Animal–Sediment Relations

The Biogenic Alteration of Sediments

TOPICS IN GEOBIOLOGY
Series Editor: F. G. Stehli, University of Florida

Volume 1 SKELETAL GROWTH OF AQUATIC ORGANISMS
Biological Records of Environmental Change
Edited by Donald C. Rhoads and Richard A. Lutz

Volume 2 ANIMAL–SEDIMENT RELATIONS
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Springer Science+Business Media, LLC

Library of Congress Cataloging in Publication Data

Main entry under title:

Animal-sediment relations.

(Topics in geobiology; v. 2)
Includes bibliographical references and index.
1. Benthos. 2. Sediments (Geology). 3. Marine sediments. I. McCall, Peter L., 1948- . II. Tevesz, Michael J. S. III. Series.
QH90.8.B46A54 1982 574.5′2636 82-16523
ISBN 978-1-4757-1319-0 ISBN 978-1-4757-1317-6 (eBook)
DOI 10.1007/978-1-4757-1317-6

Originally published by Plenum Press, New York in 1982
Softcover reprint of the hardcover 1st edition 1982
A Division of Springer Science+Business Media, LLC

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Preface

In 1881, Charles Darwin published *The Formation of Vegetable Mould through the Action of Worms*. In his book he described the feeding activities of terrestrial oligochaetes and their effect on the physical and chemical properties of the soil and soil fertility. In his autobiography he confided:

> I have now (May 1, 1881) sent to the printers the MS. of a little book on The Formation of Vegetable Mould through the Action of Worms. This is a subject of but small importance; and I know not whether it will interest any readers, but it has interested me. It is the completion of a short paper read before the Geological Society more than forty years ago, and has revived old geological thoughts.

Darwin was wrong. In the two years following the publication of the book, 8500 copies were sold. The book was more immediately popular than *The Origin of Species*. (Of course, it also followed the publication of that by now famous book on evolution.) Later workers were to confirm Darwin's observations on the effects of oligochaetes on soil structure and fertility and further document soil alterations produced by other animals (Taylor, 1935; Satchell, 1958; Edwards and Lofty, 1972).

Still other studies have shown that the biogenic alteration of sediments is a pervasive process in aquatic environments as well. Dapples (1942) authored one of the first large-scale reviews of aquatic animal–sediment interactions and emphasized that benthic macroinvertebrates profoundly affect sediment properties and processes in the marine realm:

> In many, but not all, environments in which marine deposits accumulate benthonic life is abundant. Certain of these organisms burrow for shelter or food, or they may ingest the sediments in search of any contained organic material. Either of these two behaviors results in some alteration of the sediments already deposited. A list of such changes includes obliteration of stratification, destruction of gradation of grain size resulting from normal settling

> through an aqueous medium, trituration and solution of rock masses and fragments, formation of tubes and burrows, addition of faecal matter, initiation of cementation, bleaching of the sediments, and reduction of the amount of contained organic material.
>
> On the basis of present meagre quantitative information, there is reason to believe that the larger organisms which contribute to diagenetic changes are holothurians and worms, whereas, rock boring organisms and echinoderms are secondary in importance. Obviously, the degree to which any of the alterations already listed may take place is dependent upon the quantity of these organisms dwelling in any particular area and, hence, is in turn dependent upon the localities which possess the optimum living conditions.

Rhoads (1974) recently summarized the effects of marine bottom-dwelling organisms on the properties of mud bottoms in shallow marine environments, and Rowe (1974) produced a sketchier outline for the less well-known deep-sea environments. Their conclusion, based on quantitative results, was that benthic flora and fauna, especially macroinvertebrates (primarily molluscs, annelids, and arthropods) are able to produce large changes in the physical and chemical properties of marine sediments. Petr (1977) produced a short review of the early literature on the effects of invertebrates on freshwater sediments.

As a perusal of the reference lists of any of the following chapters demonstrates, there has been a great deal of work on animal–sediment relations in the last several years. And, as the text of these chapters demonstrates, there have appeared a number of new ideas concerning the ways in which organisms affect sediments. We have reviewed animal–sediment relations in comparable aquatic environments where organisms are liable to have large and observable effects on bottom properties—Recent marine (Part I) and freshwater (Part II) soft bottoms (unconsolidated fine clastics)—and have tried to add a time dimension by examining what kinds of information have been extracted from the rock record of these two environments (Part III). The volume and sophistication of our present knowledge of animal–sediment relations descend in the same order. There has been a greater number of workers working for a longer period of time on marine than on nonmarine animal–sediment relations. There is a smaller amount of less conclusive work on ancient marine animal–sediment relations. We know the least about ancient freshwater sediments.

In Chapter 1, Rhoads and Boyer eschew a review of the kinds and rates of sediment mixing in marine sediments, since Aller (1978) and Lee and Schwarz (1980) have already reviewed the area. They have instead concentrated on biogenic changes in physical and chemical properties that occur in the course of the ecological succession of organisms following some disturbance of the bottom. They pay detailed attention to the many activities of organisms that affect sediment transport and particularly emphasize the interrelated influence of tubes, pelletal layers, and microbial mucopolysaccharide binders on entrainment properties. In Chapter 2, Aller examines the numerous ways in which macrobenthos alter the horizontal and vertical distribution of particles and solutes in marine sediments and alter the rate of diagenesis of organic matter. Macrobenthos not only alter the flux of materials between sediments and the overlying water column, but also influence the temporal and spatial distributions of other benthic organisms.

In Chapter 3, McCall and Tevesz review the present state of knowledge concerning the effects of the major groups of freshwater lake macrobenthos on the physical properties and transport of clastic lake sediments. They conclude with speculation that the animal–sediment interactions they describe may be of great import to the study of the evolution of benthic communities as well as to the study of sedimentologic processes. In Chapter 4 Fisher reviews the present state of knowledge concerning the effects of the same major groups of freshwater benthos on chemical properties of the sediments and chemical mass transfer between sediments and overlying water.

In Chapter 5, Byers reviews recent work on the relation of marine trace fossils to sedimentology that has appeared since the volume of Frey (1975). He ends with some ideas about what these biogenic sedimentary structures can tell us about the history of life. In Chapter 6, Tevesz and McCall review the meager knowledge concerning freshwater trace fossils. The few excellent studies available serve as examples of the potential for reconstructing the physical–chemical properties of ancient aquatic substrata.

In Chapter 7, Matisoff reviews the various kinds of quantitative models that have been constructed to describe the effects of organisms on particle mixing and chemical mass transfer between sediment pore fluids and overlying waters. He compares results obtained from different kinds of models and suggests their utility in deciphering the sedimentary record of biological mixing.

Some readers may be unfamiliar with several terms that appear throughout this volume. The book concerns the effects of *benthos* (bottom-dwelling organisms) on sediment properties. Most authors have written about *macrobenthos* (the adult stages of which remain in a 1-mm mesh sieve during the process of separating organisms from sediment). Some attention is also paid to *meiobenthos* (organisms from 1 mm to about 100 μm in diameter)—including nematodes, harpacticoid copepods, ostracods, and various aschelminthes—and *microbenthos* (organisms smaller than 100 μm in diameter)—which include protists, fungi, and bacteria. Macrobenthos are further classified according to life habits (Fig. 1). *Epi-*

		Filter Feeder	Deposit Feeder	Herbivore	Carnivore
EPIFAUNAL	Mobile	Crustaceans		Gastropods* Echinoids	Gastropods Crustaceans Asteroids
	Sedentary				Coelenterates
	Attached	Sponges Bivalves Polychaetes Bryozoans			Coelenterates* (Corals)
INFAUNAL	Mobile	Polychaetes	Bivalves Polychaetes Oligochaetes		Gastropods Crustaceans Polychaetes
	Sedentary	Bivalves Chironomids	Polychaetes Crustaceans		Coelenterates
	Attached	Bivalves			

Figure 1. Life habits of benthic macroinvertebrates, with examples. There is no one-to-one correspondence between taxa and life habits, and this list of taxa is not exhaustive. Asterisk (*) indicates the predominant life habitat of the taxon. After Eicher and McAlester (1980).

fauna spend the majority of their time on the substratum surface; *infauna* live primarily beneath the substratum surface. *Vagile* benthos move actively on or in the substratum, *sedentary* benthos do not, and *attached* benthos are incapable of movement along the bottom. *Filter feeders* gather their food from the water overlying the bottom or, in rare cases, from sediment pore water. *Deposit feeders* gather their food by feeding directly on unconsolidated sediment deposits. *Herbivores* feed selectively on live plant material and *carnivores* prey on other animals.

We have not made many freshwater–marine comparisons of animal–sediment relations to identify or explain differences and commonalities. This attempt is premature given our present state of knowledge. We can only conclude now that functionally similar organisms have a similar effect on similar bottoms in both marine and freshwater environments. We think that future comparisons will be more cogent. However, we hope at least that the co-occurrence in one book of work on animal–sediment relations in freshwater and marine environments and in ancient rocks will promote a cross-fertilization of methods and ideas among workers that will result in geologically and ecologically interesting and useful conclusions.

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Contents

I. Recent Marine Environments

II. Recent Freshwater Environments

Chapter 3 · The Effects of Benthos on Physical Properties of Freshwater Sediments

Peter L. McCall and Michael J. S. Tevesz

Chapter 4 · Effects of Macrobenthos on the Chemical Diagenesis of Freshwater Sediments

J. Berton Fisher

III. Ancient Environments

Chapter 5 · Geological Significance of Marine Biogenic Sedimentary Structures

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