Monitoring in Coastal Environments Using Foraminifera and Thecamoebian Indicators

Monitoring in Coastal Environments Using Foraminifera and Thecamoebian Indicators addresses one of the fundamental problems for environmental assessment – how to characterize the state of benthic environments cost effectively in regard to both contemporary and historical times. Foraminifera and thecamoebians facilitate biological characterization of a variety of freshwater and coastal marine environments; they react quickly to environmental stress, either natural or anthropogenic. Because of their small size, they occur in large numbers in small-diameter core samples, and since they have a hard shell, they yield fossil assemblages that can be used as proxies to reconstruct past environmental conditions. This book presents a comprehensive overview of sampling and sample processing methods as well as many examples in which these methods have been applied – from pollution impact studies to earthquake history investigations.

This book is the first of its kind to describe comprehensively specific methodologies for the application of foraminifera and thecamoebians in freshwater and marine environmental assessment. It introduces the topic to nonspecialists with a simple description of these two groups of protozoan organisms and then moves on to detailed descriptions of specific methods and techniques. Case studies are presented to illustrate how these techniques are applied. The appendix includes a glossary of terms and a taxonomic description of all species mentioned in the book.

The main audience for this book will be resource managers and consultants in the public and private sectors who are working on coastal environmental problems. It will also serve as supplementary text for graduate students in many courses that deal with environmental monitoring, micropaleontology, or marine ecology, which are typically found in departments of environmental science, oceanography, marine geology, earth science, marine biology, and geography.

David B. Scott is a Professor at the Centre for Marine Geology, Dalhousie University. Professor Scott has worked with Professor Medioli and Dr. Schafer for over twenty-five years, producing over 100 research papers. Scott and Medioli were the first to show that marsh foraminifera could be used as accurate sea-level indicators, and how they are used around the world by many researchers. They also pioneered the use of fossil testate rhizopods for reconstructing pollution history, storminess, and a myriad of other uses that are detailed in the book.

Franco S. Medioli is Professor Emeritus at the Centre for Marine Geology, Dalhousie University. He is the author and co-author of some ninety scientific papers and book chapters in scientific journals on a variety of microfossils (Ostracoda, Foraminifera, Nannoplankton, Thecamoebians). In the early 1980s, Professors Medioli and Scott developed a micropaleontological procedure for relocating past sea levels using marsh foraminifera, and their method has become more or less standard for most researchers in the field all over the world. They were forerunners in the use of fossil thecamoebians as proxies for reconstructing paleoecological histories of freshwater deposits, and their work in this field spawned a growing number of papers on lacustrine pollution reconstructions.

Charles T. Schafer is an Emeritus Research Scientist at Canada's Bedford Institute of Oceanography in Dartmouth, Nova Scotia. His twenty-seven-year tenure with the Geological Survey of Canada is highlighted by studies on the application of benthic foraminifera as proxy indicators of polluted north temperate coastal environments. Dr. Schafer's research papers on this topic, and on other applications of foraminifera as sentinels of environmental impact, exceed 100 and are often cited in this field of marine research. His detailed survey of benthic foraminifera distribution patterns in Chaleur Bay, a very large and complex east-coast Canadian estuary, stands as a hallmark baseline study. Many of his publications demonstrate the development of unique SCUBA and manned submersible techniques for quantitative sampling and in situ experimental work.

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Contents

Preface

This book represents a summary of the experience and knowledge amassed by the authors in total of over ninety years of research on foraminifera and thecamoebians. Naturally, it was not possible to include everything that has been written on the subject, and we have drawn heavily on our own work for case studies. It is appropriate here to acknowledge some of the earliest pioneer workers on this subject, particularly Orville Bandy and his former students at the University of Southern California, who were among the first to show how foraminifera could be used as marine pollution indicators. Fred Phleger and his students at the Scripps Institute of Oceanography did pioneering work on modern distributions of coastal foraminifera. One of those students, Jack Bradshaw, introduced David Scott to this field in the early 1970s. At the time when the likes of Bandy and Phleger performed their early work, microfossils were restricted mainly to biostratigraphic applications, and their utility as environmental indicators was almost completely overlooked. We owe them a debt of gratitude for persisting and making this book possible.

This work could never have been completed without the help of countless students, technicians, and colleagues at both Dalhousie University and the Bedford Institute of Oceanography. Anyone who might have participated on surveys or published findings in refereed journals over the past twenty-five years is here collectively thanked. Some of the most interesting work is in the form of undergraduate theses, some of them published, some not; material from a number of these has been utilized for case studies, giving credit where credit was due.

We are indebted to the people who have worked with us over the years. Tony Cole, a paleontological technician at the Bedford Institute of Oceanography, did much of the laboratory work for Charles Schafer over the past twenty-five years and is an author and co-author in her own right. Tom Duffett and Chlöe Younger, technicians at Dalhousie University, have collected and processed countless samples over the past several decades. Eric Collins, Dalhousie University, helped Scott and Medioli in the field and with data-processing problems over the past fifteen years; he has been instrumental in many projects, not the least of which was his own Ph.D. thesis.

Several past Dalhousie students and post-doctoral fellows helped in the preparation of a short-course manual derived from this book: R. T. Patterson (Carleton University), F. M. G. McCarthy (Brock University), E. Reinhardt (McMaster University), S. Asioli (University of Padua), and R. Tobin (Dalhousie University) are all recognized for their contributions. One of the co-authors, Franco Medioli, spent months assembling the artwork. Some of our colleagues from outside the field of

micropaleontology were kind enough to review this manuscript in its almost final form and added many comments that will surely help the users of this book. In particular, Jim Latimer of the U.S. Environmental Protection Agency did a lengthy and thorough review that was of great benefit. Some of our colleagues at the Bedford Institute of Oceanography, Dale Buckley and Ray Cranston, also reviewed the manuscript, as well as Chuck Holmes of the U.S. Geological Survey and several students in Scott's 1999 micropaleontology class at Dalhousie. James Kennett, University of California (Santa Barbara), kindly supplied the senior author with an office in 1996–97 where the first cohesive writing of parts of this book took place.

Many agencies helped fund research over the past thirty-five years that is used throughout this book. These are listed in chronological order: The Geological Survey of Canada, Dalhousie University, National Science and Engineering Research Council (Canada), the Bradshaw Foundation (San Diego, California), Sea Grant (California and South Carolina), the National Science Foundation (U.S.A.), Energy, Mines and Resources Research agreements (Canada), Japanese Science Society, and the Environmental Protection Agency (U.S.A.).

Last but not least, we must thank our families, especially Kumiko, Caterina and Dana, and the friends who have so graciously put up with us during the preparation of this book.

Scope of This Book

Literature on coastal benthic foraminifera is spread over hundreds of different journals in many different languages; this makes its perusal extraordinarily challenging and sometimes impossible. However, this is the very situation that underscores the potential of these organisms as proxy indicators of environmental changes that are an inherent feature of many marginal marine settings. The proliferation of scientific reports is due largely to the fact that the most widely known application of microfossils is, in general, in the petroleum industry where they help in the identification of different biostratigraphic horizons, so that potentially productive subsurface reservoirs can be delineated. This aspect of foraminiferal application is covered by many publications that are readily available, and is not treated in this book.

There is an aspect of microfossils that has not been assembled adequately in book form, that of environmental applications. Texts on the application of microfossils as environmental proxies are limited in number and are usually aimed at specialists. This is particularly unfortunate in that the future of applied micropaleontology appears to lie in the broader field of environmental studies, where its applications are almost limitless. This book has been written for the nonspecialist and in nonspecialist terms; it stresses ways to use these organisms and their fossil remains as environmental proxies. Deliberate emphasis is placed on continental margin areas where over 50% of the world's people live, and where most contemporary marine environmental stress problems occur. The authors have attempted to review and highlight some of the key application pathways and to present the relevant information to the nonspecialist in a simple and practical form that deliberately avoids specialized micropaleontological discussions.

Who Should Read This Book

Over the past decade there has been a growth in government policies aimed at meeting the goals of both resource conservation and sustainable development of renewable and nonrenewable coastal-marine resources. This situation has created a demand for cost-effective, baseline assessment and long-term monitoring protocols within the resource-management community. Living benthic foraminifera and thecamoebian indicator species – and their fossil assemblage counterparts – represent a unique set of tools in understanding temporal and spatial variability and, more importantly, the implications of positive and negative anthropogenic impacts. The evolution of these tools and approaches reflects the fact that scientific data on the functional capacity of ecosystems are difficult and relatively expensive to obtain. Conversely, attributes that help to define ecosystems, such as species diversity and distribution patterns, can be evaluated more easily although they fail to explain dynamic processes (e.g., Fairweather, 1999).

As such, this book will be of particular value to resource managers and conservation scientists who must work in a multidisciplinary setting, and under strict budgetary constraints. Strategies described throughout the text should help a generalist supervisor/manager to formulate monitoring and assessment strategies that can be structured into cost-effective proposals and contracts. The subject material outlined in the following chapters is to be augmented in 2001 by a short course for resource supervisors/managers and community conservation organizations that is aimed at facilitating the formulation of monitoring/assessment protocols on a case-by-case basis.

The book is not intended as a review of the literature on the ecology and paleoecology of testate rhizopods. For greater depth and understanding, the reader should consult some key foraminiferal and thecamoebian literature: for foraminifera, Phleger (1960), Loeblich and Tappan (1964), Murray (1973, 1991), Boltovskoy and Wright (1976), Haq and Boersma (1978), Haynes (1981), Lipps (1993), Yassini and Jones (1995), or Sen Gupta (1999); and for thecamoebians, Leidy (1879), Loeblich and Tappan (1964), Ogden and Hedley (1980), and Medioli and Scott (1983).