Chapter 8 British Cretaceous fossil reptile sites

Introduction: Cretaceous stratigraphy and sedimentary setting

The Cretaceous System in Britain (Figure 8.1), (Figure 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 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 Glade, 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 (Figure 8.3), (Figure 8.5) and (Figure 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 03 31]; *Iguanodon,* Murchison, 1829, pp. 103–5); Rudgwick Brickworks ([TQ 083 344]; dinosaur; Horsham Museum); Longbrook Brickworks ([TQ 117 188]; pterosaur, crocodilian, fishes; Wells Collection); Itchingfield ([TQ 123 287]; *Iguanodon*); Southwater ([TQ 15 26]; pterosaur); Horsham ([TQ 17 30]; *Goniopholis, Iguanodon,* hypsilophodontid); Henfield Brickpit ([TQ 218 143]; *Iguanodon;* Young and Lake, 1988, p. 23); Bolney [TQ 26 22]; *Hylaeosaurus;* Pereda-Suberbiola, 1993); Wivelsfield ([TQ 34 20]; *?Iguanodon;* various localities with fossil fishes; Young and Lake, 1988, p. 23); Balcombe Quarry ([TQ 30 30]; *Iguanodon*); Philpots Quarry ([TQ 355 322]; *Iguanodon;* Allen 1976, 1977); Tilgate Forest ([TQ 27 35], exact localities uncertain; *Plesiochelys, Tretosternon, Goniopholis, Suchosaurus, Heterosuchus, Pelorosaurus, Iguanodon, Hylaeosaurus,* pterosaurs); Cuckfield ([TQ 300 256], 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 325 189]; microvertebrates; crocodilian and dinosaurian remains; Young and Lake, 1988, p. 24; A. Ross, pers. comm., 1993).

EAST SUSSEX: Hamsey Brick Works ([TQ 398 159], pterosaur; Martin Collection); Berwick Brick Pit ([TQ 523 070]; *Plesiochelys, Leptocleidus,* Andrews, 1922; White, 1928, pp. 29–30); Pevensey ([TQ 64 04]; *Iguanodon*); Burwash ([TQ 67 24]; *Plesiochelys, Goniopholis*); Brightling ([TQ 68 21]; *Goniopholis*); Bexhill ([TQ 74 07]; *Iguanodon,* pterosaur, *'Iguanodon'* footprints at [TQ 7446 0705], [TQ 741 071], [TQ 738 070], [TQ 7095 0640]; 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 767 079]; '*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 764 124]; *Goniopholis, Iguanodon,* Sweeting, 1925; White, 1928, pp. 65–6); Brede ([TQ 82 18]; several sites, including Hare Farm Lane, [TQ 832 184], q.v.; *Goniopholis, Saurosuchus, Iguanodon;* Topley, 1875, pp. 62–3; Allen, 1949); Knellstone, Udimore ([TQ 88 19]; *Iguanodon,* etc.; Allen, 1949, p. 279); Peasmarsh, Waterfall Wood ([TQ 86 21]; *?Heterosuchus,* etc., Allen, 1949); Tighe Farm ([TQ 936 266]; 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 67 41]; '*Plesiosaurus'*); Tunbridge Wells ([TQ 58 39]; *Megalosaurus*); Southborough ([TQ 58 42]; *Thecospondylus;* Seeley, 1882b); New Barn ([TQ 61 68]; 'turtle').

SURREY: Harting Combe, near Haslemere (*'Iguanodon'* footprints; Delair and Sarjeant, 1985, p. 146); Clockhouse Brickworks ([TQ 175 386]; *Iguanodon,* microvertebrates; Jarzembowski, 1991a).

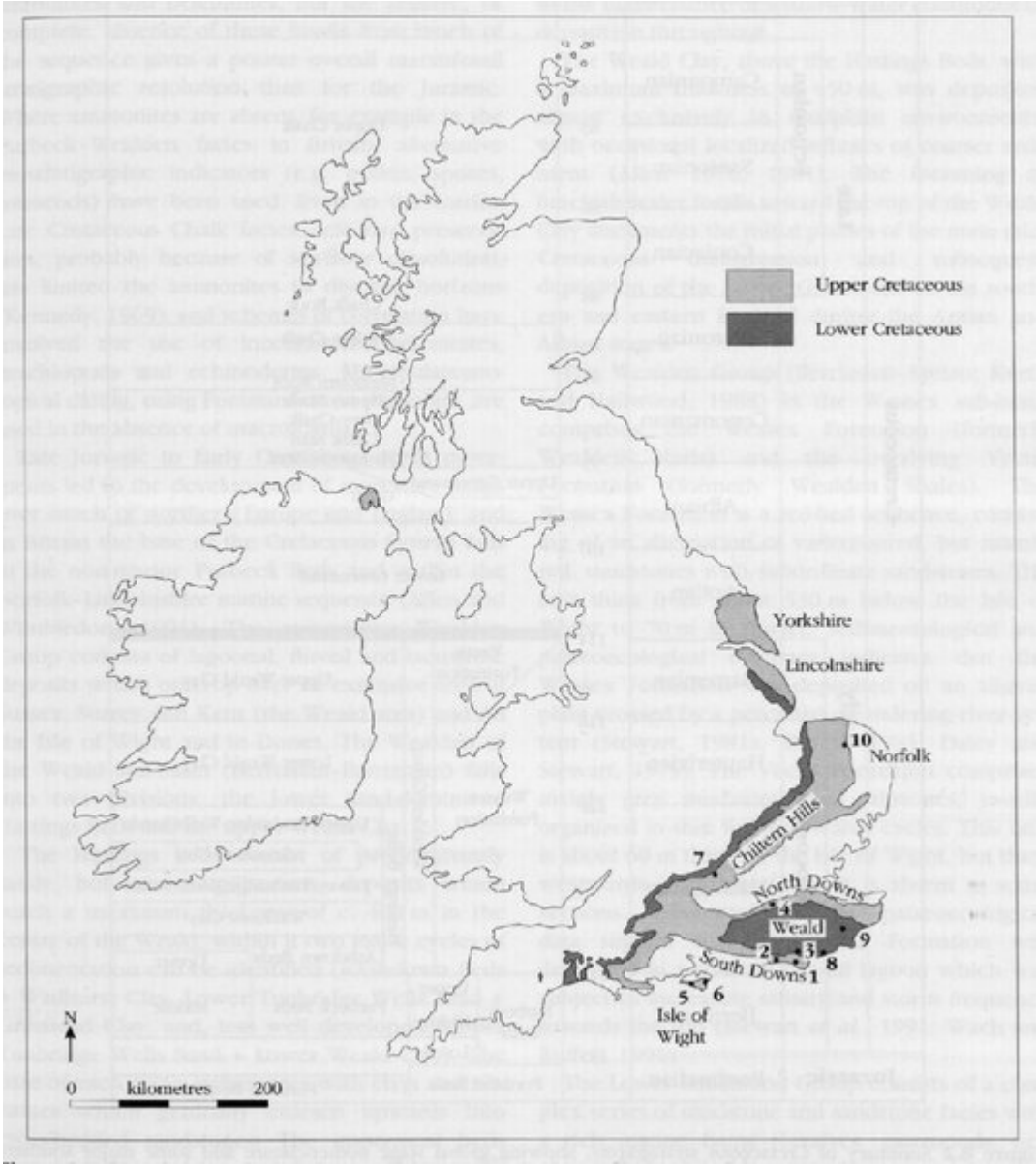
In the Isle of Wight the Wealden beds are represented by predominantly argillaceous facies of the Wealden Marls and the Wealden Shales (Wessex and Vectis formations), which are seen best in coast sections between Brook and Atherfield Point on the south-west coast and at Yaverland on the south-east coast.

Outside the Wealden of the Weald and the Isle of Wight Early Cretaceous reptiles are known from the Spilsby Beds (Portlandian-Berriasian) of Spilsby, Lincolnshire [TF 40 66], from Speeton, Yorkshire ([TA 11 80]; 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 67 88]; *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).

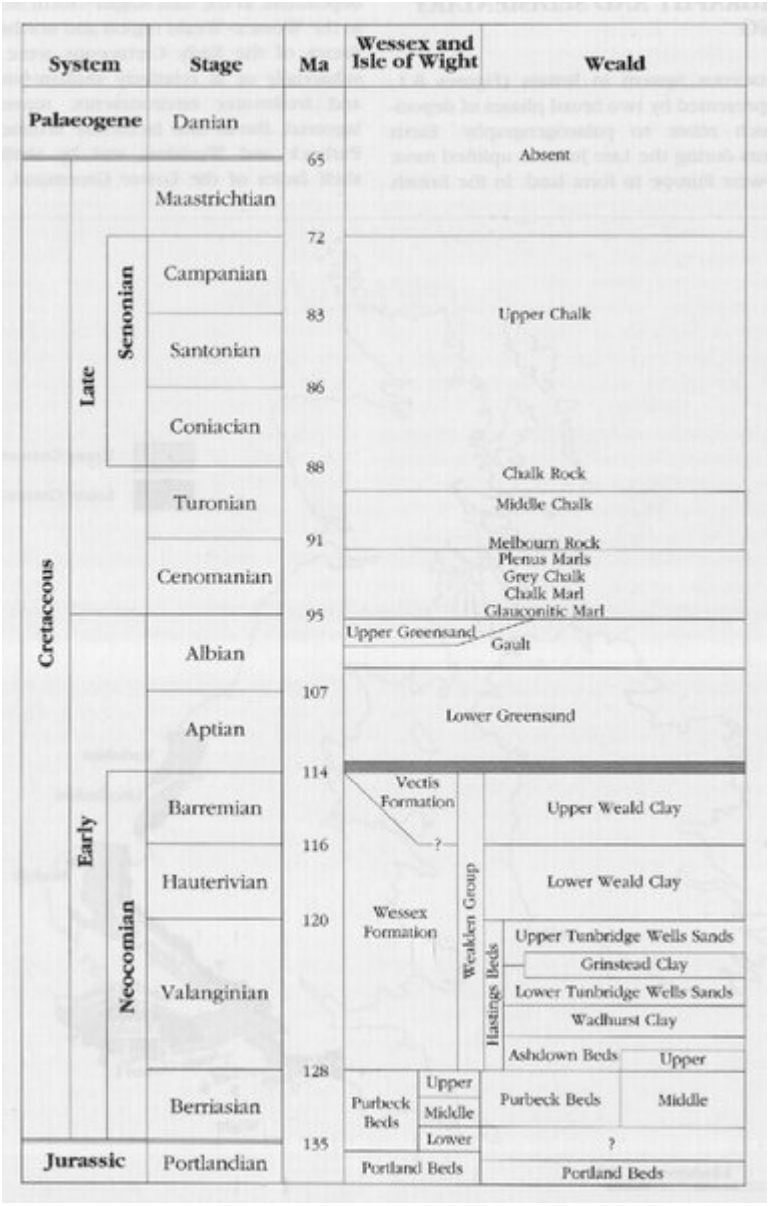
Six early Cretaceous GCR sites are selected (Figure 8.1), including three sites in the Hastings Beds of East Sussex, one in the Weald Clay of Surrey, and two in the Wealden of the Isle of Wight:

1. Hastings, East Sussex [TQ 831 095]–[TQ 853 105]. Early Cretaceous (Berriasian–Valanginian), Hastings Beds (Ashdown Beds, Tunbridge Wells Sand).
2. Black Horse Quarry, Telham, East Sussex [TQ 769 142]. Early Cretaceous (Valanginian), Hastings Beds.
3. Hare Farm, Brede, East Sussex [TQ 832 184]. Early Cretaceous (Valanginian), basal Wadhurst Clay.
4. Smokejacks Pit, Ockley, Surrey [TQ 113 373]. Early Cretaceous (Barremian), Weald Clay.
5. Brook–Atherfield Point, Isle of Wight ([SZ 375 842]–[SZ 452 788]). Early Cretaceous (Barremian-Early Aptian), Wessex and Vectis formations (Sudmore Point Sandstone–Chale Clay).
6. Yaverland, Sandown, Isle of Wight ([SZ 613 850]–[SZ 622 835]). Early Cretaceous (Barremian-Early Aptian), Wealden Marls (Perna Beds Member).

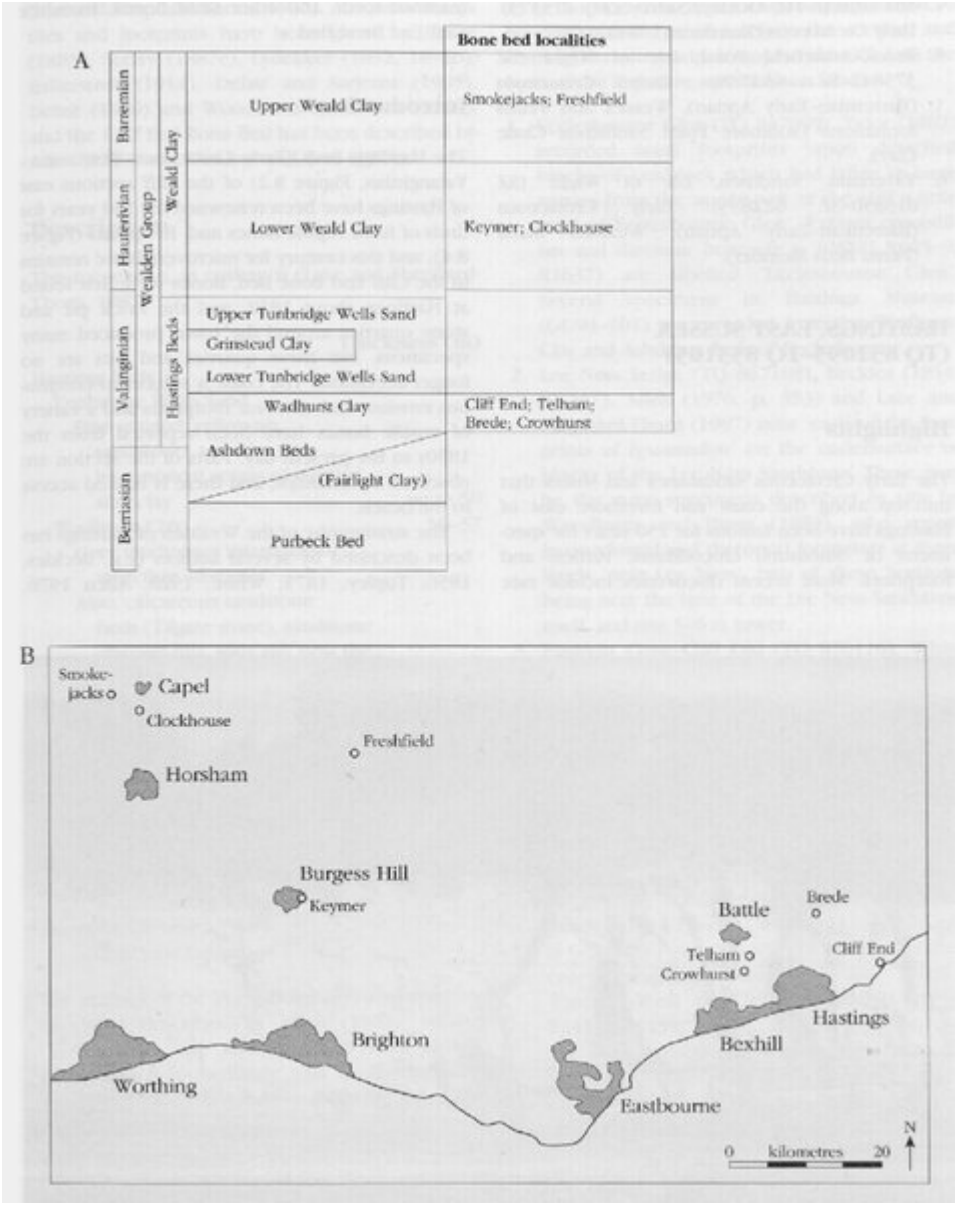
References



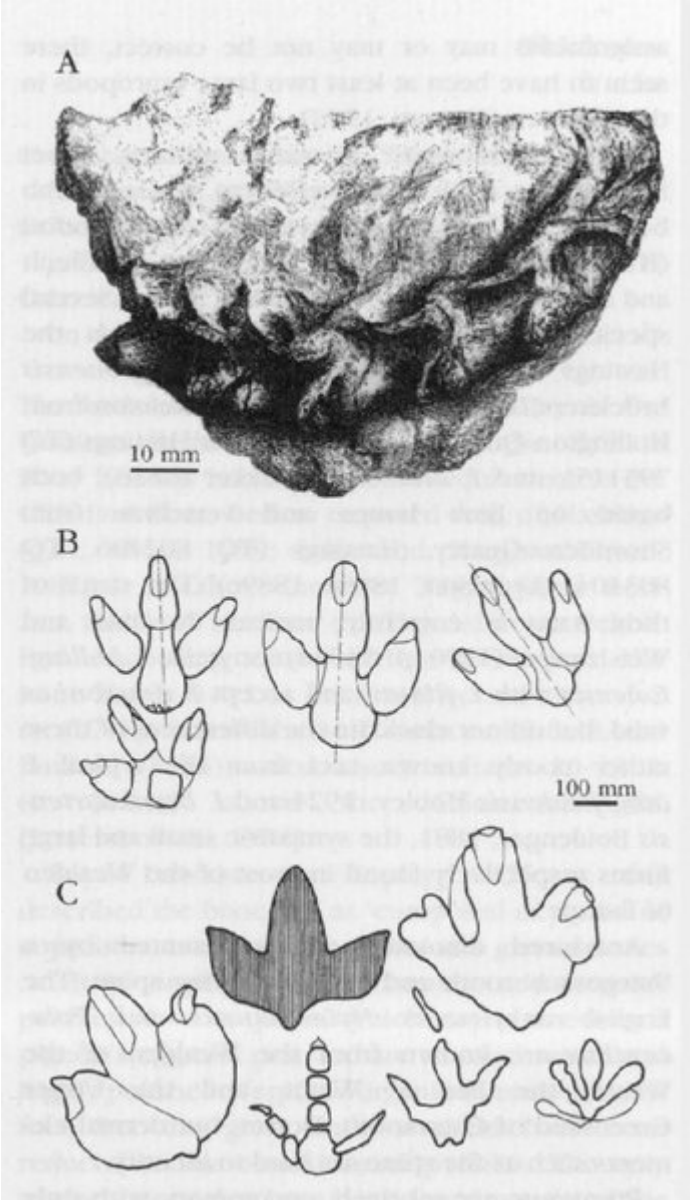
(Figure 8.1) Map showing the distribution of Cretaceous (Lower and Upper) rocks in Great Britain. GCR Cretaceous reptile sites: (1) Hastings; (2) Black Horse Quarry, Telham; (3) Hare Farm, Brede; (4) Smokejacks Pit, Ockley; (5) Brook–Atherfield Point, Isle of Wight; (6) Yaverland; (7) Wicklesham Pit,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



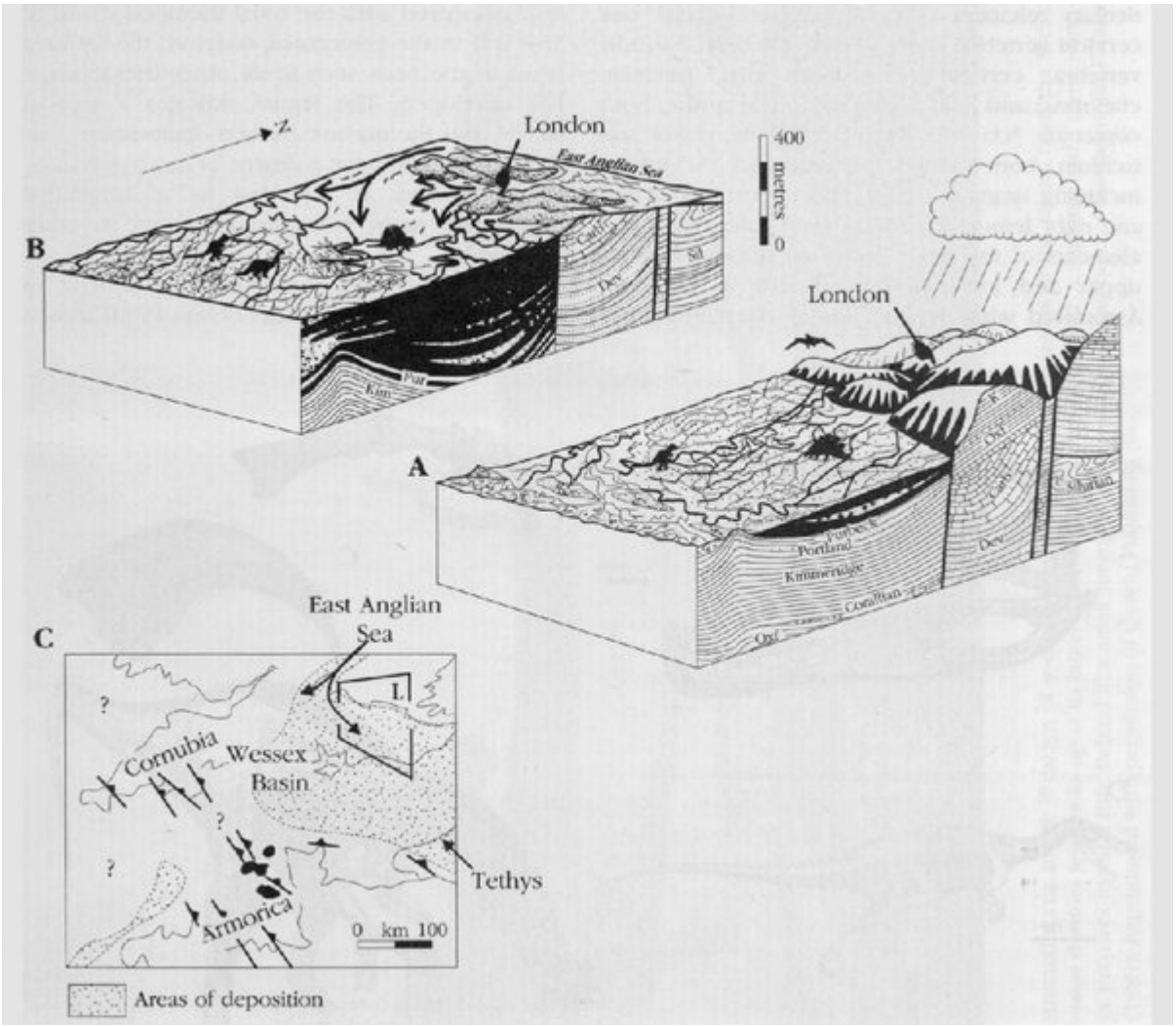
(Figure 8.2) Summary of Cretaceous stratigraphy, showing global stage nomenclature and some major southern British formations. Based on Harland et al. (1990).



(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.



(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).



(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.