# Kimmeridge Bay (Gaulter Gap–Broad Bench), Dorset

[SY 898 789]—[SY 908 787]

## Highlights

Gaulter Gap–Broad Bench includes the famous fossil reptile sites of Kimmeridge Bay (Figure 7.4). Nearly 20 species of crocodilians, pterosaurs, dinosaurs, plesiosaurs and ichthyosaurs have been found there, including the original specimens of seven species.

## Introduction

The Kimmeridge Clay of Kimmeridge Bay, Dorset, is world-famous for its marine reptiles (see (Figure 7.8)). Several fine ichthyosaur skeletons have been collected, as well as skulls, vertebrae and limb bones of a variety of other fossil reptiles. The cliffs and foreshore reefs of Kimmeridge Bay are subject to continuing erosion, and several finds have been made in recent years. It clearly has considerable potential for future discoveries. The geology of the site has been recorded by many authors, but in most detail by Cope (1967; *in* Torrens, 1969a; *in* Cope *et al.,* 1988b). The fossil reptiles have been described by Owen (1869, 1884a), Hulke (1869a, 1869b, 1870a, 1870b, 1870c, 1871a, 1871b, 1872a, 1874a), Woodward (1885), Lydekker (1888a, 1889a), Huene (1922), Tarlo (1960), McGowan (1976), Brown (1981) and Unwin (1988a).

## Description

The Kimmeridge Clay in Kimmeridge Bay is a 138 m sequence of grey to dark grey-blue, ammonite-bearing mudstones and shales with sporadic cementstone (limestone/dolostone) bands. The dominant argillaceous units comprise alternations of homogeneous and sometimes blocky mudstones and finely laminated, fissile, bituminous shales. Mudstone units appear to be quite structureless but, after weathering, a certain degree of mottling may be seen. The base of the mudstone units weathers out more sharply than the upper sections and the upper boundaries appear to be transitional to the bituminous shales. These are rather thinner than the mudstone units, between 0.1 and 0.4 m thick, the mudstones measuring between 0.1 m and about 1 m in thickness. Erosion of the mudstones and shales is rapid, but the cementstone bands resist erosion and stand out.

At Kimmeridge Bay, the beds dip south-east and there are several faults. The general sequence, based on Cope (1967; *in* Torrens, 1969a; *in* Cope *et al.,* 1980b) is:

| | Thickness (m) |
|---|---|
| Late Kimmeridgian (formerly Mid Kimmeridgian) | |
| *wheatleyensis* Zone | |
| Grey Ledge Stone Band | 0.7 |
| *scitulus* Zone | |
| Upper Cattle Ledge Shales | 10.8 |
| Cattle Ledge Stone Band | 0.5 |
| Lower Cattle Ledge Shales | 15.0 |
| Yellow Ledge Stone Band | 0.4 |
| | **27.4** |
| *elegans* Zone | |
| Hen Cliff Shales | 21.5 |
| Double band of cementstone with shale | 1.1 |
| | **22.6** |
| Lower Kimmeridgian | |

| | |
|---|---|
| *autissiodorensis* Zone | |
| Maple Ledge Shales | 22.5 |
| Maple Ledge Stone Band | 0.3 |
| Gaulter's Gap Shales | 32.0 |
| Washing Ledge Stone Band | 0.35 |
| Washing Ledge Shales (upper part) | 8.0 |
| | **63.15** |
| *eudoxus* Zone | |
| Washing Ledge Shales (lower part) | 5.0 |
| The Flats Stone Band | 0.5 |
| Shales | 3.0 |
| *Nannocardioceras* Bed | 0.02 |
| Shales | 1.0 |
| Shales | seen to 15.0 |
| | **24.52** |

The sediments of the *Aulacostephanus eudoxus* and *A. autissiodorensis* Zones are exposed between Broad Ledge and Maple Ledge. The named stone bands reach shore level as follows: The Flats at Broad Bench [SY 897 787] and at The Flats [SY 905 792]; Washing Ledge [SY 907 791]; Maple Ledge [SY 909 789]. Hen Cliff, between Clavell Tower and Cuddle, exposes the *elegans, scitulus* and *wheatleyensis* Zones (the *Pectinatites* Zones). The stone marker bands include the Yellow Ledge which reaches the shore at Yellow Ledge [SY 912 782], and the Cattle Ledge and the Grey Ledge higher in the cliff.

The fauna of the Kimmeridge Clay is restricted to the mudstones and bituminous shale units and in both units is essentially the same, being dominated by infaunal bivalves, including *Lucina* and *Protocardia.* There is also an encrusting epifauna, but this is restricted, consisting only of oysters (*Liostrea* and *Nanogyra*). Minor elements include *Discina, Lingula, Entolium* and aporrhaid gastropods. The other biofabrics in the mudstones are quite different from those in the bituminous shales, indicating different postmortem histories of the fauna and thus different environmental conditions (Aigner, 1980). This limited biota indicates somewhat oxygen-depleted bottom conditions, and that the reptiles must have occupied a mid-water zone.

Most specimens bear the locality and horizon description 'Kimmeridge'. However, a few more specific references indicate that reptiles have been found at all points round Kimmeridge Bay and in Hen Cliff (see (Figure 7.6)), and at various levels in the *Aulacostephanus* Zones and *Pectinatites* Zones. Arkell (1933, p. 451) considered that most specimens came from the Early Kimmeridgian and noted that the types of *Steneosaurus manseli* and Ichthyo*saurus enthekiodon* were found embedded in reefs exposed at low water in the bay. Delair (1986, p. 133) notes parts of a disarticulated specimen of the ichthyosaur *Ophthalmosaurus* from 'a level approximately 2.5 feet below the base of the *wheatleyensis* Subzone' at Rope Lake Head. Hulke (1869a, p. 386) reported a large 'saurian humerus' (the type of *Ornithopsis manseli* Hulke, 1869a) from 'amongst the layers of shale immediately above the band of cementstone which rises from East to West on the west side of Clavell's Tower, between Kimmeridge Bay and Clavell's Head'. This probably refers to the Maple Ledge Shales above the Maple Ledge Stone Band (thus *autissiodorensis* Zone), at a site around [SY 909 789]. Clarke and Etches (1992) record a fine mandible of *Liopleurodon macromerus* from the *autissiodorensis* Zone of 'Kimmeridge Bay'. Hulke (1871b, p. 442) described a crocodile snout (the type of *Teleosaurus megarhinus* Hulke, 1871) that had fallen from the cliff in the bay. The exact locality is uncertain, but it must have come from one of the *Aulacostephanus* Zones. A specimen of *Plesiosaurus* collected in 1971 (CAMMZ T962) is recorded to have come from 5 ft below The Flats Stone Band at Broad Bench ([SY 898 789]), thus in shales of the *eudoxus* Zone. Likewise, Unwin (1988a) reports vertebrae and limb elements of the pterosaur *Germanodactylus* from '5 m below the Flats Stone Band (*eudoxus* Zone… at Charnel [SY 899 789])'.

Several finds have been reported from the early portion of the Late Kimmeridgian. Hulke (1870c) described some *Plesiosaurus* vertebrae (the types of *P. manseli* Hulke, 1870) from the cliffs east of Clavell Tower, thus probably *scitulus* Zone. Brown (1981, p. 315) ascribes these to the *pectinatus* Zone (Late Kimmeridgian), but this is unlikely since that zone only appears in the cliffs between Rope Lake Head and Encombe Bay, 2–3 km south east of the Clavell Tower. Cope (1967, p. 10) mentions further remains from the Late Kimmeridgian, the anterior part of a skeleton of

*Ophthalmosaurus* 12 ft (4 m) above the Cattle Ledge Stone Band (*scitulus* Zone), and a pliosaur tooth about 5 ft (1.5 m) above the Yellow Ledge Stone band (*scitulus* Zone). A limb bone of *Pliosaurus* (DORCM G187) was found on the foreshore below Clavell Tower.

All of the finds appear to have been made in the shales. Hulke (1869b, p. 390) characterized the matrix of a *Steneosaurus* as 'hard pyritic claystone'. The skeletal elements are frequently disarticulated, but not particularly worn; teeth may be in place and delicate bone processes unbroken. The only nearly complete skeletons found appear to be those of ichthyosaurs (Hulke, 1871a; Cope, 1967, p. 10; Macfadyen, 1970, p. 126). The pterosaur *Germanodactylus* consisted of partially disarticulated bones, some of which were heavily crushed (Unwin, 1988a).

### Fauna

Mansel-Pleydell (1888) and Delair (1958, 1959, 1960) gave long lists of reptiles from Kimmeridge Bay, totalling 33 or more species. As a result of recent revisions of the ichthyosaurs (McGowan, 1976; Angela Kirton, pers. comm.), pliosaurs (Tarlo, 1960) and the plesiosaurs (Brown, 1981), many of these species have been synonymized. A revised list of the reptiles is given here, with the repository numbers of type specimens. The approximate numbers of specimens of each species in major British collections are appended in order to give an impression of the relative abundance of each form.

| | Numbers |
|---|---|
| **Archosauria: Crocodylia: Thalattosuchia** | |
| *Dakosaurus maximus* (Plieninger, 1846) Type specimen of *Steneosaurus manseli* Hulke,1870; BMNH 40103 | 1 |
| *Machimosaurus mosae* Sauvage and Lienard, 1879 | 1 |
| *Steneosaurus megarhinus* (Hulke, 1871) Type specimen: BMNH 43186 | 1 |
| **Archosauria: Pterosauria** | |
| *Rhamphorhynchus* sp.' | 1 |
| *Germanodactylus* sp. | 1 |
| **Archosauria: Dinosauria: Saurischia:** Sauropoda | |
| *Pelorosaurus manseli* (Hulke ms., Lydekker, 1888) Type specimen: BMNH 41626 | 1 |
| **Sauropterygia: Plesiosauria: Elasmosauridae** | |
| *Colymbosaurus trochanterius* (Owen, 1840) Includes type of *Plesiosaurus manseli* Hulke, 1870: BMNH 40106 | 6 |
| *'Plesiosaurus brachistospondylus'* Hulke, 1870 Type specimen: BMNH 45869 | 3 |
| *'Plesiosaurus'* sp. | 4 |
| **Sauropterygia: Plesiosauria: Pliosauridae** | |
| *Pliosaurus brachydeirus* Owen, 1841 | 2 |
| *Pliosaurus brachyspondylus* (Owen, 1840) | 1 |
| *Pliosaurus* sp. | 9 |
| *Liopleurodon macromerus* (Phillips, 1871) | 8 |
| **Ichthyopterygia: Ichthyosauria** | |
| *Macropterygius dilatatus* (Phillips, 1871) | 1 |
| *Macropterygius ovalis* (Phillips, 1871) Type specimen: OUM J.12487 | 1 |
| *Macropterygius trigonus* (Owen, 1840) | 1 |
| *Nannopterygius enthekiodon* (Hulke, 1870) Type specimen: BMNH 46497, a | 1 |
| *Ichthyosaurus* sp. | 1 |

## Interpretation

The Kimmeridge Clay marks a period of widespread clay sedimentation in north-west Europe in environments that were clearly fully marine. The thick series of clays and bituminous shales are considered to have been deposited in calm bottom waters, and anaerobic conditions may have prevailed in a stratified water column (Aigner, 1980), an environment similar to the present-day Black Sea. The sediments are essentially terrigenous in origin, indicating considerable erosion from a nearby landmass (?the London–Ardennes island and Cornubia), although there are no obvious plant macrofossils.

The remains of crocodiles from Kimmeridge Bay are mainly partial skulls with occasional associated vertebrae. *Dakosaurus,* a large animal, often up to 4 m long, is represented by a partial skull of a relatively short-snouted form (BMNH 40103). Hulke (1870a) described it as the type specimen of *Steneosaurus manseli.* Owen (1884a) referred this species to a new genus, *Plesiosuchus,* but Woodward (1885) included it in *Dakosaurus.*

*Machimosaurus* and *Steneosaurus* are long-snouted teleosaurs, common in marine deposits from the Early Jurassic to the Early Cretaceous of Europe and other continents. *M. mosae* was based on specimens from the Kimmeridgian of Issoncourt (near Verdun), and Lydekker (1888a) referred to this species the occipital region of a cranium and an associated mandible from Kimmeridge Bay (BMNH R1089). These specimens were originally figured by Owen (1869) as *Pliosaurus trochanterius,* but Deslongchamps (1869, p. 329) realized their crocodilian nature and ascribed them to *Metriorhynchus,* a determination followed by Woodward (1885). The species *M mosae* was apparently based on heterogeneous material, some of it probably mosasaurian, and it is probably invalid (Krebs, 1967; Steel, 1973, p. 25). Thus the Dorset material could be ascribed to the type species, *M. hugii* Meyer, 1837. *Steneosaurus megarhinus* (Hulke, 1871b) was based on a slender rostrum, 430 mm long and with greatly expanded premaxillae each containing five alveoli ((Figure 7.5)A. Hulke originally ascribed this to *Teleosaurus.*

The pterosaur '*Rhamphorhynchus'* is represented by a single specimen (BMNH R1936), and *Germanodactylus* likewise (Etches Collection K96; Unwin, 1988a). Both finds extend the ranges of these taxa from Germany to England, and into even earlier Kinuneridgian strata than those at Solenhofen. Pterosaurs are better known from the Kimmeridge Clay of Weymouth, but the Kimmeridge Bay *Germanodactylus* is the oldest of the family Germanodactylidae in the world, and possibly the oldest pterodactyloid pterosaur (Unwin, 1988a).

The sauropod *Pelorosaurus* is represented by a large humerus (BMNH 41626). This 'stupendous bone' (Hulke, 1869a), when pieced together, had a length of 0.8 m. Hulke (1869a, 1874a) considered that it belonged to a great crocodile. He named it *Ischyrosaurus* Hulke, 1874, and Lydekker (1888a, p.152) later placed it with the large sauropod dinosaurs in *Ornithopsis manseli* Lydekker, 1888. *Ornithopsis,* and many other generic names given to large dinosaur bones from the Late Jurassic and Early Cretaceous of Europe, have been synonymized with *Pelorosaurus* (Steel, 1973, pp. 68, 70; McIntosh, 1990). *Pelorosaurus* is placed in the Brachiosauridae, but familial assignment of such isolated elements is clearly problematic.

The most abundant remains from Kimmeridge Bay are plesiosaurs (Figure 7.5)B. *Colymbosaurus trochanterius* (Owen, 1840), of which *Plesiosaurus manseli* Hulke, 1870 is a synonym (Lydekker, 1889a; Brown, 1981, pp. 316–17, 337), is the largest Late Jurassic plesiosauroid, with an estimated total length of 6.15 m for the type specimen of *P. manseli* (BMNH 40106). The specimen consists of an extensive series of vertebrae, pieces of two humeri and several paddle bones. Other specimens of *C. trochanterius* from Kimmeridge Bay are a series of vertebrae and isolated limb bones. The type specimen of *P. brachistospondylus* Hulke, 1870 consists of five compressed dorsal vertebrae, some rib fragments and finger elements. Hulke (1870a) regarded the great height and breadth of the vertebrae as unique, but Brown (1981, p. 322) considered the species a *nomen dubium.*

The pliosaurs are represented largely by jaw fragments and teeth, belonging to all three Kimmeridgian species recognized by Tarlo (1960) as valid. *P. brachydeirus* is distinguished from *P. brachyspondylus* on the basis of details of the vertebrae and from *Liopleurodon macromerus,* with its short mandibular symphysis, as well as characters of the vertebrae and tooth arrangement. The assignments of many of the Dorset specimens were made before Tarlo's work and revisions may be necessary.

Finally, at least five specimens of ichthyosaurs have been collected. Phillips (1871, p. 339) described the new species *Ichthyosaurus ovalis* on the basis of some vertebral centra from Kimmeridge Bay which have never been figured (identified as OUM J.12487 on labels). McGowan(1976) recorded it under *taxa dubia* because no type material was designated in the original description. Hulke (1870b) described some ichthyosaur teeth and jaw fragments as the new genus *Enthekiodon,* but he did not name a species. Hulke (1871a) then reported a very fine ichthyosaur skeleton from Kimmeridge Bay which he named *I. enthekiodon* (Figure 7.5)C. It showed the skull, vertebral column, ribs and limb fragments. The skull is 0.62 m long and the body about 2.8 m long. It had a medium-length snout and was distinguished from other forms by characters of the vertebrae and the very small paddles. Huene (1922, p. 98) established a new genus, *Nannopterygius,* for this species and McGowan (1976, p. 671) considered it to be a valid taxon. Hulke (1872a) described further ichthyosaur teeth and skull fragments from Kimmeridge Bay.

The preserved reptile fauna from Kimmeridge Bay, then, consists mainly of medium to large-sized marine forms: crocodilians, plesiosaurs, pliosaurs and ichthyosaurs. All of these were probably fish-eaters, although they may also have fed on the abundant cephalopods. The crocodilians could doubtless walk and feed on land. Rare bones of large sauropod dinosaurs were washed in. Turtles have not been found and pterosaur remains are rare, although these forms are rather well known from the Kimmeridge Clay around Weymouth.

### Comparison with other localities

Marine reptiles have been recorded from all 60 sites in the Kimmeridge Clay of Dorset, Wiltshire, Oxfordshire, Buckinghamshire, Cambridgeshire, Norfolk, Lincolnshire and Yorkshire (listed at the start of the chapter). However, most sites have yielded little more than a few vertebrae or limb elements of one or two species. Sites comparable to Kimmeridge Bay include Smallmouth Sands, Weymouth [SY 66 97]–[SY 672 771], and other sites listed under that locality.

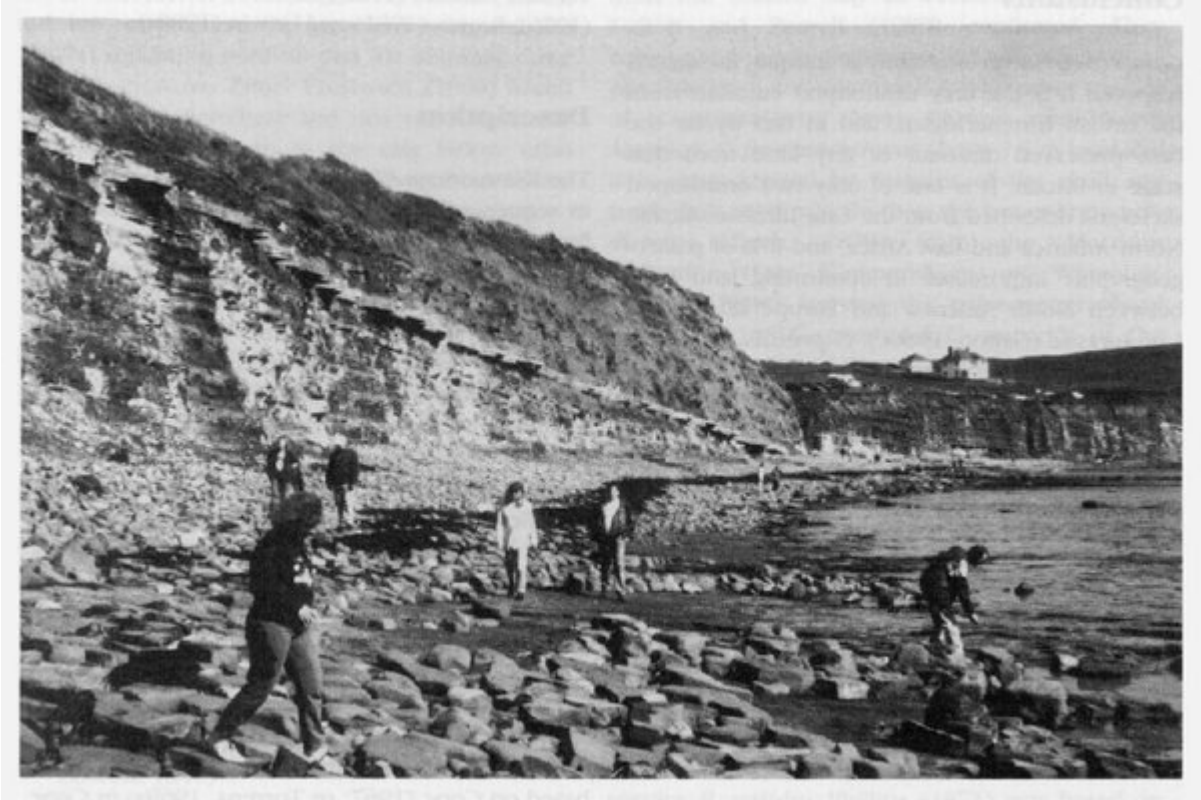
The crocodile *Dakosaurus* (Jurassic–Early Cretaceous of Europe) occurs in the Kimmeridge Clay of Ely, Shotover, Norfolk and Boulogne-sur-Mer (Steel, 1973, pp. 42–4). *Machimosaurus* has been recorded from the Kimmeridgian of Shotover, Boulogne-sur-Mer, Verdun and Hanover, as well as the Late Jurassic of Portugal and the Portlandian of Switzerland and Austria (Steel, 1973, p. 25). *Steneosaurus* is known from the Jurassic of many localities in Europe and elsewhere. It has been recorded from the Kimmeridgian of Shotover, Moulin Wibert at Bologne-sur-Mer and Cap de la Heve, Normandy (Steel, 1973, pp. 26–34). The dinosaur *Pelorosaurus* is well known from the Wealden of Sussex and the Isle of Wight, and the Kimmeridgian of Weymouth, Ely, Boulogne-sur-Mer and Wimille, near Boulogne (Steel, 1970, pp. 68, 70).

*Colymbosaurus trochanterius* is known from several former localities in Wiltshire, Oxfordshire, Cambridgeshire and Norfolk (Brown, 1981, pp. 315–16). The pliosaurs are known from a similar range of sites, with good material from Swindon, Shotover, Ely and Stretham (Tarlo, 1958, 1959b, 1959c, 1960). Ichthyosaurs have been recorded from many localities, with good representation at Weymouth, Swindon, Shotover and Ely. Kimmeridgian plesiosaurs are known from France, the Moscow Basin, Greenland and Sichuan (China), and Kimmeridgian ichthyosaurs from France (Boulogne), Germany and Argentina (McGowan, 1976).

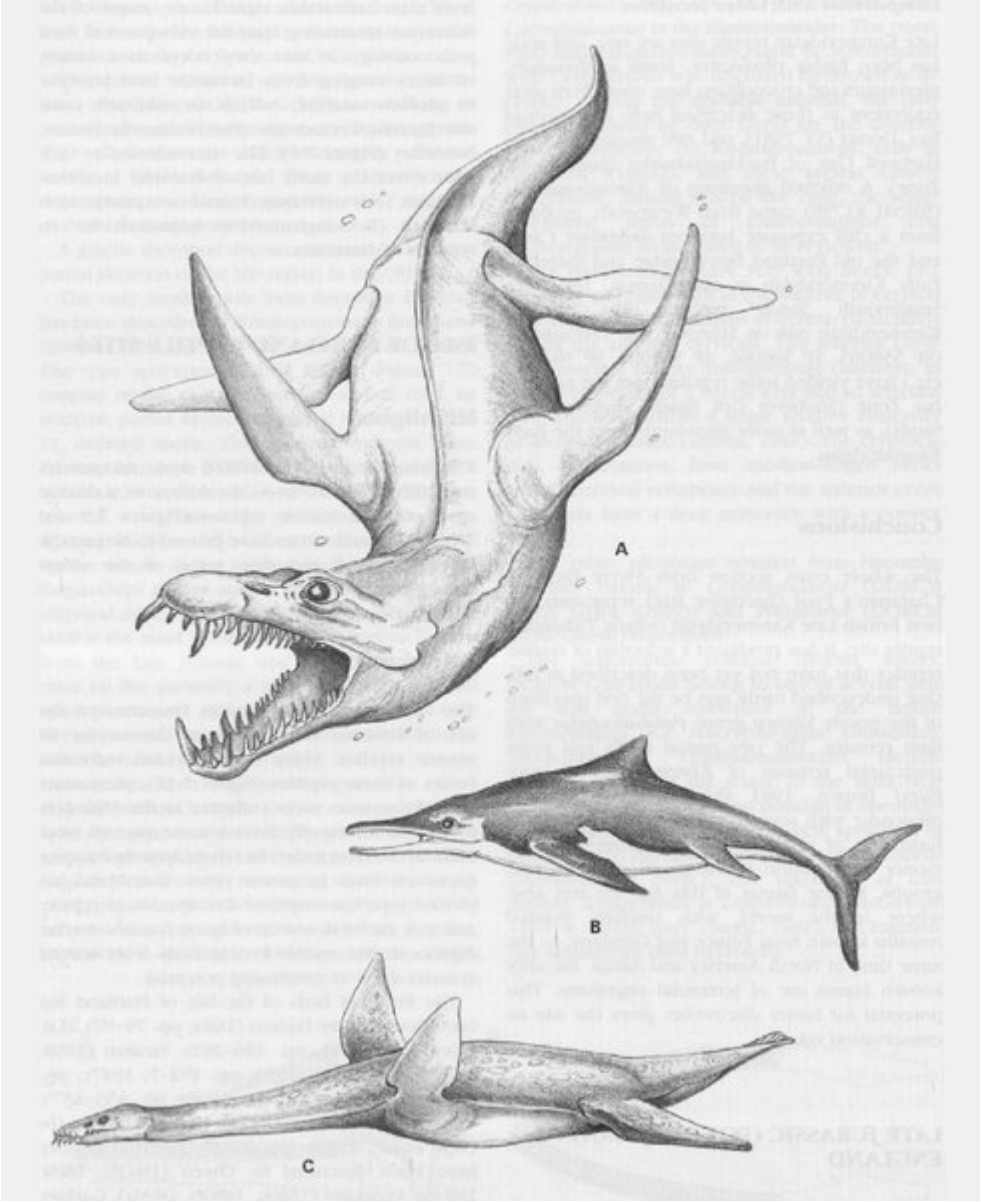
## Conclusions

Kimmeridge Bay has yielded more type specimens of reptiles than any other Kimmeridgian site. It is particularly important for the plesiosaurs, ichthyosaurs and crocodilains, many of which are best represented here. Because of the sporadic occurrences of Kimmeridgian plesiosaurs and ichthyosaurs elsewhere in the world, Kimmeridge Bay is particularly important, and it has figured prominently in recent reviews of marine reptiles (Tarlo, 1960; McGowan, 1976; Brown, 1981). The pterosaurs *Rhamphocephalus* and *Germanodactylus,* although more poorly preserved than the original material from Bavaria, are significantly older (Unwin, 1988a). The conservation value lies in the international importance of the site and its considerable potential for future finds.

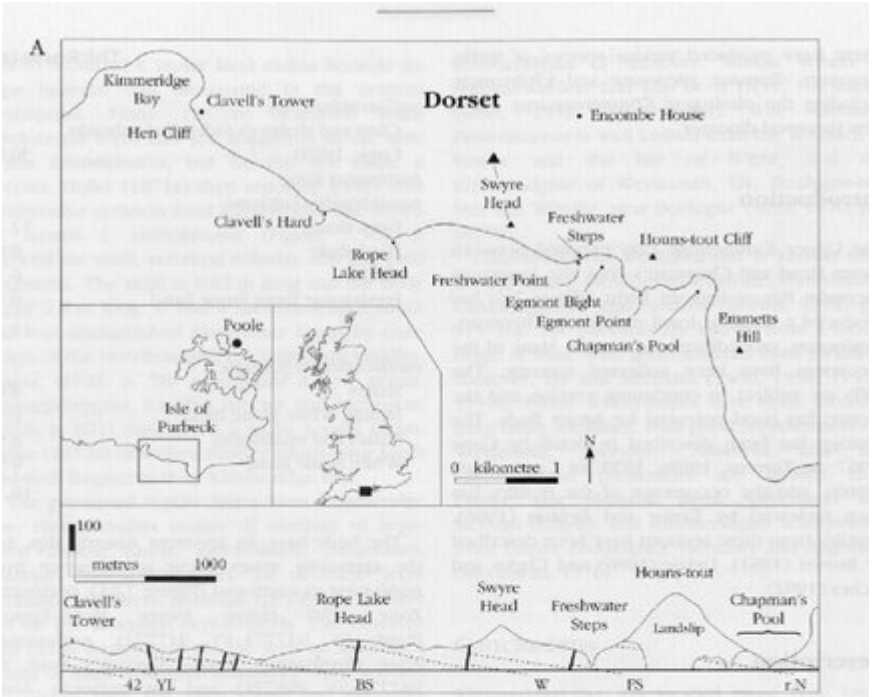
**References**



*(Figure 7.4) The Kimmeridgian of Kimmeridge Bay, showing dipping limestone and shale units, facing south. (Photo: M.J. Benton.)*



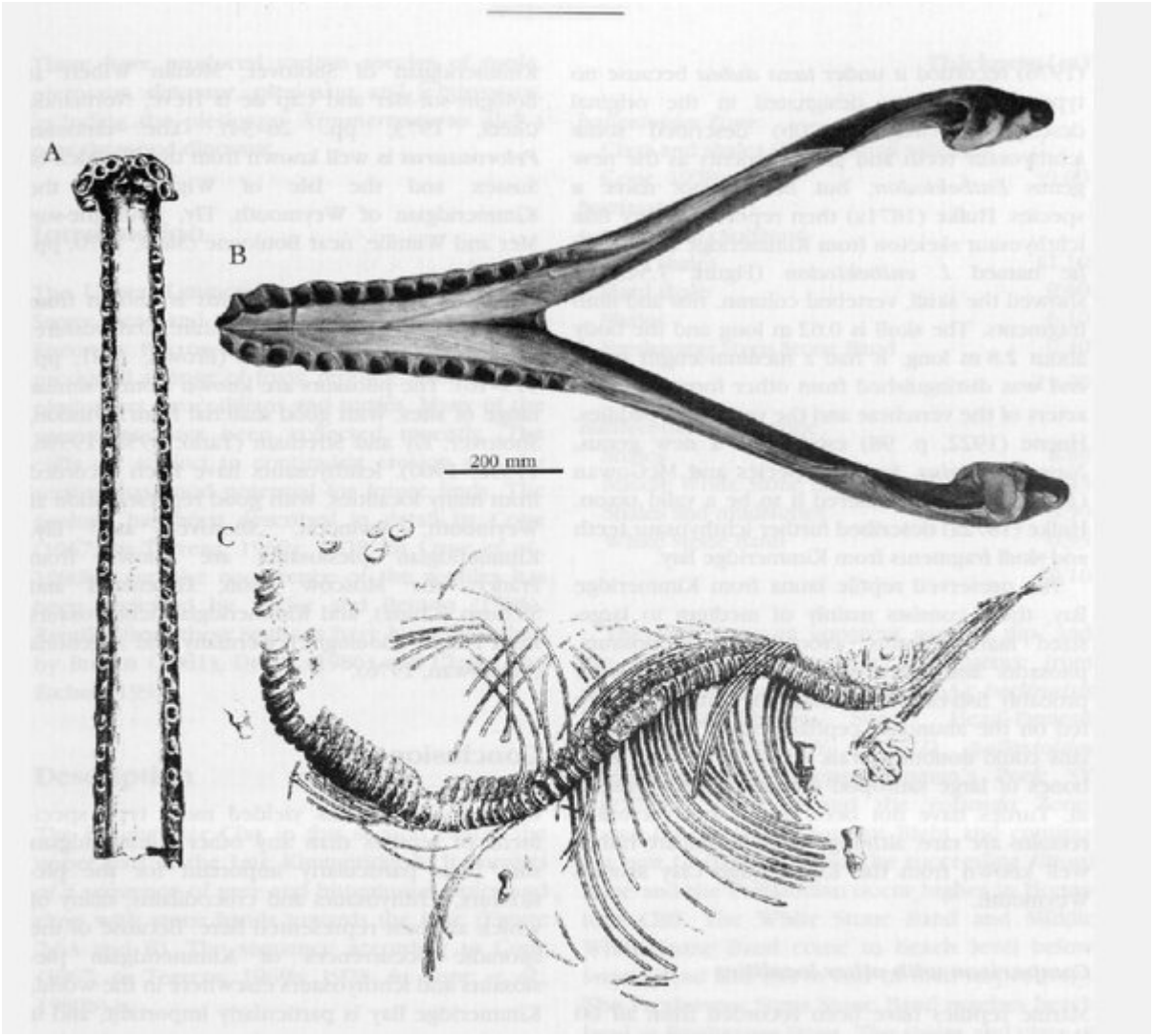

*(Figure 7.8) Some typical marine reptiles of Late Jurassic times in southern England. (A) The pliosaur Liopleurodon, one of the largest marine predators of all time at 12 m long. (B) The ichthyosaur Ophthalmosaurus, which was 2–4 m long. (C) The plesiosauroid Ctyptoclidus, which was 4 m long. These animals occur typically in the Oxford Clay and Kimmeridge Clay faunas. Drawn by John G. Martin, copyright City of Bristol Museums and Art Gallery.*




B

| Zones | Description | Code |
|---|---|---|
| **Upper Kimmeridgian** | | |
| *fittoni* | | |
| *rotunda* | *rotunda* Nodules (L) | r.N |
| *pallasioides* | | |
| *pectinatus* | White S.B. (B); Freshwater Steps S.B. (M) | W FS |
| *hudlestoni* | | |
| *wheatleyensis* | Blackstone (T) | BS |
| *scitulus* | Yellow Ledge S.B. (B); Cattle Ledge S.B. (U) | YL |
| *elegans* | Blake's Bed 42 (B) | 42 |
| **Lower Kimmeridgian** | | |
| *autissiodorensis* | | |
| *eudoxus* | | |
| *mutabilis* | | |
| *cymodoce* | | |
| *baylei* | | |

*(Figure 7.6) (A) Locality map and vertical section of the Swyre Head–Chapman's Pool Kimmeridge Clay site on the Isle of Purbeck, Dorset. The beds dip gently southwards, and the shales and mudstones are punctuated by distinctive limestone beds ('stone bands') which have been named. These may also be matched with the (B) tabulation of the ammonite zones of the Kimmeridgian. Abbreviations: (42) Blake's Bed 42; (BS) Blackstone; (FS) Freshwater Steps Stone Band; (r.N) rotunda Nodules; (SB) Stone Band; (W) White Stone Band; (YL) Yellow Ledge Stone Band; (in the zonal chart, B, L, M, U and T refer to basal, lower, middle, upper and topmost parts of the zones). After Taylor and Benton (1986); based on Cope (1967, 1978); Cope et al. (1980b); Cox and Gallois (1981).*




*(Figure 7.5) Kimmeridgian reptiles from Kimmeridge Bay, Dorset. (A) The elongate slender snout of the marine crocodile Steneosaurus megarhinus (Hulke, 1871) in ventral view; (B) lower jaw of Colymbosaurus trochanterius (Owen, 1840) in crown view; (C) skeleton of the ichthyosaur Nannopterygius (Ichthyosaurus) enthekiodon (Hulke, 1871). (A) after Hulke (1871b); (B) after Owen (1861); (C) after Hulke (1871a).*