GEOPHYSICAL GEODESY

The Slow Deformations of the Earth

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CONTENTS

PREFACE

The study of geodesy is the study of the shape and gravity field of the Earth. The methods used to carry out these investigations include terrestrial triangulation, levelling, and gravity surveys and the methods based on the technologies developed for space research, such as the tracking of artificial satellites and the Moon. These observations have revealed that the shape and gravity field of the planet vary over relatively short time intervals, from a few hours to several decades. Geophysical and geological evidence points to an Earth that undergoes considerable deformation at very short periods of an hour and less, as revealed by seismology, as well as at very long periods of 10^6 years and longer, and the geodetic observations, by spanning these two extremes, form an integral part of any study of the Earth's dynamic behaviour. I have used the term *geophysical geodesy* here to describe those geodetic methods that, alongside the geological and geophysical evidence, contribute to the study of the slow deformations of the Earth. It includes the study of crustal motion, of the spatial and temporal variations in the gravity field, and of the planet's rotation and tidal deformations.

I have attempted in this book to provide a geophysical and geological rationale for the geodetic experiments that have been carried out in the past and for those that are now possible. I have also attempted to provide insight into the methods, principles, and potential of geodetic science for earth scientists not versed in the intricacies of this subject. It represents, therefore, neither a textbook in geodesy nor geophysics and it does not attempt a complete discussion of either discipline. I have had to assume that the reader has already been introduced to both disciplines, as represented in, for example, the books by Officer (1974), Stacey (1977*a*), Kaula (1966*a*, 1968), Heiskanen and Moritz (1967), and Bomford (1971). Where necessary, I have attempted to give a balanced selection of references to permit the reader to seek out background material. The book is aimed at graduate students in geodesy and geophysics but students in their final or honours year of their first degree should find it helpful. The book is also directed at scientists working at the interface between the two subjects: at geodesists who wish to understand the geophysical implications of their measurements and at geophysicists who would like to know more about how the geodetic results have been achieved.

Chapter 1 gives a brief overview of the role of geodetic observations in the study of the dynamics of the Earth. Chapters 2–4 of the book provide in a summary form the geodetic and geophysical background

material that is required for subsequent chapters. Chapter 2 reviews some basic geodetic concepts dealing with reference frames relative to which the motions and deformations are measured, and with the mathematical properties of the external gravity field. Chapter 3 summarizes geophysical problems and phenomena that are relevant to understanding the geodetic observations. Many geodetic observations are contaminated by mass-shifts in the oceans and atmosphere and a review of the relevant properties and time-dependent behaviour of the hydrosphere is given in Chapter 4. The next four chapters discuss geodetic measurement procedures. Both terrestrial and spatial methods are included. The classical terrestrial observations discussed in Chapter 5 provide a partial record of deformation and movement that extends back into the nineteenth century, and these observations can be important, even when the measurement may have been relatively imprecise. Chapter 6 treats geodetic methods that use artificial satellites, either as sensors of the gravitational field or as a means for measuring the rotational motions and deformations of the Earth. These methods were born with the first artificial satellite launch in 1957 and their major contribution has been towards the determination of the global gravity field. Recent contributions are to the study of the kinematics of crustal motion and, through the introduction of satellite-borne altimeters, to the study of the dynamics of the ocean surface. Chapter 7 discusses the application of laser tracking of the Moon to the study of the dynamics of the Earth–Moon system, and Chapter 8 discusses the application of long-baseline radio interferometer observations of stellar sources to the measurement of the planet's rotation and deformation. The next three chapters discuss some of the geophysical implications of these results and how the observations may be integrated with other geological and geophysical evidence for the deformation of the Earth. The chapters include discussions of gravity (Chapter 9), tectonic motions and crustal deformation (Chapter 10), and the planet's rotation and tides (Chapter 11). This subdivision is convenient even if it is a somewhat arbitrary one. Gravity and crustal motion observations, for example, often contribute to the same tectonic problems, such as the study of the spreading margins or of convergent margins of the tectonic plates. An alternative approach would have been by theme. For example, one theme, the viscosity of the Earth, occurs throughout these chapters: rotation and tide observations provide estimates of the global dissipation function Q; gravity observations provide constraints on the viscosity of predominantly the crust and lithosphere but also on the mantle, observations of crustal deformation and relative sea-level changes provide further estimates of mantle viscosity. A second theme, to which both gravity and crustal deformation observations have much to contribute, is the structure and dynamics of the crust and lithosphere. A third possible theme is the core–mantle

interaction: rotation and tide observations provide insight into core–mantle coupling processes while gravity observations may contribute to understanding the geometry of the core–mantle interface. But this approach results in ignoring a number of other geophysical applications and the more traditional subdivision is maintained.

In selecting specific examples of the application of geodetic measurements to geophysical and geological problems, personal interests have certainly led to bias, but I have attempted to select topics that illustrate the full range of applications and may be in the forefront of future research. I have certainly not exhausted the range of topics that will undoubtedly benefit from the present and future geodetic measurements.

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