Fossil Reptiles of Great Britain

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Chapter 8

British Cretaceous fossil reptile sites

INTRODUCTION: CRETACEOUS STRATIGRAPHY AND SEDIMENTARY SETTING

The Cretaceous System in Britain (Figures 8.1, 8.2) 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 Wessex–Weald region 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

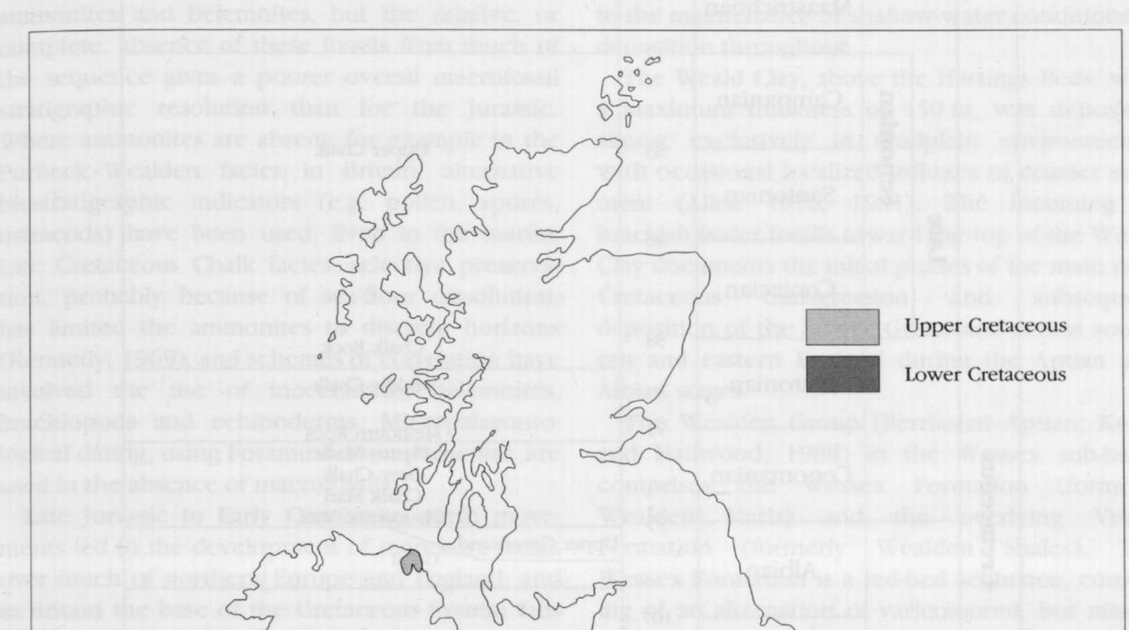

Figure 8.1 Map showing the distribution of Cretaceous (Lower and Upper) rocks in Great Britain. GCR Cretaceous reptile sites: (1) Hastings; (2) Black Horse Quarry, Telham; (3) Hare Farm, Brede; (4) Smokejacks Pit, Ockley; (5) Brook–Atherfield Point, Isle of Wight; (6) Yaverland; (7) Wicklesham Pit, Faringdon; (8) East Wear Bay, Folkestone; (9) Culand Pits, Burham; (10) St James's Pit, Norwich.

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<tr><th>System</th><th>Stage</th><th>Ma</th><th>Wessex and Isle of Wight</th><th>Weald</th></tr>
<tr><td>Palaeogene</td><td>Danian</td><td></td><td colspan="2" rowspan="2">Absent</td></tr>
<tr><td>Cretaceous, Late</td><td>Maastrichtian</td><td>65</td></tr>
<tr><td>Cretaceous, Late, Senonian</td><td>Campanian</td><td>72</td><td colspan="2" rowspan="3">Upper Chalk</td></tr>
<tr><td>Cretaceous, Late, Senonian</td><td>Santonian</td><td>83</td></tr>
<tr><td>Cretaceous, Late, Senonian</td><td>Coniacian</td><td>86</td></tr>
<tr><td>Cretaceous, Late</td><td>Turonian</td><td>88</td><td colspan="2">Chalk Rock
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Plenus Marls
Grey Chalk
Chalk Marl
Glauconitic Marl</td></tr>
<tr><td>Cretaceous, Early</td><td>Albian</td><td>95</td><td>Upper Greensand</td><td>Gault</td></tr>
<tr><td>Cretaceous, Early</td><td>Aptian</td><td>107</td><td colspan="2">Lower Greensand</td></tr>
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<tr><td>Cretaceous, Early, Neocomian</td><td>Hauterivian</td><td>116</td><td rowspan="2">Wealden Group: Wessex Formation</td><td>Lower Weald Clay</td></tr>
<tr><td>Cretaceous, Early, Neocomian</td><td>Valanginian</td><td>120</td><td>Hastings Beds: Upper Tunbridge Wells Sands
Grinstead Clay
Lower Tunbridge Wells Sands
Wadhurst Clay
Ashdown Beds</td></tr>
<tr><td>Cretaceous, Early, Neocomian</td><td>Berriasian</td><td>128</td><td>Purbeck Beds: Upper, Middle, Lower</td><td>Purbeck Beds: Upper, Middle
?</td></tr>
<tr><td>Jurassic</td><td>Portlandian</td><td>135</td><td>Portland Beds</td><td>Portland Beds</td></tr>
</table>

Figure 8.2 Summary of Cretaceous stratigraphy, showing global stage nomenclature and some major southern British formations. Based on Harland *et al.* (1990).

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 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 stratigraphic resolution than for the Jurassic. Where ammonites are absent, for example in the Purbeck–Wealden facies in Britain, alternative biostratigraphic indicators (e.g. pollen, spores, ostracods) have been used. 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, using Foraminifera in particular, are used in the absence of macrofossils.

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 outcrop over an extensive area of Sussex, Surrey and Kent (the Weald area) and on the Isle of Wight and in Dorset. 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; within it two 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 + Lower Weald Clay). The base of each cycle commences with clays and siltstones which gradually coarsen upwards into cross-bedded sandstones. The uppermost beds may include pockets and lenses of bone-rich gravel. These pass upwards into cross-laminated siltstones with the horsetail *Equisetites* and then return to argillaceous rocks forming the base of the following cycle. These sediments have, in the past, been interpreted as deltaic in origin, but the more recent work of Allen (1976, 1981) indicates that they were deposited in lagoonal to lacustrine mudplain environments in which salinity was controlled by the rates of run off of surface freshwater and evaporation. The occurrence of soil horizons, dinosaur footprints and the remains 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 (Allen 1976, 1981). The incoming of brackish water fossils toward the top of the Weald Clay documents the initial phases of the main mid-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 red-bed sequence, consisting of an alternation of varicoloured, but 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 (Stewart, 1981a, 1981b, 1983; Daley and Stewart, 1979). The Vectis Formation comprises mainly grey mudstones and siltstones, usually organized in thin fining-upwards cycles. This unit is about 60 m thick on the Isle of Wight, but thins westwards into Dorset, and it is absent in some sections. Sedimentological and palaeoecological data suggest that the Vectis Formation was deposited in a shallow coastal lagoon which was subject to increasing salinity and storm frequency towards the top (Stewart *et al.*, 1991; Wach and Ruffell, 1991).

The Lower Greensand Group consists of a complex series of mudstone and sandstone facies with a rich marine fauna (bivalves, gastropods, brachiopods, echinoids, ammonites, crustaceans, corals), 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-east 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 often 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 marine fossils, such as bivalves, ammonites and serpulid worms. In Cambridgeshire Albian fossils are reworked into the Cenomanian Cambridge Greensand. Further 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.

Transgression, initiated in the Aptian, continued until near the close of the Cretaceous and brought changes in sedimentation which led to massive developments of coccolith ooze that now forms the Chalk. Subsequent sedimentation was occasionally interrupted when regressive phases led to deposition of 'nodular chalk' and associated hardgrounds.

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

REPTILE EVOLUTION DURING THE CRETACEOUS

The Cretaceous Period is known for its highly diverse dinosaur faunas. In Britain the best represented forms are the ornithischians which occur abundantly in the Wealden Group of southern England. These include the well-known ornithopods *Iguanodon* and *Hypsilophodon*, and the armoured ankylosaurs (e.g. *Polacanthus*). The sauropods and theropods were also important elements in Cretaceous terrestrial ecosystems, and theropods include the unusual scavenging or piscivorous form *Baryonyx* from the Weald Clay. The Wealden Group gives Britain an enviable record of Early Cretaceous dinosaurs, arguably the best in the world. Comparable faunas are known from North America (especially the Cloverly Formation of Montana and Wyoming), Europe (the Wealden of France, Belgium and north Germany, and equivalent units in Spain and Portugal), Mongolia (mainly Mid-Cretaceous in age), and sparse faunas from South America, Africa and Australia.

British records of Mid- and Late Cretaceous dinosaurs are less satisfactory because of the shift to marine sedimentation. Worldwide, however, dinosaurs showed major advances in the Late Cretaceous. New groups of ornithopods, particularly the duck-billed hadrosaurs, came to dominate terrestrial faunas and their relatives, the horned ceratopsians, also became diverse elsewhere. The sauropods were only patchily represented during Late Cretaceous times, and the stegosaurs had declined dramatically. Ankylosaurs witnessed a modest radiation, and carnivorous theropods, large (e.g. *Tyrannosaurus rex*) and medium-sized (e.g. *Struthiomimus, Stenonychosaurus*), are known from several parts of the world. Late Cretaceous dinosaur faunas are best known from North America (the midwest states of Montana, the Dakotas, Colorado, Wyoming, Texas and the province of Alberta, as well as some eastern states) and Mongolia. Some significant Late Cretaceous dinosaur faunas are also becoming better known from South America, India, China and Romania.

Among other terrestrial reptile groups, such as turtles, crocodilians, lizards and snakes, major evolutionary steps took place. The turtles diversified on land and in the sea, and many modern families appeared. Lizards also diversified on land, giving rise to many modern groups, as well as some extinct ones, most notable of which were the large marine mosasaurs and their relatives. In addition, snakes arose from 'lizards' during the Early Cretaceous, and some early constricting (non-poisonous) groups became established. Crocodilians diversified mainly on land and in fresh waters, while the marine metriorhynchids of the Jurassic declined. Many new crocodilian groups appeared, including the mammal-like terrestrial notosuchians, the giant sebecosuchians, both of these mainly in southern continents, and the modern eusuchians. Species of true crocodile and alligator are known from the Late Cretaceous.

In the air pterosaurs had become greatly advanced, and by the end of the Cretaceous occupied a variety of adaptive zones as highly efficient fish-eating soarers, as well as insectivorous forms using flapping flight. Cretaceous pterosaurs were all pterodactyloids, the advanced clade, and their size was, on the whole, much larger than the sparrow- to seagull-sized Jurassic pterosaurs. British Cretaceous pterosaur records are patchy, and not comparable in quality with the finer Early Cretaceous forms from Brazil (Santana Formation) and Mongolia, or the forms from the marine Late Cretaceous of the mid-American seaway area (Kansas, Texas). These animals were accompanied by birds which had arisen from advanced theropod dinosaurs during the Late Jurassic. Birds have a very weak Cretaceous record, with good representation only of the Late Cretaceous coastal forms in Kansas and Texas, and little in Britain.

Marine reptiles show very considerable changes in the Cretaceous. Ichthyosaurs never again achieved the importance they had in the Jurassic, and remains are patchily distributed in many parts of the world through the period, with the last ones seemingly being Cenomanian in age. Plesiosaurs also dwindled in significance, although several groups, especially giant pliosaurs and long-necked elasmosaurs, lasted right to the end of the Cretaceous, and are represented especially in southern continents and in Texas. Cretaceous ichthyosaur and plesiosaur fossils are rare in Britain. The main Cretaceous marine group was the mosasaurs, giant marine lizards, which became top carnivores, possibly as a result of the decline of the pliosaurs. Mosasaurs are patchily represented in the British Chalk, although they are better known in the type Maastrichtian of the Netherlands and in Belgium, in the United States and in parts of north Africa. At the end of the period the mosasaurs, with the other large marine reptiles of the Jurassic and Cretaceous (e.g. ichthyosaurs and plesiosaurs), which had started to decline earlier, also disappeared. The end-Cretaceous mass extinction event is best known, however, for the demise of the dinosaurs, although by very latest Cretaceous times the group seems to have been somewhat depleted both in numbers and diversity.

BRITISH CRETACEOUS REPTILE SITES

British Cretaceous localities have provided good material of many typical reptile groups, particularly of ornithischian dinosaurs, which are known from several localities in the Early Cretaceous rocks of the Weald of Sussex, Surrey and Kent, and the Isle of Wight. Saurischian dinosaurs, the theropods and sauropods, are rare. Important finds of pterosaurs are known from the Gault of Folkestone, the Cambridge Greensand and also from the Middle Chalk where they are associated with well preserved remains of lizards, snakes and turtles. Terrestrial turtles and crocodilians are also known from the Wealden, and the Cambridge Greensand. The marine plesiosaurs and ichthyosaurs are also represented in most of the sequence, and mosasaurs are known from a few localities in the Chalk.

The strength of the British Cretaceous record lies in the relatively well-dated and rich Early Cretaceous terrestrial faunas of the Wealden; this provides the richest and best view of Early Cretaceous vertebrates anywhere in the world. Some Mid- and Late Cretaceous faunas are good, but they represent mainly marine components of the reptilian faunas, and there are better faunas elsewhere. The British record is of no value in depicting Late Cretaceous terrestrial reptilian evolution.

EARLY CRETACEOUS: WEALDEN (BERRIASIAN–BARREMIAN)

The lagoonal, lacustrine and fluvial deposits of the Wealden Group of the Weald and the Isle of Wight are famed for their dinosaur faunas which are the most varied in Europe (Figures 8.3, 8.5 and 8.8). The Brook–Atherfield section on the south-west coast of the Isle of Wight exceeds the contemporaneous dinosaur-rich sediments of Mongolia and the United States of America both in the abundance and variety of the material.

The Wealden of the Weald (Berriasian–Barremian) is well known for its fossil reptiles, and specimens have come from many localities, most of which are inland extractive sites and no longer accessible. Dinosaurs, crocodilians and pterosaurs are known from all Wealden formations, but they occur most frequently in the Hastings Beds. The succeeding Weald Clay has yielded fewer remains, but has recently produced the unusual theropod dinosaur *Baryonyx*. Well-recorded reptile sites include the following:

WEST SUSSEX: Loxwood (TQ 0331; *Iguanodon*, Murchison, 1829, pp. 103–5); Rudgwick Brickworks (TQ 083344; dinosaur; Horsham Museum); Longbrook Brickworks (TQ 117188; pterosaur, crocodilian, fishes; Wells Collection); Itchingfield (TQ 123287; *Iguanodon*); Southwater (TQ 1526; pterosaur); Horsham (TQ 1730; *Goniopholis, Iguanodon*, hypsilophodontid); Henfield Brickpit (TQ 218143; *Iguanodon*;

Young and Lake, 1988, p. 23); Bolney (TQ 2622; *Hylaeosaurus*; Pereda-Suberbiola, 1993); Wivelsfield (TQ 3420; ?*Iguanodon*; various localities with fossil fishes; Young and Lake, 1988, p. 23); Balcombe Quarry (TQ 3030; *Iguanodon*); Philpots Quarry (TQ 355322; *Iguanodon*; Allen 1976, 1977); Tilgate Forest (TQ 2735, exact localities uncertain; *Plesiochelys, Tretosternon, Goniopholis, Suchosaurus, Heterosuchus, Pelorosaurus, Iguanodon, Hylaeosaurus*, pterosaurs); Cuckfield (TQ 300256, original *Iguanodon* quarry; *Archaeochelys, Plesiochelys, Tretosternon, Cimoliasaurus, Goniopholis, Suchosaurus, Heterosuchus, Ornithocheirus, Iguanodon, Valdosaurus, Hylaeosaurus, 'Megalosaurus', Pelorosaurus, Pleurocoelus*, including type specimens of eight species, but now largely filled in; Mantell, 1825, 1827, 1833, 1850a, 1850b; Murchison 1829; Galton, 1981b, p. 32; locality on Whiteman's Green determined by Swinton, 1970, pp. 29–30; also Topley, 1875, pp. 91–5; White, 1924, pp. 8–10); Keymer Tile Works (TQ 325189; microvertebrates; crocodilian and dinosaurian remains; Young and Lake, 1988, p. 24; A. Ross, pers. comm., 1993).

EAST SUSSEX: Hamsey Brick Works (TQ 398159, pterosaur; Martin Collection); Berwick Brick Pit (TQ 523070; *Plesiochelys, Leptocleidus*, Andrews, 1922; White, 1928, pp. 29–30); Pevensey (TQ 6404; *Iguanodon*); Burwash (TQ 6724; *Plesiochelys, Goniopholis*); Brightling (TQ 6821; *Goniopholis*); Bexhill (TQ 7407; *Iguanodon*, pterosaur, '*Iguanodon*' footprints at TQ 74460705, TQ 741071, TQ 738070, TQ 70950640; Beckles, 1854; Tylor, 1862; Delair and Sarjeant, 1985; Lake and Shephard-Thorn, 1987, p. 20; Delair, 1989; Woodhams and Hines, 1989); Little Galley Hill, Bulverhythe (TQ 767079; '*Iguanodon*' footprints; Beckles, 1854; Tylor, 1862; White, 1928, pp. 25, 28, 53; Ballerstedt, 1914; Sarjeant, 1974, p. 531; Delair and Sarjeant, 1985, pp. 142–3); Crowhurst Pit, Rackwell Wood (TQ 764124; *Goniopholis, Iguanodon*, Sweeting, 1925; White, 1928, pp. 65–6); Brede (TQ 8218; several sites, including Hare Farm Lane, TQ 832184, q.v.; *Goniopholis, Saurosuchus, Iguanodon*; Topley, 1875, pp. 62–3; Allen, 1949); Knellstone, Udimore (TQ 8819; *Iguanodon*, etc.; Allen, 1949, p. 279); Peasmarsh, Waterfall Wood (TQ 8621; ?*Heterosuchus*, etc., Allen, 1949); Tighe Farm (TQ 936266; bone bed; Lillegraven *et al.*, 1979, p. 27; K.A. Kermack, pers. comm.). Sites around Hastings are detailed in the Hastings report.

KENT: Brenchley (TQ 6741; '*Plesiosaurus*'); Tunbridge Wells (TQ 5839; *Megalosaurus*); Southborough (TQ 5842; *Thecospondylus*; Seeley, 1882b); New Barn (TQ 6168; 'turtle').

SURREY: Harting Combe, near Haslemere ('*Iguanodon*' footprints; Delair and Sarjeant, 1985, p. 146); Clockhouse Brickworks (TQ 175386; *Iguanodon*, microvertebrates; Jarzembowski, 1991a).

In the Isle of Wight the Wealden beds are represented by predominantly argillaceous facies of the Wealden Marls and the Wealden Shales (Wessex and Vectis formations), which are seen best in coast sections between Brook and Atherfield Point on the south-west coast and at Yaverland on the south-east coast.

Outside the Weald and the Isle of Wight Early Cretaceous reptiles are known from the Spilsby Beds (Portlandian–Berriasian) of Spilsby, Lincolnshire (TF 4066), from Speeton, Yorkshire (TA 1180; various marine reptiles from Valanginian and Hauterivian; Drake and Sheppard, 1909; R. Rawson, pers. comm., 1981; J.W. Neale, pers. comm., 1982), and from Ridgway Hill, Dorset (SY 6788; *Iguanodon, Plesiosaurus* and *Pliosaurus*; Reid, 1899), Swanage (*fide* Buckland), and Upwey. In Europe, comparable Wealden faunas are known from Belgium (Bernissart coal mines; Casier, 1978; Norman, 1980), France (Buffetaut *et al.*, 1991), Germany (Hannover; Norman *et al.*, 1987), and North America (Cloverly Formation, Wyoming; Ostrom, 1970; upper parts of the Morrison Formation, Wyoming; Dodson *et al.*, 1980).

Six early Cretaceous GCR sites are selected (Figure 8.1), including three sites in the Hastings Beds of East Sussex, one in the Weald Clay of Surrey, and two in the Wealden of the Isle of Wight:

1. Hastings, East Sussex (TQ 831095–TQ 853105). Early Cretaceous (Berriasian-Valanginian), Hastings Beds (Ashdown Beds, Tunbridge Wells Sand).
2. Black Horse Quarry, Telham, East Sussex (TQ 769142). Early Cretaceous (Valanginian), Hastings Beds.
3. Hare Farm, Brede, East Sussex (TQ 832184). Early Cretaceous (Valanginian), basal Wadhurst Clay.

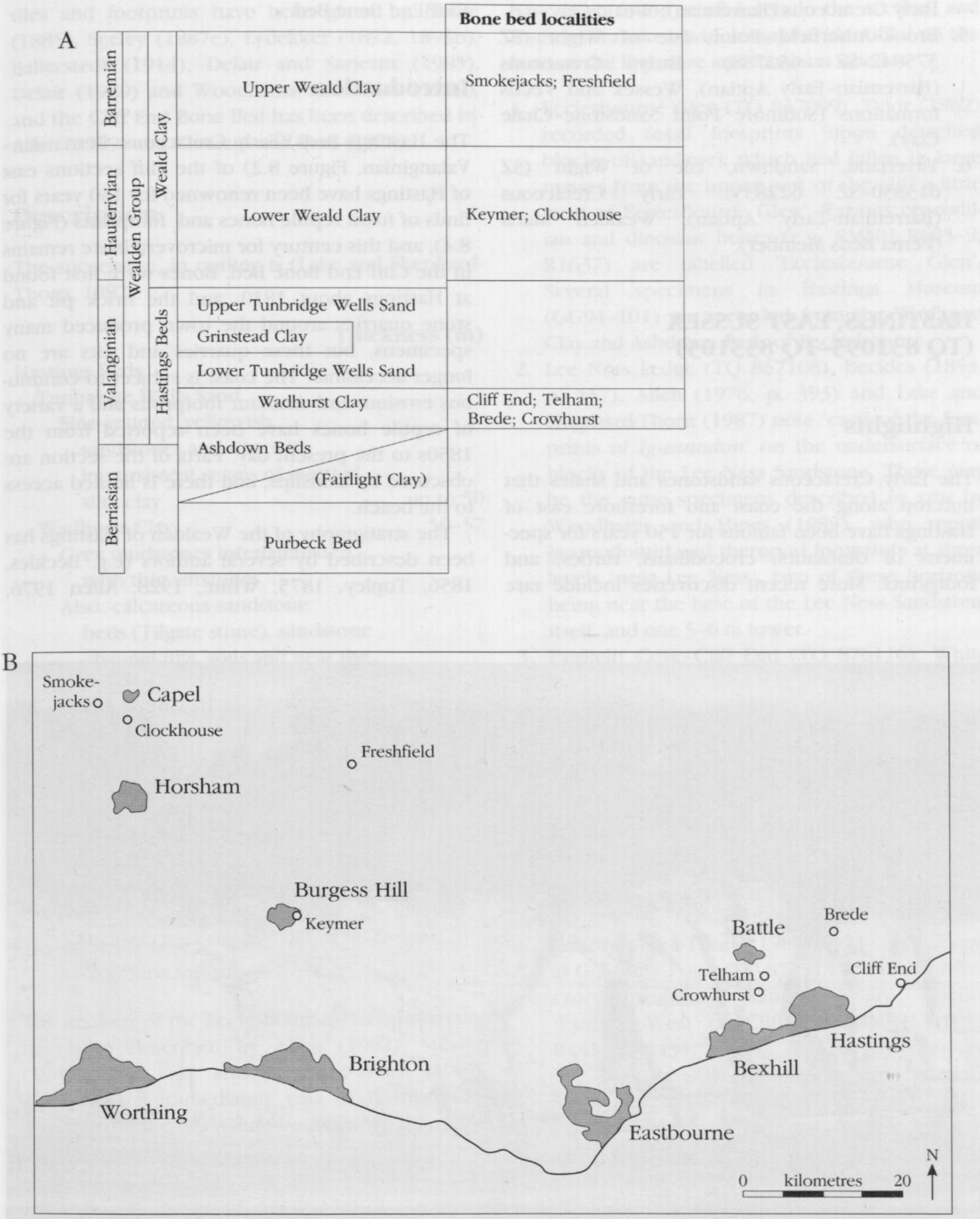

Figure 8.3 The Wealden of the Weald. (A) Summary stratigraphic succession, showing the relative temporal position of the bone beds; (B) map of some key Wealden reptile sites. Courtesy of E. Cook.

4. Smokejacks Pit, Ockley, Surrey (TQ 113373). Early Cretaceous (Barremian), Weald Clay.
5. Brook–Atherfield Point, Isle of Wight (SZ 375842–SZ 452788). Early Cretaceous (Barremian–Early Aptian), Wessex and Vectis formations (Sudmore Point Sandstone–Chale Clay).
6. Yaverland, Sandown, Isle of Wight (SZ 613850–SZ 622835). Early Cretaceous (Barremian–Early Aptian), Wealden Marls (Perna Beds Member).

HASTINGS, EAST SUSSEX (TQ 831095–TQ 853105)

Highlights

The Early Cretaceous sandstones and shales that outcrop along the coast and foreshore east of Hastings have been famous for 150 years for specimens of dinosaurs, crocodilians, turtles, and footprints. More recent discoveries include rare mammal teeth, and other small bones, from the Cliff End Bone Bed.

Introduction

The Hastings Beds (Early Cretaceous: Berriaisian–Valanginian, Figure 8.2) of the cliff sections east of Hastings have been renowned for 150 years for finds of fossil reptile bones and footprints (Figure 8.4), and this century for microvertebrate remains in the Cliff End Bone Bed. Bones were first found at Hastings about 1830, and the brick pit and stone quarries around the town produced many specimens, but these quarries and pits are no longer accessible. The coast is subject to continuous erosion, and dinosaur footprints and a variety of reptile bones have been reported from the 1850s to the present day. Parts of the section are obscured by landslips, and there is limited access to the beach.

The stratigraphy of the Wealden of Hastings has been described by several authors (e.g. Beckles, 1856; Topley, 1875; White, 1928; Allen 1976;

Figure 8.4 The cliff at Cliff End, east of Hastings, with the Cliff End Bone Bed near the top of the section. Fossil footprints and reptile bones have been found at, and in the vicinity of this locality. (Photo: E. Cook.)

Lake and Shephard-Thorn, 1987). Accounts of reptiles and footprints have been given by Hulke (1885), Seeley (1887e), Lydekker (1892, 1893b), Ballerstedt (1914), Delair and Sarjeant (1985), Delair (1989) and Woodhams and Hines (1989), and the Cliff End Bone Bed has been described by Allen (1949) and Clemens and Lees (1971).

Description

The succession, in outline is (Lake and Shephard-Thorn, 1987):

	Thickness (m)
Hastings Beds	
Tunbridge Wells Sand	
Fine-grained, yellowish sandstones and silts with impersistent seams of mottled silty clay	up to 50
Wadhurst Clay	50–57
Grey mudstones interlaminated with thin siltstones.	
Also: calcareous sandstone beds (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 sandstones, while the strata below are dominantly massive mottled spherosideritic clays with subordinate sandstone beds.	
Near the base:	
Lee Ness Sandstone	1–2

The geology of the Ecclesbourne–Fairlight section has been described by Allen (1962), Stewart (1981b) and Lake and Shephard-Thorn (1987). The sections immediately east of Hastings Old Town show the top Ashdown Beds and the cliff is topped by the Cliff End Sandstone, the lowest unit of the Wadhurst Clay. The lowest exposed unit, the Lee Ness Sandstone, is seen on the foreshore at low tide. These units appear throughout the section, repeated by faults and with varying dips as a result of the WNW–ESE-trending Battle–Fairlight anticline. Individual horizons show lateral facies variation – the Cliff End Bone Bed does not occur throughout.

Most reptile remains do not have accurate locality or horizon data. Bones and footprints seem to have been found at all levels in the section, and from several sites, which may be identified on the basis of the literature and museum labels.

1. Ecclesbourne Glen (TQ 837099). Tylor (1862) recorded fossil footprints 'upon detached blocks of sand-rock which had fallen in large masses from the upper part of the cliff a little west of Ecclesbourne Glen'. Various crocodilian and dinosaur bones (e.g. BMNH R605–9, R1637) are labelled 'Ecclesbourne Glen'. Several specimens in Hastings Museum (GG94–101) are recorded from the Wadhurst Clay and Ashdown Beds of Ecclesbourne.
2. Lee Ness Ledge (TQ 867108). Beckles (1854, p. 457), Allen (1976, p. 393) and Lake and Shephard-Thorn (1987) note 'casts of the footprints of *Iguanodon*' on the undersurface of blocks of the Lee Ness Sandstone. These may be the same specimens described *in situ* by Woodhams and Hines (1989), who report iguanodontid and theropod footprints at three levels 'near Lee Ness', two of these horizons being near the base of the Lee Ness Sandstone itself, and one 5–6 m lower.
3. Fairlight Cove–Cliff End (TQ 876116). White (1928, p. 30) noted 'a few footprints of *Iguanodon*, on a slab of light-grey sandstone ... on the shore close to the base of the cliff' at Cliff End. Allen (1976, p. 393) notes large dinosaur footprints at the top of the Ashdown beds at Cliff End. Footprints have been seen along this section in fallen blocks (P. Allen, pers. comm. to M.J.B., 1982). Tylor (1862) also recorded footprints from the following sites: TQ 835097, TQ 854104, TQ 860107, and Lake and Shephard-Thorn (1987, p. 21) noted some at Goldbury Point (TQ 877114). Several turtles, crocodilians and dinosaurs are labelled 'Fairlight West' or 'Cliff End' (BMNH R1954, R4416, R4434, R4439, HASTM GG80–6, 88, 92, 105–7, 313). Source horizons are the 'Ashdown Sands' and the 'Fairlight Clays' (upper and lower portions of the Ashdown Beds respectively). In general, bones and footprints may be found anywhere along the section where there is fresh exposure.

Iguanodontid footprints figured by Ballerstedt (1914, figs 2, 4) 'aus dem Wealden von Hastings' may come from this area too: one of them is a photograph by C. Dawson, presumably the archaeologist associated with the Piltdown find, and with Tielhard de Chardin, who was involved with the first collections from the Cliff End Bone Bed.

Reptile remains are also known from the Cliff End Bone Bed (less than 5% of all bones: Patterson, 1966; two teeth, K.A. Kermack, pers. comm. 1982). The Cliff End Bone Bed fauna consists largely of sharks' teeth, and those of the actinopterygian fish *Lepidotes*, together with rare mammal teeth. The Bone Bed, exposed in the cliffs at TQ 887129 (Figure 8.4), 2.5 m above the Cliff End Sandstone (Lake and Shephard-Thorn, 1987, pp. 67–71), is a poorly sorted cross-bedded coarse sandstone or fine-grained conglomerate of quartz and chert pebbles and abraded fragments of sideritic mudstone, with abundant fragments of fishes and reptiles as well as mollusc debris.

Fauna

As already indicated, some specimens are labelled as coming from Ecclesbourne, Fairlight or Cliff End. The majority, however, are labelled 'Hastings' and although many probably came from the cliffs east of the town, some must have been found in the old quarries and brickpits. In the following list, only those specimens definitely recorded from the cliffs are listed, and numbers of all 'Hastings' material are given.

	Numbers
Testudines: Cryptodira	
Tretosternon bakewelli (Mantell, 1827)	
HASTM GG92, 96	3
Plesiochelys brodiei Lydekker, 1889	3
Archosauria: Crocodylia:	
Neosuchia: Goniopholididae	
Goniopholis crassidens Owen, 1842	
BMNH R605, R607	10
Goniopholis sp.	
BMNH R608; HASTM GG80–2, 84–6, 88, 105–7, 313	17
Archosauria: Crocodylia: Neosuchia:	
Pholidosauridae	
Suchosaurus sp.	
BMNH R4416, R4439	2
Archosauria: Crocodylia: Neosuchia:	
Bernissartiidae	
Bernissartia sp.	1
Archosauria: Crocodylia: Neosuchia: *inc. sed.*	
Heterosuchus valdensis Seeley, 1887	
Type specimen: BMNH 36555	1
Archosauria: Pterosauria:	
Pterodactyloidea	
Ornithocheirus sp.	
HASTM GG100, 101	2
Archosauria: Dinosauria:	
Saurischia: Theropoda	
Megalosaurus dunkeri Dames, 1884	
BMNH R1954	4
Megalosaurus sp.	
HASTM GG98	2
Archosauria: Saurischia: Sauropoda	
Cetiosaurus brevis Owen, 1842	4
Ornithopsis hulkei Seeley, 1870	5
Archosauria: Dinosauria: Ornithischia	
Iguanodon sp.	
BMNH R1637	20+
'?stegosaur'	
BMNH R4434	1
Polacanthus sp.	1
Sauropterygia: Plesiosauria	
Cimoliasaurus valdensis Lydekker, 1889	
BMNH R609	3
'plesiosaur'	
HASTM GG94, 95	2

Interpretation

The Tunbridge Wells Sand has been interpreted as a fluvio-deltaic deposit, the Wadhurst Clay and Grinstead Clay as pro-deltaic or lagoonal in origin, and the Ashdown Beds as fluvial (Lake and Shephard-Thorn, 1987). The environments of deposition in the Wealden of the Weald had formerly been interpreted as largely deltaic (e.g. Allen, 1959, 1962; Taylor, 1963), but Allen (1976, 1981) revised his former theory in favour of a model (Figure 8.8) 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 (1981) argued that many of the rivers were braided in their proximal portions, whereas Stewart (1981a, 1981b, 1983) emphasized evidence for meandering streams. The climate was warm, with marked wet and dry seasons and 'herds of dinosaurs travelled freely across the basin and maintained themselves in it'.

The Cliff End Bone Bed was interpreted as a high-energy deposit by Allen (1949) and correlated by him with the Telham Bone Bed, exposed near Battle, and with other occurrences of the Cliff End Bone Bed inland (Figure 8.3). Allen (1949) regarded this 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 turtles *Tretosternon* and *Plesiochelys* are represented by fragmentary remains of the carapace, plastron and limbs. Such remains are relatively common in the Wealden of the Weald, but they are inadequate for a proper understanding of their anatomy and relationships.

The crocodilians are more abundant. *Goniopholis*, represented by numerous vertebrae, limb bones, teeth, jaws and scutes, was a moderate- to large-snouted aquatic crocodilian. The genus is known from the Late Jurassic and Early Cretaceous of Europe and North America (Steel, 1973). *Suchosaurus*, an aquatic medium-sized pholidosaur, is represented by some teeth. *Bernissartia* (partial skeleton) was a small (1 m long) animal with characteristic heterodont teeth, conical and pointed in the anterior part of the jaws, and rounded and blunt further back. The genus is known also from the Wealden of Bernissart, Belgium and the Isle of Wight and the Early Cretaceous of Galve, Spain (Buffetaut, 1975; Norell and Clark, 1990).

The type of the crocodilian *Heterosuchus valdensis* (Figure 8.5A) probably came from the cliff section at Hastings. The specimen consists of a water-worn slab containing about 12 vertebrae of a small crocodilian (Seeley, 1887e). Further material from the Wealden of Sussex and the Isle of Wight was ascribed to this form by Lydekker (1888a), and Woodward and Sherborn (1890, p. 231) identified as *Heterosuchus* sp. specimens from the Isle of Wight and from the Middle Purbeck of Durlston Bay. The genus has been synonymized with *Hylaeochampsa* Owen, 1874, erected for Isle of Wight material (Steel, 1973, p. 53), but this cannot be demonstrated since the two taxa are based on non-overlapping material (Buffetaut, 1983; Clark and Norell, 1992). Indeed, Clark and Norell (1992) argue that the taxon is a *nomen dubium*, since it lacks diagnostic material. They regard it as a neosuchian, possibly a eusuchian, on the basis of its procoelous vertebrae and the well-developed condyles on the trunk vertebrae. If it is a eusuchian, as *Hylaeochampsa* is, then it is one of the oldest in the world.

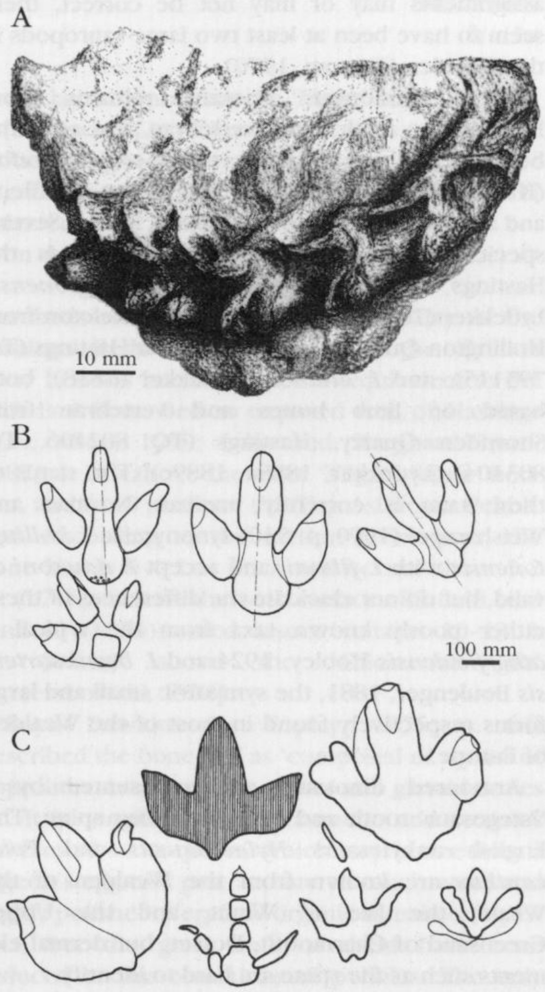

Figure 8.5 Fossil reptile remains from the Early Cretaceous Hastings Beds of Hastings. (A) Sequence of dorsal vertebrae of the crocodilian *Heterosuchus valdensis* Seeley, 1887; (B) iguanodontid footprints; (C) theropod footprints from the foreshore. (A) After Seeley (1887c); (B) and (C) after Woodhams and Hines (1989).

A large carnivorous dinosaur, generally ascribed to *Megalosaurus* is represented by teeth and limb bones from Hastings. The generic assignment is unlikely, since *Megalosaurus* is typical of the Mid Jurassic. There is a problem over the definition of the two Wealden 'species', *M. dunkeri* and *M. oweni*, and Huene (1923) ascribed these to the new genus *Altispinax*, but the specimens are too incomplete for certain assignment. Molnar (1990) regards *M. dunkeri* as a 'problematic carnosaur' and *M. oweni* as a *nomen dubium*.

Some large bones, ribs and vertebrae from Hastings have been named *Cetiosaurus* and *Ornithopsis* (Lydekker, 1892, 1893b). While these assignments may or may not be correct, there seem to have been at least two large sauropods in the Wealden (Ostrom, 1970).

The commonest dinosaur remains from Hastings are teeth, jaws, vertebrae, ribs and limb bones of the large bipedal ornithopod *Iguanodon* (Hulke, 1885). The specific assignment is difficult and awaits revision (Norman, 1980, 1986). Several species of *Iguanodon* were named from the Hastings area, including *I. hollingtonensis* Lydekker (1889), based on a partial skeleton from Hollington Quarry, St Leonards, near Hastings (TQ 795115), and *I. dawsoni* Lydekker (1888), both based on limb bones and vertebrae from Shornden Quarry, Hastings (TQ 802106, TQ 803104) (Lydekker, 1888a, 1889e). The status of these taxa is currently unclear. Norman and Weishampel (1990, p. 530) synonymize *I. hollingtonensis* with *I. fittoni*, and accept *I. dawsoni* as valid, but do not elucidate the differences of these rather poorly known taxa from the typical *I. atherfieldensis* Hooley, 1924 and *I. bernissartensis* Boulenger, 1881, the sympatric small and large forms respectively found in most of the Wealden of Europe.

Armoured dinosaurs are represented by a '?stegosaur' tooth and a ?*Polacanthus* spine. The English ankylosaurs *Hylaeosaurus* and *Polacanthus* are known from the Wealden of the Weald, the Isle of Wight, and the Upper Greensand of Charmouth, Dorset, but dermal elements such as the spine are hard to identify.

Pterosaurs are relatively uncommon, with only a few wing bones of '*Ornithocheirus*' known. Plesiosaurs, typically marine animals, are also uncommon; some vertebrae and limb bones of *Cimoliasaurus* suggest that they may have wandered into coastal fresh waters at times.

The iguanodontid and theropod footprints from Hastings (Tagart, 1846; Beckles, 1854; 1856; Tylor, 1862; White, 1928; Delair and Sarjeant, 1985; Lake and Shephard-Thorn, 1987, pp. 19–21; Woodhams and Hines, 1989) are large (0.3–0.6 m long), tridactyl (three-toed) imprints (Figure 8.5B, C). The 'toes' are broad, short and curved to a point and there is a broad heel impression. They are generally seen as casts on the underside of sandstone beds, or as wave-eroded hollows in silts on the present foreshore. Theropod prints have narrower toes than the iguanodontid prints, and they should have evidence of sharp claws if preservation is good enough. They are much rarer than the iguanodontid prints.

Comparison with other localities

In the Hastings area several quarries in the Wadhurst Clay and Ashdown beds have yielded similar fossil reptiles. These include St Leonards (0.02–0.1 m thick bed in Hall and Co.'s Quarry behind the church just off the West Marina; TQ 797088; *Tretosternon, Goniopholis, Pleurocoelus, Iguanodon*, 'stegosaur', *Ornithocheirus, Cimoliasaurus*, Parish, 1833; Topley, 1875, p. 61; White, 1928, p. 47; Allen, 1949, p. 276); Hollington Quarry ('quarry at Rose Cottage', Topley, 1875, p. 61; TQ 795115; *Tretosternon, Goniopholis, Megalosaurus, Iguanodon, Hylaeosaurus*, 'stegosaur', *Cimoliasaurus*, Lydekker, 1889f, p. 355; 1890b, pp. 40–3; White, 1928, pp. 66, 71); Little Ridge Farm Quarry (TQ 809127; *Iguanodon*); Shornden Quarry (TQ 802106; *Iguanodon*); Silver Hill/Tivoli Brickworks (TQ 799115; *Iguanodon*); Bucks Hole Quarry (TQ 806110, TQ 806112; *Iguanodon, Cimoliasaurus*); Ore (?TQ 826108; *Goniopholis, Megalosaurus, Iguanodon, Cimoliasaurus*). Unfortunately, none of these sites is still extant.

The Cliff End Bone Bed is currently exposed (Lake and Shephard-Thorn, 1987, pp. 37, 39) near the steps from the Undercliff to Watchbell Street, Rye (TQ 91952018), and formerly in a brickpit near Baldslow (TQ 810133). Bone beds which may be equivalent to the Cliff End Bone Bed are seen at Reyson's Farm, near Brede (TQ 832192) and West Ascent, St Leonards (TQ 79820885).

Conclusions

The most varied faunas of Early Cretaceous dinosaurs are known from the Wealden of Europe. One of the best of these faunas is that from the Hastings Beds in their type area, and the fossils include skeletons and footprints. Moreover, this is the only extensive, eroding coastal setting in these non-marine strata, which therefore has considerable potential for future finds. Previous finds include a selection of terrestrial and aquatic reptiles – two genera of turtles, four genera of crocodilians, one genus of theropod, two of sauropods, three of ornithischians, one genus of pterosaur and one plesiosaur. Also, further collecting from bone-rich horizons – such as the Cliff End Bone Bed – may yield new genera of smaller reptiles: lizards, snakes, turtles.

The conservation value lies in the combination of this potential for future discoveries and the importance of the fossil faunas recovered from the site over the past 150 years.

BLACK HORSE QUARRY, TELHAM, EAST SUSSEX (TQ 769142)

Highlights

Black Horse Quarry, Telham is the main site of the Telham Bone Bed, a sediment which produced specimens of turtles, crocodilians, pterosaurs, dinosaurs, and a plesiosaur. This bone bed has produced relatively small bones, which supplement the larger elements found in coastal sites.

Introduction

Black Horse Quarry, Telham Hill, near Battle, east Sussex was formerly a well-known source of Early Cretaceous reptile remains. The dissociated bones were found in a thin bone bed, the Telham Bone Bed (Figure 8.2, 8.3), for which this is the type locality. Although not currently exposed, it could be re-excavated; the quarry is presently 6–7 m deep in parts. The site has been described by Binfield and Binfield (1854), Topley (1875), Woodward and Sherborn (1890), White (1928) and Lake and Shephard-Thorn (1987).

Description

The section at Black Horse Quarry (Boyd Dawkins, *in* Topley, 1875, pp. 63–4; thicknesses approximate) was:

	Thickness ft	in
Surface soil	1	0
Rust-coloured grey and white shales with indurated layers	3	0
Rust and slate-coloured shales with ironstone	3	0
Rust and slate-coloured shales without ironstone (*Cyrena*)	6	0
Slate-coloured shales with a layer of a lighter colour (*Cyrena* and plants)	3	0
Shale and clay (*Cypridea, Cyrena* and vegetable matter)	3	6
Grey clay with nodules; the 'bone bed' [0–4 inches] in its lower part	2	0
Calcareous grit [Tilgate Stone], fine grained and hard, dug for roads	2	6
Calcareous grit [Tilgate Stone], blue on the unweathered surface	2	0

The beds are within the Wadhurst Clay of the Hastings Beds (Valanginian) and the Telham Bone Bed has been regarded as equivalent to the Cliff End Bone Bed as exposed east of Hastings (q.v.; Allen, 1949; Lake and Shephard-Thorn, 1987). It lies above the main 'Tilgate Stone' horizon, and 6–10 m above the Top Ashdown Pebble Bed. According to the section given here, the bone bed is 0–0.1 m thick and occurs about 5.2 m (17 ft) below the soil surface. Binfield and Binfield (1854) noted insect remains 10–13 ft (*c.* 3–4 m) above the 'Calcareous grit' (Jarzembowski, 1976).

Boyd Dawkins (*in* Topley, 1875, p. 64) described the bone bed as 'composed of a mass of coprolites, bones, teeth, scutes and ganoid scales . . . It is conglomeratic in character and contains pebbles of white quartz, which vary in size from a pigeon's egg to a pea, and are all much worn and highly polished. Very few organic remains are perfect, but the great bulk of them have been reduced to the conditions of pebbles. The only perfect bones that have been found consist of the hard and solid phalanges of the larger reptilia . . . In the interior of one long dinosaurian bone there were fragments of jet . . . The condition of all these remains is precisely identical with those from the Crag 'coprolite' beds, and the bone-beds of the Rhaetic and Carboniferous rocks'.

Fauna

Many Wealden reptiles are labelled 'Battle' or 'Telham' and Black Horse Quarry must have been the source of most of these. Some specimens (BMNH R2845–6) bear the label 'Lambert's Quarry, Black Horse', probably in reference to the former owner. Boyd Dawkins (*in* Topley, 1875, p. 64) listed reptile remains that he had identified from Black Horse Quarry. In the following list, numbers of specimens in the collections of BGS(GSM), BMNH and HASTM are given as an approximate guide to relative abundance:

	Numbers
Testudines: Cryptodira	
Plesiochelys sp.	5
Tretosternon bakewelli (Mantell, 1827)	3
Archosauria: Crocodylia: Neosuchia	
Goniopholis crassidens (Owen, 1842)	8
Suchosaurus cultridens (Owen, 1842)	3
Archosauria: Pterosauria: Pterodactyloidea	
Ornithocheirus? clifti (Mantell, 1844)	?
Archosauria: Dinosauria: Saurischia: Theropoda	
'*Megalosaurus' dunkeri* Dames, 1884	1
'*Megalosaurus*' sp.	2
Archosauria: Dinosauria: Saurischia: Sauropoda	
?*Cetiosaurus* sp.	1
Pleurocoelus valdensis Lydekker, 1890	1
Archosauria: Dinosauria: Ornithischia	
Iguanodon sp.	10
Hylaeosaurus armatus Mantell, 1833	1
Sauropterygia: Plesiosauria:	
'*Plesiosaurus*' sp.	4

Interpretation

Allen (1949, pp. 279–82) interpreted the Telham Bone Bed as a river deposit, pebbles and bones of which were rolled along for some distance before deposition. Allen (1976, pp. 393, 406) equated the Telham Bone Bed tentatively with either the Broad Oak Top Pebble Bed or the Cliff End Pebble (Bone) Bed (both low in the Wadhurst Clay Formation). The Bone Bed facies all appear to occur in 'the muddier parts of the shoreface, beneath a metre or so of water'.

The turtles *Plesiochelys* and *Tretosternon* are represented by broken carapace and plastron pieces not adequate for proper identification. These turtles were moderate to large in size (0.3–1 m plastron length). They are both classed as chelydroids (Młynarski, 1976, pp. 55, 60), or *Plesiochelys* may be a chelonioid (Gaffney 1975b).

The crocodilians *Goniopholis* and *Suchosaurus* are based on fairly common teeth and vertebrae. These were both long-snouted aquatic forms, although the latter genus is essentially known only from teeth.

Both Topley (1875, p. 64) and Woodward and Sherborn (1890, p. 255) noted a pterosaur in the Black Horse Quarry fauna, but the specimen(s) have not been located. *Ornithocheirus clifti* was initially interpreted as a bird because of its hollow limb bones and its exact relationships are uncertain (Wellnhofer, 1978, p. 58).

The carnivorous dinosaur *Megalosaurus* is represented by vertebrae and teeth. Most of these have been named *M. dunkeri*, a species known also from the Wealden of Hannover (Germany), as well as other places in the south of England. *Megalosaurus* is typical of the Mid Jurassic, and Huene (1926) renamed this species *Altispinax* on the basis of the high neural spines on the vertebrae.

Herbivorous dinosaurs include the large sauropods ?*Cetiosaurus* and *Pleurocoelus*, the former represented by vertebrae, the latter by teeth from Black Horse Quarry. These generic assignments are probably incorrect – the Wealden sauropods urgently require restudy (Ostrom, 1970). *Iguanodon*, the commonest Wealden dinosaur, is recorded from Black Horse Quarry on the basis of teeth, vertebrae, limb bones and phalanges. *Hylaeosaurus*, an armoured ankylosaur has been identified tentatively on the basis of a vertebra.

Comparison with other sites

The nearest exposures of the Telham Bone Bed are at Rackwell Wood, Crowhurst (TQ 764124; Sweeting, 1925; White, 1928, pp. 65–6; Lake and Shephard-Thorn, 1987, p. 38), in Crowhurst Park (TQ 781138; R.D. Lake, pers. comm. to M.J.B., 1982), and at Maplehurst Wood (TQ 81001307; Lake and Shephard-Thorn, 1987). Allen (1949, pp. 279–82) noted further exposures at Baldslow (TQ 8013), Brede (Post Office; Kicker Wood; Reyson's Farm; Cat's Nest; Broadlands, TQ 826183; ?TQ 8320; TQ 832192; ?TQ 837192); Peamarsh (Waterfall Wood; TQ 8621); Udimore (Knellstone; TQ 8819); Stone (Stone Hole Quarry; Tighe Farm; ?TQ 9428, TQ 936266). The Telham Bone Bed is apparently equivalent to the Cliff End Bone Bed (Allen, 1976) which is seen in blocks on the foreshore at Cliff End, Pett (TQ 887130).

Most of the turtles, crocodilians, pterosaurs and dinosaurs in the Black Horse Quarry fauna are common in the Wealden of southern England, and indeed many of them in Early Cretaceous sediments elsewhere in the world. New excavations are required, and more extensive series of specimens are needed, for more precise identifications, and for fuller comparisons, of the taxa present.

Conclusions

Black Horse Quarry, Telham has provided good collections of Wealden reptiles. Although the bones are disarticulated, and generally water-worn, the remains are relatively abundant in the thin bone bed. This is the type locality of the Telham Bone Bed, and it is the best site for fossil reptiles in that unit, an attribute that in combination with its potential for re-excavation gives the site its conservation value.

HARE FARM LANE, BREDE, EAST SUSSEX (TQ 83141844)

Highlights

Hare Farm Lane, Brede is the best site for the Brede Bone Bed. It has produced specimens of dinosaurs and crocodilians, and there is potential for future significant discoveries.

Introduction

The Brede Bone Bed, another of the bone beds within the Wadhurst Clay (Figure 8.2, 8.3), is most readily accessible in Hare Farm Lane, Brede, and this site has yielded the most complete fauna (Allen, 1949). Literature recording the reptile fauna is limited to Lydekker (1890) and Allen (1949, 1976), but the diversity could be greatly enhanced by re-excavation of this lane-side cutting.

Description

The Brede Bone Bed has been described in some detail at the Hare Lane locality (Allen, 1949, pp. 276–9): 'The bone bed comprises thin lenticles of buff sand up to 2 feet long, 1 foot wide and 2 inches thick . . . The lenticles cut across the current-bedding of the surrounding siltstones and shales, and on top are bevelled off to a common level . . . Rootlets from the overlying soil-bed pass through the bone-bed . . . The buff sand constituting the bone-bed . . . is non-pebbly, rather argillaceous and poorly sorted, and always contains bivalve casts (including *Neomiodon medius*). The detritus includes quartz and glauconite, mixed with large quantities of comminuted scales, teeth and bone varying in size from finest powders to fragments over two inches long . . .' It lies in the basal Wadhurst Clay (Valanginian) between the Top Ashdown Pebble Bed and the Brede *Equisetum lyelli* Soil Bed. Lake and Shephard-Thorn (1987, p. 29) note that the Brede Bone Bed may reflect localized concentrations of material, and is probably not laterally correlatable over long distances like the Cliff End/Telham Bone Bed.

Fauna

Allen (1949, p. 278) listed the fauna of the Bone Bed as molluscs (*Neomiodon, Viviparus*), fishes (*Lepidotus, Hybodus*) and reptiles ('chelonian fragments, crocodilian teeth, bone'). A few specimens labelled 'Brede' are preserved in the BMNH and HASTM. These may or may not have come from Hare Farm Lane.

Archosauria: Crocodylia: Neosuchia
Goniopholis crassidens Owen, 1842
BMNHR3373
Suchosaurus sp.
BMNHR4415
Archosauria: Dinosauria: Ornithischia: Iguanodontidae
Iguanodon fittoni Lydekker, 1888
BMNHR1627
Iguanodon sp.
HASTMEJB3

Interpretation

The turtle remains noted by Allen (1949) have not been further described. *Goniopholis* is represented by a partial mandible and *Suchosaurus* by a tooth: these were aquatic genera. *Goniopholis* had a long-snouted skull up to 0.7 m long.

Iguanodon, one of the commonest Wealden reptiles and the commonest dinosaur, is represented by a phalanx (*Iguanodon* sp.) and a partial skeleton (ascribed to *I. dawsoni* by Lydekker, 1890b). This specimen, consisting of a partial pelvis, several dorsal and caudal vertebrae, a partial hindlimb and other elements, apparently differed from other species of *Iguanodon* on the basis of characters of the pelvis in particular. D.B. Norman (pers. comm., 1983) considers that BMNH R1627 belongs to *I. fittoni* and differs from *I. dawsoni*, two species accepted provisionally by

Norman and Weishampel (1990) as valid (see Hastings report).

Comparison with other localities

The Brede Bone Bed was noted by Allen (1949, p. 276) at St Leonards-on-Sea (TQ 79820885; ?Cliff End Bone Bed, Lake and Shephard-Thorn, 1987, p. 39), Stubb Lane, Brede (TQ 82171853; Lake and Shephard-Thorn, 1987, p. 37), Ludley Hill, Beckley (TQ 8521), and possibly also Oxenbridge Hill, Iden (?TQ 9225). Allen (1949, p. 280) noted a bone bed supposedly equivalent to the Telham Bone Bed at Reyson's Farm (TQ 832192)

Conclusions

Hare Farm Lane is the type locality of the Brede Bone Bed. The fauna reported to date is small. Earlier dinosaur finds from Brede, including a good specimen of *Iguanodon fittoni*, point to the potential of this site and that it is a key Wealden bone bed site, hence its conservation value.

SMOKEJACKS PIT, OCKLEY, SURREY (TQ 113373)

Highlights

Smokejacks Pit, Ockley is famous as the site which yielded *Baryonyx*, the meat-eating dinosaur with a giant hook claw. This recent dinosaur find supplements earlier discoveries of *Iguanodon* and crocodilians at Smokejacks, and bones and teeth have now been found at several levels.

Introduction

Smokejacks Pit at Wallis Wood, Ockley, near Dorking, Surrey (Figure 8.1) has been operated as a private brickworks for some time and is presently under the ownership of the London Brick Company (bought from the Ockley Brick Company). The quarry exposes sections in the Weald Clay, in the Barremian (Early Cretaceous). Remains of the dinosaur *Iguanodon atherfieldensis* were collected in 1945–6, and further material of this species, and of *I. bernissartensis*, has been collected since. The discovery, in 1983 of the theropod *Baryonyx walkeri*, with its 300 mm long claw (Figure 8.9), has brought the locality to attention. Since 1983 fossil reptile material has been recovered from several horizons within the quarry. The pit is still operational and, because work is relatively slow, fresh bones are occasionally seen and collected.

The first finds of dinosaurs from Smokejacks Pit were reported by Rivett (1953, 1956) who collected 'upwards of 100 bones' belonging to several individuals of *Iguanodon atherfieldensis*. Further specimens were excavated by the BMNH, but not reported. In January 1983 William Walker discovered an ironstone nodule in the pit which contained a giant claw. A rescue excavation by staff from the BMNH led to the discovery in the following month of a partial skeleton of a theropod dinosaur, which Charig and Milner (1986, 1990) named *Baryonyx walkeri*. The specimen has taken nearly 10 years of laborious preparation because of the impenetrability of the ironstone matrix.

Subsequent collecting by a variety of people has produced evidence of reptiles at several horizons and in several parts of the pit. John Cooper of Worthing found scattered large *Iguanodon* bones in 1987 and these were excavated with the assistance of the BMNH. Further material of the same individual was excavated by David Cooper, M.J.B. and colleagues from Bristol University in 1992 (Figures 8.6 and 8.7). Allen (1976, 1981) and Jarzembowski (1991a) have given preliminary descriptions of the site.

Description

Smokejacks Pit shows a section in the clays and subordinate sandstones of the Weald Clay, which lies above the Hastings Beds in the Early Cretaceous (Barremian) (Rawson *et al.*, 1978). Topley (1875, p. 106) mentioned the Weald Clay of Smokejacks Farm, and included it in his 'No 5. Sand and Sandstone with Calcareous Grit'. The sediments currently exposed in the pit represent about 27 m of Weald Clay below BGS bed no. 5c (Alfold Sand Member; Allen, 1976), which suggests that it is in the Upper Weald Clay, and is dated as early Barremian (Jarzembowski, 1991a).

Rivett (1956) recorded several general sections in the brickpit, the one for the central part being:

Figure 8.6 Excavation of a partial *Iguanodon* skeleton at Smokejacks Brickpit in summer, 1992. (Photo: M.J. Benton.)

	Depth (in)
Topsoil turning to clay	0–12
Red Clay	12–36
Sandy Clay	36–60
Reddish Clay	60–72
Thinly bedded sandstone	72–108
Sandy clay and sandstone	108–174

The original discoveries of *Iguanodon* bones were in the 'harder rock' 'from 6–12 feet from the surface'. Rivett (1956) later gave the depth beneath the surface as '8 to 15 feet'. Nevertheless, it seems that they came from the two sandstone beds listed above. Rivett (1953, 1956) noted further that iron pyrites was found associated with, and impregnating, some of the bones, and that the bones were 'often resting on, or embedded in, the sand beds.' Some of the bones were broken and water-worn and they had evidently been transported, but most were relatively well preserved. Rivett (1953, 1956) also noted the presence of rounded pebbles, which he interpreted as gastroliths.

Other fossils known from Smokejacks Pit include plants (ferns, conifers), with some specimens interpreted as angiosperm-like vegetative parts (Hill *et al.*, 1992). If this interpretation is correct, these could be the oldest angiosperm macrofossils known. The invertebrate fauna includes ostracods, conchostracans, egg cases of cartilaginous fishes, molluscs and insects. The insect fauna consists of cockroaches, beetles, true flies, bugs, termites, crickets, grasshoppers, lacewings, scorpionflies, wasps and dragonflies (Jarzembowski, 1991a, 1991b).

The excavation of *Baryonyx* provides information on the taphonomy of large vertebrate remains from the Weald Clay in Smokejacks Pit. The bones located *in situ*, although largely disarticulated and scattered, all came from within the confines of an area measuring 5 m by 2 m, and the general arrangement of the bones demonstrated that none was far from its natural position; most of the pieces of skull, pectoral girdle and forelimbs were located at one end and most of the pelvic girdle and hindlimbs at the other. In general, the bones of *Baryonyx* were not found to be

Figure 8.7 Dr Glenn Storrs consolidates an *Iguanodon* vertebra in Smokejacks Brickpit, part of the partial skeleton excavated in summer, 1992. (Photo: M.J. Benton.)

distorted or crushed to any significant extent. This may relate to the mode of fossilization, for most of the remains became encased in ironstone, presumably not long after burial. However, the few bones preserved in clay also appear to be unaffected by compaction. It may be significant that many of the bones appear to have become disarticulated prior to fossilization.

There are other modes of fossil reptile occurrence in Smokejacks Pit. Teeth and scutes of crocodilians and dinosaurs have been found seemingly isolated, and fish remains occur in lenses of siltstone. Others, such as the *Iguanodon* skeleton excavated in 1987–92, are remains of a single large dinosaur skeleton, but disarticulated and scattered over a wider area, in this case some 200 bones recovered from an area measuring approximately 7 m by 4 m. The sedimentary situation in this case seems to represent overbank deposits produced during a flood (E. Cook, pers. comm., 1993).

Fauna

The Rivett collection is housed in the BMNH. Rivett (1953, 1956) ascribed his finds to *Iguanodon* and some he identified as belonging to a large sauropod. Other material from Smokejacks is also in the BMNH.

Archosauria: Dinosauria: Crocodilia:
Goniopholididae
Isolated teeth of ?goniopholidids.
Archosauria: Dinosauria: Saurischia: Theropoda:
Baryonychidae
Baryonyx walkeri Charig and Milner, 1986
Type specimen: BMNH R9951
Archosauria: Dinosauria: Saurischia: Sauropoda:
Titanosauridae
Titanosaurus-like sauropod (Rivett, 1953)
Archosauria: Dinosauria: Ornithischia:
Ornithopoda: Iguanodontidae
Iguanodon bernissartensis Boulenger, 1881
BMNH and David Cooper collection
Iguanodon atherfieldensis Hooley, 1925
BMNH R6432–640

Interpretation

Allen (1976, p. 414; 1990) interpreted the Weald Clay, including that at Smokejacks Brickworks, as having been deposited in an alluvial and lagoonal mudplain with short-lived sand channels (Figure 8.8). Salinities varied from freshwater to nearly marine. All facies were liable to exposure, as shown by large footprints in sandstone (at Capel, TQ 18294048), suncracks and mudflake conglomerates, as well as soil beds and the presence of horsetails. The fauna is terrestrial and aquatic (fresh–brackish), containing numerous insect remains in addition to the reptiles, but with freshwater aquatic insects and fishes.

Crocodilian teeth and scutes are found, scattered about the site, and possibly coming from various horizons. They have been collected by many visitors to the site, but not curated or studied yet.

Iguanodon atherfieldensis, a large, herbivorous, bipedal or facultatively quadrupedal ornithopod dinosaur, is represented by vertebrae and limb bones, mostly the remains of small or immature animals. *I. atherfieldensis* is far more gracile than the other well-known forms of *Iguanodon* from the Hastings Beds (*I. dawsoni, I. anglicus, I. fittoni*) and it is notable for its distinc-

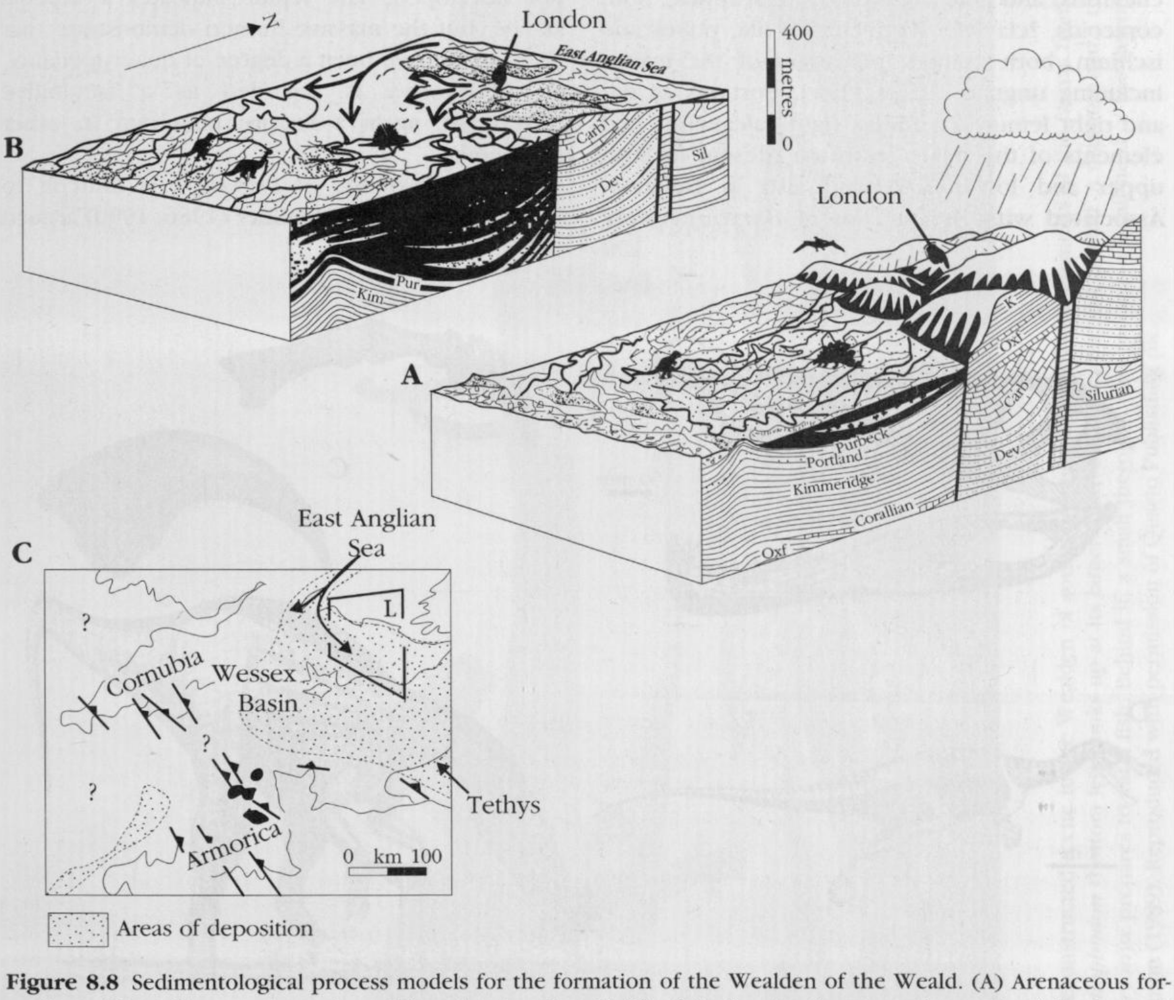

Figure 8.8 Sedimentological process models for the formation of the Wealden of the Weald. (A) Arenaceous formations; (B) argillaceous formations; (C) regional setting. Uplift of the London horsts, to the north of the basin of deposition, produced an area of high relief and an extensive source of sediment (A). Braided alluvial sand plains expanded southwards from the uplands, and the lowlands supported diverse floras and faunas, including dinosaurs (A). Downfaulting and denudation of the London horsts reduced relief and the rate of sediment supply (B), and the Weald area became a brackish–freshwater lagoonal–alluvial mudplain. Again, abundant vegetation grew around the lakes, and a diverse fauna of fishes, insects and reptiles inhabited the area.

tive postcranial morphology (Norman, 1986). The large contemporary form *I. bernissartensis*, found rarely in the Wealden Marls of the Isle of Wight (Barremian–Early Aptian), but better known from the Early Cretaceous on the continent (Norman, 1980, 1987; Norman *et al.*, 1987), is represented by the 1987–92 specimen found by David Cooper.

To date more than half of the skeleton of *Baryonyx walkeri* has been recovered (Figure 8.9). This includes parts of the skull (conjoined premaxilla, anterior left maxilla, conjoined nasals, lacrimal, frontals, anterior braincase and occiput), lower jaw (left dentary with some associated postdentary elements), axial skeleton (axis, one cervical vertebra, some dorsal vertebrae, a caudal vertebra, cervical ribs, dorsal ribs, gastralia, chevrons) and limb skeleton (both scapulae, both coracoids, ?clavicle, fragments of ilia, pubes and ischium, both humeri, phalanges of the manus including unguals [?large claw], portions of left and right femur, left fibula, right calcaneum, and elements of the pes). Teeth are present in both upper and lower jaws and also in isolation. Associated with the remains of *Baryonyx* were fish teeth and scales, an isolated humerus from a small individual of *Iguanodon*, and a small claw. Polished lithic fragments also found associated have been interpreted as probable gastroliths.

Baryonyx possesses some unique characters: an extremely narrow snout with a spatulate expansion at the tip and a slight downturn of the premaxilla seen in lateral view; a long low external naris situated far back from the front of the snout; and a probable mobile articulation involving a loose 'hinge' between the premaxilla and maxilla. *Baryonyx* possesses an unusually high number of marginal teeth (32 alveoli in the lower jaw, compared with the usual theropod count of 16), and in the postcranial skeleton, the upward bend of the neck seen in all other theropods is not developed. The femur indicates a bipedal stance, but the massive humeri demonstrate that there must have been a degree of quadrupedality, and *Baryonyx* is regarded as a facultative quadruped, again a feature unknown in other theropods.

The mode of life of *Baryonyx* is difficult to determine. Charig and Milner (1986, 1990) argued

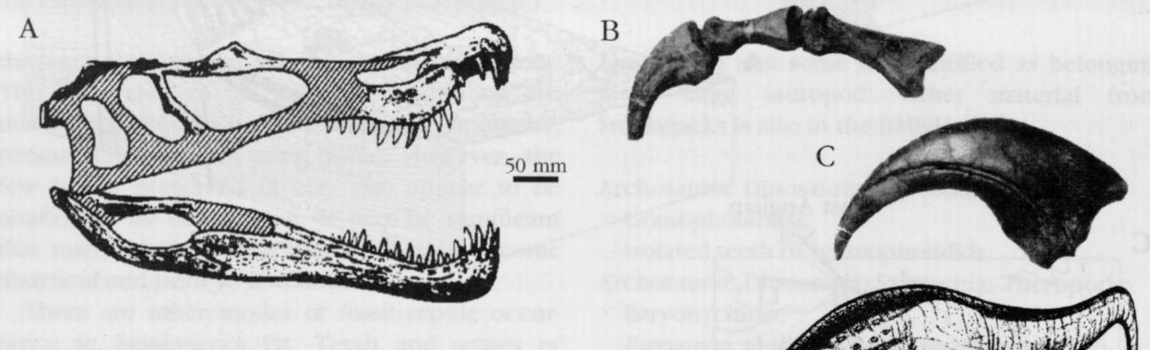

Figure 8.9 The most famous recent British dinosaur discovery, the enigmatic theropod *Baryonyx walkeri* Charig and Milner, 1986 ('Superclaw'), from the Early Cretaceous Weald Clay of Smokejacks Pit, Ockley, Surrey. (A) Skull bones as preserved; (B) normal digit, presumably from the hand; (C) the claw; (D) restoration of the skeleton; (E), imagined life appearance. (A) and (C) after Charig and Milner (1990); (B), (D) and (E) after Milner (1987).

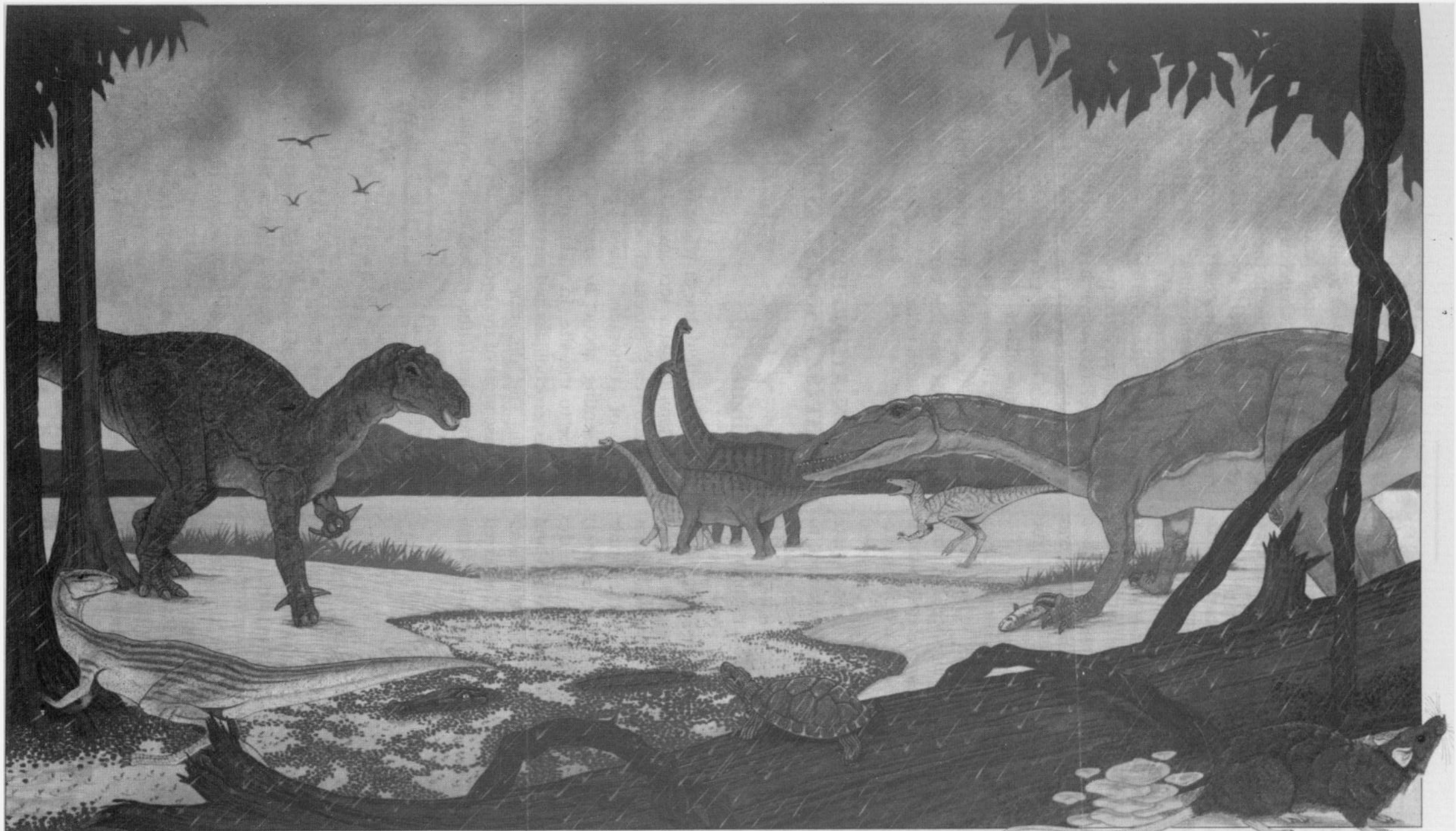

Figure 8.10 A reconstructed scene in the Wealden of southern England, combining elements of the faunas from the Weald and from the Isle of Wight. The small ornithopod *Hypsilophodon* (bottom left) looks up at its larger relative *Iguanodon*, just behind. A mammal and a turtle stand in the bottom right, while behind them the theropod *Baryonyx* prepares to eat a fish. Behind it, a small theropod runs towards a small herd of the sauropod *Pelorosaurus*. Based on a painting by Graham Rosewarne in Benton (1989). Reproduced with permission of Quarto Publishing plc.

for ichthyophagy on the basis of the enlarged claw, the numerous finely serrated teeth, the superficially crocodilian-like appearance of the skull, and the fish scales in its gut region. They envisioned *Baryonyx* as a quadrupedal predator crouching on river banks and using the large claw (presumably on the hand) like a gaff (Figure 8.10), in a way comparable to the method used by grizzly bears today. Kitchener (1987) took a contrasting approach, suggesting that the combination of the flexible snout tip, large sharp talon, the powerfully developed forelimbs and the narrow snout could be adaptations toward a scavenging lifestyle. However, Reid (1987) was not convinced by a carrion-feeding habit for the animal.

The unusual characters of *Baryonyx* have presented problems in classification. Charig and Milner (1986) considered that its specializations merited erection of a new theropod family which they named Baryonychidae. The only other material directly comparable with *Baryonyx* consisted of two fragmentary snouts from the Aptian (late Early Cretaceous) of Niger previously ascribed to the mandibular symphysis of a spinosaurid dinosaur. Buffetaut (1989, 1992) noted that, although there were some differences between *Spinosaurus* and *Baryonyx*, they share several characters, particularly the structure of the teeth and jaws. These characteristics suggested that they were closely related to each other and might indicate the inclusion of *Baryonyx* in the family Spinosauridae. Charig and Milner (1990) accepted the similarity of *Baryonyx* to the fragmentary skull specimens from Niger and southern Morocco, but argued that the latter were not spinosaurids. Molnar (1990) referred *Baryonyx* provisionally to 'problematic carnosaurs'.

Comparison with other localities

Reptiles are rare in the Weald Clay. The only other important site is at Berwick, East Sussex – the Cuckmere Brick Co. pit (TQ 523070) which has yielded the turtle *Plesiochelys* sp., and much of the skull and skeleton of a plesiosaur, the type specimen of *Leptocleidus superstes* Andrews, 1922. Other Weald Clay sites include Clockhouse, Rudgwick and Keymer (see above). The so-called spinosaurids from the Gadoufauna of Nigar (Aptian) and from southern Morocco (Early Cretaceous) are the nearest relatives of *Baryonyx*.

Conclusions

The general rarity of fossil reptiles in the Weald Clay makes Smokejacks Pit important. Furthermore, the abundance of the remains of *Iguanodon* collected in the 1940s and 1990s suggests that there are pockets containing concentrations of bones. This seems to be corroborated by the taphonomic data obtained from the *Baryonyx* excavation. *Baryonyx walkeri* is known only from Smokejacks Pit and is unique among all other theropod dinosaurs. The unusual features of *Baryonyx* have not only resulted in the establishment of a new genus and species for the animal, but also a new family of theropods, the Baryonychidae. *Baryonyx* is the most dramatic new dinosaur discovery from Europe for a long time. The site has tremendous potential for further finds and this contributes significantly to its conservation value.

BROOK–ATHERFIELD, ISLE OF WIGHT (SZ 375842-SZ 452788)

Highlights

Brook–Atherfield, Isle of Wight is one of the most important dinosaur sections in Europe. Over the past 200 years, dozens of nearly complete skeletons of dinosaurs have been excavated, representing about 20 species, some of them unique to the site. In addition, many species of turtles, crocodilians and pterosaurs have also been found. The dinosaur fauna is of importance because most of the specimens are well localized, and the fauna is the richest in the world for the Early Cretaceous.

Introduction

The Wealden Group of the south-west coast of the Isle of Wight (Figure 8.11) is world-famous for their rich reptile faunas (Figures 8.14 and 8.15). They have yielded abundant material in the past and good finds are made frequently because of continuing erosion. This section is currently the best source of dinosaur material in Britain and it is just as rich as the well-known deposits in North America and Mongolia.

The section between Compton Bay and Atherfield Point has been described by White

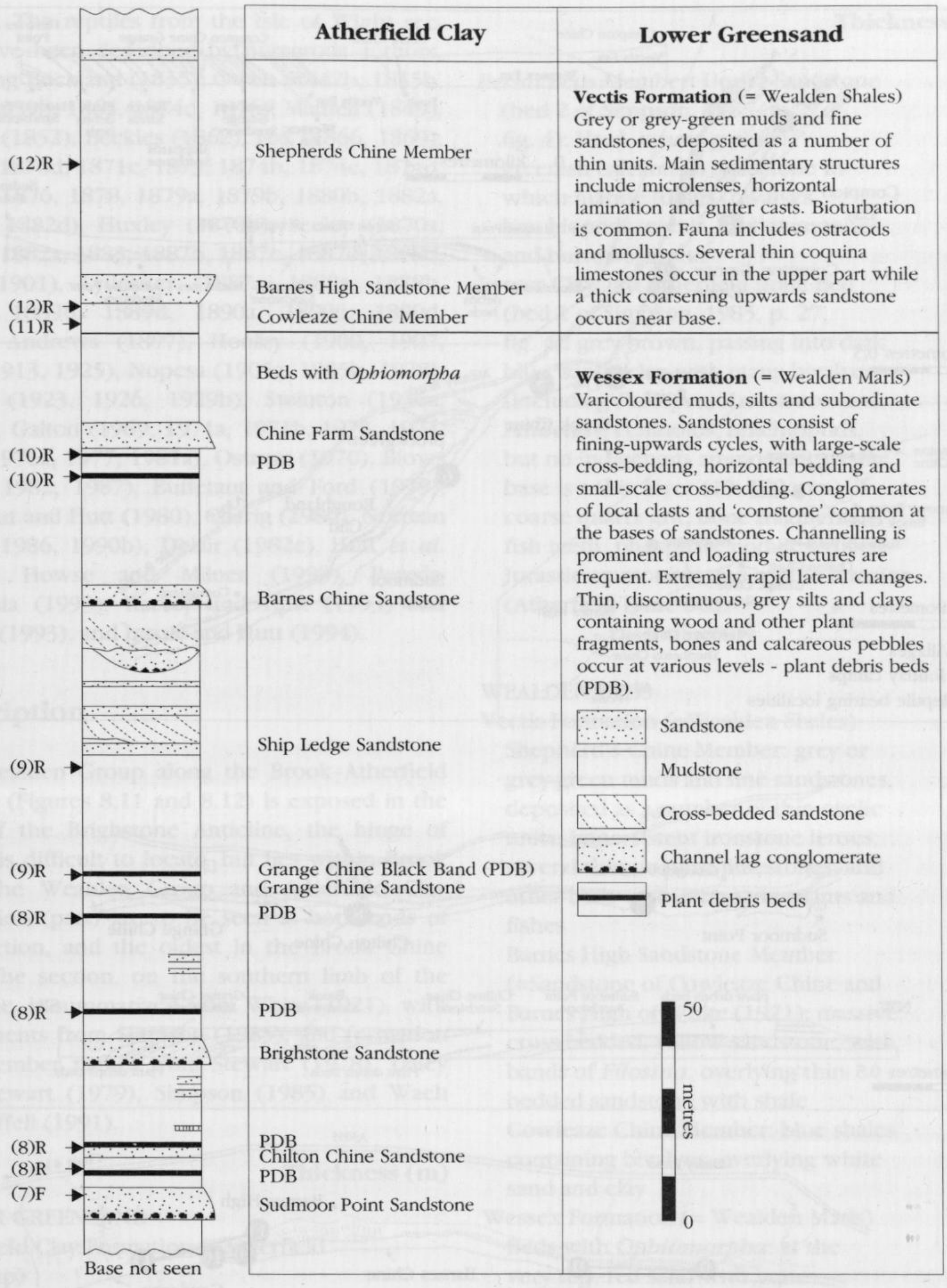

Figure 8.11 Summary sedimentary log through the Wealden beds (the Wessex and Vectis formations) of the south-western coast of the Isle of Wight between Sudmoor Point and Atherfield Point. Known reptile bone-bearing horizons are noted (R), as are footprint beds (F), and the numbers 7–12 match those used in the text in the locality descriptions. After Stewart (1981b).

(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 range up to Early Aptian (Kerth and Hailwood, 1988; Hughes and McDougall, 1990; Allen and Wimbledon, 1991). The section is best known for its dinosaurs, having yielded remains of about 100 individuals belonging to 15 or so species, although Swinton (1936a) recognized 22 valid

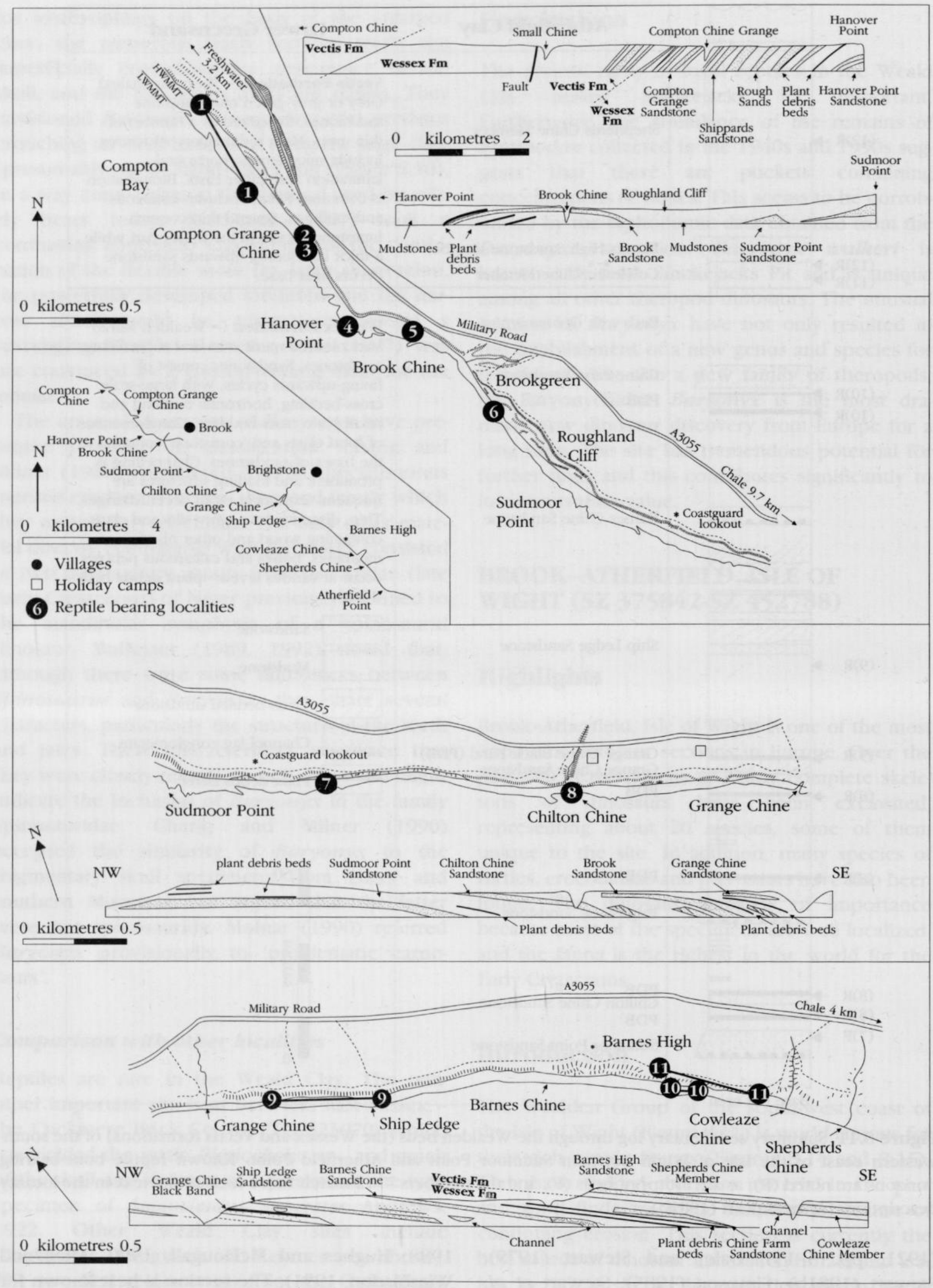

Figure 8.12 Maps and diagrammatic cliff views of the coastal section from Compton Chine to Atherfield Point, on the south-western coast of the Isle of Wight. Fossil reptile localities are indicated as 1–11, corresponding to the sites described in the text. After Stewart (1981b).

species. The reptiles from the Isle of Wight section have been described by numerous authors, including Buckland (1835), Owen (1842b, 1855b, 1858, 1859b, 1864, 1874c, 1876), Mantell (1849), Wright (1852), Beckles (1862), Fox (1866, 1869), Hulke (1870d, 1871c, 1873, 1874b, 1874c, 1874d, 1874e, 1876, 1878, 1879a, 1879b, 1880b, 1882a, 1882c, 1882d), Huxley (1870b), Seeley (1870a, 1875c, 1882a, 1883, 1887b, 1887c, 1887d, 1888d, 1892, 1901), Lydekker (1887a, 1888a, 1888b, 1889a, 1889b, 1889d, 1890a, 1890c, 1890d, 1891), Andrews (1897), Hooley (1900, 1907, 1912, 1913, 1925), Nopcsa (1905a, 1905b, 1928), Huene (1923, 1926, 1929b), Swinton (1936a, 1936b), Galton (1969, 1971a, 1971b, 1973, 1974, 1975, 1976a, 1977, 1981a), Ostrom (1970), Blows (1978, 1982, 1987), Buffetaut and Ford (1979), Buffetaut and Hutt (1980), Charig (1980), Norman (1980, 1986, 1990b), Delair (1982c), Hutt *et al.* (1989), Howse and Milner (1993), Pereda-Suberiola (1993), Radley and Hutt (1993) and Radley (1993), and Insole and Hutt (1994).

Description

The Wealden Group along the Brook–Atherfield section (Figures 8.11 and 8.12) 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 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 teeth (presumably derived) of *Hybodus* and *Lonchidon*, 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 and burrows) 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*, overlying 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 (Radley and Hutt, 1993)	14
Chine Farm Sandstone: white and yellow sand, with fragments and large trunks	

	Thickness (m)
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/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; 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/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 sandstone (near the bottom of Chilton Chine);	4
Marls/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 reptile localities, there is a large amount of information about provenances of finds made in the Compton Bay–Atherfield section. The information given below is extracted particularly from White (1921), other sources (cited below) and from museum labels. Unusually, there has always been a tradition among collectors of recording the locations of fossil reptile finds with a degree of precision encountered nowhere else in Britain. Nearly all the specimens have a label designation such as 'Brook Bay' or 'Cowleaze Chine', which restricts the provenance to a particular part of the stratigraphic column, and further collector information such as 'at beach level' or 'in a 6ft thick sandstone' is sometimes sufficient to identify the exact horizon. The records given below are arranged geographically from north-west to south-east along the section (Figure 8.11), thus descending stratigraphically from Compton Bay to Sudmoor Point, and then ascending to Atherfield Point.

Compton Bay
(There is a fault at about SZ 371849).

1. 'White sandy clay, with bones' (2 m thick), above 4 m of 'deep red marls' immediately north-west of the fault (White, 1921, p. 9). This bone-bearing horizon, at about SZ 370850 (?) in the cliff, lies 82 m below the Perna Bed (28 m Wealden Shales, 54 m Wealden Marls). A recent find of *Polacanthus* (1979) by William Blows was probably from this bed (BMNH R9293; Blows, 1982, 1987). Blows (1987) records that the remains lay scattered within a confined pocket exposed near a shipwreck, and only visible at low tide on the beach at SZ 347854. The site occurs in the lowest bed of the Vectis Formation and represents the first recorded find of *Polacanthus* from this stratigraphic unit (A. Insole, pers. comm. to W. Blows, 1987). The sediment containing the remains was a pale grey, non-fissile, massive clay otherwise generally devoid of fossils. A femur of ?*Dryosaurus* (BMNH R8670) from Compton Bay (? this bed) is mentioned by Galton (1975, p. 750).

2. Sandstone containing '*Iguanodon*' footprints (Beckles, 1862) at about SZ 376842 on the beach ('600 yards west of Hanover Point': White, 1921, p. 14). This sandstone is in the Wessex Formation (repeated by the fault) just above the lignite band north-west of

Shippard's (Compton Grange) Chine (?Compton Grange Sandstone of Stewart's unpublished section).

3. Plant debris bed at SZ 377840, about 200 m west of Hannover 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*, Figure 8.14C) and other vertebrate remains 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 Osborne White (1921, fig. 1, p. 12).' White (1921) illustrates three lignitic bands, none of which is anywhere near the site mentioned by Buffetaut and Ford (1979). The map reference is probably correct since these 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.

4. Hanover Point sandstones: '*Iguanodon*' footprints are to be seen on reddish and grey sandstones on the foreshore reef at Hanover Point and to the north-west in bed CH8 of Stewart (1978), and abundantly in the overlying red mudstones (Daley and Insole, 1984, p. 10). Beckles (1862, p. 443) described such prints from 'the shore at low water, between Brook Point [i.e. Hanover Point] and the Chine to the west of it.' A specimen of *Iguanodon* was excavated on the foreshore reef at Hanover Point in 1984 (S. Hutt, pers. comm. to M.J.B.). Various other dinosaur remains have been recorded from Hanover Point (in IWCMS), but most seem to have come from localities in Brook Bay just to the south-east (see below).

Brook Bay

5. Hanover Point to Brook Chine: A specimen of *Iguanodon* was collected in 1872 between the cliff and the 'pine raft' (Seeley, 1875c; Blows, 1978, pp. 26–34), and there are several further dinosaur remains in the IWCMS from 'Hanover Point'. Buckland (1835, p. 428) recorded *Iguanodon* vertebrae 'along a quarter mile of this shore [near Brook], but most abundantly at a spot called Bull-face Ledge near Brook Point, where the iron-stone is abundantly loaded with prostrate trunks of fossil trees.' Mantell (1846, p. 94) further noted that many hundreds of bones had been collected along this stretch of shore where they had been eroded from beds of sandy clay with *Unio* immediately above the 'pine raft'. These sandstones are probably equivalent to those seen at Hanover Point and immediately to the west of it, since the same beds are seen at both sides of Hanover Point because of the sharp angle in the coastline here. Hulke (1882a, p. 135) described some *Iguanodon* remains from 'a bed of hard nodules intercalated between the red and purple clays below and the iron-stained flint-gravel which caps the cliff west of Brook Chine . . . A few yards east of where this nodule-bed touches the cliff-foot, the cliff is cut through by a small gully worn by a little rill. In the east bank of this gully were the fossils.' Hulke describes the nodule bed as apparently dipping west and passing beneath the sand seawards towards the 'pine raft'. The source bed, then, is probably close to those described by Buckland (1835) and Mantell (1846) on the coastal strip between Hanover Point and Brook Chine (SZ 379837–SZ 385835). Seeley (1882a, p. 367) further described a dinosaur coracoid 'from the cliff midway between the pine raft and Brook Chine, at about 10 feet above high-water mark'. Andrews (1897) reported an *Iguanodon* cranium found 'on the shore near Brook Point'. Most other specimens labelled as 'Brook' or 'Brook Bay' probably came from this section, and this includes material described by Seeley (1883, 1887b, 1888d) and Lydekker (1887a, 1890c, 1890d). Delair (1989) notes Victorian finds of '*Iguanodon* ichnites', in sandstones on the shore west of Brook Point.

6. Brook Chine to Sudmoor (Sedmore) Point: parts of the cliff have collapsed along this section, and exposure is poor, except at Sudmoor Point. Some of the specimens labelled as 'Brook' may have come from this section, but there are no specific records.

7. Sudmoor Point to Chilton Chine: Sudmoor Point Sandstone: tridactyl '*Iguanodon*' and '*Megalosaurus*' footprints have been recorded in the sandstone between Sudmoor Point and

Chilton Chine by several authors (Beckles, 1862, p. 444 ('Southmore'); White, 1921, p. 7; Blows, 1978, pp. 44–58; Insole, *in* Daley and Stewart, 1979; Delair, 1989). The recent finds, from the Sudmoor Point Sandstone were made from a foreshore ledge at low tide level just west of Chilton Chine. These consisted of over 30 imprints of different shapes and sizes and constituting portions of 10 separate tracks (Blows, 1978). Insole (1982) regards all the tracks as being iguanodontid. Limb bones of *Valdosaurus* were found recently west of Chilton Chine (Radley, 1993).

8. Sudmoor Point to Chilton Chine: several bone-bearing horizons occur in the marls, sandstones and plant debris beds above the Sudmoor Point Sandstone (White, 1921, p. 14). Hulke (1870d) described a large vertebra whose locality was considered to be 'a bed which occurs near the top of the high cliff between Brooke and Chilton', and this could lie either to the west or east of Sudmoor Point. Buffetaut and Ford (1979) noted the occurrence of *Bernissartia* teeth 'from the *Unio* bed on the cliff at Sudmore Point' (?exact horizon). Galton (1975, p. 750) noted an ornithopod femur (BMNH R8670) from a 'bone bed between high and low water, Clinton Chine' (?Chilton Chine), and thus probably a bed just below the Chilton Chine Sandstone. Hulke (1879a) described a centrum from the cliff near Chilton, which could refer to a location to the east or west of the chine. There is further localized material from these beds in the IWCMS. The locality is a small conglomeratic lens, rich in *Margaritifera* ('*Unio*'), between the Chilton Chine Sandstone and Sudmoor Point Sandstone (Bed SS3 of Stewart, 1978; A. Insole, pers. comm., 1993).

Brighstone (or Brixton) Bay

9. Brighstone Bay (Grange [Brighstone] Chine to Barnes Chine): the upper portion of the Wealden Marls sequence is exposed between Grange Chine and Barnes Chine and there are several plant debris beds with bones – in particular the Grange Chine (Brixton Chine) Black Band at the top of the east side of Grange Chine. The iguanodontid dinosaur *Vectisaurus valdensis* was collected in a clay at the cliff-foot, '300 yards east of the flagstaff near Brixton Chine' (Hulke, 1879b). The flagstaff was at the small headland east of Grange Chine (SZ 427813) (S. Hutt, pers. comm.), so that the skeleton was found on Ship Ledge at about SZ 429812, probably in the marls below the Ship Ledge Sandstone. A theropod was collected in 1978 by William Blows from the mottled red and blue marls above the Grange Chine Black Band at SZ 423815 (W. Blows, pers. comm.), and several IWCMS specimens have also been found here. Several specimens bear the labels 'Jolliffe's Road, Brixton' or 'Jolliffe's Road, Barnes Chine' (e.g. BMNH R5226-7, R5338, IWCMS 3306), but this name cannot be found on 6-inch OS maps. A trackway of trifid impressions was noted from a low intertidal locality between Brook and Brighstone by Beckles (1862). Other finds from Brighstone (Brixton) Bay are not localized further (Wright, 1852, p. 89; Hulke, 1874b, 1874c).

10. Barnes Chine–Cowleaze Chine (upper portion of Wealden Marls): White (1921, p. 13) mentions 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 debris bed, a few metres higher has also yielded bones. Several specimens have been recorded from these beds. Hulke (1882b) noted a good skeleton of *Polacanthus* found 'in a bed of blue shaley clay, a short distance east of Barnes Chine. The bed is easily recognized by the large quantities of lignite which it contains.' A theropod femur (BMNH R5194) is labelled 'Wealden from bone bed under Barnes High, Brighstone Bay, found on beach.' Galton (1973) suggested that this was the *Hypsilophodon* Bed (base of Wealden Shales; top of cliff at Barnes High), but it is more likely to have been one of the plant debris beds which outcrop at beach level. Blows (1978, pp. 34–42) described the excavation of an *Iguanodon* pelvis from one of these beach-level lignite beds between Barnes High and Cowleaze Chine. Delair (1982c) reported a spine of ?*Polacanthus* 'from the uppermost of the two lignite bone beds in the Wessex Formation (Wealden Marls), exposed in the low foreshore cliff below the south-east face of Barnes High, Isle of Wight (SZ 439805)'. Further bones have been found in these plant debris beds (IWCMS 5122, 5129, 5136–9). Two 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, and a partly articulated *Iguanodon* (IWCMS 5126) was found about 10 m below the top and 400 m west of Cowleaze Chine (SZ 441804) (Insole, 1980). Several further specimens have been collected from these beds recently, including the new sauropod, from SZ 437807 (Radley, 1993; Radley and Hutt, 1993).

11. Barnes Chine–Cowleaze Chine (*Hypsilophodon* Bed): the *Hypsilophodon* Bed is one of the best known units of the sequence (Figure 8.13). It can be traced from the top of the cliff just west of Barnes Chine (SZ 434808) to beach level just west of Cowleaze Chine (SZ 443801). Owen (1855b, p. 2) noted a skeleton from 'about a hundred yards west of Cowleaze Chine.' Huxley (1870b) described specimens from the bed 'which forms the floor of Cowleaze Chine and rises to the top of the sea cliff at Barne's High'. Hulke (1873) reported *Hypsilophodon* remains 'from the same Cowleaze bed' and further specimens (Hulke, 1874d) from the same unit 'in a block of sandy clay-stone.' Owen (1874b, p. 13) quoted from a letter by Fox: 'this slab was found in the fallen cliff, about 150 yards east of 'Barnes High', directly fronting the den of my *Polacanthus* ... The skull and broken jaw were found about 60 yards further eastward' (SZ 437806, SZ 438806). Hulke (1882c, p. 1036) described the bed in some detail: 'The rock varies much often within the space of a few yards. Generally the upper 3ft of it consist of a cap of grey sandstone resting on sandy clay; this is succeeded by about the same depth of mottled-red and blue clay lying on the bands of sandstone. The *Hypsilophodon* remains are almost restricted to the lower half of the bed.' He mentioned the only other bones from the bed: rare remains of *Goniopholis* (?) and turtles. White (1921, p. 13) gave the relevant section as:

	Thickness	
	ft	**in**
White sand and clay	2	6
White rock	2	6
Red sand, with bones (*Hypsilophodon* Bed)	3	0

He noted that near Cowleaze Chine the 'white rock' was a pale, calcareous, silty stone containing *Unio* and bones, and that remains of *Hypsilophodon* had also been found in the marls a little below the *Hypsilophodon* Bed in Brixton Bay (White, 1921, p. 15). Galton (1974, pp. 15–18) gave more details of the *Hypsilophodon* Bed and of its lateral variation. He noted finds of bones both in the bed itself and in the white rock above, and emphasized that the locality designation usually given, 'Cowleaze Chine', is rather inappropriate since specimens came from sites 100–900 m west of the chine. Several recent finds have been made in the *Hypsilophodon* Bed (IWCMS 5123-4) and the 'White Rock' (IWCMS 5143, 5165, 5180). Insole (1980) noted remains of *Hypsilophodon* in red-mottled grey marls 'immediately beneath the *Hypsilophodon* Bed about 200 metres west of the Chine' (i.e. Cowleaze Chine, thus about SZ 442802).

12. Barnes Chine–Atherfield Point (Vectis Formation): Hooley (1912) reported a partial *Iguanodon* skeleton from 8 ft (2.5 m) above the *Hypsilophodon* Bed at the base of the blue shales 150 yards west of Cowleaze Chine. White (1921, p. 15) noted bones of *Iguanodon, Goniopholis* and *Ornithodesmus* from the shales above the *Hypsilophodon* Bed and in the Barnes High Sandstone. Buffetaut and Ford (1979) recorded teeth of *Bernissartia* 'in the Wealden Shales overlying the *Hypsilophodon* Bed at Cowleaze Chine.' A partial *Iguanodon* skeleton (BMNH R5331) is labelled 'from the shales between the grey sandstone and purple-coloured marls overlying the *Hypsilophodon* Bed, 300 yards west of Cowleaze Chine'. The exact horizon of another partial *Iguanodon* skeleton ('lignite band, 100 yards west of Cowleaze Chine'; probably from a plant debris bed within the White Rock; A. Insole, pers. comm., 1993) is uncertain. Hooley (1900) reported a fossil tortoise from 'about 10 feet above low water-mark opposite Shepherd's Chine' (SZ 446798). Further bones are labelled 'Wealden Shales, Sheperd's Chine' (IWCMS 4128, 4199–200). Hooley (1913) noted two specimens of *Ornithodesmus* from a rock fall at Atherfield, and the label (BMNH R3877–80) indicates a locality 20 yards west of Shepherd's Chine (SZ 447789). Many of the other fossil reptiles collected by Hooley are labelled 'Tie Pits, Atherfield' (BMNH speci-

Figure 8.13 The *Hypsilophodon* Bed at Cowleaze Chine, high in the Wealden sequence. Stephen Hutt points to the horizon from which several complete skeletons of *Hypsilophodon* have been excavated. (Photo: M.J. Benton.)

mens), which probably refers to the broad area of collapsed and pitted cliffs between the coastguard station and Atherfield Point. These include a partial skeleton of *Goniopholis* found about 80–90 ft (25–28 m) below the top of the Vectis Formation (Hooley, 1907), thus just below the middle of the Shepherd's Chine Member. There was a small brickpit immediately west of Atherfield Point, and in the upper part of the Vectis Formation, which probably yielded these older specimens, as well as some new finds of *Iguanodon* (A. Insole, pers. comm., 1993). The *Iguanodon* (IWCMS 5196) came from the '*Diplocraterion* Band' of the Shepherd's Chine Member and is encrusted in oysters, pyritized and marked with some predatory scratches (J. Radley, pers. comm., 1993). Stewart *et al.* (1991, p. 125) note plesiosaur remains from black mudstones near the top of the Shepherd's Chine Member. Tridactyl footprints have been found recently loose on the shore between Cowleaze Chine and Atherfield Point (SZ 444801–453792; Radley, 1993).

The preservation of the reptile remains from the Compton Bay–Atherfield section is variable. Bones found *in situ* are in various degrees of articulation or are isolated elements, and they may be crushed or virtually unaffected by compaction. The well-recorded (Blows, 1987) new specimen of *Polacanthus* (Figure 8.15G) is atypical of the preservation at this locality, being semi-articulated and in good condition, with the delicate processes of most elements intact. 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 (J. Radley, pers. comm., 1993).

Fauna

Large numbers of reptiles from various sites in the Compton–Atherfield section are preserved in British museums, especially BMNH and IWCMS. Type specimens are noted, and an estimate is given of the numbers of specimens of each species in major collections. Clearly there is much more material in other collections, but the figures will give an impression of relative abundance. Reptiles from all horizons are treated together since most occur throughout the succession (except *Hypsilophodon*).

	Numbers
Testudines: Cryptodira: Pleurosternidae	
Helochelydra Nopsca, 1928 (no species name)	
Type specimen: BMNH R171	1
Testudines: Cryptodira: Plesiochelyidae	
Plesiochelys brodiei Lydekker, 1889	
Type specimen: BMNH R1444 (cast)	2
Plesiochelys valdensis Lydekker, 1889	
Type specimen: BMNH 28967	1
Plesiochelys vectensis Hooley, 1900	
Type specimen: BMNH R6683	1
Plesiochelys sp.	2
'chelonian'	1
Archosauria: Crocodylia: Neosuchia: Goniopholididae	
Goniopholis crassidens Owen, 1841	12
Goniopholis minor Koken, 1887	1
Goniopholis sp.	*c.* 60
Oweniasuchus sp.(?)	1
Vectisuchus leptognathus Buffetaut and Hutt, 1980	
Type specimen: Staatl. Mus. Naturk. Stuttgart 50984	1
Archosauria: Crocodylia: Neosuchia: Pholidosauridae	
Pholidosaurus meyeri (Dunker, 1844)	3
Suchosaurus cultridens Owen, 1841	1
Suchosaurus sp.	1
Archosauria: Crocodylia: Neosuchia: Atoposauridae	
Theriosuchus sp.	1
Archosauria: Crocodylia: Neosuchia: Bernissartiidae	
Bernissartia sp.	(40 teeth)
Archosauria: Crocodylia: Neosuchia: Eusuchia	
Hylaeochampsa valdensis (Seeley, 1887)	1
Hylaeochampsa vectiana Owen, 1874	
Type specimen: BMNH R177.1	1
Hylaeochampsa sp.	2
'crocodilian'	1
Archosauria: Pterosauria: Pterodactyloidea: Ornithodesmidae	
Ornithodesmus latidens Seeley, 1901	

	Numbers
Type specimen: BMNH R176	3
Ornithodesmus sp.	2
'pterosaur'	1
Archosauria: Dinosauria: Saurischia: Theropoda	
Aristosuchus pusillus (Owen, 1876)	
Type specimen: BMNH R178	?5
Calamospondylus foxi Lydekker, 1889	
Type specimen: BMNH R901	1
Ornithodesmus cluniculus Seeley, 1887	
Type specimen: BMNH R187	1
Thecocoelurus daviesi (Seeley, 1888)	
Type specimen: BMNH R181	1
'coelurosaur'	2
Megalosaurus dunkeri Koken, 1887	1
Megalosaurus sp.	21
?Allosaurid	1
Archosauria: Dinosauria: Saurischia: Sauropoda	
Astrodon valdensis (Lydekker, 1889)	
Type specimen: BMNH R1730	3
Cetiosaurus sp.	4
'diplodocid'	1
Pelorosaurus hulkei (Seeley, 1870)	22
(?)*Titanosaurus valdensis* Huene, 1929	
Type specimen: BMNH R151	2
'sauropod'	5
brachiosaurid	1
Archosauria: Dinosauria: Ornithischia: Ornithopoda: Hypsilophodontidae	
Hypsilophodon foxi Huxley, 1870	
Type specimen: BMNH R197	26
'hypsilophodontid'	1
Valdosaurus canaliculatus Galton, 1975	
Type specimen: BMNH R185, R186	4
Archosauria: Dinosauria: Ornithischia: Ornithopoda: Iguanodontidae	
Iguanodon atherfieldensis Hooley, 1925	
Type specimen: BMNH R5764	1
Iguanodon bernissartensis Boulenger, 1881	23
Iguanodon gracilis (Lydekker, 1888)	
Type specimen: BMNH R142	7
Iguanodon sp.	105
Vectisaurus valdensis Hulke, 1879	
Type specimen: BMNH R2494	4
Archosauria: Dinosauria: Ornithischia: Ankylosauria: Nodosauridae	
Polacanthus foxi Hulke, 1882	
Type specimen: BMNH R175	5
Polacanthus sp.	*c.* 30
'nodosaur'	4

	Numbers
Sauropterygia: Plesiosauria	
'*Plesiosaurus* sp.'	10

Interpretation

Stewart *et al.* (1991) interpret the Wealden Group on the west coast of the Isle of Wight (Figures 8.11 and 8.12) as a sequence that records a shift from terrestrial deposition to fully marine. The lower unit, the Wessex Formation, is a fluviatile/coastal plain unit; the Vectis Formation above was deposited in a lagoon that was shallow and temporarily emergent, and the overlying Atherfield Clay Formation consists of marine units. Climatic conditions were seasonal, with wet and dry seasons in warm temperate to 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 is 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. These authors note that 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.

Turtles are relatively uncommon in the Wealden of the Isle of Wight. Fewer than ten specimens are known, compared with many hundreds of crocodilians and dinosaurs. The genus *Helochelydra* Nopsca, 1928 belongs to *Tretosternon* Owen, 1842 (Młynarski, 1976, pp. 60–1). All other forms have been referred to the genus *Plesiochelys*, a well-known Late Jurassic and Cretaceous form of disputed affinities (Gaffney, 1976; Młynarski, 1976). The species *P. brodiei* and *P. valdensis* were erected by Lydekker (1889d, pp. 236–9) on the basis of well-preserved carapaces (also Lydekker, 1889b, pp. 199–201). Hooley (1900) erected the third species, *P. vectensis*, again on the basis of a carapace. The species are distinguished by minor differences in the shapes of various plates in the carapace. An examination of the illustrations suggests, for example, that *P. valdensis* and *P. vectensis* may be identical.

A variety of small and large crocodilians is known from the Isle of Wight, and with a variety of terrestrial and aquatic adaptations. *Goniopholis*, which is well known in the Late Jurassic and Early Cretaceous of Europe and North America, is represented on the Isle of Wight by many specimens. Lydekker (1890a, pp. 229–30) mentioned some material of *G. crassidens* from the Isle of Wight (Figure 8.14A), and Hooley (1907) described a relatively complete skeleton from Atherfield. The skull was 540 mm long and it was capable of a gape of over 1 m. *Oweniasuchus* and *Vectisuchus* are also goniopholids. *V. leptognathus* has been described on the basis of a partial skeleton and skull (Figure 8.14B), which is characterized by a long slender snout (Buffetaut and Hutt, 1980). *Pholidosaurus* and *Suchosaurus* are pholidosaurids, a largely aquatic group. The goniopholids were ecological counterparts of today's crocodilians and alligators, and the pholidosaurids of gavials (Buffetaut, 1982, pp. 29–38). Buffetaut (1983) has also noted the occurrence of *Theriosuchus*, based on odd teeth and a skull fragment. *Theriosuchus* is an atoposaurid (Benton and Clark, 1988, p. 321), previously known only from the Purbeck (q.v.).

More advanced crocodilians from the Compton–Atherfield section include *Bernissartia* and *Hylaeochampsa*. *Bernissartia*, a small crocodilian with button-like teeth (Figure 8.14C) for crushing molluscs, has recently been identified from several locations (Buffetaut and Ford, 1979). *Hylaeochampsa* was a 2 m long crocodilian known from the Purbeck and Wealden of England; Owen (1874c) described *H. vectiana* on the basis of a partial skull with large orbits (Figure 8.14D), and Lydekker (1888a, p. 75) referred some Isle of Wight material to *H. valdensis* (Seeley, 1887). Both *Bernissartia* and *Hylaeochampsa* are of some importance, the latter being the oldest known eusuchian (Benton and Clark, 1988, p. 323; Clark and Norell, 1992), the former being close to the origin of the Eusuchia (Norell and Clark, 1990), and each is placed in its own family.

Remains of pterosaurs are rare, but significant.

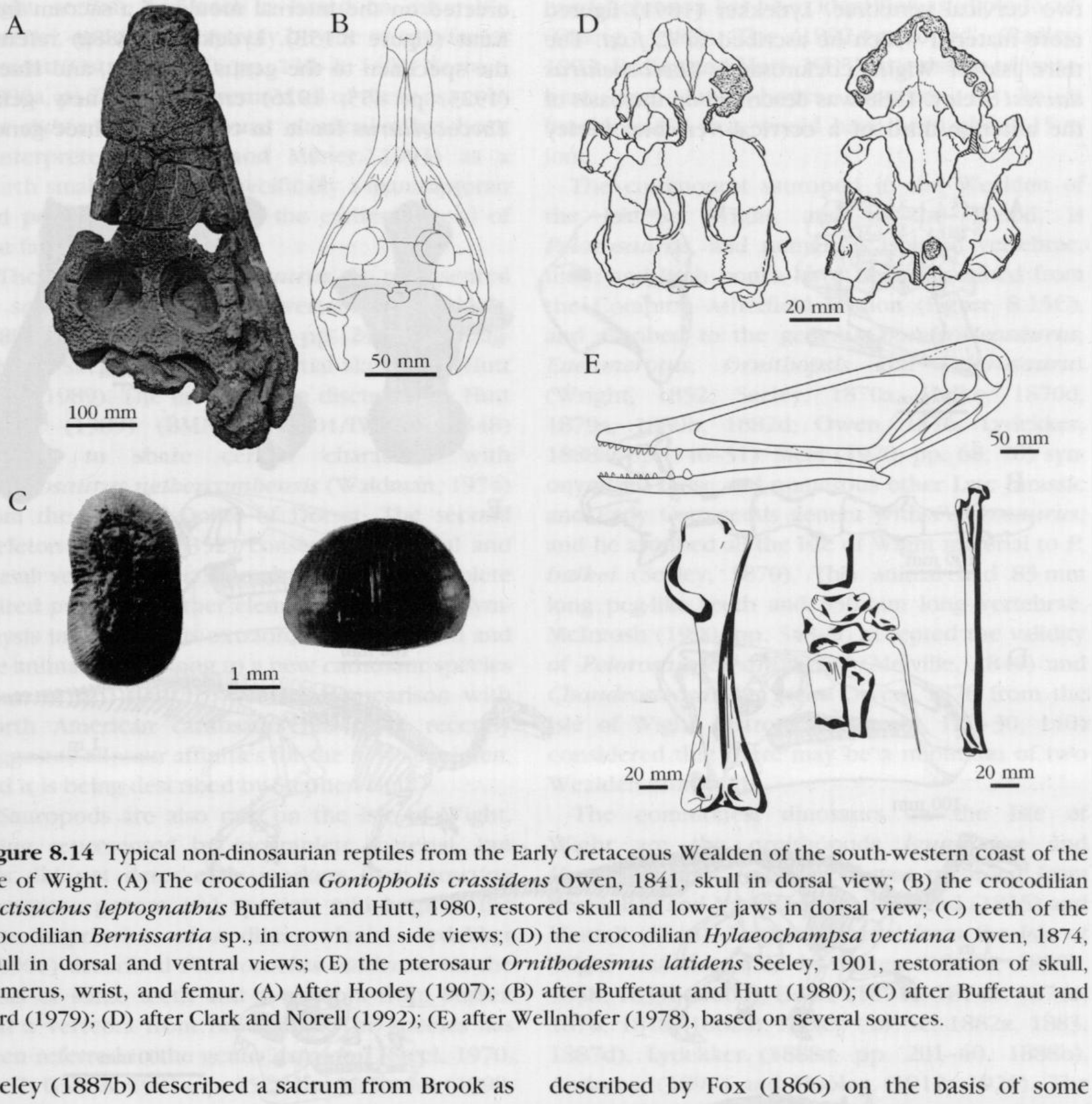

Figure 8.14 Typical non-dinosaurian reptiles from the Early Cretaceous Wealden of the south-western coast of the Isle of Wight. (A) The crocodilian *Goniopholis crassidens* Owen, 1841, skull in dorsal view; (B) the crocodilian *Vectisuchus leptognathus* Buffetaut and Hutt, 1980, restored skull and lower jaws in dorsal view; (C) teeth of the crocodilian *Bernissartia* sp., in crown and side views; (D) the crocodilian *Hylaeochampsa vectiana* Owen, 1874, skull in dorsal and ventral views; (E) the pterosaur *Ornithodesmus latidens* Seeley, 1901, restoration of skull, humerus, wrist, and femur. (A) After Hooley (1907); (B) after Buffetaut and Hutt (1980); (C) after Buffetaut and Ford (1979); (D) after Clark and Norell (1992); (E) after Wellnhofer (1978), based on several sources.

Seeley (1887b) described a sacrum from Brook as *Ornithodesmus cluniculus* (BMNH R187) and interpreted it as that of a bird. Lydekker (1888a, p. 42) suggested that it was, in fact, a pterosaur, but Howse and Milner (1993) have reinterpreted it as a theropod dinosaur (see below). Seeley (1901, p. 173) later named a partial pterosaur skeleton and skull from Atherfield (BMNH R176) as *O. latidens* (Figure 8.14E) and Hooley (1913) described it in detail. Wellnhofer (1978, pp. 54–5) suggested that both species may be the same. *Ornithodesmus* was a large animal (skull 560 mm long (?), estimated wing-span 5 m) and it is placed in its own family.

Four species of carnivorous theropod, three 'coelurosaurs', and one carnosaur have been described. *Calamospondylus oweni* was described by Fox (1866) on the basis of some pelvic remains (Figure 8.15A), and is probably the same as *Aristosuchus pusillus*, which was described by Owen (1876) on the basis of some sacral and lumbar vertebrae and a claw. Owen (1876) regarded the remains as those of a crocodilian and ascribed his new species to *Poikilopleuron*, a genus known from the Mid Jurassic of France. Seeley (1887c) noted that *Poikilopleuron* was very like *Megalosaurus*, and that the Isle of Wight animal was a 'coelurosaur' for which he erected the new genus *Aristosuchus*. Lydekker (1888a, pp. 157–9) agreed with this, and Huene (1926) amplified the original description. Galton (1973) ascribed a partial femur from Barnes High to *A. pusillus*. *Calamospondylus foxi* Lydekker (1889a) was probably rather similar, but it was based on only two cervical vertebrae. Lydekker (1891) figured more material which he ascribed to *C. foxi*. The third Isle of Wight 'coelurosaur', *Thecocoelurus daviesi* Seeley, 1888 was described on the basis of the anterior third of a cervical vertebra. Seeley (1888d) referred this to *Thecospondylus*, a genus erected on the internal mould of a sacrum from Kent (Figure 8.15B). Lydekker (1888a) referred the specimen to the genus *Coelurus*, and Huene (1923, p. 455; 1926) erected the new genus *Thecocoelurus* for it. In conclusion, three genera

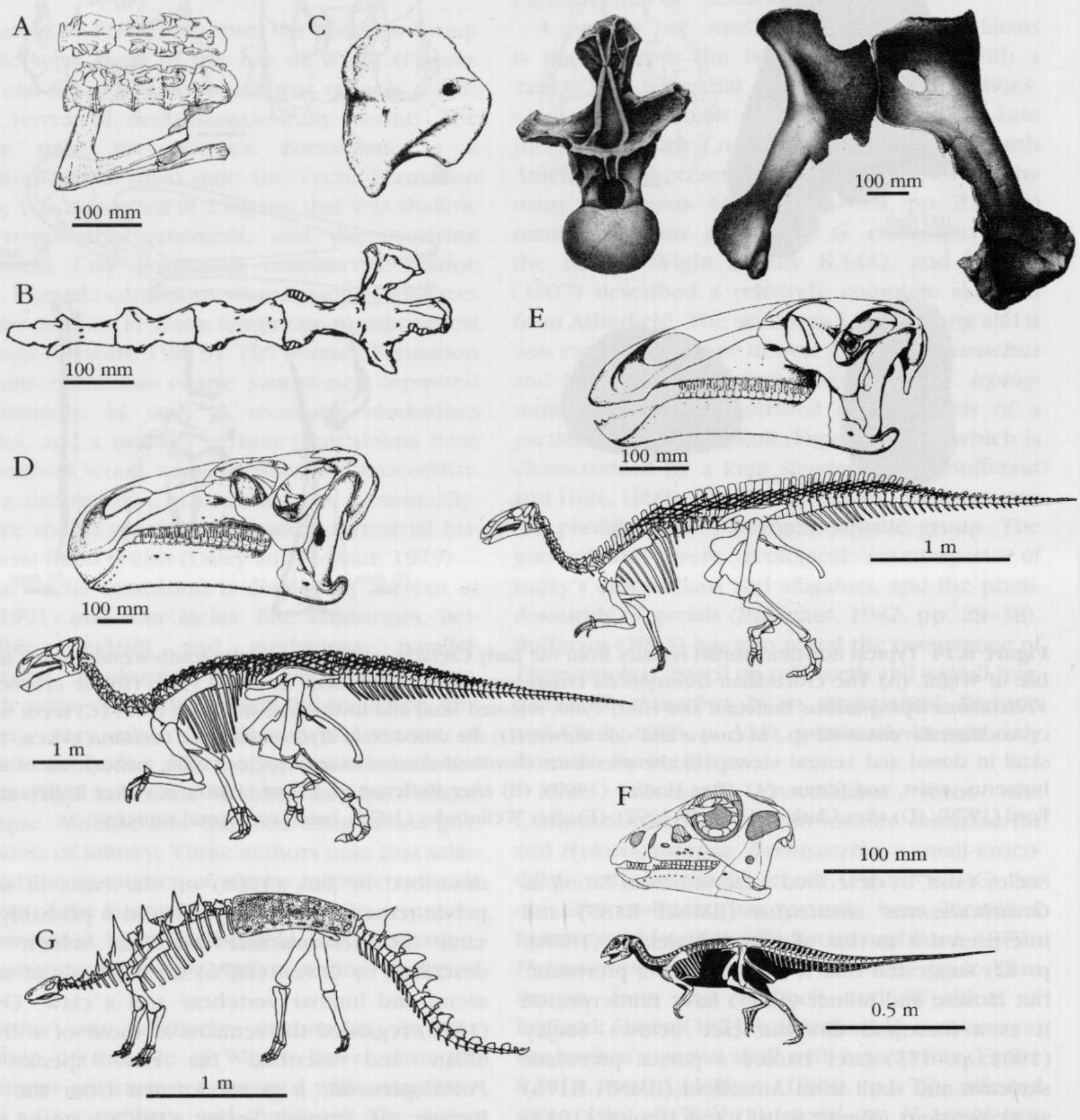

Figure 8.15 Typical dinosaurs from the Early Cretaceous Wealden of the south-western coast of the Isle of Wight. (A) The theropod dinosaur *Calamospondylus oweni* Fox, 1866, sacrum and pubis in dorsal and lateral views; (B) the theropod dinosaur *Thecospondylus horneri* Seeley, 1882, natural cast of the sacral cavity; (C) the sauropod dinosaur *Pelorosaurus hulkei* (Seeley, 1870), a dorsal vertebra in anterior view, a coracoid, and the pubis and ischium; (D) the large ornithopod *Iguanodon atherfieldensis* Hooley, 1925, skull and skeleton; (E) the large ornithopod *Iguanodon bernissartensis* Boulenger, 1881, skull and skeleton; (F) the small ornithopod *Hypsilophodon foxii* Huxley, 1869, skull and restored skeleton; (G) the ankylosaur *Polacanthus foxi* Hulke, 1881, skeleton. (A) After Seeley (1887c); (B) after Seeley (1882a); (C) after Hulke (1880b, 1882d), Seeley (1882); (D) and (E) after Norman (1980, 1986); (F) after Galton (1974); (G) after Blows (1987).

of 'coelurosaur' have been named from the Isle of Wight section, but each is based on miserable material, and there may only be one or two forms present (Ostrom, 1970, pp. 130-1, 140). Norman (1990a, p. 282) wisely termed all of these as *nomina dubia*. *Ornithodesmus cluniculus* has been reinterpreted (Howse and Milner, 1993) as a fourth small theropod, specifically a maniraptoran and possibly a troodontid, the earliest record of that family, if confirmed.

The carnosaur '*Megalosaurus*' is represented by some teeth, claws and vertebrae (Lydekker, 1889a, pp. 44-5, 166; 1891, pp. 244-5), a fragmented skeleton and two partial skeletons (Hutt *et al.*, 1989). The first skeleton discussed by Hutt *et al.* (1989) (BMNH R10001/IWCMS 6348) appears to share certain characters with *Megalosaurus nethercombensis* (Waldman, 1974) from the Inferior Oolite of Dorset. The second skeleton (IWCMS 6352) consists of cervical and dorsal vertebrae, ilia, sacral vertebrae, complete paired pubes and other elements. The pubic symphysis in this form is extraordinarily enlarged and the animal may belong to a new carnosaur species (Hutt *et al.*, 1989, p. 140). A comparison with North American carnosaurs has more recently suggested allosaur affinities for the new specimen, and it is being described by Stephen Hutt.

Sauropods are also rare on the Isle of Wight, being represented by incomplete material, but this did not deter early workers from erecting numerous genera and species, which gives the false impression of a diverse fauna. Lydekker (1890c) described *Pleurocoelus valdensis* on the basis of some teeth and a vertebra from Sussex and a vertebra from Brook Bay. The species has been referred to the genus *Astrodon* (Steel, 1970, p. 67; Galton, 1981a, p. 252), but McIntosh (1990, p. 348) is uncertain of the validity of the latter genus. The meagre remains indicate a relatively small sauropod (vertebrae 100-130 mm long compared with 500 mm in *Diplodocus*). Several vertebrae from the Isle of Wight were referred by Lydekker (1888a, pp. 139-41) to *Cetiosaurus brevis* Owen, 1842, but this species is invalid since the type specimen belongs to *Iguanodon* (Steel, 1970, p. 64; Ostrom, 1970, p. 129). Lydekker (1887a, 1888a, pp. 135-6) described two partial caudal vertebrae from the Isle of Wight as *Titanosaurus* sp., and Huene (1929b) erected the new species *T. valdensis* for these. Ostrom (1970, p. 130) confirmed the titanosaurid nature of these, and McIntosh (1990, p. 351) ascribed them to *Macrurosaurus semnus* Seeley, 1869, known also from the Cambridge Greensand. An unusual caudal chevron has been identified as 'diplodocid' (Charig, 1980). The '1992 sauropod' (Radley, 1993; Radley and Hutt, 1993), consisting of vertebrae and limb bones, appears to be a brachiosaurid that would have been about 15 m long.

The commonest sauropod in the Wealden of the Isle of Wight, and of the Weald, is *Pelorosaurus*, and numerous isolated vertebrae, teeth and limb bones have been described from the Compton-Atherfield section (Figure 8.15C), and ascribed to the genera *Chondrosteosaurus, Eucamerotus, Ornithopsis* and *Pelorosaurus* (Wright, 1852; Seeley, 1870a; Hulke, 1870d, 1879a, 1880b, 1882d; Owen, 1876; Lydekker, 1888a, pp. 146-51). Steel (1970, pp. 68, 70) synonymized these and numerous other Late Jurassic and Early Cretaceous genera with *Pelorosaurus*, and he ascribed all the Isle of Wight material to *P. hulkei* (Seeley, 1870). This animal had 85 mm long peg-like teeth and 350 mm long vertebrae. McIntosh (1990, pp. 348-9) accepted the validity of *Pelorosaurus conybeari* (Melville, 1849) and *Chondrosteosaurus gigas* Owen, 1876 from the Isle of Wight. Ostrom (1970, pp. 129-30, 140) considered that there may be a minimum of two Wealden sauropods.

The commonest dinosaurs on the Isle of Wight are the ornithopods *Iguanodon* and *Hypsilophodon*. *Iguanodon* was recorded from Brook Bay and Yaverland by Buckland (1835) and Mantell (1846). Further material from the Isle of Wight was described by Owen (1842b, 1855b, 1858, 1859b, 1864), Hulke (1871c, 1874b, 1874e, 1876, 1878, 1882a), Seeley (1875c, 1882a, 1883, 1887d), Lydekker (1888a, pp. 201-40, 1888b), Andrews (1897) and Hooley (1912, 1925). The species currently recognized from the Isle of Wight (Figure 8.15D and E) are *I. bernissartensis* (including *I. gracilis*) and *I. atherfieldensis* (Norman and Weishampel, 1990, p. 530), although Steel (1970, pp. 17-19) and Ostrom (1970, pp. 131-4) had accepted others as valid. The various species attained lengths of 5-8 m, and they may have fed on vegetation from trees.

Hypsilophodon, a small bipedal herbivore 1.5-2.5 m long (Figure 8.15F), was originally considered to be a juvenile *Iguanodon* (Mantell, 1849; Owen, 1855b; Fox, 1869). A good skull was described as *H. foxi* by Huxley (1870b). Numerous further finds were made (Hulke, 1873, 1874d, 1882c; Lydekker, 1888a, pp. 193-5; Nopcsa, 1905a). Since then, several studies on the anatomy, lifestyle and relationships of *Hypsilophodon* have been published (e.g. Swinton, 1936b; Galton, 1969, 1971a, 1971b, 1974, 1975). It has been variously interpreted as a tree-percher and as an active cursorial biped, the latter being the current view.

The other ornithopods from the Wealden of the Isle of Wight are less well known. *Vectisaurus valdensis* was described (Hulke, 1879b) on the basis of six vertebrae and an ilium. Galton (1976a) referred a further three specimens (vertebrae, pelvis and dentary) to the species and concluded that it was an iguanodontid. However, Norman (1990b) argued that *Vectisaurus* is a juvenile *Iguanodon atherfieldensis*. Finally, Galton (1975) erected the species *Dryosaurus*? *canaliculatus* for two small femora (previously referred to *Hypsilophodon foxi* by Lydekker, 1888a) and later made this the holotype of the genus *Valdosaurus* (Galton, 1977; Galton and Taquet, 1982).

Most of the Isle of Wight ankylosaurs have been referred to *Polacanthus foxi* (Figure 8.15G), but a few were classified as *Hylaeosaurus armatus*, a form originally described from the Wealden of Cuckfield. Fox (1866) reported a skeleton of an armoured reptile, lacking the skull, from Brighstone Bay and mentioned Owen's new name *Polacanthus*. However, Owen never described the specimen, and Hulke (1882b) supplied a detailed account, with the name *P. foxi*. Further descriptions of '*Hylaeosaurus*' and of *Polacanthus* from the Isle of Wight are those of Hulke (1874c), Lydekker (1888a, 1890d), Seeley (1892), Nopcsa (1905b), Blows (1982, 1987), Delair (1982c) and Pereda-Suberbiola (1991). Nopcsa (1928) erected the genus and species *Polacanthoides ponderosus* for a partial skeleton from Atherfield. Most authors noted the close similarity of *Polacanthus* and *Hylaeosaurus* (Hulke, 1882b; Lydekker, 1888a; Seeley, 1892; Ostrom, 1970, pp. 134–5; Coombs, 1978; Coombs and Maryanska, 1990), although Steel (1970), Blows (1987), and Pereda-Suberbiola (1993) argued for the validity both genera. Ostrom (1970, pp. 135, 141) suggested that *Polacanthoides* may be distinct from the other two genera, but others (Coombs, 1978; Coombs and Maryanska, 1990) have synonymized *Polacanthus* and *Polacanthoides* with *Hylaeosaurus*.

The plesiosaur remains (teeth, vertebrae and limb bones) from Tie Pits, Atherfield (BMNH R5180–5, 7–8), Brook (IWCMS 1586) and Compton Bay (BMNH R5186) do not appear to have been described, although they are mentioned by Stewart *et al.* (1991, p. 125), and it is consequently hard to assess their significance in the fauna.

Footprints variously ascribed to *Iguanodon* and '*Megalosaurus*' have been reported from several locations along the section (e.g. Beckles, 1862; Blows, 1978; Delair, 1989; S.H. Hutt, pers. comm.). They are found as trackways, or isolated prints weathered out in sandstone units on the foreshore. They are generally large three-toed prints, and resemble specimens from the Purbeck beds of Swanage and the Wealden of the Sussex coast (see above). Newer finds include four-toed casts from Brook, which may have been produced by a sauropod or an ankylosaur (J. Radley, pers. comm., 1993).

Comparison with other localities

The nearest comparable Wealden locality to the Compton–Atherfield section is the stretch of coast at Yaverland (see below) which exposes similar rocks and has yielded *Suchosaurus, Pelorosaurus, Iguanodon, Yaverlandia* and *Polacanthus*. The exposed Isle of Wight Wealden is largely, or wholly, Barremian in age (mid-Early Cretaceous), whereas reptile 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) (*Iguanodon, Baryonyx*, ?crocodilians).

The turtles *Tretosternon* and *Plesiochelys* are well known from the latest Jurassic (Purbeck) and the Cretaceous of Europe (Młynarski, 1976, pp. 55, 60).

The crocodilian *Bernissartia* is known from the Wealden of Belgium, Sussex and eastern Spain, as well as possibly the Early Cretaceous of Texas (Buffetaut and Ford, 1979; Norell and Clark, 1990) and the ?latest Jurassic of Wimille, northern France (Cuny *et al.*, 1991). *Hylaeochampsa* may also be known from the Wealden of Sussex, but the synonymy is uncertain (Clark and Norell, 1992). *Goniopholis* occurs widely in the Late Jurassic and Cretaceous of Europe, North and South America, while *Oweniasuchus* is known from the Purbeck of Swanage, and ?Early Cretaceous of Portugal (Steel, 1973). *Vectisuchus* is restricted to the Isle of Wight. *Pholidosaurus* occurs in the Purbeck of Swanage and the Wealden of Germany, as well as the ?Late

Cretaceous of Brazil; *Suchosaurus* has been reported from the Early Cretaceous of the Weald and of Portugal (Steel, 1973). *Theriosuchus* is known best from the Purbeck of Swanage.

The Isle of Wight 'coelurosaurs' are hard to compare with relatives elsewhere because of the inadequate material. The theropod *Megalosaurus* has been reported from all parts of the world and from earliest Jurassic to latest Cretaceous. *M. dunkeri* is reputed to come from the Purbeck, Wealden and Lower Greensand of southern England (Steel, 1970, pp. 43–5). The sauropod *Pleurocoelus* is known from the Wealden of Sussex, and the Early Cretaceous of Maryland and Texas, USA (McIntosh, 1990). Diplodocids are known from the Late Jurassic of North America, Tanzania and China (Charig, 1980), *Pelorosaurus* is known from the Early Cretaceous of England, as is *Macrurosaurus* (McIntosh, 1990).

Of the ornithischians, *Vectisaurus*, is restricted to the Isle of Wight. The genus *Hypsilophodon*, however, is known from the Early Cretaceous of Spain (Las Zabacheras Beds, Teruel) and reputedly also from the Early Cretaceous Lakota Formation of North America (*H. wielandi*: Galton and Jensen, 1979), but Sues and Norman (1990, p. 500) note this last taxon as *nomen dubium*. Other hypsilophodontids are known from the Kimmeridge Clay of Weymouth (?), the Late Jurassic Morrison Formation of North America and Tendaguru Beds of Tanzania, the early to mid-Cretaceous of Montana, USA (Cloverly Formation), Antarctica, Victoria (Otway Group) and New South Wales (Griman Creek Formation), Australia, and the Late Cretaceous of Montana, Wyoming, South Dakota and Colorado, USA and Alberta and Saskatchewan, Canada (Sues and Norman, 1990). *Iguanodon* is best known from the Wealden of southern England and Belgium, but it has also been reported from the Purbeck beds of Swanage, the Wealden of Germany, the Lower Greensand of southern England, and the Early Cretaceous of Spain, Mongolia and North America (Norman and Weishampel, 1990, p. 530). *Valdosaurus canaliculatus* is known from the Wealden of Tilgate Forest, Sussex, and from Cornet, Bihor, Romania and the species *V. nigeriensis* from the El Rhaz Formation (Aptian), Gadoufaoa, Niger, West Africa (Sues and Norman, 1990, p. 500). *Valdosaurus* is closely similar to the hypsilophodontid *Dryosaurus* (e.g. Galton, 1977), a form known from the Late Jurassic of western North America and Tanzania.

The ankylosaur *Polacanthus* ranges from the Wessex Formation to the Lower Greensand (Ferruginous Sands) (Barremian to Lower Aptian) mostly from the Isle of Wight, with one specimen known from the mainland. This block came from the Upper Greensand (Albian) at Charmouth, Dorset, and contained parts of four disarticulated, but associated, dorsal vertebrae, a rib section and portions of flat dermal armour (sacral shield). If *Hylaeosaurus* is a synonym then the range extends to the Wealden of the Weald area. Further, if *Hoplitosaurus* is synonymous with *Polacanthus*, as Pereda-Suberbiola (1991) suggests, the range expands to include the Early Cretaceous Lakota Formation of South Dakota (source also of the North American *Iguanodon* and *Hypsilophodon*).

Plesiosaurs are rare in the Wealden. Isolated bones have also been registered from Ridgeway Hill, Dorset (SY 6785), Cuckfield and Hastings, Sussex (Lydekker, 1889a, pp. 188–90, 224–7), Berwick, Sussex (TQ 5205: Andrews, 1922), Telham, Sussex (TQ 769142) and Brenchley, Kent (TQ 6741).

Wealden dinosaur footprints are also known on the Isle of Wight from Yaverland, and from several sites along the Sussex coast from Bexhill to Cliff End (Beckles, 1854; Tylor, 1862; White, 1928; Delair and Sarjeant, 1985; Delair, 1989; Radley, 1993), as well as from the former West Germany (Bückeburg and Bad Rehburg, Niedersächsen) and Belgium (Bernissart) (Haubold, 1971, pp. 79, 86–9).

Conclusions

The Wealden section between Compton Bay and Atherfield Point is one of the most famous sources of dinosaurs in the world, and Britain's best. A large reptile fauna is known, including turtles and plesiosaurs, but the archosaurs are best represented. The seven genera of crocodilians include a good selection of aquatic goniopholids and pholidosaurids, as well as some forms close to the origin of the modern crocodilians, the eusuchians (*Hylaeochampsa, Bernissartia*). Remains of pterosaurs (*Ornithodesmus*) may represent a unique group. Of the dinosaurs, fragmentary 'coelurosaur' and sauropod remains are known, but the best represented dinosaurs are the ornithopods *Hypsilophodon, Iguanodon* (two species), *Valdosaurus*, and the armoured ankylosaur *Hylaeosaurus*. *Valdosaurus* and *Iguanodon* are of biostratigraphic importance, providing evidence of a land connection between northern Europe and Africa across Tethys during the Early Cretaceous, and *Hypsilophodon* and *Hylaeosaurus* relate the Isle of Wight dinosaur fauna with the Early Cretaceous faunas of Dakota in North America.

The international importance of finds from this site and the continuing potential for significant future discoveries give it a very high conservation value.

YAVERLAND, SANDOWN, ISLE OF WIGHT (SZ 613850–SZ 622853)

Highlights

Yaverland is an important Early Cretaceous dinosaur site, especially as the location which yielded *Yaverlandia*, the oldest pachycephalosaur (bone-headed dinosaur) known. Both dinosaur bones and footprints are still found at Yaverland.

Introduction

The cliff section and beach at Yaverland are a well-known source of Wealden dinosaurs. Remains were reported as long ago as 1835 and finds are still being made. Although rather overshadowed by the Compton–Atherfield section on the western side of the Isle of Wight, Yaverland is an important supplementary source of reptiles and these include the unique pachycephalosaur *Yaverlandia* (Figure 8.16).

The section in the Wealden at Yaverland (Sandown Bay) has been described by Reid and Strahan (1889, p. 17) and White (1921, pp. 15–19). The beds lie on the northern limb of the Sandown Anticline, the hinge zone of which occurs at Sandown Fort. The reptiles have been described by Buckland (1829c, 1835b), Mantell (1846, 1854), Reid and Strahan (1889), Gibson (1858), White (1921) and Galton (1971c).

Description

A summary of White's (1921) section is given, with recent stratigraphic nomenclature from Daley and Stewart (1979) and Simpson (1985).

	Thickness (m)
Lower Greensand	
Perna Beds	
(bed 2) Calcareous sandstone	0.1
(bed 1) Thick, blue, sandy clay; Atherfield Bone Bed at base with a derived vertebrate fauna including *Hybodus* and *Lonchidon* (Patterson, 1966)	1.15
.... disconformity	
Vectis Formation (=Wealden Shales)	
Shales, grey or blue, with ostracods and bivalves interbedded with thin (0.12 m) beds of shelly limestone and rare ironstones	*c.* 37
Sandstone, yellow and white (equivalent of the Barnes High Sandstone)	*c.* 2.4
Shales, grey with molluscs and ostracods with a 0.1 m band of clay ironstone in the middle	*c.* 10.5
Wessex Formation (=Wealden Marls)	
Marl, grey with coloured mottlings and irregular bands of large calcareous nodules in upper part	*c.* 3.0
Silt, pale greenish-grey; hard and vesicular in places, with one or more bands of rolled concretions; much pyritized carbonized wood, *Margaritifera* (some phosphatized), reptilian bones, scales of *Lepidotus*, etc.	0.45
Clays, green, red and variegated (behind the old sea-wall)	*c.* 6.0
Clays and marls, variegated, with bands of cross-bedded sand	seen to 15.0

Reptile remains have been described from the shore and cliff. Buckland (1829c; 1835, pp. 425–8) noted isolated dinosaur bones 'in the iron sand which forms the shore, a little east of Sandown Fort, between high and low water'. The Sandown Fort noted here is not the current one, which was built in the 1870s, but an earlier structure some 500 m to the south-west (approximately SZ 605846): there have been no exposures of bedrock at this site in living memory (A. Insole, pers. comm., 1993). This would place the site on the southern limb of the Sandown Anticline and within the Wessex Formation. Mantell (1846, p. 95) noted an *Iguanodon* tibia from the same site (also Mantell, 1847, pp. 137–8). Reid and Strahan (1889, p. 17) implied that Buckland's and

Mantell's bones came from the conspicuous yellow and white sandstone in the Wealden Shales, and Buckland's (1835) reference to 'iron sand' could be interpreted in such a way. However, no finds have been made since in that unit, nor in any of the ironstones in the Vectis Formation (White, 1921, p. 18). It must be assumed that these early discoveries were not *in situ*, and that they were washed up on the beach (at about SZ 620853). Gibson (1858) refers to this eastern end of the section as Buckland's site and notes that 'large vertebrae and other portions of bone are frequently found, but always much rolled and broken.'

Gibson (1858) reported an *Iguanodon* femur in a low cliff of 'Weald Clay' exposed by a storm 'a little to the west of Sandown Fort . . . lies immediately above the ferruginous sandstone in which Dr Buckland discovered the metacarpal bone. The clay-bed in which the bone was found is near the centre of the arch which . . . is formed by the Wealden in Sandown Bay, dipping slightly westward . . . about half-a-mile' from Buckland's beach site. Therefore, Gibson's find was on the western limb of the anticline at about SZ 612849, thus in the low cliff currently exposed, or possibly a portion now covered by the concrete sea-wall. Mantell (1854, pp. 98–9, 226) noted *Iguanodon* remains from the foot of a small cliff that forms the sea boundary of Yaverland Farm, but this farm no longer exists and the site is hard to identify.

White (1921, pp. 15–19) described the occurrence of reptiles in two silty plant debris beds within the Wessex Formation which are to be seen in the cliff 10–50 m west of the old sea-wall (now collapsed), thus at about SZ 616851. He mentions bones and teeth of *Iguanodon* and carnivorous reptiles in the lower bed and from the top of a multiple plant debris bed unit, which is occasionally exposed on the beach east of the old wall, thus at about SZ 617852; it includes a basal bone-rich lag deposit (J. Radley, pers. comm.). The higher plant debris bed 'is rich in the remains of reptiles (chiefly *Iguanodon*, including *I. mantelli* Meyer, together with less common *Goniopholis crassidens* Owen and turtle (*Plesiochelys*?), and is the principal source of the wave-washed bones usually to be seen on the shore between Yaverland sea-wall and Redcliff . . . This bed comes down to the beach about 70 yards east of the sea-wall', thus at about SZ 619852. The type specimen of the pachycephalosaur *Yaverlandia* came 'from the Upper Silty Bed north of the sea wall below Yaverland Battery' (Galton, 1971c, p. 41). Numerous remains in IWCMS are labelled 'silty beds', 'upper silty bed' or 'lower silty bed', and finds are regularly made in these units in the cliff and on the beach.

Dinosaur footprints were found at Yaverland in early April 1979, a large series of iguanodont trackways exposed on the shore (Delair, 1989). Subsequently, several horizons have been found to contain footprints (Radley, 1993).

The bones from Yaverland are generally isolated and in reasonable condition if collected *in situ*, but often much abraded if picked from the beach. Few articulated elements have been collected, although J. Radley (pers. comm., 1993) notes occasional articulated vertebrae. The finds range in size from 10 mm crocodilian teeth to 1.5 m long dinosaur limb bones (Gibson, 1858).

Fauna

The main repositories for Yaverland material are the BMNH and IWCMS. Very few of the specimens have been described, and the names are taken from the museum labels. An estimate of the numbers of specimens of each form is given:

	Numbers
Testudines: Cryptodira	
Plesiochelys sp.	2
Tretosternon bakewelli (Mantell, 1833)	1
Archosauria: Crocodylia: Neosuchia	
Goniopholis crassidens Owen, 1841	11
Suchosaurus cultridens Owen, 1841	1
'crocodilian'	2
Archosauria: Dinosauria: Saurischia: Theropoda	
Megalosaurus dunkeri Koken, 1887	2
Megalosaurus sp.	6
Archosauria: Dinosauria: Saurischia: Sauropoda	
Cetiosaurus brevis Owen, 1842	1
Pelorosaurus hulkei (Seeley, 1870)	1
Archosauria: Dinosauria: Ornithischia: Ornithopoda: Iguanodontidae	
Iguanodon bernissartensis Boulenger, 1881	2
Iguanodon mantelli Meyer, 1832	1
Iguanodon sp.	*c.* 40
Archosauria: Dinosauria: Ornithischia: Pachycephalosauria: Pachycephalosauridae	
Yaverlandia bitholos Galton, 1971	
Type specimen: IWCMS 1530	1

Numbers

Archosauria: Dinosauria: Ornithischia:
Ankylosauria: Nodosauridae

Polacanthus foxi Hulke, 1882	2
Polacanthus sp.	3

Sauropterygia: Plesiosauria

'*Plesiosaurus* sp.'	2

Interpretation

The range and relative numbers of reptiles recorded from Yaverland are similar to those from the Compton–Atherfield section. Turtles are not common, and consist of partial carapaces ascribed to the typical Wealden genera *Plesiochelys* and *Tretosternon*. Crocodilians are more abundant, with several finds of teeth, scutes and vertebrae of the aquatic metamesosuchians *Goniopholis* and *Suchosaurus*.

Among the dinosaurs, several limb bones and vertebrae of the carnivore '*Megalosaurus*' have been collected, and the material is more extensive than that from the Compton–Atherfield section. However, the smaller 'coelurosaurs' do not appear to be represented. A couple of large limb bones in the BMNH have been ascribed to the sauropod genera *Cetiosaurus* and *Pelorosaurus*.

As in the Compton–Atherfield section, the most abundant remains are those of ornithopod dinosaurs. The commonest genus is *Iguanodon*, with numerous finds of limb bones, vertebrae, teeth and a partial jaw (IWCMS 3866). Several of these have been ascribed to species of *Iguanodon*, but the taxonomy of that genus is in some confusion (Norman and Weishampel, 1990). The most important specimen from Yaverland (Figure 8.16) is the type specimen of the pachycephalosaur *Yaverlandia bitholos* Galton, 1971. This has a thickened skull cap (14.2 mm thick, 45 mm long: original skull length *c.* 70 mm) which is a feature characteristic of the group. This may

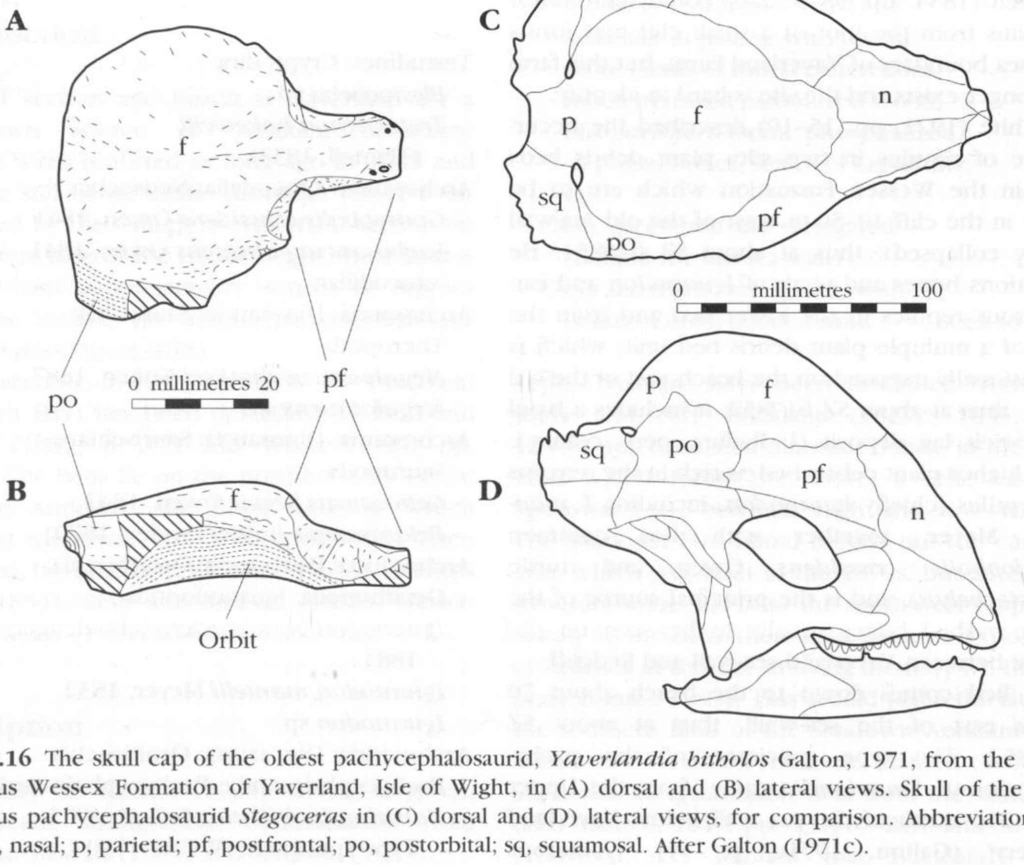

Figure 8.16 The skull cap of the oldest pachycephalosaurid, *Yaverlandia bitholos* Galton, 1971, from the Early Cretaceous Wessex Formation of Yaverland, Isle of Wight, in (A) dorsal and (B) lateral views. Skull of the Late Cretaceous pachycephalosaurid *Stegoceras* in (C) dorsal and (D) lateral views, for comparison. Abbreviations: f, frontal; n, nasal; p, parietal; pf, postfrontal; po, postorbital; sq, squamosal. After Galton (1971c).

have been used as a battering ram in intraspecific competition (Galton, 1971c). A partial brain cast is preserved. *Yaverlandia* is the oldest member of the group and shows characters intermediate between hypsilophodontids and typical Late Cretaceous pachycephalosaurs (Galton, 1971c; Wall and Galton, 1979).

The ankylosaur *Polacanthus* is represented by several dermal spines and scutes, and there are two plesiosaur vertebrae (IWCMS 5059, 5108).

Comparison with other localities

The most productive comparable section is the coast between Compton Bay and Atherfield which exposes similar beds: it has yielded a similar fauna, although '*Megalosaurus*' is apparently more abundant at Yaverland. The west coast fauna includes all the Yaverland genera except the pachycephalosaur *Yaverlandia*, yielding material attributed to 11 genera. Pachycephalosauria are known elsewhere from the Late Cretaceous of North America (*Pachycephalosaurus, Stegoceras, Gravitholus, Ornatotholus, Stygimoloch*), Mongolia (*Tylocephale, Goyocephale, Prenocephale, Homocephale*), Madagascar (*Majungatholus*) and China (*Wannanosaurus*) (Maryanska, 1990). *Stenopelix* from the Early Cretaceous of Germany, formerly regarded as a pachycephalosaur, is probably something else (Wall and Galton, 1979), which makes *Yaverlandia* the earliest member of the group.

Conclusions

Yaverland is important as a supplementary site yielding the same fauna of dinosaurs, and other fossil reptiles, as the west coast Compton-Atherfield section. It is unique as the site of *Yaverlandia*, the oldest pachycephalosaur dinosaur known. Yaverland still frequently yields good dinosaur specimens and footprints, and the combination of these attributes gives its conservation value.

EARLY CRETACEOUS (APTIAN–ALBIAN)

The Aptian and Albian stages in Britain are important for reptile faunas that include a variety of marine and terrestrial forms, and significant finds have come from the Lower Greensand (Aptian–Early Albian), Gault Clay (Albian), Upper Greensand (Late Albian), and from the areally restricted Cambridge Greensand (remanié latest Albian material in a basal Cenomanian matrix). Another reworked deposit, the Lower Greensand of Potton, Bedfordshire, contains reworked fossils from the Late Jurassic or Wealden. Reptile remains in the Lower and Upper Greensand are usually fragmentary and sparse. The Gault Clay has yielded abundant and well-preserved remains, particularly from the cliff sections of Folkestone.

Lower Greensand reptile sites include the following:

DORSET: Punfield Cove, Swanage (SZ 032798; *Iguanodon*, '*Megalosaurus*', sauropod; Buckland, 1835; Strahan, 1898, pp. 122–32; Delair, 1966, p. 58; Rawson *et al.*, 1978, pp. 41–2).

BUCKINGHAMSHIRE: Brick Hill (SP 9131, ?exact locality; *Dakosaurus*, plesiosaur, ichthyosaur).

BEDFORDSHIRE: Potton (TL 2249; various localities on Old Potton–Sandy railway line; *Dakosaurus, Cimoliasaurus, Pliosaurus*, '*Ichthyosaurus*', *Iguanodon*, '*Megalosaurus*', *Craterosaurus*, etc.; Seeley, 1869a, pp. 74–80, 1869b, 1874a; Nopcsa, 1912; Casey, 1961; Edmonds and Dinham, 1965; Galton, 1981b).

CAMBRIDGESHIRE: Upware, Commissioner's Pit (TL 539708; *Goniopholis*, '*Plesiosaurus*', *Pliosaurus*, '*Ichthyosaurus*', *Iguanodon*; Walker, 1867; Keeping, 1883; Whitaker *et al.*, 1891, pp. 22–32; Casey, 1961; Rawson *et al.*, 1978).

ISLE OF WIGHT: Atherfield (SZ 4579, ?exact locality; plesiosaur, turtle; Atherfield Clay); Blackgang Chine (SZ 484768; *Iguanodon*; Fitton, 1847; Mantell, 1854, pp. 170–3); Sandown (?SZ 625855; ichthyosaur, plesiosaur); Shanklin (?sauropod; Sandrock Series).

SURREY: Godalming (SU 9643; pliosaur; Swinton, 1930).

KENT: Chipstead (TQ 501560; '*Plesiosaurus*'); Maidstone *Iguanodon* Quarry (TQ 746558; *Iguanodon*, turtle, plesiosaur, pliosaur; Bakewell, 1835; Owen, 1841c, p. 452; Bensted, 1860; Topley, 1875, pp. 117–18; Worssam, 1963, pp. 26, 37, 48, 107, 136; Delair, *in* Swinton, 1970, p. 301); Hythe (TR 163352; *Dinodocus*, *Polytychodon*; Mackeson, 1840; Owen, 1841c, pp. 449–52; Topley, 1875; Woodward, 1908c; Smart *et al.*, 1966, pp. 77–8); Folkestone (TR 2235; plesiosaur, ichthyosaur; Topley, 1875, p. 422; Smart *et al.*, 1966, pp. 93–6; Padgham, 1972).

The Cambridge Greensand is a remanié deposit of early Cenomanian age, containing reptile bones 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 remains are associated with abundant phosphate 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). Typical source localities may have resembled the sequence at Barnwell (TL 5667), where at least four levels of phosphates are developed, including the Barnwell Hard Band in which abundant vertebrate remains have been found (A.C. Morter, pers. comm.). Seeley (1869a) noted 30 or more Cambridge Greensand sites, and he and others (Owen, 1859c, 1861c; Huxley, 1867b; Seeley, 1869a, 1870b, 1873, 1874c, 1875b, 1876b, 1876c, 1876d, 1879; Lydekker, 1888a, 1889a, 1889b) described 80 or more species of turtles, crocodilians, dinosaurs, ichthyosaurs, plesiosaurs and especially pterosaurs. Seeley's 40 or so pterosaur 'species' have been synonymized to four or five by Unwin (1991). There are few extant exposures of the Cambridge Greensand: it may be seen at Barrington (TL 3949) and Arlesey (TL 185350; M.B. Hart, W.J. Kennedy, pers. comm., 1993).

Upper Greensand (Late Albian) reptiles have been found at these localities:

DORSET: Melbury Down, near Shaftesbury (SP 9020; *Trachydermachelys*; Jukes-Browne and Hill, 1900, pp. 158–61; Andrews, 1920; White, 1923, p. 63); Charmouth, ?exact locality; ichthyosaur; Jukes-Browne and Hill, 1900, pp. 183–9).

SOMERSET: Kilmerton (?exact locality; ichthyosaur).

WILTSHIRE: Shute Farm, Warminster (ST 844411; ichthyosaur, *Polysphenodon*; Jukes-Browne, 1896; Jukes-Browne and Hill, 1900, pp. 237–41); Savernake (SU 2166; plesiosaur; Jukes-Browne and Hill, 1900, pp. 262–5).

ISLE OF WIGHT: St Lawrence Cliff (SZ 5376; *Hylaeochelys*; Owen, 1881; Parkinson, 1881; Jukes-Browne and Hill, 1900, pp. 132–6).

BEDFORDSHIRE: Ampthill (LT 0338; ichthyosaur).

MIDDLESEX: Croydon, London (TQ 3164; ichthyosaur).

KENT: Folkestone (TR 2235; ichthyosaur; Topley 1875, p. 152).

Two Greensand exposures are selected as GCR sites:

1. Wicklesham Pit, Faringdon, Oxfordshire (SU 292943). Early Cretaceous (Late Aptian), Faringdon Sponge Gravels (Lower Greensand).
2. East Wear Bay, Folkestone, Kent (TR 243366). Early Cretaceous (Albian), Lower–Upper Gault.

WICKLESHAM PIT, FARINGDON, OXFORDSHIRE (SU 292943)

Highlights

Wicklesham Pit, Faringdon is a productive Greensand site where the abundant isolated bones and teeth of reptiles are found reworked from older levels. Remains of turtles, crocodilians, ichthyosaurs, plesiosaurs and dinosaurs have been reported.

Introduction

The Lower Greensand (Late Aptian) of Faringdon, Oxfordshire has been known as a source of fossil reptile bones for many years. Wicklesham Pit is the best current source of such bones. The bones occur in the Faringdon Sponge Gravels, beds famous for their invertebrate fossils (Arkell, 1947a; Casey, 1961; Krantz, 1972). The Lower Greensand occurs as several outliers south and east of Faringdon which are surrounded by Late Jurassic (Kimmeridge Clay, Corallian, etc.). Arkell (1947a, pp. 155–60) reviewed the occurrence and geology of the Faringdon Lower Greensand. Fossil reptile specimens from Faringdon have been noted by several authors, but the fauna has never been described.

Description

The sequence of the Faringdon Sponge Gravels has been given by Krantz (1972):

	Thickness (m)
Iron-rich sands	0–15
Laminated clays	0.9–16.8
Clay-rich sands, with two Fuller's earth bands	15–33
Red Gravels: quartz-rich sandstones, conglomerates with bioclasts, and cross-bedded coarse sands with sponges	2–8.7
Yellow gravels: fine- to medium-grained quartz-rich sandstones, with well-preserved sponges, brachiopods, bryozoa and echinoids	0–10

The Red Gravels and Yellow Gravels together are generally referred to as the Sponge Gravels, but the term is occasionally reserved for the Yellow Gravels alone. The Sponge Gravels are a basal conglomerate of the Lower Greensand which rest unconformably on Kimmeridge Clay or Corallian, and the unit is laterally extensive, extending 10 km or more south-east from Faringdon, according to borehole evidence (Krantz, 1972).

Arkell noted that Wicklesham Pit (photograph: 1947a, pl. 5) exposed an 8 m section of the Red Gravel. At 2–3 m from the bottom, he noted a pebble bed, about 0.3 m thick, 'full of bored mudstone nodules, and black phospathic fragments of ammonites (*Prionodoceras*) derived from the basal Kimmeridge [sic] Clay and Upper Calcareous Grit'. The pit has recently been reworked, and it displays an 8–10 m section of red-brown and brown unconsolidated sands with limestone beds and lenses. The exact localities of the older Faringdon fossils are uncertain - there were several pits operational at one time, including Little Coxwell Pit (SU 285943) and Faringdon Pit (SU 288943), both of which still exhibit sections (Krantz, 1972).

Fossils occur in consolidated and unconsolidated coquinas. These are all stained brown by iron oxide and phosphate, and include bryozoans, sponges, echinoderm spines, brachiopods, bones, phosphatic pebbles, ammonites, belemnites and fish teeth. The invertebrates are generally in good condition - brachiopod valves may still be articulated (though not in life position) - but the colonial organisms, such as sponges, are clearly not in growth position.

Fauna

On a brief visit to Wicklesham pit in 1983, M.J.B. collected fragments of vertebrae and ribs, probably from large marine reptiles. Similar specimens, as well as teeth, have been collected by field parties from Oxford University and Oxford Brookes University, among others (H.P. Powell, A. Kearsley, pers. comm., 1983). Reptile specimens from Faringdon are housed in the BGS(GSM), BMNH, CAMSM and OXFPM.

Testudines:
'turtle'
CAMSM B58645 (scute)
Archosauria: Crocodylia
Dakosaurus
CAMSM B58636, B58707–9 (teeth)
Ichthyosauria
'*Ichthyosaurus*'
CAMSM B58640–2 (teeth); CAMSM B58643–4, B58696 (vertebrae)
Sauropterygia: Plesiosauria
Colymbosaurus
CAMSM Zr 2240–5, 2250–3, 52368–9; CAMSM B58703–6 (teeth); BMNH 11901, 46382; CAMSM B5871 (vertebrae; limb bones)
Pliosaurus:
CAMSM B58638–9, (teeth); CAMSM B58695 (vertebra)
Archosauria: Dinosauria
?sauropod, stegosaur, or ankylosaur: OXFPM (3 unnumb. teeth)

Interpretation

Arkell (1947a) suggested that the Faringdon Sponge Gravels collected as a sand-and-gravel bank on the sea bed some distance offshore in pre-existing hollows in the Kimmeridge Clay. Krantz (1972) noted that, although the unconsolidated sands and gravels accumulated within a channel during a transgressive episode, the contained invertebrate fossils are frequently very well preserved. She resolved this apparent paradox by suggesting that the fossils accumulated mainly on the protected western side of the channel where only the upper layers of the Sponge Gravels were reworked, and that the waters were rich in $CaCO_3$, which prevented the dissolution of calcareous fossils. Krantz (1972) argues that the sponges and bryozoans were torn up from their life positions on neighbouring hardgrounds formed on exposed areas of Corallian rock and were then mixed with previously abraded and sorted shell material. The overall palaeogeographic setting seems most comparable with a forereef deposit (Krantz, 1972). The vertebrate fossils appear to derive mainly from the Kimmeridge Clay, whereas the invertebrates are coeval with the time of deposition.

The reptile remains consist of teeth and vertebrae, which are usually identifiable at least as 'ichthyosaur' or 'plesiosaur'. Fragments of ribs and limb bones are hard to identify. The fauna, as far as can be assessed, is typical of the Kimmeridge Clay, from which most of the fossils apparently derive; marine ichthyosaurs, plesiosaurs and pliosaurs predominate. Some giant marine crocodilians (*Dakosaurus*) are also represented. The 'turtle' scute is more of a rarity, although several Kimmeridge Clay turtles are known. The dinosaur teeth are rather like the sculptured peg-like teeth of stegosaurs or ankylosaurs, but they lack the 'frilled' cutting edge, possibly as a result of abrasion; they seem very small for sauropod teeth. Woodward and Sherborn (1890, p. 219) note the plesiosaur genus *Cimoliasaurus latispinus* (Owen, 1854) from Faringdon. This is based on a vertebra (BMNH 11901) referred to a species originally described from the Lower Greensand of Maidstone (Lydekker, 1889a, pp. 222–3), but the species is likely to be a *nomen dubium*, being founded on scrappy material. *Cimoliasaurus* may be the same as *Colymbosaurus* (Brown, 1981), a long-ranging genus known especially from the Late Jurassic and Early Cretaceous of England, but with some earlier and later records.

Conclusions

The best available Greensand-type mid-Cretaceous site in Britain. A moderately diverse fauna of turtles, crocodilians, ichthyosaurs, plesiosaurs and dinosaurs is present. The site provides crucial evidence on the reworking of material from the Kimmeridge Clay locally and this important remanié fauna and the continuing availability of the site for collection substantiate its conservation value.

EAST WEAR BAY, FOLKESTONE, KENT (TR 243366)

Highlights

East Wear Bay, Folkestone is the most productive British Gault Clay reptile site (Figure 8.17). Abundant specimens of turtles, pterosaurs, ichthyosaurs and plesiosaurs have been reported,

Figure 8.17 The Gault clays at East Wear Bay, Folkestone. (Photo: D.J. Ward.)

including the first specimens of two species. This is one of the best mid-Cretaceous fossil reptile faunas in the world.

Introduction

The Gault on the coast east of Folkestone has been known as a good source of fossil vertebrates for 150 years. The fauna of turtles, ichthyosaurs, plesiosaurs, pliosaurs and pterosaurs (Figure 8.18) includes many good specimens, and the types of two species. The section is currently well exposed, with new portions revealed by marine erosion and land-slipping, and the site continues to yield reptile bones.

The Gault section has been described by many authors, such as De Rance (1868), Price (1875), Topley (1875, pp. 145–7), Jukes-Browne and Hill (1900, pp. 69–83), Smart *et al.* (1966, pp. 56–8, 99–101, 112–13) and Owen (1971, pp. 11–15; 1976). Reptile finds have been discussed by Owen (1874a), Seeley (1877), Woodward and Sherborn (1890) and Persson (1963).

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 cropout, 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 and 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

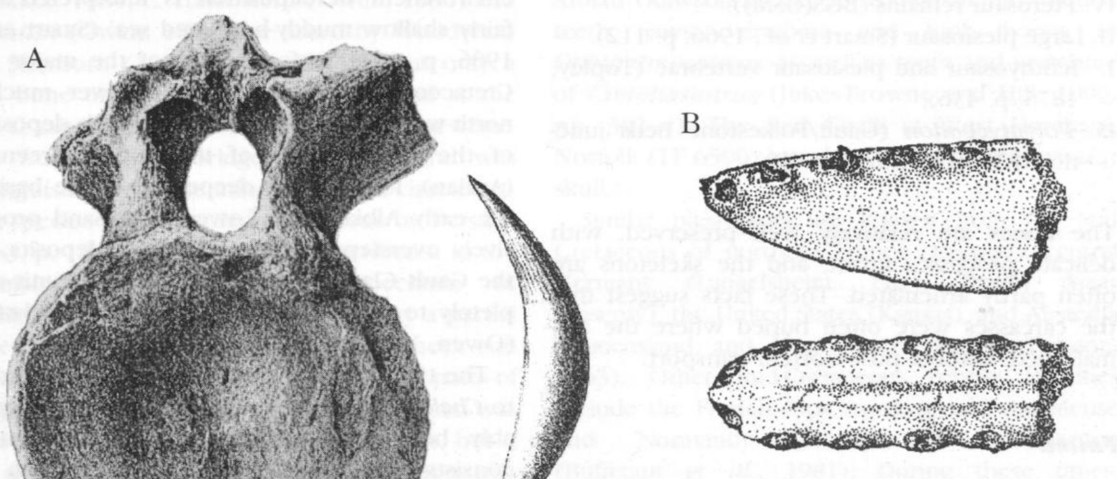

Figure 8.18 Reptiles from the mid-Cretaceous Gault of Folkestone. (A) The elasmosaur *Mauisaurus gardneri* Seeley, 1877, tooth and dorsal vertebra; (B) the pterosaur *Ornithocheirus daviesi* (Owen, 1874), top of snout in medial and ventral views. (A) After Seeley (1877); (B) after Owen (1874a).

Owen (1971, 1976) gives more detailed logs. An ammonite biostratigraphy has been worked out (Jukes-Browne and Hill, 1900; Spath, 1923–43; 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. Fossils include common molluscs, fishes and crustaceans.

Reptiles have been found throughout the whole section, and the horizons are compiled below from Price (1875), Topley (1875, p. 436), Jukes-Browne and Hill (1900), Smart *et al.* (1966, pp. 112–13) and museum records. Most of the museum specimens and described fossils were not localized to an horizon.

XII. Turtle bones and jaw, ichthyosaur and plesiosaur vertebrae (Topley, 1875, p. 436).
XI. Ichthyosaur remains (BGS(GSM)).
X. 'Bones of Chelonians and fish, and the eggs of a species of Crocodilian' (Jukes-Browne and Hill, 1900, p. 79).
IX. Turtle remains (BGS(GSM)), *Polyptychodon* (Price, 1874).
VIII. Turtle remains (BGS(GSM)), ichthyosaur and plesiosaur vertebrae (Topley, 1875, p. 436).
VII. *Polyptychodon* (Price, 1875), turtle (CAMSM).
IV. Pterosaur remains (BGS(GSM)).
II. Large plesiosaur (Smart *et al.*, 1966, p. 112).
I. Ichthyosaur and plesiosaur vertebrae (Topley, 1875, p. 436).
Ia. *Polyptychodon* (Gault/Folkestone Beds junction: BMNH); turtle (BMNH).

The bones are relatively well preserved, with delicate processes intact, and the skeletons are often partly articulated. These facts suggest that the carcasses were often buried where the animals died, without post-mortem transport.

Fauna

Fossil reptiles from the Gault of Folkestone are preserved in several museums: BMNH, BGS(GSM), CAMSM and OUM. In the following list, all species are listed, and type specimens noted where relevant. An estimate for the total number of specimens of each is also given as an approximate guide to the relative abundance of each species.

	Numbers
Testudines: Cryptodira: Chelonioidea: Protostegidae	
Rhinochelys elegans Lydekker, 1889	1
Rhinochelys sp.	24
Cimochelys benstedi (Mantell, 1847)	1
Archosauria: Pterosauria: Pterodactyloidea: Ornithocheiridae	
Ornithocheirus daviesi (Owen, 1874) Type specimen: BMNH 43074	4
Ornithocheirus sp.	6
Ichthyopterygia: Ichthyosauria: Ophthalmosauridae	
Ophthalmosaurus campylodon (Carter, 1846)	6
Ophthalmosaurus sp.	20
Sauropterygia: Plesiosauria: Plesiosauroidea	
Cimoliasaurus cantabrigiensis Lydekker, 1889	1
Mauisaurus gardneri Seeley, 1877 Type specimen: BMNH 47295	1
Sauropterygia: Plesiosauria: Pliosauroidea	
Polyptychodon interruptus Owen, 1841	5
'plesiosaur'	4

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, p. 102). 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 turtles from Folkestone, originally ascribed to *Chelone, Protostega* and *Rhinochelys*, all probably belong to the last genus. The material consists mainly of carapace and plastron elements, as well as limb bones, and a skull of *R. elegans* (BMNH R27). *Rhinochelys* had a 30–60 mm long skull which is characterized by its short snout and other features. It is classed in the family Protostegidae, a group of turtles mainly from the Late Cretaceous and Early Palaeogene of North America (Collins, 1970). A specimen of a partial plastron (BMNH 47210) from Folkestone is assigned to *Cimochelys benstedi* by Collins (1970, p. 375) and is, she suggests, possibly the postcranial material of *Rhinochelys*.

A few slender bones of pterosaurs have been found at Folkestone. *Ornithocheirus daviesi* is represented by a mandible (BMNH 43074, the type specimen; Figure 8.18B) and some limb bones, while *Ornithocheirus* sp. is also based on limb bones. The type mandible is 47 mm long, has five alveoli on each side and the jaw end is rounded. Referred limb bones include a 220 mm tibia from Folkestone, as well as specimens from the Cambridge Greensand (Owen, 1874a; Lydekker, 1888a, pp. 23–4). Wellnhofer (1978, pp. 56–7) accepts *O. daviesi* as a valid species, but the distinguishing characters are not made clear.

Ichthyosaurs are represented by teeth, vertebrae, and limb elements of *Ophthalmosaurus*. *O. campylodon* is known from the Cambridge Greensand and the Chalk of Kent and Cambridgeshire. Similar material has been found in the Gault of France, Germany and Russia (Lydekker, 1889a, pp. 15–20). *Ophthalmosaurus* was a large genus, with centra 100 mm in diameter and a skull 2.5–3.0 m in length. McGowan (1972) ascribed all Cretaceous ichthyosaurs, including *Ophthalmosaurus*, to *Platypterygius*.

Several species of plesiosaurs have been recorded. *Cimoliasaurus cantabrigiensis* Lydekker, 1889, *C. constrictus* (Owen, 1850) and *C. smithi* (Owen, 1884) are noted by Woodward and Sherborn (1890) in the BMNH, but only a limb bone of '*C. smithi*' has been found at the site. *C. cantabrigiensis* was based on some vertebrae from the Cambridge Greensand and was distinguished on some minor vertebral characters. This species was regarded as dubious by Persson (1963, p. 18), and he tentatively ascribed it to the Rhomaleosauridae. The type specimen of *Mauisaurus gardneri* is represented by a partial skeleton, a tooth, the vertebrae of the neck and back (Figure 8.18A), most limb bones and parts of the pectoral girdle (Seeley, 1877). The animal was large with vertebrae up to 100 mm across, but it had a very long neck, typical of an elasmosaurid. Persson (1963, p. 19) retained *M. gardneri* as a valid species of elasmosaurid.

The larger pliosaur *Polyptychodon* is represented by several teeth and limb bones. Similar material is also known from the Upper Greensand and Cambridge Greensand. The species *P. interruptus* was regarded as valid by Persson (1963).

The reptile fauna is essentially coastal marine, containing turtles, fish-eating ichthyosaurs and plesiosaurs, as well as the top carnivore *Polyptychodon*. Pterosaurs may have been washed in from the land, or they may have died while feeding on fish.

Comparison with other localities

Reptiles are known from several sites in the Gault, but none is as rich as East Wear Bay, Folkestone. Other sites in Kent and West Sussex include Wrotham (TQ 6159; *Iguanodon*); Horish Wood, Maidstone (TQ 786575; turtle, ichthyosaur, *Polyptychodon*, pterosaur; Casey, 1959; Worssam, 1963, pp. 6, 58, 62); Henfield (TQ 2116; *Rhinochelys*; White, 1924, p. 28); Upper Beedon Pit (TQ 205123; ichthyosaur vertebra; White, 1924, pp. 27–8); in Oxfordshire: Towersey, near Thame (SP 7305; ichthyosaur); in Buckinghamshire: Ford (SP 7709; ichthyosaur; Jukes-Browne and Hill, 1900, pp. 277–8), Bishopstone, near Aylesbury (SP 8010; *Ophthalmosaurus*); in Hertfordshire: Puttenham (SP 8814; *Ophthalmosaurus*; Jukes-Browne and Hill, 1900, pp. 280–2); in Cambridgeshire: Barnwell (TL 4658; ichthyosaur vertebrae; Jukes-Browne and Hill, 1900, p. 292).

An age-equivalent horizon to the Gault is the Red Chalk at Hunstanton, Norfolk (TF 673414 to TF 674419; a 1.3 m bed ascribed to the Mid–Late Albian (Rawson *et al.*, 1978) which has yielded teeth, jaws, vertebrae and limb bones of *Ophthalmosaurus*, as well as teeth and vertebrae of *Cimoliasaurus* (Jukes-Browne and Hill, 1900, pp. 302–4). The Red Chalk at West Dereham, Norfolk (TF 6500) has also yielded an ichthyosaur skull.

Similar plesiosaurs are known from the Mid Cretaceous of northern France (Louppy), central Germany (Langelsheim, etc.), Russia (near Moscow), the United States (Kansas), and Australia (Queensland and New South Wales) (Persson, 1963). Other mid-Cretaceous reptile localities include the French Alps (turtles), and the Meuse and Normandy (ichthyosaurs, plesiosaurs) (Buffetaut *et al.*, 1981). During these times, ichthyosaurs and plesiosaurs had waned from their Late Jurassic diversities, and faunas are rather sparse in all parts of the world where they occur. On land, dinosaurs were flourishing, with new groups such as pachycephalosaurs and ceratopsians appearing, and the ornithopods and theropods further diversifying. Pterosaurs and crocodilians were also abundant in terrestrial deposits, and new groups were coming on the scene. The Gault of Folkestone contains few terrestrial elements, other than the rare pterosaur bones, but it shows good examples of the rare mid-Cretaceous ichthyosaurs, plesiosauroids and pliosaurs.

Conclusions

The section at East Wear Bay, Folkestone is Britain's best Gault reptile site. It has yielded one of the best mid-Cretaceous reptile 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 of Britain (Cenomanian–Maastrichtian) have produced rather sparse remains of mainly marine reptiles, and these are usually represented by isolated elements. However, examples have been found of most reptiles representative of the time, particularly of mosasaurs which had evolved during the Late Cretaceous as top carnivores in the Chalk sea. Ichthyosaurs, by Late Cretaceous times, had dwindled in significance, and the last specimens date from the Cenomanian. Plesiosaurs, in the form of elasmosaurids and pliosaurids, survived through the Late Cretaceous to the end of the period, but in reduced diversity and mainly in the southern hemisphere. Other marine tetrapods of the Late Cretaceous include turtles, notably the giant protostegids of the Niobrara Sea in Kansas and the marine diving hesperornithid birds of the same region. Pterosaurs are found occasionally in marine sediments, and Late Cretaceous forms were essentially the large to very large pteranodontids and azhdarchids. Terrestrial reptiles are rare in the Chalk, which is a marine deposit, so there is little evidence in Britain of the dramatic changes which occurred elsewhere during the Late Cretaceous. Dinosaurs burgeoned, with hadrosaurs, ceratopsians and ankylosaurs becoming especially diverse. Lizards, snakes and crocodilians also radiated, and rare examples have been found in the Chalk.

Reptiles have been found at 50 Chalk localities, based on literature references and museum specimens. These are listed below by county from the south-west to north-east, with zones indicated, where known:

DORSET: Weymouth (Lower Chalk; ?exact locality; *Rhinochelys*; Delair, 1958, p. 54).

SOMERSET: Frome (ST 7747?; *Polyptychodon*).

WILTSHIRE: Norton Ferris (Lower Chalk, *varians* Zone; ST 7936; unidentified bones); Porton Railway Cutting (Upper Chalk, *coranguinum* Zone; SU 1936; *Leiodon*; Jukes-Browne and Hill, 1904, pp. 83–4); Highfield (Upper Chalk, *marsupites* Zone, ?SU 0038; plesiosaur; Jukes-Browne and Hill, 1904, pp. 83–4); Harnham (Upper Chalk, *quadratus* Zone; ?SU 1428; *Leiodon*, plesiosaur; Jukes-Browne and Hill, 1904, pp. 83–4).

HAMPSHIRE: Horsebridge (Upper Chalk, *quadratus* Zone; SU 3430; mosasaur); Shawford waterworks, Southampton (SU 4725; *Rhinochelys*, *Mosasaurus*); Portsdown (Upper Chalk, *mucronata* Zone; SU 6406; *Leiodon*, Jukes-Browne and Hill, 1904, pp. 59–60).

ISLE OF WIGHT: Shanklin (SZ 5881; *Polyptychodon*).

WEST SUSSEX: Charlton (Upper Chalk; SU 8812; *Chelone*); Arundel, (TQ 0107; *Chelone*); Houghton (Lower Chalk; TQ 0111; '*Cimoliosaurus*', *Polyptychodon*); Washington, near Worthing (TQ 1212; *Coniasurus*; White, 1928, pp. 36, 40); Steyning (Lower Chalk; TQ 1711; '*Cimoliosaurus*', *Polyptychodon*; White, 1928, p. 36).

EAST SUSSEX: Saddlescombe (Middle–Upper Chalk, TQ 27001162; '*Cimoliosaurus*'; White, 1928, pp. 38, 40, 44; Young and Lake, 1988, p. 68); Brighton (?exact locality; *Chelone*); Kemp Town, Brighton (TQ 3303; *Leiodon*; White, 1928, pp. 32, 42, 50, 53, 56–7, 59); Clayton Pit, Falmer (Upper Chalk; TQ 3508; *Coniasaurus*, *Polyptychodon*; White, 1928, pp. 35–6, 38); Balcombe Pit, Glynde (Lower Chalk; TQ 46050850; *Chelone*, *Polyptychodon*; White, 1928, pp. 48, 51; Lake and Shephard-Thorn, 1987, pp. 69–70); Southerham Grey Pit, Lewes (Lower–Middle Chalk; TQ 42800900; *Chelone*, *Protostega*, *Rhinochelys*, *Dolichosaurus*, *Mosasaurus*, *Polyptychodon*, '*Cimoliosaurus*', *Ornithocheirus*; Jukes-Browne and Hill, 1904, pp. 46–58; Lake and Shephard-Thorn, 1987, p. 68).

SURREY: Dorking (L. Chalk; TQ 160503/TQ 200510?; *Protostega*, *Mosasaurus*, *Polyptychodon*;

Owen, 1860); Betchworth (Lower Chalk, *subglobosus* Zone, TQ 205515; *Ornithocheirus*).

KENT: Folkestone (Lower Chalk etc., *?naviculare* Zone; TR 2438 and east; *Rhinochelys, Polyptychodon, Ophthalmosaurus, Acanthopholis*; Huxley, 1867b; Etheridge, 1867; Jukes-Browne and Hill, 1904, pp. 135, 137; Smart *et al.*, 1966, pp. 118–19, 128–9); Lidden Spout, near Folkestone (TR 281387; *Dolichosaurus*); Dover ('Chalk Marl', 'Grey Chalk', Lower Chalk, TR 3141, ?exact locality; some from Round Down Tunnel at TR 297395; *Chelone, Rhinochelys, Polyptychodon, Ophthalmosaurus*; Jukes-Browne and Hill, 1904, pp. 135–43); Ramsgate (Upper Chalk; TR 3865; *Mosasaurus*); Northfleet (TQ 6274; *Chelone*); Gravesend (Upper Chalk, *coranguinum* Zone; ?TQ 6474; *Polyptychodon*; Jukes-Browne and Hill, 1904, p. 166); Offham (TQ 6557; *Polyptychodon*); Snodland (?TQ 697625; *Ornithocheirus*); Halling (Lower–Middle Chalk; TQ 7064, various quarries; *Chelone, Lytoloma, Polyptychodon, Leiodon, Coniasaurus, Ornithocheirus*); Cuxton (Middle Chalk; ?TQ 7066; *Polyptychodon, Mosasaurus*; Jukes-Browne and Hill, 1904, pp. 159–60; Woodward, 1906); Wouldham (TQ 7164; *Chelone*, mosasaur, *Polyptychodon*); Borstal (Lower/Middle Chalk, '*Terebratulina* Zone'; ?TQ 7366; *Polyptychodon*; Jukes-Browne and Hill, 1904, p. 160); Rochester (?TQ 7268; *Chelone, Trionyx, Polyptychodon*); Maidstone (Lower–Upper Chalk; ?TQ 7655; *Chelone, Polyptychodon, Ornithocheirus*); Charing (?TQ 942506; *Polyptychodon, Coniasaurus*; Worssam, 1963, p. 79, etc.).

HERTFORDSHIRE: Hitchin (Lower Chalk, *subglobosus* Zone; TL 1829, ?exact locality; '*Iguanodon*', *Ornithocheirus*).

CAMBRIDGESHIRE: Barrington (TL 3949; *Ophthalmosaurus*); Haslingfield (TL 4052; *Polyptychodon*); Hauxton (TL 4352; *Polyptychodon*); Trumpington (TL 4454; *Ophthalmosaurus*); Cambridge (TL 4658, various localities; *Ophthalmosaurus*); Cherry Hinton (Lower Chalk; TL 483557, TL 485558; *Cimochelys, Dolichosaurus, Polyptychodon*); Coldham's Common, Cambridge (TL 4858; turtle); Swaffham Fen (TL 5464; *Ophthalmosaurus*); Isleham (TL 6434; *Ophthalmosaurus*).

NORFOLK: Hunstanton (?Upper Chalk; TF 6740; *Ophthalmosaurus, Polytychodon*); Marham (Lower Chalk, *subglobosus* Zone; TF 712092; *Ophthalmosaurus*); Norwich (Upper Chalk; St James' Pit, Lollard's Pit, Catton Grove Chalk Pit, Whitlingham; TG 242094, TG 241089, TG 228108, TG 272087; *Mosasaurus, Leiodon*; see below).

HUMBERSIDE: Sewerby Cliff, Bridlington (Upper Chalk, *quadratus* Zone, TA 1766; '*Tylosaurus*').

Of these sites, the only significant ones, which have yielded more than a few bones, are Glynde, Southerham, Dorking, Folkestone, Dover, Halling, Burham, Rochester, Charing, Cherry Hinton, Hunstanton and Norwich.

Two sites are selected as GCR sites on the basis of their important Chalk reptile faunas. The first, at Culand Pits, Burham, is well known for its content of exceptionally well-preserved terrestrial reptiles (e.g. pterosaurs and lizards) which are associated with more typical marine mosasaurs and plesiosaurs. The second, at St James's Pit, Norwich, is Britain's best mosasaur locality.

1. Culand Pits, Burham, Kent (TQ 738617). Late Cretaceous (Cenomanian–Turonian), Lower Chalk–Upper Chalk.
2. St James's Pit, Norwich, Norfolk (TG 242094). Late Cretaceous (Campanian), Upper Chalk ('Norwich Chalk').

CULAND PITS, BURHAM, KENT (TQ 738617)

Highlights

The Culand Pits, Burham are Britain's richest Chalk (Late Cretaceous) reptile site (Figure 8.19). In their heyday, they were then source of beautiful specimens of turtles, marine lizards, pterosaurs and plesiosaurs. The specimens include original material of five new species, and the pterosaurs and marine lizards have attracted particular attention.

Introduction

The two Culand Pits on Blue Bell Hill near Burham, the Lower Pit (TQ 737613) and the Upper Pit (TQ 739619), have yielded some of the most important fossil reptiles from the British

Figure 8.19 The rather overgrown Upper Culand Pit, Burham, showing the Middle and Upper Chalk, source of several specimens of fossil turtles, marine lizards, pterosaurs and plesiosaurs. (Photo: M.J. Benton.)

Chalk (Figure 8.20), which form the basis for several descriptive papers. The chalk quarries are still accessible, although no longer working and further finds could only 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). Jukes-Browne and Hill (1903, p. 35) give a sketch section which makes this clear. The lowest units of the Chalk, the Chloritic Marl and the Chalk Marl (Cenomanian, *mantelli* Zone), were recorded in the tramway between Burham Brick Pit (TQ 723610) and the Chalk Quarries (Jukes-Browne and Hill, 1903, pp. 46–7). Further details of the quarries are given in a series of papers by Dibley (1900, 1904, 1907, 1918, Dibley and Spath, 1926) and by Dines *et al.* (1954). Kennedy (1969, pp. 482–6) gave a section, with details of the ammonites, for the Lower Chalk. The reptiles have been described by Owen (1842b, 1842e, 1851b, 1852a), Owen (*in* Dixon, 1850), Bowerbank (1846, 1848, 1852), Mantell (1842), Lydekker (1889b), Woodward (1888), Woodward and Sherborn (1890), Seeley (1870b) and Wellnhofer (1978).

Description

A combined section of the Chalk in the two quarries, summarized from Jukes-Browne and Hill (1903, pp. 49, 382; 1904, pp. 158–9) and Dines *et al.* (1954, pp. 32, 37, 42), 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
	16.3

Culand Pits, Burham

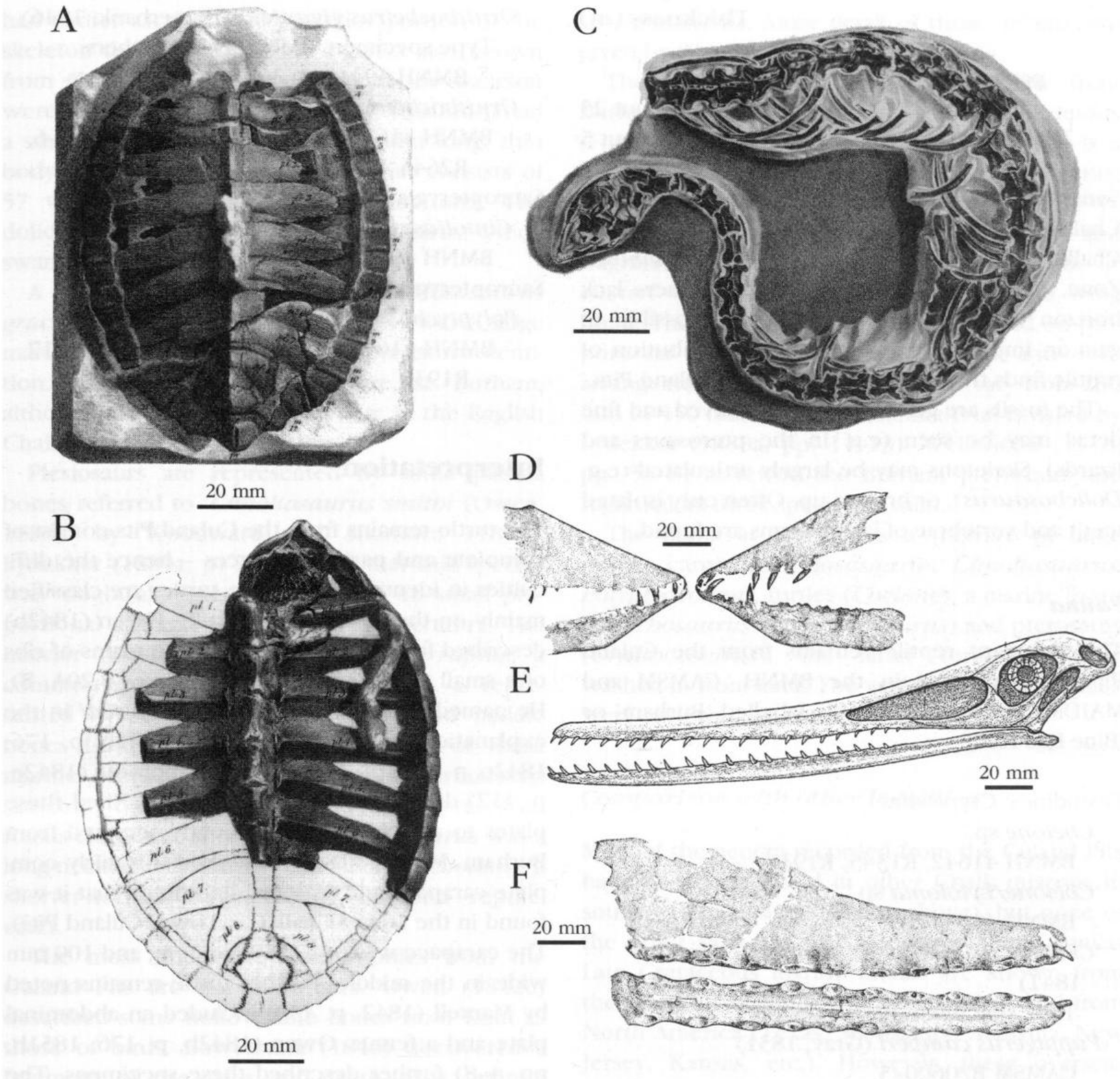

Figure 8.20 Typical reptiles of the Late Cretaceous Middle Chalk of the Culand Pits, Burham, Kent. (A) and (B) The turtle *Chelone (Cimolochelys) benstedi* (Mantell, 1841), carapace in dorsal and ventral views; (C) the elongate marine lizard *Dolichosaurus longicollis* Owen, 1850, crushed skull and anterior part of skeleton; (D) the pterosaur *Ornithocheirus compressirostris* (Owen, 1851), skull in lateral view; (E) *O. cuvieri* (Bowerbank, 1851), anterior part of snout in lateral and crown views; (F) *O. giganteus* (Bowerbank, 1846), anterior part of snout, right and left sides. (A)–(C) After Owen (1851b); (D)–(F) after Wellnhofer (1978), from various sources.

	Thickness (m)
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. 46.0
LOWER CULAND PIT	
Middle Chalk and Melbourn Rock	9.1

	Thickness (m)
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	

	Thickness (m)
passing gradually down into grey chalk	about 25
Bed 5. Grey marly chalk	about 5

Some museum specimens are labelled 'Lower Chalk' (BMNH 28706) and others as 'Middle Chalk' (BMNH 49008-10) or '*H. subglobosus* Zone, Middle Chalk' (R3735-6), but others lack horizon information. Hence, it is impossible to gain an impression of the vertical distribution of reptile finds through the Chalk in the Culand Pits.

The fossils are generally well preserved and fine detail may be seen (e.g. in the pterosaurs and lizards). Skeletons may be largely articulated (e.g. *Dolichosaurus*), or broken up. Often only isolated teeth and vertebrae of larger forms are found.

Fauna

The abundant reptile remains from the Culand Pits are preserved in the BMNH, CAMSM and MAIDM. These are generally labelled 'Burham' or 'Blue Bell Hill'.

Testudines: Cryptodira
'*Chelone* sp.'
BMNH 41642, R1345, R1934
'*Chelone/Lytoloma* sp.'
BMNH 49008-10
'*Chelone (Cimochelys) benstedi*' (Mantell, 1841)
Type specimen: BMNH 28706
Puppigerus camperi (Gray, 1831)
CAMSM B20600-5
'*Protostega* sp.'
BMNH R3736
'chelonian'
BMNH R3735
Lepidosauria: Squamata: Sauria: Dolichosauridae
Dolichosaurus longicollis Owen, 1850
Type specimen: BMNH 49002. Also BMNH 32268
Lepidosauria: Squamata: Sauria: Mosasauridae
Mosasaurus sp.
MAIDM unnumb.
Archosauria: Pterosauria: Pterodactyloidea: Ornithocheiridae
Ornithocheirus compressirostris (Owen, 1851)
Type specimen: BMNH 39410; others: BMNH 39411, 39416, 49003-4, MAIDM unnumb.
Ornithocheirus cuvieri (Bowerbank, 1851)
Type specimen: BMNH 39409
Ornithocheirus giganteus (Bowerbank, 1846)
Type specimen: BMNH 39412. Others, BMNH 39413-5, 39417
Ornithocheirus sp.
BMNH 41637, 49005-6,R1357-8, R1935-6, R2644
Sauropterygia: Plesiosauria: Plesiosauroidea
'*Cimoliasaurus smithi*' (Owen, 1884)
BMNH 49007
Sauropterygia: Plesiosauria: Pliosauroidea
Polyptychodon interruptus Owen, 1841
BMNH 41641, 41644, 46959, 49007, R1217, R1938

Interpretation

The turtle remains from the Culand Pits consist of complete and partial carapaces - hence the difficulties in identification, since turtles are classified mainly on the basis of their skulls. Owen (1842b) described four marginal plates and remains of ribs of a small turtle from Burham (Figures 8.20A, B). He named this fragment *Chelone benstedi* in the explanation to the figure (Owen, 1842b, p. 176; 1842e, p. 412, pl. 39, fig. 5). In a footnote (1842e, p. 412) dated 'April, 1842', Owen ascribed these plates to a skeleton more recently acquired from Burham. Mantell (1842) described this fairly complete carapace and plastron, and noted that it was found in the Lower Chalk (i.e. Lower Culand Pit?). The carapace was oval, 150 mm long and 100 mm wide in the middle. Further turtle remains noted by Mantell (1842, p. 158) included an abdominal plate and a femur. Owen (1842b, p. 176; 1851b, pp. 4-8) further described these specimens. The small size of these turtles led some authors (e.g. Lydekker, 1889b) to consider them to be juveniles, whereas others regarded them as adults (e.g. Woodward, 1888, pp. 275-6).

The other turtles listed above, on the basis of old museum labels, include several forms that may be wrongly identified - *Puppigerus camperi* is a common Eocene species, for example (Moody, 1974). Owen (1851b, pp. 9-11) called these *Chelone camperi* and Lydekker (1889b, p. 31) noted the probable mistake.

The lizard *Dolichosaurus* was described by Owen (*in* Dixon, 1850, pp. 388-95; 1851b, pp. 22-9); Mackie (1863); Lydekker (1888a, p. 275) and Woodward (1888, pp. 281-2). The type specimen (BMNH 49002) is a crushed skull and a series of vertebrae and ribs, with scattered, short limb bones (Figure 8.20C). Owen (1842e, p. 412) had earlier ascribed the posterior portion of the skeleton to *Rhaphiosaurus*, a genus also known from Cambridge. The two parts of the skeleton were later associated and renamed. This lizard had a small head with conical teeth and a long, thin body; the presacral vertebral column consists of 57 vertebrae and is about 450 mm long. The dolichosaurs are elongate marine lizards which swam in a snake-like fashion.

A jaw in MAIDM is referred to '*Mosasaurus gracilis*' Owen, 1850. Mosasaurs were large marine lizards with specialized predatory dentition. They are surprisingly rare at Burham, although more common elsewhere in the English Chalk.

Plesiosaurs are represented by some paddle bones referred to '*Cimoliasaurus smithi* (Owen, 1884)' by Woodward and Sherborn (1890). Lydekker (1889a, p. 215) noted that this species was 'doubtful', since it was based on small proportional characteristics of a dorsal vertebra. The heavier pliosaur *Polyptychodon interruptus*, a common species in the English Chalk, is represented by several teeth, vertebrae and paddle bones from the Culand Pits. Neither of these marine reptiles is known from an articulated skeleton, but comparison with better-preserved fossils elsewhere shows that *Cimoliasaurus* was a long-necked fish-eater, and *Polyptychodon* a shorter-necked, large-headed fish- and reptile-eater.

The most important fossil reptiles from the Culand Pits are the pterosaurs. Owen (1842e) described some hollow limb bones from Kent as those of birds. Bowerbank (1846) discovered a fragment of the jaws and teeth of a definite pterosaur, with portions of the hollow limb bones, in the Lower Chalk of 'Halling', and named them *Pterodactylus giganteus*. Woodward (1888, p. 238) noted that these finds actually came from Burham, as indicated by Bowerbank (1852). Owen (1846, pp. 545–8) reaffirmed the 'bird nature' of his bones and named them *Cimoliornis*. Bowerbank (1848, 1852) described further pterosaur jaw material from Burham as *P. cuvieri*, and argued again that pterosaurs were reptiles. Owen (*in* Dixon, 1850, pp. 401–4; 1851b, pp. 88–104; 1852) finally acknowledged that the hollow bones belonged to pterosaurs and not birds, and he described (1851b) a third species from Burham, *P. compressirostris*, also on the basis of a snout. These three species were subsequently shown (Seeley, 1870b, pp. 28–94, 112–18) to belong to the Cretaceous genus *Ornithocheirus*. More detail of these debates are given by Woodward (1888, pp. 283–5).

The three species of *Ornithocheirus* from Burham are based on partial skulls and skeletons (Figure 8.20D–F). The type of *O. giganteus* is a partial skull, pectoral girdle and other fragments, and other limb bones come from the same site. *O. compressirostris* is based on a partial skull and fragments of limb bones, all from Burham. *O. cuvieri* was also based on a snout and a wing bone. The three species are distinguished on proportional differences of the snout shape and tooth arrangement. The estimated lengths vary from 250 mm to 450 mm. The available material is listed by Lydekker (1888a, pp. 11–13). Wellnhofer (1978, pp. 56–8) reviewed the Burham pterosaurs and regarded all three species as valid.

The fauna at Burham is a mixture of large marine carnivores (*Mosasaurus*, *Cimoliasaurus*, *Polyptychodon*), turtles (*Chelone*), a marine lizard (*Dolichosaurus* and ?*Mosasaurus*) and pterosaurs (*Ornithocheirus*), the latter forms probably washed in from land. The vertebrates of the Chalk were reviewed by Woodward (1888).

Comparison with other localities

Most of the genera recorded from the Culand Pits have also been found in other Chalk quarries in southern England (see listing above), but none of the other sites has such a diverse fauna. 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.). However, these overseas Chalk localities are dominated by mosasaurs (Russell, 1967), a group that is barely, if at all, represented in the Culand Pits.

Conclusions

The Culand Pits at Burham have yielded the most complete fauna of Chalk reptiles in Britain. The mosasaurs, so typical of certain localities, are rare, but several well-preserved fossils of turtles, lizards, plesiosaurs and pterosaurs have been collected. These include type specimens of five species. This is the best British Chalk reptile site with potential for new finds and a key Late Cretaceous site of international importance, hence its considerable conservation value.

ST JAMES'S PIT, NORWICH, NORFOLK (TG 242094)

Highlights

St James's Pit, Norwich is Britain's best mosasaur locality. Mosasaurs were giant marine lizards, which are well known from North America, the Low Countries and parts of Africa. The remains from St James's Pit are rather fragmentary, but the best in Britain.

Introduction

The Chalk pits of Norwich have long been known as a source of remains of mosasaurs. St James's Pit is the best available site for future finds in Britain. The geology of the site has been described by Jukes-Browne and Hill (1904) and Peake and Hancock (1978). The mosasaur fossils have seemingly never been described.

Description

Several quarries were formerly worked in a strip of Upper Chalk around the north-east side of Norwich. These include Lollard's Pit, Gas Hill (TG 241098), St James's Pit (TG 242094), Kett's Cave (TG 237093) and Catton Grove Pit (TG 228108). The Chalk belongs to the zone of *Belemnitella mucronata* (Late Campanian; Rawson *et al.*, 1978, p. 52). The thick sequence of the 'Norwich Chalk' has yielded abundant fossils, and the chalk contains occasional flints and iron-stained bands (Jukes-Browne and Hill, 1904, p. 259; Peake and Hancock, 1978). There is no information on the exact horizon of the bones.

St James's Pit, currently used as a recreation area, has a sloping north face approximately 50 m high. This is largely covered by sand and gravel from above, but the Chalk may be exposed with only a little digging. The Chalk appears to be well bedded with some pyrite nodules, but no flints.

Fauna

Several teeth, vertebrae and other bones of mosasaurs have been found at Norwich. Specimens are preserved in the BGS(GSM), BMNH, CAMSM and NORCM.

Lepidosauria: Squamata: Sauria: Mosasauridae

Leiodon anceps Owen, 1841

CAMSM B20608–9, B20611–2 (teeth);

NORCM 13–65 (pelvis)

Leiodon sp.

BMNH R2767 (vertebra); BMNH R6376, unnumb. (teeth)

?'*Mosasaurus oweni*' (Hector, 1874)

CAMSM B20627

Mosasaurus sp.

BMNH 37000a. 48940d (teeth, vertebrae: Lollard's Pit); BGS(GSM) 5560, 99085; NORCH 36–64 (vertebrae)

'mosasaur'

BMNH 37000 (vertebrae); BGS(GSM) 114240–3 (various: St James's Pit)

Interpretation

Mosasaurs were large marine reptiles of the Late Cretaceous. Remains are known from various parts of the United States (Gulf Coast, New Jersey, Kansas), Belgium, the Netherlands, France and Sweden (Russell, 1967). Although related to varanid lizards, the mosasaurs achieved large size (up to 17 m long) and were clearly formidable predators. They lived generally in subtropical epicontinental seas of less than 180 m depth, and many species had a wide geographic range. The fragmentary remains from Britain probably belong to species that occur elsewhere in Europe and North America. The specimen ascribed to *Mosasaurus oweni* is probably wrongly assigned; this form was originally described from New Zealand.

Comparison with other localities

Mosasaurs are known from several sites in the English Upper Chalk. In the pits around Norwich, remains are known from Lollard's Pit, Gas Hill (TG 241089; Bayfield, 1864); Catton Grove Chalk Pit (TG 228108; P. Lawrence, pers. comm., 1982); and Whitlingham (TG 272078). Mosasaurs are known from several other English localities, such as Dorking (Surrey) and Halling (Kent), as noted in the Chalk locality lists (q.v.).

Conclusions

Mosasaurs are present at several British Chalk localities, but rarely represented by more than an odd tooth or vertebra. The old chalk quarries at Norwich preserve only mosasaurs, and St James's Pit has the greatest potential for future finds, which gives its conservation value.