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Eugen Seibold • Wolfgang Berger

The Sea Floor

An Introduction to Marine Geology

Fourth Edition

 Springer

Eugen Seibold
Freiburg, Germany

Wolfgang Berger
Geosciences Research Division
Scripps Institution of Oceanography Geosciences
Research Division
La Jolla, California
USA

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Preface to the Third Edition

Man's understanding of how this planet is put together and how it evolved has changed radically during the last 30 years. This great revolution in geology – now usually subsumed under the concept of *Plate Tectonics* – brought the realization that convection within the Earth is responsible for the origin of today's ocean basins and continents, and that the grand features of the Earth's surface are the product of ongoing large-scale horizontal motions. Some of these notions were put forward earlier in this century (by A. Wegener, in 1912, and by A. Holmes, in 1929), but most of the new ideas were an outgrowth of the study of the ocean floor after World War II. In its impact on the earth sciences, the plate tectonics revolution is comparable to the upheaval wrought by the ideas of Charles Darwin (1809–1882), which started the intense discussion on the evolution of the biosphere that has recently heated up again. Darwin drew his inspiration from observations on island life made during the voyage of the *Beagle* (1831–1836), and his work gave strong impetus to the first global oceanographic expedition, the voyage of *HMS Challenger* (1872–1876). Ever since, oceanographic research has been intimately associated with fundamental advances in the knowledge of Earth. This should come as no surprise. After all, our planet's surface is mostly ocean.

This book is the result of our conviction that to study introductory geology and oceanography and environmental sciences, one needs a summary of the tectonics and morphology of the sea floor, of the geologic processes active in the deep sea and in shelf seas, and of the climatic record in deep-sea sediments.

Our aim is to give a brief survey of these topics. We have endeavored to write for all who might be interested in the subject, including those with but little background in the natural sciences. The decade of the 1980s was characterized by an increasing awareness of man's dependency on natural resources, including the ocean as a weather machine, a waste bin, and a source of energy and minerals. This trend, we believe, will persist as resources become ever more scarce and as the impact of human activities on natural cycles escalates in the coming decades. An important part of this awareness will be an appreciation for the elementary facts and concepts of marine geology, especially as they apply to processes within hydrosphere and atmosphere.

In what follows, we shall first give a brief overview of the effects of endogenic forces on the morphology of the sea floor. Several excellent summaries for the general reader are available for this topic, which is closely linked to the theory of continental drift, and has been a focus of geologic discussion for the last three decades. For the rest, we shall emphasize the exogenic processes, which determine the physical, chemical, and biological environment on the sea floor, and which are especially relevant to the intelligent use of the ocean and to an understanding of its role in the evolution of climate and life.

The results and ideas we report on are the product of the arduous labors of many dedicated marine geologists. We introduce some particularly distinguished scientists by portrait (Fig. 0.1). Of course, there are many more, and most of them are alive today. We have occasionally mentioned the authors of important contributions. However, we did not find it possible in a book like this to give credit systematically where it is due. We sincerely apologize to our colleagues for this unscholarly attitude, citing necessity in defense. For those who wish to pursue the subjects discussed in greater depth, we append suggested readings at the end of each chapter, as well as a list of key references.

For this second edition, we have extensively rewritten those parts of the first edition where substantial and fundamental progress has occurred in the fields of interest. Also, we have incorporated many of the suggestions for improvements that were communicated to us by several colleagues and reviewers. There are, however, limitations to the scope of subjects that can be treated in a short introduction such as this: we attempted neither a balanced nor an encyclopedic survey of all of marine geology with its many ramifications. We tried to keep highly technical information to a minimum, relegating certain necessary details to the Appendix.

Both authors wish to express their profound gratitude to collaborators and students who, over the years, have shared the excitement of discovery and the toil of research on numerous expeditions and in the laboratory. We also owe special thanks to the colleagues who helped us put this book together, by sending reprints and figures, or by offering advice.

Freiburg, Germany
La Jolla, CA, USA
Spring 1993

E. Seibold
W.H. Berger

Preface to the Fourth Edition of “The Seafloor”

This book is the fourth edition of the Seibold-Berger text on elementary marine geology mainly based on introductory lectures to students in Kiel and in La Jolla. W. Berger added materials concerning new developments in the field, some 30 years after E. Seibold determined the nature and range of subjects discussed in the second and third editions of the text. There are several things that set this text apart from many similar ones. Eugen Seibold (1918–2013), distinguished pioneer of marine geology (Fig. 1), emphasized observation of modern marine environments and the relationships between ongoing ocean processes and ancient marine rocks. His interest in ancient rocks and in sedimentation on Atlantic-type margins is reflected throughout in the book.

E. Seibold emphasized open questions, that is, the fact that much remains unknown in the (historically very young) fields of geology and especially of marine geology, notably at the cutting edge of exploration. As a consequence, he emphasized elementary findings that have proven their worth. He favored simple conceptualization, as in his classic paper on sediments in shelf seas (Fig. 2; Sect. 9.5.1). He clearly preferred concepts based on observation to nomenclature and to speculation. The term “new” did not carry special weight with him. On the contrary, if a newly introduced concept had not run a decade-long gauntlet of critique and survived, he remained doubtful of its viability. His basic philosophy is evident in all editions of *The Sea Floor*, including the present one. Also, it governs his book *The Memory of the Sea* (in German), and it emerged strongly in discussions, official or private. Also, it helped guide the synthesis reports of Leg 41 of the Deep Sea Drilling Project (off NW Africa), for which he was co-chief (together with the marine geologist Yves Lancelot).

Since the time of the early editions of this book, emphasis has grown in “earth system science,” with forays into geophysics, geochemistry, oceanography, and indeed all of the



Fig. 1 Eugen Seibold, pioneer of marine geology (Photo courtesy of Dr. Ilse Seibold, Freiburg)

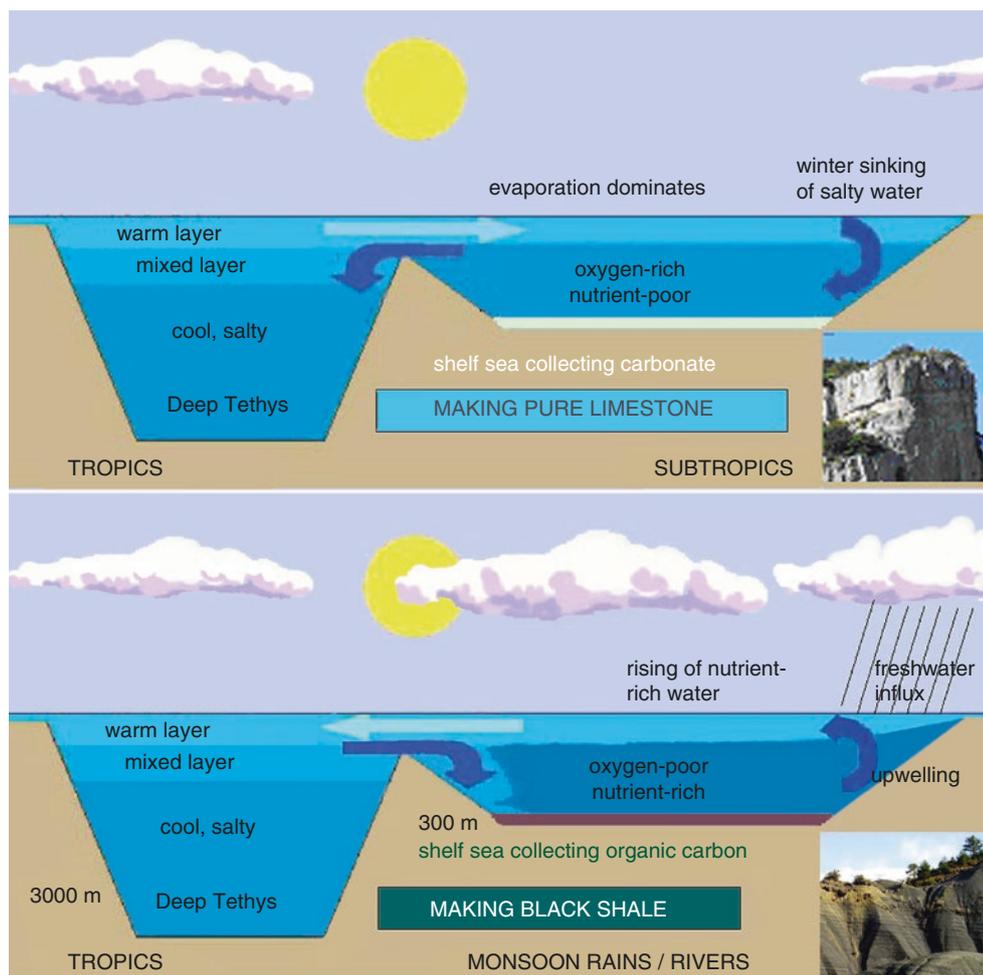


Fig. 2 Eugen Seibold's scheme of making carbonate or organic-rich shale in shelf seas, depending upon the contrast in circulation in arid and humid regions. Upper panel (a): arid conditions, schematic; compare Persian Gulf. Lower panel (b): humid conditions, schematic; compare Baltic Sea. Inset photos: Mesozoic shelf deposits, marine carbonate rocks (arid) and black shale (humid) in southeastern France (for oceanography, see Sect. 9.5) (After ideas of E. Seibold, published in 1971)

climate-related sciences including ecology (Figs. 3 and 4). It is an approach that Eugen Seibold urged and fostered. In his acceptance speech of the Blue Planet Prize (in 1994), he said this: "What is a marine geologist? A marine geologist investigates the present situation of the seafloor and the processes which shape it. Furthermore, he tries to learn from the layers beneath the seafloor, i.e. he tries to learn from the past. With this knowledge from the present and the past, he has a responsibility to comment also on future developments if he is able to do so with scientific reasoning ..." Evidently, he saw a marine geologist as a scientist who takes the ocean and climate change seriously. In this fourth edition, I have emphasized this approach. Space requirements calling for trade-off in space resulted in some cutting back of important items, notably the celebrating of contributions of some important pioneers he had identified.

Time scale matters in all of history. We now do have an excellent scale for the entire Cenozoic (i.e., the last 65 million years) largely through the untiring efforts of the Woods Hole biostratigrapher W. A. Berggren and his colleagues. A reliable scale is necessary to put rates of change in evolution and items of geologic history into perspective (Fig. 5). The established geologic time scale for pre-Cretaceous time is from reliable and traditional sources, being fundamental in geologic work (Fig. A3.1, in the Appendix).

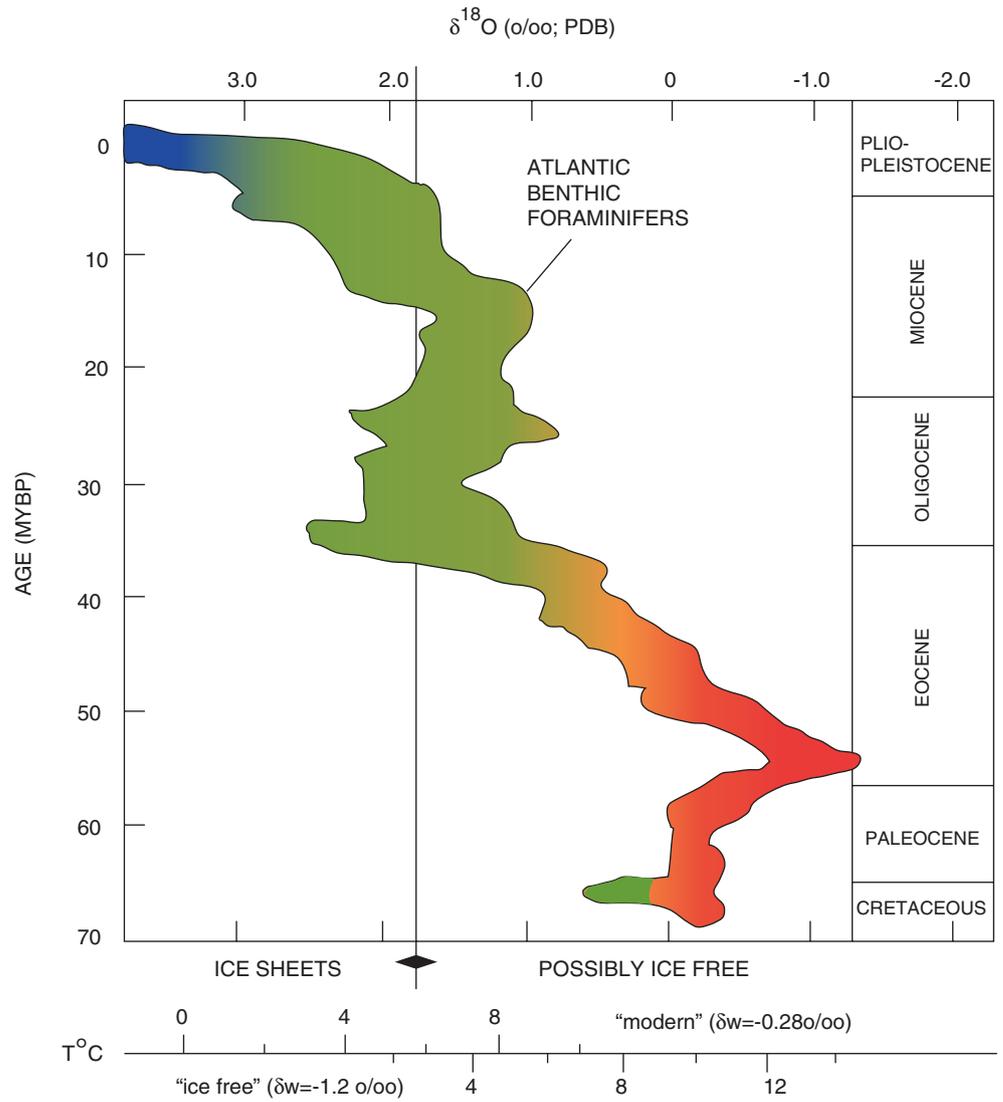


Fig. 3 A chief result from deep-sea drilling: the cooling of the planet since the early Eocene as seen in a temperature proxy on the deep seafloor (oxygen isotopes of benthic foraminifers; red, warm; yellowish green, intermediate; blue, cold (ice age)) (After K. G. Miller, R. G. Fairbanks, and G. S. Mountain, who compiled data from (Atlantic) DSDP sites (1987; *Paleoceanography* 2:1))

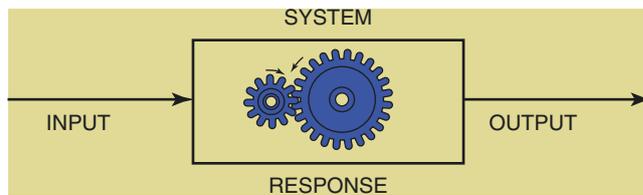


Fig. 4 The concept of earth system science. Input is exogenic and endogenic forcing; output is the recorded climate change and sedimentation (After J. Imbrie et al., 1982, in W. H. Berger and J. C. Crowell, (eds.) *Climate and Earth History. Studies in Geophysics*)

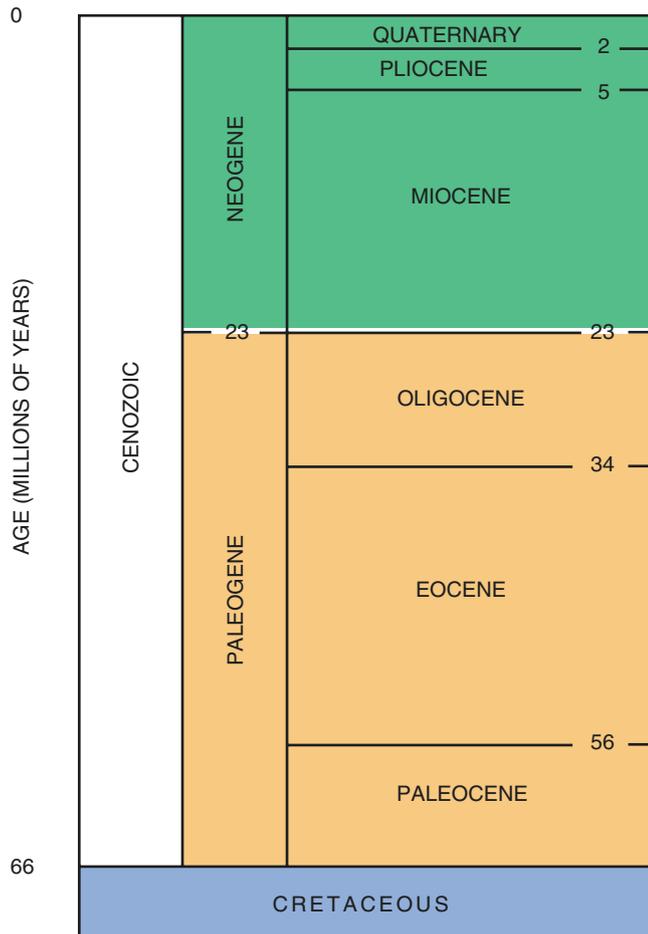


Fig. 5 Cenozoic time scale, simplified. Time scale of "the Age of Mammals," that is, the time since the Cretaceous, following the extinction of ammonites and dinosaurs. Numbers are published estimates of ages of stratigraphic boundaries in millions of years, mainly from the most recent ODP volumes. Note the

great lengths of the Eocene and the Miocene, epochs that dominate the Paleogene and the Neogene periods, respectively. In turn, Cenozoic sediments and events dominate the marine geologic history of the modern ocean. Cretaceous deposits are found below somewhat less than one half of the seafloor

I am indebted to Eugen Seibold for many discussions and also to many other colleagues (including my mentors D. L. Eicher, Colorado, F. B. Phleger and F. L. Parker (La Jolla), and Gerold Wefer at the Marum Institute, University of Bremen) for advice or for offering (or reviewing) illustrations of important geological concepts. Authors are acknowledged in the appropriate figure captions. Many others, including pioneers in the field, contributed important ideas. Trying to mention them all here would run the risk of leaving off many important contributors. Many or most are listed in "suggested readings." In any case, it is well to realize that the selection of "pioneers" is quite arbitrary. Older pioneers of marine geology (starting in the nineteenth century) tend to be underrepresented, and the reverse is true for teachers and colleagues of the authors of this book.

Concerning this or any other textbook, it may be well to keep in mind what the famous Californian physicist Richard Feynman (1918–1988) said; that is, science begins with doubting traditional textbook assertions. Feynman made an interesting observation, but actually marine geology is too young a science to have a long list of textbooks for testing his statement. It seems that this particular field advanced not so much by raising doubts about what was being taught by the professionals but mainly by making new observations and measurements, commonly by using new methods, and by integrating with results from other disciplines (including physics). In this actual history of scientific research, much new information was delivered by geophysics ("physics applied to geology" in the words of erstwhile S.I.O. director Fred Spiess) and by deep-ocean

coring and drilling (i.e., by engineering feats) in the second half of the last century. The ensuing results have changed our understanding of all aspects of seafloor lore. And yes, the advances did make old geology texts obsolete while building on established concepts that remained useful.

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Eugen Seibold (1918–2013)

Seibold was born in Stuttgart. He studied geology in Bonn and in Tübingen. Subsequently, he taught at the University of Tübingen but moved to Kiel in 1958 to study modern marine sedimentation and manage the Geological-Palaeontological Institut of the university as its director. From 1980, he accepted positions as the president of the DFG (the German National Science Foundation), as the vice-president of the European Science Foundation, and as the president of the International Union of Geological Sciences. He was president of the European Science Foundation from 1984 to 1990 and a member of various academies, including the Leopoldina (Akademie der Naturforscher, Halle, in Saxony-Anhalt) and the Académie des Sciences in Paris.

Seibold's many contributions to geology were well recognized – he was a recipient of internationally known awards (e.g., the Gustav Steinmann Medal, the Hans Stille Medal, the Leopold von Buch Plakette), as well as the Walter Kertz Medal in geophysics and the Blue Planet Prize of the Asahi Foundation. The Asahi Foundation's prize especially recognizes contributions of relevance to society. The prize was used, in part, to fund the Eugen and Ilse Seibold Prize, an award furthering Japanese-German scientific interaction.

Among outstanding paradigms within Seibold's many contributions (including geologic education), one might emphasize his insights regarding the role of exchange between marginal basins and the open sea in determining the deposits accumulating in shelf basins. He assigned an estuarine-type exchange to black shale sedimentation and an anti-estuarine type to carbonate deposits. Both types of sediment are prominent in the geologic record (and are conspicuous in the Jurassic of southern Germany, his original training ground). Significantly, black shales are commonly a source for hydrocarbon products, while carbonates often serve as reservoir rocks. Obviously, both rock types help define our time in human history. It is typical for Seibold that he thought we should know about their origin.

[Source of information: largely the Deutsche Forschungsgemeinschaft, DFG]

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