British Middle Jurassic Stratigraphy

B.M. Cox*

and

M.G. Sumbler*

* formerly of the British Geological Survey, Keyworth, Nottingham

GCR Editor:

D. Skevington

JOINT NATURE CONSERVATION COMMITTEE

Published by the Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough, PE1 1JY, UK

First edition 2002

Typeset in 10/12pt Garamond ITC by JNCC
Printed in Great Britain by CLE Ltd on 100 gsm Silverblade Matt.

ISBN 1 86107 479 4.

A catalogue record for this book is available from the British Library.

Recommended example citations

Cox, B.M. and Sumbler, M.G. (2002) *British Middle Jurassic Stratigraphy*, Geological Conservation Review Series, No. 26, Joint Nature Conservation Committee, Peterborough.

Cox, B.M. (2002) Peashill Quarry, Dorset. In *British Middle Jurassic Stratigraphy* (eds B.M. Cox and M.G. Sumbler), Geological Conservation Review Series, No. 26, Joint Nature Conservation Committee, Peterborough, pp. 45–7.

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Acknowledgements

Compilation of this volume by the authors began in 1995 as a contract between the British Geological Survey (BGS) and the Joint Nature Conservation Committee (JNCC), but completion of the work has extended well beyond the original tenure of that contract. The volume comprises a description of sites originally selected for the Geological Conservation Review (GCR) in the 1980s by C.F. Parsons (Aalenian–Bajocian GCR 'Block'), D.W. Cripps (Bathonian GCR 'Block') and K.L. Duff (Callovian GCR 'Block').

At the instigation of the JNCC, Dr Kevin N. Page (formerly with English Nature) prepared initial drafts of the Callovian sites; he acknowledges constructive comments from Prof. J.H. Callomon, Dr K.L. Duff and Dr J.K. Wright. We thank Dr Page and the other contributors (Dr M.J. Barker (University of Portsmouth), Dr N. Morton (formerly at Birkbeck College, University of London) and R.J. Wyatt (formerly with the British Geological Survey)) for their passive forbearance, and Dr D. Skevington (the GCR editor) for his support and encouragement.

Information from unpublished theses is, where possible, quoted with the permission of the authors and/or their host universities; these include J.E. Andrews (University of Leicester, 1984), M. Ashton (University of Hull, 1977), M.J. Bradshaw (University of Oxford, 1978), D.W. Cripps (University of Aston, 1986), S. Gowling (University of Hull, 1987), J.P. Harris (University of Leicester, 1984), S. Holloway (University of Keele, 1981), S.E. Livera (University of Leeds, 1981), C.F. Parsons (University of Keele, 1980) and H.S. Torrens (University of Leicester, 1966). In addition, other individuals and museum curators have imparted information about particular specimens or localities, notably Phil Powell (University Museum, Oxford) and John Crossling (formerly of the Warwickshire Museum).

For original photographic material, we thank Bob Chandler (Figures 2.19 and 2.28), Dr Keith Duff (Figure 2.8), Prof. John Hudson (Figure 6.40) and Dr Paul Taylor (on behalf of The Natural History Museum; Figures 2.22, 3.12, 5.18 and 5.19). Prof. Hudson has provided helpful comments as both colleague and referee. To anyone whose contribution we have inadvertently failed to acknowledge, please accept our apologies. We have endeavoured to ensure a uniformity of style and fact; in any editing or rewriting of contributions, we take full responsibility for changes thereby made. Readers are referred to the forthcoming second edition of the Geological Society of London's publication on the correlation of Jurassic rocks in the British Isles for an update on British Middle Jurassic stratigraphy.

Acknowledgments

The present volume has been seen to completion by the JNCC on behalf of the three conservation agencies, the Countryside Council for Wales, English Nature, and Scottish Natural Heritage. Thanks are due to the JNCC GCR Publications Editorial and Production Team: Neil Ellis (GCR Publications Manager), Emma Durham and Anita Carter (Production Editors). The diagrams were produced by J S Publications of Newmarket. Where the content of illustrations has been replicated or modified from the work of others, appropriate acknowledgements are given in the captions. The National Grid is used on diagrams with the permission of the Controller of Her Majesty's Stationery Office, © Crown copyright licence no. GD 27254X/01/00. Photographs are accredited in the captions.

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Preface

There is such a diversity of rocks, minerals, fossils and landforms packed into the piece of the Earth's crust we call 'Britain' that it is difficult not to be impressed by the long, complex history of geological change to which they are testimony. But if we are to improve our understanding of the nature of the geological forces that have shaped our islands, further unravel their history in 'deep time' and learn more of the history of life on Earth, we must ensure that the most scientifically important of Britain's geological localities are conserved for future generations to study, research and enjoy. Moreover, as an educational field resource and as training grounds for new generations of geologists on which to hone their skills, it is essential that such sites continue to remain available for study. The first step in achieving this goal is to identify the key sites, both at national and local levels.

The GCR, launched in 1977, is a world-first in the systematic selection and documentation of a country's best Earth science sites. No other country has attempted such a comprehensive and systematic review of its Earth science sites on anything near the same scale. After over two decades of site evaluation and documentation, we now have an inventory of over 3000 GCR sites, selected for 100 categories covering the entire range of the geological and geomorphological features of Britain.

This volume, detailing the Middle Jurassic stratigraphy GCR sites, is the 26th to be published in the intended 42-volume GCR series. Not only does it contain the descriptions of key localities that will be conserved for their contribution to our understanding of the stratigraphy of rocks of this age, but it also provides an excellent summary of the palaeontological and sedimentological features, and palaeogeographical significance to be found in them; it also outlines the research that has been undertaken on them. The book will be invaluable as an essential reference book to those engaged in the study of these rocks and will provide a stimulus for further investigation. It will also be helpful to teachers and lecturers and for those people who, in one way or another, have a vested interest in the GCR sites: land owners and occupiers, planners, those concerned with the practicalities of site conservation and indeed the local people for whom such sites are an environmental asset. The conservation value of the sites is mostly based on a specialist understanding of the stratigraphical, palaeontological and sedimentological features present and is therefore, of a technical nature. The account of each site in this book ends, however, with a brief summary of the geological interest, framed in less technical language, in order to help the non-specialist. The first chapter of the volume, used in conjunction with the glossary, is also aimed at a less specialized audience. This volume is not intended to be a field guide to the sites, nor does it cover the practical problems of their ongoing conservation. Its remit is to put on record the scientific justification for conserving the sites.

This volume deals with the state of knowledge of the sites available at the time of writing, in 1995–2001, and must be seen in this context. Stratigraphy, like any other science, is an ever-developing pursuit with new discoveries being made, and existing models are subject to continual testing and modification as new data come to light. Increased or hitherto unrecognized significance may be seen in new sites, and it is possible that further sites worthy of conservation will be identified in future years.

There is still much more to learn and the sites described in this volume are as important today as they have ever been in increasing our knowledge and understanding of the geological history of Britain. This account clearly demonstrates the value of these sites for research, and their important place in Britain's scientific and natural heritage. This, after all, is the *raison d'être* of the GCR Series of publications.

N.V. Ellis
GCR Publications Manager
May 2002

Chapter 1

General introduction to the Aalenian to Callovian stratigraphy of Great Britain

B.M. Cox

INTRODUCTION

The GCR sites described in this volume are representative of the British geological record of Earth history from about 178 to 157 million years ago (Ma) (Harland *et al.*, 1990). This interval is known as the Mid Jurassic Epoch (part of the Jurassic Period), and the rocks that formed during that time, and bear witness to its events and environments, constitute the Middle Jurassic Series (part of the Jurassic System) (Figure 1.1).

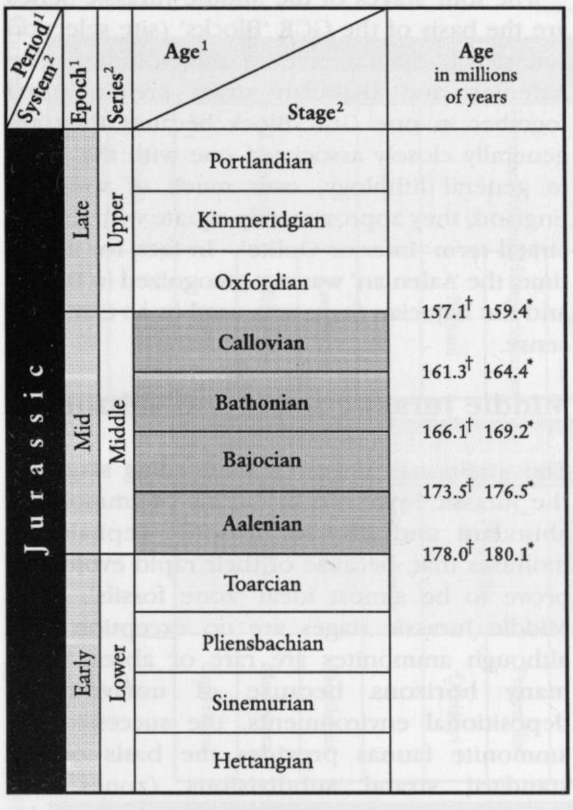

Figure 1.1 Major Jurassic subdivisions. ([1] = Geological time terms; [2] = Chronostratigraphical (time-rock) terms; † = Harland *et al.* (1990); * = Gradstein and Ogg (1996) (95% confidence level).)

PALAEOENVIRONMENT AND PALAEOGEOGRAPHY

During the Early Jurassic Epoch, Britain was largely covered by shallow shelf-seas; Lower Jurassic rocks and their fossils indicate fully marine environments. However, towards the end of the epoch, there was a significant fall in sea level accompanied by domal upwarping and contemporaneous volcanicity in the central North Sea Basin (Bradshaw and Cripps, 1992). Consequently, Middle Jurassic rocks reflect a variety of depositional environments including shallow marine, fluvial, deltaic, saltmarsh and coastal lagoonal (brackish-water and freshwater). In addition, carbonate (limestone) as well as clastic (mudstone, siltstone, sandstone) sedimentation was often widespread. This has generally been thought to be the result of warmer climates in Mid Jurassic times (e.g. Ager, 1975; Frakes, 1979; Bradshaw and Cripps, 1992) although, paradoxically, Frakes (1992) reported a cooling trend. These two factors – depositional environments and increased carbonate sedimentation – are largely responsible for the distinctive characteristics of the Middle Jurassic succession in Britain which, for the most part, is in marked contrast to the marine mudstone-dominated Lower and Upper Jurassic successions.

THE MIDDLE JURASSIC OUTCROP

On maps showing the solid geology of England, Middle Jurassic rocks crop out in an almost continuous strip from the Dorset coast to the North Yorkshire coast, broken only in the Market Weighton area, north of the Humber Estuary (Figure 1.2). They also occur beneath younger rocks in the whole of the land area to the east of the outcrop, with the exception of a large area beneath East Anglia and the Thames Valley (an area corresponding with the so-called 'London Landmass'; see Figure 1.6). In Scotland, Middle Jurassic rocks crop out in Ardnamurchan, on the Hebridean islands of Skye, Raasay, Eigg, Muck, Mull and possibly Shiant, and on the north-east coast at Brora (in the former county of Sutherland) and near Balintore (in the former county of Ross and Cromarty).

STRATIGRAPHICAL NOMENCLATURE

The Middle Jurassic Series is divided into four stages – the Aalenian, Bajocian, Bathonian and Callovian stages. With the exception of the Aalenian Stage, which was introduced by Mayer-Eymar (1864), these stratal divisions were established by d'Orbigny (1850a), although the term 'bathonien' had been used earlier by d'Halloy (1843) (Figure 1.1). For many years, British geologists included the Callovian Stage in the Upper Jurassic Series because the base of the

Figure 1.2 Simplified sketch map showing the main British Middle Jurassic outcrops (onshore area only).

Callovian succession in England (its type area; Callomon, 1964) approximately coincides with the end of the paralic and carbonate sedimentation that characterizes the bulk of the Middle Jurassic strata. The contentious subject of where the Middle–Upper Jurassic boundary should be drawn has been discussed by Melville (1956) and Torrens (1980a), and at various international colloquia (Callomon, 1965; Maubeuge, 1970). However, following Arkell (1946, 1956a), the original three-fold gross lithological division proposed by von Buch (1839) for the Jurassic strata of Germany is now used as the basis of subdivision of the Jurassic System throughout the world, and current practice thereby takes the base of the Upper Jurassic Series at the base of the Oxfordian Stage. The position of the base of the Middle Jurassic Series, at the base of the Aalenian Stage, has also been the subject of debate, as reviewed by Torrens (1980a). Although the Bathonian and Callovian stages take their names from localities in Britain (Bath, in Somerset, and Kellaways, in Wiltshire, respectively), neither of them will be formally defined here, as more complete sequences through their basal boundaries (on which definition of stages depends) exist elsewhere in Europe.

The four stages of the Middle Jurassic Series are the basis of the GCR 'Blocks' (site selection categories) documented in this volume. The Aalenian and Bajocian strata are included together in one GCR Block because they are generally closely associated one with the other in general lithology; over much of southern England, they approximately equate with the old stratal term 'Inferior Oolite'. In fact, for a long time, the 'Aalenian' was not recognized in Britain and the Bajocian Stage was used in an extended sense.

Middle Jurassic zones and subzones

The traditional means of subdividing stages in the Jurassic System is by means of ammonites, abundant and diverse nektonic cephalopod molluscs that, because of their rapid evolution, prove to be almost ideal 'zone fossils'. The Middle Jurassic stages are no exception and, although ammonites are rare or absent from many horizons because of unfavourable depositional environments, the succession of ammonite faunas provides the basis of the standard stratal subdivisions (zones and subzones) (Figure 1.3). In those parts of the succession where ammonites are abundant (e.g. the Callovian rocks of the East Midlands), a particular zone or subzone may correspond precisely with an ammonite biozone or subbiozone and be identified on that basis. However, in many areas – for example the Aalenian–Bajocian strata of the Cotswolds and East Midlands where ammonites are rare – it is not possible to apply an ammonite biozonation from first principles and, clearly, in areas where ammonites are completely absent, as in much of the Bathonian succession in both England and Scotland, ammonite biozonation is impossible.

Stage	Zone	Subzone
Aalenian	Concavum	Formosum
		Concavum
	Bradfordensis	Gigantea
		Bradfordensis
	Murchisonae	Murchisonae
		Obtusiformis
		Haugi
	Scissum	
	Opalinum	

Stage	Substage	Zone	Subzone
Bajocian	Upper	Parkinsoni	Bomfordi
			Truellei
		Garantiana	Acris
			Tetragona
			Dichotoma
		Subfurcatum	Baculata
			Polygyralis
			Banksi
	Lower	Humphriesianum	Blagdeni
			Humphriesianum
			Romani
		Sauzei	
		Laeviuscula	Laeviuscula
			Trigonalis
			Sayni
		Ovalis	
		Discites	

Stage	Substage	Zone	Subzone
Bathonian	Upper	Discus	Discus
			Hollandi
		Retrocostatum	Hannoveranus
			Blanazense
			Quercinus
	Middle	Bremeri	Fortescostatum
			Bullatimorphus
		Morrisi	
		Subcontractus	
		Progracilis	Progracilis
			Orbignyi
	Lower	Tenuiplicatus	
		Zigzag	Yeovilensis
			Macrescens
			Convergens

Stage	Substage	Zone	Subzone
Callovian	Upper	Lamberti	Lamberti
			Henrici
		Athleta	Spinosum
			Proniae
			Phaeinum
	Middle	Coronatum	Grossouvrei
			Obductum
		Jason	Jason
			Medea
	Lower	Calloviense	Enodatum
			Calloviense
		Koenigi	Galilaeii
			Curtilobus
			Gowerianus
		Herveyi	Kamptus
			Terebratus
			Keppleri

Figure 1.3 Chronostratigraphical subdivisions of the Middle Jurassic Series (for sources, see text).

In such situations, the standard ammonite-based zones are identified, wholly or in part, by indirect or circumstantial evidence (e.g. by using ostracod faunas or by event-marker correlation). In this account, the Middle Jurassic zones and subzones, into which the succession is divided without gaps or overlaps, are therefore treated as chronostratigraphical subdivisions of stages. They may be *recognized* by ammonite faunas but are not *defined* by them. They are labelled with the name of an ammonite species but these are written in Roman font with an initial capital; they are thereby differentiated from biozones/sub-biozones, which take the full italicized taxonomic name of their index species. The standard zonation used herein follows Parsons (1980a) as modified by Callomon and Chandler (1990) and Callomon (in Callomon and Cope, 1995) for the Aalenian and Bajocian strata; Torrens (1980a) as modified by Dietl and Callomon (1988), Callomon (in Callomon and Cope, 1995) and Page (1996a) for the Bathonian strata; and Callomon (1964) as modified by Callomon and Sykes (1980), Callomon *et al.* (1989) and Page (1989) for the Callovian strata (Figure 1.3).

Although ammonites are rare or absent at many levels of the Middle Jurassic succession, at others the ammonite faunas are sufficiently abundant and well known that they have been used to develop ever more sophisticated schemes of stratal subdivision and correlation. The early Mid Jurassic Epoch is a time of exceptional interest for students of ammonite evolutionary history (Callomon and Chandler, 1990). A major radiative expansion saw the appearance of three ammonite superfamilies – the Haplocerataceae, Stephanocerataceae and Perisphinctaceae – which thereafter dominated the shelf seas of the world well into the Cretaceous Period. It was such ammonites in the Aalenian–Bajocian succession of Dorset that led S.S. Buckman (1860–1929) to undertake his detailed assessment of their stratigraphical occurrence and develop his scheme of so-called 'hemerae' (from the Greek word *hemera* meaning 'day'), each representing a relatively short period of geological time, and characterized by particular ammonite taxa. Unfortunately, this early and valuable work of Buckman (1893a, 1902a) was somewhat discredited by his later work, which became less based on accurate field observation and more on intuition and guesswork. However, in recent years, the Aalenian and Bajocian ammonite stratigraphy of Dorset has been re-investigated, and Buckman's early findings have proved to be entirely reliable (Callomon and Chandler, 1990; Callomon, 1995; Callomon in Callomon and Cope, 1995). This has led to the concept of so-called 'ammonite faunal horizons' or 'biohorizons' (Callomon, 1985a,b; Page, 1995; Figure 1.4). For the time duration of individual horizons, Buckman's term 'hemera' might still be used, but the horizons themselves are perceived as a bed, or series of beds, characterized by a particular assemblage of ammonites and within which no further stratigraphical refinement – on the basis of the contained ammonite fauna – can be made. They are usually named after a suitable index species, as well as being consecutively numbered or lettered. It is important to appreciate that there may be intervals of geological time between biohorizons that are unrepresented in the ammonite record. Consequently, biohorizons do not form part of the chronostratigraphical hierarchy of terms (system, stage, series, etc.) in which the rock succession is divided into sequential subdivisions without gaps or overlaps, and each unit of higher rank (e.g. a series) is a grouping of units of lower rank (in this example, stages). A scheme of ammonite biohorizons has also been established for the Lower Callovian Substage (Callomon and Page in Callomon *et al.*, 1989) and, according to Callomon (1995), the beds into which Brinkmann (1929a) divided the Callovian Oxford Clay Formation of Peterborough (see Chapter 4), on the basis of the kosmoceratid ammonite faunas, conform almost ideally with the definition of biohorizons. Work is still ongoing to establish and finalize a scheme of ammonite biohorizons for the Bathonian succession, based on the more ammonitiferous successions of southern Europe (Callomon in Westermann and Callomon, 1988; Mangold and Rioult, 1997). Most recently, Page (1996a) has made a first attempt at formulating a scheme of ammonite biohorizons for the Bathonian succession of southern England; these should be regarded as provisional. Indeed, the complete listing of biohorizons shown in Figure 1.4 is open to continual revision. Many of them have no published specifications regarding their particular and diagnostic ammonite assemblages and, in many cases, further descriptive systematic and taxonomic work is required to clarify definitions.

Stage/Substage	Zone	Subzone		Ammonite biohorizon
Lower Bajocian	Humphriesianum	Blagdeni	Bj-19	*Teloceras coronatum*
			Bj-18	*Teloceras blagdeni*
		Humphriesianum	Bj-17	*Stephanoceras blagdeniforme*
			Bj-16	*Stephanoceras gibbosum*
			Bj-15	*Stephanoceras humphriesianum*
		Romani	Bj-14b	*Chondroceras wrighti*
			Bj-14a	*Chondroceras delphinum*
			Bj-13	*Stephanoceras umbilicum*
	Sauzei		Bj-12	*Stephanoceras rhytum*
			Bj-11b	*Nannina evoluta*
			Bj-11a	*Otoites sauzei*
	Laeviuscula	Laeviuscula	Bj-10	*Witchellia laeviuscula*
			Bj-9	*Witchellia ruber*
		Trigonalis	Bj-8b	*Shirbuirnia trigonalis*
			Bj-8a	*Witchellia nodatipinguis*
		Sayni	Bj-7b	*Witchellia connata*
			Bj-7a	*Witchellia gelasina*
	Ovalis		Bj-6c	*Witchellia 'pseudoromani'* MS
			Bj-6b	*Fissilobiceras gingense*
			Bj-6a	*Euhoploceras zugophorum*
			Bj-5	*Witchellia romanoides*
			Bj-4	*Bradfordia inclusa*
	Discites		Bj-3	*Hyperlioceras subsectum*
			Bj-2b	*Hyperlioceras rudidiscites*
			Bj-2a	*Hyperlioceras walkeri*
			Bj-1	*Hyperlioceras politum*
Aalenian	Concavum	Formosum	Aa-16	*Euhoploceras acanthodes*
			Aa-15	*Graphoceras formosum*
		Concavum	Aa-14	*Graphoceras concavum*
			Aa-13	*Graphoceras cavatum*
	Bradfordensis	Gigantea	Aa-12	*Brasilia decipiens*
			Aa-11	*Brasilia gigantea*
		Bradfordensis	Aa-10	*Brasilia bradfordensis, similis*
			Aa-9	*Brasilia bradfordensis, baylii*
			Aa-8	*Brasilia bradfordensis, subcornuta*
	Murchisonae	Murchisonae	Aa-7	*Ludwigia murchisonae*
			Aa-6	*Ludwigia patellaria*
		Obtusiformis	Aa-5	*Ludwigia obtusiformis*
		Haugi	Aa-4	*Ancolioceras opalinoides*
	Scissum		Aa-3	*Leioceras bifidatum*
			Aa-2	*Leioceras lineatum*
	Opalinum		Aa-1	*Leioceras opalinum*

Substage	Zone	Subzone		Ammonite biohorizon
Lower Callovian	Calloviense	Enodatum	XVIII	*Sigaloceras anterior*
			XVIIb	*Sigaloceras enodatum* β
			XVIIa	*Homoeoplanulites difficilis*
			XVI	*Sigaloceras enodatum* α
		Calloviense	XV	*Sigaloceras micans*
			XIV	*Sigaloceras calloviense*
	Koenigi	Galilaeii	XIII	*Kepplerites galilaeii*
		Curtilobus	XII	*Kepplerites trichophorus*
			XIb	*Kepplerites indigestus*
			XIa	*Cadoceras 'gregarium'* MS
			X	*Kepplerites curtilobus*
		Gowerianus	IX	*Kepplerites gowerianus*
			VIII	*Kepplerites metorchus*
	Herveyi	Kamptus	VII	*Macrocephalites polyptychus*
			VI	*Macrocephalites kamptus* β
			V	*Macrocephalites kamptus* α
		Terebratus	IVb	*Macrocephalites terebratus* γ
			IVa	*Macrocephalites terebratus* β
			III	*Macrocephalites terebratus* α
		Keppleri	II	*Macrocephalites verus*
			I	*Kepplerites keppleri*
Upper Bathonian	Discus	Discus	Bt-20	*Clydoniceras hochstetteri*
			Bt-19	*Clydoniceras discus*
		Hollandi	Bt-18	*Clydoniceras hollandi*
	Retrocostatum	Hannoveranus	Bt-17	*Clydoniceras* cf. *schippei*
			Bt-16	?*Homoeoplanulites* sp.
		Blanazense	Bt-15	*Procerites twinhoensis*
		Quercinus	Bt-14	*Procerites hodsoni*
			Bt-13	*Procerites quercinus*
Middle Bathonian	Bremeri	Fortescostatum	Bt-12	*Wagnericeras bathonicum*
		Bullatimorphus	Bt-11	*Bullatimorphites bullatimorphus*
	Morrisi		Bt-10	*Morrisiceras morrisi*
	Subcontractus		Bt-9	*Tulites modiolaris*
			Bt-8	*Bullatimorphites* ex gr. *rugifer*
	Progracilis	Progracilis	Bt-7	*Procerites imitator*
			Bt-6	*Procerites progracilis*
		Orbignyi	Bt-5	*Procerites/Prohecticoceras*
Lower Bathonian	Tenuiplicatus		Bt-4	*Asphinctes tenuiplicatus*
	Zigzag	Yeovilensis	Bt-3b	*Procerites fullonicus*
			Bt-3a	*Procerites fowleri*
		Macrescens	Bt-2	*Morphoceras macrescens*
		Convergens	Bt-1	*Parkinsonia convergens*
Upper Bajocian	Parkinsoni	Bomfordi	Bj-28	*Parkinsonia bomfordi*
			Bj-27c	*Parkinsonia pseudoferruginea*
		Truellei	Bj-27b	*Strigoceras truellei*
			Bj-27a	*Parkinsonia parkinsoni* α
	Garantiana	Acris	Bj-26b	*Parkinsonia rarecostata*
		Tetragona	Bj-25	*Garantiana tetragona*
		Dichotoma	Bj-24	*Garantiana dichotoma*
	Subfurcatum	Baculata	Bj-23	*Leptosphinctes davidsoni*
		Polygyralis	Bj-22	*Caumontisphinctes polygyralis*
		Banksi	Bj-21	*Caumontisphinctes aplous*
			Bj-20	*Teloceras banksi*

Figure 1.4 Ammonite biohorizons recognized in the British Middle Jurassic Series (for sources, see text).

MIDDLE JURASSIC FAUNA AND FLORA

As well as the ammonites, there were many other animals and plants living in Mid Jurassic times (Oakley and Muir-Wood, 1967; Gould, 1993; for descriptions of Mesozoic palaeontological GCR sites see Benton and Spencer, 1995 (fossil reptiles); Dineley and Metcalf, 1999 (fossil fishes); and Cleal *et al.*, 2001 (fossil plants)). The many different depositional environments that developed in Britain during that time mean that the fossil record is rich and varied (Figure 1.5). In the clear warm seas in which the limestones formed, calcareous seaweeds (red algae) were common. Invertebrate faunas living on the seabed included simple and compound corals, calcareous sponges and bryozoa, which sometimes formed small patch reefs. Abundant bivalve molluscs burrowed in the soft sea-floor sediments (both carbonate and mud), and some surface-dwellers, for example oysters, built up shell reefs. Oysters, being able to tolerate the more brackish waters of some coastal environments, are common throughout a range of sediment types. Gastropods (snails), asteroids (starfish) and echinoids (sea urchins) browsed on the sea floor where crinoids (sea lilies) also grew. The snail *Viviparus* inhabited the less saline environments such as near-coastal lagoons, and the bivalve *Unio* lived in freshwater habitats; microscopic crustaceans (ostracods and conchostracans) were common to both these environments. Smooth terebratulid and ribbed rhynchonellid brachiopods occurred in an abundance that was never repeated on such a scale in later geological times, probably because of competition from the bivalve molluscs. Microscopic organisms included foraminifera, ostracods (also present in brackish-water and freshwater habitats) and phytoplankton (dinoflagellates and coccolithophorid algae). Lobster- and shrimp-like crustaceans dwelt in both muddy and carbonate seabed environments, often leaving characteristic burrows within sediments, and belemnites, squid-like relatives of the ammonites, swarmed in the muddy seas. Belemnites and fish were probably the main food of the aquatic reptiles, which were the largest vertebrate animals in the sea. These included ichthyosaurs, plesiosaurs, pliosaurs, crocodiles (steneosaurs and teleosaurs) and turtles. The fish included both holostean and teleostean bony fishes as well as sharks and rays (Dineley and Metcalf, 1999).

On land, dinosaurs had already become established but in the Mid Jurassic, new groups such as sauropods, large theropods, avialan theropods (bird-relatives), stegosaurs and ankylosaurs appeared. Some dinosaurs, for example *Cetiosaurus*, were vegetable feeders, many of which waded in swamps; others, for example *Megalosaurus*, were flesh-eaters. Apart from the dinosaurs, crocodilians radiated extensively, and a range of meat- and fish-eaters evolved. Mammal-like reptiles, lizards and amphibians, such as frogs and salamanders, were also part of the terrestrial fauna in which primitive mammals, probably no bigger than rats, formed a minor but important part. Some of the mammals had teeth adapted for feeding on insects; others may have lived mainly on plant fruits. Land plants in Mid Jurassic times were varied and abundant, but of particular prominence were the gymnosperms, notably conifers, cycads and ginkgoes (the maidenhair tree). Ferns and horsetails were also abundant. True flowering plants (angiosperms) had not yet appeared although some of the cycads (e.g. *Williamsonia*) bore flower-like cones (Cleal *et al.*, 2001). Insect life included forms such as dragonflies, crickets, cockroaches, bugs and beetles but other familiar forms, such as bees, wasps and butterflies, did not appear until the flowering plants became established in the Early Cretaceous Epoch.

GCR SITE SELECTION

The rationale behind the selection of sites follows that of the Geological Conservation Review in general; i.e. the selected sites are (a) those of importance to the international community of Earth scientists because they are type localities for time intervals or their boundaries, or for fossil species, or are of historical significance in the development of the science; (b) those that contain exceptional geological features; and (c) those that are nationally important because they are representative of a geological feature, event or process that is fundamental to Britain's Earth history (Ellis *et al.*, 1996). The last-named category is particularly relevant to the present volume in which the type localities or best representative sections of named rock units or their boundaries are conspicuous. Many Middle Jurassic sites in Britain also belong to

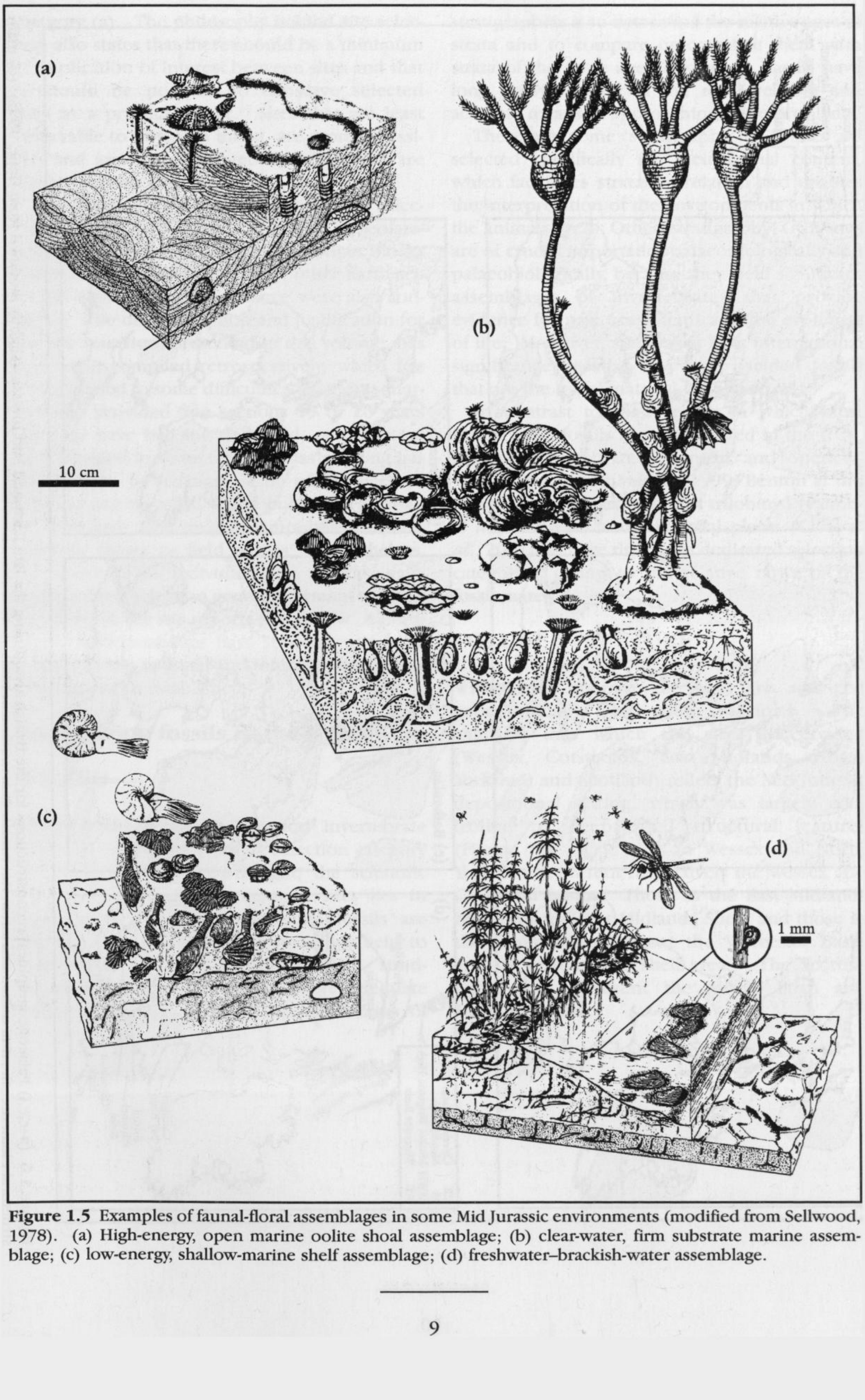

Figure 1.5 Examples of faunal-floral assemblages in some Mid Jurassic environments (modified from Sellwood, 1978). (a) High-energy, open marine oolite shoal assemblage; (b) clear-water, firm substrate marine assemblage; (c) low-energy, shallow-marine shelf assemblage; (d) freshwater–brackish-water assemblage.

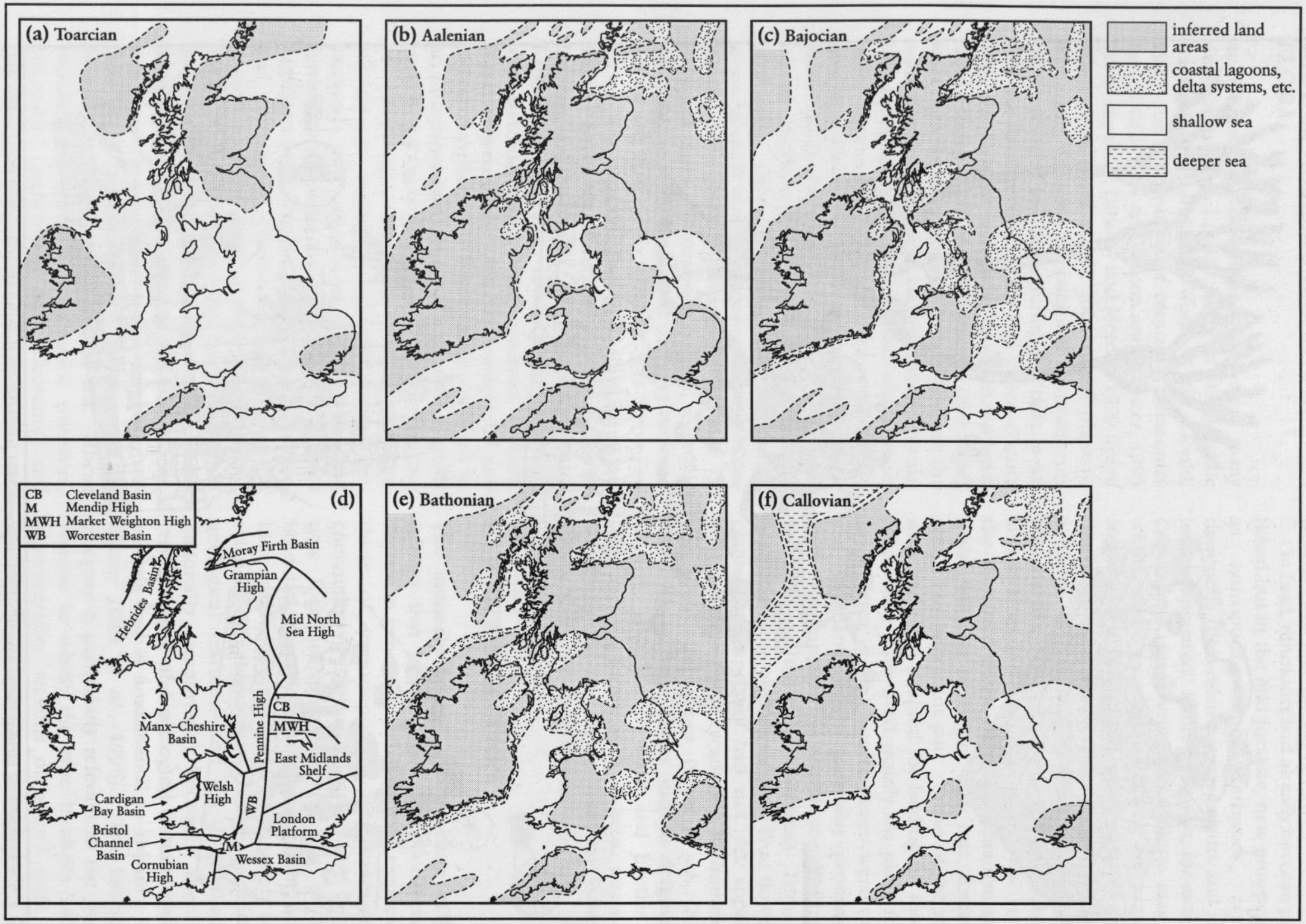

Figure 1.6 (a–c,e,f) Palaeogeographical reconstructions for the British area during the late Early and Mid Jurassic (slightly modified from Cope, 1995); (d) main structural elements affecting sedimentation in the British area in the Mid Jurassic (terminology as used in this volume). The 'London Platform' is a structural high, the limits of which remained generally constant. The emergent part of the Platform, the position and limits of which varied, is referred to as the 'London Landmass'. (Compiled from various sources.)

category (a). The philosophy behind site selection also states that there should be a minimum of duplication of interest between sites and that it should be possible to conserve selected sites in a practical sense. Sites that are least vulnerable to potential threat, are more accessible, and are not duplicated by other sites are preferred (Ellis *et al.*, 1996).

The Middle Jurassic sites were originally selected in the early 1980s by C.F. Parsons (Aalenian–Bajocian Block), D.W. Cripps (Bathonian Block) and K.L. Duff (Callovian Block); other Earth scientists with relevant experience were also consulted. The documentation and justification for the site selection, presented in this volume, has thus been compiled retrospectively, which has inevitably led to some difficulties. Working quarries that provided fine sections 15 or 20 years ago may have become degraded, or the exposure changed in some other way as working has proceeded. In addition, some of the selected sites are not recorded in the published geological literature but only in unpublished postgraduate theses or field guides. Nevertheless, the credentials of individual sites that originally justified their selection generally remain valid, as described in the site reports that follow. A number of additional sites have subsequently been added as their national and international importance has been established.

Invertebrate fossils in the GCR

N.V. Ellis

Although the relatively common invertebrate fossils do not have a separate selection category in the GCR in their own right, the scientific importance of many stratigraphy sites lies in their fossil content. Invertebrate fossils are important in stratigraphy because they help to characterize stratal units. In practice, stratigraphy is at its most secure where adequate fossils are found. One of the main tasks of stratigraphers is to determine the relative ages of strata and to compare or correlate them with strata of the same age elsewhere. Fossils have long provided one of the most reliable and accurate means of approaching these problems.

Therefore, some 'stratigraphy' GCR sites are selected specifically for their faunal content, which facilitates stratal correlation and enables the interpretation of the environments in which the animals lived. Other 'stratigraphy' GCR sites are of crucial importance palaeontologically and palaeobiologically, because they yield significant assemblages of invertebrates that provide evidence for past ecosystems and the evolution of life. Moreover, some sites have international significance because they have yielded fossils that are the 'type' material for a species.

In contrast to the manner in which most invertebrate fossils are represented in the GCR, fossils of vertebrates (Benton and Spencer, 1995; Dineley and Metcalf, 1999; Benton *et al.*, in prep.), arthropods (except trilobites) (Palmer *et al.*, in prep.) and terrestrial plants (Cleal *et al.*, 2001) do have their own dedicated selection categories, owing to the relative rarity of the fossil material.

VOLUME STRUCTURE

Within this volume, the sites are arranged geographically from south to north. The chapters into which the sites are divided (Wessex, Cotswolds, East Midlands, North Yorkshire and Scotland) reflect the Mid Jurassic depositional setting, which was largely controlled by deep-seated structural features (Figure 1.6). The sites in Wessex and North Yorkshire represent respectively the Wessex and Cleveland basins. Those in the East Midlands represent the East Midlands Shelf, and those in the Cotswolds represent the Worcester Basin and its surrounding shelf areas. The Scottish GCR sites represent the Moray Firth and Hebrides basins.