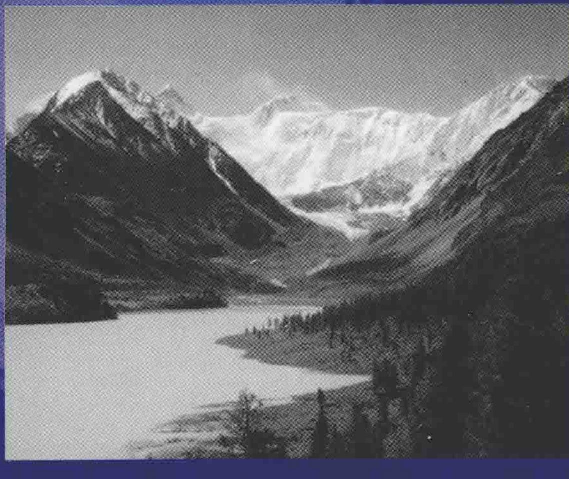
Earth Paleoenvironments: Records Preserved in Mid- and Low-Latitude Glaciers

Volume 9

Edited by
L. DeWayne Cecil, Jaromy R. Green and
Lonnie G. Thompson



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Developments in Paleoenvironmental Research

VOLUME 9

Dedication

This book is dedicated to the scientists and explorers who came before us and those that will follow us.

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Preface

The earth is in a state of constant physical, chemical, and biological change on a global scale. Global environmental alterations have occurred throughout the existence of the earth and will invariably happen in the next millenium and beyond. Global change can have immediate as well as future consequences that could affect all life on earth. As a result, the importance of understanding current and potential global environmental change has radically increased.

Numerous global environmental change studies are currently underway. From monitoring ongoing natural events such as earthquakes and volcanoes to delineating potential anthropogenic effects from industrial chemical fallout from the atmosphere, all studies focus on understanding the immediate and potential environmental change and monetary impacts associated with such events. The study of global environmental change caused by anthropogenic influences requires knowing how and when the influences occurred and what effects the environment will suffer. Once these are known, the resultant future climatic and environmental changes can be projected. Additionally, studies of natural climatic and environmental alterations require the knowledge of long-term historical changes in order to predict or understand future shifts. Knowledge of past changes can only be acquired by studying and analyzing preserved environmental records that act as archives of these changes.

Preserved archives of past climatic and environmental conditions do exist in nature. For example, glaciers, ice caps, and ice sheets around the world can be repositories of climatic and environmental change. Ice cores from the polar regions have provided the scientific community with an unprecedented picture of past environmental change through chemical, isotopic, and stratigraphic data. High-resolution ice core records have also been obtained from high altitude sites in the tropics. However, weather patterns and climate changes affect high-latitude regions of the world differently than mid- to low-latitude areas. In addition, the majority of the world's population, at least 85 percent, lives between 50° N and 50° S. Therefore, understanding potential environmental change in mid- and low-latitude regions is of prime importance and could be accomplished by utilizing ice cores collected from selected alpine areas.

Research on temperate ice cores faces the challenge of several commonly held beliefs about ice cores in "warm" environments. First, that the influence of meltwater percolation – which tends to smooth glaciochemical variations in the glacier forming firn and snow– precludes the use of isotopic and chemical tracers. Second, that the high accumulation rates typical for temperate glaciers and ice sheets limit the length of the record to at most, a few centuries. Third, that the availability of other climate proxies, such as pollen and tree-ring records, makes temperate ice cores unnecessary.

Research at several mid-latitude sites worldwide has shown that these common beliefs are not warranted. Glacial research has already proven that ice cores collected from mid-latitude glaciers preserve the isotopic record with surprising accuracy and, for some glaciers, represents thousands of years of record. In addition, ice cores archive not only natural variations in climate and the environment but anthropogenic influences introduced over the last two centuries as well. Such additional anthropogenic information can aid in distinguishing between natural and human additions to the environment and thus further refine the understanding of future global, environmental, and climate change.

There is now a small army of diverse researchers worldwide turning to the archived environmental record in mid- and low-latitude ice cores to answer diverse questions from natural and anthropogenic influences on climate change to rates of glacial retardation and growth. With the advent of ultra-sensitive analytical methods such as accelerator mass spectrometry and the experiences of diverse research teams, glaciers worldwide, with their environmental records and markers locked in, are becoming accessible.

These new scientific tools and their application to understanding our influence on global environmental processes are the focus of this book. In the field of glacial research and the associated global impacts on humans there is no set of handy formulas into which various parameters can be substituted to obtain answers for the complex problems facing the world's population. This book was designed with that fact in mind.

The papers collected here represent some of the leading research and methods development in the growing scientific field of documenting global climatic and environmental changes using records archived at mid- and low-latitude sites; historically, presently, and in the future. It is hoped that current researchers and students will find the introductory "how-to" methods section useful in their work. Additionally, with a good solid grounding in the methods utilized in bringing ice core records from remote, harsh environments to the laboratory for analyses and interpretation, students will be prepared to appreciate the significance of any glacial research they may find in the literature.

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Foreword

Several compilations of papers on ice-core science have been published over the last twenty-five years, among them Robin's, "The Climatic Record in Polar Ice Sheets" (*Cambridge*, 1983), and Oeschger and Langway's definitive, "The Environmental Record in Glaciers and Ice Sheets" (*Wiley*, 1989). The focus of these books (and many others) is the subject of ice cores from polar regions, and for good reason. Polar ice cores have yielded spectacular results, including the discovery of abrupt climate change events during the last glacial period, and the record of atmospheric greenhouse gas concentrations that demonstrate unequivocally the human influence on the atmosphere.

One of the consequences of the success of polar ice core science has been that the potential of ice cores in mid- and low-latitudes has been largely overlooked for much of the last two decades. This is not to imply that no one was doing research in this area. Indeed, Paul Mayewski's University of New Hampshire team (Mayewski is now at the University of Maine) were successfully drilling in the Himalaya in the early 1980s, while Lonnie Thompson and his crew from Ohio State University were on Quelccaya ice cap in Peru in the early 1970s (they obtained the first tropical ice core there in 1983), and have drilled dozens of high-altitude, low-latitude cores since then. Yet it was arguably not until 1995, when W. S. Broecker retracted his former skepticism in an editorial piece in Nature praising the success of Thompson's team on Huascarán (Peru) that the community at large became aware of the importance of these records:

"For years he fought not only the cold condition of his field sites, but also the lukewarm reception by many of those in our field (including me, W. S. Broecker). "Obtaining the cores from Huascarán places Lonnie Thompson in the ranks of our great explorers." (*W. S. Broecker*, Nature 376, p. 212, 1995).

This is the first book that has been devoted entirely to ice cores from mid- and low-latitudes. In the papers compiled here, researchers highlight the work they have done over the past few decades--in parallel with the work done on polar ice cores--at high altitudes on glaciers ranging from China and Tibet to South America and Africa.

Why are these records important? Their heuristic value alone ought to be sufficient justification for the modest amount of funding (compared with polar ice-coring projects) that has been devoted to obtaining them. Cores from mid- and low-latitudes allow us to extend our look at the earth's recent history, in the beautiful, high-resolution detail that only ice cores achieve, across virtually the entire globe: ice cores have now been obtained from all the continents except Australia. Even Africa, a place that rarely conjures up images of ice, has revealed its secrets through the ice cap on Kilimanjaro. Ice cores from these regions contain information that is more directly relevant to human history than are ice cores from the polar regions. Ice cores obtained from the Alps (*Schwikowski*, this volume) for example, demonstrate both the dramatic increase in air pollution in Europe over the last century and the reduction in such pollution since regulatory measures were put into effect in the 1970s. These records thus provide stark evidence both of our ability to change the composition of the earth's atmosphere, and of our ability to do something about it. They also illustrate the dependence of human civilization on climate: cores from the Andes, in particular, show evidence that significant droughts coincided with the decline of major South American cultural groups.

Second, these records are important for their scientific value. Ice cores from the Andes appear to be remarkably faithful recorders of conditions in the tropical Pacific, offering the potential to document the frequency and magnitude of El Niño events in the past. Such knowledge is in turn an essential component in determining the sensitivity of tropical climate variability - which dominates global climate variability--to increased radiative forcing from anthropogenic greenhouse gases. Ice cores from Asia similarly offer the possibility of better understanding variability in the intensity and timing of monsoon rainfall. Ice cores from both regions, and elsewhere, contribute to our understanding of atmospheric transport of pollutants such as heavy metals, radioactive isotopes, organic pollutants and sulfate and nitrate aerosols (the primary causes of acid rain) (*Schuster* et al., this volume). On longer timescales, the growing network of cores from the tropics contributes to our understanding of the causes of ice ages and of variability in the climate system on century to millennial timescales. It has been conventional to attribute climatic variability on these timescales to various factors - such as sea ice-albedo feedbacks - to features of the climatic system that are unique to the polar regions. In part because of information from tropical ice cores, there is increasing interest in the scientific community on the potential role of the tropics in climatic change, both in the past and in the future.

It is my hope that readers will view the present volume not so much as a summary of work accomplished, but as inspiration for future work. There is much that remains to be done on ice cores that have already been drilled. Unlike the major drilling programs in Antarctica and Greenland, carried out by large teams of researchers from many different universities (more than 40 institutions worldwide are involved in the recent and ongoing deep drilling efforts in Greenland), the cores from mid- and low- latitudes have been obtained exclusively by small teams from just one or two universities. Consequently, only a handful of the great number of possible measurements that can be done on the ice - ranging from trace gas concentrations to rare cosmic-ray produced isotopes - have been completed on these cores. Fortunately, researchers have been careful to archive sections of ice at their home institutions, so material is still available.

There are also many remaining sites to be drilled. This is especially true of temperate glaciers and ice caps - defined not by their latitude but by the presence of ice that reaches the melting point during the summer. (Glaciers that, due to their high altitude, remain below the melting point throughout the year - often called "polar" glaciers, even if they are at not in the polar regions - dominate the list of sites where mid- and low-latitude ice cores have been obtained). It is commonly believed that temperate glaciers are of limited use because meltwater formed during the summer percolates through the summer snow and erases or homogenizes the chemical information contained therein. Yet useful information may in some cases be preserved because the formation of impermeable ice layers at the end of the summer prevents infiltration. Great success has been demonstrated on the Upper Fremont Glacier in Wyoming, where seasonal variations in stable isotope signatures (a widely-used measure of temperature) are preserved (*Naftz et al.,* this volume). Temperate glaciers with ice hundreds or thousands of years old exist throughout the high-precipitation regions of the Canadian and Chilean west coasts, in New Zealand, and elsewhere. Even longer records are preserved beneath rocky debris in numerous additional glaciers on the drier side of these ranges. Obtaining some of these records will be easy; others, particularly those in remote locations and where rock debris is a problem, will be difficult. In some cases, the scientific payoff will not be immediately apparent to all. Yet the achievements so far suggest the effort is worthwhile. And as Lonnie Thompson has warned us, the cost of waiting may be to lose these precious records entirely, as almost all glaciers in tropical and middle latitudes are disappearing rapidly.

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Special thanks are due Ms. Nola Hartgraves for her excellent job of formatting and collecting the papers into the volume you are reading. Thanks Nola!