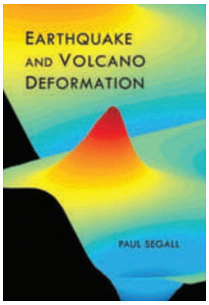
Deformation explained



Earthquake and Volcano Deformation

by Paul Segall

PRINCETON UNIV. PRESS: 2010. 458PP. £62.00

Measuring the shape of the Earth and how it changes with time is the provenance of the field of geodesy, and has a legacy dating back hundreds of years. These measurements show that the Earth deforms in response to earthquakes and magmatic movements. During the past few decades our ability to make precise measurements of these geophysical processes has greatly improved; the modern geodesist's tool bag includes underground, seafloor, surface, air- and space-borne sensors. In his book *Earthquake and Volcano Deformation*, Paul Segall examines what this explosion of knowledge can tell us about the Earth.

We now know that the surface of the Earth is constantly deforming. For example, the number of known deforming volcanoes has tripled to more than 120 in the past 10 years. But, as Segall notes in the preface to his new book, deformation measurements alone are of little use. Instead, we want to know what the data are telling us about processes in the Earth. How much magma is accumulating beneath 'that volcano' in Iceland? Which part of the fault did not slip during the Haiti earthquake and might rupture in the future? Segall's book provides the theoretical background necessary to begin to address these questions.

The book is the first to focus on the models used to relate subsurface fault and magma motion to surface deformation. Based on a course taught by the author at Stanford University at the upper undergraduate to graduate level, the book has been more than a decade in the making. For years, faculty at various institutions (myself included) have begged for incomplete drafts of the manuscript to use as a reference when teaching, so it is satisfying to see the complete work now available to all. It is clearly written and the content is logically presented, as one might expect from material that has been taught to hundreds of students by an excellent teacher.

The strength of the book lies in Segall's ability to explain in a clear and comprehensive way how Earth deformation models are constructed, and what their limitations are. The book begins by explaining the simplest means of relating fault motion to surface motion — by assuming that the Earth is flat, homogeneous and perfectly elastic. Subsequent chapters systematically describe the development of tools used to calculate surface displacements from more realistic models, and test the importance of each of these refinements against surface observations. Segall explores the influence of variations in rock character and type, gravity, topography, Earth curvature and crack-like faults.

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In many cases the simplest models may suffice. But Segall notes several examples where new, increasingly dense and precise observations require more realistic models. For example, gravity and the Earth's curvature only influence deformation associated with the largest earthquakes, which rupture up to 1,000 km of a fault. However, gravity does influence deformation in the years to decades after an earthquake or magmatic intrusion occurs. Segall devotes several chapters to how time-dependent deformation can be mathematically related to the viscosity of the subsurface, the extent of liquid saturation and how stress builds up on a fault between earthquakes. The chapters on modern friction theory and its impact on time-dependent fault deformation are particularly unique and useful.

I suspect that few universities have the resources to teach a stand-alone specialized course using this textbook, but many faculty members will use this book as one of several recommended textbooks for upper-level courses in volcanology, tectonics or crustal deformation. Each chapter ends with a nice summary and set of problems; a solution manual is available from the publisher and an online *errata* page is planned. The growing number of researchers and graduate students using geodetic data to study earthquake and volcanic deformation should have this book on their shelves as a reference because of its uniquely comprehensive and pedagogic content. Other scientists or students, including seismologists, structural geologists and earthquake engineers, who have a need or desire to understand the physics behind the ground movements that they study, will also find the book useful.

Those involved in geophysical monitoring of subsurface energy systems for carbon sequestration, enhanced hydrocarbon extraction and geothermal energy production might also be interested. These human-induced injections and withdrawals of subsurface fluids have caused observable surface deformation, and have frequently been modelled with the types of analytic models described in this textbook, including by the author himself.

In summary, this is a timely and well-written book that introduces the mathematical tools needed to interpret the onslaught of new surface-deformation data. To find the same material covered in this textbook, a scientist would have to dig through hundreds of scientific papers and books, and even then would not find the topics as clearly presented or accompanied by new advances in the field. ❐

REVIEWED BY MATT PRITCHARD
Matt Pritchard is in the Earth and Atmospheric Sciences Department, Cornell University, Ithaca, New York 14853, USA.
e-mail: pritchard@cornell.edu