

Physics of Sedimentology

Textbook and Reference

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Preface to the Second Edition

I was asked by the publisher to prepare a revised second edition after the copies of the first edition were sold out. I happily complied, because my slim volume has achieved a purpose. Many readers wrote me during the last decade and half, not only from US and UK, but also from India, Cuba, Brazil, China, and other developing countries. They were geology students, and they complained that their college curriculum did not include a very healthy dose of physics. There has been an over-emphasis on natural-history approach. My readers found my slim volume unique in revealing to them a physicist's logic in analyzing geological problems.

As I wrote in the original preface, common-sense induction from observations is necessary, but not sufficient. There are infinite observations to be made, but, as Karl Popper said, a million white swans cannot prove that all swans are white, while the sighting of one black swan is sufficient to falsify the postulate. Geological deductions from the few fundamental principles of physics are not unlimited. Deductions which are physically impossible can be ruled out as working hypotheses. Geology may seem complex to geology students, only if they have not learned to eliminate the physically impossible.

I often heard the murmurings of my geologist friends that they do not believe in thermal convection of the earth's mantle. I used to feel the same way until my friend Leon Knopoff told me that the "belief" should not be an expression of an opinion or of a faith, but it is an issue of physics. A dimensionless number dictates whether thermal convection is or is not going to take place. It would be physically impossible not to have convection when the Rayleigh Number exceeds a certain critical value. I could understand Knopoff because there are such dimensionless numbers in sedimentology. For example, whether the motion of the basal boundary layer of a density flow is turbulent or laminar depends upon the Reynolds number of the fluid motion; there is no room for intuitive speculations.

Reading the text of the first edition again, I found little need for revision. The Newtonian Laws of Motion are as good today as they were 15 years ago, nor have the fundamental physical principles of sedimentology changed. I did find that

an amendment of Chapt. 5 and 6 desirable. Progress has been made in understanding the physical motions of rockslides and of subaqueous density flows. I could amend the chapters on the basis of new insight, and I depended greatly on the two excellent review articles by Chris Kilburn and by Thierry Mulder and Jan Alexander.

I also have some new ideas on the subject of teaching and research since my retirement from ETH. I did add a few words on Chapt. 14 *Why Creativity in Geology?*

I am suggesting to the publisher a change of the subtitle of this book to *A Readable Textbook of Physics for Geology Students*. Physics is a required course for all geology students in college. Unfortunately, the classes are commonly taught by physics professors with little interests in geology. College physics is just an in-depth repetition of middle-school physics. Most geology students find little relevance of physics which they have learned to the geology which they are studying. Few acquire the skill of analyzing geological problems as one of Newtonian physics. I wrote in the original preface that my purpose in writing the book is less to teach sedimentology, but rather to instill in students the skill to view earth phenomena as physical processes. I am proposing to the curriculum committee of the geology or earth science department in all universities that they consider to teach a course Physics for Geology Students as a complement or substitute for the ordinary College Physics course. I do think that the geologists of the 21st century should be able to think as a physicist as well as they can think as a geologist.

London, Summer 2003 Kenneth J. Hsü

Addendum

I was pleasantly surprised that the first edition of the *Physical Principles of Sedimentology* has become a collector's item; used copies are sold on the internet market at more than twice the original publication price. The fact is a verification of my prediction that the geologists of the 21st century are thinking as physicists.

Preface to the First Edition

This is a textbook for geology undergraduates taking their first course in sedimentology, for graduate students writing a term paper on sedimentology or preparing for their qualifying examinations, and for instructors, who deem it necessary to infuse a more physical-science approach to the teaching of geology. I also hope that some physics students might find the book readable and comprehensible, and that some of them might be inspired to start a career in the physics of geology.

This textbook is a revision of my lecture notes for my course *Principles of Sedimentology* at the Swiss Federal Institute of Technology. It is a two-unit semester course given to second- or third-year undergraduate students, who have acquired a basic knowledge in physics, chemistry, mathematics, and geology. The purpose of teaching this course is to bridge the gap between what has been learned in middle school and in the first year of university to what shall be learned in geology during later years. I intend especially to impart the impression to my students that the study of geologic processes is applied physics, applied chemistry, and applied mathematics. The content of the book is somewhat more extensive than what I have taught, and could be used as a textbook for a three-unit semester course, or even for a two-semester course, if a lecturer chooses to do so. We teach a second course in sedimentology, for which the students are recommended to consult textbooks on depositional environments and facies models. This textbook is not intended to replace, but to supplement those.

James Hutton in the late 18th century and Charles Lyell in the middle of the last century established the natural-history approach to study geology, and the success of the method is witnessed by the progress of the science over the last 2 centuries. The logic is inductive reasoning: Noting that quartz sands are terrigenous detritus derived from deeply weathered terranes, quartz sandstones or orthoquartzites are given paleoclimatic significance. Observing that marine organisms lived, died and are buried in marine sediments, fossil ecology becomes a key to interpreting sedimentary environments. There needs to be no reference to Newtonian mechanics or to Gibbsian thermodynamics, because physical laws cannot be invoked to prove or falsify the interpretation.

The method is necessary, reliable, but, in some cases, insufficient. Ortho-quartzites may have been altered from radiolarian oozes, not from quartz sands. Shallow marine microfossils are found in some deep-sea sediments. Simple rules of thumb may not give the correct explanation of complex processes. While the natural-history approach is necessary, the method is, in some cases, insufficient, and we need to know the physics of the processes involved. What seems likely may be physically impossible. What seems improbable may be the only physically viable explanation. This is the physical-science approach to geology.

The diverse natural phenomena are infinite, and specialization of the earth sciences seems a necessity. Sedimentologists are specialists of sedimentary rocks; they are able to extract valuable data on earth history from the kaleidoscopic sedimentary record. Physical principles are, however, few in number and they are taught to geology students. Recognizing that earth phenomena are physical processes, a person using the physical-science approach can apply the three laws of motion, three laws of thermodynamics, the principles of the conservation of energy and of matter, and perhaps a few other fundamental relations in science, to explain a diversity of geologic processes.

M. King Hubbert advocated and exemplifies the efficacy of the physical science approach in geology. Hubbert was a physics student in college, and may not have taken any undergraduate course in hydrology, petroleum geology, or tectonics. Yet, he made his greatest scientific contributions in these three fields of specialization: in hydrology with this theory of groundwater motion, in petroleum geology with his research on the oilproduction technique of hydraulic fracturing, and in tectonics with his analysis of the role of pore pressure in overthrust mechanics. Similarly, the concept of platetectonics, the new paradigm of geology, is innovated by students of geophysics who knew little geology and still less tectonics; they made a simple assumption that diverse earth phenomena are the physical consequences of moving rigid plates on the surface of the earth.

As I have indicated, my purpose in teaching this course is less to teach sedimentology, but rather to instill in students the skill to view earth phenomena as physical processes. In fact, my original aim was to write on the *Physical Principles of Geology*, and this was the title of the book which I was contracted in 1971 to write. After 2 decades, I see my limitations and elect only to write on those *Principles* as illustrated by sedimentary processes.

I have tried to avoid the authoritarian attitude in writing this textbook, although I realize that we cannot start out from kindergarden. Since my students are mostly freshmen or sophomores in college, I made middleschool physical sciences a prerequisite for my course, and I presumed that they have a rudimentary knowledge of differential and integral calculus. I expect the same for my readers.

Textbooks are commonly not readable. After having written three books on geology for general readers, I find no reason why should I not also use the same “trade-book” style to compose a textbook for geology students. Several of my colleagues and students have read a draft of the manuscript and they found the claim of my subtitle – “*A Readable Textbook*” – justified.

I am indebted to many persons in having produced this volume, but I could single out only a few in this short acknowledgment. M. King Hubbert was the inspiration of my teaching philosophy. Several friends, especially Max Carman, Gerald Middleton, and Harvey Blatt gave me encouragement. Dave Kersey consented to be a co-author when I first began to write, but he had to back out because of his other commitments. My former assistants, Helmut Weissert, Guy Lister, David Hollander, Ulrich Henken-Mellies and Jon Dobson, helped in many ways in my teaching of the course, and their numerous corrections of the earlier drafts helped improve the manuscript.

I owe a special thanks to Ueli Briegel who not only instructed me in the use of the word-processor, but also consented to make a laser-print copy of the manuscript for photo-offset production. His effort preserves the aesthetics of the volume and at the same time reduces the cost to potential readers. Albert Uhr and Urs Gerber prepared the illustrations. I am indebted to the many colleagues and publishers who gave me permission for reproducing modified versions of their original illustrations.

The book is dedicated to the memory of my first wife Ruth. She grew up in the land where the word *Heimweh* originated. I promised her that i would write a textbook, so that I would become known, so that I might be offered a job in Switzerland, so that she could return to her native country. It has not turned out that way. Her ashes went to Basel first, before I was called to Zurich, before I became established, before this book was written. Life is full of its little ironies, as my favorite writer Thomas Hardy would say.