Acquisition and Analysis of Terrestrial Gravity Data

Gravity surveys, detecting minute variations of the gravitational field at the Earth's surface, have a huge range of applications, indicating density variations in the subsurface, identifying man-made structures, characterizing local changes of rock type, or even mapping deep-seated structures at the crust/mantle boundary. This important one-stop book combines an introductory manual of practical procedures with a full explanation of analysis techniques, enabling students, geophysicists, geologists, and engineers to fully understand the methodology, applications, and limitations of a gravity survey.

Filled with examples from a wide variety of acquisition problems, the book instructs students in avoiding common mistakes and misconceptions. The authors also explore the increasing near-surface geophysical applications being opened up by improvements in instrumentation, and provide some more advanced-level material to give a useful introduction to potential theory.

Springing from the authors' extensive teaching experience and professional participation in a wide range of engineering applications, this book shares their considerable insight into data-acquisition procedures and analysis techniques. A key text for graduate students of geophysics, this is also an invaluable resource for professionals using gravity surveys, from civil engineers and archaeologists, to oil and mineral prospectors and geophysicists seeking to learn more about the Earth's deep interior.

Leland Timothy Long is Emeritus Professor of Geophysics at the Georgia Institute of Technology, where he has taught geophysics for more than 40 years, on topics including exploration geophysics, potential theory, seismology, data analysis, and earth science. He is also a licensed Professional Geologist in Georgia and consults on topics of gravity data interpretation, seismic hazard, and blast vibration. Professor Long's research interests in potential methods include the interpretation of regional crustal structures for seismic hazards, deflections of the vertical, statistical properties of gravity fields, and microgravity for the detection of sinkholes. His research interests in seismology have emphasized seismicity, seismic networks, induced seismology, many aspects of theoretical seismology related to scattering and scattering inversion, and near-surface surface wave analysis. In 2006, Professor Long was awarded the Jesuit Seismological Association Award honouring outstanding contributions to observational seismology.

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Dedicated to our mentors and students.

In particular to Dr. Alan R. Sanford who instilled the importance of examining problems in revolting detail, to Dr. Joseph W. Berg for his enthusiasm for new ideas and participation in the science community, and to the many students who participated in the acquisition and analysis of gravity data while at Georgia Tech and who have continued these virtues in their work, teaching, and life.

Contents

Preface

Gravity data acquisition and analysis is most often presented in outline form as one of the smaller chapters in books on general geophysical exploration methods. This limited description means that the details of field techniques and data analysis are lost or greatly abbreviated and left to the individual to learn through experience. The objective of this book is to offer a detailed presentation of gravity data acquisition and analysis in a single package. The examples are taken from geophysical engineering problems as well as the analysis of regional and global data.

The objective is to completely cover the information needed for a novice to understand how and why gravity data are acquired and analyzed. A student completing a course using this text could easily acquire gravity data and would be prepared to initiate independent research on the analysis of potential data. A consulting geophysicist will find a base of both theoretical- and application-oriented information in this text, while a geologist or engineer can use this book to better understand the advantages and limitations of the gravity method. The general approach of this text has evolved over the past 20 years through experience gained from the acquisition of more than 40,000 values of gravity and in teaching courses in potential methods.

The text is intended for a wide range of users. It is written so that the basic applications are easily understood by those with limited training in mathematics. At the same time, the text occasionally introduces more advanced topics from potential theory for those with greater skills in mathematics. The text does not present extensive equations for the many possible specific models. Some simple shapes lead to complex equations that are computationally intense and generally of little practical use. Instead, the text presents the simpler models as a means of illustrating concepts or as a method of approximating structures. Sufficient background is presented in the equations and analysis techniques for those wishing to create their own more detailed models. In general, methods that allow automatic modeling of the gravity fields using approximations will be emphasized. Inversion methods are presented for the geophysicists needing more advanced analysis techniques for larger datasets.

Most texts are lacking on advice for data acquisition and the quality control needed to prevent corruption of the data. This text presents important aspects of data acquisition and provides organizational tools needed to carry out a successful survey. The text draws on examples from a wide variety of acquisition problems. They range from environmental and engineering problems, such as locating sink holes, to examples from crustal structure analysis and global gravity fields.

This book is a user's manual for those wishing to obtain and use gravity data, as well as a textbook for the introduction to more advanced concepts in tectonics and geodesy.