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Introduction

In almost every churchyard, you'll find gravestones so old that their inscriptions have disappeared. Over the years, drop after drop of a mild acid has eaten away the stone from which many old gravestones were carved, obliterating the names of those long gone. We know this mild acid as rainwater, formed by the condensation of water vapour containing traces of atmospheric gases like carbon dioxide (CO_2) and sulphur dioxide (SO_2). It's the gases that make it acid. Rain eats rock by weathering.

Weathering is fundamental to climate change. Over time, it moves mountains. Freezing and thawing cracks new mountain rocks apart. Roots penetrate cracks as plants grow. Rainwater penetrates surfaces, dissolving as it goes. The CO_2 in the dissolved products of weathering eventually reaches the sea, where it forms food for plankton, and the seabed, in the remains of dead organisms. Once there, it goes on to form the limestones and hydrocarbons of the future; one day, volcanoes will spew that CO_2 back into the atmosphere and the cycle will begin all over again.

The carbon cycle includes the actions of land plants, which extract CO_2 from the air by photosynthesis. When plants die, they rot, returning their CO_2 to the air. Some are buried, preserving their carbon from that same fate, until heat from the Earth's interior turns them back into CO_2, which returns to the air. This natural cycle has been in balance for millions of years. We have disturbed it by burning fossil carbon in the form of coal, oil or gas.

This book is the story of climate change as revealed by the geological record of the past 450 million years (450 Ma). It is a story of curiosity about how the world works and of ingenuity in tackling the almost unimaginably large challenge of understanding climate change. The task is complicated by the erratic nature of the geological record. Geology is like a book whose pages recount tales of the Earth's history. Each copy of this book has some pages missing. Fortunately, the American, African, Asian, Australasian and European editions all miss different pages. Combining them lets us assemble a good picture of how Earth's climate has changed through time. Year by year, the picture becomes clearer, as researchers develop new methods to probe its secrets.

As we explore the evolution of Earth's climate, we will follow the guidance of one of the giants of 18th-century science, Alexander von Humboldt, who wrote in 1788, '*The most important result of research is to recognize oneness in multiplicity, to grasp comprehensively all individual constituents, and to analyze critically the details without being overwhelmed by their massiveness*'[1]. All too often, those who seek to deny the reality of modern climate change ignore his integrative approach to understanding nature by focusing on just one or two aspects where the evidence seems, at the moment, to be less than compelling.

Can the history of Earth's climate tell us anything about how it might evolve if we go on emitting gigatonnes (Gt) of CO_2 and other greenhouse gases into the atmosphere? That is the key question behind the title to this book. I wrote it because I have spent most of my career working on past climate change, and it worries me that few of the results of the growing body of research on that topic reach the general public. Even many professional Earth scientists I meet, from both academia and industry, know little of what the most up-to-date Earth science studies tell us about climate change and global warming. For the most

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part, they have specialised in those aspects of the Earth sciences that were relevant to their careers. Unfortunately, their undoubted expertise in these topics does not prevent some of them from displaying their ignorance of developments in the study of past climate change by trotting out the brainless mantra, 'the climate is always changing'. Well, of course it is, but that ignores the all-important question: Why?

What we really need to know is in what ways the climate has been changing, at what rates, with what regional variability, and in response to what driving forces. With these facts, we can establish with reasonable certainty the natural variability of Earth's climate, and determine how it is most likely to evolve as we pump greenhouse gases into the atmosphere. This book attempts to address these issues in a way that should be readily understandable to anyone with a basic scientific education. It describes a voyage of discovery by scientists obsessed with exposing the deepest secrets of our changing climate through time. I hope that readers will find the tale as fascinating as I found the research that went into it.

The drive to understand climate change is an integral part of the basic human urge to understand our surroundings. As in all fields of science, the knowledge necessary to underpin that understanding accumulates gradually. At first we see dimly, but eventually the subject matter becomes clear. The process is a journey through time, in which each generation makes a contribution. Imagination and creativity play their parts. The road is punctuated by intellectual leaps. Exciting discoveries change its course from time to time. No one person could have discovered in his or her lifetime what we now know about the workings of the climate system. Thousands of scientists have added their pieces to the puzzle. Developing our present picture of how the climate system works has required contributions from an extraordinary range of different scientific disciplines, from astronomy to zoology. The breadth of topics that must be understood in order for us to have a complete picture has made the journey slow, and still makes full understanding of climate change and global warming difficult to grasp for those not committed to serious investigation of a very wide-ranging literature. The pace of advance is relentless, and for many it is difficult to keep up. And yet, as with most fields of scientific enquiry, there is still much to learn – mostly, these days, about progressively finer levels of detail. Uncertainties remain. We will never know everything. But we do know enough to make reasonably confident statements about what is happening now and what is likely to happen next. Looking back at the progress that has been made is like watching a timelapse film of the opening of a flower. Knowledge of the climate system unfolds through time, until we find ourselves at the doorstep of the present day and looking at the future.

While the story of Earth's climate evolution has a great deal to teach us, it is largely ignored in the ongoing debate on global warming. The idea of examining the past in order to discover what the future may hold is not a new one. It was first articulated in 1795 by one of the 'fathers of geology', James Hutton. But it is not something the general public hears much about when it comes to understanding global warming. This book is a wake-up call, introducing the reader to what the geological record tells us.

Information about the climate of the past is referred to as 'palaeoclimate data' (American spelling drops the second 'a'). As it has mushroomed in recent years, it has come to claim more attention from Working Group I of the Intergovernmental Panel on Climate Change (IPCC). The Working Group comprises an international group of scientists, which surveys the published literature every 5 years or so to come up with a view on the current state of climate science. It has been reporting roughly every 5 years since its first report in 1990. Each of its past two reports, in 2007[2] and 2013[3], incorporated a chapter on palaeoclimate data. The Working Group's report is referred to as a 'consensus', meaning the broad agreement of the group of scientists who worked on it. Just one chapter in a 1000-page report does not constitute a major review of Earth's climate evolution: the subject deserves a book of its own, and there are several, as you will see from the Appendix to the present book.

The study of past climates used to be the exclusive province of geologists. They would interpret past climate from the character of rocks: coals represented humid climates; polished three-sided pebbles and cross-bedded red-stained sands represented deserts; grooved rocks indicated the passage of glaciers; corals indicated tropical conditions; and so on. Since the 1950s, we have come to rely as well on geochemists using oxygen isotopes and the ratios of elements such as magnesium to calcium (Mg/Ca) to tell us about past ocean temperatures. And in recent years we have come to realise that cores of ice contain detailed records of past climate change, as well as bubbles of fossil air; glaciologists have joined the ranks.

Climate modellers have also contributed. Since the 1950s, our ability to use computers has advanced apace. We now use them not only to process palaeoclimate data and find correlations, but also to run numerical models of past climate systems, testing the results against data from the rock record. Applying numerical models to past climates that were much colder or much warmer than today's has an additional benefit: it helps climate modellers to test the robustness of the models they use to analyse today's climate and to project change into the future. One of my reasons for writing this book is to underscore how research into past climates by both of these research streams, the practical and the theoretical, adds to our confidence in understanding the workings of Earth's climate system and in predicting its likely future.

My take on the evolution of Earth's climate is coloured by my experience. Early in my geological career, I applied knowledge of how oceans and atmospheres work to interpret the role of past climates in governing the distribution of the phosphatic sediments that form the basis for much of the fertiliser industry. That work broadened into a study of how climate affects runoff from large rivers like the Nile and the Amazon, as well as the accumulation of sediments on the world's continental shelves. Working for Exxon Production Research Company (EPRCo) in Houston, Texas, in the mid-1970s, I developed a model for how climate controlled the distribution of petroleum source beds: rocks rich in organic remains that, when cooked deep in the subsurface, yield oil or gas. Explorers tested my model's predictions by drilling. Later, with the BP Research Company (BPRCo), I studied how the changing positions of past continents, along with changing sea levels and climates, affected the distribution and character of sources and reservoirs of oil and gas, as the basis for developing predictions for explorers to test by drilling.

In the late 1980s to mid-1990s, as director of the UK's main deep-sea research centre, the Institute of Oceanographic Sciences Deacon Laboratory, I learned a great deal more from my physical, biological and chemical oceanographer colleagues about the ocean's role in climate change. I applied that knowledge to analysing the response of the upwelling currents off Namibia and Portugal to the glacial-to-interglacial climate changes of the last Ice Age.

In order to develop accurate forecasts of climate change, one has to have an observing system, much like that used for weather forecasting. In 1997, I joined UNESCO's Intergovernmental Oceanographic Commission (IOC) to direct a programme aimed at developing a Global Ocean Observing System (GOOS), which would provide the ocean component of a Global Climate Observing System (GCOS). The task further broadened my understanding of climate science. Then, from 2004 to 2010, I directed the Antarctic research activities of the International Council for Science (ICSU), while based at the Scott Polar Research Institute of the University of Cambridge. There I was awarded emeritus status, starting in 2010. These recent appointments exposed me to the thinking of the polar science community about the role of ice in the climate system. Few people can have been as fortunate as I in being exposed to the current state of knowledge about the operations of the climate system from the perspectives of the ocean, the atmosphere, the ice and the geological record.

Because of that diverse background, I was asked to advise the Geological Society of London on climate change. Many of the world's major scientific bodies, including the US National Academy of Sciences and the UK's Royal Society, have felt moved in recent years to publish statements on the science of global warming as part of their remit to inform the public and policy makers about advances in science. The Geological Society of London became interested in 2009 in developing such a statement, and its then president, Professor Lynne Frostick, invited me to chair the group that would draft it. Entitled 'Climate Change: Evidence from the Geological Record', the statement was published on the Society's Web page[4] and in its magazine, *Geoscientist*, towards the end of 2010[5]. I led basically the same team in writing an addendum to the statement in 2013, to show what advances had been made in the intervening 3 years and to provide a palaeoclimate-based statement that could be evaluated alongside the 5th Assessment Report of the IPCC's Working Group I, published in September 2013. We operated independently of the IPCC, and drew our own conclusions. The Society published the addendum in December 2013[4].

As the Society's statement was being developed, I realised that it did not allow the space to reveal either the human stories behind the long development of modern climate science or the full extent of advances emerging through palaeoclimatic research. So I resolved to write a book about climate change from the palaeoclimate perspective – the 'long' view – drawing on the Society's statement and summarising the history and knowledge of climate processes that took place over millions of years under conditions very different from today's. This book is the result. It shows how the climate record of past times is the key to understanding the natural variability of our climate, and explains why that knowledge is a necessary complement to what we learn from meteorologists and modern climatologists focusing on the instrumental records of the past 150 years.

The book focuses on the past 450 Ma or so of Earth's climate, starting with the period when land plants first emerged, because plants play an important role in tying up carbon on land. For most of the past 450 Ma, our planet has been a lot warmer than it is now. Our climate is usually of the greenhouse variety, with abundant CO_2 warming the part of the atmosphere in which we live: the troposphere. This long history of warmth is not widely recognised, because in the past 50 Ma Earth's atmosphere has lost much of its CO_2 and moved into an icehouse climate, characterised by cool conditions and polar ice. That cooling has intensified to the point where, over the past 2.6 Ma, Earth has developed large ice sheets in both polar regions. This period has earned a popular title: the Ice Age. We are living in a geologically brief warm interlude within that Ice Age. Before an ice sheet formed on Antarctica, 40–50 Ma ago, global temperatures were warmer by 4–6 °C than they are today. Where will our climate go next? Will we stay in the icehouse or move back into the greenhouse? The latest news from NASA's Jet Propulsion Laboratory, dated 12 May 2014, is that the West Antarctic Ice Sheet has begun an irreversible decline, making it likely that we are now moving away from the icehouse and towards the greenhouse[6].

Increasing scrutiny of the palaeoclimate record over the past few decades has helped us to explain why our present climate is the way it is. Most of the fluctuation from warm to cold climates through time takes place because of changes in the balance of Earth's interior processes. Changes over millions of years involve periods of excessive volcanic activity, associated with the break up and drift of continents, which fills the air with CO_2 and keeps the climate warm, and periods of continental collision, which build mountains and encourage the chemical weathering of exposed terrain, sucking CO_2 out of the atmosphere and keeping the climate cool. Continental drift moves continents through climatic zones, sometimes leaving them in the tropics, sometimes at the poles. It also changes the locations of the ocean currents that transport heat and salt around the globe. Individual volcanic eruptions large enough to eject dust into the stratosphere provide short-term change from time to time, while the equally erratic but more persistent volcanic activity of large igneous provinces, involving the eruption of millions of cubic metres of lava over a period of a million years or so, can change the climate for longer periods; at times, they may have done so enough to cause substantial biological extinctions.

External changes are important, too. The Sun is the climate's main source of energy. Orbital variations in the Earth's path around the Sun, combined with regular changes in the tilt of the Earth's axis, superimpose additional change on these millions-of-years-long changes, through cycles lasting 20 000 to 400 000 years (20–400 Ka). Variations in the Sun's output superimpose yet another series of changes, with variability at millennial, centennial and decadal scales. Examples include the 11-year sunspot cycle and its occasional failure. The best-known such failure is the Maunder Minimum between 1645 and 1715 AD, at the heart of the Little Ice Age. Large but rare meteorite impacts have had similar, albeit temporary, effects.

Internal oscillations within the ocean–atmosphere system, like El Niño events and the North Atlantic Oscillation, cause further changes at high frequencies but low amplitudes, and are usually regional in scope. Whatever the climate at any one time, it is modified by internal processes like those oscillations, and by the behaviour of the atmosphere in redistributing heat and moisture rapidly, by the ocean in redistributing heat and salt slowly and by the biota. An example of the latter is the 'biological pump', in which plankton take CO_2 out of surface water and transfer it to deep water and, eventually, to sediments, when they die. These processes can make attribution of climate change difficult, as can the smearing of the annual record in deep-water sediments by burrowing organisms.

In spite of the potential for considerable variation in our climate, close inspection shows that at any one time the climate is constrained within a well-defined natural envelope of variability. Excursions beyond that natural envelope demand specific explanation. As we shall see, one such excursion is the warming of our climate since late in the last century.

This book looks at these various processes and puts them into perspective in their proper historical context. Chapter 2 follows the evolution of thinking about climate change by natural scientists, philosophers and early geologists from the late 1700s on. It touches on the debates of the early 1800s on the virtues of gradual versus sudden change and highlights the growing realisation that the world cooled towards an Ice Age in geologically recent times. Chapter 3 takes us into the minds of 19th-century students of the Ice Age and examines the astonishing discovery that its climate cycles were probably controlled by metronomic variations in the behaviour of the Earth's orbit as it responded to the gravitational influences of the great gas planets, Venus and Jupiter.

The arrival of new technologies on the scene, often from different disciplines, changes the way in which science works; think of the effect of the telescope on Galileo's perception of astronomy. Geology is no exception. In Chapter 4, we explore the extraordinary mid-19th-century discovery of the absorptive properties of what we now know as the greenhouse gases, such as water vapour, carbon dioxide and methane, which changed the way we view past climates. At the end of that century, a Swedish chemist, Svante Arrhenius, made the first calculations of what emissions of CO_2 would do to the climate. Few people realise that he did so at the urging of a geological colleague, to try to see if variations in atmospheric CO_2 might explain the fluctuations in temperature of the Ice Age. An American geologist, Thomas Chamberlin, used Arrhenius's findings to construct an elegant hypothesis as to how CO_2 controlled climate, but it was soon forgotten for lack of data. Much of what he had to say on the subject has since been proved correct.

In Chapter 5, we examine the evolution of ideas in the early part of the 20th century about the way in which the continents move relative to one another through continental drift, which geophysicists discovered in the 1960s was driven by the process of plate tectonics. Once again, new technologies played a key role: in this case, the echo-sounder and the magnetometer. Knowing the past positions of the continents provides us with the maps of past geography – the palaeogeographic base maps – needed to determine the past locations of sedimentary deposits that are sensitive to climate, like coal swamps and salt pans. Along the way, we see how studies of past climates benefited from access to the accurate dating of rocks, minerals and fossils at the smallest possible intervals of time. Once again, a new technology was key: radiometric dating by the use of natural radioactivity.

Chapter 6 describes how the new science of palaeoclimatology developed, with Earth scientists plotting their indicators of past climates on maps, using yet another new technology – oxygen isotopes – to determine the temperature of past seawater. Geologists investigated the origins of sedimentary cycles, coming up with hypotheses explaining the evolution of climate from the Carboniferous glaciation roughly 300 Ma ago to the end of the Cretaceous at 65 Ma ago. Yet another new technology changed the picture again, this time in the shape of numerical models of the climate system, which capitalised on the rapid development of the computer. We see early attempts to use numerical models to find out why the Cretaceous Period was so warm, and note that until the mid-1980s, the analysis of palaeoclimates virtually ignored CO_2.

Chapter 7 takes us into the Cenozoic Era, which includes what used to be known as the Tertiary, between 65 and 2.6 Ma ago, and the Quaternary, lasting from 2.6 Ma ago to the present. Here we follow the cooling of our climate from the warmth of the Cretaceous seas that flooded western Europe and central North America 60–100 Ma ago to the current Ice Age, which characterises the Pleistocene Period (2.6 Ma to 11.7 Ka ago) and the present Holocene Period (starting 11.7 Ka ago). We look at how climate changed, and at how our knowledge of climate change was dramatically expanded by drilling into the largely undisturbed sediments of the deep ocean floor. As we saw in Chapter 6, many of the theories explaining the changes in climate of the Cenozoic Era prior to the 1980s developed in the absence of substantial knowledge about the past composition of the air.

A clear understanding of the roles of greenhouse gases in the climate system demands an ability to measure those gases and examine their properties: capabilities that were limited until the mid 1950s, and which then took another 30 years to penetrate the world of geological thought. Chapter 8 explores the massive strides made over the past 50 years in enhancing that knowledge base and in formulating theories to explain how greenhouse gases behave within the air and ocean. Along with that understanding came the realisation that, in order to understand the climate problem, we must see our planet holistically – as a whole – and not in a reductionist way. Humboldt was right: everything is connected. One key consequence was the development of a new field of scientific endeavour, biogeochemistry, which has proved especially important for understanding how the carbon cycle works. Answering questions about the evolution of the climate system also came to involve a more international approach, in which national scientists increasingly worked with each other across borders on major scientific issues such as climate change that were not susceptible to resolution by individual investigators or even individual nations.

Chapter 9 reminds us of the amazing discovery that ice cores contain bubbles of fossil air holding pristine samples of CO_2 and other greenhouse gases. We also see how palaeoclimatologists eventually learned how to measure the amount of CO_2 in the atmosphere in the ages before the oldest ice cores (which span the past 800 Ka) using fossil leaves, tree rings, planktonic remains, soils, corals and cave deposits. These data are being used to check numerical models of past climates and to test the theory that the warm periods of the past occurred when CO_2 was most abundant.

Our planet's climate has experienced large cycles through time. Chapter 10 explores how these cycles relate to changes in plate tectonic processes, sea level, emissions of CO_2 and the weathering of emerging mountain chains as continents collided. It investigates the evidence for changes to our climate, and the creation of major biological extinctions, caused by occasional meteorite impacts and/or massive eruptions of plateau basalts.

In Chapter 11, we examine the evidence for how CO_2 and climate changed together through the Mesozoic and Cenozoic Eras, and explore two case histories. The first is from the Palaeocene–Eocene boundary 55 Ma ago, when a massive injection of carbon into the air caused dramatic warming, which at the same time made the seas more acid. It took the Earth 100 Ka to recover – now, there's a lesson from the past! The second is from the mid-Pliocene, about 3 Ma ago, when CO_2 levels rose to levels much like today's, but when temperatures were warmer and the sea level was higher: another lesson from the past. These periods are not precise analogues for today, because the world was configured slightly differently then. But they can teach us something about what is happening now and what might happen in the future.

Chapter 12 begins our exploration of the Ice Age of the past 2.6 Ma, noting how much of what we know comes from cores of sediment extracted with great difficulty from the ocean bed. It was a big surprise in 1976 when it emerged that marine sediment cores display signs of change in the Earth's orbit and the tilt of the Earth's axis through time. These cores also display unexpected millennial signals.

Our exploration of Ice Age climate continues in Chapter 13, where we examine the contribution made by ice cores collected in recent decades. We see what the records tell us from Greenland and from Antarctica, and explore the linkages between the poles. The latest research shows that during the warming from the Last Glacial Maximum, CO_2 in the Antarctic region rose synchronously with temperature, not after it, as had been thought. The chapter ends with a survey of plausible explanations for the fluctuations of the Ice Age, concluding that CO_2 played a crucial role in the changes from glacial to interglacial and back over the past 800 Ka.

In Chapter 14, we focus on the changes that took place over the past 11.7 Ka, forming the latest interglacial: the Holocene. Insolation – the amount of heat received due to the motions of the Earth's orbit and the tilt of the Earth's axis – was greatest in the Northern Hemisphere at the beginning of the Holocene, but the great North American and Scandinavian ice sheets kept the Northern Hemisphere cool until they had completely melted by the middle Holocene. All that while, Northern Hemisphere insolation was in decline, moving Earth's climate towards a Neoglacial Period, the peak of which we reached in the Little Ice Age of the past few hundred years. CO_2 played no active part in this cooling.

Chapter 15 focuses on the end of the Holocene – the past 2000 years, up to the present – reviewing cyclical changes in solar output. It explores the development and extent of the Medieval Warm Period centred on 1100 AD and the subsequent Little Ice Age, and includes a review of the 'Hockey Stick' controversy. Multiple sources of palaeoclimatic data now make it abundantly clear that the years since 1970 were the warmest of the past 2000. Yet astronomical calculations show that despite variations in the sun's output, our climate should still be like that of the Little Ice Age. Only by adding our emissions of greenhouse gases like CO_2 to palaeoclimate models can we recreate the climate that we see today.

The concluding chapter, Chapter 16, provides an overview of Earth's climate evolution, concluding that, from the evidence of previous chapters, we should expect to see sea level rises of 6–9 m as temperatures rise 2–3 °C above the 'preindustrial' levels typical of the years before the Industrial Revolution. Those conditions were typical of recent interglacials, which were warmer than our own. We will not see such rises in sea level this century, because it takes a long time for the Earth system to arrive at an equilibrium, in which the ocean is heated as fully as it can be for a given level of atmospheric CO_2 and no more ice will melt.

As in any other field of science, the 200-year history of past climate studies has been punctuated with arguments and disagreements, but the influence of CO_2 on climate eventually emerged as highly significant. The exciting developments documented in this book revolutionised the way Earth science is done as much as did the discovery of plate tectonics. The demands of climate science now require sedimentologists and palaeontologists to become familiar with the host of related disciplines that deal with processes taking place on and above the Earth, and to take a holistic approach to interpreting their data. Due to the rapid evolution of these topics and techniques, including the use of computers to model palaeoclimate behaviour, much of what we now know is quite recent, and little publicised except in scientific journals.

In brief, the geological evidence now suggests that emitting further large amounts of CO_2 into the atmosphere over time will almost certainly push our climate from icehouse to greenhouse, something not experienced since the late Eocene about 40 Ma ago. We now have a strong enough base of geological evidence to agree that '*In the light of the evidence presented here it is reasonable to conclude that emitting further large amounts of CO_2 into the atmosphere over time is likely to be unwise, uncomfortable though that fact may be*'[4]. The evidence emerging from the past gives much the same answers about the nature of our future climate as those emerging from a different scientific community, the IPCC's Working Group I.

Hasn't all this been said before, in classical texts on palaeoclimatology? No, in the sense that my approach combines a depiction of the science with a study of its evolution and of the role of individuals and their imagination in reaching our current understanding of Earth's climate system. But there is growing appreciation that '*evidence from the Quaternary stratigraphic record provides key baseline data for predictions of future climate change*'[7].

Agreeing with Nate Silver[8], I argue that the way to test research findings like those laid out here is to see whether or not they make accurate predictions in the real world. Our ability to predict well is a measure of our scientific progress. If you start with an absolute belief that humans do not cause global warming then, following Bayes's Theorem, no amount of evidence will persuade you otherwise. But you have to recognise that what you hold is a belief, not scientific understanding.

One thing you will need to consider carefully is context. In this book you will see evidence that CO_2 does correlate with temperature. Correlation is not causation, but that is a trite observation that ignores context. When you know that CO_2 is a greenhouse gas that both absorbs and re-emits radiation, you should expect a correlation with temperature from that context. That's the prediction and it's easy to test. What then becomes interesting are the instances when the two do *not* correlate, for which we have to find alternative hypotheses. We have to think! Thus far, nobody has managed to explain what, if not our emissions of greenhouse gases and related feedbacks, has caused the global warming since 1970.

I will leave this introduction with two key questions for you to consider as you read on: **Can what we see of climate in the geological record tell us anything about what might happen if we go on emitting more and more carbon dioxide and other greenhouse gases into the atmosphere?** and **What are the chances that our increasing use of fossil fuels will drive Earth's climate out of the icehouse, where it has been stuck for several million years, and back into the greenhouse – the dominant climate mode for much of the past 450 million years?** We will revisit these questions at the end of the book.

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