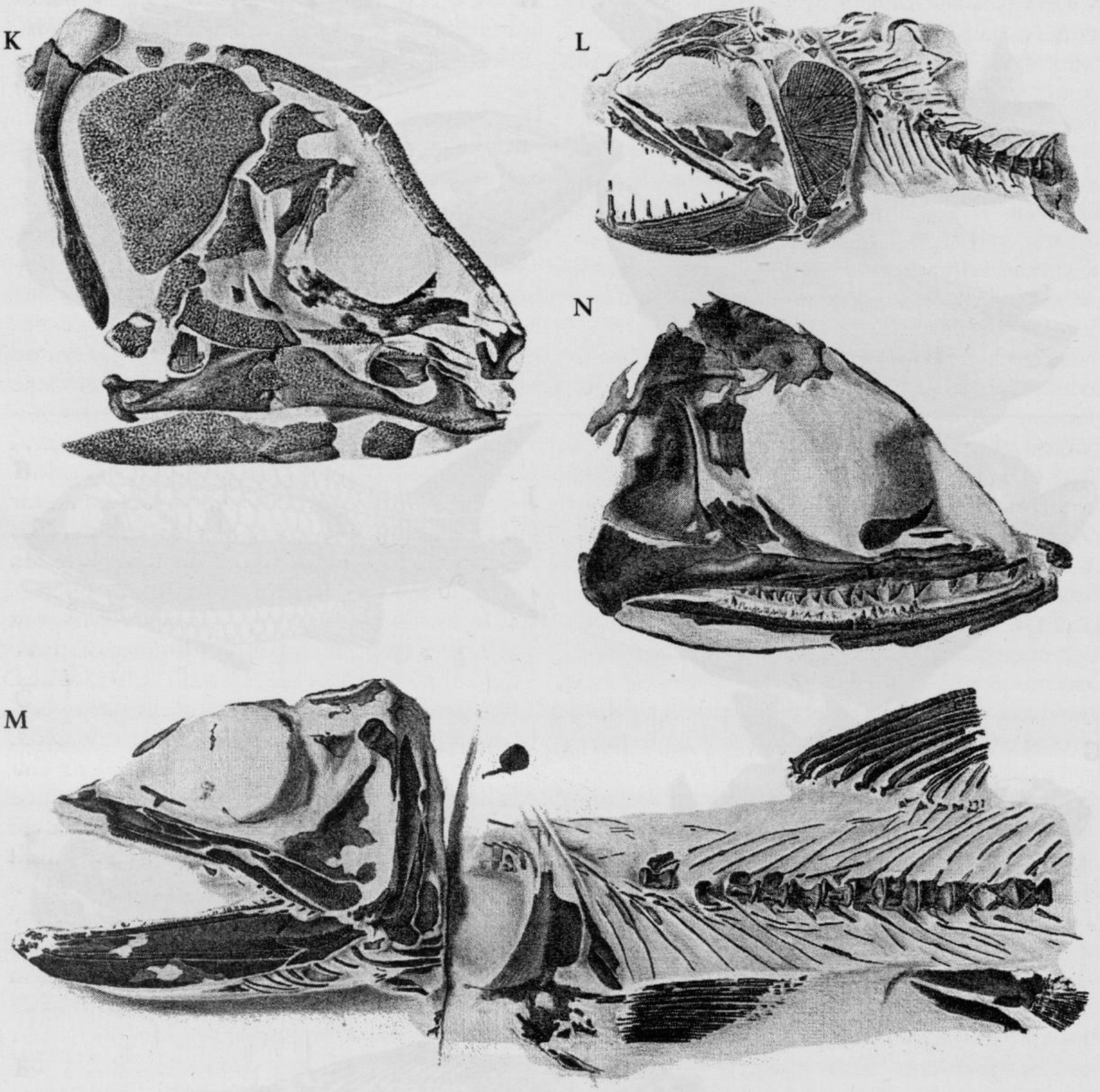

Figure 13.19 – *contd.* (K) *Macropoma mantelli* Agassiz, crushed skull in right lateral view , × 0.6; (L) *Enchodus lewisiensis* Mantell, head and anterior part of trunk in lateral view , × 0.9; (M), (N) *Halec eupterginus* (Dixon): (M) head and abdominal region in lateral view , × 0.9, (N) head in lateral view , × 1.

Figure 13.19D). The specialized caturid *Lophiostomus dixoni* Egerton is known from partial fish and fragmentary jaws in the Turonian Chalk of Sussex (Woodward, 1902–1912). *Lophiostomus* is a small fish with a large head (head reaches about 60 mm) which had widely gaping jaws lined with regular series of conical teeth (Woodward, 1902–1912).

The teleosts were conspicuous members of the osteichthyan fauna; some were also very large, active predatory fishes. Deep-bodied and slender fusiform types existed, and the eel-like *Dercetis*, with its wide gape and formidable array of small teeth, indicate a range of lifestyles comparable to that in many Recent shallow tropical seas. There were also numerous small fishes such as *Acrognathus*, and deep-bodied larger forms like *Berycopsis* that may have swum in schools.

Nine species of teleosts are present in the

Lewes Chalk assemblage, and Southerham is the type locality for six (Woodward, 1902–1912). The fauna includes representatives of the Elopiformes, the Icththyodectiformes, an anguilliform and the enigmatic plethodonts.

Elopiforms are represented by the type specimen of the small albuloid *Osmeroides lewesiensis* (Mantell). Another species, *O. levis* Woodward, is also found in the Southerham fauna and both were described in detail by Forey (1973a). The third 'pseudotarpon' elopiform *Protelops anglicus* Woodward is known only from fragmentary jaws lined with long, slender teeth arranged in two or more series on the border of the mouth or fused to the palate (Woodward, 1908, 1902–1912).

The large predaceous pachyrhizodontid *Pachyrhizodus*, with its characteristic dentition (Woodward, 1902–1912; Longbottom and Patterson, 1987; see Blue Bell Hill report), has also been recovered from the Lower and Middle Chalk succession in the Machine Bottom Pit. Two species, *P. gardneri* (Mason) and the type specimen of *P. megalops* (Woodward) (an imperfect head), are recorded in the collections (Forey, 1977). It is now known that *Thrissopater* is a junior synonym of *Pachyrhizodus* (Frickhinger, 1991; Figure 13.19C).

The large carnivorous Ichthyodectiformes (Nelson, 1973) are represented by the type specimens of two species, *Ichthyodectes minor* (Egerton) and *Xiphactinus mantelli* (Newton), in the Southerham fauna (Woodward, 1902–1912). Fragmentary jaws of *I. minor* are known from several Turonian Chalk localities and are characterized by the sharp hollow teeth set into deep sockets (Woodward, 1902–1912; Bardack, 1965; Nelson, 1973; see Blue Bell Hill report). Better-preserved specimens of the genus were recovered from the Upper Cretaceous of Kansas and named *Portheus* by Cope (1872) and *Xiphactinus* by Leidy (1857). Newton (1877) was able to reassign much of the British material to *X. mantelli*, a large form probably attaining lengths of up to 4–5 m (Woodward, 1902–1912). The fossil material includes fragmentary jaws and large isolated bones, such as fin rays and vertebrae.

The plethodont *Plethodus* is the only genus of this enigmatic group recorded from the Chalk (Longbottom and Patterson, 1987; see Blue Bell Hill report). The typical crushing dentition is clearly seen in the type species, *P. expansus* Dixon, described from detached dental plates from the Turonian Chalk of Lewes. These plates are up to 0.1 m in length, and the species may have reached 1 m or so in length. The pentagonal dental plates of *P. pentagon* Woodward have also been recorded in the Machine Bottom Pit.

The higher teleost or euteleost fauna (Figure 13.19) of the Lower and Middle Chalk succession of Southerham is largely the same as that from Blue Bell Hill (q.v.), although there are some differences. Again all the fish taxa recognized in the Southerham fauna are highly advanced eutelosts or 'neoteleostean' fishes (Rosen and Patterson, 1969; Rosen, 1973) and the assemblage contains the same orders (Ctenothrissiformes, Aulopiformes, Mytophiformes, Polymixiiformes and Beryciformes) as at Blue Bell Hill (q.v.). Therefore, in the following text, descriptions of fishes already described for the Blue Bell Hill report are kept to a minimum and the reader is advised to consult the Burham interpretative section for more information.

Among the neoteleosts represented at Southerham are the type specimens of three extinct Cretaceous ctenothrissoid fishes, *Aulolepis typus* Agassiz, *Ctenothrissa microcephala* (Agassiz) and *C. radians* (Agassiz). These genera are also found at Blue Bell Hill (q.v.). Both species of *Ctenothrissa* were named from fairly well-preserved fish from the Mantell Collection of Lower–Middle Chalk fishes from Southerham (Woodward, 1902–1912). *Aulolepis* is a monospecific genus restricted to the English Chalk, which differs from *Ctenothrissa* in the morphology of the head and jaws, and in possessing non-pectinate scales (Patterson, 1964, 1968; Figure 13.19G).

The common Chalk euteleost predatory fishes, the 'enchodonts' (aulopiforms; Goody, 1969; Rosen, 1973; Longbottom and Patterson, 1987), are represented in the Southerham fauna by six species (Woodward, 1902–1912), and like the aulopiforms at Blue Bell Hill (q.v.), include representatives of three groups: the enchodontoids, the cimolichthyids and halecoids. The eel-like dercetid *Dercetis* is also found at Southerham (Woodward, 1902–1912). The enchodont *Apateodus striatus* Woodward, 1901 (Figure 13.19A) had a long pointed head and snout, with a thickened palate possessing two large, well-spaced fangs (Goody, 1969; Figure 13.19A,A'). The enchodontoids are represented by two species, *Enchodus lewesiensis* (Mantell) and *E. pulchellus* Woodward, in the Lewes collections (Woodward, 1902–1912; Goody, 1969;

Figure 13.19L). The cimolichthyid *Cimolichthys lewesiensis* Leidy is an elongated form with an ornamented head and a long pointed snout (Woodward, 1902–1912; Figure 13.19H). Several dental fangs are present on the palatine and dentary, and the laterally compressed palatal teeth have a barb at their tip (Goody, 1969; Longbottom and Patterson, 1987). *C. lewesiensis* also possessed a series of dermal scutes which ran along the dorsal edge of the body from behind the head to the dorsal fin and a second smaller series along the lateral line of the trunk (Woodward, 1902–1912). *Cimolichthys lewesiensis* is the type species, the barbed teeth of which have been found in all facies, throughout the Chalk. The halecoid *Halec eupterygius* (Dixon) is a more generalized aulopiform (Rosen, 1973; Figure 13.19M,N), with a deeply fusiform body and laterally compressed head, ornamented with ridges and tubercles of ganione (Goody 1969; Woodward, 1902–1912). The last enchodont at Southerham is the type specimen of the dercetid *Dercetis elongatus* Agassiz, a Chalk representative of a Cretaceous family of long, thin, eel-like fishes that possessed a very wide gaping mouth lined with numerous small, sharp teeth (Woodward, 1902–1912; Rosen, 1973). *Dercetis* is easily recognizable from large V-shaped scutes arranged in two or three series along the trunk. The shape of these can be used to differentiate species even from fragmentary or detached material (Longbottom and Patterson, 1987).

The sardinoidid myctophiform *Acrognathus boops* Agassiz is a small fish, attaining a size of a little over 0.1 m, with thick uniform cycloid scales (Rosen, 1973). *Acrognathus* possessed an elongated trunk, and a large head with huge orbits. The small delicate jaws were lined with minute teeth (Woodward, 1902–1912). Although *A. boops* is the type species of the genus, the material recovered from the Chalk at Lewes and pits in Surrey is fragmentary (Woodward, 1902–1912). The genus is better known from a second species, *A. libanicus* Woodward, from the Upper Cretaceous of Lebanon (Rosen, 1973).

Acanthomorphs in the Chalk fauna of Lewes include the polymixiid *Berycopsis elegans* (Dixon), the trachichthyoids *Hoplopteryx lewesiensis* (Mantell), *H. superbus* (Dixon) and *H. simus* Woodward, 1902, and the holocentroid *Caproberyx*. *Hoplopteryx* was a deep-bodied fish that is characterized by expanded sensory canals upon the frontal region of the skull, an upturned mouth lined with tiny teeth and large eye (Woodward, 1902–1912; Figure 13.19B). Species of *Hoplopteryx* from the English Chalk were commonly referred to the extant beryciform genus *Beryx* by early authors (e.g. Agassiz, 1833–1845; Dixon, 1850), but the various genera can be distinguished by many characters (Woodward, 1902–1912). *Holopteryx lewesiensis* reached up to 0.3 m. It bore a large dorsal fin which extended along almost half the length of the back and had finely rugose ornamented scales. *Caproberyx suberbus* was a much bigger fish, attaining 0.45 m, had a more elongated trunk than *H. lewesiensis* and more strongly ornamented scales (Patterson, 1964). *Holopteryx simus* is known from Burham, Kent (q.v.), and is a small species (length about 0.2 m), which possessed unusually coarse and well-developed ornament on the bones of the head (Woodward, 1902–1912). All three species occur in Lower Chalk ('*H. subglosus*' Zone) of Kent and Sussex, with *H. superbus* also found in the Middle Chalk of the same region, and *H. lewesiensis* ranging up to the *M. cortestinunium* Zone of the Upper Chalk of Surrey (Woodward, 1902–1912).

The Southerham fauna includes a nearly complete type specimen of the Cretaceous coelacanth *Macropoma mantelli* Agassiz (Figure 13.19K). This species is known from several complete specimens from the Turonian of the Machine Bottom Pit and other localities in south-east Britain (Woodward, 1902–1912). *Macropoma mantelli* reached lengths of up to 0.6 m and possessed a large, robust head, the bones of which were coarsely ornamented with pits and tubercles. The jaws were lined with irregularly arranged large and small conical teeth, whilst the palatal bones possessed clustered large teeth. Coprolites assigned to this coelacanth are also found in the Lewes collections.

Fossil reptiles recovered from the Lower and Middle Chalk succession of the Machine Bottom Pit (Jukes-Brown and Hill, 1903, pp. 46–58, 404) include turtles, plesiosaurs and mosasaurs, as well as the piscivorous pterosaurs. Predatory tetrapod communities, dependent upon fish in the Late Cretaceous seas, are known from many parts of the world. Those in southern England would have apparently had an abundant food supply, to judge from the record of fishes in the Chalk here. Although the quarry is not an SSSI for these marine reptiles, the fauna is listed in the review of fossil reptile sites (Benton and Spencer, 1995). However, the authors mistakenly ascribe the finds to the Grey Pit at Southerham (q.v.), because of the confusion over names.

Comparison with other localities

The faunas are broadly similar in composition and preservation to those described from Burham in Kent (q.v.). However, in detail there are minor differences, such as in the absence of pycnodonts in the Burham assemblages, but overall the two faunas complement one another.

Conclusion

The Machine Bottom Pit at Southerham has yielded one of the most complete Lower and Middle Chalk fish faunas, including 27 type specimens, which provide its conservation value. Eleven of these are amongst the earliest neoteleosts, the largest living group of bony fishes, and the Southerham specimens are important in defining basal characteristics of the group.

SOUTHERHAM GREY PIT (TQ 427090)

Highlights

Southerham Grey Pit in East Sussex (Figure 13.20) exposes a Chalk succession slightly older than that in the neighbouring Machine Bottom Pit. Fossil fish remains have been recovered in recent years by bulk sampling the sediments of a large channel structure that occur between the Grey Chalk and Chalk Marls. The site has excellent potential for new finds.

Introduction

The Southerham Grey Pit or Eastwoods Cement Company Pit exposes a total of 50 m of the Chalk Marl and Grey Chalk in the Lower Chalk succession (Lower–Middle Cenomanian). Now disused, it was worked relatively recently (White, 1926; Kennedy, 1969) and is not, therefore, the source of the large collections of chalk fish made in the 19th century. Nevertheless, the exposed Lower Chalk sequence in the Grey Pit can be correlated with the nearby overgrown section within the fossiliferous Machine Bottom Pit (q.v.), and the pit is important as the stratigraphically highest productive site for Lower Chalk fishes.

The geology of the Grey Pit has been described in detail by Kennedy (1969, pp. 497–499), who also produced a bed-by-bed account of the palaeontology of the section. Subsequent workers (e.g. Wright and Kennedy, 1984; Lake *et al.*, 1987) have refined Kennedy's description, improving the quality of the biostratigraphical subdivision of the section and providing a correlation with the Lower Chalk sequence on the south coast. The fishes have not been formally described.

Description

The section has not been fully described, but detailed logs of the exposed faces in the Grey Pit were produced by Kennedy (1969) and Lake *et al.* (1987). Kennedy (1969) gave an excellent account of the fossils of the Lower Chalk succession exposed in the pit at that time, but made no mention of any fossil fishes in either the Chalk Marl or overlying Grey Chalk.

The Chalk Marl succession in the pit is highly fossiliferous, comprising an alternating sequence of marls and thick shelly limestone bands (Kennedy, 1969). The limestone bands in particular, produce a well-preserved uncrushed ammonite and inoceramid bivalve fauna, on which biostratigraphical subdivision is based. However, the zonal and subzonal boundaries are difficult to determine in the Chalk Marl of the Lewes area (Lake *et al.*, 1987). The boundary between the Chalk Marl and overlying Grey Chalk in this quarry is sharp (Figure 13.17) and occurs within the *acutus* Subzone (Lake *et al.*, 1987). The Grey Chalk at Southerham is much more calcareous than elsewhere, although the thin marl seams which do occur are laterally persistent and can be correlated to other pits in the area. At the top of the Grey Chalk section in the Grey Pit a 6 m band of limestone with large scour structures has been observed. This unit is present in the Machine Bottom Pit (q.v.) and corresponds to 'Jukes-Browne Bed 7' of the Dover–Folkestone Grey Chalk sequence (Lake *et al.*, 1987).

Fossil fishes have been recovered in recent years by bulk sampling the basal infill of a large channel structure between the Grey Chalk and Chalk Marls within the section (Lake *et al.*, 1987). The structure has a lateral extent of

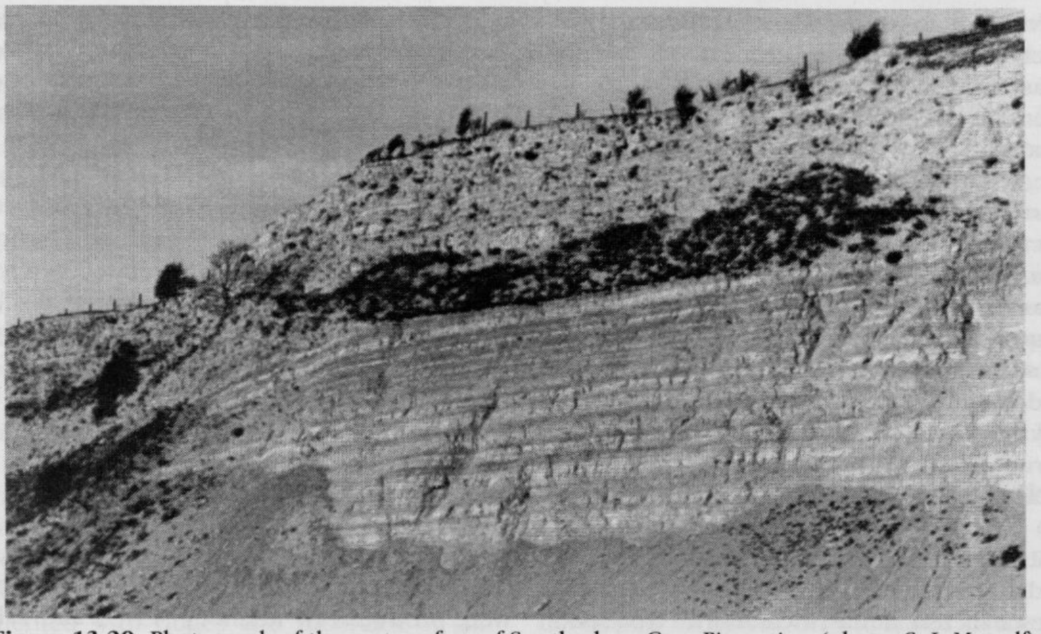

Figure 13.20 Photograph of the eastern face of Southerham Grey Pit section (photo: S. J. Metcalf).

around 100 m across the northern face and has been described in detail by Lake *et al.* (1987). It cuts down from a level 1.5 m above the base of the Grey Chalk through 6 m of the underlying Chalk Marl. The basal infill comprises a thin (0.1–0.7 m) phosphatic rubble, which is also found in vertical burrows in the underlying chalk. The basal bed largely comprises a coarse calcarenite with a high content of echinoid debris. Pebble-sized clasts include reworked angular chalk, glauconitized and phosphatized pebbles and small phosphatic coprolites. Small fish teeth can be extracted from this unit by acid preparation. The channel structure is inaccessible in the quarry face, but fallen blocks are commonly found in the talus slopes (D. Ward, pers. comm., 1994).

Fauna

The fauna recovered from acid preparation of the channel infill sediments has not been formally described (for example, the assemblage is referred to by Lake *et al.*, 1987, p.68, as 'much pelletal phosphate with small fish teeth'). The list of species is taken from the unpublished results of D. Ward (pers. comm., 1995).

Chondrichthyes: Elasmobranchii: Neoselachii: Squalomorphii
- *Notorhynchus aptiensis* (Pictet, 1865)
- *Protosqualus* sp.

Chondrichthyes: Elasmobranchii: Neoselachii: Squatinomorphii
- *Squatina* sp.

Chondrichthyes: Elasmobranchii: Neoselachii: Galeomorphii
- *Cretolamna (Lamna) appendiculata* (Agassiz, 1843)
- *Cretolamna* sp.
- *Leptostyrax* sp.
- *Paranomotodon* sp.
- *Paraorthacodus* sp.
- *Scyliorhinus* sp.
- *Squalicorax (Corax) falcatus* (Agassiz, 1843)
- *Synechodus* sp.
- *Synodontaspis (Carcharias) striatula* (Dalinkevicius, 1935)

Chondrichthyes: Elasmobranchii: Neoselachii: Batomorphii
- *Squatirhina* sp.
- *Turonibatis cappettai* Landemaine, 1991

Interpretation

The channel lag deposit from which the fish fauna was recovered formed during a break in sedimentation in the Chalk Marl and Grey Chalk succession, and therefore the fish remains may have been concentrated or reworked from older deposits. However, the channel infill is an important source of Lower Chalk fishes, and their ages are roughly constrained to the *M. dixoni* and basal *A. rhotomagense* Zones.

The acid residues from the channel infill are made up of neoselachian taxa entirely, with no bony fish or archaic shark material (D. Ward, pers. comm., 1995). The fauna includes squalomorph, squatinomorph, galeomorph and batomorph neoselachians and is almost identical to that from Totternhoe (q.v.). The squalomorphs are represented by two small species, the squalid *Protosqualus* and the hexanchid *Notorhynchus aptiensis* (Pictet). *Protosqualus* teeth are common in many of the Chalk residues, including Totternhoe (q.v.) and the Lime Kiln Quarries at Southerham (q.v.). *Notorhynchus* is a Recent cow-shark that has seven branchial slits, and its fossil record is comprised solely of isolated teeth (Cappetta, 1987). The teeth are large and like those of the other Chalk hexanchids, *Hexanchus* and *Notidanodon*. The Grey Pit teeth are clearly referrable to the Lower Cretaceous (Aptian) species *N. aptiensis*, recovered from the 'Gargasian' sequence of southern France (Pictet, 1865), and this record extends the range of the species into the Upper Cretaceous (Cappetta, 1987). The species *N. serratissimus* (Agassiz, 1843) occurs in the Ypresian (Lower Eocene) of the Isle of Sheppey (q.v.), and thus the occurrence of *N. aptiensis* in the Grey Pit fauna fills a significant gap in the fossil record of this genus.

All the other elements of the Grey Pit microshark fauna are recorded from acid preparation of the Totternhoe Stone of Totternhoe (q.v.) by D. Ward (pers. comm., 1995), and details are not given here (see 'Interpretation' section of the Totternhoe report).

Comparison with other localities

The Cenomanian faunas of Southerham Grey Pit and the Totternhoe Stone are virtually identical, despite slightly different depositional environments. However, both assemblages are concentrated in lag deposits and are roughly equivalent in age (*M. dixoni* and *A. rhotomagense* Zones of the Lower Chalk). The acid residues from Southerham lack some of the larger elements of the Totternhoe Stone, such as the hybodont shark *Ptychodus*.

Conclusion

The conservation value of Southerham Grey Pit results from its Cenomanian microshark fauna that contains a diverse assemblage of neoselachian elements, including rare teeth of the seven-gilled cow-shark *Notorhynchus*. This living form is otherwise only known from Lower Cretaceous and Lower Eocene sequences, and the occurrence of this genus in the Upper Cretaceous of Southerham fills an important gap in the fossil record of this group.

SOUTHERHAM (LIME KILN QUARRIES; TQ 42650965)

Highlights

Although limited in diversity, the microshark fauna extracted from the phosphatic unit above Strahan's Hardground in the Lime Kiln Quarries of Southerham in East Sussex (Figure 13.21), is extremely important, being one of the very few Middle Chalk fish assemblages in the country.

Introduction

The largest sections in the Lewes area of the Middle and Upper Chalk (Turonian–Coniacian) succession are exposed in the disused quarries associated with the defunct cement works at Southerham. These pits are known collectively as the Lime Kiln Quarries and comprise the old Navigation (or Snowdrop) Pit (to the north), Chandlers Yard and the Southerham Works Quarry (in the south). The sections are now inaccessible but did provide an almost complete sequence through the Ranscombe, Lewes and Seaford Members of the Middle and Upper Chalk.

The Middle Chalk has never produced an abundant vertebrate fauna and the Upper Chalk is similarly impoverished. Thus the fish that can be recovered from the phosphatic New Pit Beds, overlying 'Strahan's Hardground', low down in the Middle Chalk (Ranscombe Member) section at Southerham Works Quarry, are extremely important.

The geology of the Middle and Upper Chalk succession in parts of the Lime Kiln Quarries has been documented by Strahan (1896) when the pit was still working, and subsequently by White (1926), Mortimore (1986) and Lake *et al.* (1987). The fish material has not been formally described, although it is listed by Strahan (1896, p. 464) and more recently sampled by D. Ward (pers. comm., 1995).

Figure 13.21 Photograph of Lime Kiln Quarries, the marly chalk seen (above the talus) in the left (north) face of the quarry is in the Zone of *Holaster subglobosus*; that in the lowest 3 m or so of the farther (east) face is in the Zone of *Schloenbachia varians*. (Photo: BGS no. 2962; Crown Copyright Reserved).

Description

The Lime Kiln Quarries expose over 40 m of Middle and Upper Chalk succession. Fish remains are only recorded from the basal 20 m of the section within an anomolous phosphatic flint sequence forming the uppermost levels of the New Pit Beds (Ranscombe Griotte Chalk Member of the Middle Chalk). These beds were formerly exposed in the southern end of the Southerham Works Quarry and were described by Strahan (1896), and his section appears to have been made about 230 m NNE of the railway level crossing (as reported by Lake *et al.*, 1987) where the phosphatic chalk deposit was thickest. The measurements have been converted to metres (after Lake *et al.*, 1987):

	Thickness (m)
Massive chalk with flints	
Flakey white chalk with a few flints and *Holaster planus*	1.22
[passing down into]	
Phosphatic chalk with many small fish teeth, a few spines of *Cidaris* and some nodules, partly green, partly brown, up to 1½ inch [0.04 m] in diameter	0.46
[a sharp line of demarcation]	
Hard creamy limestone with calcite in veins and cavities, nodular (some of the nodules being green-coated), lumps of decomposed iron-pyrites	0.46
Hard, white, compact chalk, traversed by branching pipes and thin laminae of phosphatic chalk	0.91
Hard white, compact chalk, with the pipes [burrows] and laminae of phosphatic chalk less abundant and dying away downward	0.91

These beds overlaid the massive 'Strahan's Hardground'. The overlying phosphatic lag deposit was restricted in lateral extent (approximately 18.3 m in width; Lake *et al.*, 1987) and thinned rapidly towards both ends of the Works Quarry section. It was largely composed of shell fragments, phosphatized foraminiferan tests, pale brown coprolites, and scattered fish teeth and bones. The greenish mineral which Strahan described was probably glauconite and appeared as dark green specks set within the pale grey chalk (Lake *et al.*, 1987). Much of the vertebrate material is less than a millimetre in size, although larger bone and tooth fragments also occur and the coprolites may reach 0.04 m. Strahan (1896) equated the phosphatic chalk with the Chalk Rock of the Chilterns, and in doing so, took it to mark the base of the Upper Chalk. However, recent geophysical and field evidence indicates that this is not the case, and that the phosphatic beds lie within the top 15 m of the New Pit Beds (known as the New Pit Marls) at the top of the Ranscombe Member in the Middle Chalk succession (Mortimore, 1986). The New Pit Beds fall within the *Terebratulina lata* Zone of the Middle Turonian (Mortimore, 1986). The occurrence of a phosphatic chalk at this level in the Middle Chalk is unique in the British Chalk sequence (Lake *et al.*, 1987). However, the deposit may correspond to the weakly phosphatized Tilleul Hardgrounds 1 and 2 of Haute Normandie on the northern coast of France (Kennedy and Juignet, 1974).

Fauna

The fauna recovered from the phosphatic lag horizon has not been described, but is listed by E.T. Newton (*in* Strahan, 1896, p. 464) and has been sampled by acid preparation more recently by D. Ward (pers. comm., 1995).

Chondrichthyes: Elasmobranchii: Euselachii: Hybodontoidea
Ptychodus sp.
Chondrichthyes: Elasmobranchii: Neoselachii: Squalomorphii
Protosqualus sp.
Chondrichthyes: Elasmobranchii: Neoselachii: Galeomorphii
Cretolamna sp.
'*Hemiscyllium*' sp.
'*Odontaspis*' sp.
'*Oxyrhina*' sp.
Scyliorhinus sp.
Squalicorax (Corax) falcatus (Agassiz, 1843)
Chondrichthyes: Elasmobranchii: Neoselachii: Batomorphii
Turonibatis cappettai Landemaine, 1991

Interpretation

Although according to Strahan (1896, p. 464) 'in the phosphatic band fish remains abounded, both minute pellets and teeth', the fauna listed here and given by D. Ward (pers. comm., 1995) is limited in diversity. The identifiable assemblage is composed wholly of shark teeth and these include representatives of the hybodonts *Ptychodus*, and neoselachian sharks, including the squalid *Protosqualus*, the common Chalk lamniforms *Cretolamna* and *Squalicorax falcatus* (Agassiz), the scyliorhinid *Scyliorhinus*, and the batoid *Turonibatis cappettai* Landemaine, 1991 (D. Ward, pers. comm., 1995). All these genera have been suitably described elsewhere (see the Totternhoe report above for the description of the neoselachian taxa, and the Machine Bottom Pit report for that of *Ptychodus*).

Ward (pers. comm., 1995) also recorded '*Hemiscyllium*' sp. in the acid residues from this site. This genus is an extant orectolobiform galeomorph, the 'epaulette' shark (Steel, 1991), known in the fossil record from Palaeocene and Eocene deposits of Belgium (Herman, 1974, 1977) and not previously recorded from the Upper Cretaceous, although the Hemiscyllidae are represented by three other genera from the Cenomanian (Cappetta, 1980, 1987). *Hemiscyllium* teeth are less than 1 mm in width and clearly cuspate (Cappetta, 1987), with a rudimentary pair of lateral cusplets flanking the main cusp. Today *Hemiscyllium* is a small benthic shark which inhabits the warm waters and coral reefs of the Indo-Pacific region (Steel, 1991). The dentition is of a clutching type.

In the original list of Strahan (1896), both '*Odontaspis*' sp. and '*Oxyrhina*' sp. were listed. *Odontaspis* is a modern lamniform, known as the 'sand tiger shark' (Steel, 1991), which has been recorded in rocks of Campanian age in North America (Cappetta and Case, 1975). *Odontaspis* had tearing-type teeth with up to three pairs of very sharp and high cusplets flanking a large main cusp, with prominent cutting edges. '*Oxyrhina*' is a defunct genus that includes three Chalk species (Woodward, 1902–1911), now assigned to three different lamniform genera (Longbottom and Patterson, 1987): the alopiid *Paranomotodon (Oxyrhina) angustidens* (Reuss), and the cretoxyrhinids *Plicatolamna (Oxyrhina) crassidens* (Dixon) and *Cretoxyrhina (Oxyrhina) mantelli* (Agassiz). All of these are large predaceous sharks with tearing-type dentitions (Figure 13.22) similar to the modern mako shark *Isurus* (Cappetta, 1987).

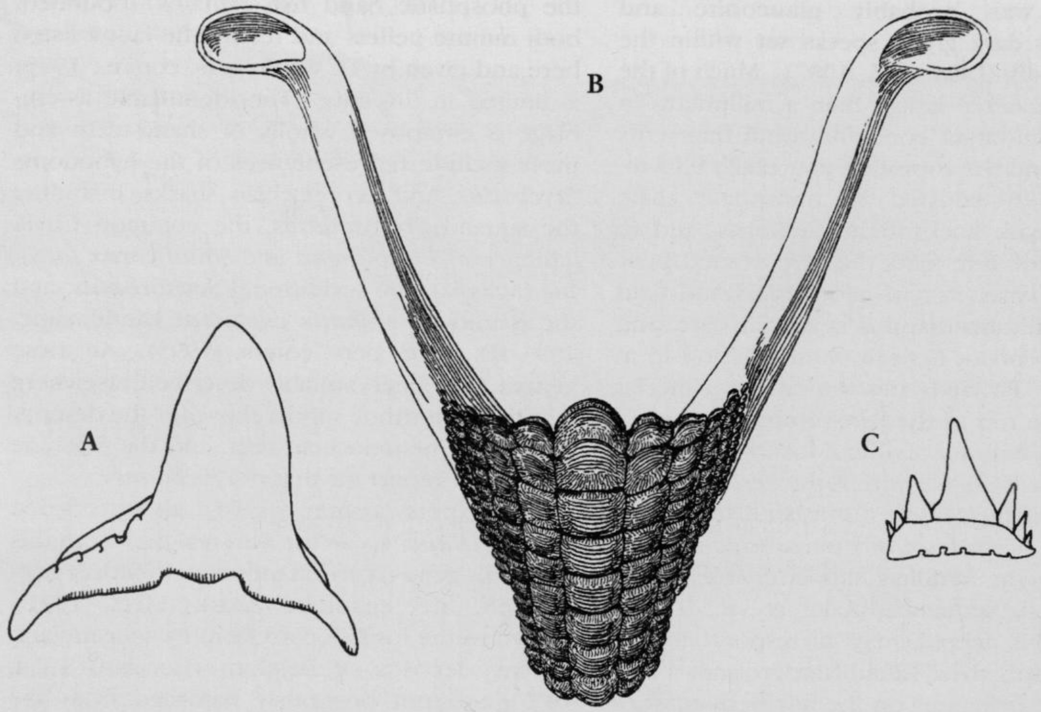

Figure 13.22 Chondrichthyan fishes from the Chalk at Southerham Lime Kiln Quarry. (A) *Plicatolamna crassidens* × 1.0; (B) *Ptychodus decurrens* Agassiz, a restoration of the lower jaw × 1.0; (C) *Paranometodon angustidens* × 2.0. (From Longbottom and Patterson, 1987.)

Comparison with other localities

Excavations between 1975 and 1985 for a new road near Southerham at TQ 427094, revealed a similar horizon at approximately the same level within the Middle Chalk (Lake *et al.*, 1987). The excavated section showed a fully developed hardground, approximately 0.7 m thick, with a convoluted, iron-stained surface, which was strongly mineralized (particularly in the upper 0.2 m) with glauconite and phosphates (Lake *et al.*, 1987). Burrows within the hardground were filled with pelletal phosphatic chalk and other debris, and the surface was overlain by 30 mm of similar sediment. The bed may be equivalent to 'Strahan's Hardground', or another lenticular phosphatic bed occurring at roughly the same level in the upper New Pit Marls (Lake *et al.*, 1987, p. 72). An invertebrate assemblage from these sediments was described by Lake *et al.* (1987) from these sediments, but no mention of any fish remains was made. However, there is a limited potential for fossil fish finds, in that bulk processing of any phosphatic horizons found by future excavations at this level might reveal the true extent of the fish fauna.

Conclusion

The restricted fish fauna recovered from the phosphatic chalk overlying Strahan's Hardground at the Lime Kiln Quarries at Southerham is important as it is one of the few Middle Chalk assemblages recorded and gives the site its conservation value. Recent excavations at the same level in the Middle Chalk at Southerham have revealed a second phosphatic unit, and further remains may be recovered by future excavations.

BOXFORD CHALK PIT (SU 431719)

Highlights

Boxford Chalk Pit in Berkshire (Figure 13.23) is extremely important as being one of the best Upper Chalk sites still actively producing fossil fishes. Bulk sampling of the unusual phosphatic horizons at the quarry in recent years has revealed a rich microshark fauna, which includes some extremely rare taxa not previously described from the British Chalk sequence. The site is still accessible and future excavations will undoubtedly produce more remains.

Introduction

Boxford Chalk Pit is one of the few remaining pits in the Upper Chalk (Upper Turonian–Santonian) succession of southern Britain still producing vertebrates. At this site there are many thin phosphatic horizons overlying phosphatized hardgrounds in the upper half of the *M. coranguinum* Zone (Santonian Chalk), which yield abundant coprolites and many tiny fish teeth. The material recovered by bulk sampling includes an important microselachian component with many taxa yet to be described.

The small quarry is disused and rather overgrown (Figure 13.23), with dangerous talus slopes below the main faces. However, the faces are clean and further finds could be made with minor re-excavation. The geology of the site has been described by White (1907).

Description

The section was originally described by H.J. Osborne White for the Geological Survey Memoir (1907) and is reproduced here with modifications:

Thickness (m)

4. Soft to very hard yellowish-white chalk, having a lumpy appearence on weathered surfaces, and containing a few flints in the lower part. Harder portions occur in ill-defined bands, and in elongate bodies at various angles to the bedding planes. Softer parts distinctly phosphatic, the wash-residues being rich in brown polished coprolites, phosphatic clasts of foraminifera, and organic debris. Brown phosphatic, and light or dull green glauconitic concretions, of angular form (up to ¼ inch [6 mm] in diameter) are very abundant in places. Many oyster shells *c.* 3.0
3. Firm, irregularly-jointed white chalk, with one distinct band of nodular, and a few seams of tabular flint, near the middle. Lower part of the bed yields asteroid ossicles, fragments of *Inoceramus*, and broken *Cidaris* plates. A thin seam of grey rubbly marl at the base *c.* 4.3
2. Yellow, rocky chalk, minutely banded with iron stains, and green concretions. Top of this hard band even and clearly defined, in places a very thin brown glaze. From it descend borings filled either with the marl or with soft chalk containing phosphatized materials like those in bed (4): 0.3–0.8
1. Soft, white, blocky chalk, passing up into the above rock. One prominent band of big flint nodules (studded with asteroid ossicles, plates of *Cidaris*, etc.) about 5 feet [1.5 m] down. Smaller scattered, finger-shaped and globular flints 2.1

The sequence of hard and phosphatized chalk is uncommon in the White Chalk in the Boxford

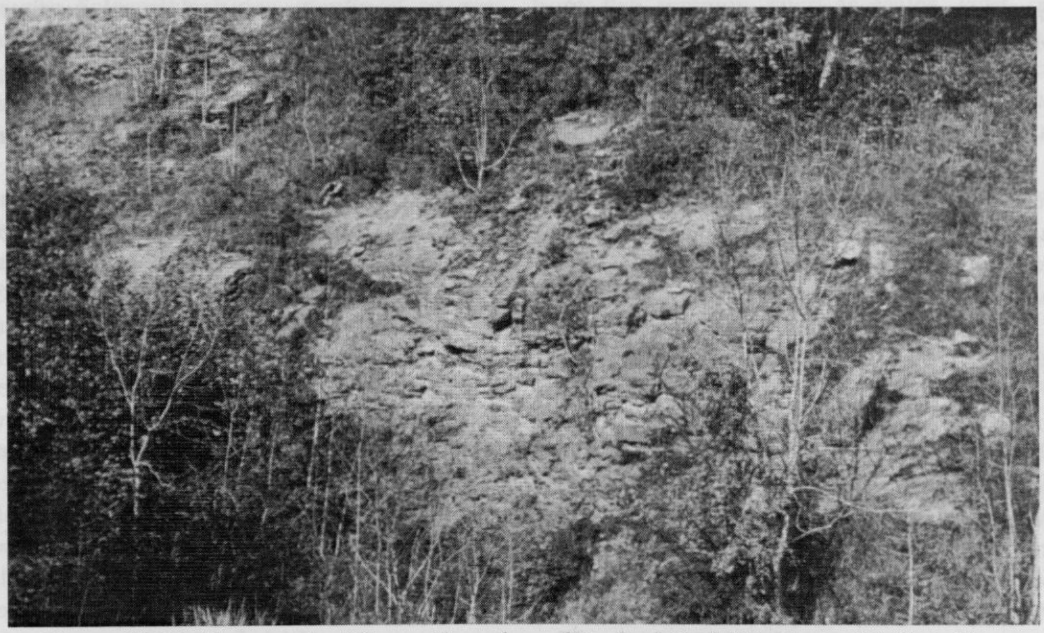

Figure 13.23 Photograph of the southern face of Boxford Chalk Pit (photo: S.J. Metcalf).

area, and many more phosphatic beds occur lower down in the *M. coranguinum* Zone in this region (White, 1907). Most of the vertebrate material was derived from the uppermost phosphatic unit (Bed 4 in the log; White, 1907, p. 25), which is similarly rich in invertebrates, many of which are phosphatized.

Fauna

The microvertebrate remains yielded by acid preparation have not been formally described; the list below has been compiled from the unpublished results of D. Ward (pers. comm., 1995).

Chondrichthyes: Elasmobranchii: Neoselachii: Squatinomorphii
Squatina sp.
Chondrichthyes: Elasmobranchii: Neoselachii: Galeomorphii
Cretolamna (Lamna) appendiculata (Agassiz, 1843)
Cretolamna sp.
'*Hemiscyllium*' sp.
Pararhincodon crochardi Herman, 1977
Paratriakis sp.
Scyliorhinus sp.
Squalicorax (Corax) kaupi (Agassiz, 1843)
Synechodus sp.
Chondrichthyes: Elasmobranchii: Neoselachii: Batomorphii
Ganopristis sp.
Rhinobatos sp.
Squatirhina sp.

Interpretation

The phosphatized condensed sequence at Boxford is relatively rich in fossil sharks. These include the usual complement of galeomorph sharks, for example *Cretolamna*, *Scyliorhinus*, *Squalicorax* and *Synechodus*, which are common in all British Chalk horizons, although many other common galeomorph taxa recorded from other Chalk sites, such as *Paranomotodon*, *Cretoxyrhina* and *Plicatolamna*, are missing. No squalomorph shark is present at Boxford, although teeth of the ubiquitous *Squatina* were recovered from acid residues (D. Ward, pers. comm., 1995). Ptychodont sharks were also not found at Boxford, although several species of *Ptychodus* have been recorded at other Upper Chalk horizons (Woodward, 1902–1911). The neoselachian fauna includes some unusual elements quite different from those from the Lower and Middle Chalk localities.

In common with the galeomorph assemblage from 'Strahan's Hardground' at Southerham Lime Kiln Quarries (q.v.), the Boxford fauna includes tiny teeth from the extant orectolobiform '*Hemiscyllium*' sp. (D. Ward, pers. comm., 1995) and a second orectolobiform, *Pararhincodon crochardi* Herman (Figure 13.24A). This latter genus is an extinct Cretaceous and Palaeocene relative of the Recent orectolobiform Parascyllidae, represented today by two genera of small elongated sharks in the Pacific (Cappetta, 1987). The genus is known from isolated teeth of the type species, *P. crochardi*, from Turonian rocks of Belgium (Herman, 1977) and a single incomplete skeleton of a second species, *P. lehmani* Cappetta, 1980, from the Cenomanian of Lebanon (Cappetta, 1980). The teeth of *P. crochardi* are very small (about 1 mm high) and are strongly asymmetrical.

The second unusual galeomorph at Boxford is the triakid carcharhiniform *Paratriakis* (Figure 13.24B,C). This genus has previously been recorded from complete skeletons in the Upper Santonian Chalk of Lebanon (Davies, 1887), as well as from isolated teeth from the Campanian and Turonian of northern France and Belgium (Herman, 1977). Teeth of *Paratriakis* are similar to those of the extant smooth dogfish *Triakis*, with a large, straight, central cusp flanked by either one or two pairs of lateral cusplets or a smooth cutting edge (Cappetta, 1987). *Paratriakis* is the oldest undisputed member of the Triakidae, and its presence in the Boxford fauna is the first recorded occurrence of it in the British Chalk.

Three batomorph genera are found in the phosphatic beds at Boxford. The enigmatic Cretaceous ray *Squatirhina* is present, but has also been recovered from the Totternhoe Stone of Totternhoe (q.v.) and its occurrence in the Boxford fauna is unremarkable. *Rhinobatos* is a similar rhinobatid genus, the isolated teeth of which are common in most shallow-water deposits from the Lower Cretaceous onwards (Cappetta, 1987). This genus is characterized by small teeth (up to 2 mm wide) which have a rather massive and high, globose crown, with a pronounced transverse ridge on the oral side (Cappetta, 1987). *Rhinobatos* includes several extant species which frequent warm or tropical

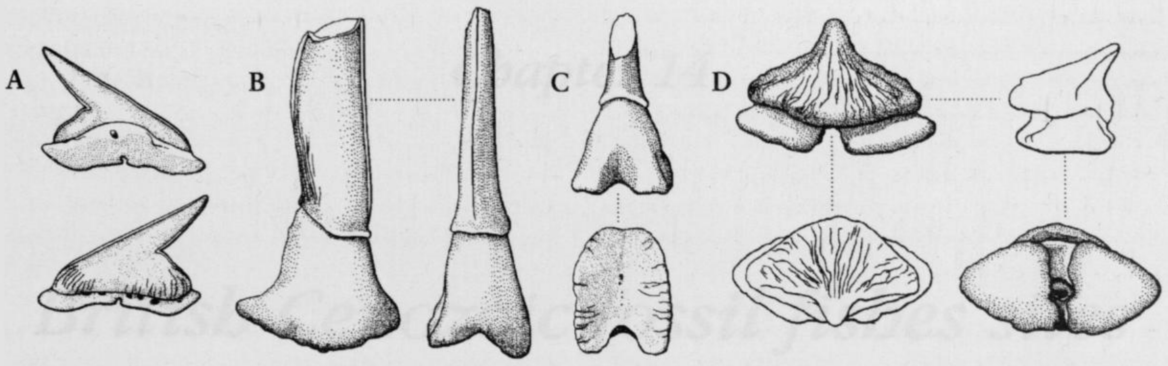

Figure 13.24 Fossil elasmobranchs from the Chalk at Boxford Chalk Pit. (A) *Pararhinocodon angustidens*, × 16; (B), (C) *Paratriakis* sp., rostral teeth, × 2.5; (D) *Ganopristis* sp. (after Cappetta, 1987), oral tooth, × 10.

seas, but almost nothing has been written on the dental morphology of these forms, making elucidation of the fossil species and their relationship to the extant forms extremely difficult (Cappetta, 1987). Living rhinobatids are benthic animals feeding on molluscs and crustaceans. Although they mainly frequent the warm waters of the continental shelf, they do not always indicate shallow depths, as several species descend to more than 200 m.

A second suborder of batomorphs represented in the Boxford fauna comprises the sclerorhynchoid rays, which are characterized by a long, flattened rostrum and a rather whip-like tail. The sclerorhynchoids were well represented in the Chalk seas, and include one extinct family, the Sclerorhynchidae, confined to the Upper Cretaceous (Cappetta, 1987). Teeth of *Ganopristis*, a Maastrichtian sclerorhynchid ray (Figure 13.24D) have been recovered from the Boxford phosphate bed acid residues (D. Ward, pers. comm., 1995). These are large, laterally compressed rostral teeth (up to 25 mm in length). The oral teeth are much wider (up to 35 mm in width) than long and have a central cusp marked by short vertical folds upon the labial and, sometimes, lingual faces (Cappetta, 1987). This occurrence may be the earliest for the genus.

Comparison with other localities

Fossil fish remains are not uncommon in the Upper Chalk succession of southern Britain, with over 30 localities recorded by Jukes-Browne and Hill (1904). However, they are not so nearly abundant or well preserved as fishes from the Lower Chalk, and many of the sites have been overlooked as sources of Chalk fishes. Sites that have yielded fish remains from the *M. coranguinum* Zone are Porton railway cutting, Wiltshire (SU 1936), Witherington railway cutting, Wiltshire, Winchester pits, Hampshire, Beachy Head–Brighton cliff section, Sussex (TV 5895–TQ 3503), Gravesend, Kent (TQ 6474), Strood pits, Kent (TQ 7269), Charlton pits, Kent, Lewisham pits, Kent (TQ 3774), and Haling and South Croydon pits, Surrey. Much of the material consists of isolated lamniform and ptychodont shark teeth, but some of these sites also yielded abundant 'enchodont' teeth, along with other bony fish remains, such as scales, jaws, rostra and a few partial skeletons of the smaller species. The large bones of the coelacanth *Macropoma* are uncommon in the Santonian Chalk, but have been found at Brighton, Sussex and in coastal sections between Dover and Margate, Kent. They have not been recorded from Boxford.

Conclusion

Although much of the Santonian microshark fauna recovered from Boxford is similar to that from earlier Chalk localities, the site has also revealed an important neoselachian component, including several shark and ray taxa not previously recorded from the British Upper Chalk, hence the site's conservation value.