

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 (Pozzani 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 DEDCORP 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

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Seismic Modeling Of The Earths Crust

Imke de Pater, Jack J. Lissauer



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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 **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.

Deep Seismic Sounding of the Earth's Crust and Upper Mantle Irina P. Kosminskaya, 2012-12-06. Deep seismic sounding was proposed by G. A. Gamburtsev and developed under his guidance during the period 1948-1955 at the Institute of Physics of the Earth of the Academy of Sciences of the USSR. During that period also the first geophysical results concerning the deep structure of the Earth's crust in several regions in Tien Shan, the Pamir, and Turkmenia were observed. Beginning with 1956 the deep seismic sounding method has been used widely by geophysical research groups as well as by geophysical service organizations for regional studies in the USSR. Descriptions of this work have been given in reports by Yu. N. Godin, V. V. Fedynskii, D. N. Kazanli, and others. New variants of the deep seismic sounding method have been developed: continuous profiling (Yu. N. Godin and others) and point soundings (N. N. Puzyrev and others). Deep seismic soundings have been carried out outside of Russia also, and studies have been carried out on the use of the deep seismic sounding method in marine applications (E. I. Galperin, S. M. Zverev, I. P. Kosminskaya, Yu. P. Neprochnov, and others). Over the past decade the deep seismic sounding method has joined the suite of geophysical studies as a highly detailed method for studying the Earth's crust and upper mantle to depths of 50 to 100 km on land and of 15 to 25 km in the deep oceans.

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.

Active Geophysical Monitoring Hitoshi Mikada, Michael S. Zhdanov, Junzo Kasahara, 2019-10-05. Active Geophysical Monitoring, Second Edition presents a key method for studying time evolving structures and states in the tectonically active Earth's lithosphere. Based on repeated time lapse observations and interpretation of rock induced changes in geophysical fields periodically excited by controlled sources, active geophysical monitoring can be applied to a variety of fields in geophysics from exploration to seismology and disaster mitigation. This revised edition presents the results of strategic systematic development and the application of new technologies. It demonstrates the impact of active monitoring on solid Earth geophysics also delving into key topics such as carbon capture and storage, geodesy and new technological tools. This book is an essential for graduate students, researchers and practitioners across geophysics. Outlines the general concepts of active geophysical monitoring with powerful seismic vibrators and MHD generators. Provides historical background for previous studies of seismically active zones. Covers the theory and technology of active monitoring including signal processing, data analysis, novel approaches to numerical modeling and interpretation. Discusses case histories and presents the results of worldwide regional active monitoring experiments. Thoroughly updated to include recent developments such as updates relating to carbon capture and storage, microgravity, InSAR technologies, geodesy, reservoir monitoring, seismic reflection and more.

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.

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/depater.

Technical Abstract Bulletin Defense Documentation Center (U.S.), 1964.

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