British Tertiary Stratigraphy

Brian Daley

School of Earth, Environmental and Physical Sciences
University of Portsmouth
Portsmouth, UK

and

Peter Balson

British Geological Survey,
Keyworth, Nottingham, UK

GCR Editor: **L.P. Thomas**

JOINT NATURE CONSERVATION COMMITTEE

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

First edition 1999

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

ISBN 1 86107 469 7

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

Recommended Example Citations

Balson, P. (1999) The Lenham Beds. In *British Tertiary Stratigraphy*, Geological Conservation Review Series No.15, (B Daley and P. Balson). Joint Nature Conservation Committee, Peterborough, pp. 243–252.
Daley, B. (1999) London Basin: eastern localities. In *British Tertiary Stratigraphy*, Geological Conservation Review Series No. 15, (B. Daley and P. Balson). Joint Nature Conservation Committee, Peterborough, pp. 23–72.

Contents

Acknowledgements

The authors would like to acknowledge the help and encouragement of Bill Wimbledon who first involved them in the site selection phase of the Geological Conservation Review, and who later interested them in writing the Palaeogene (Brian Daley) and Neogene (Peter Balson) parts of what was to become the 'British Tertiary Stratigraphy' GCR volume. Bill's enthusiasm and advice have been welcome over the lengthy period of time that it has taken to bring the project to fruition. Both authors are also grateful to Neil Ellis of JNCC, who more recently provided guidance and support when the decision was made to make a single volume comprising both the Palaeogene and Neogene texts, and particularly during a successful attempt to ensure a more complete coverage of Palaeogene sites than had been originally envisaged. The authors also thank the GCR Publications Team in JNCC, Anita Carter and Neil Cousins, for their work on the production of the book. One of the authors (BD) also thanks Valerie Wyld, formerly of JNCC, for her co-operation and patience in the production of various early versions of the Palaeogene typescript.

Brian Daley is particularly indebted to Nicholas Edwards (Honorary Research Fellow in the University of Portsmouth), who first introduced him to the study of the Palaeogene and with whom he has collaborated for some three decades. His help in the field and constructive editorial skills proved to be of great value. Brian Daley has also benefited greatly from the advice and guidance of Roland Goldring, since commencing research on the Palaeogene under his tutelage, and is also very grateful to Allan Insole with whom he has collaborated for many years. Among the experts on the Palaeogene sites described in this volume, Brian Daley expresses particular thanks to David Bone and Roland Goldring who provided unpublished descriptive material on the sites at Bognor Regis and Pincent's Kiln respectively, and also to Dennis Curry, who has made such a substantial contribution to our understanding of the Tertiary over a period of many decades. Some acknowledgement is also due to Guy Plint and the late Fred Stinton, both of whom submitted site descriptions to the Nature Conservancy Council (NCC) some years ago.

A number of colleagues were kind enough to read over earlier drafts of some of the Palaeogene site descriptions. Particular thanks must go to Nicholas Edwards, Roger Bristow, John Cooper, Dennis Curry, Dick Edwards, Richard Ellison, Roland Goldring, Richard Hamblin, Jerry Hooker, Ed Jarzembowski, Chris King, Jonathan Todd and David Ward (who provided a guided tour of a number of Palaeogene localities in Kent). The support of colleagues at the University of Portsmouth is also much appreciated.

Acknowledgements

Finally, Brian Daley would like to thank his wife, Pamela, for her consistent encouragement and support.

Peter Balson would like to acknowledge the assistance and numerous contributions which he has received since first becoming interested in the East Anglian Crags as an undergraduate 25 years ago and subsequently developing this interest as a postgraduate working on the Coralline Crag under the supervision of Martyn Pedley.

In particular he wishes to acknowledge the many useful discussions and contributions from his colleagues at the British Geological Survey and especially from Bernard Humphreys, Steve Mathers and Jan Zalasiewicz both in the office and in the field whilst visiting many of the Red Crag sites described in this volume. He would also like to thank Brian Moorlock for reading and commenting upon a draft of the manuscript.

For many years Bob Markham has provided much useful information on localities and Crag molluscs as well as access to the collections at the Ipswich Museum on innumerable occasions. Arie Janssen, formerly at the National Museum of Natural History in Leiden, provided invaluable assistance to enable the updating of Neogene mollusc names but is not responsible for any errors which may have been introduced by the author. He was also involved in helpful discussions on the topic of the Lenham Beds fauna

Peter Balson is also particularly indebted to Chris King for assistance and discussions in the field of microfaunas and Neogene stratigraphy of the North Sea Basin.

Finally, Peter Balson would also like to express his particular thanks to Helen Glaves for her support and tolerance during difficult times.

Brian Daley and Peter Balson
June 1999

Access to the countryside

This volume is not intended for use as a field guide. The description or mention of any site should not be taken as an indication that access to a site is open or that a right of way exists. Most sites described are in private ownership and their inclusion herein is solely for the purpose of justifying their conservation. Their description or appearance on a map in this work should in no way be construed as an invitation to visit. Prior consent for visits should always be obtained from the landowner and/or occupier.

Information on conservation matters, including site ownership, relating to Sites of Special Scientific Interest (SSSIs) or National Nature Reserves (NNRs) in particular counties or districts may be obtained from the relevant country conservation agency headquarters listed below:

Countryside Council for Wales,
Plas Penrhos,
Ffordd Penrhos,
Bangor,
Gwynedd LL57 2LQ.

English Nature,
Northminster House,
Peterborough PE1 1UA.

Scottish Natural Heritage,
12 Hope Terrace,
Edinburgh EH9 2AS.

Foreword

So much geology is packed into the piece of the Earth's crust we call 'Britain' that it is hard not to be inspired by the tremendous changes that it has undergone over geological time and the wide variety of environments it has experienced. Deserts, tropical seas, swamps, rivers, ice ages and volcanoes have all left their mark in the rocks and landforms of Britain whilst a wealth of fossils has provided the evidence for contemporary lifeforms and the conditions in which they lived. These rocks, landforms and fossils – our 'Earth heritage' – have been studied and used to demonstrate and test our understanding of Earth processes and Earth history since the earliest days of geological investigations. As a result, Britain has a founding place in the development of the science of geology. Of course, many gaps remain in our knowledge; doubtless, new theories and interpretations will in time be presented to enhance our present understanding and, in some cases, revolutionize it. It is essential that we recognize the contribution that the Earth heritage of Britain has made and will continue to make, and ensure that the most important of Britain's geological localities are conserved for future generations to study, research and enjoy.

It was hard to know where to begin the considerable task of making an inventory of Britain's most important geological and geomorphological sites. Even more demanding was the task of selecting for conservation a set of localities that would adequately represent all the various aspects of our geological heritage and justifying their value for geological research and SSSI status. However, this bold objective was the aim of the Geological Conservation Review (GCR), which began in 1977. In this cause over 200 people have subsequently been involved in selecting and documenting more than 3000 GCR sites covering some 100 different aspects of the Earth sciences. A vast archive of information about these sites has been carefully collected, reviewed and customized to facilitate publication in this series of GCR volumes. The depth and breadth of the Review has proven to be a world-first for its comprehensiveness. In consequence, many other countries have learnt a great deal from this model and the approach adopted by the GCR contributors.

This volume is the fifteenth 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 Tertiary Period, but also provides an excellent summary of the Tertiary succession in Britain and the considerable research that has been undertaken on it in the latter part of the twentieth century. The volume is a testimony to the sites' importance, justifying their place in the GCR and their ongoing conservation through the SSSI system. I am confident that 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 for whom such Tertiary sites are a valuable educational field resource and for those people who, in one way or another, have a vested interest in them: owners, occupiers, planners and indeed the local people for whom such sites are an environmental asset.

The 388 pages of this book represent more than just a publication. An immense body of work has been necessary to arrive at this point – not just the time taken to publish the book, but to research and write it, and further back still, to select the sites for the GCR, a task which began 20 years ago. A large number of sites were assessed and visited, and an essential core – those described in this book – were ultimately selected. Since the original site selection phase, the GCR site lists for the Palaeogene and Neogene have not remained static. Seven new Palaeogene Stratigraphy sites were added in 1994 whilst, in keeping with the current interpretation of 'Neogene' in Britain, those 'Crag' sites formerly considered as Pleistocene in age have now been included in the Neogene part of the book.

Dr Brian Daley is to be commended for his long and continuous association with the GCR and in particular for his major role in the development of the 'British Tertiary Stratigraphy' volume since it was first planned in the early 1980s. His work has been important in securing the conservation and documentation of the Palaeogene sites covered in this volume, whilst his forbearance at the decision to delay original publication and widen the scope of the original intended 'Palaeogene Stratigraphy' book to become 'Tertiary Stratigraphy' is much appreciated. Dr Daley is to be congratulated on the breadth of coverage and clarity achieved in his Palaeogene chapters. The sheer size and geological complexity of some of his sites has not made it an easy task to capture the critically important features from each, but he has done an admirable job in evaluating and discussing their importance.

Credit must also go to Dr Peter Balson for the latter part of the book, in providing detailed informative accounts of the Neogene sites. Although these are stratigraphically less extensive than most of the Palaeogene sites and cover shorter periods of geological time (some sites representing days or even hours of sediment deposition!), they nonetheless are important in helping us to understand the development of Neogene Britain and the determination of the Pliocene–Pleistocene boundary.

Both Brian Daley and Peter Balson have provided a great service to conservation and the continuing study of Tertiary rocks in Britain. Furthermore, as the first volume of the Series to be published solely by JNCC, 'British Tertiary Stratigraphy' has a special place for me and my colleagues who serve on the Joint Nature Conservation Committee. It represents our continuing commitment to keeping our geological heritage both valued and properly documented. I look forward to the completion of the GCR Series.

Angus Stirling

Sir Angus Stirling
Chairman, Joint Nature Conservation Committee
April 1999

Preface

Although knowledge of the Tertiary geology of the British area has been revolutionized by offshore discoveries consequent upon the search for hydrocarbons, the scientific importance and research potential of the onshore sites in southern and south-eastern England remain undiminished. These sites, some of which are the most stratigraphically extensive of Tertiary sites in western Europe, provide considerable insights into environmental conditions and their evolution on the western margins of the north-west European Palaeogene basin and, later on, Neogene (essentially Pliocene) conditions preceding the onset of glaciation in the Quaternary.

The principle aim of this volume is to provide descriptions and a scientific evaluation of those Tertiary sites assigned GCR status on the grounds of their stratigraphical importance. Following introductions to the Tertiary (Chapter 1) and the Palaeogene (Chapter 2), Chapters 3 to 7 deal with sites of Palaeogene age. Some 34 Palaeogene sites are described, ranging in age from late Palaeocene to early Oligocene. Some are extensive both stratigraphically and geographically and may individually represent many different palaeoenvironments and a depositional history extending over millions of years; by contrast, the smaller sites may represent a particular or even unique facies development and/or biota. Working pits of Palaeogene age exploited by a continuous process of 'cut and fill' such as those in the Ball Clays of Dorset and Devon have not been included in the present volume. Such sites can provide valuable geological data, but are difficult to conserve in a conventional manner. The latter part of the book (Chapters 8 to 11, written by Peter Balson) deals with the Neogene sites, two in Kent and 22 in East Anglia. These contrast in nature with the Palaeogene localities, in that all are restricted both stratigraphically and geographically but together constitute a network of sites providing an opportunity to establish some understanding of vertical and lateral biotic and environmental variation. Of the 24 Neogene sites described, two are from the Lenham Beds, 13 in the Coralline Crag and nine in the Red Crag.

The sites included in this volume are those deemed stratigraphically important on at least a national level. Amongst the criteria used to select them have been their chronostratigraphical and/or lithostratigraphical significance together with their value in palaeoenvironmental, palaeogeographical and palaeoclimatological interpretation. Aspects of sedimentology, macropalaeontology and micropalaeontology are included in the scope of this volume, especially when they have a clearly contributory stratigraphical or environmental significance. However, the evaluation of certain fossil groups represented both at these and other Tertiary sites is considered in more detail elsewhere in palaeontologically thematic GCR volumes.

With few exceptions, the Tertiary stratigraphy sites comprise poorly lithified sequences. A number are coastal cliff sites whose erosion historically provided new exposures and new discoveries but which are now the subject of conflicting interests. In consequence, such developments as 'coastal protection' have already damaged some of these sites and will continue to detract from their geological conservation. The inland sites are also subject to a variety of threats. Some have degraded naturally, whilst others such as former quarries or pits have been used for waste disposal. Such soft lithology sites clearly present a specific set of conservation problems that will need to be continually addressed in order to maintain access for research and educational purposes, an essential facet of our geological heritage.

Brian Daley
June 1999

Chapter 1

Introduction to the Tertiary

B. Daley

THE TERTIARY SUB-ERA: SUBDIVISION AND NOMENCLATURE

The Tertiary Sub-era comprises all but the final two million years or so of the Cenozoic (Cainozoic, Kainozoic), the era of recent life (from the Greek *kainos*: recent), which encompasses the history of the Earth from the end of the Cretaceous to the present day. The beginning of the Tertiary is widely accepted as 65 Ma.

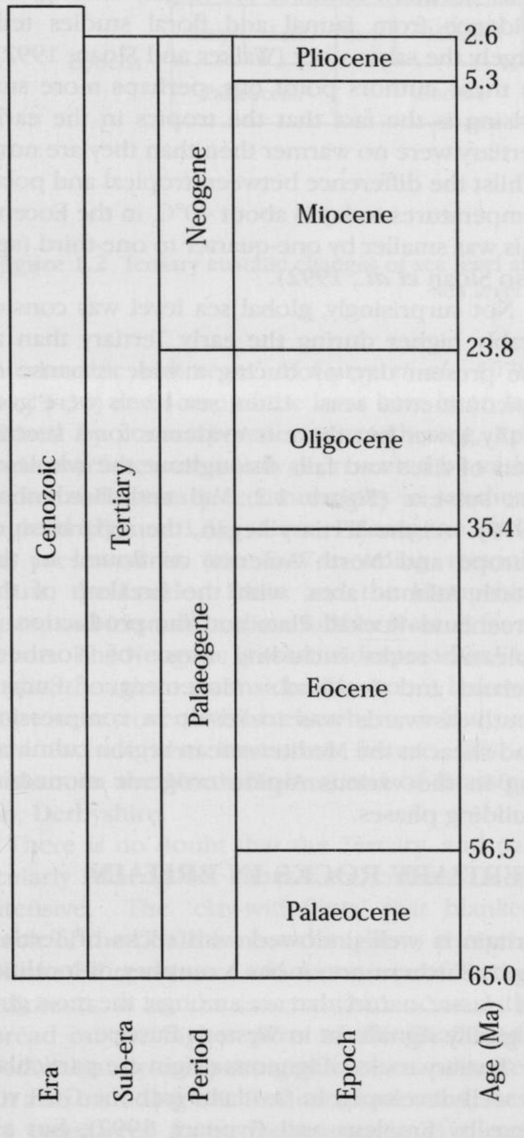

Figure 1.1 A time-scale for the Tertiary Sub-era after Harland *et al.* (1990), with the Plio-Pleistocene boundary dated at 2.6 Ma (after Berggren *et al.*, 1995). See Chapter 8 for a discussion of Plio-Pleistocene boundary dates.

Anderton *et al.* (1979) put its end at 2.5 Ma; Pomerol (1982a) made it 2 Ma and Harland *et al.* (1990) placed it at 1.64 Ma (see Figure 1.1). The definition of the top of the Tertiary Sub-era, the Pliocene–Pleistocene boundary, is considered in more detail in Chapter 8 of this volume.

The term Tertiary was first introduced by Cuvier and Brongniart (1810) to describe the strata above the Chalk in the Paris Basin. In 1833, Charles Lyell subdivided the Tertiary into three, based on a recognition that increasingly younger strata contain fossils more closely related to present-day species. These were the Eocene (*eos*: dawn of), the Miocene (*meios*: less) and the Pliocene (*pleios*: more). Beyrich (1854) subsequently introduced the term Oligocene (*oligos*: few) and Schimper (1874) the term Palaeocene (*palaeos*: ancient) for the youngest and oldest part of the Eocene respectively, to complete the currently accepted grouping of the Tertiary Sub-era into five epochs. At around the same time, a recognition that the younger part of the Tertiary had fossils with a 'Mediterranean' affinity whilst the older strata were characterized by those of a 'tropical' nature, led to its division into two. According to Pomerol (1982a, p. 12), Hoernes placed the Miocene and Pliocene together into the Neogene (from *neos*: new and *genos*: birth) shortly before Naumann (1866) grouped the three earlier epochs into the Palaeogene (Figure 1.1).

UNDERSTANDING THE TERTIARY

That Tertiary faunas and floras are essentially modern in aspect has made the task of palaeogeographical and palaeoenvironmental interpretation considerably easier than for earlier periods of geological time. Though by no means devoid of problems, the possibility of interpretation based on a knowledge of their modern relatives has facilitated a more confident approach to interpretation and a degree of 'fine tuning' not readily practicable where more ancient fossils are concerned. Using ostracods and forams, for example, it has been possible to determine quite narrow ranges of salinity and depth, rather than the broader generalizations so often unavoidable with older strata. The dinosaurs that had dominated the Earth in Mesozoic times had died out before the Tertiary began, to be replaced by the more readily comprehensible mammals, which began to establish themselves in the Palaeocene prior to their great diversification at the beginning of the Eocene (Pomerol, 1982a). The flora too became distinctly modern in aspect; the angiosperms flourished and their development throughout the sub-era has made it considerably easier for researchers to develop an understanding of Tertiary palaeogeography and climatic change, compared with earlier geological times.

Other aspects of the Tertiary Sub-era also facilitated interpretation. For example, Tertiary land masses can be positioned with some certainty and in some cases even elevations may be inferred. Although some 12° of latitude further south in the early Tertiary than at present (Irving, 1967), Palaeogene 'Proto-Britain', bounded by its equivalents to the present Celtic Sea, English Channel and North Sea, was probably broadly recognizable as the ancestor of our present-day Britain.

Understanding the Tertiary has been particularly enhanced by the existence of large expanses of undisturbed and non-lithified oceanic sediments which provide unbroken successions representing the whole of the sub-era and contain a record of organic, isotopic and other data for this period of geological time. Much of stratigraphical as well as palaeoenvironmental value has been derived from such areas. Zonal schemes using planktonic foraminifera and calcareous marine nannoplankton, so important in Tertiary biostratigraphy, have been developed in this context. Information from deep ocean studies has also provided a framework for the development of a comprehensive magnetostratigraphical scheme for the Tertiary Sub-era. The subsequent correlation between geomagnetic polarity reversal sequences and biostratigraphical zones has facilitated the development of an integrated magneto-biostratigraphy that has significantly improved the time-scale for the Tertiary. Aubry *et al.* (1986) have stressed the importance of its value in the Palaeogene stratigraphy of north-western Europe, where the accurate correlation of a series of discontinuous sedimentary sequences, both in space and time, is particularly important since they contain the classic stratotypes of the Palaeogene epochs. More recently, a better understanding of the Tertiary succession in this area is being realized by the application of the techniques of sequence stratigraphy (see, for example, Neal (1996) on the Palaeogene).

THE GLOBAL CONTEXT

As the Cenozoic began, the Earth presented several unusual aspects. It had been warm for many millions of years, with the Jurassic to Cretaceous the longest period of the Phanerozoic without a global glaciation. Such global warmth continued into the Cenozoic. Apparently there were no ice-caps at either the North or South Poles. Oxygen isotope studies of oceanic sediments from high southern latitudes suggest that temperatures were 10–15°C higher than at present. Whilst isotopic data for analogous northern latitudes are largely lacking, the evidence from faunal and floral studies tells largely the same story (Walker and Sloan, 1992). As these authors point out, perhaps more surprising is the fact that the tropics in the early Tertiary were no warmer then than they are now. Whilst the difference between tropical and polar temperatures today is about 40°C, in the Eocene this was smaller by one-quarter to one-third (see also Sloan *et al.*, 1992).

Not surprisingly, global sea level was considerably higher during the early Tertiary than at the present day, producing a wide expanse of epicontinental seas. Later, sea levels were generally lower but there is evidence for a succession of rises and falls throughout the whole of the sub-era (Figure 1.2; Vail and Hardenbol, 1979). As the Tertiary began, the separation of Europe and North America continued in the North Atlantic area, with the breakup of the Greenland–Rockall Plate and the production of volcanic rocks including those of Northern Ireland and Scotland. Movement of Eurasia south-eastwards was to result in compression and shear in the Mediterranean region culminating in the various Alpine orogenic mountain-building phases.

TERTIARY ROCKS IN BRITAIN

Britain is well endowed with rocks of Tertiary age. Furthermore, it has a number of localities of 'classic' nature that are amongst the most geologically significant in Western Europe.

Tertiary rocks of igneous origin are particularly well developed in Scotland (see the GCR volume by Emeleus and Gyopari, 1992), but are also represented much further to the south by, for example, the Lundy Granite. By contrast, whilst plant-bearing sediments have been found interbedded with Tertiary lavas in Scotland (the

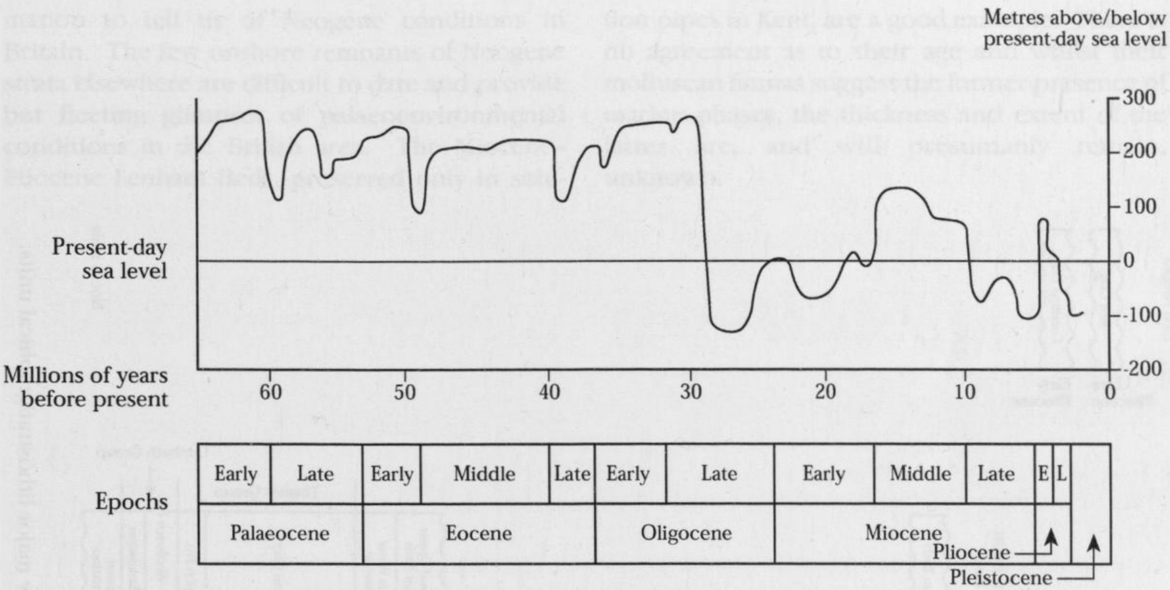

Figure 1.2 Tertiary eustatic changes of sea level after Vail and Hardenbol (1979). Metres above or below sea level are tentative.

'interbasaltic sediments' of Curry *et al.*, 1978, pp. 29–30) and some of the lavas have been lateritized by contemporaneous weathering, epigenic processes are mainly represented by much thicker sedimentary accumulations in southern England (Figure 1.3). Here, Palaeogene rocks are preserved in two E–W trending tectonic basins, the London Basin and the Hampshire Basin, and in small outliers further west as far as Devon. The Neogene is most widespread in East Anglia, though to a considerable extent below a Pleistocene cover, whilst elsewhere, a few outliers include the limestone fissure fills of Lenham in the North Downs, and of Brassington, Derbyshire.

There is no doubt that the Tertiary, and particularly Palaeogene, strata were formerly more extensive. The 'clay-with-flints' that blankets much of the Chalk is now thought to comprise the altered remains of a former cover of Tertiary sediments, as are the sarsens which occur widespread on the higher parts of the Chalklands. Predominantly comprising siliceous sandstones, but also including silicified conglomerates, these are considered to be the remnants of silcrete duricrusts, which developed in a variety of Tertiary sediments in Palaeogene times (Jones, 1981, pp. 94–9; Hepworth, 1998).

What seems equally clear is that, for a long period, dating from about the end of Cretaceous times (65 Ma), much of the land mass of what is now Britain had been uplifted and was being actively eroded. The first seven million years or so of the Tertiary appear to be unrepresented by any onshore sediments, but in the late Palaeocene there began a long period of sedimentation in south-eastern England that lasted at least until the beginning of Oligocene times.

With the exception of a few outliers of early Palaeogene age that provide information about the contemporaneous palaeogeography of the south-western areas, there is little tangible onshore evidence to help with our determination of the Palaeogene palaeogeography of much of the British area away from the south-east. It is clear that in the western part of this Palaeogene 'Proto-Britain', sediments were accumulating in basins such as that recognized in the Mochras borehole in North Wales (Woodland, 1971) where some 525 m of sediment were deposited in late Oligocene and perhaps early Miocene times. However, for strata as early as those of Palaeocene age, the provenance of pebbles from central southern England suggests that, in places, active erosion had already breached the Chalk cover to erode older Mesozoic strata.

Apart from that derived from a study of the Pliocene strata in East Anglia, there is little infor-

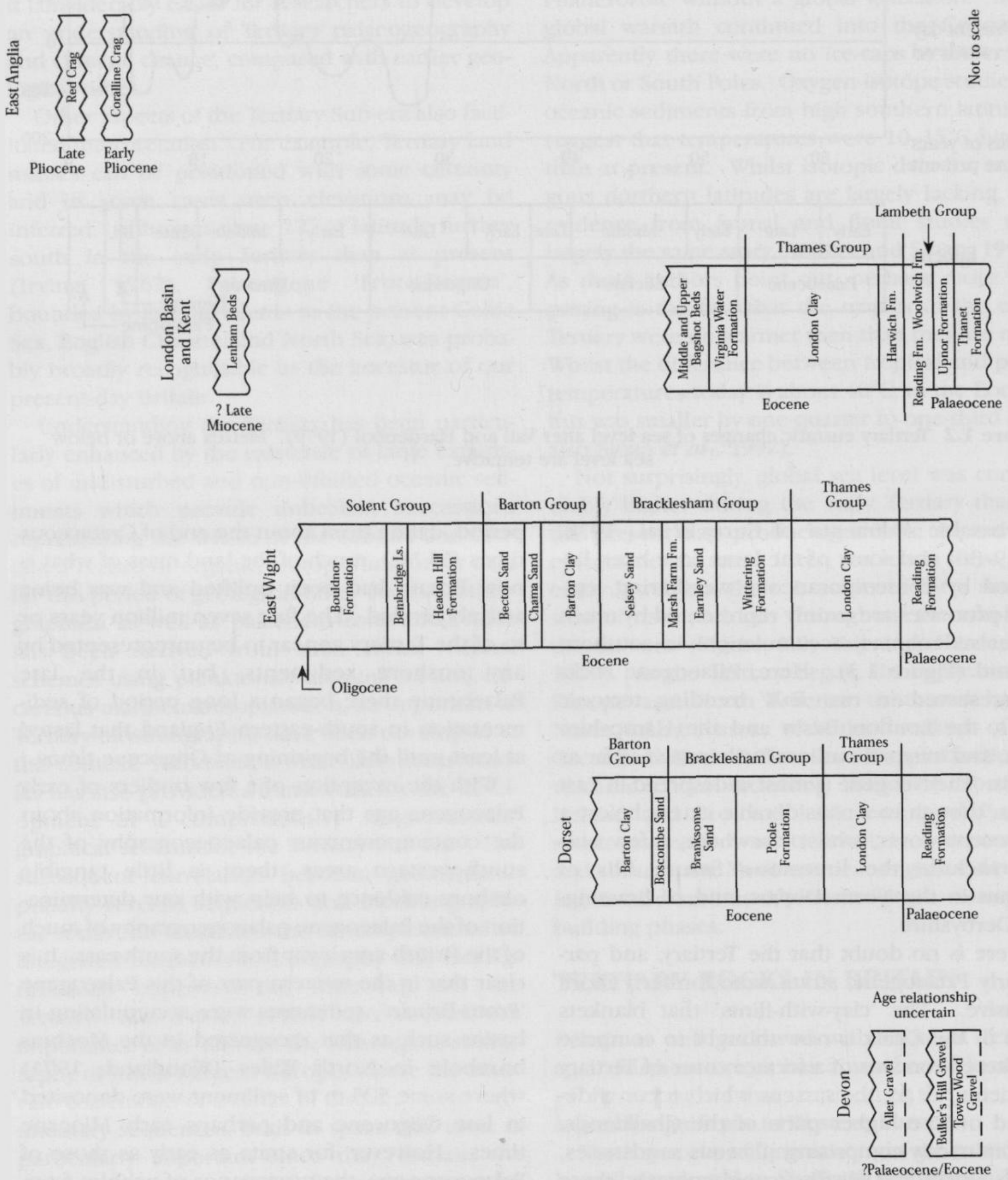

Figure 1.3 Generalized Tertiary succession in southern and eastern England, to show major lithostratigraphical units.

mation to tell us of Neogene conditions in Britain. The few onshore remnants of Neogene strata elsewhere are difficult to date and provide but fleeting glimpses of palaeoenvironmental conditions in the British area. The Miocene–Pliocene Lenham Beds, preserved only in solution pipes in Kent, are a good example. There is no agreement as to their age and whilst their molluscan faunas suggest the former presence of marine phases, the thickness and extent of the latter are, and will presumably remain, unknown.