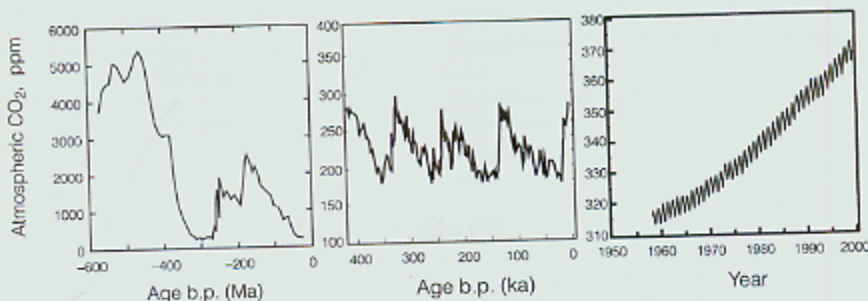


## Preface

Our planet's atmosphere is thought to have changed gradually and over a very wide range of  $\text{CO}_2$  concentrations throughout history. From ancient atmospheric gases trapped in ice bubbles, we have strong evidence indicating that atmospheric  $\text{CO}_2$  values reached minimum concentrations of approximately 180 parts per million during the Last Glacial Maximum, which was only 15,000 years ago. At the other extreme, calculations suggest that some 500+ million years ago the atmospheric  $\text{CO}_2$  concentrations may have been about 4000 to 5000 parts per million. The available evidence suggests that the decline in atmospheric  $\text{CO}_2$  over time has been neither steady nor constant, but rather that there have been periods in Earth's history when  $\text{CO}_2$  concentrations have decreased and other periods in which  $\text{CO}_2$  levels were elevated. The changes in atmospheric  $\text{CO}_2$  concentrations over geological time periods are the result of biological, chemical, and geological processes. Biogeochemical processes play a significant role in removing organic matter from the active carbon cycle at Earth's surface and in forming carbonates that are ultimately transported to the continental plates, where they become subducted away from Earth's surface layers.

Atmospheric  $\text{CO}_2$  concentrations rose rapidly as Earth transitioned out of the last Ice Age, and the atmosphere has changed dramatically since the dawn of the Industrial Age with especially large increases over the past five decades. Both terrestrial and aquatic plant life significantly influence the sequestration of atmospheric  $\text{CO}_2$  into organic matter. There is now substantial evidence to show that these terrestrial and marine photosynthetic organisms currently play a major



**Illustration.** Illustrated are the changes in the atmospheric carbon dioxide concentrations over three time periods. The left plate shows long-term decreases in atmospheric carbon dioxide levels over the last 550 million years and the role of the biota in significantly decreasing carbon dioxide levels when plants invaded land. The middle plate shows the variations in carbon dioxide levels over the last 400,000 years. The right plate shows the imprint of humans over the last half century, increasing carbon dioxide levels significantly well above interglacial levels. Data are based on graphics in Chapters 1, 2, 4, and 5.

role in reducing the rate of atmospheric CO<sub>2</sub> increase. It is thought that, in turn, and over much longer time periods, atmospheric CO<sub>2</sub> concentrations greatly affected both the evolution and the functioning of biota.

In this volume, we explore interactions among atmospheric CO<sub>2</sub>, ecosystem processes, and the evolution and functioning of biological organisms. The motivation for this volume originated from a Packard Foundation award to the University of Utah to promote basic interdisciplinary research involving geochemistry, paleontology, and biology and interactions among atmospheric CO<sub>2</sub>, plants, and animals. More specifically, this volume is the result of a symposium that expanded on the original interdisciplinary research by bringing together a diverse scientific audience to address these interactions from an even broader perspective. Too often by working in separate disciplines, we fail to realize our common ground and overlapping interests. In this volume, we try to capture some of the excitement revolving around the known changes in atmospheric CO<sub>2</sub>, how these changes in our atmosphere have influenced biological processes across our planet, and in turn how biological processes have produced feedback to the atmosphere and thereby have influenced the rate of change in atmospheric CO<sub>2</sub>.

The first section of this volume focuses both on understanding processes that have influenced atmospheric CO<sub>2</sub> and on quantitatively documenting the known variations in atmospheric CO<sub>2</sub> over the past several hundred million years. The chapters include coarse-scale calculations of the possible ranges of atmospheric CO<sub>2</sub> based on geological proxies as well as fine-scale, high-precision measurements based on ice cores over the past four hundred thousand years. We complete this documentation with direct observations over the past five decades from the longest continuously running atmospheric measurement program to date.

In the second section, we examine how changes in atmospheric CO<sub>2</sub> have

influenced the evolution and expansion of not only terrestrial plants but also animals, including humans. Here we see that there is strong physiological, ecological, and evolutionary evidence suggesting that changes in atmospheric  $\text{CO}_2$  have had both direct and indirect effects on the kinds of plant taxa that dominate Earth's surface. Certainly, atmospheric  $\text{CO}_2$  concentrations influence primary productivity, but apparently they also influence the abundance of different types of plants. In turn, these changes in the food supply are likely to have influenced the evolution of herbivorous animal systems. Paleontological studies provide convincing evidence of the changes in mammalian taxa, with stable isotope analyses providing information about the dietary preferences of different mammalian herbivore lineages.

The third and fourth sections of this volume explore the functioning of historical and modern ecosystems and, in particular, how the structure and functioning of current ecosystems are expected to change under future elevated atmospheric  $\text{CO}_2$  concentrations. In these sections, we focus on understanding carbon sequestration patterns of terrestrial ecosystems and how they are influenced by interactions with other aspects of the climate and physical environment. Terrestrial ecosystems cannot be fully grasped without an understanding of the animal herbivores that selectively graze on different vegetation components. Elevated atmospheric  $\text{CO}_2$  concentrations are expected to impact herbivorous animal systems indirectly through the effect of changes in food quality on herbivory. The work presented in these sections points to the need for bringing together plant, animal, and climate studies if we are to try, ultimately, to predict the consequences of changes in atmospheric  $\text{CO}_2$  on the functioning of future terrestrial landscapes.

This volume is an effort to bridge disciplines, bringing together the different interests in atmospheric science, geochemistry, biology, paleontology, and ecology. It is difficult to understand historical changes in atmospheric  $\text{CO}_2$  without appreciating the role of plants in modifying soil chemistry and photosynthesis as a carbon-sequestering process. Our understanding of the future atmosphere, and therefore our future climate system, will hinge on having knowledge of the carbon-sequestering capacities of future vegetation, especially in light of changes in the thermal environment and the nutrients required for sustained plant growth.

We thank the Packard Foundation for its generous support and for promoting interdisciplinary science.

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