

Seismic modeling study of the Earth's deep crust

José M. Carcione*, Icilio R. Finetti[†], and Davide Gei*

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 autocorrelation 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, CRCP. 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 CRCP and the German DEDOP deep-crust exploration projects (Finetti, 1994; Picli et al., 1998; Rabbel and Gajewski, 1995)]. The source and acquisition parameters for the CRCP-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

**Osvaldo Gervasi, Beniamino
Murgante, Antonio Laganà, David
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Seismic Modeling Of The Earths Crust:

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Constitution of the Earth's Interior discusses the physical and evolutionary principles connecting various elements of the knowledge about structure and dynamics of the Earth's interior. This work is divided into eight chapters that primarily focus on the physical chemical and petrological state. This text contains general data on a general stationary model which is described by equations of state combining the basic parameters including pressure temperature density gravity acceleration and mineral composition within the Earth's interior. Considerable chapters concern the chemical and petrological composition of the matter in the Earth's interior. The remaining chapters describe models containing inhomogeneities used to illustrate processes connected with phase transitions. This book will be of great value to geologists physicists and researchers. *Scientific and Technical Aerospace Reports*, 1972

Lists citations with abstracts for aerospace related reports obtained from world wide sources and announces documents that have recently been entered into the NASA Scientific and Technical Information Database **Journal** Canadian Society of Exploration Geophysicists, 1990 **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. **Natural Disasters - Volume I** Vladimir M. Kotlyakov, 2010-08-19

Natural Disasters theme in two volumes 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. Natural hazards arise unexpectedly without any discernible regularity and leave an indelible trace in nature sometimes for many decades to come.

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Cumulative Index Geophysics, Journal of the Society of Exploration Geophysicists (1936-1988 Inclusive) ; Early Geophysical Papers ; Geophysics, the Leading Edge of Exploration (selected Papers, 1982-88 Inclusive) ... William J. Zwart, 1990

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.

Initial Reports of the Deep Sea Drilling Project Scripps Institution of Oceanography, 1969

Extreme Environmental Events Robert A. Meyers, 2010-11-03. *Extreme Environmental Events* is an authoritative single source for understanding and applying the basic tenets of complexity and systems theory as well as the tools and measures for analyzing complex systems to the prediction, monitoring and evaluation of major natural phenomena affecting life on earth. These phenomena are often highly destructive and include earthquakes, tsunamis, volcanoes, climate change and weather. Early warning, damage and the immediate response of human populations to these phenomena are also covered from the point of view of complexity and nonlinear systems. In 61 authoritative state of the art articles, world experts in each field apply such tools and concepts as fractals, cellular automata, solitons, game theory, network theory and statistical physics to an understanding of these complex geophysical phenomena.

Computational Geo-Electromagnetics Viacheslav V. Spichak, 2020-02-04. *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 sous Forets Elsass 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

Computational Science and Its Applications - ICCSA 2008 Osvaldo Gervasi, Beniamino Murgante, Antonio Laganà, David Taniar, Youngsong Mun, 2008-06-28 This two volume set is assembled following the 2008 International Conference on Computational Science and Its Applications ICCSA 2008 a premium international event held in Perugia Italy from June 30 to July 3 2008 The collection of fully refereed high quality original works accepted as theme papers for presentation at ICCSA 2008 are published in this LNCS proceedings set This outstanding collection complements the volume of workshop papers traditionally published by IEEE Computer Society The continuous support of computational science researchers has helped ICCSA to become a firmly established forum in the area of scientific computing and the conference itself become a recurring scientific and professional meeting that cannot be given up The computational science field based on fundamental disciplines such as mathematics physics and chemistry is finding new computational approaches to foster the human progress in heterogeneous and fundamental areas such as aerospace and automotive industries bioinformatics and nanotechnology studies networks and grid computing computational geometry and biometrics computer education virtual reality and art Due to the growing complexity of many challenges in computational science the use of sophisticated algorithms and emerging technologies is inevitable Together these far reaching scientific areas help to shape this conference in the areas of state of the art computational science research and applications encompassing the facilitating theoretical foundations and the innovative applications of such results in other areas

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