J.N.C.C.

Fossil Reptiles of Great Britain

M.J. Benton and P.S. Spencer

Department of Geology,
University of Bristol,
Bristol, UK.

GCR Editors: W.A. Wimbledon and D. Palmer

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Chapter 6

British Mid Jurassic fossil reptile sites

INTRODUCTION: BRITISH MID JURASSIC REPTILE SITES

Fossil reptiles have been found in numerous localities in the Mid Jurassic (Aalenian–Callovian) of southern England and west Scotland, but the most productive sources for reptiles are mainly in rocks of Bathonian and Callovian age. The typically shallow-water lagoonal and littoral marine facies of the Bathonian (e.g. Forest Marble) have produced many important finds of dinosaurs, pterosaurs and mammal-like reptiles (some of the last of this group in the world), in addition to marine reptiles, while the Callovian Oxford Clay is famous for its plesiosaur remains, which occur throughout the outcrop. Fuller details of British Jurassic geology, reptile evolution worldwide and British Jurassic sites are given in the introduction to Chapter 5.

British Mid Jurassic reptile sites are listed below, grouped roughly in stratigraphic order, and excluding the selected GCR sites, which are listed at the end. Details of these sites were obtained from Fox-Strangways (1892), H.B. Woodward (1894, 1895) and Waldman (1974), as well as from museum records and other unpublished sources.

Aalenian–Bajocian (Inferior Oolite)

There are relatively few reptile sites in the Inferior Oolite (Aalenian–Bajocian) of Britain. The remains are mainly teeth and jaws of the dinosaur *Megalosaurus* and odd pieces of the crocodiles *Steneosaurus* and *Teleosaurus*.

DORSET: Eype, near Bridport (SY 4592; *Teleosaurus*); Bradford Abbas (SY 5915; '*Stegosaurus*' spines); Nethercombe Quarry, Sherborne (ST 636175; type of *Megalosaurus nethercombensis* from *humphriesianum* Zone); Lower Eastham Farm, Crewkerne (ST 458104; *Ichthyosaurus* in Yeovil Sands); Cold Harbour Road Quarry, Sherborne (?ST 642173; type of *Megalosaurus hesperis* from *parkinsoni* Zone in quarry behind the houses on the north side of Cold Harbour Road, now built over).

SOMERSET: Doulting Quarries, Shepton Mallet (ST 6543; *Megalosaurus*).

GLOUCESTERSHIRE: Stroud – ?exact locality (SO 8505; *Megalosaurus*); Frith Quarry, Stroud (SO 868083; plesiosaur tooth in Lower *Trigonia* Grit [*discites* Zone, Lower Bajocian]); Rodborough Hill, Stroud (SO 8404; *Teleosaurus*); Leckhampton Quarries (SO 950185; *Steneosaurus, Teleosaurus* from the Gryphite Grit [*laeviuscula* Zone, Lower Bajocian], also fragments of *Ichthyosaurus, Pliosaurus*); Crickley Hill Quarry (SO 928164; ?*Megalosaurus*).

NORTH YORKSHIRE: White Nab, Scarborough Bay (TA 058864; ?*Cetiosaurus* from *humphriesianum* Zone; ?also *Ichthyosaurus, Plesiosaurus*).

Bathonian (including White Limestone, Great Oolite, Forest Marble, Lower Cornbrash, etc.)

Reptile remains are common in the 'Great Oolite' and Forest Marble of Gloucestershire and Oxfordshire in particular, but dozens of localities are known throughout the British Bathonian (Figures 6.1 and 6.2). The commonest forms are crocodilians (*Steneosaurus, Teleosaurus*), dinosaurs (*Megalosaurus, Cetiosaurus, 'Stegosaurus', Lexovisaurus*), pterosaurs (*Rhamphocephalus*), plesiosaurs (*'Cimoliasaurus'*), and turtles (*Protochelys*). References include Phillips (1871), H.B. Woodward (1894), A.S. Woodward (1910), Huene (1926), Arkell (1933, 1947a, 1947b), Torrens (1968, 1969a, 1969b), Palmer (1973), Sellwood and McKerrow (1974); Metcalf *et al.* (1992) and Evans and Milner (1994).

DORSET: Long Burton, near Sherborne (ST 6513; ?*Megalosaurus* from ?Forest Marble); Yetminster (ophthalmosaur; from a nodular Cornbrash limestone immediately underlying the Oxford Clay; Delair, 1986); Watton Cliff (West Cliff) (SY 451901-SY 453907; microvertebrate remains, including frogs, salamanders, lizards, crocodiles, dinosaurs from the Forest Marble: Evans, 1991, 1992b); Swyre (SY 525868; amphibian and reptile microvertebrate bones and teeth from the Forset Marble: Evans, 1991b, 1992b).

SOMERSET: Closworth (ST 5610; type of *Steneosaurus stephani* from the Cornbrash).

AVON: Bath – ?exact locality (ST 7565; type of *Steneosaurus temporalis* from the Great Oolite [*aspidoides* Zone, Upper Bathonian]).

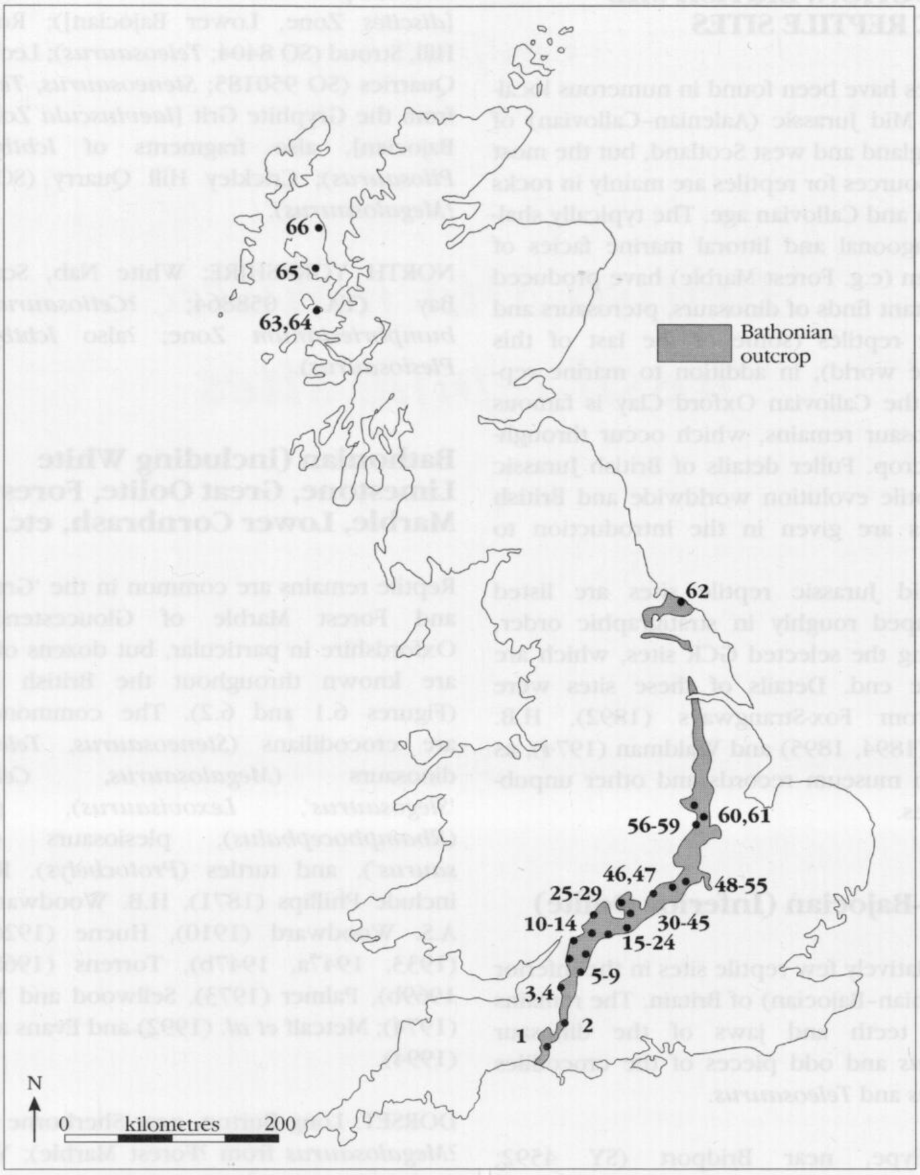

Figure 6.1 Distribution of British Bathonian tetrapod localities. Dorset: Long Burton (1), Watton Cliff (1a), Swyre (1b); Somerset: Closworth (2); Avon: Bath (3); Wiltshire: Avoncliff (4), Bradford-on-Avon (5), Frankley (6), Box Tunnel (7), Atford (8), Malmesbury (9), Leigh Delamere (9a); Gloucestershire: Minchinhampton (10), Sapperton Tunnel (11), Avening (12), Cirencester (13), Tarlton Clay Pit (13a), Sevenhampton (14), Chedworth (15), Stanton (16), Bibury (17), Naunton (18), Kyneton Thorns (19), Huntsman's Quarry (20), Eyeford (21), New Park Quarry (22), Oakham (23), Longborough Road Quarry (24); Oxfordshire: Chipping Norton (25), Sarsden (26), Over Norton (27), Sharp's Hill (28), Temple Mills Quarry (29), Enstone (30), Stonesfield (31), Slape Hill (32), Glympton (33), Bladon (34), Hanborough (35), Enslow Bridge (36), Bletchingdon Station (37), Shipton Quarry (38), Kirtlington (39), Hampton Common (40), Fritwell (41), Littlemore (42), Woodeaton (43), Ardley (44), Stratton Audley (45); Buckinghamshire: Stony Stratford (46), Olney (47); Northamptonshire: Blisworth (48), Cogenhoe (49), Northampton (50), Kingsthorpe (51), Rushden (52), Thrapston (53), Ilchester (54), Oundle (55); Leicestershire: Essendine (56), Belmesthorpe (57); Cambridgeshire: Peterborough (58), Botolph's Bridge (59), Orton Longueville, Peterborough (60), Stilton (61); Yorkshire: Scarborough (62); Hebrides: Eigg (63), Muck (64), Elgol, Skye (65a, b), Bearreraig, Skye (66). Based on information in Evans and Milner (1994), Metcalf *et al.* (1992), and original.

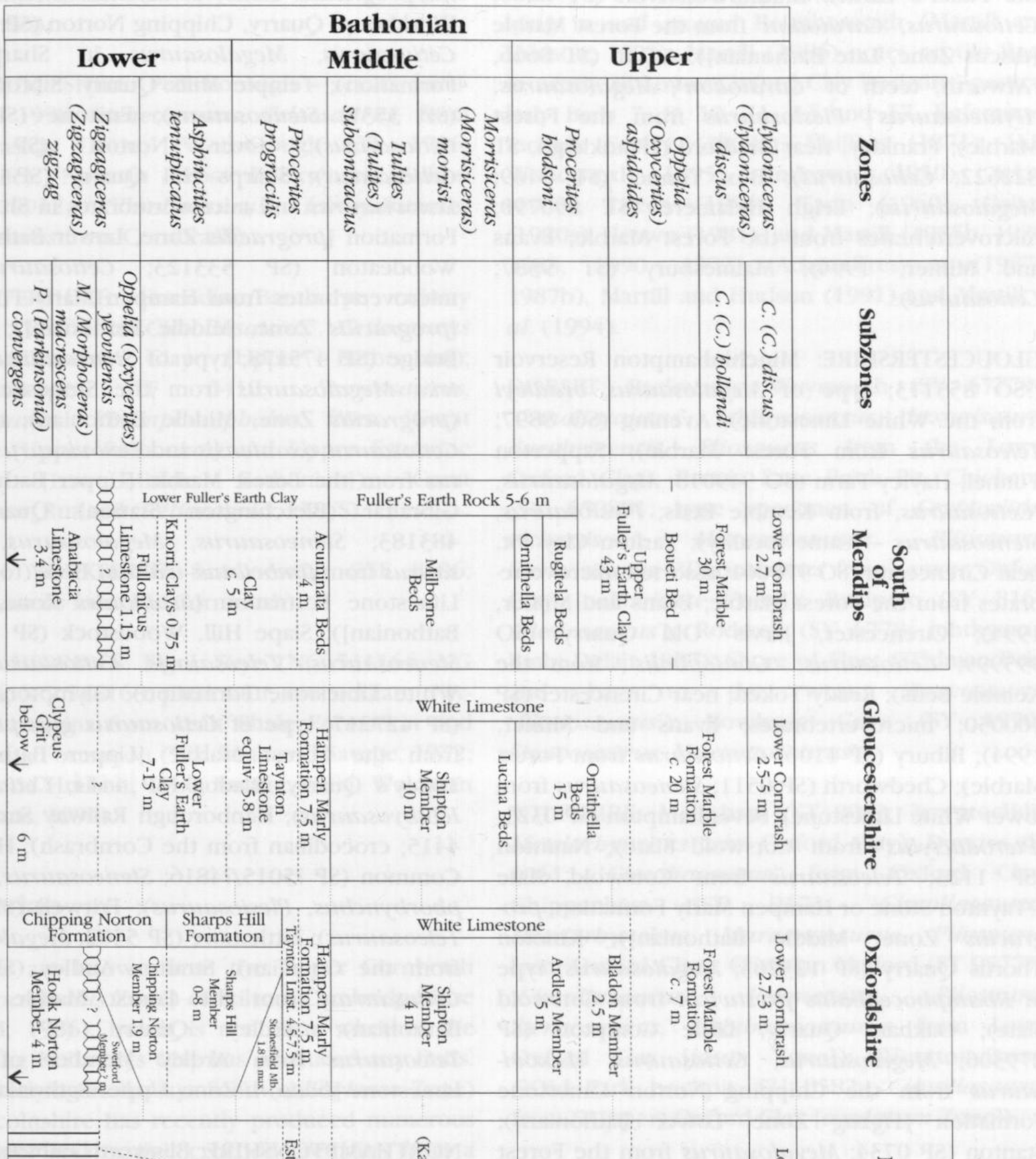

Figure 6.2 Stratigraphy of the British Bathonian (after Cope *et al.*, 1980b), with ages of the localities listed in Figure 6.1 indicated.

WILTSHIRE: Avoncliff (ST 8059; *Teleosaurus* from the Fuller's Earth); Bradford-on-Avon (ST 8260; *Cetiosaurus*, '*Cardiodon*' from the Forest Marble [discus Zone, Late Bathonian]); Atford (ST 8666, ?Atworth; teeth of '*Cardiodon*', *Megalosaurus*, '*Hylaeosaurus*', *Plesiosaurus* from the Forest Marble); Frankley, near Bradford (?Frankleigh, ST 822622; *Cetiosaurus*); Box Tunnel (ST 8469; *Megalosaurus*); Leigh Delamere (ST 890790; microvertebrates from the Forest Marble; Evans and Milner, 1994); Malmesbury (ST 9387; *Cetiosaurus*).

GLOUCESTERSHIRE: Minchinhampton Reservoir (?SO 855113; type of *Megalosaurus bradleyi* from the White Limestone); Avening (SO 8897; *Teleosaurus* from Forest Marble); Sapperton Tunnel, Hayley Farm (SO 949018; *Megalosaurus*, ?*Cetiosaurus*, from Kemble Beds; *Plesiosaurus*, *Steneosaurus* - ?same locality); Tarlton Clay Pit, near Cirencester (SO 970001; assorted microvertebrates from the Forest Marble; Evans and Milner, 1994); Cirencester, Jarvis' Old Quarry (SO 995999; *Cetiosaurus*, '*Goniopholis*', from the Kemble Beds); Ready Token, near Cirencester (SP 100050; microvertebrates; Evans and Milner, 1994); Bibury (SP 1106; *Cetiosaurus* from Forest Marble); Chedworth (SP 0511; *Steneosaurus* from lower White Limestone); Sevenhampton (SP 0321; '*Pterodactylus*' from Cotswold Slate); Naunton (SP 1123; *Teleosaurus* from Cotswold Slate [?Taynton Stone or Hampen Marly Formation, *progracilis* Zone, Middle Bathonian]); Kineton Thorns Quarry (SP 123263; *Megalosaurus*; type of *Rhamphocephalus prestwichi* from Cotswold Slate); Oakham Quarry, Little Compton (SP 279306; *Megalosaurus, Cetiosaurus*, ?*Lexovisaurus* from the Chipping Norton Limestone Formation [*zigzag* Zone, Lower Bathonian]); Stanton (SP 0734; *Megalosaurus* from the Forest Marble); Hornsleasow (Snowshill) Quarry (SP 131322; *Cetiosaurus, Megalosaurus*, small carnivorous dinosaurs, pterosaurs, crocodiles, tritylodontid, chelonians, 'lizard' from Chipping Norton Limestone Formation [*zigzag* Zone, Lower Bathonian]; (Vaughan, 1989; Metcalf *et al.*, 1992).

OXFORDSHIRE: Smith's Quarry, Sarsden (SP 300266; type of *Rhamphocephalus depressirostris, Megalosaurus, Cetiosaurus* from the 'basement bed of Great Oolite Series' [?Sharp's Hill Beds, Lower Bathonian]); Padley's Quarry, Chapelhouse, Chipping Norton (SP 329281; *Cetiosaurus* from Sharps Hill Member [*tenuiplicatus/progracilis* Zone, Lower-Middle Bathonian]); Workhouse Quarry, Chipping Norton (SP 318276; *Cetiosaurus*, *Megalosaurus* in Sharps Hill Formation); Temple Mills Quarry, Sibford Ferris (SP 3537; *Steneosaurus*); Enstone (SP 3724; *Cetiosaurus*); Over Norton (SP 3128; *Cetiosaurus*); Sharps Hill Quarry (SP 338358; *Lexovisaurus* and microvertebrates in Sharps Hill Formation [*progracilis* Zone, Lower Bathonian]); Woodeaton (SP 533123; *Cetiosaurus* and microvertebrates from Hampen Marly Formation [*progracilis* Zone, Middle Bathonian]); Enslow Bridge (SP 475178; type of *Steneosaurus meretrix*; *Megalosaurus* from the Stonesfield Slate (*progracilis* Zone, Middle Bathonian); types of *Cetiosaurus oxoniensis* and *Lexovisaurus? vetustus* from the Forest Marble [Upper Bathonian]); Gibraltar (Bletchington Station) Quarry (SP 483183; *Steneosaurus*, *Megalosaurus*, *Cetiosaurus* from *fimbriatus-waltoni* Beds (top White Limestone Formation [*aspidoides* Zone, Upper Bathonian]); Slape Hill, Woodstock (SP 423196; *Steneosaurus, Teleosaurus, Cetiosaurus* from White Limestone Formation); Glympton Quarry (SP 427217; type of *Cetiosaurus glymptonensis* from the Forest Marble [Upper Bathonian]); Tolley's Quarry, Bladon (SP 4414; *Cetiosaurus*, *Ichthyosaurus*); Hanborough Railway Station (SP 4415; crocodilian from the Cornbrash); Hampton Common (SP ?5015/?4816; *Steneosaurus*, *Rhamphorhynchus*, *Plesiosaurus*); Fritwell (SP 5229; *Teleosaurus*); Littlemore (SP 5302; *Megalosaurus* from the Corallian); Stratton Audley (SP 6026; *Cetiosaurus* from the Forest Marble (Upper Bathonian); Ardley Quarry (SP 539272; *Teleosaurus* from Ardley Member of White Limestone [*hodsoni* Zone, Upper Bathonian]).

NORTHAMPTONSHIRE: Blisworth railway cutting (SP 725543; *Cetiosaurus*, *Steneosaurus* from 'Great Oolite' [Blisworth Limestone, *hodsoni* Zone, Upper Bathonian]); Cogenhoe (SP 8360; *Cetiosaurus* from Cornbrash); Northampton, Buttock's Booth (SP 7864; *Steneosaurus* from 'Great Oolite' [Blisworth Limestone, *hodsoni* Zone, Upper Bathonian]); Kingsthorpe, Northampton (SP 7563; *Steneosaurus* from 'Great Oolite'); Rushden Quarry (SP 951661; '*Cimoliasaurus*' from Cornbrash); Irchester (SP 8968; *Steneosaurus*); Islip Ironstone Quarry, Thrapston (SP 975782 etc.; *Steneosaurus, Megalosaurus, Muraenosaurus* from Cornbrash); Oundle (TL 0388; crocodile from 'Great Oolite').

BUCKINGHAMSHIRE: Olney (SP 8851; *Plesiosaurus, Cetiosaurus* from the top of the Cornbrash).

CAMBRIDGESHIRE: Peterborough – ?exact locality (TL 1998; *Steneosaurus, Teleosaurus,* from Cornbrash); Orton, Peterborough (TL 1796; crocodile); Norman Cross Brickworks, Stilton (TL 170912; '*Cimoliasaurus*', *Ichthyosaurus, Teleosaurus* from Cornbrash).

LEICESTERSHIRE: Essendine/Banthorpe railway cutting (TF 0412; '*Cimoliasaurus*', *Cetiosaurus* from Blisworth Clay [Upper Bathonian]); Belmesthorpe (TF 0410; *Steneosaurus, Teleosaurus, Rhamphocephalus* from 'Great Oolite' [Upper Bathonian] and Upper Estuarine 'Series' [Lower-Middle Bathonian]); Great Casterton, Rutland (*Cetiosaurus*, LEICS).

NORTH YORKSHIRE: Scarborough (?SE 8606; *Plesiosaurus* from the Cornbrash).

INNER HEBRIDES: Elgol, Skye (NG 531164, NG 519154, NG 518168; plesiosaur, crocodilian, tritylodont remains from Lealt Shale Formation and Kilmaluag Formation (Waldman and Savage, 1972; Harris and Hudson, 1980; Savage, 1984; Waldman and Evans, 1994).

Callovian

Reptiles are known from the Upper Cornbrash (*macrocephalus* Zone) of Stilton, Cambridgeshire (Martill, 1986), but it is not clear whether the overlying Kellaways Clay has produced any finds. The overlying Kellaways Sand (*calloviense* Zone) of Lincolnshire has recently produced numerous plesiosaur and marine crocodile remains from a scattering of temporary exposures around Lincoln (Brown, 1990; Brown and Keen, 1991) and in the Peterborough district (Martill, 1985b), and the Kellaways Rock (also *calloviense* Zone) has yielded a plesiosaur (*Cryptoclidus*) in Yorkshire. The Lower Oxford Clay (particularly the *jason* Zone) has produced abundant plesiosaurs (*Cryptoclidus, Liopleurodon, Muraenosaurus, Peloneustes, Pliosaurus, Simolestes, Tricleidus*), ichthyosaurs (*Ophthalmosaurus*), crocodilians (*Metriorhynchus, Steneosaurus*), pterosaurs ('*Rhamphorhynchus*') and dinosaurs (*Callovosaurus, Cetiosauriscus, Dryosaurus, Eustreptospondylus, Lexovisaurus, Metriacanthosaurus, Ornithopsis*, and *Sarcolestes*) from localities from Dorset to Peterborough, with the richest localities lying in and around Peterborough (Martill and Hudson, 1991). Martill (1986) notes reptile finds in nearly all Lower Oxford Clay horizons, particularly Beds 7, 8, 10, 11, 13 and 17. References include Seeley (1869a), Phillips (1871), H.B. Woodward (1895), Andrews (1910), Arkell (1933), Leeds (1956), Tarlo (1960), Galton (1980a), Brown (1981), and Martill (1985b, 1986, 1988, 1990, 1992), Adams-Tresman (1987a, 1987b), Martill and Hudson (1991) and Martill *et al*. (1994).

DORSET: Backwater, Weymouth (SY 677790; '*Cimoliasaurus*', *Ichthyosaurus, Lexovisaurus durobrivensis, Pliosaurus* from the Lower Oxford Clay); Putton Lane Brick Pit, Chickerell (SY 650801; type specimen of *Cryptoclidus richardsoni, Muraenosaurus, Pliosaurus, Steneosaurus, ?Dacentrurus* from Lower Oxford Clay [*calloviense* Zone]); Radipole (SY 8167; '*Plesiosaurus*'); Rodwell (SY 6778; ichthyosaur limb; Delair 1987); Shore of Fleet (?Tidman Point and bay to the west; *Steneosaurus*, '*Plesiosaurus*'); Bowleaze Cove (SY 19702; *Steneosaurus*, *Muraenosaurus*).

WILTSHIRE: Melksham (ST 9063; ?cryptoclidid, *Metriorhynchus* from Oxford Clay); Devizes (SU 0061; '*Cimoliasaurus*' from Oxford Clay); Chippenham (ST 9173; '*Cimoliasaurus*', *Metriorhynchus, Muraenosaurus, Pliosaurus*, from Oxford Clay); Christian Malford (ST 957774; '*Cimoliasaurus*', *Peloneustes, Pliosaurus, Steneosaurus, Ophthalmosaurus* from Lower Oxford Clay [*jason* Zone]); Wootton–Bassett (?Old Park brickpit, SU 0582; '*Cimoliasaurus*' from (?Upper) Oxford Clay [*cordatum* Zone]).

OXFORDSHIRE: Long Marston [?= Marston] (SP 5309; '*Cimoliasaurus*', *Steneosaurus* from Oxford Clay); Shotover Hill (SP 5706; '*Cimoliasaurus*', *Pliosaurus* from Oxford Clay); Cowley Field, Oxford (SP 5703, pit filled; '*Cimoliasaurus*', *Ophthalmosaurus, Cryptoclidus*, type of '*Plesiosaurus*' *hexagonalis* [*nomen dubium*] from Oxford Clay); St Clements, Oxford (SP 5306, pits filled; *Ophthalmosaurus, Rhamphorhynchus* from Oxford Clay); Summertown Brick Pit, near Oxford (SP 5109; type of *Eustreptospondylus oxoniensis, Muraenosaurus plicatus* [*nomen dubium*], '*Cimoliasaurus*' *oxoniensis*, as well as crocodiles, *Ophthalmosaurus* from Middle Oxford Clay [Upper Callovian, *athleta* Zone]); Wolvercote Brick Pit (SP 494105; '*Megalosaurus*', *Cryptoclidus*, *Ophthalmosaurus* from Oxford Clay); Shellingford Crossroads Quarry (SU 326942; *Pliosaurus*, ?*Goniopholis* from Oxford Clay); St Edmund Hall, Oxford (SP 518063; crocodile from Oxford Clay [*lamberti* Zone]); Iffley Road Sports Ground, Oxford (SP 524054; '*Plesiosaurus*' from Oxford Clay); Cumnor (?SP 4704; '*Pliosaurus*' from Oxford Clay).

BUCKINGHAMSHIRE: Calvert Brick Pit, and other localities (?), Buckingham (SP 6933; *Ophthalmosaurus* from Oxford Clay); Bletchley Brick Works (SP 868327; *Ophthalmosaurus* from Oxford Clay); Newton Longville Brickworks (SP 853322; *Pliosaurus* from Oxford Clay); Fenny Stratford (SP 8834; *Steneosaurus* from Oxford Clay); Caldecotte Reservoir, Milton Keynes (SP 892352; *Ophthalmosaurus* from Lower Oxford Clay [*coronatum* Zone]; Martill, 1986).

BEDFORDSHIRE: Marston Moretaine (SP 9941; *Peloneustes* from Oxford Clay); Stewartby Clay Pit (TL 0142; *Ophthalmosaurus*, *Liopleurodon* from Oxford Clay); Kempston (?Clay Pits around TL 0345, or Green-End Old Pit, TL 007475; *Peloneustes* from Oxford Clay); Bedford (TL 0449; '*Cimoliasaurus*', ?*Lexovisaurus*, *Steneosaurus* from Oxford Clay); Ravensden, Bedford (TL 0754; *Pliosaurus* in Oxford Clay).

CAMBRIDGESHIRE: Orton Brick Pit (TL 165937; *Cryptoclidus*, *Ophthalmosaurus* from Lower Oxford Clay); Norman Cross Brick Pit (TL 173916; unidentifiable reptile from Lower Oxford Clay); Yaxley Brick Pit (TL 178932; *Cryptoclidus*, *Pliosaurus*, *Steneosaurus*, *Metriorhynchus* from Lower Oxford Clay); Eyebury Brick and Tile Works (TL 1859; type of *Pliosaurus evansi* from Lower Oxford Clay); St Neots Brickyard (TL 1860; *Pliosaurus* from Oxford Clay [*coronatum* Zone]); London Road, Peterborough (?TL1896; *Muraenosaurus*, *Cryptoclidus*, *Steneosaurus*, *Metriorhynchus*, *Cetiosauriscus* from Lower Oxford Clay); Woodston Lodge, Peterborough (TL 1897; *Ophthalmosaurus*, *Liopleurodon* from Oxford Clay); Fletton Brick Works (various pits around TL 1995; have probably yielded the majority of 'Peterborough' reptiles; types of *Neopterygius entheciodon*, *Ophthalmosaurus icenicus*, *Apractocleidus teretipes*, *Cryptoclidus eurymerus*, *Muraenosaurus durobrivensis*, *M. leedsi*, *Peloneustes philarchus*, *Simolestes vorax*, *Tricleidus seeleyi*, *Metriorhynchus cultridens*, *M. durobrivensis*, *Mycterosuchus nasutus*, *Steneosaurus depressus*, *S.durobrivensis*, *S. hulkei*, *S. leedsi*, *S. obtusidens*, *Cetiosauriscus leedsi*, *Lexovisaurus durobrivensis*, '*Stegosaurus*' *priscus*, *Sarcolestes leedsi*, amongst others from Lower Oxford Clay [*jason* Zone]); Peterborough Gas Works (?TL 199991; type of *Ornithopsis leedsi* probably from the junction of the Kellaways Clay with the overlying Kellaways Sand; Martill, 1986; Brown and Keen, 1991); Barrow Pit, Farcet (TL 200958; *Cryptoclidus*, *Liopleurodon*, *Metriorhynchus* from Lower Oxford Clay); Stanground (TL 2097; *Ophthalmosaurus*, *Steneosaurus?*, *Muraenosaurus* from Lower Oxford Clay [*jason* Zone]); Dogsthorpe Brick Pit, Peterborough (TF 219019; *Metriorhynchus*? from Lower Oxford Clay [*jason* Zone]; *Liopleurodon*; Dawn, 1991); Eye (TL 2202; *Steneosaurus* from Lower Oxford Clay); Whittlesey Clay Pits (TL 252976 and/or TL 250976; '*Cimoliasaurus*', *Lexovisaurus durobrivensis*, *Muraenosaurus*, *Ichthyosaurus*, *Peloneustes*, *Pliosaurus*, *Steneosaurus*, *Metriorhynchus* from Lower Oxford Clay [*jason* Zone]); St Ives Brickyard (?TL 304718; type of *Rhamphorhynchus jessoni*, *Pliosaurus* from Middle Oxford Clay).

LINCOLNSHIRE: Reepham (TF 046747; *Cryptoclidus eurymerus*, *Muraenosaurus leedsii*, *Steneosaurus* sp., *Metriorhynchus* sp., *Liopleurodon ferox* from the Kellaways Sand [*calloviense* Zone]; Brown, 1990; Brown and Keen, 1991).

HUMBERSIDE: Mill Hill, Elloughton, near Brough (SE 942278; *Cryptoclidus*, *Muraenosaurus*, etc. from Kellaways Sand [*calloviense* Zone]; Brown and Keen, 1991).

YORKSHIRE: Hackness, Scarborough (SE 9690; *Ichthyosaurus*, *Plesiosaurus*); Gristhorpe (TA 1283; *Steneosaurus* from Kellaways Beds).

Six reptile-bearing sites have been selected as GCR sites from the huge numbers that have been noted in the literature, as those representing the greatest range of faunas and preservation types, and as having the greatest potential for future collecting. These are all Bathonian; none of the Aalenian or Bajocian sites was strong enough for inclusion. In addition, none of the important Callovian localities could be selected because they have either been lost to infill or degradation, or they are currently worked in a way that prevents the conservation of fossiliferous horizons. In addition, it is not possible to say that any one or two Oxford Clay sites is likely to be more or less productive than any other. The Mid Jurassic sites are:

1. Kildonnan and Eilean Thuilm, Eigg (NM 495870, NM 483913). Mid Jurassic (?Lower Bathonian). Kildonnan Member, Great Estuarine Group.
2. New Park Quarry, Longborough, Gloucestershire (SP 171296). Mid Jurassic (Lower Bathonian), Chipping Norton Member, Chipping Norton Formation.
3. Stonesfield, Oxfordshire (SP 387171). Mid Jurassic (Middle Bathonian), Stonesfield Member, Sharps Hill Formation.
4. Huntsman's Quarry, Naunton, Gloucestershire (SP 126253). Mid Jurassic (Middle Bathonian), Eyford Member ('Cotswold Slates').
5. Shipton-on-Cherwell Quarry, north-west corner, Oxfordshire (SP 475178). Mid Jurassic (Upper Bathonian), Ardley and Bladon members, White Limestone Formation, Forest Marble Formation and Lower Cornbrash.
6. Kirtlington Old Cement Works, Kirtlington, Oxfordshire (SP 494199). Mid Jurassic (Upper Bathonian), White Limestone Formation to Lower Cornbrash.

MID JURASSIC (BATHONIAN) OF SCOTLAND

The lagoonal facies of the Great Estuarine Group (Bathonian) of the Inner Hebrides in west Scotland have been known as sites for reptiles since the mid-19th century when Hugh Miller noted reptile material, mainly of plesiosaurs, in the Kildonnan Member of Eigg ('Hugh Miller's Bone Bed'). Further remains of reptiles have been found recently throughout the Group from several locations (Harris and Hudson, 1980; Martill, 1985a). Productive Bathonian sites in the Great Estuarine Group are restricted to the Kilmalaug Formation (Figure 6.2), in which some of the youngest tritylodontid mammal-like reptiles, and other specimens of reptiles and mammals, have been found (Waldman and Savage, 1972; Savage, 1984; Waldman and Evans, 1994), and to the Kildonnan Member of the Lealt Shale Formation.

KILDONNAN AND EILEAN THUILM, EIGG (NM 495870, NM 483913)

Highlights

Kildonnan and Eilean Thuilm, Eigg are the site of Hugh Miller's Bone Bed, a famous and extraordinary occurrence in the Middle Jurassic of the Hebrides (Figure 6.3). Reptile bones were first found here in 1844 and 1845 and since then, bones of marine turtles, crocodiles and plesiosaurs have been found. This is unusual, as most other British Bathonian sites represent fully terrestrial situations.

Introduction

Hugh Miller first found reptile bones in the Great Estuarine Group on the northern and eastern coasts of the island of Eigg in 1844 and 1845. The bone bed, now known as Hugh Miller's Reptile Bed, was relocated early this century by the Geological Survey fossil collector Tait (Barrow, 1908) and again in the 1950s, and several small collections of bones have been made since then. The bone-bearing horizons may be seen *in situ* at Kildonnan, while only isolated blocks containing bones have been found on the reworked raised beach opposite the small island Eilean Thuilm.

Hudson (1966) described the location, exposure and sedimentology of the Reptile Bed in great detail. The locality on the north coast, opposite Eilean Thuilm, is readily accessible from the settlement of Cleadale on the western side of the island, by crossing a shoulder of the main raised plateau between Guala Mhor and Leit an Aonaich. The eastern site is now reached in a rather different way from that described by Hudson (1966): it is best to descend the cliff further north from Kildonnan, at the field boundary near NM 492858 named Bealach Clith, where a well-marked path leads diagonally down the cliff northwards. The dolerite sill and the shelter rocks are still to be seen, as Hudson (1966) describes.

Hugh Miller visited Eigg in the Free Church yacht *Betsey* in 1844 and 1845. In 1844 he found reptile bones in loose blocks opposite the island of Eilean Thuilm at the northern tip of the island; he called this locality Ru-Stoir, a name which does not occur on any map. In 1845 he found the bed *in situ* on the eastern coast of the island about midway between the headland Rudha nan

Figure 6.3 Hugh Miller's Bone Bed on Eigg, showing collecting operations in 1972. (Photo: R.J.G. Savage.)

Tri Clach and the settlement of Kildonnan. Miller described the locality in his book *The Cruise of the Betsey* (1858). Miller's collections went to the Royal Scottish Museum, Edinburgh, where they remained unrecognized for nearly a century.

The Reptile Bed was referred to the Lower Shales of the Great Estuarine Series by Barrow (1908), who listed some of the fossils. Hudson (1962) established that the Great Estuarine Group was Late Bajocian and Bathonian in age and that the 'Lower Shales' were equivalent to the *Estheria* Shales of Skye. He designated the outcrop north of Kildonnan, which includes the Reptile Bed, the type locality of the *Mytilus* Shales, a lower subdivision of the Lower Bathonian *Estheria* Shales.

Hudson (1966) rediscovered the precise locations of the Reptile Bed and collected some reptile bones. Barney Newman also made collections in 1961 (Newman, *in* Persson, 1963), but these have never been described. Further collections were made by D.S. Brown (The University, Newcastle upon Tyne) in 1974–7, and these may be described in the future (D.S. Brown, pers. comm., 1993).

Description

Harris and Hudson (1980) revised the stratigraphy of the Great Estuarine Group of the Inner Hebrides, and named the unit with the Reptile Bed the Kildonnan Member of the Lealt Shale Formation. The new name, Kildonnan Member, is directly equivalent to the older term *Mytilus* Shales. It falls in the lower portion of the Great Estuarine Group, near the base of the Bathonian (Hudson, *in* Cope *et al.*, 1980b). Hudson (1966) and Harris and Hudson (1980, p. 239; fig. 6, p. 237) identify the occurrence of two bone beds, the lower horizon being Hugh Miller's Bone Bed ('Reptile Bed') and the upper, occurring 12.5 m above, containing the remains of fish only ('Fish Bed').

The section of the Kildonnan Member exposed in patches on the wave-swept bench and beach is based on Hudson (1966), Harris and Hudson

(1980, p. 237) and J.D. Hudson (pers. comm., 1993):

	Thickness (m)
9. Algal Bed	0.40
8. Limestones with *Placunopsis*	*c.* 2.00
7. *Unio* Bed	0.22
6. Shales with *Neomiodon*, etc.; includes Bivalve–Septarian Bed and Fish Bed	1.80
5. Shales with *Praemytilus*	*c.* 12.00
4. Complex Bed (sandstone with abundant phosphatic debris)	1.00
3. Shales with small *Praemytilus*	2.50
2. Reptile Bed, limestone	0.15
1. Shales with fish scales and *Praemytilus* (base not exposed)	3.00
Total	*c.* 23.07

The Reptile Bed is a very hard, dark grey, shelly sideritic limestone, only a few centimetres thick, which weathers to a deep red on the surface. It contains shells (abundant gastropods and rarer bivalves), as well as black, phosphatic fish scales, teeth and fin spines and black reptile bones. Some layers contain *Unio* shells which often have a nacreous appearance. The fish remains are noted as scales of *Lepidotus*? and teeth of *Hybodus, Acrodus* and ?*Saurichthys apicalis* Agassiz (Miller, 1858; Barrow, 1908). Patterson (*in* Hudson, 1966, p. 275) confirmed one or two species of *Hybodus* from Newman's more recent collections. Some of Newman's non-plesiosaurian specimens appear to have come from a greenish marl, which is clearly not the Reptile Bed, but may be from a neighbouring horizon (D.S. Brown, pers. comm., 1993).

Fauna

The reptiles from Hugh Miller's Reptile Bed have never been described fully or figured, but various details may be gleaned from the literature and other sources. Miller (1858) recorded crocodilian ribs and many plesiosaur bones from the northern locality and plesiosaur bones from the eastern locality. Barrow (1908) listed a ?crocodilian tooth, a ?dinosaur vertebra and other reptilian remains from the northern shore, and a pterosaur bone, reptilian vertebra and other bones from the eastern shore.

Newman (*in* Persson, 1963, p. 22; *in* Hudson, 1966, p. 275) noted turtles, crocodilians, turtles and plesiosaurs in his collections, a fauna confirmed by D.S. Brown (pers. comm., 1993), but Brown stresses that the Reptile Bed itself apparently yields only plesiosaur remains and fish remains. The plesiosaur material includes skull elements, vertebrae, ribs, pelvic and limb elements. None of these remains was found associated, although Martill (1985a) noted an articulated plesiosaur specimen from Eigg (noted as 'Mull' in his account). Newman considers that two kinds of plesiosaurs are present. The reptile collections are located as follows: Miller Collection (NMS); Newman Collection (BMNH R8159–61, and unnumb.); Brown Collection, Newcastle upon Tyne, Dental School (temporary). Brown (pers. comm., 1983), lists the known reptile remains as:

1. ?crocodilian elements (Newman Coll.; Brown Coll.);
2. ?turtle bones (Newman Coll.; Brown Coll.);
3. plesiosaur: vertebrae, ribs, limb and girdle elements, several teeth and disarticulated skull bones of an elasmosaur, a long-necked form, rather like the Late Jurassic *Muraenosaurus.*

Interpretation

Hudson (1962, 1966) suggested that the Great Estuarine Group was deposited in shallow lagoons with variable, but generally low, salinity. Harris and Hudson (1980) noted desiccation cracks and algal stromatolites at several horizons which demonstrated that the lagoons at times dried out, or had extensive marginal mud flats. The rarity of *in situ* plant remains further suggested that, during Great Estuarine Group times, the Inner Hebrides area never became a fully vegetated land surface. The Reptile Bed could have originated as a winnowed shell and bone concentrate on the lagoon floor. The abundant and well-preserved *Unio* shells cannot have travelled far, and they suggest that the water could have been almost fresh at times. Dispersed reptile bones and fish remains are to be accounted for by slow rates of deposition rather than by long-distance transport.

Vertebrate remains, consisting mainly fish teeth and scales, are common throughout the Great Estuarine Group, but only in the Kildonnan Member of the Lealt Shales on Eigg are they concentrated to form bone beds, and it is only at this location that the bones of marine reptiles are found in any abundance.

Comparison with other localities

The most closely comparable localities to Hugh Miller's Reptile Bed occur on Skye in units of the Great Estuarine Group:

1. 'Vertebrate Beds' with reptile bones in the upper part of the Kilmaluag Formation (formerly called Ostracod Limestones) near the top of the Great Estuarine Group, on the northern side of Glen Scaladal, Elgol (NG 519165; Harris and Hudson, 1980, pp. 244–6, who give the map reference in reverse). Waldman and Savage (1972) noted true mammals and therapsids (*Stereognathus hebridicus*) from 'marlstone bands' at their unspecified locality UB 7111, which is essentially the same site (NG 520157, fide Evans and Milner, 1994). Also the site of Waldman and Evans's (1994) choristodere skull, from a location on the shore just north of Glen Scaladal.
2. Kilmaluag Formation (?) on the shore and cliff south of Glen Scaladal 'at a small promontory of limestone about 100 m South of Carn Mor' (J.D. Hudson, pers. comm., 1982) – ?the promontory at NG 519154 (Andrews, 1985, p. 1135).
3. Hudson and Morton (1969, p. D29) noted a plesiosaur from the Bearreraig Sandstone (Late Bajocian) near Rigg, Trotternish (NG 521566).
4. Andrews and Hudson (1984) reported a single large cast of a dinosaur footprint from the Lonfearn Member of the Lealt Shale Formation, beneath the cliffs south of Rudha nam Braithairean (NG 526625), Trotternish, Skye.
5. Martill (1985a, p. 162) notes six ichthyosaurs from the Great Estuarine Group of the Isle of Skye. No more locality information given.

Elsewhere in Britain, plesiosaur remains are rare in the Bathonian. A plesiosaur humerus (CAMSM J5736) has been found in the Cornbrash (Callovian) of Scarborough (?exact locality), and several plesiosaur teeth, vertebrae and limb bones are known from the Stonesfield Slate (Mid Bathonian) of Stonesfield, Oxfordshire (BMNH, CAMSM – see Stonesfield report). Occasional teeth and isolated bones ascribed to plesiosaurs have been noted from several other localities in the Bathonian of Oxfordshire, Buckinghamshire and Cambridgeshire, but none of these matches the more extensive remains from Eigg.

Conclusions

The two localities of Hugh Miller's Reptile Bed on Eigg are historically important, and they have yielded small collections of identifiable reptile bones. The sites are still accessible, depending on how storms have moved the loose boulders on the beach, and the Reptile Bed is readily identifiable, but thin. The sites are better documented than their approximate equivalents on Skye. There are no comparable formations outside the Hebrides. These are the best Bathonian sites for marine reptiles and an important intermediate between the well-known Early and Late Jurassic marine faunas, hence their national importance and considerable conservation value.

MID JURASSIC (BATHONIAN) OF SOUTHERN ENGLAND

The remains of dinosaurs, crocodilians, pterosaurs, plesiosaurs and turtles are known from a large number of localities in the Bathonian of Gloucestershire and Oxfordshire (Figure 6.1). Many of these are important from an historical point of view as well as being productive sources of reptiles. The majority of the remains come from rocks that are interpreted as subaerial lagoonal and lacustrine deposits, and these document a number of major faunal changes. Most notable was the disappearance of the tritylodontids, the last surviving members of the essentially Permo-Triassic mammal-like reptiles. A number of new groups appeared, including the choristoderes, the avialan dinosaurs, and possibly the lizards (see Figure 6.5). These British records are international 'firsts' and 'lasts' (more detail in the introduction to Chapter 4).

The GCR sites, New Park Quarry (SP 171296), Stonesfield (SP 387171), Huntsman's Quarry (SP 126253), Shipton-on-Cherwell (SP 475178) and Kirtlington (SP 494199), provide a coverage of faunas which range in age from the Early to the Late Bathonian.

NEW PARK QUARRY, LONGBOROUGH, GLOUCESTERSHIRE (SP 176282)

Highlights

New Park Quarry is the source of specimens of fossil crocodiles and dinosaurs, including the theropod *Megalosaurus*, the sauropod *Cetiosaurus* and the stegosaur *Lexovisaurus*. The site is important as one of the oldest Bathonian sites in the world.

Introduction

New Park Quarry, Longborough, 3 km NNW of Stow-on-the-Wold, has yielded the finest fauna of Mid Jurassic (Bathonian) dinosaurs in Britain this century. The quarry was in operation in the 1920s when the remains of several crocodiles came to light (Richardson, 1929). Around 1935, a collection of well-preserved dinosaur bones, representing several genera, was obtained (Gardiner, 1935), and the British Association for the Advancement of Science sponsored an excavation that produced many more specimens (Gardiner, 1937, 1938).

Figure 6.4 Exposure of the Chipping Norton Limestone Member in New Park Quarry. Reptile bones were recovered from the top of the underlying Hook Norton Limestone Member, in the floor of the quarry. (Photo: M.J. Benton.)

Reynolds (1939), Galton and Powell (1983) and Galton (1985b) described the stegosaur remains, some of the oldest of that group in the world, but the other material is yet to be studied. The quarry still offers good exposures in the Chipping Norton Limestone Member and could be re-excavated for further reptile finds (Figure 6.4).

Description

H.B. Woodward (1894, pp. 143–4) briefly described the geology of New Park Quarry, and Richardson (1929, p. 89) added a section. Arkell and Donovan (1952, p. 249) gave a fuller account with stratigraphic information:

	Thickness ft	in
Chipping Norton Limestone		
6. Flaggy oyster limestone. *Exogyra* sp.	2	0
5. Marl with oysters, chiefly *Exogyra* sp.		10
4. False-bedded, white, shelly oolite	*c.* 18	0
?Roundhill Clay		
3. Impersistent seam of clay and locally sandy marl with small irony claystone pellets		nil to 8
Hook Norton Limestone		
2. Nodular buff limestones, with dark fossil bones 1–2 feet down. *Parkinsonia neuffensis* auct. from this bed, *teste* P.J. Channon	5	0
1. Brownish and buff limestones with sandy marl partings	seen to 5	0

The Chipping Norton Limestone (5–6 m thick) consists of wavy-bedded white or cream coloured sandy limestone which weathers to a reddish colour in places. Low-angle cross-beds are present. The rock takes on a more nodular appearance in the lower portions. Richardson (1929, p. 89) reported that the 'black pebble-like bodies' (in bed 3 of Arkell and Donovan 1952) consisted of manganese, limonite, calcium carbonate and phosphate. The lower unit (1–2 m visible; bed 1 of Arkell and Donovan, 1952) is similar to the main limestone, but appears to be less nodular.

Richardson (1929, p. 89) noted crocodiles (9 fragments of a mandible of *Steneosaurus* and a scute of *Teleosaurus subulidens*) in the Chipping Norton Limestone (Arkell's bed 4), and the bones collected in the 1930s were found in a hard cream-coloured limestone which was worked for road metal (Reynolds, 1939, p. 193). Arkell and Donovan (1952, p. 249) clearly identify their bed 2 as the source of bones of *Steneosaurus* and *Megalosaurus*, and they indicate that the other bones in the British Museum and the Stroud Museum came from this horizon.

The sequence at New Park Quarry spans most of the Chipping Norton Formation, which is dated as belonging to the *zigzag* Zone, the basal zone of the Early Bathonian (Torrens, *in* Cope *et al.*, 1980b). The Chipping Norton Limestone (=Chipping Norton Member) is ascribed to the *yeovilensis* Subzone of the *zigzag* Zone on the basis of specimens of the ammonite *Oppelia* (Torrens, 1969b, p. 74). The Hook Norton Limestone (=Hook Norton Member) at New Park Quarry has yielded specimens of the ammonites *Parkinsonia neuffensis* Oppel and *P. subgalatea* Buckman (Reynolds, 1939; Arkell, 1951–8, p. 160; Arkell and Donovan, 1952, p. 249), which indicate a zonal assignment to the *convergens* Subzone (Torrens, 1969b), the lowest Subzone of the *zigzag* Zone, hence earliest Bathonian (Torrens, 1969b; Cope *et al.*, 1980b, fig. 6a). Thus, some of the crocodiles come from the top of the *zigzag* Zone, and the dinosaurs and some crocodiles from the base of the *zigzag* Zone.

The reptile remains from New Park Quarry in museum collections have been prepared so that no matrix remains; hence, nothing can be said of the relationship of the bones to the sediment nor of the relative association of the bones. Nevertheless, it seems evident that all elements were disarticulated and must have been transported at least a short distance. There is no sign of major abrasion to the bones, although some delicate processes have been lost.

Fauna

The reptilian fauna from New Park Quarry was described by Reynolds (1939), and the species are listed together with a note of major specimens in the BMNH, BGS(GSM) and SDM. The Stroud Museum display of these specimens is described by Walrond (1976):

Archosauria: Crocodylia: Thalattosuchia:
Steneosauridae
Steneosaurus cf. *subulidens* (Phillips, 1871)
BMNH R.6307; BGS(GSM) 37520–2 (mentioned, Richardson 1929, p. 89); SDM 44.42, 44–8, 51–7, 59–68

Dinosauria: Saurischia: Theropoda: Megalosauridae
Megalosaurus sp.
BMNH R.9666–76, R.9678–9, R.9681–7, R.9689–700; SDM 44. 1, 4–10, 12–5, 18, 21, 23–6

Dinosauria: Saurischia: Sauropoda: Cetiosauridae
Cetiosaurus sp.
SDM 44. 30–40

Dinosauria: Ornithischia: Stegosauria: Stegosauridae
Lexovisaurus? vetustus (Huene, 1910)
SDM 44. 41; BMNH R.5838

Interpretation

The remains of the marine crocodile *Steneosaurus* include skull bones, a braincase, several partial snouts, isolated teeth, scutes, vertebrae and a scapula. The New Park crocodile evidently had a skull 0.3–0.6 m long and probably a total body length of 1.5–3.0 m, thus a fairly large animal. Comparisons are difficult because of the confused taxonomy of Jurassic marine long-snouted crocodiles and, in particular, the distinction between the genera *Pelagosaurus, Steneosaurus* and *Teleosaurus* and the multiplicity of their included species (Westphal, 1962; Steel, 1973). Bathonian species include *S. boutilieri, T. cadomensis, T. geoffroyi* and *T. gladius* from the 'Fullers Earth' and 'Great Oolite' of Normandy; *S. brevidens, S. latifrons, T. cadomensis* and *T. subulidens* from the 'Great Oolite' of Oxfordshire and Northamptonshire; and *S. stephani* from the Cornbrash of Closworth, Somerset. All of these specimens come from the Mid or Late Bathonian, younger than the New Park material.

The remains of *Megalosaurus* include a good sacrum, some caudal vertebrae, a rib, two coracoids, a scapula, a humerus, three ischia, a femur, a metatarsal and a partial lower jaw. The postcranial bones are well preserved, and the lower jaw shows seven teeth in various stages of growth. Other Mid Jurassic material of *Megalosaurus* is known from the Upper Inferior Oolite of Sherborne, Dorset (*M. hesperis* Waldman, 1974; *M. nethercombensis* Huene, 1923), the Stonesfield Slate (*sensu lato*) of Oxfordshire, Gloucestershire and Dorset (*M. bucklandi* Meyer, 1835; *M. bradleyi* Woodward, 1910; *M. incognitus* (Huene, 1932)), the Oxford Clay of Dorset (*M. parkeri* Huene, 1926) and the Bathonian of Morocco (*M. mersensis* Lapparent, 1955). The New Park material could belong to any of these species, or to some other.

The bones of the sauropod *Cetiosaurus* from New Park Quarry include ribs, a coracoid and a pair of ischia. Because of their size (the ischia are 1.0 m long), these specimens undoubtedly belong to *Cetiosaurus*, but they cannot be assigned to a species since the taxonomy is in need of revision. At least eleven species have been described from the Mid and Late Jurassic of England, France and Morocco, and the Early Cretaceous of England. The Mid Jurassic forms are *C. rugulosus* (Owen, 1841), *C. oxoniensis* Phillips, 1871 and *C. glymptonensis* Phillips, 1871 from the 'Great Oolite' of Wiltshire, Gloucestershire, Oxfordshire and Northamptonshire, and *C. mogrebiensis* Lapparent, 1955 from the Bathonian of Morocco. It has never been made clear what the diagnostic characters of each species are supposed to be. The New Park sauropod is slightly older than all of these forms.

The 'dermal plates of *Stegosaurus*' from New Park represent some of the earliest records of stegosaurid dinosaurs. Galton (1983c) and Galton and Powell (1983) described a dorsal vertebra (OUM J29770) and a cervical centrum (OUM J29827) from Sharps Hill, Oxfordshire as the oldest British stegosaurid, and this claim was repeated by Boneham and Forsey (1991) who reported further stegosaur remains from Sharps Hill. However, the Sharps Hill Member lies partly in the *progracilis* Zone, the earliest zone of the Mid Bathonian, and partly in the *tenuiplicatus* Zone, the topmost zone of the Early Bathonian (Torrens, 1968; Torrens *in* Cope *et al.*, 1980b), hence above the Chipping Norton Formation. Therefore, the New Park stegosaur finds are one or two ammonite zones older than those from Sharps Hill, and in any case, *Tatisaurus oehleri*, from the Lower Lufeng Formation (Sinemurian–Hettangian) of Yunnan Province, China, hitherto regarded as an unidentifiable ornithischian, may be a true stegosaur (Dong, 1990).

Reynolds (1939) referred the two large dermal plates to the North American genus *Stegosaurus*, but Galton *et al.* (1980, p. 41) disputed this referral and suggested that the plates were probably the sacral ribs of a sauropod. However, later, Galton and Powell (1983) and Galton (1985b), in their reviews of Bathonian stegosaurs from

England, provisionally reassigned the specimens to the Stegosauridae. They noted that the plates were reasonably massive when compared with the complete series of plates of *Stegosaurus* and the few known plates of *Lexovisaurus*, and tentatively referred them to *Lexovisaurus ?vetustus* (Huene, 1910). The New Park stegosaur must have been large, since the plates are 0.25 m high.

Stegosaurs have been reported from higher in the British Mid Jurassic, from the Lower Oxford Clay (Callovian) of the Peterborough area. Hulke (1887) noted remains of a stegosaur which he termed *Omosaurus* (=*Dacentrurus*), believing it to come from the Kimmeridge Clay; these represent *Lexovisaurus durobrivensis* (Galton, 1985b). Hulke also reported armour plates, but these turn out to be from the giant teleost fish *Leedsichthys* (Martill, 1988). Stegosaur armour plates were later found in the area. A second Oxford Clay stegosaur was *'Stegosaurus' priscus* from Fletton (Nopsca, 1911), synonymized by Galton (1985b) with *L. durobrivensis*. Other isolated remains of this species have been reported from the Lower Oxford Clay of Whittlesey and Weymouth.

Comparison with other sites

The fossil reptile sites nearest in age to New Park are Oakham Quarry (SP 279306), which has produced remains of *Megalosaurus* and *Cetiosaurus*, Longborough Road Quarry (SP 171296), which has yielded *Steneosaurus*, Sharps Hill Quarry (SP 338358), which has yielded *Lexovisaurus* and Hornsleasow Quarry (SP 131322), which has yielded a variety of crocodilian and dinosaur remains. Oakham Quarry lies in the Chipping

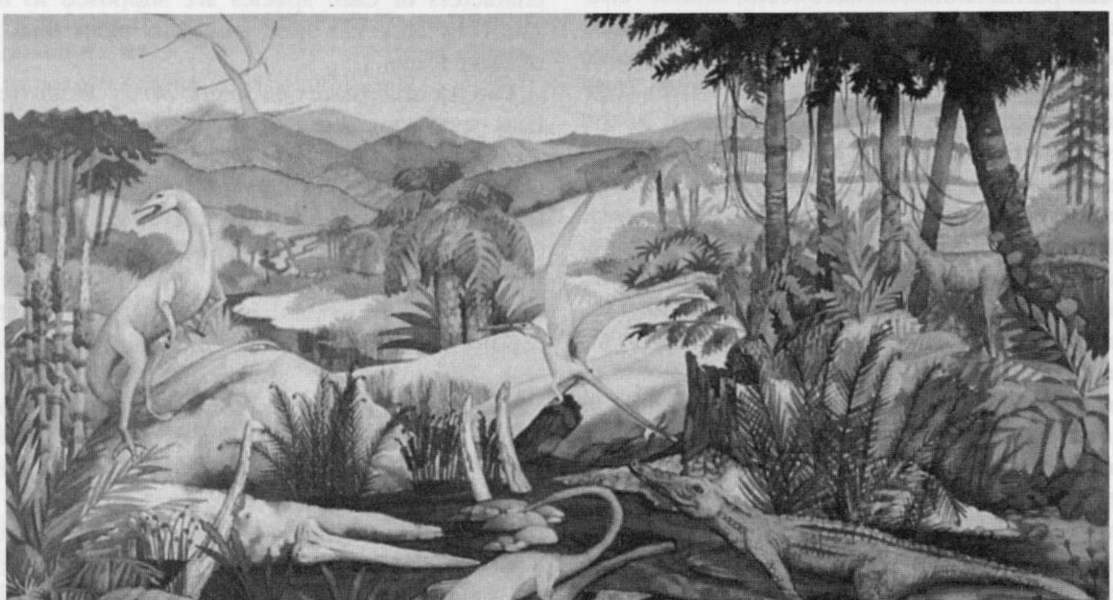

Figure 6.5 Scene in Early Bathonian times, showing a small lake in Gloucestershire surrounded by seed ferns and conifers. Fishes (*Lepidotus*) live in the water, and frogs (*Eodiscoglossus*) disport themselves around the sides. Dinosaurs include some of the earliest stegosaurs and maniraptorans (?), plated and small carnivorous dinosaurs respectively. A carcass of the large sauropod, *Cetiosaurus*, is rotting in the water, and *Megalosaurus* scavenges. Lizard-like animals, crocodiles, pterosaurs, mammals and tritylodont mammal-like reptiles complete the scene. Based on a restoration painting by Pam Baldaro, showing the scene at Hornsleasow Quarry, Gloucestershire. Reproduced with permission of the University of Bristol.

Norton Formation (*zigzag* Zone) and Longborough Road Quarry is in the Inferior Oolite (Aalenian, Bajocian) (Richardson, 1911a, pp. 227–8; Arkell and Donovan, 1952, pp. 248–9). Sharps Hill Quarry is dated as *tenuiplicatus* Zone and Hornsleasow as *zigzag* Zone, both Early Bathonian.

Richardson (1929, p. 88) recorded a vertebra of *Megalosaurus* (BGS(GSM) 37523) from a quarry in the Chipping Norton Formation in a field near the Fosse Way (?SP 193271). Richardson (1929, p. 95) also mentioned that bones had been found in the Chipping Norton Formation of a quarry ENE of Swell Buildings (?SP 164264). Only Oakham Quarry and Hornsleasow Quarry come near to New Park for the abundance and diversity of their reptile remains, but better comparisons may be made with the richer faunas of the White Limestone Formation (e.g. Eyford, Chipping Norton, Stonesfield, Slape Hill, Enslow Bridge, Kirtlington). Hornsleasow has proved extremely productive as a result of recent studies (Metcalf *et al.*, 1992), and has yielded thousands of microvertebrate remains, scales and teeth of fishes, and teeth and bones of a diverse array of amphibians (frogs, salamanders), reptiles (turtles, 'lizards', choristoderes, crocodilians, dinosaurs, pterosaurs, tritylodontids) and rarer mammals (Figure 6.5). However, that site has been essentially worked out, since the bulk of the fossiliferous clay containing fossils has been removed from the site.

The New Park stegosaur (*Lexovisaurus*? *vetustus*) is also known from isolated remains in the Lower Cornbrash (*discus* Subzone, Late Bathonian of Oxfordshire) and from the Sharps Hill Formation, Oxfordshire (*tenuiplicatus* Zone; latest Early Bathonian) (Galton, 1985b).

Elsewhere, the crocodiles are comparable with those from the Fuller's Earth of Caen and Calvados, Normandy (?Early/Mid Bathonian), and the megalosaur and cetiosaur with remains of these forms from the Bathonian of El Mers in the Moyen Atlas of Morocco (Steel, 1970, pp. 36, 64–5).

Conclusions

New Park Quarry is a very important site for terrestrial fossil reptiles, especially in view of its age. Several other sites in the Chipping Norton Limestone have yielded isolated reptile remains, but the fauna from New Park Quarry is by far the richest for large-sized reptile remains. It is comparable to many of the younger and better known sites in the Mid and Late Bathonian north of Oxford and at Eyford, Gloucestershire. The preservation of the reptiles from New Park Quarry is excellent. They will be of great value in assessing the relationships of early theropods and sauropods. The dermal plates from New Park may be the oldest remains of true stegosaurids in the world. The fact that the fossils were discovered this century suggests that more may be forthcoming if the site is excavated and enhances the conservation value.

STONESFIELD, OXFORDSHIRE (SP 387171)

Highlights

Stonesfield is the most important of the British Bathonian localities in the Cotswolds, and arguably the best Middle Jurassic terrestrial reptile site in the world. It is the source of over 15 species of fossil reptiles, including turtles, crocodilians, pterosaurs, dinosaurs and rare marine forms (ichthyosaurs, plesiosaurs), as well as mammal-like reptiles and mammals.

Introduction

The series of quarries and mines which formerly worked the Stonesfield Slate at Stonesfield (Figure 6.6) are famous for yielding one of the most diverse reptile faunas of Mid Jurassic time known. The remains are all isolated elements, but include those of terrestrial animals such as saurischian and theropod dinosaurs, pterosaurs and a tritylodont mammal-like reptile, as well as aquatic turtles and marine crocodilians, ichthyosaurs and plesiosaurs. Specimens include the type materials of *Megalosaurus bucklandi*, the first dinosaur to be described (Buckland, 1824). Although the quarrying industry at Stonesfield is now extinct, re-excavation could produce many more finds.

The Stonesfield 'slates', or 'tilestones' (Richardson *et al.*, 1946, p. 33) of Stonesfield have been well known for their fossils, which contain an unusual mixture of marine, freshwater and terrestrial forms (Arkell, 1947a, pp. 40–1). In Roman times local country houses were roofed with squared slabs of limestone 'slate'. In the 16th or 17th century it was discovered that when the

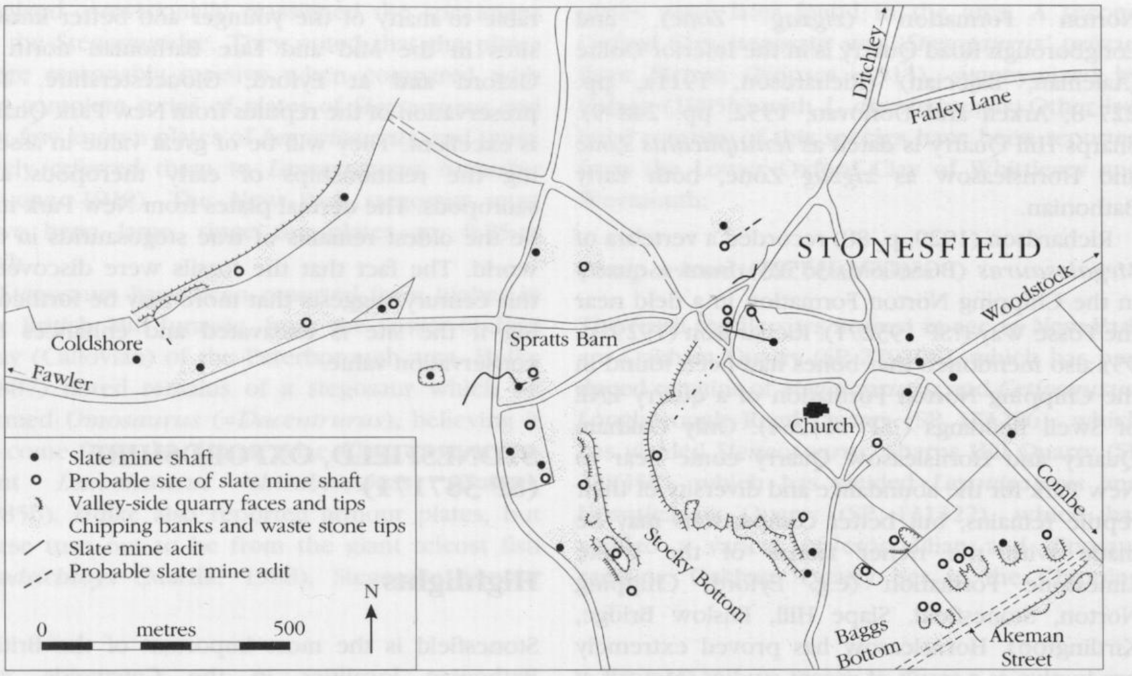

Figure 6.6 The Stonesfield Slate mines. Map based on ground surveys and studies of historical records by Aston (1974).

freshly dug stone was exposed to the frost, it would split into thinner sheets. The quarries continued and expanded production, providing roofing materials for local houses and building material for more important buildings further afield (Arkell, 1947b), and they remained productive until the late 19th century. The stone was reached by vertical shafts, usually about 6 m deep, and horizontal galleries which were driven through the bed. During the 18th and 19th centuries slate-digging was a major industry (Figure 6.6) and employed numerous craftsman. The slate-makers examined each slab and put aside fossils for sale to tourists and dons at Oxford and other universities. The last mine closed in 1911 (Arkell, 1947b; Aston, 1974, p. 35).

Stonesfield has figured prominently in the history of the study of dinosaurs (Swinton, 1970; Delair and Sarjeant, 1975). The first reptile fossil to be described from Stonesfield was a megalosaur tooth figured by Edward Lhuyd (1699, pl. 16, opposite p. 63). Joshua Platt (1758) described three large vertebrae and a left femur as the 'fossile thigh-bone of a large animal', now identified as probably that of *Megalosaurus* or *Cetiosaurus*. The femur was 29 inches (0.81 m) long and was found surrounded by fossil shells of 'sickle oysters' (*Liostrea acuminata*). A partial scapula of *Megalosaurus* from Stonesfield was acquired by the Woodwardian Museum, Cambridge in 1784, but it has never been described (Delair and Sarjeant, 1975). An anonymous article published in the *Gentleman's Magazine* for 1757 (A.B., 1757) records some finds thought to be of significant note, and suggests that the site was well known to the wider public for its large fossil bones well before the 1820s, contrary to what is normally assumed: 'But I think we can boast of as great a variety [of fossils] . . . at a small village called Stonesfield, near Woodstock in this country'. This records sharks' teeth, fish palates, echinoids, oysters, belemnites, 'nautilites', ferns and 'bones of quadrupedes, ribs, vertebrae &c. some of birds . . .'. Also mentioned is Joshua Platt's 'thigh bone', as that of 'the *Hippopotamus*, or sea-horse'. The anonymous author goes on to say 'I formerly met with two pieces of bone and some vertebrae of the same kind, and of a proportional bulk, at the same place. . . . Those I have been speaking of must [by analogy] be the remains of some animal of greater bulk than the largest ox'.

William Buckland (1784–1856) is well known as the describer of *Megalosaurus* from Stonesfield, although it would be truer to say that he was the first person to realize its reptilian nature. He did not record details of when he acquired his specimens, as did Mantell who col-

Figure 6.7 View of the entrance to an adit at Stonesfield, re-opened in 1980 in an operation funded by the Nature Conservancy Council. (Photo: W.A. Wimbledon.)

lected material of *Iguanodon* in 1822 and earlier. Archive evidence suggests that Buckland had good specimens of *Megalosaurus* from Stonesfield around 1818 (Delair and Sarjeant, 1975), and the 'huge lizard' was well known to Cuvier, Parkinson, Conybeare, Mantell and others before its eventual description in 1824 (Buckland, 1824). Further abundant remains of reptiles were collected during the 19th century, but finds ceased with the extinction of the quarrying industry. Figure 6.7 shows a cleaning exercise when an adit at Stonesfield was re-opened in 1980.

Description

Stratigraphic sections through the type Stonesfield Slates have been given by Fitton (1836, p. 412), Phillips (1871, pp. 148–9), H.B. Woodward (1894, pp. 29–33, 312), Walford (1895, 1896, 1897), Richardson *et al.* (1946, pp. 29–33), McKerrow and Baker (1988, pp. 63, 64) and Boneham and Wyatt (1993). Richardson *et al.* (1946, p. 30) gave the following section from the sides of a shaft at Stonesfield:

	Thickness (ft)
[White Limestone]	
Rubbly limestone	
[Hampen Marly Beds]	
Clay with *Terebratulites*	
Limestone	
Blue clay	
Oolite	
Blue clay	in total 32
[Taynton Stone]	
'Rag', consisting of shelly oolite,with casts of bivalves and univalves	*c.* 25
[Stonesfield Slate Beds]	
'Soft stuff', yellowish sandy clay, with thin courses of fibrous transparent gypsum	0.5
'Upper Head', sand enveloping a course of spheroidal laminated calcareous gritstones which produce the slate. These are called 'Potlids', from their figure, and receive with the other slaty bed the name of 'Pendle' as characteristic of workable stone. The stone is partially oolitic and shelly, sometimes full of small fragmentary masses	1.5
'Manure' or 'Race', slaty friable rock	1
'Lower Head', sand and grit, including a course of spheroidal concretions of slate, as above	1.5–2
'Bottom stuff', sandy and calcareous grit, with admixture of oolitic grains	1
[Chipping Norton Limestone]	

The Stonesfield Slate (=Stonesfield Member) consists of quartz sands and siltstones with fine laminae (0.1–0.3 m apart) of ooliths. A 20 mm thick conglomerate, containing clasts of limestones from the underlying Chipping Norton Formation and bored pebbles of other oolites, occurs in the middle of the unit (Sellwood and McKerrow, 1974). The Stonesfield Slate is no more than 1.8 m thick at its type locality and it is confined to an elliptical area within 1.5 km around Stonesfield (Aston, 1974).

The fauna of the Stonesfield Slate consists of marine invertebrates (rare ammonites, belemnites, large numbers of bivalves and gastropods [80 species altogether], rarer brachiopods, crustaceans, annelids and corals), land-derived plants (13 species), insects (seven species), about 40 species of fish, including sharks, 'holosteans' and a species of *Ceratodus*, as well as reptiles, and mammals (*Amphilestes, Phascolotherium, Amphitherium)* (Phillips, 1871, pp. 167–237; H.B. Woodward, 1894, pp. 314–17; Richardson *et al.*, 1946, pp. 28–9).

The bone in the Stonesfield Slate is well preserved and rarely abraded, although delicate processes may be broken off. The remains range from small elements (e.g. teeth, scutes, pterosaur limb bones) to complete vertebrae and partial skulls. Skeletons are disarticulated. Thus, there is evidence of short-term transport and sometimes violent breakage, and the bones may be associated with other coarse clasts (pebbles, shells, etc.).

Fauna

Major collections may be seen today in the BMNH, BGS(GSM), CAMSM and OUM. Most older university, city and private fossil collections in Britain have some teeth or bone scraps from Stonesfield, but it is clearly pointless to record all of these. The type specimen numbers are noted and an estimate of the numbers of specimens of each species in major collections is appended:

	Numbers
Testudines	
Protochelys stricklandi (Phillips, 1871)	
Type specimen: OUM	1
Archosauria: Crocodylia: Thalattosuchia: Steneosauridae	
Steneosaurus boutilieri Deslongchamps, 1869	
Steneosaurus brevidens (Phillips, 1871)	1
Teleosaurus ?geoffroyi Deslongchamps, 1867	4
Teleosaurus subulidens Phillips, 1871	
Type specimen: OUM J1419	1
Steneosaurus/Teleosaurus sp.	125+
Archosauria: Pterosauria: 'Rhamphorhynchoidea'	
Rhamphocephalus bucklandi (Meyer, 1832)	
Type specimens: ?OUM J23043, 23047–8, 28266, 28297, 28311, 2831	250+
Rhamphocephalus depressirostris (Huxley, 1859)	
Type specimen: BMNH 47991 [?Stonesfield or Sarsden]	2
?Rhamphocephalus sp.	125+
Dinosauria: Saurischia: Theropoda	
Iliosuchus incognitus Huene, 1932	
Type specimen: BMNH R83	2
Megalosaurus bucklandi Meyer, 1832	
Type specimen: OUM J12142 (=OUM J13505)	110+
Dinosauria: Saurischia: Sauropoda: Cetiosauridae	
Cetiosaurus oxoniensis Phillips, 1871	3
Dinosauria: Ornithischia: Ornithopoda	
'hypsilophodontid'	1
Sauropterygia: Plesiosauria	
'*Cimoliasaurus*'/*Plesiosaurus* sp.	17
Ichthyopterygia: Ichthyosauridae	
Ichthyosaurus ?advena Phillips, 1871 (*nom. dub.*)	2
Synapsida: Therapsida: Cynodontia: Tritylodontidae	
Stereognathus ooliticus Charlesworth, 1855	
Type specimen: BGS(GSM) 113834	1

Interpretation

The highly localized distribution of the Stonesfield Slate around the village of Stonesfield (Figure 6.6) is best explained by the deposition of clastic sediments during a transgressive event within isolated hollows above an intermittent hardground which occurs at the top of the Chipping Norton Formation (Sellwood and McKerrow, 1974, p. 206). Sellwood and McKerrow (1974, pp. 204–5) note sedimentary structures indicative of deposition of the Stonesfield Slate in upper-flow regime conditions. Storm-produced scours filled with shell-lags occur.

The fossil content points to a shallow-marine environment with a large input of terrestrial material. The bones, plants and insects may have been concentrated and preserved by rapid burial in sands brought offshore by storm-induced rip-currents. The features of bone preservation in a disarticulated state and, in coarse clastic units, point to sorting and rapid deposition, possibly during storm-events.

As in much of the Great Oolite Group of Oxfordshire, the clastic sediments and the land-derived plants and animals reflect the influence of the nearby London landmass, but the ammonites indicate that the Stonesfield Member is one of the few beds in the Bathonian of Oxfordshire to be deposited in proximity to open marine conditions.

The dating and precise stratigraphic position of the Stonesfield Slate has been problematic because of its limited exposure and outcrop, and because of the small number of ammonites. Fitton (1836) placed it below the Taynton Stone (Taynton Limestone Formation) by correlating it with the Cotswold Slate. Hull (1860) and H.B. Woodward (1895) recorded information that suggested that the Slate Beds lay at or near the top of the Taynton Stone. At this time, most authors assumed that the Stonesfield Slate was laterally equivalent to the 'Stonesfield Slate' of Eyford, Gloucestershire (the Cotswold Slate or Eyford Member), and even with units near Bath and in Northamptonshire; it was regarded as a handy marker bed for the base of the Great Oolite. However, as Arkell (1947a, pp. 37–41) pointed out, the Sharps Hill Clays and thin limestones (the Sharps Hill Member of the Sharps Hill Formation; Torrens, *in* Cope *et al.*, 1980b) are present over much of north Oxfordshire while, in the vicinity of Stonesfield, the lithologically similar Stonesfield Slate (the Stonesfield Member of the Sharps Hill Formation) comprises a separate unit.

Arkell (1931; 1933, pp. 294–7) and Richardson *et al.* (1946, pp. 25–33) placed the Stonesfield Slate between the Sharps Hill Clays and the Taynton Stone on the basis of correlations with the Ashford Mill railway cutting section (SP 387159). The 'Coral and *Rhynchonella* Bed' there was ascribed to the 'Stonesfield Slate Beds' and the Stonesfield Slate itself, which was absent there, was supposed to occur between this and the Sharps Hill Beds below. Arkell (1947a, pp. 38–41) suggested that the Stonesfield Slate occurred immediately below the Taynton Stone and that its lateral equivalent was the Upper Sharps Hill Beds (Torrens, 1968, p. 231). Subsequently, Sellwood and McKerrow (1974) suggested that the sandy beds of the Stonesfield Member could represent the reworked top of the underlying sandy beds of the Chipping Norton Formation. They would then be expected to rest directly on sandy limestones or calcareous sandstones rather than on clays, and should thus lie below the clays of the Sharps Hill Member in those localities where both members are present. However, Torrens (*in* Cope *et al.*, 1980b, fig. 6a, column B12) was not convinced by these arguments and continued to assume that the Stonesfield Slate was above the Sharps Hill Clays.

McKerrow and Baker (1988) examined the stratigraphy of two newly opened shafts at Stonesfield (as part of the GCR programme) (Hillside, SP 39181730; Home Close, SP 39181724) and in an adit to the west of the village, and compared these with the greatly extended workings in Town Quarry, Charlbury (SP 365189). They corroborated the view of Sellwood and McKerrow (1974), demonstrating that when the clay-rich Sharps Hill Member and flaggy limestones of the Stonesfield Member occur together at the same locality, the Stonesfield Member underlies the Sharps Hill Member and rests directly on the Chipping Norton Formation (both in the Sharps Hill Formation), whereas at Home Close and Hillside the Stonesfield Member is overlain directly by oolitic limestones (Taynton Limestone Formation). Boneham and Wyatt (1993) suggest that the Stonesfield Slate was formerly worked at three levels within the Taynton Limestone Formation, and that the 'Stonesfield Member' can no longer be regarded as a valid subunit of the Sharp's Hill Formation.

The ammonite fauna of the Stonesfield Member consists of 10 species belonging to the genera *Clydoniceras, Microcephalites, Oppelia (Oxycerites), Paroecotraustes, Turrelites* and *Procerites (P. progracilis, P. mirabilis, P. magnificus)* (Arkell, 1951–8, p. 240). There are problems of identification of some of these, and of comparison with similar specimens elsewhere in Britain and abroad (Torrens, 1969b, pp. 71–3; *in* Cope *et al.*, 1980b, p. 38). This fauna has been assigned to the *progracilis* Zone (early Mid Bathonian) with the Stonesfield Member at Stonesfield as the stratotype (Torrens, 1974, pp. 586–7).

The chelonian species *Testudo stricklandi* was established by Phillips (1871, p. 182) for isolated scale-like elements found in the Stonesfield Slate (Blake, 1863). Mackie (1863) had also announced the discovery of a turtle coracoid from Stonesfield, and had named it *Chelys (?)blakii.*

Lydekker (1889b, pp. 220–2) combined these in his new genus *Protochelys*. The scales are unusual in that they lack bony material, and in that they are supposedly from the crest of the back of a turtle carapace. The coracoid is probably indeed chelonian, but the scales may be remains of invertebrates, though the possibility remains that they might represent shed turtle scutes (certain extant turtles shed their carapace scutes in order to facilitate growth). We have found no recent discussion of the Stonesfield 'chelonians', although Romer (1956, 1966) classes *Protochelys* tentatively as a pleurosternid turtle, a group typical of the Jurassic. The most recent monograph on turtles (Młynarski, 1976) makes no mention of them, and quotes *Protochelys* Williston (1901) for a Late Cretaceous American animal: clearly a preoccupied name. Turtles are rare in the Mid Jurassic but, until the exact nature of the Stonesfield specimens is reassessed, nothing can be said of their significance.

The long-snouted crocodilians from Stonesfield include four species of *Teleosaurus* and *Steneosaurus*. They had long curved teeth and were clearly fish-eaters in fresh and marine water. These genera are well known from the Bathonian of Britain and France, but the Stonesfield specimens are extremely well preserved and formed the basis of a revision (Phizackerley, 1951). *T. subulidens* Phillips (1871) may be a synonym of *T. cadomensis* Geoffroy St-Hilaire (1825). The type specimens of this species, and of the others from Stonesfield, came from the Fuller's Earth and Great Oolite of Normandy, but they were all destroyed at Caen in 1944. Thus, the Stonesfield specimens take on an added significance. Although *Steneosaurus* and *Teleosaurus* are common in the English Bathonian from localities in Somerset, Avon, Wiltshire, Gloucester, Oxfordshire and Northamptonshire, only Enslow Bridge, Oxfordshire has more than one or two species. Stonesfield represents the best site in Britain for Mid Jurassic crocodiles in terms of abundance and variety.

The pterosaur *Rhamphocephalus* is known from the Stonesfield Slate (Figure 6.8A) and the Eyford Member (=Cotswold Slate) of the Eyford area, Gloucestershire (Kyneton Thorns Quarry (SP 122264), ?Sevenhampton (SP 0321), ?Huntsman's Quarry (SP 125254)). By far the best and most abundant material comes from Stonesfield, and it may include type specimens of two or three species. The remains show a 120 mm long mandible with long pointed teeth. The restored wing is about 0.75 m long, and individual vertebrae 25 mm long. Details of the bone microstructure were also observed (Huxley 1859d; Phillips, 1871, pp. 219–29). There is a problem over the original locality of the type specimen of *R. depressirostris*: Huxley (1859d) and Wellnhofer (1978, p. 41) give the locality as Sarsden ('Smith's Quarry': SP 300226), whereas the label on BMNH 47991 and Lydekker's Catalogue (1888a, p. 36) give the locality as Stonesfield. *Rhamphocephalus* is important as the only Mid Jurassic pterosaur known, apart from fragmentary remains of a single pterosaur from the Oxford Clay of St Ives, Cambridgeshire, and isolated teeth from many Cotswolds sites. The Pterosauria radiated during the Late Triassic and four main 'rhamphorhynchoid' genera are known from the Early Jurassic (*Dimorphodon* from Lyme Regis, *Parapsicephalus* from Loftus, Yorkshire, *Campylognathoides* from Holzmaden and India, and *Dorygnathus* from Germany). There is a gap in the Mid Jurassic before abundant fine remains of *Rhamphorhynchus*, *Scaphognathus* and *Anurognathus* are found in the Late Jurassic of Solnhofen, in particular. The crown-group pterosaurs, the Pterodactyloidea, are known from skeletons first from the Late Jurassic of Solnhofen (Bavaria), England and France (*Pterodactylus, Germanodactylus, Ctenochasma*), and by teeth from the Cotswolds Bathonian. It is not clear whether *Rhamphocephalus* is a pterodactyloid or not (Wellnhofer, 1978, p. 41).

Stonesfield is perhaps best known as the source of the original and most extensive material of *Megalosaurus* (Figure 6.8B; Buckland, 1824). Remains are incomplete, but most of the skull and skeleton are known. The skull was up to 1 m long, with sharp recurved teeth, each 50–150 mm long. The femur was 1 m long and the hind feet bore large recurved claws. *Megalosaurus* reached total lengths of 3.5–7.0 m, and was clearly a major and fearsome predator (Buckland, 1824; Phillips, 1871, pp. 196–219; Huene, 1906, 1923, 1926; Walker, 1964; Steel, 1970, pp. 33–4). Many more species of *Megalosaurus* have been established and *M. bucklandi* is now largely restricted to the Mid Jurassic specimens from Oxfordshire, and Stonesfield in particular. The preservation of the Stonesfield specimens is good enough to allow detailed studies of the braincase (Huene, 1906). Other species of carnivorous dinosaur from the Late Triassic of Wales, Early, Mid and Late Jurassic and Early Cretaceous of England, France, Austria, Morocco and Arizona have been ascribed to 20 or

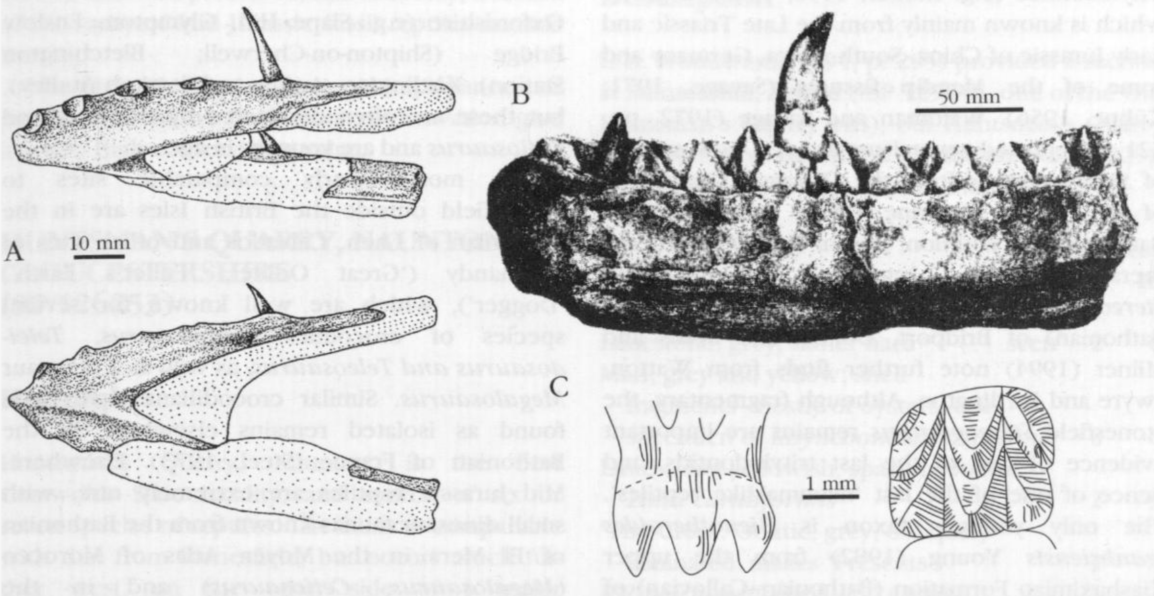

Figure 6.8 Bathonian reptiles from Stonesfield. (A) The rhamphorhynchoid pterosaur *Rhamphocephalus bucklandi* (Meyer, 1832), anterior part of the lower jaw; (B) the type specimen of *Megalosaurus bucklandi* Meyer, 1832, a partial lower jaw, seen from the inside; (C) *Stereognathus ooliticus* Charlesworth, 1855, reconstructed right upper molar, showing posterior and crown views. (A) After Wellnhofer (1978); (B) after Buckland (1824); (C) after Simpson, 1928).

more species of *Megalosaurus*. Several of these have now been placed in other genera (Huene, 1923, 1926, 1932; Walker, 1964; Waldman, 1974; Molnar, 1990; Molnar *et al.*, 1990), but more work is needed before a true picture of the morphological variation and distribution in time and space of *Megalosaurus* (*sensu stricto*) can be established.

A related species is *Iliosuchus incognitus* Huene (1932), often placed in *Megalosaurus* (e.g. Romer, 1966, p. 369), based on a small ilium from Stonesfield. Galton (1976b) has argued that it is a distinct genus with a close relative in the Morrison Formation (Late Jurassic) of Utah, which would be evidence for faunal ties between Europe and North America in the Jurassic. However, Molnar *et al.* (1990, p. 202) do not confirm this assignation.

The sauropod *Cetiosaurus* is represented by only a few elements at Stonesfield, and it was either not a major part of the fauna or the elements have not been preserved. It is much better known from the younger Bathonian White Limestone and Forest Marble of other places in Oxfordshire, Gloucestershire, Cambridgeshire and Northamptonshire.

The only ornithischian dinosaur from Stonesfield is a tooth (YPM 7367) identified as that of an ornithopod, and possibly a hypsilophodontid (Galton, 1975, pp. 742, 745, 747; Galton 1980b, pp. 74–5). If it belongs to a hypsilophodontid, it is the oldest known member of that group, of an age comparable with *Yandusaurus* He (1979) from the Xiashaximiao Formation (Bathonian–Callovian) of China (Sues and Norman, 1990).

The remains of plesiosaurs and ichthyosaurs from Stonesfield have been mentioned by Phillips (1871, p. 183) and Lydekker (1889a, p. 245). They consist of teeth, vertebrae and limb bones, but they have never been adequately described. In any case, these marine forms are rare in the British Bathonian, the only other specimens being vertebrae and teeth identified as '*Ichthyosaurus* sp.' or '*Plesiosaurus* sp.' from the White Limestone, Forest Marble and Cornbrash in a few sites in southern and midland England. Stonesfield has produced the best range of specimens of these forms, even if they are not very impressive.

Finally, the tritylodont *Stereognathus* (Figure 6.8C), represented by a jaw fragment (BGS(GSM) 113834) and one other specimen, was initially interpreted as a mammal (Charlesworth, 1855; Owen, 1857; 1871, pp. 18–21; Phillips, 1871, pp. 236–7; Goodrich, 1894, p. 424; Simpson, 1928, pp. 22–6). It is in fact one of the last surviving tritylodontids (e.g. Romer, 1956, 1966), a group which is known mainly from the Late Triassic and Early Jurassic of China, South Africa, Germany and some of the Mendip fissures (Savage, 1971; Kühne, 1956). Waldman and Savage (1972, pp. 121–2) reported several molars of a new species of *Stereognathus* from the Ostracod Limestones of the Great Estuarine Group of Skye (Late Bathonian). In addition, Ensom (1977) recorded a therapsid tooth, tentatively ascribed to *Stereognathus*, from the Forest Marble (Late Bathonian) of Bridport, Dorset, and Evans and Milner (1994) note further finds from Watton, Swyre and Kirtlington. Although fragmentary, the Stonesfield *Stereognathus* remains are important evidence of one of the last tritylodontids, and hence of one of the last 'mammal-like reptiles'. The only younger taxon is *Bienotheroides wanhsiensis* Young (1982) from the upper Xiashaximiao Formation (Bathonian–Callovian) of China (Benton, 1993).

Comparison with other localities

The fauna of the Stonesfield Slate (Stonesfield Member) is unique. However, comparisons may be made with other Early and Mid Bathonian faunas which contain some of the same species, and in particular with the Cotswold Slate (Eyford Member) of the west of Stow-on-the-Wold (*progracilis* Zone, Mid Bathonian). Localities such as Huntsman's Quarry (SP 125254), Eyford Quarries (SP 135255, etc.) and Kyneton Thorns Quarry (SP 122264) have yielded *Steneosaurus, Teleosaurus, Megalosaurus, Rhamphocephalus* and other genera. The conditions of deposition and faunal composition of the Cotswold Slate are very like those of the Stonesfield Slate, and the two units were formerly regarded as identical. The rich tetrapod fauna from the earliest Bathonian Hook Norton Member at Hornsleasow Quarry (SY 131322) (Vaughan, 1989; Metcalf *et al.*, 1992) is comparable.

Some quarries in Oxfordshire have also produced similar animals. The quarry at Sarsden, near Chipping Norton (SP 300226) produced teeth of *Megalosaurus*, a *Cetiosaurus* limb bone and bones of *Rhamphocephalus*, probably from the Taynton Stone (*prograciiis* Zone). Padley's Quarry (SP 317269) at Chipping Norton yielded specimens of *Megalosaurus, Cetiosaurus* and *Teleosaurus* from the Sharps Hill Formation (*progracilis* or *tenuiplicatus* Zones). Further similar faunas are known from the White Limestone and Forest Marble (Mid–Late Bathonian) of Oxfordshire (e.g. Slape Hill, Glympton, Enslow Bridge (Shipton-on-Cherwell; Bletchington Station), Kirtlington, Ardley and Stratton Audley), but these are often dominated by the sauropod *Cetiosaurus* and are younger in age.

The most clearly comparable sites to Stonesfield outside the British Isles are in the Bathonian of Caen, Calvados and other sites of Normandy ('Great Oolite', 'Fuller's Earth', 'Dogger'), which are well known for several species of crocodiles *Steneosaurus, Teleidosaurus and Teleosaurus,* as well as a dinosaur *Megalosaurus*. Similar crocodilians have been found as isolated remains elsewhere in the Bathonian of France (Steel, 1973). Elsewhere, Mid Jurassic reptiles are extremely rare, with small dinosaur faunas known from the Bathonian of El Mers in the Moyen Atlas of Morocco (*Megalosaurus, Cetiosaurus*) and in the Bathonian of north-western Madagascar (*Bothriospondylus*).

Conclusions

Stonesfield is arguably the most important Mid Jurassic fossil reptile site in the world, and its fauna is diverse and abundant. The four species of *Steneosaurus* and *Teleosaurus* are represented by good material and are probably the best Mid Jurassic crocodilians in the world since most of the Normandy specimens were destroyed in the war. *Rhamphocephalus*, best represented at Stonesfield, is important for studies of pterosaur evolution since it is one of the few members of this group known from the Mid Jurassic. Stonesfield is the most important site for remains of *Megalosaurus* in the world: it yielded the first and type material in the early 19th century, and continued to produce hundreds of specimens while the mines were in operation. The ornithopod tooth, interpreted tentatively as that of a hypsilophodontid, could be the oldest representative of this predominantly Cretaceous group. Apart from these terrestrial forms, Stonesfield has also produced one of the best collections of Mid Jurassic plesiosaur and ichthyosaur remains in the world, although they are very fragmentary. Finally, the tritylodont *Stereognathus* is one of the last surviving members of its group and one of the youngest 'mammal-like reptiles' in the world. Stonesfield is important for the study of fossil reptiles for two reasons: firstly, its fauna is abundant, diverse and well preserved, and secondly, because of the rarity of Mid Jurassic fossil reptiles outside Britain.

The site's historic international importance and potential for future finds from re-excavation give it a very high conservation value.

HUNTSMAN'S QUARRY, NAUNTON, GLOUCESTERSHIRE (SP 126253)

Highlights

Huntsman's Quarry, Naunton, is the best Cotswolds Slate locality, and source of six or seven species of reptiles. The fauna is comparable with that from Stonesfield, but occurs much further west, on the other side of a major palaeogeographic barrier.

Introduction

Huntsman's Quarry is the only major quarry still working in the Cotswolds Slate (=Eyford Member), formerly equated with the Stonesfield Slate (see Stonesfield report). It lies 2 km north-east of Naunton on an unclassified road that crosses Eyford Hill. The quarry has yielded a wide range of fossil reptiles in the past and is currently operated by Huntsman Quarries Ltd for road-metal and gravel and has been extended much towards the north. The exact location of the older finds is unknown, but they were probably made in the older portions of the quarry, several of which still offer good exposures (e.g. SP 123254, where a 5 m section is to be seen on the long north face of an old pit, and at SP 123252, where a 3–4 m face is still visible). The quarry has potential for future finds of reptiles since the old pits are still accessible and new quarrying operations have exposed further large areas. Some *Megalosaurus* specimens have been found recently (OUM).

The Cotswolds Slate was extensively worked for roofing slates in the 19th and early 20th century around Sevenhampton, Kineton, Naunton and Eyford (H.B. Woodward, 1894, pp. 294–6, 484–5; Richardson, 1929, pp. 102–16, 144–6; Arkell, 1933, p. 278). The fossil reptiles were examined by various Victorian authors and the fauna was reviewed by Richardson (1929), but the older, and more recent, finds are in need of redescription.

Description

H.B. Woodward (1894, p. 295) provided a section at Summerhill, Eyford (?SP 129246, one of the Old Huntsman's Quarry pits), but Huntsman's Quarry itself was first described by Richardson (1929), who gave a section (p. 114) as follows:

	Thickness ft	in
Limestone, grey, rather hard seen	2	6
Marl, grey and yellow; shell fragments–mostly of oysters; one specimen of *Rhynchonella ?concinna*	0	6
Limestone, yellowish, sparsely oolitic; *Lima cardiiformis*	2	9
'The Crop'. Oolitic, grey, obliquely-laminated: makes 'Presents'	2	8
[?*Rhynchonella* Bed, and *Ostrea acuminata* Limestones remanié]. Marl, brown, clayey, with oysters and a few pebbles bored by *Lithophaga*	0	2
[? Sevenhampton Marl] Marly limestone, crowded with oysters; *Lima cardiiformis, Modiola* sp., *Pholadomya solitaria, Pinna ampla*. and occasional plant remains, locally passing into a hard limestone	2	0
?1–5. Flagstones. Limestones, massive, flaggy, in the main blue-hearted, but locally yellow and oolitic. Contain locally pebbles of oolite, and, in cavities in the lower part of the bottom stratum (5), green clay	6	6
6. Green Clay, locally sandy average thickness	0	2
7–8. Pendle. (a) Sandstone, hard, grey (weathering brown), rarely passing into a brown, irregularly laminated fissile sandstone	2	8
(b) Limestone, hard, grey, sandy	1	6
[Non-sequence: no evidence for the equivalent to the Planking]		
9. Sandy limestone, hard, grey at the top, brown and shaly, containing flat marl pellets. Surface undulating and water-worn. *Placunopsis socialis* common in the top layer. Said to be a very bad hard bed and not worked		

Richardson (1929) equated the bulk of the exposure in Huntsman's Quarry with the 'Stonesfield

Slate Series' low in the Great Oolite Group in the classic Hampen Railway cutting section. Arkell (1933, p. 278) and McKerrow and Baden-Powell (1953, p. 92) followed this assignment. Sellwood and McKerrow (1974, p. 193) assigned beds 1–9, and the three units above these in Richardson's section, to the Cotswold Slate, which they renamed the Eyford Member (Figure 6.9). They assign the succeeding 2 m of oolitic limestone to the Taynton Limestone Formation (?upper *progracilis* Zone). The fossils came from the 'Slate Bed' (Richardson, 1929), probably equivalent to bed 7 in the log ('Pendle').

The fauna from Huntsman's Quarry consists of reptiles, fishes, arthropods, molluscs (including rare ammonites), annelids, starfish and plants (Richardson, 1929). The invertebrate fauna is distinctive, differing in many ways from that of the beds above and below, and also from stratigraphically equivalent units elsewhere. The bivalve

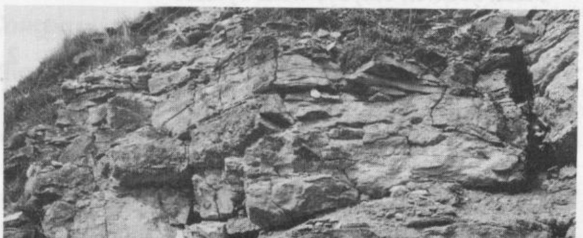

Figure 6.9 Exposure of the Eyford Member, or 'Cotswolds Slates', at Huntsman's Quarry. Reptiles occur as isolated bones at various levels in the succession. (Photo: M.J. Benton.)

Myophorella impressa (formerly *Trigonia*) is the most abundant fossil. Other bivalves include *Liostrea, Gervillella* and *Chlamys*. Rhynchonellid brachiopods and gastropods are also a common component of the fauna, but other marine invertebrates, including ammonites, echinoderms (crinoids and starfish) and barnacles (represented by plates), are rare. Insects are also present, the commonest being beetles, which are represented in the deposit by their resistant elytra. There is a substantial flora which includes ferns and early conifers (leaves, seeds and fruit), ginkgo leaves and 'carpolithes' seeds.

The reptile remains apparently occurred as isolated bones. Most of the specimens are relatively small (crocodile and dinosaur teeth, pterosaur limb bones), which suggests some degree of sorting. The association with marine invertebrates (e.g. barnacles, starfish, ammonites, belemnites) indicates transport or reworking of the terrestrial forms at least. Nothing is known of the taphonomy of the vertebrates since the matrix has been removed from the museum specimens.

Fauna

The reptilian fauna from Huntsman's Quarry includes dinosaurs, crocodilians, pterosaurs and a turtle. One of the best collections was made by the Rev. E.F. Witts (1813–86) and it is now preserved in GLCRM (Savage, 1963). Unfortunately, many museum specimens are labelled simply 'Eyeford', which could refer to any of the quarries on the east side of Eyford Hill (e.g. SP 125252, SP 126253, SP 126254, SP 128251, SP 128253, SP 128254, SP 130251, all of which may still be seen, at least in part). Specimens labelled 'Naunton' may come from Huntsman's Quarry (SP 131322), from Summerhill Quarries (?SP 129246, SP 113245), or from New Buildings Quarries (SP 135237, SP 134239). In the following list, all specimens are labelled 'Eyford' (often spelt Eyeford), unless otherwise stated.

Testudines
'Chelonian indet.'
Carapace; BMNH R2634
Archosauria: Crocodylia: Thalattosuchia: Steneosauridae
Steneosaurus brevidens (Phillips, 1871)
Teeth: BMNH 28611, R2631; GLCRM G.53–58

Teleosaurus sublidens Phillips, 1871
Teeth: BMNH 28611, R2632–3; BGS(GSM) G.1–51; jaws: BGS(GSM) G.52, 77; BGS(GSM) (various: 'Naunton')
Steneosaurus/Teleosaurus sp.
Teeth: BMNH R6777, R6778 ('Huntsman's Quarry'), R6779–81; BGS(GSM) 113735–6, 113759, 113764–8; rib: BGS(GSM) 11838; scute: BGS(GSM) 72280 ('Naunton'), BGS(GSM) GLCRM 59–60, various bones: GLCRM 558–62
Dinosauria: Saurischia: Theropoda:
Megalosauridae
Megalosaurus bucklandi Meyer, 1832
Teeth: BMNH 28608, R2635; limb bones and ribs GLCRM G.70–1, G.72–3, G.74–6
Megalosaurus sp.
Tibia: OUM J.29759
Archosauria: Pterosauria: 'Rhamphorhynchoidea'
Rhamphocephalus sp.
Limb-bones, a ?proximal phalanx and pectoral girdle elements: BMNH R6782, Munchen 1976 I.41–4 ('Huntsman's Quarry'); BGS(GSM) 113728–31, 113733, 113738, 113747, 113753, 113758, 113670, un-numb.; GLCRM G.61–2

Interpretation

The Cotswold Slates (Eyford Member) are dated to the *progracilis* Zone (early Mid Bathonian) on the basis of sparse ammonites. Richardson (1929, p. 114) noted the occurrence of *Perisphinctes gracilis* (Buckman), reidentified as *Procerites progracilis* Cox and Arkell, in the Cotswold Slates of the Eyford area. *Procerites mirabilis* Arkell was found at Eyford and Huntsman's Quarry (Arkell 1951–8, pp. 199–201; Torrens 1969b, pp. 71–2). These isolated finds place the Cotswold Slates within the *progracilis* Zone (Torrens, 1969b, pp. 71–3; *in* Cope *et al.*, 1980b, p. 35, fig. 6a), although correlation of all the beds in Richardson's (1929) section is unclear.

The turtle carapace has not been identified, but it may belong to the genus *Protochelys* which occurs at Stonesfield in rocks of similar age.

The long-snouted marine crocodilians *Steneosaurus* and *Teleosaurus* from Huntsman's Quarry are represented largely by teeth. These have been identified by comparison with other Bathonian specimens from the Stonesfield Slate (Stonesfield Member), White Limestone and Forest Marble of Oxfordshire and Northamptonshire. These crocodilians were evidently relatively rather abundant in the Cotswold Slate, rather more so than in the Stonesfield Slate.

The teeth and tibia of *Megalosaurus* have, again, been identified by comparison with material from the White Limestone of Oxfordshire, Dorset and other localities in Gloucestershire.

The pterosaur bones have been hard to identify since they consist mainly of wing elements. They may belong to the genus *Rhamphocephalus*, but the significance of that genus is unclear. A fine pterosaur skull impression from the Cotswold Slate of Kyneton Thorns Quarry nearby (SP 122264) was named as the type specimen of *Rhamphocephalus prestwichi* Seeley (1880).

In a manuscript catalogue of the Chaning Pearce collection in BRSMG, teeth of *Ichthyosaurus* and *Plesiosaurus* from Eyford are mentioned, but the specimens have not been located. Some probable plesiosaur teeth are preserved in Gloucester (GLCRM G.63–9, 78–80).

Comparison with other localities

The reptile fauna from Huntsman's Quarry may be compared with that of other quarries in the Cotswold Slate, some of which have already been mentioned. The cluster of ten or more quarries on the east side of Eyford Hill (scattered around SP 135255) have probably yielded a similar range of fossil reptiles. Specimens labelled 'Naunton' include crocodile teeth and a scute. These may have come from various sites to the north and east of Naunton (see above). Pterosaur limb bones have been obtained from the quarries on Sevenhampton Common (SP 012232) (H.B. Woodward, 1894, p. 294). *Megalosaurus* teeth and the fine skull cast of *Rhamphocephalus prestwichi* were found in Kyneton Thorns Quarry (SP 122264) (H.B. Woodward, 1894, p. 295). Comparable sites further afield in Gloucestershire and Oxfordshire are detailed in the Stonesfield report (see above).

Conclusions

Huntsman's Quarry contains the largest extant exposure of the Cotswold Slate (Eyford Member), and it has yielded the best reptile fauna of that unit. The fauna is placed temporally between that of New Park Quarry and other quarries in the Chipping Norton Formation (*zigzag* Zone), and sites in the White Limestone and Forest Marble (*subcontractus-discus* Zones) of Oxfordshire. The fauna is far less abundant and diverse than that of the Stonesfield Slate, but it is of considerable importance in view of the great local variations in deposition in the Cotswolds and Oxfordshire at the time. Its conservation value lies in this importance and its potential for future finds.

SHIPTON-ON-CHERWELL QUARRY, NORTH-WEST CORNER, OXFORDSHIRE (SP 475178)

Highlights

Shipton-on-Cherwell Quarry is the best source of Mid Jurassic crocodilians in Britain, and perhaps the best source of freshwater forms in the world. The site has also produced a range of bones of other species, including turtles and dinosaurs.

Introduction

From the older portions of Shipton-on-Cherwell Quarry the earliest recorded find was a partial *Steneosaurus* skull collected in the early 19th century (Conybeare, 1821, p. 591), and this specimen (OXMFS J1401) was the first crocodile known from the British 'oolites'. Later finds of crocodilian and dinosaurian remains were described by Phillips (1871). The crocodiles were later redescribed by Phizackerley (1951). A stegosaur femur was made type of *Lexovisaurus vetustus* by Huene (1910c), and it was redescribed by Galton and Powell (1983) and by Galton (1985b). The quarry at about SP 477177 was known as Gibraltar Quarry or 'Enslow Bridge', until about 1920,when it was engulfed by the huge Shipton Cement Quarry (Arkell, 1931, pp. 577–8). Parts of the old faces are still extant at SP 475178, and they display sections in the Upper White Limestone, Forest Marble and Cornbrash. The potential for further finds, particularly through careful sampling in the *fimbriatus-waltoni* Beds, and other clay units, adds to its value.

There is a problem over the nomenclature of the seven or so quarries around the bend in the River Cherwell in this area (Figure 6.10). Hull (1859, pp. 20–1) refers to sections at Kirtlington Station (the railway cutting, SP 482181) and 'on the right bank of the river, in a semi-circular cliff' (probably Quarry Bank, Enslow Bridge, SP 475183). Phillips (1860, pp. 117–18) describes these same sections. H.B. Woodward (1894, p. 322) gives a more detailed log for Quarry Bank: 'the section south-west of Enslow Bridge'. Further, he describes a series of quarries 'south of Bletchington station, and on the western side of the railway'. These are, no doubt, the Greenhill Quarries (SP 483179, SP 485177) on the eastern side of the railway, and an old portion of the Shipton Cement quarry (?SP 480175) on the western side of the railway. The 'Old quarry a little east of Bletchington railway-station' (H.B. Woodward, 1894, pp. 323, 373–4) is probably Phillips' *Cetiosaurus* Quarry (SP 484182). We may summarize these and later references:

1. Bletchington Station Quarry /Kirtlington Station Quarry/*Cetiosaurus* Quarry (SP 484182): Phillips (1871, p. 251); H.B. Woodward (1894, p. 323); Pringle (1926, p. 25); Richardson *et al.*, 1946, p. 67); Arkell (1947a, pp. 57–8); Huene (1910c, p. 75).
2. Quarry Bank, Enslow Bridge (SP 475183): Hull (1859, p. 21); Phillips (1871, p. 239); H.B. Woodward (1894, p. 321); Arkell (1947a, p. 58 (?): 'Bunker's Hill quarries in the woods west of Enslow Bridge').
3. North-west corner of Shipton-on-Cherwell Quarry/Gibraltar Quarry (SP 475178): Phillips (1871, pp. 151–2, 247); Odling (1913, pp. 496–8); Arkell (1931, pp. 579–80; 1947a, p. 58); Richardson *et al.* (1946, pp. 66–7); Palmer (1979, pp. 191, 202–3, 205, 208, 210: 'Shipton Quarry').
4. Lower Greenhill Quarry (SP 483179): H.B. Woodward (1894, p. 322); Odling (1913, pp. 495–6); Pringle (1926, p. 24); Arkell (1931, pp. 580–2; 1947a, pp. 58–9); Richardson *et al.* (1946, p. 68).
5. Upper Greenhill Quarry (SP 485177): H.B. Woodward (1894, p. 322); Odling (1913, pp. 494–5); Pringle (1926, p. 24); Douglas and Arkell (1928, pp. 129–30; 1932; 1935, p. 319); Richardson *et al.* (1946, pp. 67, 77–8); Arkell (1947a, pp. 59–60); Torrens (1968, p. 248); Palmer (1979, pp. 190, 208: 'Greenhill Quarry').
6. Oxford Portland Cement Works (old pit, ?SP 480175): H.B. Woodward (1894, p. 322), see no. 3.
7. Whitehill Quarry, Gibraltar. (SP 477186): Palmer (1979, pp. 190, 206, 209).

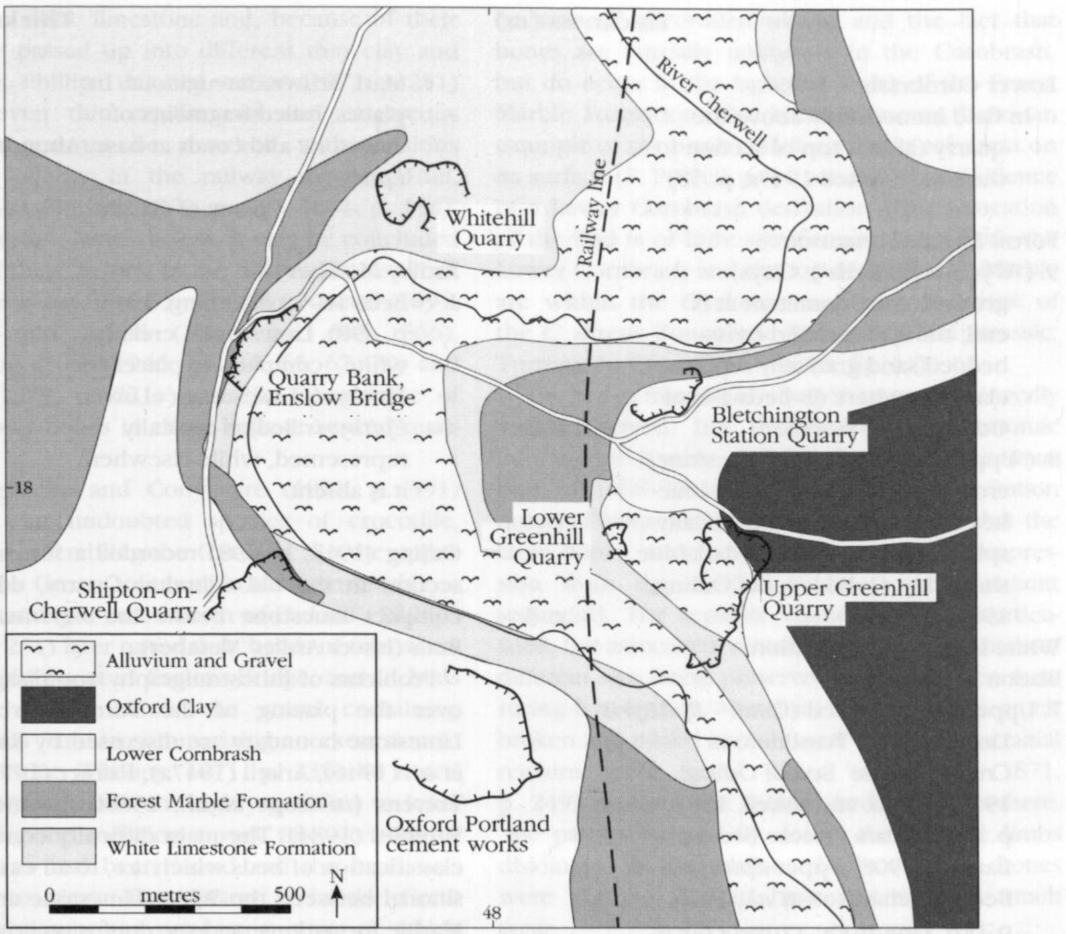

Figure 6.10 The quarries around Shipton-on-Cherwell. Up to seven quarries (detailed in the text) appear to have yielded fossil reptiles from the White Limestone and the Forest Marble formations. Based on old Ordnance Survey maps.

Richardson *et al.* (1946, p. 67) noted that Bletchington Station quarry was 'probably the original 'Gibraltar Quarry' and they refer to Phillips (1871, p. 247). However, Phillips (1871, p. 247) does not make clear whether the quarries at Enslow Bridge and Gibraltar were separate localities or part of one quarry, stating that the bones of *Cetiosaurus* came from 'the quarries at Gibraltar, near Enslow Bridge, and close to the railway station for Kirtlington and Bletchingdon'. Huene (1910c, p. 75) referred to two reptile quarries, that at Bletchington Station and one '300 m west of Bletchington Station on the other side of the river in the western valley wall'. This could be Quarry Bank or Gibraltar, about 300 m west of the station in the middle of the flood plain in the bend in the River Cherwell. McKerrow *et al.* (1969, p. 61) further complicated the issue by giving a map reference for a 'Gibraltar Quarry (477185)'. The quarry at SP 477185 (Whitehill Quarry) is a relatively recent excavation, and has nothing to do with the old Gibraltar quarry. Galton and Powell (1983, p. 220) failed to mention Gibraltar Quarry, referring to the locality simply as a 'series of quarries, about 9.6 km north of Oxford, in the west bank of the River Cherwell, which extend about 0.8 km southwards downstream from Enslow Bridge itself', but provided the grid reference SP 42477177. The grid reference appears to coincide with the assumed location of Gibraltar Quarry as is indicated in the accounts of Odling (1913, pp. 486, 496–8) and Arkell (1931, pp. 577–80).

Description

The sequence at Shipton-on-Cherwell Quarry (SP 475178) is based on Arkell's (1931, pp. 579–80) description, with modifications from Richardson *et al.* (1946, pp. 36–8).

	Thickness (m)
Lower Cornbrash	
In field immediately above the quarry (also at top of section to the south; Arkell 1947a, p. 58)	
Forest Marble Formation	
9. ('Wychwood Beds'). Clays, greenish grey dominant at N end; thinly laminated cross-bedded sand gradually replaces clays elsewhere (?=beds a–h of Odling 1913, p. 496)	1.8–3
8. ('Upper Kemble Beds') Limestone, cross-bedded, hard, white, blue-hearted, coarsely oolitic, locally split up by thick lens of dark-blue, shaly clay. (?=beds i, j of Odling, 1913, p. 496)	*c.* 3
White Limestone Formation	
Bladon Member	
7. Upper *Epithyris* Bed (Coral – *Epithyris* Limestone) (='Fossiliferous Cream Cheese' Bed of Odling 1913, p. 496, and Arkell, 1931, p. 579;'Cream Cheese Bed' of Barrow, 1908; Upper *Epithyris* Bed of Richardson *et al.*, 1946, p. 66). Limestone, cross-bedded, hard, similar to 8. Abundant *Epithyris*, *Modiola*, etc.	0.6–0.9
---- plane of erosion with a few pebbles ----	
Beds 6–3: *fimbriatus-waltoni* Beds	
6. (=Beds 2–4 of Odling, 1913, p.497). Marl, green, lignitiferous, black and shelly at base; 90 cm thick at N end, reducing to 15 cm band of white pellets at S end	0.1–0.9
5. (=Beds 5 and 6 of Odling, 1913, p. 497). Limestone, greenish grey, argillaceous, weathering soft. Abundant *Gervillia, Astarte*. Expands N	0.15–0.3
4. (=Beds 7 and 8 of Odling, 1913, p. 497). Clay, dark green with white pellets. Thins N	0.23–0.45
3. Limestone, hard, unfossiliferous, thins N	0–0.25
2. Oyster-*Epithyris* Marl (=Bed 9, first *Terebratula* bed of Odling, 1913, p. 497; Middle *Epithyris* Bed of Arkell 1931, p. 580, and Richardson *et al.*, 1946, p. 66). Marl, brown, ferruginous. In places, rolled fragments of limestone and corals at base. Abundant *Epithyris*.	0.23
------- plane of erosion -------	
Ardley Member	
1. (=Beds 10–12 of Odling, 1913, p. 498). Limestones, creamy white, compact. In places the *Epithyris* Limestone (=Lower *Epithyris* Bed) is typically represented, while elsewhere it is absent.	seen *c.* 2.0

Odling (1913, p. 498) recorded a further 3 m of section in the old Gibraltar Quarry, down to a compact limestone below the *Nerinea eudesii* Beds (lower Ardley Member).

Problems of lithostratigraphy and disagreement over the placing of the Forest Marble/White Limestone boundary are discussed by Richardson *et al.* (1946), Arkell (1947a), Palmer (1973, 1979), Torrens (*in* Cope *et al.*, 1980b, pp. 36–8) and Sumbler (1984). The main difficulty concerns the classification of beds which are, to an extent, transitional between the White Limestone and Forest Marble formations, and the confusion arising from different usage of the two formation names has been increased by the introduction of various subdivisions which have been used in different senses by different workers. The stratigraphic position of the transitional beds has recently been standardized by their inclusion in the Bladon Member of the White Limestone Formation (Sumbler, 1984).

Reptiles were found at three or four levels within the sequence: in the ?Ardley Member (?bed 1, or lower of Arkell, 1931; Richardson *et al.*, 1946), in the *fimbriatus-waltoni* Beds, in the lowest unit and the top of the Forest Marble (Arkell, 1931; Richardson *et al.*, 1946: beds 8 and 9), and in the Lower Cornbrash.

The most abundant remains appear to have come from the *fimbriatus-waltoni* Beds here and nearby. The bones excavated at Bletchington Station quarry between 1868 and 1870 lay 'on a freshly-bared surface of the Great Oolite and covered by the laminated clay and thin oolitic bands which occupy the place assigned to the Bradford Clay of Wiltshire' (Phillips, 1871, p. 248). The bones clearly lay within clay bands above an oolitic limestone and, because of their size, they passed up into different thin clay and marl units. Phillips' detailed section (1871, p. 251) shows seven thin argillaceous and calcareous units that cannot be matched with sections recorded nearby in the railway cutting (Hull, 1859, p. 20; Phillips, 1860, p. 117, 1871, p. 154), nor at Shipton. Nevertheless, it may be concluded that all of these belong to the *fimbriatus-waltoni* Beds. This is confirmed by H.B. Woodward (1894, p. 154) and Arkell (1931, pp. 565, 566). Richardson *et al.* (1946, pp. 39, 65, 67, 70) and Palmer (1979, p. 221) note the occurrence of *Cetiosaurus* bones in these beds at several quarries.

De la Beche and Conybeare (1821, p. 591) recorded 'an undoubted species of crocodile, somewhat resembling the Gavial . . . in the upper beds of the Great Oolite, or in the Cornbrash . . . at Gibraltar, eight miles north of Oxford'. Phillips (1871, p. 251) later noted that 'heads of teleosaurs are not infrequent at Enslow Bridge, and in beds of Great Oolite below the strata containing ceteosaurus', and in summarizing an excursion to Enslow Bridge (Phillips, 1871, p. 239) he noted that 'the members were highly gratified to learn that during the morning a very fine skeleton of *Teleosaurus* had been found and the head was exposed to view. This quarry is in the Great Oolite, the lower and uppermost strata of which in Oxfordshire yield remains of *Megalosaurus* while in the middle beds we find *Teleosaurus*'. These probably refer to finds in the old Gibraltar/Shipton Quarry in or below the *fimbriatus-waltoni* Beds. Further, 'remains of *Teleosaurus* were obtained at Enslow Bridge (south of Kirtlington) a little below the *Terebratula*-bed' (H.B. Woodward 1894, p. 323), thus below bed 2 of Arkell's (1931) section, probably at Shipton. *Teleosaurus* occurs as low as the Upper Shipton Member at Lower Greenhill Quarry (Odling, 1913, p. 496, Bed 18).

The large *Cetiosaurus* femur obtained in 1848 from the railway cutting south of Bletchington Station was apparently 'assigned to the base of the Forest Marble' by Prestwich and another specimen was found 'within two feet of the Cornbrash' (H.B. Woodward, 1894, p. 323). These indicate horizons equivalent to beds 8 and 9 respectively in the section given above.

Galton and Powell (1983) and Galton (1985b) suggest that the holotype of the stegosaur *Lexovisaurus? vetustus* (a right femur) probably derived from the top of the Forest Marble, because of its eroded nature and the fact that bones are virtually unknown in the Cornbrash, but do occur in the lagoonal facies of the Forest Marble Formation. The bone, however, bears an example of the bivalve *Meleagrinella echinata* on its surface (P. Powell, pers. comm.), firm evidence of a Lower Cornbrash derivation. This relocation of the find is of little significance, since both the Lower Cornbrash and the top of the Forest Marble are within the *Clydoniceras discus* Subzone of the *C. discus* Zone (Late Bathonian, Mid Jurassic; Torrens, *in* Cope *et al.*, 1980b, fig. 6a).

The bones from all levels at Shipton are generally well preserved, but disarticulated. Taphonomic information is only available for the *Cetiosaurus* find of 1868-70 at nearby Bletchington Station quarry. Phillips (1871, pp. 248-51) noted that the large bones were largely shattered (?by compression from the weight of the superincumbent sediment). The separate elements were disarticulated, but associated, remains of three individuals of different size being preserved within an area measuring 6 m by 6 m. Vertebrae and ribs were much broken and mixed in 'confused' groups. No cranial remains were found. Thus, as Phillips (1871, p. 249) realized, the animals had died elsewhere, 'the parts separated by decay; the massive limbs disjointed, and the bones displaced'. The bones were washed in, but have not suffered much wear.

Fauna

The majority of the specimens labelled 'Enslow Bridge' or 'Gibraltar' appear to have come from the old Gibraltar Quarry which is now part of the Shipton-on-Cherwell cement works. Specimens from Bletchington Station Quarry are normally noted as 'Bletchington Station' or 'Kirtlington Station', and they are not listed here. Most specimens are labelled 'Great Oolite', and they probably came from beds 3-6 (*fimbriatus-waltoni* Beds) or lower.

Testudines
'turtle scute'
OUM J17567.
Archosauria: Crocodylia: Thalattosuchia:
Steneosauridae
Steneosaurus boutilieri J.A. Deslongchamps, 1869
OUM J1401-4, J1412, J1416-7
Steneosaurus brevidens (Phillips, 1871)
BMNH R78-79, 44821

Steneosaurus aff. *larteti* (J.A. Deslongchamps, 1866)
OUM J.1408–10
Steneosaurus megistorhynchus J.A. Deslongchamps, 1866
OUM J.1414–5
Steneosaurus meretrix Phizackerley, 1951
Type specimen: OUM J.29850. Also, OUM J.29851, J.1407
Steneosaurus sp.
BGS(GSM) (old no.); OUM J.10590–1, J.29495; CAMSM J.21952–3
Teleosaurus subulidens Phillips, 1871
OUM J.13599–600
Archosauria: Crocodylia: Thalattosuchia: Metriorhynchidae
Metriorhynchus cf. *geoffroyi* Meyer, 1832
OUM J1418
Dinosauria: Saurischia: Theropoda: Megalosauridae
Megalosaurus bucklandi Meyer, 1832
OUM J.13598, J.29773, J.13882, J.29765
Dinosauria: Saurischia: Sauropoda: Cetiosauridae
?Cetiosaurus
OUM J.29806
Dinosauria: Ornithischia: Ornithopoda
?Iguanodon
OUM J.29805
Dinosauria: Ornithischia: Stegosauria: Stegosauridae
Lexovisaurus? vetustus (Huene, 1910)
Type specimen: OUM J.14000

Interpretation

The biostratigraphy is difficult to establish because of the general absence of ammonites here and in comparable units nearby. Three or four specimens of *Tulites* and *Procerites* have been recorded from Bletchington Station and Enslow Bridge, but they are either lost or stratigraphically unlocalized (Torrens, 1969b, p. 69, *in* Cope *et al.*, 1980b, pp. 37–8). The stratigraphic units are assigned within the Late Bathonian as follows (Palmer, 1979; Torrens, *in* Cope *et al.*, 1980b): Ardley Member (?lower *hodsoni* Zone), Bladon Member (?upper *hodsoni*-lower *aspidoides* Zones), Forest Marble Formation (*?aspidoides*-lower *discus* Zone), Lower Cornbrash (?upper *discus* Zone).

The reptiles from Shipton are generally large, with none of the 'lizards', pterosaurs, amphibians or mammals that are known from deposits of the same age at Kirtlington. This is probably the result of different collecting techniques, rather than any major habitat distinction. Nevertheless, the dominance by crocodilians is typical of most British Bathonian sites.

The long-snouted crocodilians *Steneosaurus, Teleosaurus* and *Metriorhynchus* are well known from several British Mid Jurassic sites from the Early Bathonian (e.g. New Park Quarry), the Mid Bathonian (Huntsman's Quarry; Stonesfield) and the Late Bathonian (e.g. Kirtlington, Oxfordshire). These forms were revised by Phizackerley (1951), but Steel (1973), in a recent review, was unable to clarify their complex taxonomy. The distinctions between the species, and the assignment of valid species to different genera, have yet to be assessed in an overview. In other words, the total of seven species from Shipton is almost certainly an overestimate and it is not clear to which genus each should be ascribed. Nevertheless, the Shipton specimens are largely skulls and lower jaws, which are taxonomically and functionally important elements, and these should be of extreme importance when a review is undertaken. The importance is heightened by the fact that the type specimens of most of the species erected by Deslongchamps and French authors, from the 'Fullers Earth' and 'Great Oolite' of Normandy, were destroyed in 1944.

Several of the crocodile skulls from Shipton are significant. OUM J.1401 (*S. boutilieri*) was the first recorded British Mid Jurassic crocodile (Figure 6.11A), and casts of it were used by E.E. Deslongchamps to supplement his studies of the Normandy crocodiles. OUM J.1403 (*S. boutilieri*) unusually preserves posterior parts of the skull and palate very well. OUM J.1416, part of the type material of *Teleosaurus brevidens* Phillips (1871), is a remarkably complete lower jaw, ascribed to *S. boutilieri* by Phizackerley (1951, pp. 1177–85). OUM J.1414 (*S. megistorhynchus*) is part of the type material of *Teleosaurus subulidens* Phillips (1871) and is a fine lower jaw. OUM J.29850 and J.29851 (formerly Oxford Zool. Dept. 1639/1 and 1639/2) are holotype and paratype respectively of *S. meretrix* Phizackerley (1951). They, and OUM J.1407, show an animal with a 1 m long, very low skull, a depressed snout and little anterior rostral expansion.

Other reptiles are less well represented. There is one plate from a turtle carapace, about which little can be said. The carnivorous dinosaur

Megalosaurus is very rare here, being represented by a scapula and isolated dagger-shaped teeth. This compares with its rarity at Kirtlington and other Late Bathonian sites also, but in the Mid Bathonian it is one of the commonest finds (e.g. Huntsman's Quarry and Stonesfield, see above). A bone referred to *Cetiosaurus* was reported in a footnote in Phillips (1871, p. 213). *Cetiosaurus* bones are relatively abundant nearby in the Late Bathonian (e.g. Bletchington Station quarry, Kirtlington Cement Quarry, Glympton (SP 427217), Stratton Audley (SP 6026) and Blisworth (SP 7253)). In the same footnote, Phillips (1871) records a specimen that he tentatively refers to *Iguanodon*, but this is questionable since *Iguanodon* comes mainly from the Early Cretaceous of Europe (Norman, 1980, 1986), with only a single occurrence from the Late Jurassic (a referred mandible from the Portlandian; see below).

Finally, the 700 mm long right femur of the stegosaur *Lexovisaurus* (type specimen of *Lexovisaurus*? *vetustus* (Huene, 1910c)), probably from the Lower Cornbrash of Shipton (see above) is of great importance (Figure 6.11B). The femur exhibits certain juvenile features such as a gentle curve between the head and shaft in anterior view, the persistence of the cleft between the lesser and greater trochanter, and the lack of prominent longitudinal ossified cords proximally and on the shaft. It is proportionately more massive when compared with those of other stegosaurs from England, such as *Dacentrurus armatus* (Owen) from the Kimmeridgian and *D.* ?*phillipsi* (Seeley) from the Oxfordian (both Late Jurassic) and *Lexovisaurus durobrivensis* (Hulke) from the Callovian (Mid Jurassic). *Lexovisaurus*? *vetustus* is one of the oldest stegosaurs known (see New Park Quarry report), and it is similar to *Kentrosaurus* (Hennig) from the Tendaguru Shale (Kimmeridgian) of East Africa and shows similarities to the Chinese Bathonian *Huayangosaurus*.

Comparison with other localities

The reptiles from Shipton-on-Cherwell Cement Works/Gibraltar Quarry (SP 475178) must first be compared with the other 'Enslow Bridge' localities. The best known is Bletchington Station Quarry (SP 484182), which has yielded remains of *Cetiosaurus, Megalosaurus* and *Steneosaurus* from the *fimbriatus-waltoni* Beds (Phillips, 1871, pp. 151, 247–94; Arkell, 1933, p. 289). The productive layer here was quarried up to the road (the A4095, also known as Lince Lane), but cannot be worked any further. A few *Cetiosaurus* bones were also found in the railway cutting south of Bletchington Station (SP 482181), possibly in the *fimbriatus-waltoni* Beds and Forest Marble. Some *Steneosaurus* teeth and bones are recorded from Lower Greenhill Quarry (SP 483179). A more useful comparison may be made with the better known faunas from Kirtlington Cement Works (SP 494199). Here, steneosaurs are relatively common in the *fimbriatus-waltoni* Beds, with some remains of *Cetiosaurus* and *Megalosaurus*. The Kirtlington Mammal Bed, at the Forest Marble/White Limestone boundary is dominated by fishes, crocodilians (?*Goniopholis*), turtles and 'lepidosaurs', with rarer frogs, salamanders, choristoderes, pterosaurs, ornithischian dinosaurs, theropods, *Cetiosaurus*, tritylodontids and mammals (Evans and Milner, 1994). The fauna of the latter unit is biased towards small fossils because of sedimentological and palaeontological factors, as well as by the means of collection. Such remains may occur at Shipton and detailed sampling of the *fimbriatus-waltoni*

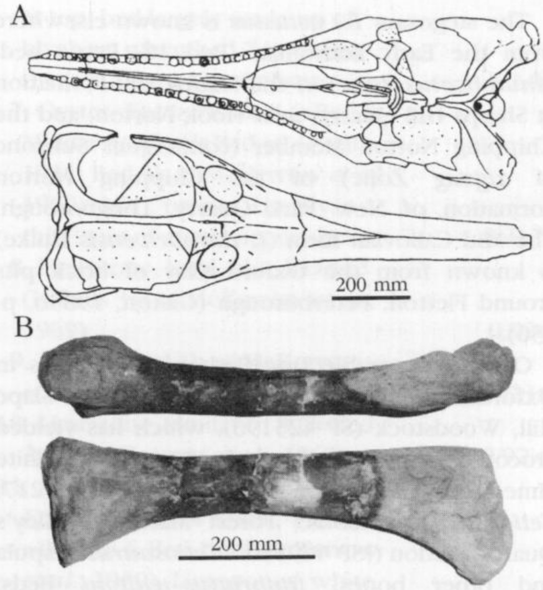

Figure 6.11 Bathonian reptiles from Shipton-on-Cherwell. (A) The crocodile *Steneosaurus boutilieri* Deslongchamps, 1869, skull in dorsal and ventral views; (B) the stegosaur *Lexovisaurus vetustus* Huene, 1910, right femur in lateral and anterior views.

Beds and other argillaceous units would be useful.

The stegosaur *L.*? *vetustus* is known elsewhere from the Early Bathonian (Bed 18, Perna bed, *tenuiplicatus* Zone) of the Sharps Hill Formation at Sharps Hill Quarry, near Hook Norton, and the Chipping Norton Member (*convergens* Subzone of *zigzag* Zone) of the Chipping Norton Formation of New Park Quarry, Longborough. The Mid Callovian form (*L. durobrivensis* Hulke) is known from the Oxford Clay of brick pits around Fletton, Peterborough (Galton, 1985b, p. 236).

Other comparable Late Bathonian localities in Oxfordshire and Northamptonshire include Slape Hill, Woodstock (SP 425196), which has yielded crocodile bones and teeth from the White Limestone, Glympton Quarry (SP 427217; *Cetiosaurus* vertebrae, Forest Marble), Tolley's Quarry, Bladon (?SP 449150: ?*Cetiosaurus* scapula and other bones, *fimbriatus–waltoni* Beds: Richardson *et al.*, 1946, p. 65), Ardley quarries (SP 539272, SP 541265; crocodile teeth and bones from the White Limestone), Stratton Audley (SP 6026; *Cetiosaurus* and other ?dinosaur bones, Forest Marble), Blisworth railway cuttings (SP 725543; *Cetiosaurus, Steneosaurus* bones in Blisworth Limestone or Clay), Kingsthorpe (SP 7563; *Steneosaurus* bones) and Thrapston LMS station quarry (SP 998777; *Steneosaurus, Cetiosaurus, Megalosaurus, 'Plesiosaurus'* from 'Great Oolite' or Cornbrash). Clearly, only Kirtlington, and possibly Thrapston, are of comparable stature to Shipton for Late Bathonian reptiles.

Conclusions

Shipton/Gibraltar quarry has yielded the largest variety of British Mid Jurassic crocodiles. The specimens consist of skulls and jaws which are of prime importance for classification and ecological studies. More specimens have been found at Stonesfield (early Mid Bathonian), but these are largely isolated teeth, scutes and bones. In view of the fact that the Normandy type specimens have been destroyed, the Shipton steneosaurs are the best in the world for studies of Mid Jurassic crocodiles. The stegosaur *Lexovisaurus*? *vetustus* is the oldest member of its genus, and one of the oldest members of Stegosauria, a group which radiated in the Late Jurassic and Early Cretaceous of Europe, Africa and North America. Shipton's crocodiles and its stegosaur make it a Mid Jurassic site of international importance, and this importance combined with a potential for future finds give its considerable conservation value.

KIRTLINGTON OLD CEMENT WORKS QUARRY, KIRTLINGTON, OXFORDSHIRE (SP 494199)

Highlights

Kirtlington Old Cement Works is the richest site in the world for small terrestrial vertebrates from the Bathonian. The diverse tiny bones of 30 frogs, salamanders, turtles, lizards, crocodilians, pterosaurs, dinosaurs, mammal-like reptiles and mammals have been found there, many of them representing the oldest occurrences of their groups in the world.

Introduction

Kirtlington Old Cement Works Quarry has produced good faunas of fossil reptiles from the White Limestone and Forest Marble (Late Bathonian). The quarry was formerly worked for the manufacture of cement, and it closed about 1930. Although exposures were excellent (Odling, 1913; Arkell, 1931), some of the faces became obscured more recently (McKerrow *et al.*, 1969; Palmer, 1973; Freeman, 1979). Fossil amphibians, reptiles and mammals have been collected in recent years from the *fimbriatus–waltoni* Beds and from the Kirtlington Mammal Bed, a microvertebrate locality near the base of the Forest Marble (Freeman, 1976, 1979; Evans *et al.*, 1988, 1990; Evans, 1989, 1990, 1991, 1992a; Evans and Milner, 1991, 1994).

Description

The succession in the quarry has been described by Odling (1913, pp. 493, 494), Arkell (1931, pp. 570–2), Douglas and Arkell (1932, pp. 123–4) and Richardson (1946, pp. 69–71, 78–9). Additional information has been provided by McKerrow *et al.* (1969) and Freeman (1979). The following composite section is based on these authors, and

Richardson *et al.* (1946), in particular, with additions from Palmer (1973, 1979) and Torrens (*in* Cope *et al.*, 1980b, p. 36):

	Thickness (m)
Lower Cornbrash	
1. Limestone, rubbly and marly	1.07
2. Limestone, tough	0.76
3. Marl and rubbly limestone, in places nodular	0.23
4. *Astarte-Trigonia* Bed. Limestone, very hard, grey	0.61
5. Clay, brown, marly	0.30
Forest Marble Formation	
1. Clay, grey and buff, with some thin, irregular hard bands	1.53
2. Clay, dark grey (=beds 3w–z of Freeman, 1979)	0.69
3. Limestone, yellowish, flaggy, locally marly and 'shaly', oolitic, with occasional inclusions of white lithographic limestone; ripple marks, rain pits (?=bed 3v of McKerrow *et al.*, 1969; Freeman, 1979)	0.61–0.92
(White Limestone Formation)	
4. Clay, grey-blue, with three pale mudstone layers, one at the bottom (=beds 3p–u of McKerrow *et al.*, 1969; Freeman 1979; = 'Unfossiliferous Cream Cheese Bed' of Odling, 1913 and Arkell, 1931). The basal unconsolidated 0.04–0.25 m brown marl unit (Bed 3p) is the Kirtlington Mammal Bed of Freeman (1979)	2
(White Limestone Formation)	
5. Coral-*Epithyris* Limestone (Upper *Epithyris* Bed or 'Fossiliferous Cream Cheese Bed' of Odling, 1913 and Arkell, 1931; ? Beds 3n-o of McKerrow *et al.*, 1969). Limestone; at northern end an extremely hard white blue-hearted lithographic rock. Passes locally into unfossiliferous oolite	1.22–2.21
6. *fimbriatus-waltoni* Beds (=Bed 10 of Arkell 1931; Beds 3k, l of McKerrow *et al.*, 1969). Clay, grey-green to greenish black, with some white pellets at top; bed largely made up of bivalves; when bed 7 is absent, there is a lignite at the base	1.07
7. Oyster-*Epithyris* Marl (=Bed 9; Middle *Epithyris* Bed of Arkell, 1931; Bed 3k of McKerrow *et al.*, 1969). Marl, brown. Locally, a thin layer of corals occurs below	0–0.75
8. Limestone, hard, blue-hearted (?=Beds 3i,j of McKerrow *et al.*, 1969)	0.92m
9. Marl (?=Bed 3h of McKerrow *et al.*, 1969)	0.23m
10. Limestone, similar to 8 (?=Bed 3g of McKerrow *et al.*, 1969)	0.84–0.92 m
11. *Epithyris* Limestone (=Lower *Epithyris* Bed of Arkell, 1931; =Bed 3a–f, Bed 1e of McKerrow *et al.*, 1969). Limestones, white, at west end of pit a mass of *Epithyris*. Thins out eastwards and replaced from beneath by lenticular limestones	2.44
12. *Aphanoptyxis ardleyensis* Bed. Limestones, well bedded	0.46–0.61
13. *Nerinea eudesii* Beds. Limestones in three courses	1.68

This section was recorded by Arkell (1931) in various parts of the quarry, which means that it is not a true log because of the large amount of lateral facies variation. The lower parts (beds 8–13 in particular) are hard to match with the logs given by McKerrow *et al.* (1969, p. 58) because certain units, such as the *Epithyris* Limestone (Bed 11; Bed 1e of McKerrow *et al.*, 1969), are laterally impersistent.

There are considerable problems with the lithostratigraphy of the units in this quarry and these particularly concern the placing of the boundary between the White Limestone and the Forest Marble. Odling (1913, pp. 493–4) placed it above his 'Bed 1. Fossiliferous Cream-Cheese Bed', thus between beds 4 and 5 of the section of Richardson *et al.* (1946). Arkell (1931) renamed and subdivided the Forest Marble into the Wychwood Beds (beds 1–3 of the section of Richardson *et al.*, 1946) and the Kemble Beds (beds 4–7). Thus, he moved the Forest Marble/White Limestone boundary to between beds 7 and 8 on the basis of correlations with supposedly similar lithologies and fossils in

Oxfordshire and Wiltshire. Richardson *et al.* (1946, pp. 69–71) changed the Wychwood Beds/Kemble Beds boundary to lie between their beds 2 and 3, and moved the Forest Marble/White Limestones boundary to lie between their beds 5 and 6. Arkell (1947a, p. 57) interpreted the sequence as follows: Wychwood Beds (beds 1–3), Kemble Beds (beds 4–5), Bladon Beds (beds 6–7), ?Bladon Beds (beds 8–10), Ardley Beds (beds 11–13), the division of the White Limestone being based on gastropods.

More recently, McKerrow *et al.* (1969) attempted a definition based largely on the occurrence of oysters and took the basal bed of the Forest Marble to be the base of the Oyster-*Epithyris* Marl (bed 7), as Arkell (1931) had initially. Palmer (1973, p. 61) points out that at Kirtlington the Coral-*Epithyris* Limestone (bed 5) contains oysters, but otherwise shows a typical White Limestone fauna and lithology, and he proposed that the Forest Marble/White Limestone boundary should be moved to between beds 4 and 5. This view was also expressed by Barker (1976) on the basis of a study of the gastropods. Palmer (1979) further argued this point and divided the White Limestone Formation into three members, of which the Ardley Member (beds 8–13) and the Bladon Member (beds 5–7) are seen at Kirtlington. Palmer (1979, p. 208, fig. 5) makes it clear that his Bladon Member is intended to include both the *fimbriatus-waltoni* and Upper *Epithyris* Beds of the Cherwell valley which rest on the *A. bladonensis* Bed. In general, Torrens (*in* Cope *et al.*, 1980b, p. 36) recommends that the base of the Forest Marble be taken as 'the base of the clay overlying the Coral-*Epithyris* bed, or of the bed above at Kirtlington' (i.e. the base of bed 3 or 4).

Reptiles occur in the *fimbriatus-waltoni* Beds (beds 2o, 3i, 4e, 6f of McKerrow *et al.*, 1969; base of the Bladon Member, Palmer, 1979) and the Kirtlington Mammal Bed. Arkell (1931, p. 572) noted that he saw the bones of *Cetiosaurus oxoniensis* Phillips (1871) associated with lignite at the base of the *fimbriatus-waltoni* Beds where they rest on the eroded surface of the underlying limestone. Richardson *et al.* (1946, p. 70) repeated this observation, but noted that the bones and lignite occurred when the Oyster-*Epithyris* Marl (bed 7) was absent and lay on the eroded top of bed 8. However (p. 71) they say that 'the main horizon for Ceteosauran [sic] remains appears to be between the clay and the Middle *Epithyris* Bed, although here at Kirtlington and elsewhere the remains are often enclosed by the clay'. *Cetiosaurus* has been found elsewhere in Oxfordshire in the *fimbriatus-waltoni* Beds (Phillips, 1871; Arkell, 1931; Richardson *et al.*, 1946). The bones in this unit are usually disarticulated, but appear to have been associated (Phillips, 1871, p. 250).

The Kirtlington Mammal Bed (bed 3p of McKerrow *et al.*, 1969) is an impersistent lens, 21.5 m long and 0.04–0.25 m thick in the north-eastern corner of the quarry (Freeman, 1979, p. 136). The contacts of this bed with the Coral-*Epithyris* Limestone below (bed 3o of McKerrow *et al.*, 1969) and another limestone above (bed 3q) are extremely sharp and probably erosional. Associated fossils (Evans and Milner, 1994) include microscopic freshwater charophytes, indeterminate plant fragments, and ostracods, as well as the dissociated remains of a variety of bony fishes (cf. *Lepidotes*, pycnodontoid, ?amioid) and sharks (*Asteracanthus, Hybodus, Lissodus*, batoid). The tetrapod remains include a variety of amphibians, reptiles and mammals (Evans and Milner, 1991, 1994). Most of these animals are represented only by their more durable parts – teeth, scutes, jaws and vertebral fragments. By contrast, a few genera (possibly those which have been least transported) have most of their skeletal elements preserved.

Fauna

The older reptile specimens labelled 'Kirtlington' in collections are assumed to come from the *fimbriatus-waltoni* Beds, since the Mammal Bed was not exploited before the work of Freeman (1976, 1979) and its fossils are generally small.

1. *fimbriatus-waltoni* Beds

Archosauria: Crocodylia: Thalattosuchia:
 Steneosauridae
 Steneosaurus brevidens (Phillips, 1871)
  BMNH R5149
 '*Steneosaurus*' aff. *larteti* (J.A. Deslongchamps, 1866)
  OUM J.1413
 Steneosaurus sp.
  BMNH R4809, R6323; OUM J.10597, J.12007; CAMSM J.21949–51, J.21954
 Teleosaurus sp.
  BRSMG Cb1271 (specimen destroyed in World War 2)

Dinosauria: Saurischia: Theropoda: Megalosauridae
Megalosaurus sp.
BMNH R5797
Dinosauria: Saurischia: Sauropoda
Cetiosaurus sp.
BMNH R5152–3, R5156–7; OUM J.13526–57, J.13596
Bothriospondylus sp.
BMNH R5150–1
Sauropterygia: Plesiosauria
?*Plesiosaurus* sp.
BMNH R2986, R5154

2. Kirtlington Mammal Bed (data from Freeman, 1979 and Evans and Milner, 1991, 1994)
Anura: Discoglossidae
Eodiscoglossus oxoniensis Evans, Milner and Mussett, 1990
Holotype: BMNH R11700
Caudata: Albanerpetontidae
Albanerpeton sp.
Caudata: *inc. sed.*
Marmorerpeton freemani Evans, Milner and Mussett, 1988
Holotype: BMNH R11364
Marmorerpeton kermacki Evans, Milner and Mussett, 1988
Holotype: BMNH R11361
Salamander A
Salamander B
Testudines: Cryptodira
cf. Pleurosternidae
Lepidosauromorpha: *inc. sed.*
Marmoretta oxonienesis Evans, 1991
Holotype: BMNH R12020
Lepidosauria: Sphenodontida
Sphenodontian (Evans, 1992a)
Lepidosauria: Squamata: Sauria
Saurillodon sp.
Scincomorphs
Anguimorph
?Gekkotan
Archosauromorpha: Choristodera
Cteniogenys sp.
Archosauria: Crocodylia: Neosuchia
?*Goniopholis/Nannosuchus* sp.
atoposaurid
Archosauria: Pterosauria
Rhamphorhynchoid
Pterodactyloid
Archosauria: Saurischia
Megalosaurus sp.
'maniraptoran' and other small theropods
?*Cetiosaurus*
Archosauria: Ornithischia: Ornithopoda
Fabrosaurid, cf. *Alocodon*
Synapsida: Therapsida: Cynodontia: Tritylodontidae
Stereognathus ooliticus Charlesworth, 1855
Mammalia: Triconodonta: Morganucodontidae
Wareolestes rex Freeman, 1979
Mammalia: Docodonta: Docodontidae
Simpsonodon oxfordiensis Kermack, Lee, Lees and Mussett, 1987
Mammalia: Symmetrodonta: Kuehneotheriidae
Cyrtlatherium canei Freeman, 1979
Mammalia: Eupantotheria: Peramuridae
Palaeoxonodon ooliticus Freeman, 1979
Mammalia: Eupantotheria: Dryolestidae
?Dryolestid

Interpretation

The biostratigraphy of the Bathonian at Kirtlington is difficult since no ammonites have been found locally, and very few elsewhere in comparable rocks (Torrens, 1969a; *in* Cope *et al.*, 1980b). Finds of ammonites in the White Limestone of the Oxford area have permitted correlation of this unit with the *subcontractus* and *morrisi* Zones (Mid Bathonian), and the *hodsoni* and lower *aspidoides* Zones (Late Bathonian), while the Forest Marble Formation is largely *aspidoides* and basal *discus* Zones (Late Bathonian), on the basis of correlation of beds above and below.

The approximate zonal assignments of the three members of the White Limestone Formation are: Shipton Member, ?*subcontractus, morrisi* Zones, Ardley Member, ?lower *hodsoni* Zone, and Bladon Member, ?upper *hodsoni*–lower *aspidoides* Zones (Palmer, 1979; Torrens, *in* Cope *et al.*, 1980b). However, the evidence for zonation of these members is 'not compelling' (Torrens, *in* Cope *et al.*, 1980b, p. 37). Ostracod zonation (Bate, 1978) places the White Limestone of the Oxford area in ostracod zones 5–8, the Forest Marble and Cornbrash resolving to the top of zone 8 and above (=upper *discus* Zone).

The reptile-bearing *fimbriatus–waltoni* Beds (base of the Bladon Member) are dated as ?upper *hodsoni* Zone (basal Late Bathonian) (Torrens, *in* Cope *et al.*, 1980). However, the occurrence of the ostracod *Glyptocythere penni* in the *fimbriatus–waltoni* Beds led Bate (1978) to suggest that this unit belongs to the *discus* Zone. The Kirtlington Mammal Bed falls within the *aspidoides* or *discus* Zone (Freeman, 1979, p. 136).

Environmental interpretations have been made on the basis of the sedimentology of the *fimbriatus-waltoni* Beds. McKerrow *et al.* (1969, pp. 61–4, 80) noted the abundance of lignite and occasional caliche-like nodules which they interpreted as indicating shallow water with occasional subaerial exposure. The nodules appear to be distinct from the small pellets of 'race' common in many calcareous clays close to the ground surface, which are produced by recent weathering. Klein (1965, p. 173) considered that similar nodules from other Great Oolite clays represent caliche, indicating emergence, although Palmer (1979, p. 210) regarded them as pebbles formed by erosion of an incompletely cemented limestone bed. Palmer (1979, pp. 210–11) noted the complex channelled interdigitations of this unit at Shipton (SP 4717), and suggested that deposition of some of the clays was local and catastrophic, and that the nodules were derived from elsewhere. There is a non-sequence at the top of the *fimbriatus-waltoni* Beds, and localized emergence at this level is probable, which may be related to nodule formation. Palmer (1979) supposed a quiet-water lagoonal environment subject to periodic current activity and influx of new sediment, perhaps during storms.

The marl sediment of the Kirtlington Mammal Bed contains subangular pebbles of oolitic limestones, comminuted shell debris, individual ooliths and rare silica sand grains, all of which suggest a temporary freshwater pool that received periodic influxes of poorly sorted sediment derived from local erosion of earlier Mid Jurassic limestones (Freeman 1979, p. 139). The ostracods, charophytes and fishes lived in the pool, and the plants, amphibians, reptiles and mammals presumably lived nearby. Freeman (1979) noted that the mammal and theropod teeth were distributed in clumps, and that this might indicate their concentration in the faeces of larger animals, such as carnivorous dinosaurs ('coprocoenoses').

As outlined by Evans (1990, p. 234), in Bathonian times Kirtlington lay on or near the south-west shore of a small island barrier some 30 km from the coast of the Anglo-Belgian landmass at a subtropical latitude of about 30°N (Palmer, 1979). Lignite, charophytes and freshwater ostracods and gastropods in the marly sediments suggests a coastal environment, which had low relief, with creeks, lagoons and freshwater lakes, rather like the Florida Everglades (Palmer, 1979). The vertebrate fauna of the Kirtlington Mammal Bed, with its amphibians and aquatic reptiles (choristoderes, crocodilians and turtles), agrees well with such a palaeoenvironmental scenario. Terrestrial elements are rather rare, being largely represented by reptile jaw fragments and teeth; these components may have been reworked from localities further inland.

The faunas of the two reptile-bearing beds at Kirtlington are rather different, which probably relates to preservational and environmental conditions rather than to the very slight age difference. They will be discussed separately.

The *fimbriatus-waltoni* Beds fauna is dominated by crocodilians and sauropod dinosaurs. The long-snouted crocodilians *Steneosaurus* and *Teleosaurus* are represented by vertebrae, teeth and jaws. Their long recurved teeth, strong jaws and adaptations for swimming suggest that they were fish-eaters in fresh or marine water. The taxonomy of these forms is complex (Steel, 1973), so that the species assignments may be incorrect. These crocodiles are relatively common in the Bathonian of England and France (see above). In the Late Bathonian of England specimens are known from the upper White Limestone of a few localities elsewhere in Oxfordshire and in the Blisworth Limestone (=White Limestone) and Blisworth Clay of Northamptonshire.

The carnivorous dinosaur *Megalosaurus* is represented only by a tooth. However, a variety of vertebrae, limb bones and skull elements (including the brain case) of the large sauropod *Cetiosaurus* have been found. More than 10 species of this genus have been erected for Jurassic and Cretaceous material (Steel, 1970, p. 64). The Mid Jurassic forms are *C. rugulosus* (Owen, 1845) from Wiltshire, *C. oxoniensis* Phillips (1871) and *C. glymptonensis* Phillips (1871) from Oxfordshire and Northamptonshire and *C. mogrebiensis* Lapperant (1955) from the Moyen Atlas of Morocco. The morphological distinctions between these species have not been elucidated (*C. rugulosus* is based on a tooth, *C. glymptonensis* on a caudal vertebra and the other two on incomplete postcranial skeletons). Further, many other generic names have been applied to large sauropod bones, and the differences have often not been made clear. Nevertheless, most of the Mid Jurassic English material may be placed in *C. oxoniensis*, the best-known species. This animal had a 1.65 m femur, and was about 15 m long overall. The braincase resembles that of the Triassic *Plateosaurus*, the neck was relatively short and the vertebrae showed primitive features (almost solid construction, and no bifurcation of the neural spines).

Two vertebrae of another sauropod, *Bothriospondylus*, have also been found at Kirtlington. This genus is known mainly from the Late Jurassic and Early Cretaceous, but two forms occur in the Bathonian, *B. robustus* Owen (1875) from Wiltshire and *B. madagascariensis* Lydekker (1895) from Madagascar. The vertebrae of *Bothriospondylus* are deeply excavated, presumably to reduce their weight. Its total body length was 15–20 m.

Two vertebrae have been named as those of a plesiosaur. If correctly identified, these may belong to the genera '*Cimoliasaurus*' of *Muraenosaurus*, known from the Bathonian of sites in Northamptonshire, Cambridgeshire, Leicestershire and Eigg, western Scotland. Assuming their correct identification, the presence of plesiosaurs in the *fimbriatus-waltoni* Beds would indicate marine conditions, but their rarity here may connect with a predominantly lagoonal/coastal situation.

The amphibians, reptiles and mammals from the Kirtlington Mammal Bed have been summarized by Freeman (1979) and Evans and Milner (1991, 1994). Details of the collecting and preparation techniques are given in Freeman (1976, 1979), Kermack *et al.* (1987) and Evans (1989). The amphibians and reptiles (Figure 6.12) are described here (the mammals will be detailed in the GCR Fossil Mammals and Birds volume).

The amphibians include a frog referrable to the family Discoglossidae (*Eodiscoglossus oxoniensis*) and five species of salamander (*Albanerpeton, Marmorerpeton kermacki, M. freemani* and two unnamed forms). *Eodiscoglossus oxoniensis* (Figure 6.12A) is the earliest identifiable discoglossid frog known, and one of the oldest frogs of any sort (Evans *et al.*, 1990). The specimens of *E. oxoniensis* from Kirtlington are comparable with *E. santonjae* from the Early Cretaceous of Montsech, Lérida, Spain, but they may be clearly distinguished by characters of the ilium and premaxilla. The only older frogs are the primitive *Triadobatrachus* from the Early Triassic of Madagascar and *Vieraella* from the Early Jurassic of Argentina.

The record of *Albanerpeton* is one of the oldest of this enigmatic family, the oldest being from the Bajocian of Aveyron, France (Evans and Milner, 1994). The albanerpetontids are also known from the Cretaceous of North America and the Miocene of France. *Marmorerpeton kermacki* (Figure 6.12B) and *M. freemani* are the earliest known salamanders (i.e. true Caudata; Evans *et al.*, 1988), more primitive than any other known forms by the absence of intravertebral spinal nerve foramina in the atlantal centrum. However, in other features these taxa resemble members of the family Scapherpetonidae, which comprises neotenous forms otherwise known only from the Late Cretaceous and Palaeocene. Salamanders A and B are yet to be described.

Turtles are represented by many specimens (Freeman, 1979; Evans and Milner, 1994) which augment the sparse Mid Jurassic record of that group. The oldest turtles, *Proterochersis* and *Proganochelys*, come from the Late Triassic of Germany and the oldest cryptodire, the main modern group is *Kayentachelys* from the Early Jurassic of North America. Turtle fragments are known from Stonesfield and other British Bathonian sites, but the Kirtlington material includes more diagnostic skull and carapace fragments of a pleurosternid (Evans and Milner, 1994).

Lepidosauromorphs are represented at Kirtlington by a variety of forms. The Lepidosauromorpha (Benton, 1985; Evans, 1988a; Gauthier *et al.*, 1988c) include the Lepidosauria (sphenodontids plus squamates) and a number of basal Permo-Jurassic groups. *Marmoretta oxoniensis* (Figure 6.12C) is a small probably insectivorous form, apparently a common component of the fauna (Evans, 1991). True lepidosaurs are represented by some sphenodontids (Evans, 1992a) and squamates (two scincomorph lizards, one of which is *Saurillodon*, an anguimorph and a possible gekkotan). These are important since lepidosaurs are not well known in the Mid Jurassic: the nearest well-documented faunas are the sphenodontids from the Late Triassic and Early Jurassic fissures of the Bristol area and South Wales (see above) and from the Early Cretaceous of Durlston Bay (Purbeck). Sphenodontids are known also from the Late Jurassic of Germany (Solnhofen), France (Cerin) and North America (Morrison Formation) (Fraser and Benton, 1989). The first true lizards are known otherwise only from the Late Jurassic (Oxfordian of Guimarota, Leiria, Portugal; Kimmeridgian of Cerin, Ain, France; Portlandian of Solnhofen, Bavaria, Germany; Benton, 1993).

Cteniogenys (Figure 6.12D) is represented by many isolated skull and postcranial elements. The genus was named on the basis of some isolated

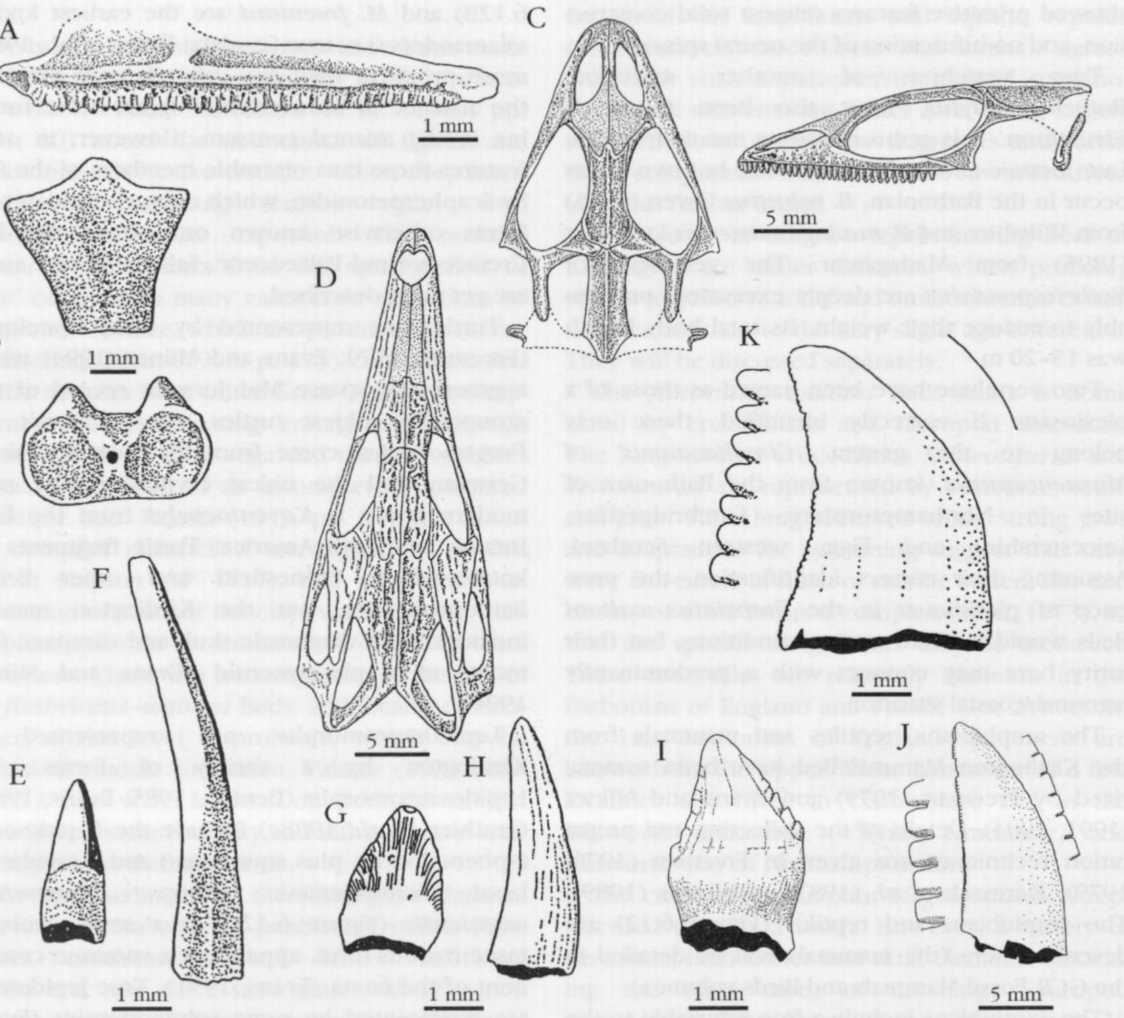

Figure 6.12 Bathonian amphibians and reptiles from Kirtlington Old Cement Works Quarry. (A) The frog *Eodiscoglossus oxoniensis* Evans, Milner and Mussett, 1990, right maxilla in medial view; (B) the salamander *Marmorerpeton kermacki* Evans *et al.*, 1988, atlantal centrum in ventral and anterior views; (C) the lepidosauromorph *Marmoretta oxoniensis* Evans, 1991, reconstructed skull in lateral and dorsal views; (D) the choristodere *Cteniogenys oxoniensis* Evans, 1990, reconstructed skull in dorsal view; teeth of: (E) rhamphorhynchoid pterosaur; (F) pterodactyloid pterosaur; (G) goniopholidid crocodile; (H) atoposaurid crocodile; (I) fabrosaurid dinosaur; (J) megalosaurid dinosaur; (K) maniraptoran dinosaur. All after Evans and Milner (1994).

dentaries from the Late Jurassic of Wyoming by Gilmore (1928), who identified the bones as representing a lizard. This interpretation was also given for specimens from Guimarota in Portugal by Seiffert (1973) and Estes (1983). The material from the Kirtlington Mammal Bed, however, demonstrates that *Cteniogenys* is a choristodere, an archosauromorph diapsid (Evans, 1989, 1990, 1991). It appears to be the smallest choristodere known but, allowing for its size, it appears to be related to the Rhaetian *Pachystropheus* (see Aust Cliff report), the gavial-like aquatic Late Cretaceous and Palaeocene *Champsosaurus* and *Simoedosaurus*, and a new form from the Oligocene of France. Comparison with known choristoderes suggests that *Cteniogenys* is the most primitive of the known genera (Evans, 1989). The available skull and postcranial material indicate that the Kirtlington form is represented by animals of more than one age class; the largest specimens are well ossified and can be assumed to be the adults.

The abundant crocodile teeth are nearly all shed crowns; Freeman (1979, p. 140) reports only three with roots. They apparently show little resemblance to *Teleosaurus* and Freeman (1979, p.140) compares them with the small Late Jurassic goniopholid *Nannosuchus* from the Purbeck (?juvenile *Goniopholis*). Evans and Milner (1993) note also some rare *Theriosuchus*-like atoposaurid teeth, a form otherwise known from the Wealden. If the identifications are correct, these would be the oldest records in the world of goniopholidids and atoposaurids (Figure 6.12 G,H).

The pterosaur teeth have been identified as of rhamphorhynchoid and pterodactyloid types (Evans and Milner, 1991, 1994), and similar identifications have been made from Hornsleasow. The long slender rhamphorhynchoid teeth (Figure 6.12E) could correspond to *Rhamphocephalus*, a form better known from the Mid Bathonian of Stonesfield and the Early Bathonian of sites around Eyford (see above). If the shorter blunter pterosaur teeth (Figure 6.12F) are truly pterodactyloid, this would be another oldest record, since pterodactyloid skeletons are reported first from the ?Oxfordian (Guimarota, Portugal) and the Kimmeridgian (Morrison Formation, Wyoming; Kimmeridge Clay, Dorset; Tendaguru Beds, Tanzania; Benton, 1993).

The theropod teeth are described by Freeman (1979, p. 142) as 'smaller than those of ... *Megalosaurus bucklandi*, ranging in height from 1.6 to 7.4 mm. They may be the teeth of either juvenile *M. bucklandi* or of coelurosaurs'. It is important to note their relative rarity here, especially since *Megalosaurus* teeth are among the commonest reptile finds at Stonesfield. Many of the smaller theropod teeth (Figure 6.12K) most closely resemble those of maniraptoran dinosaurs such as *Deinonychus* and *Troodon*, typically Cretaceous forms (Evans and Milner, 1991, 1994).

Ornithischian dinosaurs are represented by teeth similar to those of the ornithopod *Alocodon*, possibly a fabrosaurid (Evans and Milner, 1991, 1994, Figure 6.12I). Freeman (1979, p. 142) compared his ornithischian teeth with those of *Scelidosaurus* (Sinemurian, Charmouth, Dorset) or *Echinodon* (Berriasian, Durlston Bay, Dorset).

Finally, the rare tritylodont teeth (*Stereognathus*) described by Freeman (1979) and Evans and Milner (1994) are of considerable importance. The tritylodonts are best known from the Late Triassic and Early Jurassic of South Africa, China, Germany and some of the British fissures (Kühne, 1956, Savage, 1971). Mid Jurassic forms are known from the Stonesfield Slate of Stonesfield (*progracilis* Zone, Mid Bathonian; Simpson, 1928, pp. 22–6), the Ostracod Limestones of the Great Estuarine Group of Skye (Late Bathonian; Waldman and Savage, 1972) and the Forest Marble of Bridport, Dorset (Late Bathonian; Ensom, 1977). The Kirtlington specimens are the youngest known tritylodonts, and the last surviving mammal-like reptiles from Britain, and are superseded in age only by *Bienotheroides* from the Mid or Late Jurassic of China.

Comparison with other localities

The reptiles from Kirtlington Cement works compare best with faunas collected nearby in the Mid and Late Bathonian. Sites around Shipton-on-Cherwell Quarry (see above) have yielded remains of turtles, the crocodilian *Steneosaurus*, and the dinosaurs *Megalosaurus*, *Lexovisaurus* and *Cetiosaurus* from the *fimbriatus-waltoni* Beds (upper White Limestone) and from the Forest Marble and Lower Cornbrash. However, none of these sites has yielded *Bothriospondylus*, plesiosaurs, choristoderes, lepidosaurs, tritylodontids or the other small vertebrates known from Kirtlington. This is probably because careful washing and sorting of large amounts of sediment has not yet been carried out. Other comparable, but less abundant, faunas have been collected from the Forest Marble of Wiltshire, the upper White Limestone Formation and Forest Marble of Gloucestershire and Oxfordshire, and the Blisworth Limestone and Blisworth Clay of Northamptonshire (see above).

Some older localities in the British Bathonian may be better for comparison because they have yielded rich faunas: Hornsleasow (earliest Bathonian), New Park Quarry (Early Bathonian), Stonesfield (early Mid Bathonian) and Huntsman's Quarry (early Mid Bathonian). None of these has yet turned up such an array of well-preserved microtetrapod material.

The Kirtlington Mammal Bed fauna bears a significant resemblance to later Mesozoic freshwater assemblages, rather than earlier ones (Evans *et al.*, 1988; Evans and Milner, 1994). The salamanders cannot with certainty be referred to later families, but elements of the salamander–discoglossid–albanerpetontid–turtle–

crocodile–choristodere association are found in later assemblages, such as those of Late Jurassic age at Guimarota (Oxfordian) and Solnhofen (Portlandian), the Late Jurassic/Early Cretaceous Purbeck in Dorset (q.v.), the Early Cretaceous at Una, Spain, and the Late Cretaceous of the Judith River (=Lance Formation) of North America.

Conclusions

Kirtlington Quarry represents the best Late Bathonian site for a variety of amphibian and reptile groups, and it is the source of numerous new forms. The *fimbriatus–waltoni* Beds reptiles are comparable with those from the same unit at several other sites in Oxfordshire, but the variety of material is greater than elsewhere, and the site is still readily accessible for further excavation. The fauna of the Kirtlington Mammal Bed is without rival for its age; the selection of large and small reptiles has still to be studied fully, but they could rival the older Stonesfield fauna in their importance. The Mammal Bed fauna includes a unique freshwater assemblage of small reptiles and amphibians, several of which are the earliest known occurrences of their respective groups (the first discoglossid frog, salamanders, pleurosternid turtle, true lizards of several groups, goniopholidid and atoposaurid crocodilians, pterodactyloid pterosaur and ?maniraptoran dinosaur). The amphibian and reptile fauna is extensive, including frogs, salamanders, turtles, lepidosauromorphs, sphenodontids, lizards, choristoderes, crocodilians, pterosaurs and small dinosaurs.

The diversity and importance of the fossil vertebrates and potential for future finds give the site its high conservation value.