J.N.C.C.

Fossil Reptiles of Great Britain

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Chapter 5

British Early Jurassic fossil reptile sites

INTRODUCTION: JURASSIC STRATIGRAPHY AND SEDIMENTARY SETTING

In Britain, rocks of Jurassic age occur in England in a long, almost continuous outcrop, running from Dorset to Yorkshire, also in South Wales and in scattered patches in the islands off north-west Scotland, and in north-east Scotland (Figure 5.1). The Jurassic System is represented by rocks of predominantly shallow marine origin, with mainly fine-grained sediments such as marine shales, clays and mudstones. Shallower facies, marked by greater terrestrial input, include deltaic sequences

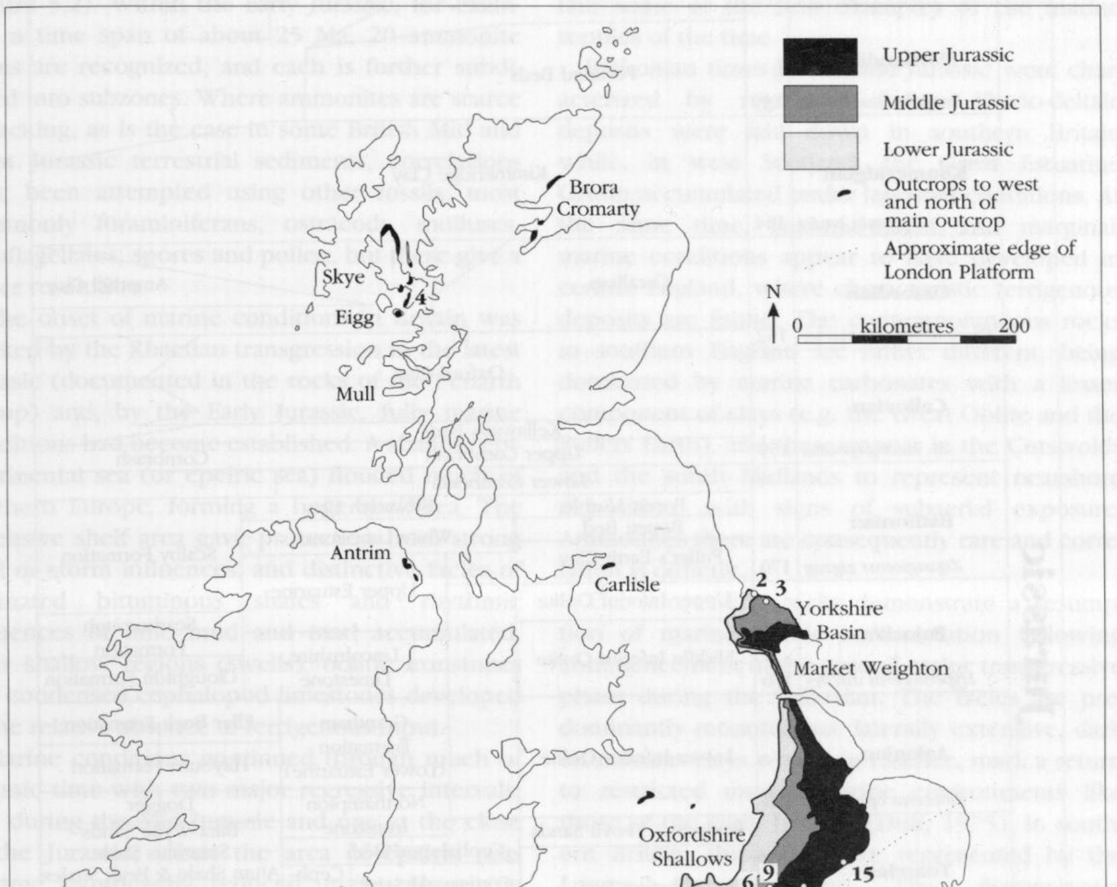


Figure 5.1 Map showing the distribution of Jurassic (Lower, Middle and Upper) rocks in Great Britain. GCR Jurassic reptile sites: (1) Lyme Regis; (2) Whitby; (3) Loftus; (4) Eigg; (5) New Park Quarry; (6) Stonesfield; (7) Huntsman's Quarry; (8) Shipton-on-Cherwell Quarry; (9) Kirtlington Old Cement Works; (10) Furzy Cliff, Overcombe; (11) Smallmouth Sands; (12) Kimmeridge Bay; (13) Encombe Bay; (14) Chawley Brickpits; (15) Roswell Pits, Ely; (16) Isle of Portland; (17) Bugle Pit, Hartwell; (18) Durlston Bay.

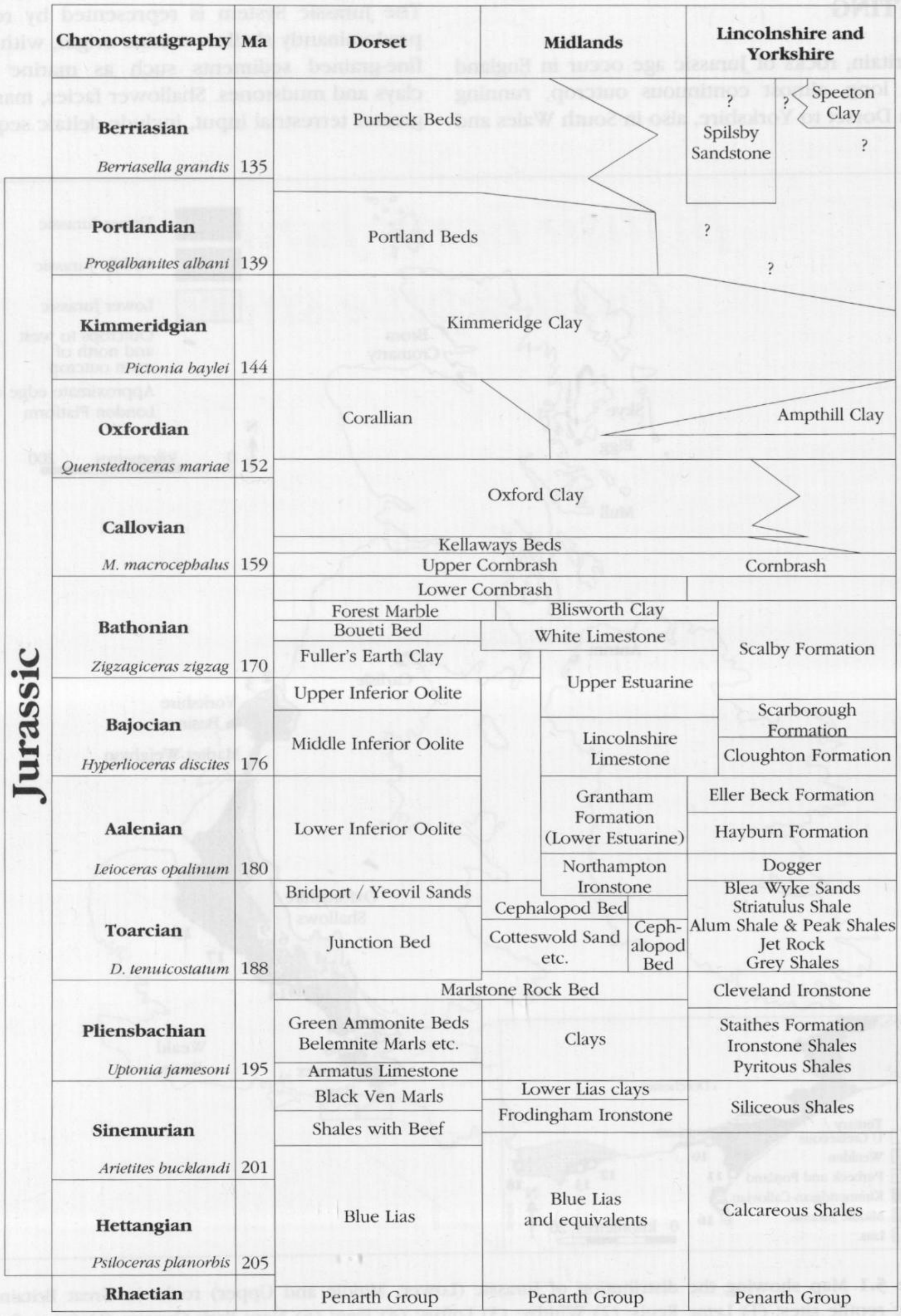


Figure 5.2 Summary of Jurassic stratigraphy, showing global standards and some major British formations (based on Harland *et al.*, 1990).

of clays and sandstones, while those with little terrestrial input include shelf carbonates. The last are characteristic of the Mid Jurassic (Aalenian–Bathonian) and Late Jurassic (Oxfordian, Portlandian) and are commonly oolitic in character.

Rich faunas of ammonites allow precise biostratigraphic correlation for most of the Jurassic (Figure 5.2). Within the Early Jurassic, for example, a time span of about 25 Ma, 20 ammonite zones are recognized, and each is further subdivided into subzones. Where ammonites are scarce or lacking, as is the case in some British Mid and latest Jurassic terrestrial sediments, correlations have been attempted using other fossils, most commonly foraminiferans, ostracods, molluscs, dinoflagellates, spores and pollen, but these give a lower resolution.

The onset of marine conditions in Britain was marked by the Rhaetian transgression in the latest Triassic (documented in the rocks of the Penarth Group) and, by the Early Jurassic, fully marine conditions had become established. A shallow epicontinental sea (or epeiric sea) flooded much of northern Europe, forming a huge shelf sea. The extensive shelf area gave protection from strong tidal or storm influences, and distinctive facies of laminated bituminous shales and rhythmic sequences of lime mud and marl accumulated. Over shallow regions (swells), oolitic ironstones and condensed cephalopod limestones developed in the relative absence of terrigenous input.

Marine conditions continued through much of Jurassic time with two major regressive intervals, one during the Mid Jurassic and one at the close of the Jurassic, when the area of epeiric seas became significantly reduced, eventually giving way to the subaerial facies of the Portland and Purbeck beds.

The lowest units of the British Jurassic (Lias) consist primarily of marine clay–shale facies which in outcrop are more calcareous in the south and more sandy in the north. Two principal shale groups, those of the Lower and Upper Lias, are developed and are separated by the shallower-water facies of sandy shales, sandstones and oolitic ironstones of the Middle Lias. Fine-grained yellow sands of Upper Lias and earliest Bajocian age (e.g. Bridport sands), outcrop from Gloucester southwards to the Dorset coast. The biota of the Lias is dominated by a variety of marine benthic forms which indicate rather harsh bottom conditions. However, at times, environmental conditions appear to have deteriorated further so that only very low-diversity invertebrate fossil faunas occur. The sequences of unbioturbated bituminous laminated shales, characterized by the Jet Rock of Yorkshire, lack even protobranch bivalves, and represent the onset of sterile bottom conditions. Under these conditions, mid-water swimmers died and sank and were buried undisturbed; consequently such sequences contain some of the best examples of the marine reptiles of the time.

Bathonian times in the Mid Jurassic were characterized by regressive facies. Fluvio-deltaic deposits were laid down in southern Britain while, in west Scotland, the Great Estuarine Group accumulated under lagoonal conditions. At the same time, lagoonal-marsh and marginal-marine conditions appear to have developed in central England, where characteristic terrigenous deposits are found. The contemporaneous rocks in southern England are rather different, being dominated by marine carbonates with a lesser component of clays (e.g. the Great Oolite and the Fullers Earth), and these appear in the Cotswolds and the south Midlands to represent nearshore deposition, with signs of subaerial exposure. Ammonites there are consequently rare and correlation is difficult.

The succeeding rocks demonstrate a resumption of marine clastic sedimentation following commencement of the second major transgressive phase during the Callovian. The facies are predominantly monotonous, laterally extensive, dark bituminous clays which, in essence, mark a return to restricted muddy marine environments like those of the Early Jurassic (Duff, 1975). In southern Britain, these beds are represented by the Lower Oxford Clay. The deeper-water Kimmeridge Clay (clays, mudstones and shales) is comparable, being rich in preserved organic material (including kerogen), and in containing a restricted marine benthos.

The Portland Group shows evidence of shallowing and renewed regression, and preserves a range of facies. The Cherty Beds are rich in sponge spicules and seem to have been deposited in calm marine water. The upper parts of the succession include shallow-water oolites, micrites and eventually evaporites (represented by halite and anhydrite) and soils, which document the progress of the regression. Marine incursions, including the Cinder Bed 'event', occur in the mid to Late Purbeck beds which are predominantly non-marine, and which span the Jurassic–Cretaceous boundary.

REPTILE EVOLUTION DURING THE JURASSIC

Marine reptile evolution during the Jurassic is essentially the story of the radiations of the ichthyosaurs and the sauropterygians (Benton 1990a, 1990d). Ichthyosaurs had arisen in the Triassic, and they are known abundantly from the Muschelkalk of central Europe and, further afield, from Japan, Spitsbergen and Canada. Late Triassic ichthyosaurs are known from all parts of the world, but they are represented in Britain only in the Rhaetian 'Bone beds'. However, by Early Jurassic times, ichthyosaurs are found abundantly in Britain, and all phases of their evolution may be followed. Ichthyosaurs in the Jurassic were dolphin-like animals that for the most part fed on cephalopods, fishes and other reptiles, judging from the evidence of stomach contents and coprolites, and they show relatively little morphological diversification. Elsewhere, Jurassic ichthyosaurs are well known from the Early Jurassic of Germany (especially from Holzmaden in Baden-Württemberg) and from the Late Jurassic of Germany and France, but they are rare elsewhere.

Plesiosaur evolution in the Jurassic is also well documented in Britain (Brown, 1981), with complete specimens known from the marine formations. An apparent split into long-necked plesiosauroids and short-necked pliosauroids may be traced back into the British Lias, and comparative materials are known only from Germany.

Other marine niches were occupied during Jurassic times by pleurosaurs, relatives of the sphenodontids (lepidosaurs), which are known mainly from Germany, with no British representatives, and by crocodiles. The steneosaurs and teleosaurs of the British Early and Mid Jurassic are excellently preserved and compare very well with the Early Jurassic German and the Mid Jurassic French material respectively. These crocodiles were slender gavial-like fish-eating animals with long slender snouts and evidently marine habits. The Late Jurassic metriorhynchids (geosaurs), known from the Late Jurassic of Britain and Germany, were even more aquatically adapted, having fully formed paddles for limbs and a tail fin.

On land, the Jurassic Period heralded the rise of the dinosaurs which came to dominate all terrestrial tetrapod faunas (Benton 1989, 1990a, 1990d). Early Jurassic faunas worldwide were still dominated by Triassic hold-over groups, such as the prosauropods and the basal ornithischians. However, new groups appeared in the Mid Jurassic, such as the sauropods, large theropods, avialan theropods (bird-relatives), stegosaurs and ankylosaurs. During the Late Jurassic, the huge sauropods dominated as top herbivores and the theropods occupied a range of niches as carnivores. Among the ornithischian dinosaurs, the thyreophorans (armoured dinosaurs) were the most important.

Other diapsid reptiles diversified during the Jurassic into a wide range of new forms, and many Triassic groups continued to radiate (Benton 1990a, 1990d). Archosaurs were the most abundant diapsids on land. Apart from the dinosaurs, crocodilians radiated extensively, and a range of carnivorous and piscivorous forms evolved: these are represented in Britain only in the Mid Jurassic. Lepidosaurs such as sphenodontids and squamates (lizards) remained generally small. Choristoderes, an enigmatic diapsid group hitherto known mainly from the Late Cretaceous and Palaeogene, appeared by Mid Jurassic times, and possibly in the Rhaetian (see Aust Cliff report, above).

BRITISH JURASSIC REPTILE SITES

Most fossil reptiles obtained from the Jurassic of Britain are marine forms, but these are supplemented by important terrestrial reptiles (dinosaurs and others) collected from the subaerial facies of the Mid Jurassic (e.g. Forest Marble, Stonesfield Slate), but also from all the representative marine units (Figures 5.1 and 5.2). The most spectacular remains, including those of plesiosaurs, ichthyosaurs and marine crocodilians, derive from bituminous shale units, and important collections have come from the Early and Late Lias (Hettangian–Sinemurian), the Oxford Clay (Callovian) and the Kimmeridge Clay (Kimmeridgian). These remains are commonly complete, or nearly complete, articulated skeletons, the result of their original deposition on undisturbed stagnant bottom waters unique to the northern European Jurassic shelf sea. The marine reptiles from the Oxford Clay (Callovian) are uniquely well preserved and form a centrepoint of all international taxonomic studies.

Well articulated Early Jurassic (Hettangian–Sinemurian) plesiosaurs and ichthyosaurs from Lyme Regis are unique, including forms apparently intermediate between the long-necked elasmosaurids and the shorter-necked pliosauroids typical of the later Jurassic and Cretaceous. Plesiosauroids and pliosauroids from the Mid and Late Jurassic are also well represented in British Jurassic rocks. The ichthyosaurs from Britain are among the best in the world and contain many unusual forms marking the wide diversity of a group otherwise adapted for fast marine locomotion (e.g. the swordfish-like forms *Eurhinosaurus* and *Excalibosaurus*).

British Jurassic sites also provide good coverage of terrestrial reptiles, particularly the Early Jurassic dinosaur *Scelidosaurus* from Lyme Regis, the oldest thyreophoran and the unique Mid Jurassic dinosaurs: these are matched only in China. The Mid Jurassic sauropods (*Cetiosaurus*), theropods (*Megalosaurus*), thyreophorans (*Lexovisaurus, Dacentrurus*) and other less well-known forms fill an important gap in terrestrial records of Europe and North America.

The Mid Jurassic sites of central England and north-west Scotland contain the earliest members of several groups including choristoderes (unless the Rhaetian *Pachystropheus* is a choristodere; see Aust Cliff report), possible squamates, as well as some of the youngest known mammal-like reptiles (tritylodontids). British Jurassic squamates are particularly important, with the oldest in the world having been recognized recently in the Middle Jurassic rocks of the Cotswolds (Evans and Milner, 1991, 1994). In addition, the fauna of Late Jurassic/Early Cretaceous lizards from the Purbeck of Dorset is the most diverse of this age in the world. Comparable forms are known from Portugal, Germany and North America (Estes, 1983). Jurassic sphenodontids are less well represented in Britain than in Germany. Turtles are also reported from the British Mid and Late Jurassic, and the latter are important (especially those from Portland) as some of the best preserved of their age. Comparable material is known from the Late Jurassic of Switzerland and North America.

EARLY JURASSIC

The Early Jurassic (Lias) of Britain is famous for its faunas of marine reptiles. Hundreds of good specimens have been obtained from localities along the entire length of the outcrop which stretches in a continuous belt between Dorset and the Yorkshire coast. Sites, other than Lyme Regis, that have yielded Early Jurassic reptiles are listed below. The listings are based on material in BATGM, BMNH, BRSMG, CAMSM, LEICS, OUM, SDM, YORYM, and Hawkins (1840), Woodward and Sherborn (1890), Fox-Strangways (1892), H.B. Woodward (1893, 1894, 1895), Arkell (1947a), Delair (1958, 1959, 1960, 1968, 1973) and Macfadyen (1970). Reptile-bearing fissures of Early Jurassic age from the areas of Bristol and South Wales are listed in the Triassic chapter. Note that the use of the names *Ichthyosaurus* and *Plesiosaurus* is based on old documentation: all specimens require revision.

Lower Lias

The British Lower Lias has yielded remains of ichthyosaurs and plesiosaurs from dozens of localities from Dorset to Yorkshire. Many of these finds are only isolated bones, so that the majority of sites may be classed as not significant. Other reptiles include two dinosaurs, a possible sphenodontid and a pterosaur. Ichthyosaurs and plesiosaurs have been collected from at least 40 localities in the Lower Lias of England, along the entire length of its outcrop from Dorset to the Yorkshire coast. Abundant remains have come from the quarries around Street, Somerset (ST 4836) and Barrow-upon-Soar, Leicestershire (SK 5818), but there is very little chance of more finds unless excavations are resumed. All other sites have produced only sparse remains and those that still offer exposure can be said to have only low potential for future finds. These other sites, listed by county from the south-west to the north-east, are:

DEVON: Axminster, Tolcis Quarry (SY 280010; *Ichthyosaurus*, shale between half foot and foot limestone).

SOMERSET: Street – 18 or more quarries (ST 4836; *planorbis* Zone; Thomas Hawkins' 'Sea-Dragons'; two species of ichthyosaur, including neotype of *Leptopterygius tenuirostris* (McGowan, 1989a), type of *Protichthyosaurus protaxalis* and five species of plesiosaur, including types of *Plesiosaurus arcuatus*, *P. eleutheraxon* and *P. hawkinsi*); Street on the Fosse, south-east of Glastonbury (type of *Plesiosaurus megacephalus*); Walton, near Street (ST 4636; *Ichthyosaurus, Plesiosaurus*); Somerton, near Street (ST 4828; *Plesiosaurus*); Glastonbury (ST 5039; *Ichthyosaurus*); West Pennard (ST 5438; *Ichthyosaurus*); Keinton Mandeville (ST 5530; *Ichthyosaurus*, from *planorbis* Zone); Watchet (ST 0743; *Ichthyosaurus, Plesiosaurus* from Blue Lias on shore); Kilve, St Audrie's Bay (ST 144447; *Ichthyosaurus*; Deeming *et al.*, 1993; Lilstock foreshore (ST 196463; *Excalibosaurus*; McGowan, 1986).

SOUTH GLAMORGAN: Penarth (ST 1871; *Plesiosaurus*).

GWENT: Sedbury Cliff (ST 559930; possible sphenodontid (M.J. Simms, pers. comm.).

AVON: Bath (ST 4765; *Ichthyosaurus, Plesiosaurus*); Weston, near Bath (ST 7267; *Ichthyosaurus, Plesiosaurus*); Saltford, near Bath (ST 6867; *Ichthyosaurus* from railway cutting; donated to BRSMG by Brunel); Keynsham (ST 6568; *Ichthyosaurus, Plesiosaurus* near station); Bitton, Keynsham (ST 6869; *Plesiosaurus*); Nempnett (ST 5360; *Ichthyosaurus*); Barrow Gurney (ST 5367; *Plesiosaurus*); Banwell (ST 5959; *Ichthyosaurus*); Willsbridge, near Bitton (ST 6670; *Ichthyosaurus, Plesiosaurus*); Westfield, Radstock (ST 6854; *Ichthyosaurus*); Stoke Gifford (ST 6279; *Ichthyosaurus*); Bristol (exact locality uncertain; *Ichthyosaurus, Plesiosaurus*); Ashley Hill, Bristol (ST 6069; *Plesiosaurus*); Hengrove, Bristol (ST 6069; *Plesiosaurus*).

GLOUCESTERSHIRE: Gloucester (SO 8518; *Ichthyosaurus, Plesiosaurus*); Cheltenham: Battledown Brickworks (SO 967225; *Plesiosaurus* from *ibex* Zone); Hock Cliff, Saul (SP 7310; *Ichthyosaurus, Plesiosaurus*); Stenehouse, Strand (SO 8005; *Plesiosaurus*); Westbury-on-Severn (SO 8505; *Ichthyosaurus, Plesiosaurus*); Eastington (SO 7705; *Ichthyosaurus* from *bucklandi* Zone); Tewkesbury (various localities: Woolbridge (SO 8023), Brockridge Common (SO 8938), Hill Croome (SO 8940), Defford Common (SO 9043): *Ichthyosaurus, Plesiosaurus* in the 'saurian beds' (J. Buckman)); Bredon (SO 9237; *Ichthyosaurus* from *semicostatum/obtusum* Zone); Blockley (SP 1635; *Plesiosaurus*).

HEREFORD AND WORCESTER: Bengeworth (SO 9443; *Ichthyosaurus*); Himbleton (SO 9458; *Ichthyosaurus, Plesiosaurus*); Grafton (SO 9837; *Ichthyosaurus*); Bickmarsh (SP 1049; *Ichthyosaurus*); Honeybourne (SP 1143; *Ichthyosaurus, Plesiosaurus* from *turneri* Zone).

WARWICKSHIRE: Stratford-upon-Avon (exact locality uncertain, around SP 1559; *Ichthyosaurus*); Wilmcote (SP 168583; *Ichthyosaurus, Plesiosaurus*, ?exact locality; *Megalosaurus tibia-angulata* Zone, near railway station (Woodward, 1908b)); Harbury, Portland Cement Co. Quarry (SP 3959; *Ichthyosaurus, Plesiosaurus*, type of *Macroplata tenuiceps* (plesiosaur) from *angulata* Zone (Swinton, 1930)); Temple Grafton Quarry (SP 121539; 'reptiles'); Shipston-on-Stour (SP 2540; ichthyosaur, dinosaur); Southern (SP 4161; *Ichthyosaurus, Plesiosaurus*); Little Lawford (SP 4677; *Ichthyosaurus*); Rugby, Victoria Quarry (SP 4976; *Ichthyosaurus, Plesiosaurus*); Newbold (SP 4977; *Ichthyosaurus, Plesiosaurus*); Stockton, Nelson's Quarry and others (SP 4363; *Ichthyosaurus, Plesiosaurus*).

LEICESTERSHIRE: Barrow-upon-Soar, quarries around and in the town (SK 595163, 598161, and many others; *Ichthyosaurus, Stenopterygius, Temnodontosaurus, 'Plesiosaurus', Rhomaleosaurus* and type of the megalosaur *Sarcosaurus woodi* (Andrews, 1921a; Martin *et al.*, 1986)); Normanton Hills (SK 539245; ichthyosaur remains; LEICS).

LINCOLNSHIRE: Long Bennington (SK 8445; *Plesiosaurus*).

NOTTINGHAMSHIRE: Elston (SK 7748; ?*Plesiosaurus*); Barnstone Quarry (SK 736356; *Ichthyosaurus, Plesiosaurus* from bed 3S in the pre-*planorbis* beds); Cropwell Bishop, near Barnstone (?pliosauroid).

NORTH YORKSHIRE: Robin Hood's Bay (NZ 9604; *Ichthyosaurus, 'Teleosaurus'*, plesiosaurs, bed 18 of *bucklandi* Zone).

Middle Lias

Ichthyosaurus has been reported from the Middle Lias of Golden Cap, near Charmouth, in Dorset; and from Ilminster and Dundas, in Somerset, but remains are so poor that the sites are not worth tracing. A recent find from the Middle Lias of Dorset probably comes from the Eype Clay at Thorncombe Beacon (SY 436912; Ensom, 1989b). Three other sites include Houston Quarry, Ilminster, Somerset (?ST 362153; *Stenopterygius hauffianus*, in upper *margaritatus* Zone

(McGowan, 1978)); Wotton-under-Edge, Avon (ST 7593; *Ichthyosaurus* in Middle Lias); Bugbrooke, Northamptonshire (SP 6757; *Ichthyosaurus, Plesiosaurus*); Isle of Raasay, Inner Hebrides (Scalpa Sandstone Formation; articulated plesiosaur remains; Martill 1985a).

Upper Lias

A few sites in the Upper Lias of Somerset, Northamptonshire and North Yorkshire have yielded good specimens of ichthyosaurs, plesiosaurs, marine crocodiles and one pterosaur.

SOMERSET: Strawberry Bank, Ilminster (ST 361148; 30 specimens of the marine crocodile *Pelagosaurus typus* from the 'Fish and Saurian Bed' (*exaratum* Zone, *falciferum* Subzone), quarry now filled (Duffin, 1979b)).

NORTHAMPTONSHIRE: Bugbrook(e) (SP 6757; *Ichthyosaurus, Rhomaleosaurus*; Middle-Upper Lias); Greens Norton (?SP 664492; *Steneosaurus*); Blisworth (SP 7253; *Ichthyosaurus*); Crick (SP 5872; *Thaumatosaurus*, from railway cutting); Market Harborough bypass, near Dingley (SP 753882; ichthyosaur; LEICS); Kingsthorpe, Northampton (SP 7662; *Ichthyosaurus, Thaumatosaurus, Steneosaurus*, type of *Rhomaleosaurus thorntoni* Andrews, 122 (BMNH R4853) – quarries at SP 758643 and SP 765653); Wellingborough (SP 8969; *Microcleidus* in *bifrons* Zone).

LEICESTERSHIRE: Rutland Water Dam excavations (SK 9307; ichthyosaurs in LEICS).

LINCOLNSHIRE: Stibbington (TL 092991; *Ichthyosaurus, Plesiosaurus, Steneosaurus* in *thouarsense* and *bifrons* Zones).

NORTH YORKSHIRE: Kettleness alum-works (NZ 8316; types of *Thaumatosaurus cramptoni* and *Plesiosaurus propinquus*, and *Stenopterygyius, Steneosaurus* in *communis* Zone); Saltburn (NZ 6621; *Plesiosaurus* in *capricornis* Beds); Staithes–Runswick Bay coast section (NZ 7919–NZ 8116, including Port Mulgrave; *Steneosaurus* (Walkden *et al.*, 1987)).

Three Lias localities, one from Dorset and two from Yorkshire, are selected for protection as GCR sites for their unusually prolific faunas of marine reptiles, as well as important terrestrial reptiles including pterosaurs and dinosaurs, some of which are not known outside Britain:

1. Lyme Regis coast (Pinhay Bay–Charmouth), Dorset (SY 3291–SY 3793). Early Jurassic (Hettangian–Pliensbachian), Lower Lias (*Ostrea* Beds–Green Ammonite Beds).
2. Whitby Coast (East Pier–Whitestone Point), Yorkshire (NZ 901115–NZ 928104). Early Jurassic (Toarcian), Upper Lias (Grey Shales Formation, Jet Rock Formation, Alum Shale Formation).
3. Loftus, Yorkshire (NZ 736200–NZ 757193). Early Jurassic (Toarcian), Upper Lias (Grey Shales Formation, Jet Rock Formation, Alum Shale Formation).

LYME REGIS (PINHAY BAY–CHARMOUTH), DORSET (SY 3291–SY 3793)

Highlights

Lyme Regis is the most famous British Early Jurassic marine reptile site, and one of the best in the world. For over 200 years abundant skeletons of ichthyosaurs and plesiosaurs have been found in the cliffs near the town, and the value of the site is enhanced by additional finds of rare terrestrial animals, such as the pterosaur *Dimorphodon* and the armoured dinosaur *Scelidosaurus*.

Introduction

The Lias exposures on the coast around Lyme Regis, Dorset (Figures 5.2 and 5.3A, B), are world-famous for their fossil reptiles. Specimens have been collected since at least 1790 (Delair, 1969a), and from 1810 to 1840 the younger Mary Anning found many fine ichthyosaurs and plesiosaurs. These were offered for sale and formed the basis of the earliest detailed descriptions of Mesozoic fossil reptiles (Home, 1814, 1816, 1818, 1819a, 1819b; De la Beche, 1820; De la Beche and Conybeare, 1821; Conybeare, 1822, 1824). Since then many hundreds of specimens, including pterosaurs, have been collected and finds are still being made.

Lyme Regis is historically important as the place where the first unarguably complete skeletons of ichthyosaurs and plesiosaurs were found which, because of the collecting and selling efforts of

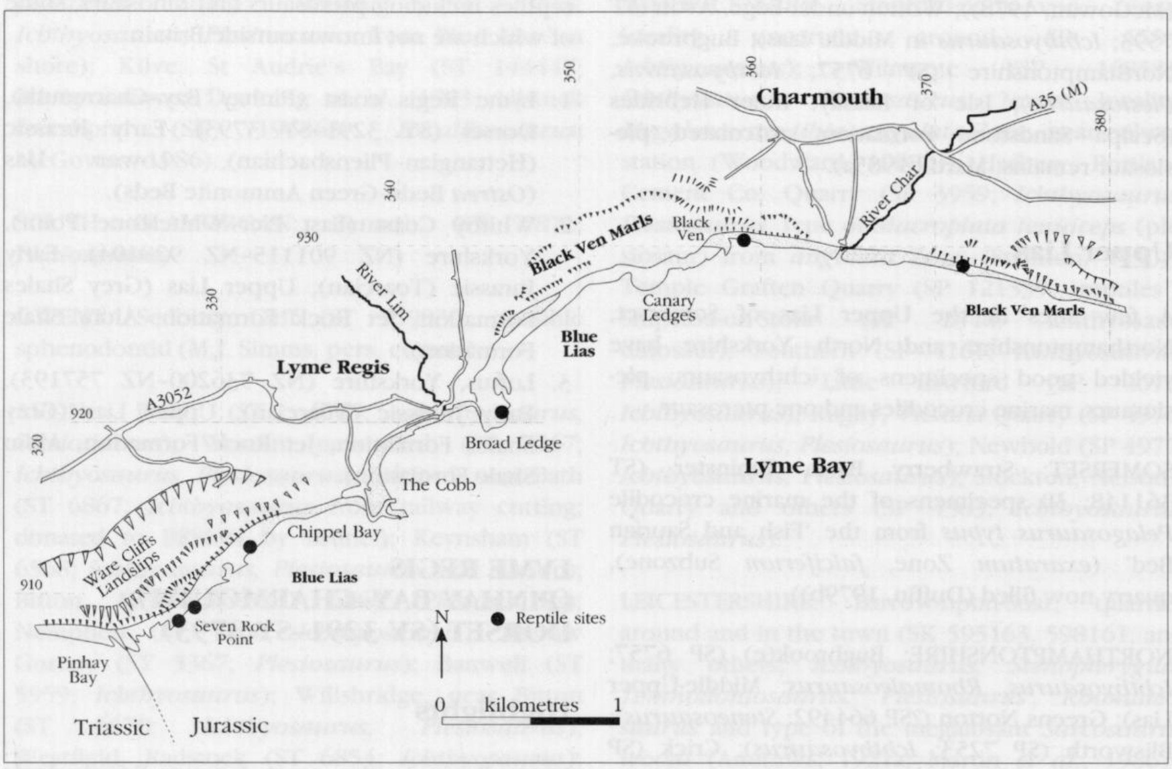


Figure 5.3 The reptile-bearing Lower Jurassic of Lyme Regis. (A) Map of the coastal section from Pinhay Bay to Charmouth, showing the major units, and indicating areas that have yielded fossil reptiles in the past.

Mary Anning, formed the basis for the study of Mesozoic marine reptiles during most of the 19th century (Taylor and Torrens, 1987).

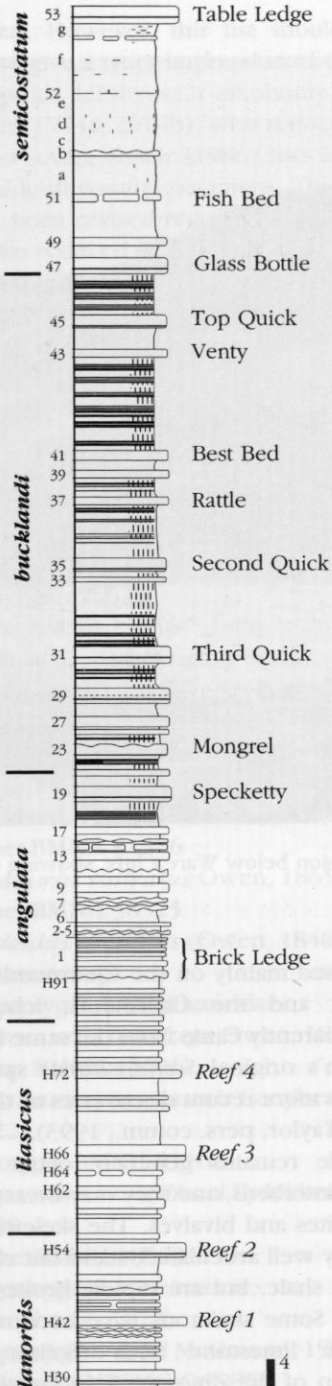
Description

There are numerous detailed accounts of the stratigraphy of the Lyme Regis section (e.g. Lang, 1914, 1924, 1932; Lang *et al.*, 1923, 1928; Lang and Spath, 1926; Palmer, 1972). The general succession (Getty, *in* Cope *et al.*, 1980a) is:

	Lang's Bed Numbers	Thickness (m)
----- unconformity -----		
Green Ammonite Beds	122–130	32
Belemnite Stone	121	0.15
Belemnite Marls	106–120	23
Armatus Limestone	105	0.4
Black Ven Marls	76–104	43
Shales with Beef Beds	54–75	23
Blue Lias	25–53	27
Ostrea Beds (=pre-*planorbis* Beds)	1–24	2.5

The Blue Lias is a sequence of laterally extensive, alternating thin-bedded (and nodular) limestones and shales exposed in cliffs and on the foreshore west of the Cobb, and in Church Cliffs, just east of Lyme Regis (Figure 5.4). Large ammonites and bivalves are abundant in certain limestone beds. The Shales with Beef Beds between Lyme Regis and Charmouth consist of thin papery shales, marls and limestone nodule beds with much fibrous calcite ('beef'), pyrite and selenite. Fossils include ammonites, poorly preserved bivalves, belemnites and fishes. The Black Ven Marls, in the cliff and foreshore west and east of Charmouth, consist of blue-black mudstones and paper shales with occasional limestones. Many species of ammonites, bivalves, brachiopods, foraminifers and insects occur. Deposition of all units was marine and, although not marginal, was probably close to shore because of the presence of insect, plant and dinosaur remains.

Reptiles have been collected from the *bucklandi* Zone (McGowan, 1989a, p. 424), the Saurian Shales at the top of the Blue Lias (Lang's Bed 52: *scipionianum* Subzone, *semicostatum* Zone, Early Sinemurian), from the Shales with



Formation	Lang Bed numbers	Stage	System
Black Ven Marls	90-104 gap 76-89		
Shales with Beef	54-75	Sinemurian	
Blue Lias	1-53		Jurassic
	H25-84	Hettangian	
Ostrea Beds	H1-24		
Penarth Group		Rhaetian	Triassic

Figure 5.3B The reptile-bearing Lower Jurassic of Lyme Regis. The rock succession of the Blue Lias, based on the work of W.D. Lang. From House (1990).

Figure 5.4 The Lower Lias sediments at Lyme Regis: view of the succession below Ware Cliffs, showing interbedded limestones and shales. (Photo: G.W. Storrs.)

Beef Beds (*semicostatum–turneri* Zones, Early Sinemurian) (Macfadyen, 1970, p. 97), Bed 85 of the Black Ven Marls (McGowan, 1993), and rarely from the '*Obtusum* Shale' of the Black Ven Marls (*obtusum* Zone; Late Sinemurian) (Delair, 1960, p. 75; Martill, 1991) and the lower Belemnite Marls (Ensom, 1987a, 1989a). A partial ichthyosaur in the Philpot Museum, Lyme Regis, from Charton Bay apparently came from the pre-*planorbis* Beds, well below the usual reptile-bearing beds (Taylor, 1986, p. 312).

Specific localities include the eastern end of Pinhay Bay (Seven Rock Point) where the Saurian Shales crop out twice (SY 32629277 and SY 32779285: Lang, 1924; Pollard, 1968; McGowan, 1989a, p. 424), Devonshire Point (SY 332913: Delair, 1966, p. 62), Broad Ledge, Church Cliffs (which used to be quarried; SY 346921; McGowan, 1974b, p. 20), Black Ven Rocks (SY 358930; Delair 1960, p. 75; SY 360931; Ensom, 1989a), Stonebarrow (SY 370929; McGowan, 1993), Seaton (SY 371917; Ensom, 1987a), Stonebarrow Beach (SY 372928: Delair, 1960, p. 75), and further west (SY 376927). Recent collecting has focused mainly on the Charmouth end of the section, and the Charmouth ichthyosaur (BRSMG) apparently came from the same horizon, as did Owen's original *Scelidosaurus* specimen, as well as the more recent discoveries of the latter taxon (M.A. Taylor, pers. comm., 1993).

The reptile remains generally occur in the darker shale interbeds, and they may be associated with ammonites and bivalves. The skeletons, usually extremely well articulated, stand out clearly in the soft dark shale, but are rapidly broken up by wave action. Some skeletons have been obtained from impure limestone beds (Sollas, 1881). Fossilized skin of the dinosaur *Scelidosaurus* has been preserved, showing scales and internal structure, in the Black Ven Marls (Martill, 1988), and the marine reptiles may show stomach contents within the rib cage region (e.g. Pollard, 1968).

Fauna

Delair (1958–60) reviewed the fossil reptiles of Dorset and gave an extended list of 21 species and three forms ascribed only to genera from the

Lower Lias. However, this list should be much reduced to give a truer impression of the diversity of the reptiles. Ichthyosaur taxonomy is based on McGowan (1974a, 1974b), who reduced about 50 species to seven. Delair (1986) lists a number of additional ichthyosaur specimens. The plesiosaurs have not been revised recently, but the list given here is also reduced from 40–50 species. The estimates of numbers of specimens are based on collections in the BMNH, BGS(GSM) and OUM. They are intended to give an impression of the relative abundance of each species.

	Numbers
Sauropterygia: Plesiosauria	
Plesiosaurus conybeari Sollas, 1881	5
Type: BRSMG Cb 2479	
Plesiosaurus dolichodeirus Conybeare, 1824	20
Type: BMNH 22656	
Plesiosaurus eleutheraxon Seeley, 1865	3
Types: BMNH 39851, R227	
Plesiosaurus (?)*hawkinsi* Owen, 1840	1
Plesiosaurus macrocephalus Buckland, 1837	10
Type: BMNH R1336	
Plesiosaurus rostratus Owen, 1865	8
Type: BMNH 38525	
Eurycleidus arcuatus (Owen, 1840)	3
Plesiosaurus sp.	*c.* 100
Ichthyopterygia: Ichthyosauridae	
Ichthyosaurus breviceps Owen, 1881	7
Type: BMNH 43006	
Ichthyosaurus communis Conybeare, 1822	45
Neotype: BMNH R1162	
Ichthyosaurus conybeari Lydekker, 1888	2
Type: BMNH 38523	
Leptopterygius tenuirostris (Conybeare, 1822)	9
Leptopterygius solei McGowan, 1993	1
Holotype: MRSMG Ce 9856	
Temnodontosaurus eurycephalus McGowan, 1974	1
Type: BMNH R1157	
Temnodontosaurus platyodon (Conybeare, 1822)	10
Type: BMNH 2003	
Temnodontosaurus risor McGowan, 1974	3
Type: BMNH 43971	
Ichthyosaurus sp.	*c.* 300
Archosauria: Pterosauria: 'Rhamphorhynchoidea'	
Dimorphodon macronyx Owen, 1859	50
Type: BMNH R1034	
'rhamphorhynchoid'	1
Archosauria: Dinosauria: Saurischia: Theropoda	
?megalosaurid	2
Archosauria: Dinosauria: Ornithischia: Thyreophora	
Scelidosaurus harrisoni Owen, 1863	3
Type: BMNH R1111	

Interpretation

About 100 'new species' were described from Lyme Regis in the 19th century, when every specimen was given a name. According to our present taxonomic list, Lyme Regis has yielded type specimens of 14 species, and nine of these species only occur at Lyme Regis (*Plesiosaurus conybeari*, *P. rostratus*; *Ichthyosaurus breviceps*; *Leptopterygius solei*; *Temnodontosaurus eurycephalus*, *T. platyodon*, *T. risor*; *Scelidosaurus harrisoni* and *Dimorphodon macronyx*).

The plesiosaurs from the Lower Lias of England are the earliest well-preserved specimens known (Figure 5.5B). Specimens of comparable age consist of a few poorly preserved remains from the Schwarzjura alpha and beta of Germany. In all, only about 10 species of Lower Lias plesiosaurs are known, and the Lyme Regis material is the most abundant and varied in the world. The species of plesiosaurs are identified on characters of the pelvis and limbs, and on the relative length of the neck and size of the head. The Lyme Regis animals show a range of neck lengths from rather short (*P. rostratus*) to rather long (*P. conybeari*) and these foreshadow the later pliosaurs and elasmosaurids, respectively. The animals vary from about 2 to 6 m in total length, and the relative size of the skull and shape of the jaw indicates diets of cephalopods, fishes and marine reptiles.

The ichthyosaurs likewise are the earliest good specimens and the most abundant and well preserved from the Lias (Figure 5.5A). Material from Lyme Regis has formed the basis of recent revisions of ichthyosaur relationships and evolution (McGowan, 1973a, 1973b, 1974a, 1974b, 1989a, 1989b). Ichthyosaurs have been classified on characters of the skull and forefin, and on this basis at least eight of the Lyme Regis taxa are presently regarded as valid. The Lyme Regis species vary in

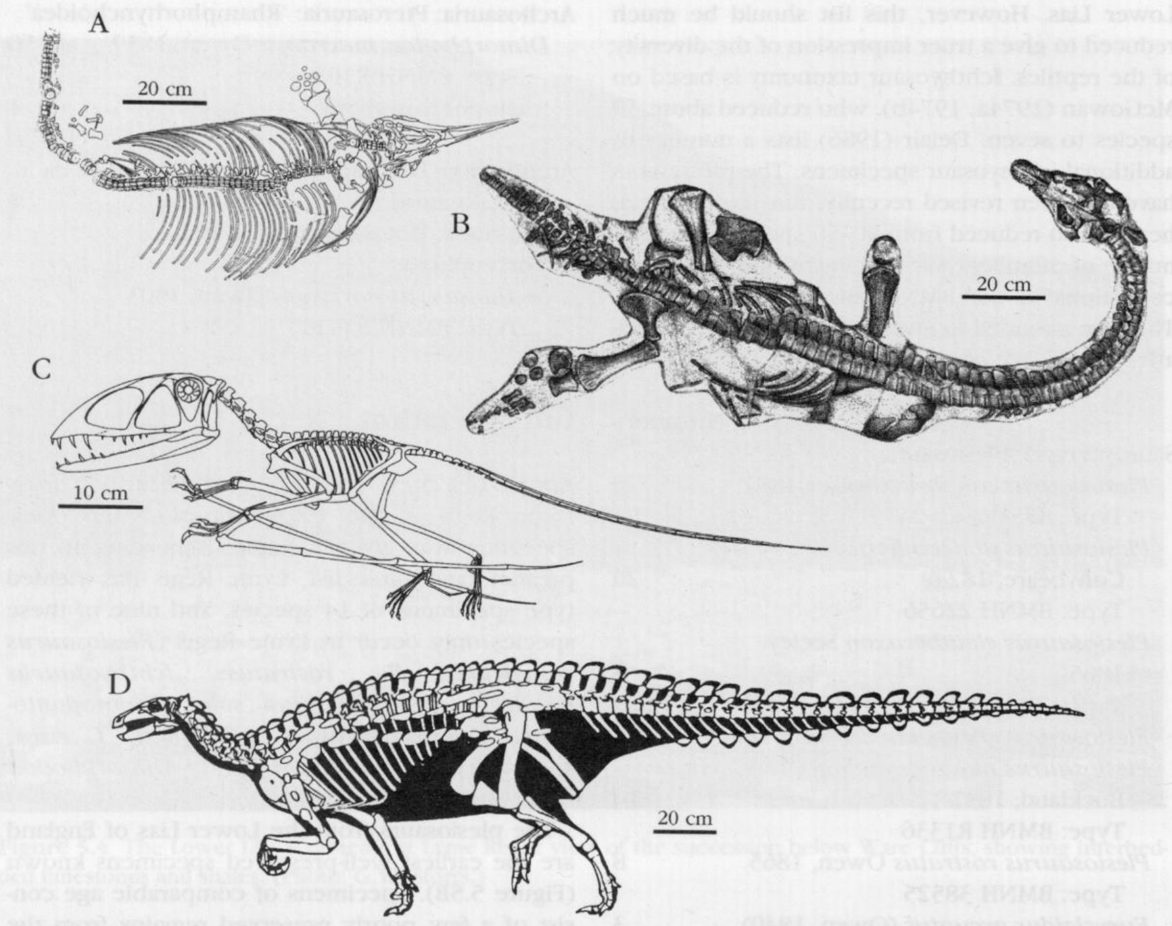


Figure 5.5 Typical reptiles from the Lyme Regis section. Skeletons of (A) *Ichthyosaurus*; (B) *Plesiosaurus*; (C) *Dimorphodon*; (D) *Scelidosaurus*. (A) and (B) from various sources; (C) from Padian (1984); (D) from Coombs *et al.* (1990).

length from 0.8 m to 9 m and they clearly fed on a wide range of sizes of fishes and invertebrates, as indicated by studies of coprolites (Buckland, 1829a) and stomach contents (Pollard, 1968). Several species of *Ichthyosaurus* were common enough for studies of growth series to be carried out in *I. communis* and *I. breviceps* (McGowan, 1973b).

I. communis is the most abundant species of ichthyosaur found at Lyme Regis, accounting for about half of the determinate skeletons. It was a moderate-sized form, reaching a maximum total length (measured from the tip of the snout to the tip of the tail) of about 2.5 m (McGowan, 1974b). The ichthyosaur *I. breviceps* is characterized by having a short snout, whereas *Leptopterygius tenuirostris* and *I. conybeari* have longer and more slender snouts. Although *L. tenuirostris* is much less common in terms of complete skeletons, it is abundantly represented by isolated remains of humeri, partial fins and rostral segments. This form is somewhat longer than *I. communis*, reaching lengths in excess of 2.5 m, while *L. solei* was over 7 m long (McGowan, 1993). The larger species of *Temnodontosaurus* are rarer. *T. eurycephalus* has a short snout and massive skull and it may have fed on other ichthyosaurs. *T. platyodon* is the second largest ichthyosaur of all time (length up to 9 m), and it occurs only at Lyme Regis. The species *T. risor* has a curved jaw-line (hence the name), but may represent immature *T. platyodon* (C. McGowan, pers. comm., 1993).

Dimorphodon is one of the oldest known pterosaurs, and it is represented by much skull and skeletal material (Figure 5.5C). Its anatomy is well known (Buckland, 1829b; Owen, 1870, 1874a; Wellnhofer, 1978, p. 33; Padian, 1983;

Unwin, 1988b). The skull is relatively large and high-vaulted, rather than long and pointed as in later pterosaurs. The limbs and girdles are strongly built. All of these features are primitive and *Dimorphodon* provides unique information on early pterosaur evolution. It appears to be a relative of the Late Triassic *Peteinosaurus* from Italy (Unwin, 1991).

The dinosaur *Scelidosaurus* (Figure 5.5D) is represented by one skull and skeleton, a juvenile collected recently (BRSMG) and other isolated remains (BMNH, DORCM, Philpot Museum, Lyme Regis; Ensom, 1987a, 1989a). It is the oldest known armoured ornithischian dinosaur. Its taxonomic position is uncertain, and it has been variously ascribed to the Stegosauria, Ankylosauria and the Ornithopoda (Owen, 1861a, 1863b; Newman, 1968; Rixon, 1968; Charig, 1979; Galton, 1975; Thulborn, 1977; Norman, 1985). Recent cladistic analyses define *Scelidosaurus* as the sister group of the Ankylosauria and Stegosauria, and these taxa together comprise the Thyreophora (Norman, 1984; Sereno, 1986). Coombs *et al.* (1990) identify a motley assemblage of basal thyreophorans, including *Scelidosaurus* and *Scutellosaurus* from the Hettangian of North America, as well as other poorly represented taxa. The type skeleton is fairly complete and shows a 4 m long animal with a small skull, strong hind limbs and dermal armour. The recently found juvenile specimen preserves the forelimbs and most elements of the skull and lower jaws, including some skin (Martill, 1988), thus complementing the previously known remains, and permitting an almost complete reconstruction of the skeleton (Norman, 1985). *Scelidosaurus* is currently of great interest because of its controversial taxonomic position close to the origin of the ornithischian dinosaurs, and a redescription is underway (Charig and Norman, in prep.). Other bones once ascribed to *Scelidosaurus* include limb bones of a ?megalosaurid.

Conclusions

For studies of fossil reptiles, the Lyme Regis coast section is one of the most important sites in Britain. It has yielded many type specimens, the remains are extremely well preserved, it still yields skeletons, and there is no comparable site of the same, earliest Jurassic, age outside Britain. The faunas of ichthyosaurs and plesiosaurs are the most diverse and abundant from the Early Jurassic of the world. The dinosaur *Scelidosaurus* and the pterosaur *Dimorphodon* are unique animals of great interest in studies on the early evolution of their respective groups. Historically, Lyme Regis is unique, its potential for future finds is excellent and so its conservation value is extremely high, even on an international level.

WHITBY–SALTWICK (EAST PIER–WHITESTONE POINT), YORKSHIRE (NZ 901115–NZ 928104)

Highlights

The Whitby coast has produced some of the best Upper Lias fossil reptiles in the world. Specimens of more than 10 species of plesiosaur, marine crocodile and ichthyosaur have been found there, some of them unique to Yorkshire.

Introduction

The Whitby coast section comprises a series of sea cliffs and ledges of Upper Lias mudstones and alum shales which rise from the east of Whitby harbour and extend to Whitestone Point (Figure 5.6A,B). The site is of historic interest in being one of the earliest localities in Britain to be exploited for its fossil reptiles. It has produced many important finds of marine crocodiles, ichthyosaurs and plesiosaurs which form part of a distinct marine fauna, and which are similar to those known from the famous localities at Holzmaden in Germany. The cliffs at Whitby are subject to continuing erosion, and the site has produced many good recent finds.

The wave-cut platform and cliffs east of Whitby harbour have been famous for their marine reptiles since the middle of the 18th century. In 1758, Mr Wooller described 'the fossil skeleton of an animal found in the alum rock . . . buried . . . by the force of the waters of the universal deluge.' In the same year, William Chapman described the same specimen as 'the fossile bones of an allegator', and the figures show that it clearly was a fine specimen of an early crocodile. The first recorded ichthyosaur from the Yorkshire coast was collected in 1819, and another one in 1821 was described by Young (1820). Further crocodiles were collected soon after from the same area in

1824 (Young, 1825; Charlesworth, 1837). Plesiosaur remains had been found by 1822 (Young and Bird, 1822), and the first plesiosaur skeleton was collected before 1842, but described somewhat later (Owen, 1865). Further crocodiles, ichthyosaurs, plesiosaurs and remains of a ?theropod dinosaur have been collected and described since then. The history is reviewed in detail by Benton and Taylor (1984).

Description

The stratigraphy of the Upper Lias (Toarcian, Early Jurassic; Figure 5.6C; see also Figure 5.7) of the Yorkshire coast has been described in detail for the sections between Port Mulgrave and Kettleness, Whitby harbour mouth and Whitestone Point, and at Ravenscar (Dean, 1954; Howarth, 1955, 1962, 1973). The general succession at Whitby, summarized by Howarth (*in* Cope *et al.*, 1980a), and with revised nomenclature from Powell (1984), is:

	Thickness (m)
------- unconformity ----------	
Whitby Mudstone Formation	
Alum Shale Member (lower part of *Hildoceras bifrons* Zone)	
Cement Shales	5.8
Main Alum Shales	15.2
Hard Shales	6.3
Jet Rock Member (*Harpoceras falciferum* Zone)	
ovatum Band	0.25
Bituminous Shales	23.0
Jet Rock	7.1
Grey Shales Member (upper and middle parts of *Dactylioceras tenuicostatum* Zone)	13.3
Cleveland Ironstone Formation (upper part)	0.6

The beds are nearly flat-lying in the sections to the east of Whitby (Figure 5.6). The Jet Rock Member occurs in the seaward portions of the wave-cut platforms at Saltwick Nab and Black Nab just to the east of Saltwick Bay. Behind these, the Bituminous Shales, *ovatum* Band and Hard Shales outcrop on the platform. The Main Alum Shales and Cement Shales occur mainly in the lower part of the cliff, and the upper part consists of the Mid Jurassic rocks above the unconformity. The Main Alum Shales and the Cement Shales were formerly quarried for the manufacture of alum at Saltwick Nab and at Black Nab.

The Jet Rock Member is a sequence of well-cemented, finely-laminated, grey or brown shales. The shales are frequently bituminous, and contain bands of small to large calcareous concretions known as 'doggers', up to 5 m in diameter. The shale unit is 1–3 m thick and the concretion bearing horizons vary between 0.1 and 1.0 m in thickness. Typical ammonites belong to the genera *Harpoceras, Hildaites* and *Eleganticeras* in the lower five metres of the Jet Rock Member and the bivalve *Inoceramus dubius* occurs above (Howarth, 1962; Hemingway, 1974).

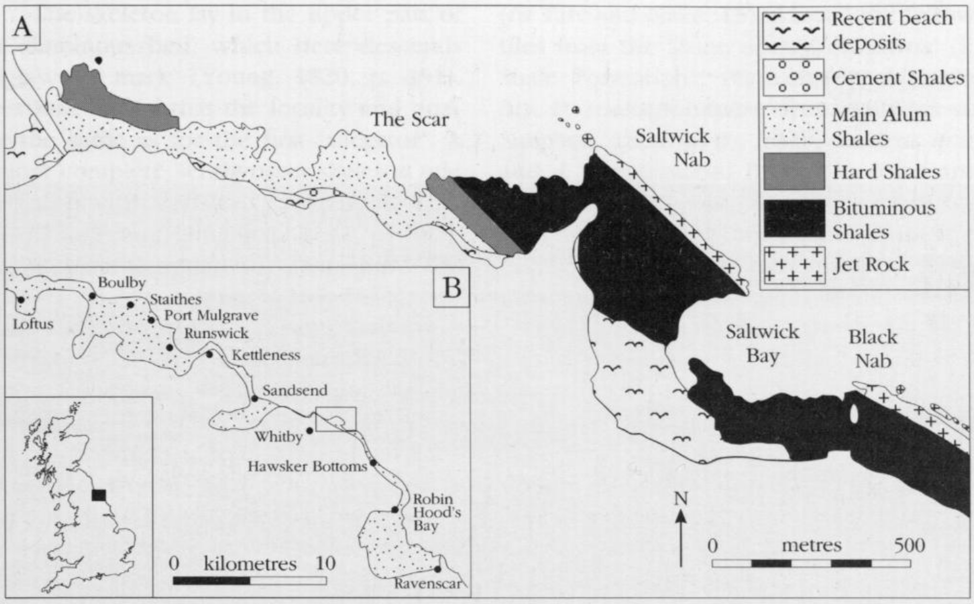
The Bituminous Shales, like the Jet Rock, contain soft jet, but this is considerably less abundant. Likewise, there are fewer calcareous concretions. The shales are less well laminated than the Jet Rock and contain less bitumen. The shale units are 3–8 m thick, and there are three or four 0.15 m bands of pyrite-coated concretions. The most common ammonites belong to the genus *Harpoceras* and the bivalve *Inoceramus* also occurs. Fossils are often pyritized (Howarth, 1962; Hemingway, 1974).

The *ovatum* Band consists of a 2 m thick bed with two dominating bands of large sideritic doggers, which weather to a dark reddish brown. The ammonite *Ovaticeras ovatum* occurs commonly and belemnites are found in associated aggregations.

The Hard Shales are a non-bituminous grey shale unit characterized by scattered calcareous concretions. A thin bed of siderite mudstones is present. The typical ammonite is *Dactylioceras commune*.

The Main Alum Shales are a sequence of alternating soft, grey, flaggy shales (0.25–5.00 m thick) and irregular bands containing scattered calcareous concretions and sideritic mudstone horizons. The shales typically weather to distinctive brittle flakes (Hemingway, 1974, p. 176). *Dactylioceras commune* is the typical ammonite in the lower 12 m of the unit, *Peronoceras fibulatum* in the upper 3 m, with the latter form occuring in association with *Hildoceras, Phylloceras, Dactylioceras, Zugodactylites, Pseudolioceras* and *Peronoceras* (Howarth, 1962; Hemingway, 1974).

The Cement Shales (0.25–4 m thick) consist of grey shales which contain the ammonite *Hildoceras bifrons* and species of *Porpoceras, Catacoeloceras* and *Phylloceras*. The bivalves *Nuculana* and *Gresslya* and belemnites, occur abundantly (Howarth, 1962). At Whitby this unit is unconformably overlain by the Dogger Formation (Aalenian, Mid Jurassic).



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Zones	Subzones	Lithostratigraphy			Howarth's Bed Numbers	Thickness	Tate & Blake (1876)	Buckman (1910, 1915)
Hildoceras bifrons	*Catacoeloceras crassum*	Whitby Mudstone Formation	Alum Shale Member	Cement Shales	65-72	5.8 m	*communis* Zone	*braunianum* Z.
	Peronoceras fibulatum			Main Alum Shales	51-64	15.2 m		*fibulatum* Zone
	Dactylioceras commune							*subcarinatum* Z.
				Hard Shales	49,50	6.3 m		*pseudovatum* Z.
Harpoceras falciferum	*Harpoceras falciferum*		Jet Rock Member	*Ovatum* Band	48	0.25 m	*serpentinus* Zone	*exaratum* Zone
				Bituminous Shales	41-47	23.0 m		
	Harpoceras exaratum			Jet Rock	33-40	7.1 m		
Dactylioceras tenuicostatum	*D. semicelatum* *D. tenuicostatum* *D. clevelandicum* *Protogrammoceras paltum*		Grey Shales Member		1-32	13.3 m	*annulatus* Zone	*tenuicostatum* Zone
		Cleveland Ironstone Formation (part) 0.65 m						

Figure 5.6 The reptile-bearing Lower Jurassic (Toarcian) of Whitby. (A) Map of the Upper Lias (Jet Rock Member and Alum Shale Member) exposed on the foreshore between Whitby Harbour and Saltwick Bay. (B) North-east Yorkshire with fossil reptile localities marked. The coastal outcrop of Lias rocks is stippled and the area shown in (A) is outlined. (C) The Lower Toarcian sequence at Whitby, showing ammonite zones and subzones, formations, bed numbers from Howarth (1962), and thicknesses for sections near Whitby (after Cope *et al.*, 1980a). The terminology used by earlier authors is also indicated. From Benton and Taylor (1984), after Howarth (1962).

The reptiles appear to have been obtained from various horizons, but since most of the material has remained unstudied until recently there has been much confusion over the precise provenances. This difficulty has been brought about by a combination of reasons, but principally through poor collection data and contradictory statements by the early authors. Recent changes in the nomenclature of ammonite zones have created further problems. Benton and Taylor (1984) reviewed the provenance of specimens on the basis of early collectors' reports and on a study of

Figure 5.7 The Upper Lias sediments east of Whitby at Saltwick Nab, showing the fossiliferous rocks on the wave-cut platform. (Photo: C. Little.)

the matrix and ammonites associated with specimens, and a clearer picture of the sources for most of the more important specimens has emerged.

The 'allegator' collected in 1758 (BMNH R1088) was originally described as coming from 'the sea-shore, about half a mile from Whitby. The ground that they lay in is what we call alum-rock, a kind of black slate that may be taken up in flakes. The bones were covered five or six feet with water every full sea' (Chapman, 1758, p. 688). Wooller (1758, p. 790) noted that 'this skeleton lay about six yards from the foot of the cliff, which is about sixty yards in perpendicular height' and that the fossil was found 'about 10 or 12 feet deep in . . . the black slate or alum rock.' Thus, the locality was most probably The Scar, a small promontory in the Alum Shales about 700 m ('half a mile') east of Whitby harbour mouth (NZ 909115). The cliff here is 50–55 m (sixty yards) high, exactly as Wooller (1758) described, and the wave-cut platform is easily accessible from Whitby. Westphal (1962, p. 106), however, contradicted this account and, in following Simpson (1884, p. XI), stated that the skeleton was found in the *Hildoceras serpentinum* Zone (= *H. falciferum* Zone), which occurs 12 m–18 m above the Jet Rock 'Series', therefore in the Bituminous Shales of the Jet Rock Formation. There is some confusion in earlier writings on the Jet Rock 'Series' and the Alum Shales, and where the intervening beds are to be placed, i.e. whether early writers ascribed the Bituminous Shales to the Alum Shales. However, none of the components of the Jet Rock Formation occurs 'half a mile' from Whitby and all the evidence points to an assignment of this crocodile to the Main Alum Shales, contrary to Westphal's statement (Benton and Taylor, 1984).

The crocodile collected in 1824 (WHIMS 770S) was found 'in the face of a steep cliff, not far from the town (Whitby)' (Young, 1825, p. 76), and Westphal (1962, p. 106) stated that it came from an alum pit within the Main Alum Shales. This would restrict the locality to the old alum works at Saltwick Nab (NZ 914112) or at Black Nab (NZ 921107).

The specimen named *Steneosaurus brevior* by Blake (*in* Tate and Blake, 1876, pp. 244–6) came from the old 'Zone of *Ammonites serpentinus*' (= *Hildoceras falciferum* Zone). This places it in the Jet Rock Formation 'immediately below . . . the Alum Shale', according to Westphal (1962, p. 106).

The first Yorkshire ichthyosaur to be reported 'was imbedded in the alum-rock, where it is washed by the tide, and covered at high water, about half a mile east from the entrance of Whitby harbour, and ten yards from the face of the steep cliff. . . . The cliff . . . is about sixty yards in height. . . . The skeleton lay in the upper part of the great aluminous bed, which here descends below high-water mark' (Young, 1820, p. 451). This leaves little doubt that the locality and horizon were the same as for the first 'allegator'. A second, more complete, ichthyosaur skeleton was 'found in the compact shale . . . on the scar' in October, 1821 (Young and Bird, 1828, p. 282). These two specimens apparently came from The Scar (NZ 909115), the source of the first crocodiles and possibly also from the Main Alum Shales there. The specimens have not been traced, but the figures indicate that they may be examples of *Leptopterygius acutirostris* (Owen, 1840a).

Forty or so specimens of ichthyosaurs were collected from the Whitby area from about 1820 (Young and Bird, 1828, pp. 283-6), but most of these were purchased by private collectors and cannot at present be traced. The bulk of these 'were found at or near Saltwick, in the main bed of the alum shale'. The Scar is mentioned again for some of the specimens, but others may have come from excavations in the alum shale cliff at Saltwick Nab (NZ 914112).

The first important plesiosaur was found 'by Mr Marshall of Whitby, imbedded in a hard rock belonging to the upper lias beds, situated between Scarborough and Whitby, near the place where that gentleman had formerly discovered the remains of a crocodile' (Dunn, 1831). If the 'crocodile' is WHIMS 770S, this plesiosaur came from the vicinity of Saltwick Bay, and probably from a nodule in the Alum Shale Formation. It was a partial postcranial skeleton, lacking much of the neck, apparently of a large plesiosauroid with a body about 3 m long. The best documented find of a plesiosaur was an almost complete articulated skeleton of a plesiosauroid about 4.5 m long with a 0.2 m long skull (CAMSM J35182). It was referred to the Lower Lias species *Plesiosaurus dolichodeirus,* or alternatively to the Owen MS species *P. grandipennis* (Phillips, 1853), but was renamed by Seeley (1865a, 1865b) who described it as the type of *P. macropterus*. Watson (1911a) redescribed it as the neotype of *Eretmosaurus* Seeley, 1874, a genus that had been erected on the basis of undiagnosable material. It was found in the early summer of 1841 by Matthew Green and two other jet collectors of Whitby in the Lias cliffs at Saltwick (Browne, 1946, p. 57).

All later finds to be described from Whitby can only be localized on the basis of crude zonal data which are the only clues as to the provenance of specimens provided by the later authors. Blake (*in* Tate and Blake, 1876) listed the following reptiles from the 'Zone of *A. communis*' (i.e. Alum Shale Formation): *Plesiosaurus homalospondylus, P. coelospondylus* (from Saltwick Alum Pit; Simpson, 1884, p. 9), *Ichthyosaurus acutirostris* and *I. longirostris*. Blake (*in* Tate and Blake, 1876, pp. 250-2) stated that '*Plesiosaurus' longirostris* came from the 'Zone of *A. serpentinus*' (i.e. Jet Rock Formation). White (1940, p. 452) notes the old zonal assignment of *Macroplata (P.) longirostris*, but mistakenly listed the specimen as coming from near the bottom of the Alum Shale.

A few specimens in collections offer some additional information on the typical occurrence of the Whitby reptiles. A recently collected ichthyosaur in the British Museum (BMNH R8309) carries the label 'Bituminous Shale, Black Nab', and a pair of ichthyosaur jaws collected in 1981 came from below the High Lighthouse (NZ 929103), most probably from the Bituminous Shales. A second skeleton of *Macroplata longirostris* was found in 1960 in the *bifrons* Zone 'between Old Peak and Blea Wyke Point, south-east of Robin Hood's Bay' (Broadhurst and Duffy, 1970). This specimen (MANCH unnumb.) is about 4 m long. A *Steneosaurus* lower jaw (BMNH R12011) was collected in 1989 in the Bituminous Shales just south of Black Nab (NZ 926104).

In conclusion, the bulk of the reptiles from Whitby appear to have come initially from the Main Alum Shales of The Scar, and later from the alum workings in the cliff at Saltwick Nab and Black Nab. A few specimens appear to have been found in the Jet Rock Formation (?Bituminous Shales), probably on the foreshore between Saltwick Nab and Black Nab.

Taphonomic study of the Whitby marine reptile remains has been hampered by the lack of suitable collection data and in addition by the incompleteness of some specimens, the result of collection failure and through artificial 'improvements' made to certain specimens. An examination of museum specimens shows most skeletons to be well preserved in an articulated state with only slight damage, probably as a result of scavenging. This was presumably minimized by the prevailing anoxic conditions in the bottom sediment, as suggested by their bituminous nature. Other partial skeletons may have been broken up prior to burial or by recent wave action before the specimens were collected from the foreshore.

Fauna

About 20 species of marine reptile have been described from the Whitby area (Benton and Taylor, 1984), of which seven may be valid, but further revision might alter the figure. Of these seven, four (*Steneosaurus brevior, S. gracilirostris, Rhomaleosaurus longirostris* and *Sthenarosaurus dawkinsi*) occur only at Whitby, and one (*Stenopterygius acutirostris*) probably occurs only in Yorkshire. The taxonomy of the Upper Lias crocodiles from Whitby has been reviewed by Westphal (1961, 1962) and Duffin (1979a, 1979b), the ichthyosaurs by McGowan (1974b, 1976, 1978, 1979), and the plesiosaurs by Watson (1909c, 1910b), White (1940), Persson (1963) and Taylor (1992b). Approximate numbers of specimens in the BMNH, CAMSM, WHIMS and YORYM are given.

	Numbers
Sauropterygia: Plesiosauria	
Eretmosaurus macropterus (Seeley, 1865a)	1
Macroplata longirostris (Blake, 1876)	1+
Type: MCZ 1033	
Microcleidus homalospondylus (Seeley, 1865)	6
Type: YORYM G502	
Sthenarosaurus dawkinsi Watson, 1909	2
Type: MANCH L8023	
Thaumatosaurus propinquus (Blake, 1876)	2
'*Plesiosaurus*' sp.	4
Ichthyopterygia: Ichthyosauridae	
Stenopterygius acutirostris (Owen, 1840)	8
Type: BMNH 14553	
Eurhinosaurus longirostris (Mantell, 1851)	1
Type: BMNH 14566	
'*Ichthyosaurus*' sp.	12
Archosauria: Crocodylia: Thalattosuchia: Teleosauridae	
Steneosaurus bollensis (Jaeger, 1828)	9
Steneosaurus brevior Blake, 1876	6
Type: BMNH 14781	
Steneosaurus gracilirostris Westphal, 1961	4
Type: BMNH 14792	
Pelagosaurus brongniarti (Kaup, 1835) (incl. ?*Teleosaurus chapmani*)	8
Pelagosaurus typus Bronn, 1841	1
Steneosaurus sp.	6
Archosauria: Dinosauria: Saurischia	
?theropod	1

Interpretation

The Whitby plesiosaurs divide up into forms with long necks and small skulls, others with relatively large skulls and one with long pointed jaws. They also range in total body length from 2 m to 6 m, and clearly used a range of hunting and feeding strategies. Their principal diet was probably cephalopods and fishes, and the larger species might also have eaten other marine reptiles. Their range of forms indicates four qualitative lineages and they provide the best information on plesiosaur evolution in the Upper Lias. Holzmaden and other German localities have also yielded good specimens of the same age, but these localities lack the variety of forms found at Whitby. At Whitby, there are at least two possible pliosauroids (plesiosaurs with short necks and large skulls), *Macroplata longirostris* which has a gracile snout and the *R. cramptoni–R. zetlandicus–R. propinquus* group with robust snouts (Figure 5.8C). There are also two or three plesiosauroids (plesiosaurs with long necks and small heads), namely *Microcleidus macropterus, M. homalospondylus* and *Sthenarosaurus dawkinsi*. *Macroplata longirostris* was about 5 m long with a head about 0.7 m long. It had a remarkably slender head and elongate rostrum, a character unknown in any other Jurassic plesiosaur. *Microcleidus homalospondylus* is represented by nearly complete skeletons which show an animal about 6 m long with an extremely long neck (2.5 m) and a relatively small skull. It had large paddles and is distinguished by characters of the vertebrae and limb girdles. *Sthenarosaurus dawkinsi* based on a partial skeleton collected at Saltwick, is another long-necked form with strong limbs. It is currently regarded as a plesiosauroid (Brown, 1981, p. 339). *Rhomaleosaurus propinquus* was about 2.5 m long and had a 0.6 m skull – relatively large.

The ichthyosaurs from Whitby are the best Upper Lias forms from Britain. However, those from Holzmaden, of approximately the same age, are more abundant, better preserved and show greater variety. Some of the ichthyosaurs from Whitby may also occur at Holzmaden, although most of the German specimens belong to different

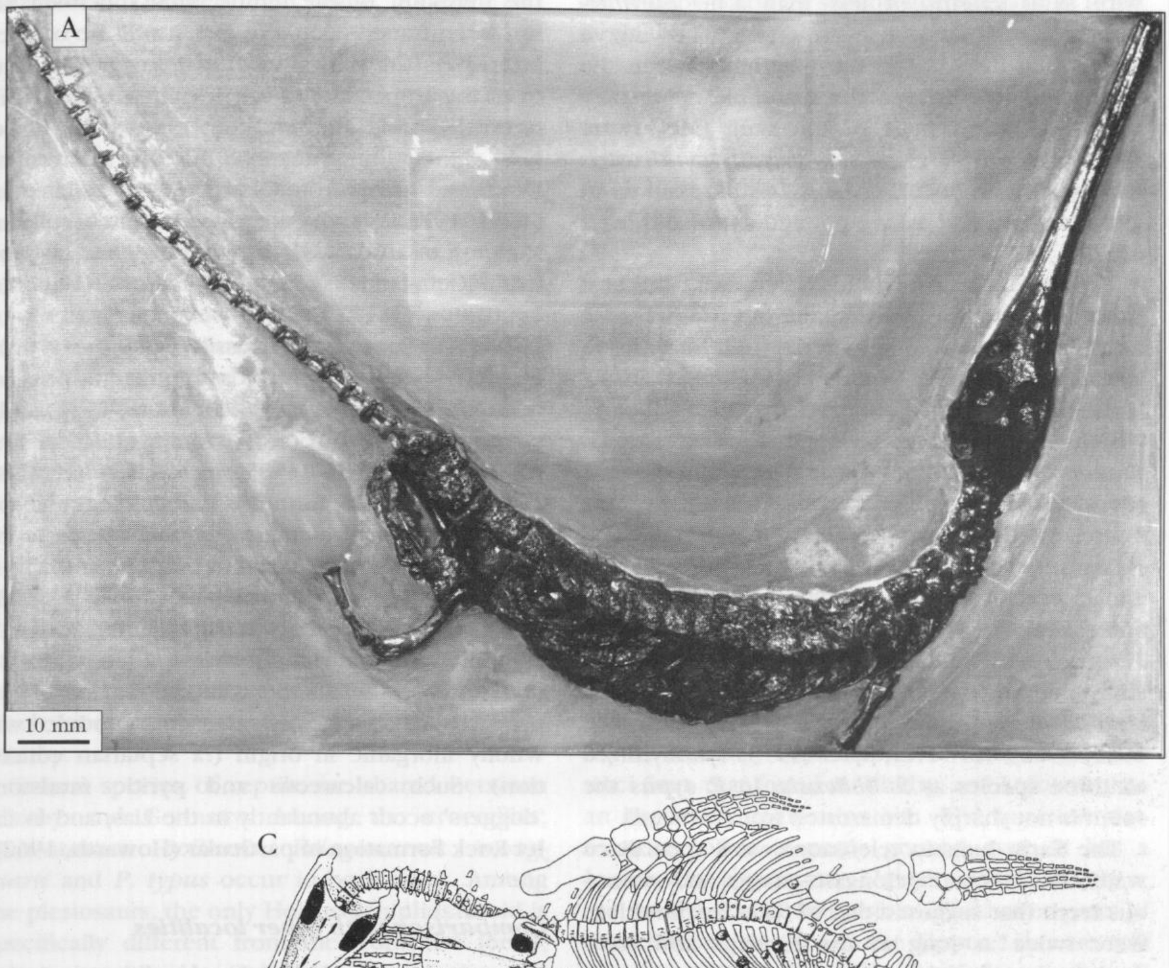

Figure 5.8 Marine reptiles from the Lower Jurassic Alum Shale Member of Whitby. (A) The crocodile *Steneosaurus gracilirostris* Westphal, 1961, type specimen (BMNH 14792); (B) the ichthyosaur *Temnodontosaurus longirostris* (Mantell, 1851), type specimen (BMNH 14566); (C) the pliosauroid plesiosaur *Rhomaleosaurus cramptoni* (Carte and Baily, 1863), type specimen (NMI F8785), skull and skeleton.

species (McGowan, 1974b, 1989b). The two Whitby ichthyosaur species recognized as valid by McGowan (1974b), *Eurhinosaurus longirostris* and *Stenopterygius acutirostris*, are distinguished largely by the relative proportions of parts of the skull (Figure 5.8B). For example, *S. acutirostris* has a larger orbit and nasal opening than *E. longirostris* in relation to the overall skull length. *S. acutirostris* is generally larger than *E. longirostris*, with skull lengths from 0.6 m to 1.50 m compared with skull lengths of less than 1 m. *Eurhinosaurus* is a swordfish-like form showing a remarkable disparity in the lengths between the upper and lower jaws, the mandible being only about half the length of the skull (McGowan, 1986, 1989b, 1989c). *Stenopterygius acutirostris* was larger than *Eurhinosaurus*, with a skull up to 1 m long, and had a long pointed snout and large orbit.

The crocodiles from Whitby represent the best Jurassic marine forms in Britain, but the preservation is not as good as in material from localities in Germany, such as Ohmden, Holzmaden, Boll, Holzheim (Baden-Württemberg) and Neumarkt (Oberpfalz). The age of these German sites is similar to that of the Whitby sediments (Posidonienschiefer, Lias epsilon 1, 2, 3, Early Toarcian). *Steneosaurus* (Figure 5.8A) and *Pelagosaurus* are teleosaurs which differ in size and in certain features of the skull and skeleton. *Steneosaurus* was 2.5–5.0 m long, whereas *Pelagosaurus* was under 1.75 m. *S. brevior* has a shorter snout (64% of skull length) than *S. bollensis* (72%) or *S. gracilirostris* (77%) (Westphal, 1961, 1962). However, Steel (1973) synonymized all three species as *S. bollensis*. In *P. typus* the snout is not sharply demarcated from the skull.

The Early Jurassic teleosaurs were specialized water-dwellers with elongate snouts and numerous teeth that suggest a diet of fish. The hind legs were twice as long as the forelegs and were doubtless powerful organs of propulsion. In general, teleosaurs are found in estuarine, shallow marine sediments, and they probably lived partly on land and fed in brackish and salt water. Teleosaurs had a strong bony armour. The group has a long history, the later forms evolving into several narrow- and broad-snouted forms in the Late Jurassic and Early Cretaceous of Europe in particular. The Early Jurassic remains of Whitby and Baden-Württemberg are the best preserved and most useful for an assessment of the relationships and biology of early marine crocodilians. These Early Jurassic teleosaurs represent the first radiation of crocodilians into the sea, after their origin in the latest Triassic as small terrestrial insectivorous animals.

Huene (1926, pp. 36–71) and Wild (1978b, p. 2) cite an undescribed specimen (WHIMS) of a 'middle sized femur' of a carnivorous theropod dinosaur from Whitby. Huene noted that he had not himself seen the specimen and cited a personal letter from 'Dr (D.M.S.) Watson'. The specimen had the fourth trochanter placed above the midpoint of the femur. This specimen has not been traced; if it is found, it will be of great interest as the only find of a theropod dinosaur from the Upper Lias of any locality. Indeed, only two other dinosaurs are known from the Upper Lias: the hind limb of the sauropod *Ohmdenosaurus* from Ohmden, near Holzmaden (Wild, 1978b), and a nearly complete skull and skeleton of an early thyreophoran, *Emausaurus*, from Klein-Lemahagen, near Rostock (Haubold, 1990).

Two probable pseudofossils from the Whitby Lias have been interpreted as reptilian: a possible teleosaur egg (YORYM 505; Melmore, 1931) and a supposed group of embryos or juveniles of four plesiosaurs (BMNH R3585; Seeley, 1887a, 1888a, 1888b, 1896). The former is certainly egg-shaped, but it consists of a mudstone and calcite 'core' surrounded by a pyrite skin, and is probably a concretion (Benton and Taylor, 1984, p. 418). The latter was reinterpreted by Thulborn (1982) as infilled *Thalassinoides* burrows surrounding a concretion, whereas Benton and Taylor (1984, pp. 418–19) suggested that the nodule was wholly inorganic in origin (?a septarian concretion). Such calcareous and pyritic mudstone 'doggers' occur abundantly in the Lias, and in the Jet Rock Formation in particular (Howarth, 1962).

Comparison with other localities

Other comparable Upper Lias localities occurring along the Yorkshire coast that have yielded a similar marine reptile fauna include Saltwick and the old alum quarries at Kettleness (NZ 8316) and Loftus (NZ 7420). Further reptile localities, including Runswick Bay, Robin Hood's Bay, Port Mulgrave, Staithes, Sandsend, Hawsker Bottoms, Boulby and Ravenscar (Old Peak–Blea Wyke Point), have also produced a comparable fauna, although the remains of marine reptiles from these localities are less abundant. The Upper Lias of England is not as rich in marine reptile fossils as the Lower Lias. Various localities in Somerset, Northamptonshire, Leicestershire, Lincolnshire and North Yorkshire have yielded isolated ichthyosaurs, plesiosaurs and steneosaurs (see above). The localities at Blisworth (SP 7354) and Wellingborough (SP 9868) are still accessible but most of the other sites are now inaccessible and have little potential for future finds.

The reptile faunas most similar to those from Yorkshire are those recorded from various localities in the Upper Lias of south-west Germany (e.g.

Holzmaden, Ohmden, Boll, Banz, Altdorf) and France (e.g. Normandy, Franche-Comté). Most of these sites cannot be compared readily with the Whitby section since the recorded finds are too sparse to constitute a 'fauna'. The exception is Holzmaden, Baden-Württemberg, where the bituminous laminated shales and grey mudstones of the Posidonienschiefer, a subdivision of the Schwarzjura ϵ (*tenuicostatum* to *bifrons* Zones of the Early Toarcian; Urlichs 1977), have produced hundreds of specimens. Hauff (1921) noted that the bulk of these came from his subdivisions II 2 to II 13 (middle ϵ, upper *tenuicostatum* Zone to upper *falciferum* Zone), thus rather older on average than the reptiles from the Yorkshire coast. Hauff (1921) records ten specimens of plesiosaurs, including four almost complete skeletons, about 350 specimens of ichthyosaurs, many of which are relatively complete, about 70 specimens of crocodiles many of which are also complete, and about 10 skeletons and bones of pterosaurs. Thus plesiosaurs and crocodiles are relatively less abundant, and ichthyosaurs are much more common at Holzmaden than around Whitby.

Several species of reptile are shared between Whitby and Germany. Among the crocodiles, *Steneosaurus bollensis*, *Pelagosaurus brongniarti* and *P. typus* occur in both areas. Among the plesiosaurs, the only Holzmaden pliosauroid is specifically different from the Yorkshire forms, but it is not clear whether any of the plesiosauroids are shared. McGowan (1979) ascribes German '*L. acutirostris*' to *L. burgundiae* (Gaudry, 1892).

Conclusions

The Yorkshire coast sites are undoubtedly the best for British Upper Lias reptiles. The coast between Whitby and Whitestone Point has yielded more specimens, and type specimens, than any other Upper Lias marine reptile site in Britain, and many of these are articulated. The fauna differs from the Upper Lias faunas of southwest Germany (e.g. Holzmaden) and France. It has produced the best collections of fossil crocodiles from the Early Jurassic of Britain. The ichthyosaurs and plesiosaurs from Whitby are the most numerous and varied of British Upper Lias sites, and the plesiosaurs in particular show a broad range of separate lineages.

The great importance and conservation value of the Whitby–Saltwick section lies, like that of Lyme Regis, in the combination of the richness of historical finds and the potential for future discoveries.

LOFTUS, YORKSHIRE (NZ 736200–NZ 757193)

Highlights

Loftus Alum Quarries have produced a diverse assemblage of marine fossil reptiles, plesiosaurs, ichthyosaurs and crocodiles. They are especially notable as the site where the pterosaur *Parapsicephalus* was found, a remarkable specimen that preserves the outline of the brain.

Introduction

The former alum workings in the Upper Lias Alum Shale at Loftus have yielded many important fossil reptile remains. These appear to form a fauna distinct from that found at Whitby, and Loftus is thus an important companion site. The quarried platform at Loftus is partly grassed over. It has a hummocky appearance (?quarry spoil) and there are several tracks still visible. The lower parts of the cliff behind (i.e. in the Upper Lias) are still largely exposed. Thus, much of the site is still available for further examination and additional finds could be made. However, the site is isolated from the sea above a cliff of Lower to Middle Lias and erosion is probably less than at Whitby. The geology has been described by Fox-Strangways (1892) and the reptiles by Carte and Baily (1863), Seeley (1865a), Tate and Blake (1876), Newton (1888), Watson (1911a), Melmore (1930), Wellnhofer (1978) and Taylor (1992a, 1992b).

Description

The extensive alum quarries on the Yorkshire coast between Loftus and Boulby yielded many reptile remains when they were in operation. Fox-Strangways (1892, p. 134) notes that 'the saurian remains were so numerous that one of the walks at Boulby House is edged with the vertebrae of these reptiles'. Although the two quarries are now linked and the former boundary cannot be detected, they operated separately throughout the

19th century. Loftus Alum Quarry (known as Lofthouse or Lingberry in the past) was operated by the Earl of Zetland and was closed in 1863, whereas Boulby Alum Quarry was closed in 1861 (Fox-Strangways, 1892, p. 453).

The sequence of the Upper Lias at Loftus is approximately the same as in the Staithes and Whitby sections, consisting of an ascending sequence through the upper part of the Cleveland Ironstone Formation and the Whitby Mudstone Formation (Grey Shales, Jet Rock Alum Shale members; Howarth, *in* Cope *et al.*, 1980b; see Whitby report above).

The Lower and Middle Lias are exposed on Hummersea Scar, west of the Alum Quarries, and on the foreshore below the quarry (*jamesoni* Zone, Early Pliensbachian, on the wave-cut platform; *margaritatus* and *spinatum* Zones, Late Pliensbachian, Cleveland Ironstone Formation on the 80–90 m cliff). The Alum Quarries have been dug back from this lower cliff line, forming a broad shelf well above sea-level, and a high cliff rises behind to a total height of 200 m. The upper part of the cliff consists of three Early Toarcian (Upper Lias) members, capped by Mid Jurassic sediments (Dogger Formation (1.5 m), Hayburn Formation (25 m), Aalenian; Fox-Strangways, 1892).

The reptiles appear to have been found in the Loftus Alum Quarries rather than in the Boulby Alum Quarries, since the specimens are labelled 'Lofthouse'. They are all recorded as 'Zone of *A. communis*' by Blake (in Tate and Blake, 1876, pp. 246, 250, 253–4) (=Early Toarcian, *Hildoceras bifrons* Zone), and they probably came from the Main Alum Shales. The provenances of some specimens can be traced from the early literature and also from examination of matrix associated with the remains, and these confirm Blake's statement. Young and Bird (1828, p. 287) noted a plesiosaur vertebra from Loftus, while Seeley (1880) described an ichthyosaur specimen (CAMSM 35176), presumably from Loftus, as *Ichthyosaurus zetlandicus*. The type specimen of the pliosaur *Rhomaleosaurus zetlandicus* (YORYM G503) also came from Loftus (Phillips, 1854; Tate and Blake, 1876, p. 250; Taylor, 1992a, 1992b), and presumably from the Cement Shales or the upper part of the Main Alum Shales, as confirmed also by the matrix of the specimen, a flaky, grey, pyritous shale containing concretions around the bones. The histories of the specimens from Loftus are detailed in Benton and Taylor (1984, pp. 410–14, 416).

Fauna

Loftus Alum Quarries have yielded many specimens according to past records, but only six may still be traced. However, these are rather important. They are preserved in the BMNH, BGS(GSM), CAMSM, WHIMS, and YORYM.

	Numbers
Sauropterygia: Plesiosauria:	
Eretmosaurus macropterus (Seeley, 1865a)	
Type: CAMSM J35182	1
Rhomaleosaurus zetlandicus (Phillips, 1853)	
Type: YORYM G503	1
'*Plesiosaurus* sp.'	1
Ichthyopterygia: Ichthyosauridae	
Stenopterygius acutirostris (Owen, 1840)	
Type of *Ichthyosaurus crassimanus* Blake, 1876: YORYM G497	1
Temnodontosaurus platyodon (Conybeare, 1822)	1
Archosauria: Pterosauria: 'Rhamphorhynchoidea'	
Parapsicephalus purdoni (Newton, 1888)	
Type: BGS(GSM) 3166	1

Interpretation

Loftus Alum Quarries have yielded type specimens of four species, of which at least two are apparently unique to this locality. *Eretmosaurus macropterus* has been recorded from Whitby.

The plesiosaur *Eretmosaurus macropterus* is represented by a fine articulated skeleton with a total length of 5 m. The skull is relatively short (0.25 m) and the teeth are long and curved. The neck is long (2 m) and consists of 39 vertebrae, and the tail is 1.3 m long. The limbs are very large: they all measure over 1 m in length. The only descriptions (Seeley, 1865a; Blake, *in* Tate and Blake, 1876, p. 246; Watson, 1911a) are brief and the specimen has never been figured.

Rhomaleosaurus zetlandicus is about 6 m long, with a long skull (1.1 m), short neck (1.5 m) and long tail (2 m). The limb bones are large. The specimen was collected in about 1850 (Phillips, 1853, 1854; Carte and Baily, 1863; Blake, *in* Tate and Blake, 1876, pp. 249–50) and has recently been redescribed in detail (Taylor, 1992a, 1992b).

Ichthyosaurus crassimanus Blake (1876, pp. 253–4) is 10 m long and has a 2 m skull. The front paddles (0.8 x 0.3 m) are larger than the hind paddles (0.6 x 0.25 m). It was described in some detail by Melmore (1930). McGowan (1974a, pp. 31–2) ascribed it to *Stenopterygius acutirostris*, but later (McGowan, 1976, p. 675, footnote; 1979, pp. 120–1) provisionally placed it in *Leptopterygius*. There is a problem regarding the locality of this specimen. Blake (*in* Tate and Blake, 1876, p. 254) noted its provenance as 'Lofthouse', but Simpson (1884, p. 12) stated that it came from Kettleness. Later authors have been noncommittal: 'Alum Shale Quarries north of Whitby' (Melmore, 1930, p. 615); 'Alum Shales north of Whitby' (McGowan, 1974a, p. 32); 'near Whitby' (Pyrah, 1979, p. 423). We assume that it came from Loftus since that is the locality quoted by its original describer. A large specimen of *Temnodontosaurus platyodon* (5 m long), with a 1.25 m head, has also been recorded (Simpson, 1884, p. 12).

The pterosaur *Parapsicephalus purdoni* (Figure 5.9), originally ascribed to the genus *Scaphognathus* (from the Late Jurassic Solnhofen Beds of Germany) by Newton (1888), is represented by a partial skull, which lacks dentition and the snout tip. The skull is long and low and has large openings, especially the antorbital fenestra. The preservation of this specimen is such that a fine brain cast is displayed, which shows how the relatively large brain fits obliquely in the skull behind the eye. The forebrain is large and the olfactory lobes are short. The large optic lobes are a reptilian feature, but they are not quite dorsal in position, which is a bird-like feature. The cerebellum is small and there are large flocculi (Newton, 1888; Wellnhofer, 1978, pp. 30, 39). *Parapsicephalus* is one of the earliest true rhamphorhynchids (Unwin, 1991) and it falls in a time interval when relatively few pterosaurs are known. Other late Early Jurassic pterosaurs include *Campylognathoides* and *Dorygnathus* from Germany and India (Wellnhofer, 1978, pp. 73–4).

Comparison with other localities

Loftus Alum Quarries are most immediately comparable with Kettleness Alum Quarries to the south (NZ 8316) and the coast at Port Mulgrave (NZ 8018). The coast east of Whitby (NZ 9012–NZ 9310) has produced more species of reptiles and more specimens, but those from Loftus are broadly different taxa. Only the plesiosaur *Eretmosaurus macropterus* is shared with

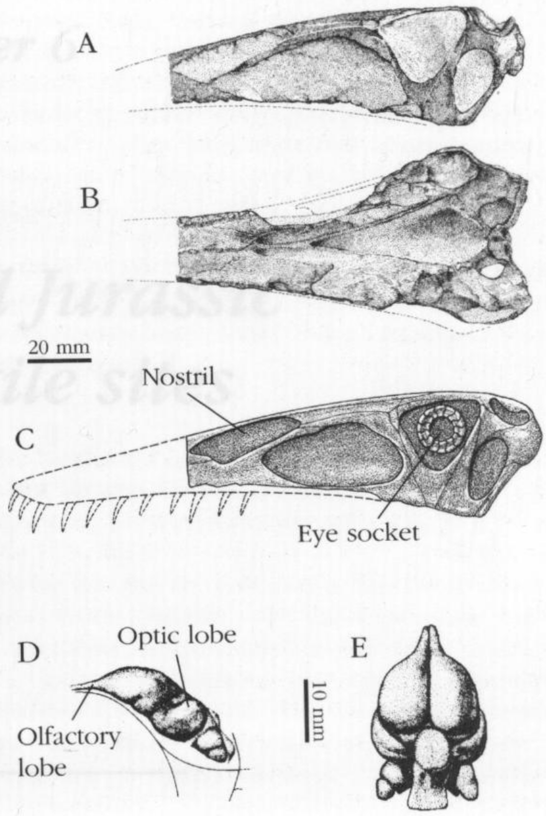

Figure 5.9 The pterosaur *Parapsicephalus purdoni* (Newton, 1888) from the Lower Jurassic Alum Shales Member of Loftus, Yorkshire. (A), (B) and (C) skull in lateral and ventral views; (D) and (E) brain cast in left lateral and dorsal views. From Westphal (1976).

Whitby. The pterosaur *Parapsicephalus* is unique to Loftus.

Conclusions

Loftus Alum Quarries have never been as rich in reptile remains as the Whitby coast, but the taxa are different. The ichthyosaurs are much larger than those from any other British Upper Lias locality. The two species of plesiosaur are also large and probably unique to Loftus. Of particular importance is the unique specimen of *Parapsicephalus*, the only British Upper Lias pterosaur described, and of great significance in general because of the fine brain cast that is preserved.

The combination of this historic importance and some potential for future finds gives the site considerable conservation value.