The Cretaceous World

The rich geological record of the Cretaceous Period reveals a world that experienced extreme climatic warmth and significantly higher global sea-levels than today. Elevated levels of atmospheric carbon dioxide have been implicated in these conditions. It thus provides a natural case study of the Earth in 'greenhouse' climatic mode, which this interdisciplinary textbook analyses from the perspective of Earth System Science. With mounting concerns over global warming today, an understanding of how the Earth system operates when in greenhouse mode is very relevant to studies of future climatic change.

Part 1 (Chapters 1–5) surveys what the Cretaceous world was like, covering the evidence for the major changes in palaeogeography, sea-levels, life and climates that took place during the period, and especially the remarkable responses to climatic conditions of high-latitude vegetation and the shallow marine biota at low latitudes. Part 2 (Chapters 6–9) explores the interactions between the physical, chemical and biological processes, both within the Earth and at its surface, that together controlled conditions on the Cretaceous Earth, and highlights how they differed from those of our present world. Comparison is made between the global carbon cycles of then and now, with particular attention to the geological sources (especially volcanism) and sinks (organic carbon on land and carbonate plus organic carbon in the sea). Other biogeochemical cycles are also discussed. The results from computer modelling of climates are also critically reviewed. Part 3 (Chapters 10–13) investigates the infamous mass extinction that terminated the period, and its causation. Finally, a short Epilogue considers broader issues arising from this case study of the Cretaceous world.

Designed for use on undergraduate and graduate courses, this textbook includes many features that will aid tutors and students alike, including full-colour figures, boxed summaries of supplementary and background information, chapter summaries, and bulleted questions and answers. The book is supported by a website hosting sample pages, selected illustrations to download, and worked exercises: **http://publishing.cambridge.org/resources/0521831121**

All the authors are based at The Open University, UK. They have shared interests in Earth System Science and the Cretaceous, with complementary areas of specialist expertise, in each case internationally recognized from numerous publications. **Peter Skelton**'s research concerns the marine sedimentary and fossil record, especially that of the giant carbonate platforms which characterized low latitudes during the Cretaceous. **Robert Spicer** uses palaeobotanical evidence to test computer-based climate models, with a particular interest in the Cretaceous flora of high latitudes, where the strongest climate signals can be detected. **Simon Kelley** applies high-precision radiometric dating methods to a variety of geological issues, such as the ages of meteorite impacts and large igneous provinces, which were major features of the Cretaceous world, and the provenance of sediments (in time as well as space). **Iain Gilmour** uses stable isotope geochemistry to trace the origins of organic compounds, and has specifically deployed this approach to investigate impact-related effects at the Cretaceous/Tertiary ('K/T') boundary. The nature of the Cretaceous world is thus a common theme for the major research groups at The Open University to which the authors variously belong — 'Environmental Change in Earth History', 'Isotope Geochemistry and Earth Systems' and 'Volcano Dynamics' — ensuring both the broadly interdisciplinary character of this book and its incorporation of some of the most recent research results. The authors presented an earlier version of this text to Open University students in 2002. Three of them have also collaborated previously in producing acclaimed Open University teaching texts, including those on Evolution (Skelton and Gilmour) and Earth System Science (Skelton, Spicer and Gilmour), while Kelley has contributed to several books on radiometric dating and noble gases.

Cover photograph Limestone that formed on a shallow marine platform in Early Albian times (*c.* 110 Ma ago), exposed in fields outside the town of Teloloapan, Guerrero State, SW Mexico, and showing classic karstic ('limestone pavement') weathering, yielding thin, well-drained soils. Such carbonate platform deposits were a common product of the climatically warm Cretaceous world, in low latitudes, giving rise today to characteristic landscapes from Mexico to the Far East. *(Peter Skelton, Open University.)*

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Edited by Peter W. Skelton

Authors:
Peter W. Skelton
Robert A. Spicer
Simon P. Kelley
Iain Gilmour

The Open University

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Preface

We live in an age of growing, and justified, concern about the impact of humans upon the Earth. And with that has come a desire for a deeper understanding of how the solid Earth and its atmosphere, oceans, and life itself, as well as extraterrestrial influences, interact with one another to yield the conditions experienced at its surface. Huge advances in recent decades both in the scope of investigative techniques, ranging from satellite imagery to mass spectrometry, and in the computing power necessary for modelling such a complex system have spawned the kind of science needed to satisfy that desire — Earth System Science. The record of the rocks shows us that the Earth is by no means a stranger to change, however, and that conditions in the geological past differed in many ways from those that we experience today. In particular, former climates were usually even warmer on average than in our current 'interglacial' state, with polar ice caps that were of only limited extent or even absent. The Cretaceous Period furnishes one of the most extreme and also accessibly recorded examples of such a contrast. Not only is that period well represented by widely exposed strata on the continents, but there still remains an extensive geological record of it on the ocean floor, which is not the case for earlier such periods because of the subduction of most pre-Cretaceous oceanic crust. By examining what the Earth was like in such a contrasting state, the Cretaceous record can provide insights into the variability of the feedbacks that govern the overall behaviour of the Earth system.

This book, then, is primarily intended as an exploration in Earth System Science, viewed through the exotic perspective of the Cretaceous world. It is this central theme that has largely determined the topics addressed by the authors. Hence, the global carbon cycle features prominently, for example, entailing coverage of the major geological sources, especially volcanism, and sinks, such as marine carbonates and high latitude coals. On the other hand, we apologize in advance for the relative lack of discussion of some of the more conventional icons of the period such as the dinosaurs, which are nevertheless only of secondary importance in this context. Besides, the latter, especially, are more than adequately treated in other publications. It would be disingenuous, however, to pretend that the actual balance of topics was wholly determined by our central theme. Inevitably, there is also some bias towards the special areas of research expertise of the authors, and we acknowledge that any other group of Cretaceous 'buffs' might well have written a somewhat different book. Also worth pointing out is that within the confines of a reasonably transportable volume it would not be possible to describe all aspects of the known Cretaceous world; the data are far too rich and extensive for that. What we have done is provide some examples of the more extreme differences between the Cretaceous world and that of the present, as well as showing how such data are culled from the rock record. Above all we would hope that any group of Cretaceous experts would stress alike the interdisciplinary nature of the enterprise, for Earth System Science is all about the connectedness of our dynamic planetary system. If our, perhaps naïve, enthusiasm for this nascent field of science succeeds at least in stimulating others to take it towards maturity, then our main objective will have been achieved.

This book is aimed at advanced undergraduates and graduates. Readers are expected to have a basic understanding of sedimentary rocks, fossils, sedimentary geochemistry and major Earth processes (such as plate tectonics and the rock cycle). Further information can also be obtained from the references cited in the text. The book was designed as a teaching text for independent study. For this reason, it includes some short bulleted questions followed directly by answers. These are designed to make the reader pause and think about fundamental points concerning the subject matter. Supplementary and/or background information, which some readers may already be familiar with, has been placed in boxes.

The Cretaceous World forms a part of an advanced undergraduate course offered by the Open University, UK, entitled S369 *The Geological Record of Environmental Change*.

The authors, February 2003.