
ELEMENTARY SEISMOLOGY

By CHARLES F. RICHTER

CALIFORNIA INSTITUTE OF TECHNOLOGY

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P R E F A C E

THIS BOOK developed from a lecture course organized particularly for students in geology who do not plan to specialize in seismology or geophysics. Because of the dual nature of the subject, it is necessary to strike a proper balance between instrumental seismology and field work.

When the course was given originally, mathematics was held to a low level. At present, geophysical theories and methods are permeating every branch of geology and effecting a gradual revolution of our thinking; for this reason it becomes desirable, if not mandatory, to give mathematics a more comprehensive treatment. To meet this requirement without too great a demand on the student, mathematics in the body of the book is kept at the minimum consistent with intelligent comprehension. Details and long proofs are given in appendixes. The fundamental concepts of stress, strain, and elasticity are developed in Chapter 16; the unprepared student will find it possible to use the book without working through this chapter. However, the material in Chapter 15, covering the principle of the seismograph, cannot be passed over if the student is to make intelligent use of the results of instrumental seismology. He might as well attempt to use modern petrological data without understanding the microscope.

Due emphasis on mathematics does not imply the other extreme of under-rating field observation and field training. Great harm is done by poorly trained men who hasten about in the field, observe a small part of the evidence, and publish premature conclusions which are actual obstacles to serious investigation. Throughout the book, and especially in Chapters 11, 13, and 14, there are suggestions for proper seismological field work.

One reason for setting forth the methods and assumptions of seismology in detail is that geologists and engineers often accept results too literally and apply them beyond the limits of accuracy. The opposite error, of rejecting definite instrumental results because they conflict with conclusions from hasty field work, is less common now than formerly. Throughout the text, possible sources of misdirection of both kinds are pointed out for the benefit of the working geologist.

Many textbook generalizations on tectonic earthquakes are based on only a small part of the available literature. For this book the collections by Montessus de Ballore and by Davison have been extended and their interpretations revised.

Although the book is intended primarily for elementary students, it includes descriptive and reference material for instructors and research workers. Except where it is necessary to refer to original contributions, publications in the more generally accessible journals have been given preference, especially the *Bulletin of the Seismological Society of America* which is available in most large libraries.

Material omitted or given abbreviated treatment as being too advanced or too special, or needing too much space, includes:

1. General geophysics apart from seismology.
2. Discussion of the cause and nature of mountain-building.
3. Derivation of earthquake mechanism from seismograms (especially when there is dip slip).
4. Microseisms (treated briefly in Chapter 23).
5. Damage and other effects of well-investigated earthquakes where there is no direct evidence of faulting.
6. Theory of elastic waves in media not homogeneous or not isotropic, including layered media.
7. Theory of plastic deformation and of fracture.
8. Calculation of earthquake energy from seismograms.
9. Seismograph construction and testing.

Geography and statistics of earthquakes are discussed in outline only; further details are given in *Seismicity of the Earth*.

The discussion of prospecting for oil and minerals by seismic methods is limited to a short statement of general principles. The interested student should refer to special handbooks. However, techniques change with extreme rapidity; books must be supplemented by study of current periodicals, and if possible by personal contact with the work.

Of special interest to engineers are Chapters 3, 8, 11, and 24, and Appendixes II and III. Appendix II, on safe construction, is presented with apology; its subject matter is too important to pass over completely, but adequate treatment including constructional details would call for another volume, by another hand.

Chapters 4 and 5 discuss a few selected earthquakes as illustrative examples. For the sake of completeness, these descriptions include material which otherwise would have been deferred to later chapters.

I am under many obligations, notably to my colleagues Beno Gutenberg, Hugo Benioff, R. H. Jahns, C. R. Allen, and Frank Press, and to Dr. Markus Båth of Uppsala, who read the manuscript and offered valuable suggestions and references. The book as it stands would have been impos-

sible without the extraordinary resources of Professor Gutenberg's personal library.

I am profoundly grateful for having had the opportunity of field work on earthquakes with the late and affectionately remembered John P. Buwalda. Over many years, I learned much from association and discussion with Harry O. Wood.†

The Seventh Pacific Science Congress in New Zealand (1949) afforded a splendid opportunity, not only to become acquainted with the local circumstances of that interesting region, but also to broaden my whole outlook in the geological sciences. In this book, California seismology has been discussed at length because it provides first-hand material for illustration. Comparison with New Zealand has been emphasized to avoid giving the book too parochial a character. For the necessary data and discussion I am indebted to Professors C. A. Cotton and W. N. Benson, Dr. C. A. Fleming, and Dr. A. R. Lillie. Professor Cotton has placed me under further heavy obligations by reviewing those chapters dealing with New Zealand; he has helped me to remove inaccuracies and add many paragraphs of new material.

Professor V. P. Gianella kindly reviewed the pages of Chapter 28 which deal with Owens Valley and Nevada earthquakes. He furnished many additional details and references.

During several visits to Pasadena, Professor Chuji Tsuboi contributed greatly to our understanding of Japan and its geophysical research, in a manner which it is a deep pleasure to acknowledge. He has read Chapter 30 and provided many valuable suggestions.

I am indebted to Lt.-Col. Ernest Tillotson for a large portfolio of original data on the African earthquake of 1928, and to Dr. J. B. Auden for notes on the tectonics of India and references on the earthquake of 1762.

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Illustration has been in charge of Mr. J. M. Nordquist. Figures have been drafted by him and by Mrs. Dorothy Hammond, Miss Phyllis Cangelosi, and Mrs. Barbara Dixon.

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Except for quoted matter, I take full responsibility for statements in the text.

C. F. R.

Pasadena, California

March 1, 1957

† Deceased, February 1958.

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