

# 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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# Contents

<b>Preface</b>	<b>8</b>	<b>3 Fluctuating sea-level</b>	<b>67</b>
<b>PART 1 Survey of the Cretaceous world</b>	<b>9</b>	3.1 Getting to grips with past changes in sea-level	67
<b>1 Introduction to the Cretaceous</b>	<b>9</b>	3.2 Results for the Cretaceous	77
1.1 A short reconnaissance trip	10	3.3 Summary	81
1.1.1 Tour stop 1: the Chalk sea	10	3.4 References	83
1.1.2 Tour stop 2: the polar forests	12	<b>4 Changing climate and biota</b>	<b>85</b>
1.1.3 Tour stop 3: the tropical carbonate factory	15	4.1 The polar forests	86
1.1.4 Tour stop 4: the susceptible sea	18	4.1.1 Arctic Alaska today	86
1.1.5 Tour stop 5: the submarine volcanic plateau — Allison's story	20	4.2 The polar light regime	90
1.1.6 Tour stop 6: Apocalypse Then	24	4.3 The Cretaceous Arctic: a case study from northern Alaska	93
1.1.7 Matters arising	25	4.3.1 The development of the Arctic Slope	93
1.2 Interesting times — putting the Cretaceous into context	26	4.3.2 Arctic Slope Cretaceous stratigraphical framework	94
1.2.1 Palaeogeography	26	4.3.3 Palaeogeographical setting	97
1.2.2 Global sea-level	28	4.3.4 The Cretaceous flora of the Arctic Slope	97
1.2.3 Climate	29	4.3.5 An insight into Cretaceous Arctic vegetation dynamics	112
1.2.4 Life	30	4.3.6 The flowering of the Arctic	114
1.3 The Cretaceous time-scale	32	4.3.7 Building a polar forest	122
1.3.1 Relative time	32	4.3.8 Arctic woods	126
1.3.2 Absolute time	39	4.4 Russia	131
1.4 Summary	40	4.4.1 The Grebenka flora	132
1.5 References	41	4.4.2 The Chauna flora	139
<b>2 The mobile palaeogeographical framework</b>	<b>43</b>	4.4.3 The Vilui flora and the continental interior environment	144
2.1 The role of plate tectonics in the Earth system	44	4.5 Nature's ancient meteorologists	148
2.1.1 Mountains	44	4.5.1 Appearance is everything	148
2.1.2 Ocean circulation	46	4.5.2 CLAMP	150
2.1.3 Magmatism	46	4.6 Polar ecosystems and climate near the end of the Cretaceous	156
2.2 Major palaeogeographical changes of the Cretaceous	48	4.7 The fauna of the polar forests	158
2.2.1 Growth of the Atlantic Ocean	52	4.8 Summary	161
2.2.2 Development of the Southern Ocean system	57	4.9 References	162
2.2.3 Tethyan history	58	<b>5 Changing climate and biota — the marine record</b>	<b>163</b>
2.2.4 Pacific Ocean events	59	5.1 Carbonate platforms	163
2.3 Implications for the Cretaceous Earth system	60	5.2 Platform crises and oceanic anoxic events	168
2.4 Summary	63	5.3 The sedimentary record in mid- to high latitudes	172
2.5 References	65	5.4 The pattern of climatic change	174
		5.5 Marine biodiversity	179
		5.6 Summary	181
		5.7 References	184

## **PART 2 The workings of the Cretaceous world** 185

### **6 Biogeochemical cycles** 185

6.1	The carbon cycle	185
6.2	The long-term carbon cycle	190
6.2.1	Cause and effect in the long-term carbon cycle	190
6.2.2	The silicate–carbonate sub-cycle	192
6.2.3	The organic matter sub-cycle	193
6.2.4	Other loops in the long-term carbon cycle	193
6.3	A quantitative model of the workings of the long-term carbon cycle	195
6.3.1	The feedback between weathering and atmospheric CO <sub>2</sub>	195
6.3.2	The feedback between land area variation and atmospheric CO <sub>2</sub>	197
6.3.3	The feedback between river runoff and atmospheric CO <sub>2</sub>	197
6.3.4	The feedback between mean land elevation and atmospheric CO <sub>2</sub>	198
6.3.5	The feedback of biological activity upon weathering rates	199
6.3.6	The effect of the variable global outgassing rate	200
6.4	The sulfur cycle	203
6.5	Coupling between the geochemical cycles of carbon, phosphorus, iron and sulfur	204
6.6	Summary	206
6.7	References	207

### **7 Volcanic inputs** 209

7.1	Volcanoes and climate	209
7.1.1	Volcanic gases	209
7.1.2	The atmosphere and volcanic aerosols	210
7.1.3	The climatic effects of explosive volcanism	216
7.1.4	The climatic effects of effusive volcanism	220
7.2	Volcanoes and the Cretaceous climate	226
7.2.1	The story of the Atlantic Ocean and Pacific Ocean floors	226
7.2.2	Oceanic spreading rates over the last 150 million years	230
7.2.3	Oceanic volcanic chains and plateaux	235
7.2.4	Oceanic plateau formation over the last 150 Ma	239
7.2.5	Cretaceous continental flood basalts	240
7.2.6	The feedback relationship between climate and Cretaceous volcanism	242
7.3	The Deccan Flood Basalt and climate change at the end of the Cretaceous	243
7.3.1	The effects of SO <sub>2</sub> released by Deccan volcanism	244
7.3.2	The effects of CO <sub>2</sub> released by Deccan volcanism	246

7.4	Summary	247
7.5	References	248

### **8 The operation of the major geological carbon sinks** 249

8.1	Climate and terrestrial carbon sinks	249
8.1.1	Terrestrial organic carbon sequestration — compiling the geological data	249
8.1.2	How much terrestrial organic carbon sequestering took place?	257
8.1.3	Carbon sequestering by silicate weathering	257
8.1.4	Carbon and climate	258
8.2	Cretaceous oceanography and marine carbon sinks	258
8.2.1	Marine carbon sinks and the conditions that sustained them	259
8.2.2	Fluctuations in the fluxes and their significance	266
8.2.3	Other effects on ocean chemistry and life	268
8.3	Summary	270
8.4	References	271

### **9 The Lost World rediscovered** 273

9.1	Climate modelling: a brief overview	274
9.2	Modelling the Cretaceous	275
9.2.1	Volcanism in the Cretaceous	279
9.2.2	Vegetation	280
9.2.3	Carbonate platforms	281
9.2.4	What next?	281
9.3	Summary	282
9.4	Further reading	282

## **PART 3 The end of an era** 283

### **10 The end-Cretaceous mass extinction** 283

10.1	Mass extinctions in the geological record	283
10.2	An impartial record?	286
10.3	The marine record of mass extinction at the K/T boundary	292
10.3.1	The microfossil record	293
10.3.2	The macrofossil record	293
10.3.3	Testing the fossil record	297
10.3.4	Geochemical evidence for a collapse of primary productivity in the oceans	299
10.3.5	Pattern of extinction of marine life at the K/T boundary	300

10.4	The fossil record of terrestrial fauna extinction at the K/T boundary	301	12	The 'smoking gun'	327
10.4.1	The record from terrestrial vertebrates	301	12.1	Crater? What crater?	328
10.4.2	The problems of the dinosaur extinction	302	12.2	Chicxulub rediscovered	329
10.5	The fossil record of terrestrial flora at the K/T boundary	304	12.3	Summary	334
10.5.1	The evidence from fossil spores and pollen	304	12.4	References	334
10.5.2	Plants as indicators of climate change at the K/T boundary	305	13	The effects of the Chicxulub impact	335
10.6	Sudden death at the end of the Mesozoic	306	13.1	Local devastation	335
10.7	Summary	309	13.2	Global effects	338
10.8	References	310	13.3	Climatic implications	339
10.9	Further reading	310	13.4	A question of cause and effect	340
11	Seeking an explanation	311	13.5	The end of an era	341
11.1	The state of play prior to the impact–extinction hypothesis	311	13.6	Summary	342
11.2	The first clues: an extraterrestrial cause for the Cretaceous–Tertiary extinction?	312	13.7	Further reading	342
11.3	An element out of place: the geochemical evidence for an impact	312	Epilogue		343
11.4	Traces of an impact: the mineralogical evidence	319	Acknowledgements		345
11.5	Summary	325	Figure references for this book		346
11.6	References	326	Index		350



## 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.