Structural Geology An Introduction | John G. Dennis

Structural Geology
An Introduction

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Cover Image

The cover photo is of the San Andreas Fault along the western foothills of the Temblor range, California, some 25 miles west of Taft. The view looks northwest from an altitude of 3,000 feet. The western strand of the fault, currently active, cuts off ridge spurs. An older strand to the east has been deeply eroded. It has not been active in recent times. The flat area at the western (left) side of the picture is the eastern edge of the Carrizo plains. Photo by Barrie Rokeach/The Image Bank.

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Preface

This book introduces the principles of structural geology for undergraduate students of geology. It also provides the basic knowledge of structural geology needed for professionals in related disciplines of science and engineering, and is designed to be equally suitable as a text for classroom instruction and for self study. Prior knowledge of elementary geology, physics, and algebra is assumed. This book succeeds my earlier *Structural Geology* (Ronald Press 1972, later John Wiley & Sons), incorporating many of its proven features. The organization and treatment reflect many years of experience in the classroom and in the field, with feedback from both students and colleagues that it would be impossible to acknowledge here appropriately.

The book approaches concepts from first principles. Descriptive matter has been separated from interpretation and theory to the greatest possible extent, and the student is led from observation to inference. I have taken particular care to identify as clearly as possible areas of doubt and uncertainty, where better understanding can be expected in the years to come.

I have tried to make the subject accessible to students who traditionally approach it with apprehension, and to show that structural geology is not a difficult subject, even though there is much meat in it. It is, above all, a fascinating subject.

The book is divided into four parts. In Part I, Fundamentals, the first chapter provides an overview of plate tectonics as a setting for examples of structures illustrated throughout the book; the remaining chapters of this part cover such fundamentals as geometrical principles, stress, strain, and flow of rocks. Part II, Continuous Structures, includes folds and fabrics. Part III, Discontinuous Structures, deals with fractures and faults. Part IV, Structures of Igneous Rocks, consists of a single chapter on the subject.

Appendix A introduces the student to graphic solutions of problems that arise in the course of geological field work and in the preparation of reports and maps. The exercises develop basic skills and good three-dimensional perception. At California State University, Long Beach, we have found them very successful in preparing students for our geological mapping courses. I have used a slightly modified version of the Laboratory Exercises in Charles Nevin's classical text (Nevin 1949). I gratefully acknowledge permission by Brian Nevin on behalf of the Nevin family. The remaining appendices contain additional material and techniques that might have encumbered the main body of the text. More advanced geometrical techniques for specialists will be found in some of the excellent manuals now available.

The book may be readily adapted to both shortened and extended courses. Boxes in the text contain material which, while useful and interesting, may be omitted where time is limited. The same is true of chapters 2, 4, and 16, although a complete course should include them. Chapter 3 may be integrated in the laboratory part of the course. On the other hand, an extended, possibly two-semester or two-quarter, course may include additional material from works listed below and under "Additional Reading" at the end of each chapter, as well as from some of the references cited at the end of the book. Review questions at the end of each chapter help to focus on important concepts in the chapter. Boldface denotes terms introduced or defined for the first time. The book concludes with a glossary that gives brief definitions of some of the more important terms found in the text.

I have included a large number of illustrations on the premise that, especially for geological structures, pictures speak more eloquently than words. While geometric and mechanical principles are best illustrated diagrammatically, I have tried also to present as much as possible of the illustrative material in photographs of actual examples; this helps enormously in creating a base for true structural intuition.

I appreciate the many permissions that were freely given to reproduce instructive illustrations throughout the text. The sources are acknowledged by name, keyed to the bibliography at the end; photographs by the British Geological Survey are reproduced by permission of the Director, British Geological Survey: U. K. Crown Copyright Reserved. I am indebted to Mason Hill; C. N. Nevin; John Christie, University of California at Los Angeles; Peter W. Huntoon, University of Wyoming; Richard Sibson, University of California at Santa Barbara; Jay Zimmerman, James W. Sears, University of Montana; Jeremy Dunning, Indiana University; Clarence J. Casella, Northern Illinois University; William B. Travers, Cornell University; and many other colleagues and students for very helpful critical advice while preparing the manuscript. I also wish to record my debt to Gilbert Wilson, who first interested me in the subject, and to Eugene Wegmann and Walter Bucher, who gave direction to my further studies. Thank you to my former student Laura Krol for compiling the glossary and index for this book. The help and advice of the editorial and production staff of Wm. C. Brown Company, particularly Edward Jaffe, Lynne Meyers, and Michelle Kiefer have been invaluable.

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Introduction

Structural geology is the science that deals with the shape and internal fabric of deformed rock bodies and the processes that deform them. It is an interesting and rewarding study that forms a link between most other branches of geology.

Some basic terms need to be defined here so that we may avoid misunderstandings as we proceed. For instance, *deformation,* as used in geology, is the process that results in a change of the shape or size of a coherent rock body. Deformation may be *continuous,* that is, distributed over the whole rock body; or it may be *discontinuous,* that is, localized in fractures or in narrow zones. The *fabric* of a rock is the internal arrangement of repetitive constituent elements, such as mineral grains or planes of weakness. *Tectonics,* in modern usage, is the study and interpretation of regional structural patterns.

Early structural geologists did not distinguish clearly between cause and effect. One of the first to do so was Eduard Suess, the great Austrian geologist, in a book analyzing the structure of the Alps (Suess 1875). In 1893 G. F. Becker showed that it was necessary to analyze the geometry of deformed rocks before attempting to interpret it in terms of causes of rock deformation. In 1911 the Austrian geologist Bruno Sander initiated an approach to structural analysis which, with some modification, is still followed today. It proceeds by the three successive steps of geometric, kinematic, and dynamic analyses of structures.

Geometric analysis describes the external form and the internal fabric of rock bodies. A complete analysis should include available observations on all scales.

Geometric analysis is not directly concerned with deformation; thus, an inventory of geometric elements includes *primary structures,* which a rock body acquires in the process of deposition or emplacement, and *secondary structures,* which it acquires as a result of diagenesis and deformation. Geometric analysis is equally concerned with the form of rock bodies, the boundaries or contacts between them, their internal fabric, and the discontinuities that traverse them.

Kinematic analysis is the analysis of *displacements.* Displacements within a body that lead to changes in size and in shape of the body constitute *strains.* Strain is caused by *stress,* which is the force per unit area acting at any point of the body. These concepts will be developed in chapter 5.

Dynamic analysis is the attempt to find the stress configuration responsible for observed strains.

The integration of geometric, kinematic, and dynamic analysis leads to *structural synthesis.* At their most complete, structural and tectonic syntheses give a picture of the evolution in time of a deformed segment of the earth's crust. This demands a proper perspective in space and in time. The methods are both analytical and historical, and the tools come from many other branches of science. However, the synthesis is only as good as each step that has led to it.

The total structure of a deformed segment of crust gives it a certain imprint, a *style,* in the same way that the sum of structural and ornamental features gives a building its particular style. In rocks, tectonic style of a given domain reflects, above all, relative mobility, intensity of deformation, and the relative and absolute sizes of the rock units involved. This is what Maurice Lugeon, an Alpine geologist who had in his family several architects, called *tectonic style.* Thus, we may speak, for instance, of *supercrustal style, fluid style, brittle style,* and many others.

We will begin our study of structural geology with a review of the global setting of geological structures. This setting has been revealed by the most encompassing synthesis in the geological sciences: plate tectonics.

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