The conservation and use of fossil vertebrate sites: British fossil reptile sites

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BENTON, M. J. & W. A. WIMBLEDON. 1985. The conservation and use of fossil vertebrate sites: British fossil reptile sites. *Proc. Geol. Ass.*, **96** (1), 1–6. Over a thousand sites in Britain have yielded fossil vertebrates, ranging in age from the Ordovician to the Pleistocene. The current British sites have been assessed as part of the Geological Conservation Review for the Nature Conservancy Council, and moves are being made to protect those with the greatest potential from damage and to promote their proper use. Provenance information has rarely been precisely recorded with British fossil vertebrates, and the large collections that are available are of limited use in studies of faunal distribution in space and time, community succession, and taphonomy. Proper excavation is to be encouraged, provided that information is recorded on the exact locality, horizon, enclosing sediment, associated fossils, orientation and mode of preservation.

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1. INTRODUCTION

Fossil vertebrates have been collected in Britain for hundreds of years and well-known early finds included dinosaur bones from the Middle Jurassic of Oxfordshire (Plot, 1677; Lhwyd, 1699; Woodward, 1728; Platt, 1758; Delair & Sarjeant, 1975), a marine crocodile from the Lower Jurassic of Whitby, Yorkshire (Chapman, 1758; Wooller, 1758), and Pleistocene elephants from the southeast of England (Anon., 1757, 1758, 1821). However, fossil vertebrates were not systematically collected until the 19th century when large numbers of marine ichthyosaurs and plesiosaurs were collected from the Lower Jurassic of Lyme Regis, Dorset and Whitby, Yorkshire (Conybeare, 1821; Young & Bird, 1822) and many dinosaurs were collected in the Lower Cretaceous of the southeast of England (Mantell, 1822, 1825) and the Middle Jurassic of Oxfordshire (Buckland, 1824). In addition, Old Red Sandstone fish were found in Scotland (Andrews, 1982), and Pleistocene mammals were found in caves (Buckland, 1822).

Throughout the remainder of the 19th century and the early 20th century, large collections were amassed, and these may now be seen in museums like (alphabetically): Brighton Museum; Bristol City Museum; The British Museum (Natural History), London; Dorset County Museum, Dorchester; Elgin Museum; The Geological Museum, London; Hancock Museum, Newcastle; Hunterian Museum, Glasgow University; Museum of Isle of Wight Geology, Sandown; Leicester Museum; Lyme Regis Museum; Maidstone Museum; Manchester Museum; the National Museum of Wales, Cardiff; Norwich Castle Museum; Oxford University Museum; Peterborough Museum; the Royal Scottish Museum, Edinburgh; the Sedgwick Museum, Cambridge University; Shrewsbury Museum; Warwick Museum; Whitby Museum; and the Yorkshire Museum, York. There is relatively little systematic collecting of reptiles in Britain now, apart from the individual efforts of amateurs, and occasional 'rescue operations' by museums and universities.

The aims of this article are to outline positive measures for vertebrate site conservation and use, and to urge that full records of excavations be made in order to enhance the scientific value of the fossils. As an example of site identification and conservation, we describe the fossil reptile sites in some detail. We also outline specific examples of site use at Bearsden, Strathclyde (Carboniferous fish), Kirtlington Quarry, Oxfordshire (Middle Jurassic mammals and reptiles), and the Yorkshire Coast (Lower Jurassic marine reptiles).

2. THE FOSSIL REPTILE SITES

Britain has many famous fossil reptile sites from all parts of the relevant time span. Altogether, about 490 different sites have yielded reptile bones or footprints, and the age distribution is roughly as follows:

Tertiary/Pleistocene		40
Cretaceous—Lower		90
	Upper	60
Jurassic—Lower		50
	Middle	90
	Upper	90
Triassic	(Scythian–Norian)	40
	(Rhaetian)	20
Permian		10
		490

The sites include quarries, coastal sections and civil engineering excavations. Of these 500, many have yielded only a single specimen or a few fragments, and many are now lost, having been filled or built over; however, many good sites remain and new ones are occasionally discovered. How can we best preserve and use them?

3. CONSERVATION

The Nature Conservancy Council (N.C.C.), the only government conservation organization in Britain, has a statutory responsibility to conserve geological localities, including vertebrate palaeontological sites, for the purposes of education and research. Sites are conserved as Sites of Special Scientific Interest (S.S.S.I's), and are also protected by the provisions of the Wildlife and Countryside Act (1981). A Geological Conservation Review Unit was established in 1977 by the N.C.C. to undertake the review and selection of sites. This selection has been carried out either by temporarily employed younger specialists, selected specifically for their expertise in particular aspects of British geology, or by established workers or consortia working part-time on the project. Within each topic a review has been made of relevant literature, sites have then been visited, assessed, and sometimes excavated. Final selection has then been based on these reviews and the informed opinions of active workers on the relative merits of the localities. The results of the Geological Conservation Review (G.C.R.), the largest work of site documentation of its kind, are to be published. This definitive Domesday Book of the Earth Sciences will form the basis for future conservation strategy. It is expected that the Review will describe a total of 2500 individual interest localities (condensing to 1500 S.S.S.I.'s because of overlap) including 70 reptile and 120 other fossil vertebrate sites.

The site selection for fossil reptiles included the following steps:–

(1) Initial data handling. We examined all published papers about British fossil reptiles and noted all site information, poor as it usually was (e.g. 'Wealden, Sussex', 'Bathonian, Oxford', 'Chalk, Dover'). We then studied most of the major museum collections, and again noted site information, especiallv in the very rare cases where some of the original collector's notes had been kept. We then organized this mass of information into broad stratigraphical and geographical blocks (e.g. Triassic of Elgin; Lower Jurassic of Yorkshire; Kimmeridge Clay of Dorset).

(2) Site location. We tried to find as many of the quarries as possible on old and new 6-inch-to-the-mile (1:10000) Ordnance Survey Maps. This stage involved the use of geological maps, relevent stratigraphical literature, historical archives, and much guesswork. Eventually, a working list of the 500 sites, with map references, was drawn up.

(3) Preliminary site sorting. Certain sites were discarded at once—those that had yielded only a few scraps, and those that had been obliterated already. This was a step designed for convenience—we could not afford to visit every site, on the off-chance of discovering a previously unknown bone-bed.

(4) Site visits and further site sorting. Every site on the reduced list of 200 or so was visited, and an attempt was made to locate the fossiliferous horizon. At this stage, further sites were struck off the list if they were filled in, or if the relevant horizons were inaccessible.

(5) Selection of major sites. Finally, the selection of key sites for each unit was made. An example of the whole procedure for the Oxfordian Stage is summarized in the Appendix.

The criteria for site selection, and the nature of proper site conservation are clearly controversial, and we will state our principles here: they depend on both scientific and practical criteria. Sites with unique faunas, type localities for sizeable faunas or key species are more or less self selecting, as far as scientific judgements and criteria are concerned. The object of the exercise is to produce a network of interrelated sites best demonstrating the evolutionary story of any given vertebrate group. Every site selected has, in our opinion, potential for excavation for new finds and thus for continuing research. In many cases the N.C.C. has cleaned or created exposures as part of the Review in an attempt to define or exploit sites' interests. Full details of the history, significance and potential of each site, in effect a justification of its selection, will be published in the G.C.R.

The practical aspects of the exercise were the limits of time and money for assessing sites—we found and considered the first 500 reptile sites within a few months (steps (1)–(3) above). Doubtless with searches of the more and more abstruse literature—such as newspapers, natural history club records and old letters—we could have found more sites. Further, with unlimited time and money, we could have visited every location and spent several days at each in excavating for bones. However, the returns per unit time/expense would decrease substantially if this were done. We estimate that we have information on 80–90 per cent of all known British fossil reptile sites, whether published or not, and that we have selected those with best potential for new finds to ±20 per cent accuracy. The G.C.R. is not intended to be a final unchanging document, and it will be constantly supplemented and up-dated.

We must also define the meaning of the proper conservation of fossil vertebrate sites, since this is clearly another controversial area. At one extreme, some people would have localities literally put behind glass, while at the other, some would advocate the complete removal of a deposit, or at least its contents, to a museum. Conservation as defined here treads a middle path, advocating use of field sites at an appropriate academic level, systematic excavations, study of vertebrates *and* their source rocks *in situ*, and therefore the long-term protection of the localities involved. What use to the future researcher is a bone in a museum drawer with no matrix and no indication of provenance?

There are two main sources of threat to palaeontological sites: those induced by the non-geologist, for instance refuse disposal in quarries, concreting of the coastline to protect cliff-top development and numerous other lesser threats; and those induced by geologists in the widest sense. Non-geological problems are simpler to assess, but are not necessarily always satisfactorily solved. Geologist-induced problems—over-use, over-collecting and commercially motivated stripping of sites—are not so easily dealt with. The conservation of biologically important sites is rather different. Many such sites are amenable to, and do not suffer unduly from, free access; but quite a few, and not just those with rare species, are best left alone, their non-conservation uses being strictly limited.

Many geological sites suffer over-use and over-hammering, but very few fossil sites have deposits which have been or could be worked out by collectors. Comparatively few sites are truly unique and totally irreplaceable. The overreaction, and one might even say hysteria, over collecting by foreign collectors at British fish sites, if it has achieved little else, has at least focussed attention on attitudes to commercial exploitation and ethics of collecting. In reality there are but a handful of vertebrate sites where the strictest controls are required (e.g. Solnhofen, Monte Bolca, Holzmaden). Many of our fossil sites are resilient, but they must not be exhausted by inappropriate or inefficient forms of research, or commercial exploitation; but even with such localities, great latitude in usage is still possible. We would suggest that there is no one kind of user for whom sites should be exclusively reserved. Both motivated amateurs and *some* commercial collectors have in the past made invaluable contributions to our national and local collections. This tradition continues (Wood, 1982).

The problem in Britain remains—too many people using too few sites, and they are the same classic sites used for generations. The most pressing need is for diversification of fieldwork to alternative sites, and also some restriction of usage on vulnerable localities. The aim of conservationists is to encourage and participate in the systematic use and excavation of sites (but not their total removal) by professional and responsible amateurs and to promote proper recording of finds and taphonomic information.

4. SCIENTIFIC IMPORTANCE OF SITE INFORMATION: FAUNAL EVOLUTION

It is becoming more common, when palaeontologists describe fossil vertebrates, to give information on the site, horizon and taphonomy of their material. However, this is often not done because the zoologically trained author may not fully see the value of such information or is not confident with anything to do with rocks. Further, with the best will in the world, very little can be made of the scant data associated with many fossil vertebrate specimens in museums. It is hardly necessary to justify the scientific value of proper site information, but a few points are noted here:

(1) A description without full details of locality and stratigraphy is restricted in its value to future collectors, palaeoecologists and evolutionary biologists who are interested in the particular specimen(s).

(2) Reconstructions of individual faunas cannot be made without convincing evidence that several animals all come from the same locality and horizon. The palaeoecology and mode of fossilisation cannot be considered without information on associated fossils, sediment characteristics and taphonomy.

(3) Reviews of the distribution in space of different fossil vertebrates depend on proper information on sites and ages.

(4) Studies of the distribution in time of different fossil vertebrates also depends on proper site and age information. Such work has been given a fresh impetus from new ideas concerning modes and rates of evolution, extinctions and adaptive radiations, and faunal replacements through time. However, basic data for such work are generally hard to obtain, despite massive museum collections of fossil vertebrates worldwide, because of the patchy records of their provenances. As an example, the broad outlines of the evolution of reptiles are well enough known, but the details of patterns of faunal evolution have yet to be established from available material. Numerous explanations of processes of faunal evolution (scenarios) have been made, but they have often gone far ahead of studies of the patterns. For example, despite the thousands of pages that have been written 'explaining' the extinction of the dinosaurs, we have yet to establish the pattern of that extinction—did all groups of dinosaurs become extinct at the same time?; did they become extinct at the same time all over the world?; were the families and orders of reptiles already in decline or were they radiating?; was their extinction contemporaneous with that of marine reptiles, marine invertebrates and plankton?; how long did it take? These points could all be established from the fossil record to a greater or lesser extent, but they require good site information with independent age data. There are numerous other aspects of the patterns of evolution of reptiles to be established, such

as the radiation of mammal-like reptiles in the Permian, the Permo-Triassic boundary extinction event, the radiations of mammal-like reptiles, rhynchosaurs and thecodontians in the Triassic, the radiation of the dinosaurs at the end of the Triassic (Benton, 1983), the radiation of marine ichthyosaurs, nothosaurs and plesiosaurs, the replacement of prosauropod dinosaurs by sauropods, the radiation of ornithischians especially in the Cretaceous, and the achievement of flight by various groups and their subsequent radiations.

Two recent examples of excavation at British fossil vertebrate sites may be mentioned here. Excavations exploiting Silesian fish beds near Glasgow have excited great scientific interest; of equal interest for the purposes of this account is the highly detailed faunal, floral, stratal, and areal recording which has characterized the project (Wood, 1982). Equally painstaking recording techniques were used on the very different deposits of the mammal and reptile bearing Jurassic rocks at Kirtlington, Oxfordshire (Freeman, 1976). Excavations at Bearsden and later large scale collecting at Kirtlington were carried out in collaboration with N.C.C., who provided assistance in the form of mechanical excavators. This collaborative effort between researchers and the Government's own conservation body points the way for future co-operation in the systematic use of vertebrate sites. It is essential that scientific exploitation of sites take full account of the long-term requirements of conservation.

The closely observed accounts mentioned above highlight another conservation problem. The publication of information on such faunas and their precise locations is, in conservation terms, a double-edged sword. On the one hand, the site's scientific value is clearly established, but such explicit details are an open invitation to the reader to use or mis-use the locality. In the view of some palaeontologists the time has come to lodge locality information in a safe repository rather than publishing it, with no thought for the possible consequences. This former procedure we would advocate where the vertebrate interest is vulnerable, rare or exhaustible. Wood's account (Wood, 1982) of the Glasgow site gives no mention of locality details; these have been lodged with the N.C.C.'s Geological Conservation Review Unit as part of its documentation data base.

5. DETECTIVE WORK: WHITBY AND HOLZMADEN

Fossil ichthyosaurs, plesiosaurs and crocodiles have been collected on the Yorkshire coast at Whitby and in alum and jet workings nearby since the 18th century. Several hundred specimens have been accumulated and their provenances range over 10 or so separate sites and several ammonite zones in the Lower Jurassic (the Lias). A few are known from the Lower and Middle Lias, but the majority come from the Upper Lias (*falciferum* and *bifrons* Zones). In the course of the present work, about 200 specimens were located in British museums, but the majority offered little more information than 'Lias, Whitby'. New finds are made sporadically—two or three skeletons or groups of bones per year—but not enough to provide the basis for a detailed study of palaeoecology. The museum material must be used, but the information is woefully inadequate. Dr. M. A. Taylor (Oxford) and M. J. B. set about the detective work of trying to determine locality and horizon for as many of the museum specimens as possible. The following kinds of information were used:

(1) Ammonites attached to the matrix of the reptile specimens.
(2) Matrix type.
(3) Associated labels.
(4) Archive letters and notes.
(5) Published accounts—both from local sources and in the scientific literature.

We regarded the ammonites and the contemporary archive material as the most useful evidence. Most published scientific accounts offered little site information, and several proved to give incorrect information! In the end, we could date and localise only about 10 per cent of the specimens accurately, and the remainder were assigned by reference to the literature and to 'secondary' museum labels (i.e. those not written by the collector). The results of our study (Benton & Taylor, 1984) show the problems of unsystematic collecting by different people over long periods of time.

The Yorkshire coast marine reptile faunas compare best with those from Holzmaden, near Stuttgart, West Germany. A comparison with this fauna is also salutary for the light it throws on the quite different records that have been kept. The reptiles consist of ichthyosaurs, plesiosaurs and crocodiles, in slightly different proportions to those from Yorkshire, and the source beds belong to the *falciferum* Zone. From the late 19th century to the present day, the collecting has remained largely in the hands of private collectors—the Hauff family—who initially owned the quarry—and in a hundred or so years they have collected over 2000 reptile specimens. These have found their way into museums and private collections all round the world. However, accurate records of exact horizon, orientation and condition of each specimen have been maintained by the Hauff family and, since 1971 by them and the Staatliches Museum für Naturkunde Stuttgart, when legal restrictions to collecting were introduced by the Baden-Württemberg Landesamt. A very detailed account of provenances and taphonomy of all finds then known was given by Hauff (1921), and further information has been published by Huene (1931), Brenner & Futterer (1976), Urlichs *et al.*

(1979) and others. A large store of information is available for detailed studies of species evolution bed-by-bed, taphonomy and population characteristics (R. Wild, pers. comm. 1983). The value of the Holzmaden reptiles is much enhanced by this information, and those from the Yorkshire coast form a sad contrast.

6. RECOMMENDATIONS FOR SITE USE

When a fossil is dug up, information is lost. In order to minimise this information loss, we strongly recommend that collectors keep detailed records of everything they find. Important specimens, and anything that is published, should be placed in a recognized institution—preferably a public or university museum. We recommend that museum curators make every effort to keep such information in archives and with the relevant specimens—and curators must closely interrogate collectors who do not keep records, using high-scale maps, photographs and sedimentary logs, in order to obtain all the information they can before the collector forgets or dies. When vertebrate bones are prepared, samples of matrix and associated megafossils should be kept with them in labelled containers. We recommend that people who describe fossil vertebrates make every effort to obtain all details of the provenance and taphonomy of their specimens, and to publish this.

The kinds of information to be recorded/curated/published are: (1) Exact location (8-figure map reference, and verbal description). (2) Exact horizon, using published logs when available, as well as photographs and annotated field sketches. (3) Sediment description, sedimentary structures and lateral variation. (4) Associated plant and animal fossils and relative abundances. (5) Relation of bones to the sediment and orientation of the specimen. (6) State of articulation. (7) Quality of preservation. (8) Evidence of pre- and post-mortem damage. (9) Is it a life or death assemblage? (10) (For 'bone-beds') numbers of specimens sorted per kg/tonne of sediment. (11) (For other faunas) exact numbers of individuals of each form in a given area/volume of sediment. (12) Any chemicals that have been used in excavation (e.g. hardeners) or preparation (e.g. acids).

7. CONCLUSIONS

(1) Proper site conservation and use is important for studies of fossil vertebrates.
(2) Important sites must be preserved from obliteration so that new controlled excavations may be made.
(3) Detailed records of provenance and taphonomy of all future finds of fossil vertebrates should be made.
(4) Studies of the palaeoecology and patterns of evolution of fossil vertebrates depend on accurate and full site information—which is often not available with museum material—and our hypotheses of processes is palaeoecology and the history of life depend on a proper analysis of the patterns.
(5) For the benefit of long-term conservation and the promotion of fossil vertebrate research, stronger ties are required between active specialists and conservationists.

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Appendix

Selection of significant sites, an example. The reptiles of the Oxfordian Stage of Britain. Site location is indicated by Ordnance Survey National Grid References. Abbreviations: BCM, Bristol City Museum; BMNH, British Museum (Natural History); DCM, Dorset County Museum; GSM, Geological Survey Museum; MM, Manchester Museum; OUM, Oxford University Museum; SMC, Sedgwick Museum, Cambridge; YM, Yorkshire Museum.

(1–2) *Site location and listing*

a) Sandsfoot Castle, Weymouth, Dorset (SY 676774): crocodile mandible (Newton, 1878) and teeth.
b) Furzy (Jordan's) Cliff, Weymouth, Dorset (SY 698818): type skeleton of *Megalosaurus parkeri* (Huene, 1923), ichthyosaur (Anonymous, 1974).
c) Osmington, Dorset (SY 7282 exact locality?): ichthyosaur fragment (DCM specimen).
d) Hill Crest Road, Weymouth, Dorset (SY 673774?): plesiosaur bone (DCM specimen).
e) Littlemoor Road, Preston, Dorset (SY 6983: exact locality?): two plesiosaur vertebrae (DCM specimens).
f) Steeple Ashton, Wiltshire (ST 9157): plesiosaur remains (BCM, GSM specimens).
g) Rood Ashton, Trowbridge, Wiltshire (ST 887560): plesiosaur vertebra (BCM specimen).
h) Heddington, Wiltshire (SU 0067): pliosaur and plesiosaur teeth (BMNH, SMC specimens)
i) Hatford, Faringdon, Berkshire (SU 3394): assorted bones (OUM specimens).
j) Stanford-in-the-Vale, Oxfordshire (SU 3493): *Megalosaurus* sacrum (OUM specimen).
k) Marcham, Oxfordshire (SU 4596): crocodile bone (OUM specimen).
l) Cothill, Oxfordshire (SU 4699): crocodile tooth (OUM specimen).
m) Bladon Fields, Oxfordshire (SP 4414): crocodile bone (OUM specimen).
n) Littlemore, Oxford (SP 5302): *Megalosaurus* ilium (OUM specimen).
o) Wheatley, Oxfordshire (SP 5907): pliosaur teeth (BMNH specimens).
p) 'Quarry Field' Headington, Oxford (SP 555071?): dinosaur, plesiosaur and crocodile elements (MM and OUM specimens).
q) Garsington, Oxfordshire (SP 5802): plesiosaur mandible (SMC specimen).
r) Great Gransden, Cambridgeshire (TL 252564 or 260561): type specimen of dinosaur *Cryptodraco* (a femur) (Galton 1980) and partial pliosaur skeleton (SMC specimen).
s) Ampthill, Bedfordshire (TL 0438): crocodile and ichthyosaur remains (SMC specimens).
t) Gamlingay, Cambridgeshire (TL 2352): ichthyosaur jaw (SMC specimen).
u) Mepal, Cambridgeshire (TL 4480): plesiosaur limb bone (SMC specimen).
v) Malton, North Yorkshire (SE 7871): pliosaur, crocodile, ichthyosaur teeth and vertebrae (BMNH, SMC, YM specimens).
w) Slingsby, Yorkshire (SE 708744): type femur of *Omosaurus phillipsi* (Seeley, 1893).
x) North Grimstone, Yorkshire (SE 8467): pliosaur and crocodile teeth (SMC specimens).
y) Scarborough, Yorkshire (TA 0488, exact locality?) pliosaur tooth (SMC specimen).

(3) *Preliminary site sorting*

Sites (c–o, q, s–u, x, y) were rejected because of the small number of finds in the past.

(4) *Site visits and further site sorting*

Visits were made to Sandsfoot Castle (a), Furzy Cliff (b), Headington (p), Great Gransden (r), Malton (v) and Slingsby (w). It was found that Great Gransden (r) quarries were already filled and that Slingsby quarry (w) was partly filled. Sandsfoot Castle (a) would be nearly impossible to excavate because of coastal defences at the base of the cliff and building on top. It was also found that there were formerly numerous quarries at Headington (p) and Malton (v), of which only a few remain, and there is no clear evidence to suggest the exact provenance of the fossil reptiles.

(5) *Selection of major sites*

Furzy Cliff, Dorset (b) was the only site remaining in the Oxfordian and it has been declared an SSSI. It has yielded several important reptile specimens. The horizon of the finds is known (Jordan Cliff Clays, *bukowskii* Subzone, *cordatum* Zone, Upper Oxford Clay, Lower Oxfordian), and there is continuous erosion of the cliff and the potential for further excavation also.