

Seismic modeling study of the Earth's deep crust

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ABSTRACT

We use seismic modeling methods to validate the interpretation of deep-crust seismic exploration. An approximation of the stacked section is obtained with the nonreflecting wave equation and the exploding-reflector approach. Using this technique and ray-tracing algorithms, we obtain a geological model by comparing the synthetic section with the real stacked section. An isotropic constitutive equation is assumed in this phase. The exact synthetic stacked section is then obtained by applying the standard processing sequence to a set of synthetic common-shot profiles computed with the variable-density acoustic wave equation. We introduce elliptical P -wave anisotropy and the effects of small-scale inhomogeneities by using a von Kármán autocovariance probability function that simulates scattering Q effects. Verification of the geological model by poststack migration constitutes an additional test. The methodology, which is suitable for areas of complex geology, is applied to a seismic line acquired in the northern Apennines as part of the Italian deep-crust exploration project, CROC. This area is particularly difficult to interpret because of the presence of a complex tectonic setting.

INTRODUCTION

The objective of seismic numerical modeling is to predict the seismogram that a set of sensors would record, given an assumed structure of the subsurface. It is a valuable tool for seismic interpretation and an essential part of seismic inversion algorithms. It is also used to provide data for testing processing algorithms and for evaluating acquisition parameters and processing options for various targets of interests before field data acquisition (Chadwick et al., 1995).

Seismic modeling has been used for hydrocarbon exploration problems (Kang and McMechan, 1990; Fagin, 1992),

for earthquake seismology problems (Priolo, 1999), and for crustal studies (Yarnold et al., 1993; Monguile, 1998; Monguile et al., 1998). Modeling synthetic seismograms may then have different purposes. In exploration geophysics, for instance, it is important to perform a sensitivity analysis related to the detectability of a petrophysical variable, such as porosity, fluid type, or fluid saturation. In earthquake seismology the scale of the investigation can be of the order of kilometers for site-response problems (Priolo, 1999) or of the order of tens of kilometers for deep crustal studies (Poussini et al., 1995). We develop a methodology to validate the seismic response of the Earth's crust on a large-scale basis for the purpose of verifying the main geological features of the upper and lower crusts obtained during the interpretation process.

The interpretation of large-scale structures of the deep crust is mainly based on P -wave information [examples of seismic data are from the Italian CROC and the German DEDORP deep-crust exploration projects (Finetti, 1994; Picli et al., 1998; Rabbel and Gajewski, 1995)]. The source and acquisition parameters for the CROC-03 seismic survey are given in Table 1 (Berthelli and Mazzotti (1999); see also Mazzotti et al. (2000) for alternative parameters). The survey has been interpreted by Finetti et al. (2001). Amplitude information is relatively important, but a precise determination of the interval velocities is difficult because the residual NMO of reflection events beyond 4–5 s becomes very small. Additional problems are the complex tectonic regime and rough topography with outcrops of high-velocity layers. Moreover, the data are usually of low S/N ratio, thus invalidating the use of techniques such as prestack depth migration. Therefore, we should deal with almost zero-offset P -wave data, and the model design should be based on the stacked time section: well data are scarce, and only oil exploration wells down to 4 km depth are available. The data generally show a rather scarce reflectivity and diffractions, which may reveal the presence of fault planes. On the basis of these facts, it is unrealistic to use sophisticated modeling techniques. Therefore, we do not consider mode conversion (i.e., S -waves) and intrinsic attenuation, which, in this situation, constitute second-order effects. Anisotropic effects on the P -wave are modeled with an

Manuscript received by the Editor July 6, 2003; revised manuscript received April 11, 2005.

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Seismic Modeling Of The Earths Crust

KJ Lindholm-Leary



Seismic Modeling Of The Earths Crust:

Seismic Modeling of the Earth's Crust, 1972 Postroenie Seismicheskoi Modeli Zemnoi Kory Igor' Nikolaevich Galkin, 1975 **Seismic Modeling of the Earth's Crust** Igor' Nikolaevich Galkin, 1975 *Seismic Modelling of the Earth's Crust* I. N. Galkin, 1996 Seismology and Structure of the Earth Barbara Romanowicz, Adam Dziewonski, 2010-04-20

Treatise on Geophysics Seismology and Structure of the Earth Volume 1 provides a comprehensive review of the state of knowledge on the Earth's structure and earthquakes. It addresses various aspects of structural seismology and its applications to other fields of Earth sciences. The book is organized into four parts. The first part principally covers theoretical developments and seismic data analysis techniques from the end of the nineteenth century until the present with the main emphasis on the development of instrumentation and its deployment. The second part reviews the status of knowledge on the structure of the Earth's shallow layers starting with a global review of the Earth's crustal structure. The third part focuses on the Earth's deep structure divided into its main units: the upper mantle, the transition zone, and upper mantle discontinuities, the D region at the base of the mantle, and the Earth's core. The fourth part comprises two chapters which discuss constraints on Earth structure from fields other than seismology: mineral physics and geodynamics. Self-contained volume starts with an overview of the subject, then explores each topic with in-depth detail. Extensive reference lists and cross references with other volumes to facilitate further research. Full color figures and tables support the text and aid in understanding. Content suited for both the expert and non-expert. *Active Geophysical Monitoring* Hitoshi Mikada, Michael S. Zhdanov, Junzo Kasahara, 2025-09-12

Active Geophysical Monitoring covers the praxis of active geophysical monitoring in a broad range of applications. Including CCUS, hydrocarbon, geothermal, reservoir development and management, groundwater, earthquake monitoring, and more. The editors and contributing authors thoroughly examine the latest developments and technologies in this new edition. The text begins with an in-depth overview of active geophysical monitoring followed by a close look at active targets and the latest technology. The theory of data analysis and interpretation follows in detail. The text closes with 15 case histories in signal processing as well as carbon capture and storage. This updated edition is an invaluable resource for geophysicists employing a range of monitoring applications. Explains the general concepts of active geophysical monitoring and the relevant historical background. Describes worldwide efforts of active geophysical monitoring and provides a perspective view on worldwide development. Updated for the last decade's development and the latest technologies. *The Three-ray Megacontinent of the Earth* Yuri Bakulin, Anatoly Zhirnov, 2019-12-10

This book explores many mysterious features of the structure and evolution of the Earth's continents still unknown to the scientific community and a wider audience. Science has now proved that the southern continents of South America, Africa, and Australia represent the southern ends of a single three-beam megacontinent. It began to form 4.4 billion years ago in a huge three-beam cavity on the planet's surface and grew vertically up to its present state. Proof of the reality of

a single three beam megacontinent is a fundamental discovery in Earth sciences and represents a new level in the understanding of the planet's structure. The text will appeal to researchers of Earth sciences, university teachers and students and secondary school teachers of geography and geology as well as all readers with an interest in the history of our planet.

Scientific and Technical Aerospace Reports, 1972 *Advances in Geophysics*, 1996-01-12. From the Foreword: This series has provided workers in many fields with invaluable reference material and criticism. Science Progress should be on the bookshelf of every geophysicist. Physics Today: The entire series should be in the library of every group working in geophysics. American Scientist.

Computational Geo-Electromagnetics Viacheslav V. Spichak, 2020-02-01. Computational Geo Electromagnetics: Methods, Models and Forecasts. Volume Five in the Computational Geophysics series is devoted to techniques for building of geoelectrical models from electromagnetic data featuring Bayesian statistical analysis and neural network algorithms. These models are applied to studying the geoelectrical structure of famous volcanoes i.e. Vesuvio, Kilauea, Elbrus, Komagatake, Hengill and geothermal zones i.e. Travale, Italy, Soultz, France, Alsace. Methodological recommendations are given on electromagnetic sounding of faults as well as geothermal and hydrocarbon reservoirs. Techniques for forecasting of petrophysical properties from the electrical resistivity as proxy parameter are also considered. Computational Geo Electromagnetics: Methods, Models and Forecasts offers techniques and algorithms for building geoelectrical models under conditions of rare or irregularly distributed EM data and/or lack of prior geological and geophysical information. This volume also includes methodological guidelines on interpretation of electromagnetic sounding data depending on goals of the study. Finally, it details computational algorithms for using electrical resistivity for properties beyond boreholes. Provides algorithms for inversion of incomplete rare or irregularly distributed EM data. Features methodological issues of building geoelectrical models. Offers techniques for retrieving petrophysical properties from EM sounding data and well logs.

Treatise on Geophysics, 2015-04-17. Treatise on Geophysics, Second Edition is a comprehensive and in-depth study of the physics of the Earth beyond what any geophysics text has provided previously. Thoroughly revised and updated, it provides fundamental and state-of-the-art discussion of all aspects of geophysics. A highlight of the second edition is a new volume on Near Surface Geophysics that discusses the role of geophysics in the exploitation and conservation of natural resources and the assessment of degradation of natural systems by pollution. Additional features include new material in the Planets and Moon, Mantle Dynamics, Core Dynamics, Crustal and Lithosphere Dynamics, Evolution of the Earth and Geodesy volumes. New material is also presented on the uses of Earth gravity measurements. This title is essential for professionals, researchers, professors and advanced undergraduate and graduate students in the fields of Geophysics and Earth system science. Comprehensive and detailed coverage of all aspects of geophysics. Fundamental and state-of-the-art discussions of all research topics. Integration of topics into a coherent whole.

Planetary Sciences Imke de Pater, Jack J. Lissauer, 2015-01-29. An authoritative introduction for graduate students in the

physical sciences this award winning textbook explains the wide variety of physical chemical and geological processes that govern the motions and properties of planets This updated second edition has been revised and improved while maintaining its existing structure and organization Many data tables and plots have been updated to account for the latest measurements A new Appendix focuses on recent discoveries since the second edition was first published These include results from Cassini Kepler MESSENGER MRO LRO Dawn at Vesta Curiosity and others as well as many ground based observatories With over 300 exercises to help students apply the concepts covered this textbook is ideal for graduate courses in astronomy planetary science and earth science and well suited as a reference for researchers Color versions of many figures movie clips

supplementing the text and other resources are available at www.cambridge.org/deptat **Energy Potential of the Russian Arctic Seas** Alexey Piskarev, Mikhail Shkatov, 2012-06-14 The structure of sedimentary basins of the Russian Arctic Seas is studied and illustrated by a number of maps cross sections and geophysical models The calculated density models of the Earth crust illustrate the deep structure of the main blocks of the crust Five major gas condensate and gas fields are discovered here three Shtokman Ludlov Ledovoe in the Barents and two Leningrad and Rusanov in the Kara Sea Geological and geophysical characteristics of the Russian Arctic Sea sedimentary basins allow an estimation of their hydrocarbon potential by comparison with the known world analogues Total potential resources of giant deposits of hydrocarbons in Russian Arctic Seas are estimated at 470 billion barrels of oil equivalent The richest resources are the Kara Sea and Laptev Sea Less rich is Barents Sea The relatively smaller contribution to the overall estimation of the resources makes the resources of East Siberian Sea and Chukchi Sea Development the energy capacity of the continental shelf of Russia can play a stabilizing role in the dynamics of oil and gas production in the period 2010 2020 A key role in developing the capacity of the Arctic shelf oil and gas play is the innovative technology in exploration production and management of the relevant investment projects World offshore experience indicates that the combination of these factors is achieved through the formation of international firms and organizations Comprehensively assesses the potential oil and gas resources in sedimentary basins within the Russian sector of the Arctic Ocean Describes the economic and legal challenges to the development of offshore fields in Russia Explores possible ways and timing to make these hydrocarbon resources available to the global market **U.S. Government Research & Development Reports**, 1967 **Earthquakes** Peter Moczo, Eva

Rutšeková, Jozef Kristek, Martin Galis, Miriam Kristekova, 2024-10-16 Discover the profound surprising and instructive tales embedded within the tragic earthquakes and tsunamis of the years 1755 1906 1960 1985 2004 2011 and 2023 Uncover the impact these events have had on our understanding of the planet we call home and explore how they shaped the destinies of entire nations In this book you will delve into the intriguing connection between seismic events and human missions to the Moon and Mars pondering the warnings they carry for our future As seismic risks on Earth escalate and humanity extends its reach into space these challenges become pivotal for both current and future seismologists Lastly this book will allow you to

embark on a riveting journey through the seismic tapestry of our past present and the uncharted territories of our future

People, Land & Water ,2006 **Annales Geophysicae** ,1995 *GEOPHYSICS AND GEOCHEMISTRY - Volume I* Jan Lastovicka,2009-11-28 Geophysics and Geochemistry is a component of Encyclopedia of Earth and Atmospheric Sciences in the global Encyclopedia of Life Support Systems EOLSS which is an integrated compendium of twenty one Encyclopedias Geophysics and Geochemistry are two closely intertwined and collaborating branches of Earth s sciences The content of the Theme on Geophysics and Geochemistry is organized with state of the art presentations covering eight main topics Foundations of Geophysics and Geochemistry Geophysical Systems Seismology and Volcanology Geomagnetism and Geoelectricity Aeronomy and Magnetosphere Gravimetry Geochemistry and Cosmochemistry Planetology Comparative Planetology of Earth like Planets and Astrobiology which are then expanded into multiple subtopics each as a chapter These three volumes are aimed at the following a wide spectrum of audiences from the merely curious to those seeking in depth knowledge University and College students Educators Professional practitioners Research personnel and Policy analysts managers and decision makers and NGOs **Radioactivity** Michael Wiescher,2025-01-16 This book provides an accessible introduction to radioactivity The first in a two volume set this volume is presented in two parts covering radiation physics and natural radiation exposure It first explores the discovery and physics of the phenomenon of radioactivity covering the discovery of radioactive decay and the historical development of the physics and applications of radioactivity through to 1940 Chapters then present descriptive summaries of the physics of the atom and the atomic nucleus mass and energy conditions the nature of isotopes and the different decay patterns Chapter three discusses decay laws and introduces natural origins of radioactivity as well as methods for producing radioactive isotopes through nuclear reaction processes in reactor and accelerator The book then provides an introduction on dosimetry radiation chemistry and impact of radiation on biological systems The second half of the book details natural radioactivity and the role of radioactivity in the formation of the planetary system and our Earth The author describes how the inner radioactivity of our planet determines its dynamics and how it could have contributed to the origins of life The volume concludes with an exploration of the external and internal radioactivity to which humans are exposed and their possible side effects This book will be of interest to non science undergraduate and physics graduate students alike as well as to interested lay people looking for an introduction to radioactivity Key Features Written in an accessible style to be understood by readers without a formal scientific education Highly illustrated throughout Authored by an expert in the field drawing from decades of experience in experimental nuclear physics **Geophysical Abstracts** ,1971-07

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