Lecture Notes in Earth Sciences

Edited by Somdev Bhattacharji, Gerald M. Friedman,
Horst J. Neugebauer and Adolf Seilacher

9

Gisela Gerdes
Wolfgang E. Krumbein

Biolaminated Deposits

Springer-Verlag
Berlin Heidelberg New York London Paris Tokyo

Authors

Dr. Gisela Gerdes
Prof. Dr. Wolfgang E. Krumbein
Geomicrobiology Division, University of Oldenburg
Carl-von-Ossietzkystr. 9–11
D-2900 Oldenburg, West Germany

ISBN 3-540-17937-2 Springer-Verlag Berlin Heidelberg New York
ISBN 0-387-17937-2 Springer-Verlag New York Berlin Heidelberg

This work is subject to copyright All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, re-use of illustrations, recitation, broadcasting, reproduction on microfilms or in other ways, and storage in data banks Duplication of this publication or parts thereof is only permitted under the provisions of the German Copyright Law of September 9, 1965, in its version of June 24, 1985, and a copyright fee must always be paid. Violations fall under the prosecution act of the German Copyright Law.

© Springer-Verlag Berlin Heidelberg 1987
Printed in Germany

Printing and binding Druckhaus Beltz, Hemsbach/Bergstr
2132/3140-543210

> Petrificata montium calcariorum non filii sed parentes sunt, cum omnis calx oriatur ab animalibus (Linnaeus, Systema Naturae, Ed. XII, T. III, p. 154, 1760-1761)

PREFACE

The geological significance of life has long attracted mankind. Not only have single groups of organisms been considered, such as frame-building animals, diatoms or "monera" (radiolarian, globigerins, forams), but unitarian pictures were also drawn concerned with the regulation and feedback of geochemical cycles by interacting metabolic pathways. The enzyme-controlled back-coupling system of living and inanimate matter fascinated Vernadsky (1863 - 1945), a mineralogist and crystallographer, and is again stressed in Lovelock's Gaia hypothesis and Krumbein's Bioplanet or Bioid approach. The role of microorganisms in this respect is well documented in terms of disintegration of rocks, production and mineralization of organic compounds, catalyzation of the oxidation and reduction of metals, biomineral formation and biogenic ore formation. Records of stromatolites arising from the vital activity of microorganisms date back to the earliest known sedimentary environments of the Precambrian era.

The aim of the work presented here is to document the in-situ stratified accretion of sediments attributable to the vital activity of microbes. Part I comments on terms which relate to microbially produced sedimentary structures and products. Part II is concerned with the occurrence of microbial mats (potential stromatolites) in modern marginal marine environments of arid and temperate coastlines. Varying modes of facies evolution in subenvironments are shown through the integration of sedimentological, microbiological and faunistic data. In Part III structures attributed to the activity of Precambrian, Permian and Lower Jurassic microbial communities are analyzed, and some complementary aspects concerned with the geological potential of microbes are summarized.

Acknowledgements (Gisela Gerdes)

Presented here is a modified version of my thesis which encompasses a number of individual publications. I am indebted to many people who accompanied my way over the past years. My benefactor in this work was W. E. Krumbein. He first introduced me to the fascinating system of microbial mats. From Gavish Sabkha and Solar Lake we went on to include the "Farbstreifen-Sandwatt" as parts of the expanding biosedimentary system. We then turned our attention to counterparts of all this in fossil records, spanning the gap between biology and geology.

My first encounter with actuopaleontology was during my cooperation with W. Schäfer. His book "Aktuopaläontologie nach Studien in der Nordsee" was the first scientific work which I was able to follow through from its conception. His "Schule des Sehens", which was transformed into reality through the reorganization of exhibits at the Senckenberg Museum, Frankfurt, remains one of the most memorable impressions of my stay in that city.

H.-E. Reineck provided support and advice in the fields of actuogeology and actuopaleontology. Our collaboration began in "Senckenberg am Meer", Wilhelmshaven. I would like to thank him for the interest he shared in my work and for all his help and advice. During our trips to ancient and modern depositional environments and through our work in the laboratory he taught me to recognize and understand sedimentary structures.

My thanks are further extended to my other benefactor, H. K. Schminke. I am grateful also to colleagues from the Geomicrobiology team and to K. Wonneberger, my former partner at Oldenburg University marine biology unit, Wilhelmshaven, for their discussion and advice. Memories of our work together on Mellum, in the Gavish Sabkha, by Solar Lake and in Elat unite me with E. Holtkamp. Our stay, laboratory work and accommodation on Mellum were made possible by the Mellum Council and in Israel by the H. Steinitz Marine Biology Laboratory, Elat and its staff. I am particularly grateful to F. D. Por for his advice during our stay in Israel. I would also like to thank all for assistance and care in the preparation of drawings, reproductions, photographs, thin sections and checking of the manuscripts: R. Flügel, G., K. Oetken and H. Gerdes, W. Golletz, A. Grünert, E. Johnston, M. and H. Müller, I. Raether, V. Schostak, L. Tränkle. I especially want to thank J. Gifford for her patient help in transforming this manuscript into readable English.

Finally, I am indebted to Dr. Engel and Springer Verlag for publication in the Lecture Notes series. I would like to thank everybody who made this possible.

S U M M A R Y

Biolaminated deposits, produced by microbial communities, were studied in modern peritidal environments and in the rock record. The term microbial mat refers to modern, the term stromatolite to ancient analogs. The term biolaminated deposits was used to encompass both microbial mats and stromatolites.

Microbial mat environments studied are the Gavish Sabkha, the Solar Lake, both hypersaline back-barrier systems at the Gulf of Aqaba, Sinai Peninsula, and the "Farbstreifen-Sandwatt" (versicolored sandy tidal flats) on Mellum, an island in the estuary embayment of the southern North Sea coast. Three facies-relevant categories were distinguished: (1) the mat-forming microbiota, (2) environmental conditions controlling mat types and lithology, (3) bioturbation and grazing.

Cyanobacteria account for biogenic sediment accretion in all cases studied. Three major groups occur: filamentous cyanobacteria, coccoid unicells with binary fission and those with multiple fission. In the presence of these groups the following mat types evolve: (1) continuously flat (stratiform) L_h-laminae (occur in all environments studied); (2) translucent, vertically extended L_v-laminae (only Gavish Sabkha and Solar Lake); (3) nodular granules (only Gavish Sabkha).

Basically, the development of mats is controlled by moisture. Thus high-lying parts where the groundwater table runs more than 40 cm below surface are bare of mats. These are: The circular slope and elevated center of the Gavish Sabkha, the shorelines of the Solar Lake and the episodically flooded upper supratidal zone of Mellum Island. The following situations of water supply were found to stimulate mat growth: (1) Capillary movement of groundwater to exposed surfaces, (2) shallowest calm water, both realized in the Gavish Sabkha and the Solar Lake. On Mellum Island, mats form in the lower supratidal zone, which is flooded in the spring tide cycle and wetted during low tide by capillary groundwater. Salinity is almost that of normal seawater, whereas in the Solar Lake, it ranges from 45 ^{o}/oo to 180 ^{o}/oo and in the Gavish Sabkha, it reaches more than 300 ^{o}/oo. Salinity increase is correlated with rising concentrations of magnesium and sulfate ions.

In the Gavish Sabkha, episodic sheetfloods cause high-rate sedimentation which is accidental to the living mats. Episodic low-rate sedimentation stimulates the mats to grow through the freshly deposited sediment layer. This occurs predominantly on Mellum Island due to eolian transport.

Within the Gavish Sabkha, mineralogy of sediments, community structures, standing crops, redox potentials and pH are highly correlative to the increasing evenness in moisture supply which is realized by the inclination of the system below mean sea level. These conditions bring about a lateral sequence of facies types which include (1) siliciclastic biolaminites at the coastal bar base, (2) nodular to biolaminoid carbonates at saline mud flats, (3) regularly stratified stromatolitic carbonates with ooids and oncoids within the hypersaline lagoon, (4) biolaminated sulfate toward the elevated center. High-magnesium calcite in facies type 3 precipitates around decaying organic matter and forms also the ooids and oncoids. These occur predominantly within hydroplastic L_v-laminae which provide numerous nucleation centers.

Within the Solar Lake, facies type 3 (stromatolitic carbonates with ooids and oncoids) is most important, and grows to extraordinary thickness at the lake's shelf. The regular alternation of dark and light

laminae results from seasonally oscillating water depths. These conditions couple back over changing light and salinity intensities to changing dominance structures of mat-building communities. Increasing salinity correlates with decreasing water depth and accounts for the relative abundance of coccoid unicells and diatoms, both active producers of extracellular slimes (L_v-laminae). Water depths locally or temporarily increased favor surface colonization by *Microcoleus chthonoplastes* (L_h-laminae).

The biolaminated deposits of the versicolored tidal flats on Mellum Island are similar to facies type 1 of the Gavish Sabkha (siliciclastic biolaminites). Differences exist in the lithology: Sediments upon or through which the mats on Mellum Island grow are made up of clean sand. The grains originate predominantly from re-worked glacial sediments and are rounded to well rounded. By contrast, the strong angularity of siliciclastic grains in the Gavish Sabkha clearly shows their status as primary weathering products.

In all environments studied, insects play a significant role. Mainly salt beetles contribute to the lebensspuren spectrum. There is no indication that burrowing and grazing beetles and dipterans are detrimental to the growing mat systems. According to the marine fauna, two distributional barriers exist: (1) physical and (2) biogeochemical factors. Physical barriers are (a) hypersalinity and barrier-closing, which restrict the marine fauna in the Gavish Sabkha and the Solar Lake to a few species, mainly meiofaunal elements such as ostracods and copepods. Only in the Gavish Sabkha, one marine gastropod species occurs which colonizes mud flats of lower salinity. A salinity barrier of about 70 $^o/oo$ separates the gastropod habitats from the zones of growing mats. Under reduced salinity, the snails are able to destroy the microbial mats completely. (b) Decreasing regularity of flooding in the microbial mat environment of Mellum Island excludes intertidal deformative burrowers such as cockles and lugworms. However, locally the mats are pierced by numerous dwelling traces. These stem from small polychaetes and amphipod crustaceans which are able to spread over the intertidal-supratidal boundary and settle up to the MHWS-level.

Biogeochemical barriers are oxygen depletion within the sediments, high ammonia and sulfide contents, which generate through bacterial break-down of organic matter. Within the highly productive mats of *Microcoleus chthonoplastes* on Mellum Island, dwelling traces of marine polychaetes and amphipod crustaceans disappear due to these conditions. The name of the mat-forming species, *Microcoleus chthonoplastes*, indicates its capacity to form "soils" (Greek chthonos). While lithology is not altered, the presence of *Microcoleus* mats leads to a habitat change which excludes trace-making "arenophile" invertebrate species and favors "chthonophile" species which do not leave traces.

Stromatolitic microstructures studied in rock specimens were interpreted using modern analogs: Microcolumnar buildups in Precambrian stromatolites, ooids and oncoids were compared with those of modern microbial mats. The nodular to biolaminoid facies type found in the Gavish Sabkha was suggested to be an analog to the Plattendolomite facies of Permian Zechstein, North Poland. Studies of the Lower Jurassic ironstone of Lorraine clearly indicate that fungi have been involved in the formation of stromatolites, ooids and oncoids.

In conclusion, the comparative study of microstructures in microbial mats and stromatolites reveals a better understanding in both fields. In many cases, it was geology which first revealed the similarity of recent forms to those ancient ones and consequently encouraged research into them.

CONTENTS