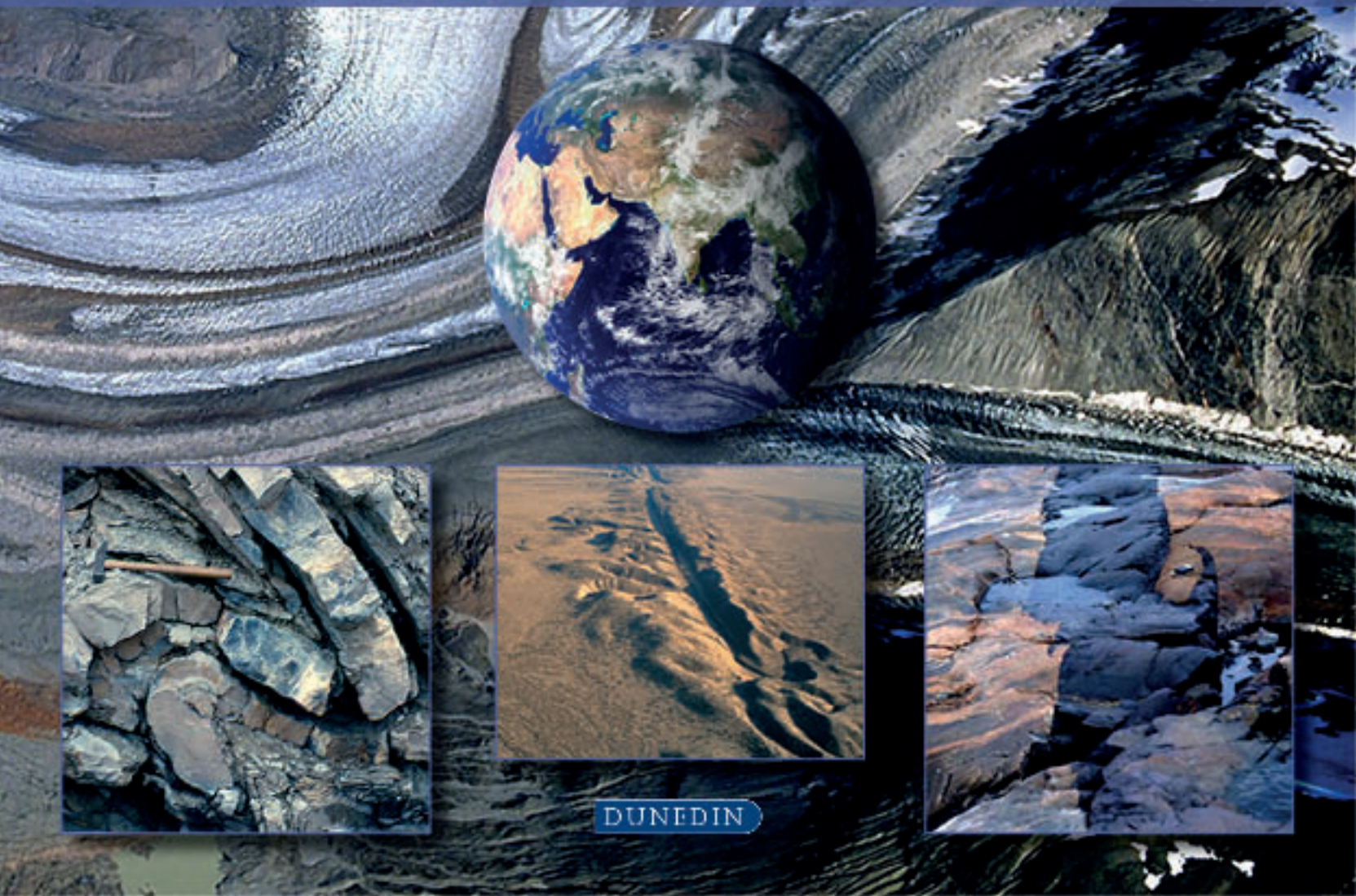
GRAHAM PARK

INTRODUCING TECTONICS, ROCK STRUCTURES AND MOUNTAIN BELTS

SECOND EDITION



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Published by
Dunedin Academic Press Ltd
Hudson House
8 Albany Street
Edinburgh EH1 3QB
Scotland

www.dunedinacademicpress.co.uk

ISBNs
9781780460949 (Paperback)
9781780466309 (ePub)
9781780466316 (Amazon Kindle)
9781780466323 (PDF)

British Library Cataloguing in Publication data
A catalogue record for this book is available from the British Library

Typeset by Biblichor Ltd, Edinburgh
Printed in Poland by Hussar Books

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Acknowledgements

I am indebted to Professor John Winchester and an anonymous reviewer for many helpful comments and suggestions that resulted in significant improvements to the first edition of the book.

I also wish to thank my wife Sylvia for her unfailing support and for subjecting the manuscript to the valuable scrutiny of a non-geologist.

The second edition has benefited from a comprehensive review by the late John Mendum.

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Preface

This book is not intended to be a textbook, but is designed to explain the key concepts of tectonics and rock structures to both students and others interested in geology – especially those who may not have a good scientific or mathematical background. The study and understanding of geological structures has traditionally been guided by the rigorous application of mathematics and physics, and conventional textbooks on structural geology have reflected this approach. However, in my experience, many students are discouraged by this aspect of the subject and consequently, in this book, I have avoided mathematical equations altogether, and reduced the geometry to the minimum I judged necessary to understand the concepts. Those who wish to gain a deeper understanding of the subject, or who are engaged on a university-level course in structural geology, are directed to the reading list, which contains several excellent textbooks and online sources recommended for further study.

The application of plate-tectonic theory has revolutionised structural geology by giving the study of structures a context in which they can be explained. Since the large-scale movements of the plates ultimately control smaller-scale structures, the study of tectonics is therefore the key to understanding the latter. I therefore introduce the reader first to large-scale Earth structure and the theory of plate tectonics. The following four chapters deal in rather more detail with what might be called 'traditional' structural geology – the study of the response of rock material to crustal forces, and the explanation for the bewildering variety of rock structures formed thereby. This aspect of geology was transformed in the 1950s and 1960s by rigorous geometrical analysis and the application of the techniques of rock mechanics. I believe that it is important for the student of geology to be aware of this background, without necessarily being able (at least initially!) to understand the mathematical or geometrical detail.

An important development in the latter decades of the last century was the emphasis by structural geologists on the movement history of rock masses relative to each other as revealed by the study of fault systems and shear zones. This enabled structural geology to be more directly related to plate tectonics and helped to integrate geological structures with tectonics; I have tried to emphasise this aspect in the book.

One of the most exciting aspects of geology is the study of the great mountain ranges ('orogenic belts'), both of the present day and of the past. The final three chapters of the book are designed to illustrate how knowledge of plate-tectonic theory, geological structures and the processes of deformation may be employed to understand these orogenic belts.

Scientists are addicted to the classification and naming of the things that fall into their domain, and structural geologists are no exception. However, I have tried to avoid the excessive use of terminology; technical terms are highlighted in **bold** where they first appear in the text, and are defined and explained in the glossary, which readers are encouraged to check when uncertain of the exact meaning of a word used in a geological context (which often differs from its everyday meaning). I have also included an index of named geological features (e.g. faults, tectonic units, etc.) indicating the page on which they are described and, if appropriate, the map on which they appear.

The Appendix contains a set of four tables that set out in a simplified way the main terminology of the geological timescale, of igneous and sedimentary rocks and of metamorphic facies, as an aid to those readers who may not be so familiar with those aspects of the subject.

Finally, I hope that the reader might share the excitement of discovering how the all-embracing theory of plate tectonics can help to explain the

Note: all terms highlighted in **bold** are defined in the Glossary at the end of the book.

multitude of complexities revealed in the study of the rocks.

Preface to the second edition

It is now eight years since the first edition was completed, and I have taken the opportunity of this new edition to make extensive revisions, particularly to the last two chapters, correcting mistakes, up-dating the interpretation and introducing better examples. Many of the diagrams have been improved, with better use of colour. In making these changes, I have been guided by the suggestions of several reviewers – a comprehensive critical review by the late John Mendum being especially helpful.

R.G.P.,
August 2020.

1 Introduction

Meaning and scope of the terms 'tectonic' and 'structure'

The adjective '**tectonic**' merely means 'structural', i.e. applying to a structure. However, in geological usage it has come to be applied particularly to large-scale structures – hence 'tectonic plate'. In order to explain rock structures, it is necessary to understand the forces operating within and on the crust that are responsible for creating them, and to do this, we need to investigate the Earth-scale processes known collectively as **plate tectonics**.

The term '**structure**' in everyday usage refers normally to a building or other artificial construction, but in geological terms it has come to mean a body of rock whose shape can be defined geometrically and which has originated by a geological process. The most obvious and best-known types of geological structure are **folds** and **faults**, which have been produced by the action of geological forces within the Earth's crust and which can give us an insight into the magnitude of these forces and how they operate. Another group of structures is typical of deep-seated metamorphic rocks where crustal forces have effected thoroughgoing changes in the rock, producing new textures through recrystallisation; the structure produced by such changes is known as the **fabric**. A fourth category of geological structures consists of igneous intrusions. Such bodies are influenced by the forces acting within the crust during their emplacement, and the igneous bodies themselves may cause structural changes in the host rocks.

Kinematic and dynamic models of deformation

Kinematics is the study of *movement* and **dynamics** the study of *forces*, and both types of model have been used in the investigation of geological structures. Dynamic models have traditionally been used by structural geologists employing the techniques of mechanical engineering and materials science. This requires a familiarity with mathematics and physics, which is a potential barrier to understanding for many students. However, whereas a background in these subjects is essential to understanding the deformation of rock in any depth, it is not really necessary to be able to grasp the essentials of structural geology at a basic level. The kinematic model of deformation has become in many ways more popular as a way of understanding geological structures. In this type of approach, structures are analysed in terms of the relative movement between blocks of crust, and the causal forces are disregarded. Thus, systems of related folds and faults are explained by a single set of relative movements. Such a system can also be integrated into the plate-tectonic model by scaling up to a higher order of magnitude but maintaining the same overall movement sense. Examples of this are discussed in chapters 10–12, where we look in detail at the structure of **orogenic belts**. At this larger scale, structures are grouped into **tectonic regimes**, based on their over-riding characteristics, and linked with their plate-tectonic setting, thus: **extensional** regimes are associated with divergent plate boundaries (**continental rift** zones); **compressional** regimes with convergent plate boundaries (subduction and collision zones); and strike-slip regimes with **transform faults**. These plate boundary types are explained in Chapter 3.

Layout of the book

The sequence of chapters reflects the author's belief that an understanding of the plate tectonic model and the evidence for it is helpful in the understanding of geological structures on the smaller scale. Thus chapters 2–3 deal with large-scale Earth structure and the theory of plate tectonics. These chapters are followed by chapters 4–9 on the process of **deformation** and on the various types of geological structure. Finally chapters 10–12 deal with the study and understanding of **orogenesis** and orogenic belts. A brief summary of each chapter follows.

◆ ***Chapter 1: large-scale earth structure***

This chapter describes firstly, the most significant features of the Earth's crust: