

HANDBOOK OF GEOPHYSICAL EXPLORATION
SECTION I. SEISMIC EXPLORATION
KLAUS HELBIG and SVEN TREITEL (Editors)

VOLUME 22

**FOUNDATIONS OF
ANISOTROPY FOR
EXPLORATION SEISMICS**

by K. HELBIG

PERGAMON

Foundations Of Anisotropy For Exploration Seismics

M.M. Poulton



Foundations Of Anisotropy For Exploration Seismics:

Foundations of Anisotropy for Exploration Seismics K. Helbig, 2015-08-11 Over the last few years anisotropy has become a hot topic in seismic exploration and seismology It is now recognised that geological media deviate more or less from isotropy This has consequences for acquisition processing and interpretation of seismic data and also helps determine the cause of anisotropy and adds to our knowledge concerning the structure of the medium at scales beyond the resolution of the seismic method This volume addresses the theoretical foundations of wave propagation in anisotropic media at an easily accessible level The treatment is not restricted to exploration seismology The book commences with fundamental material and covers the description of wave propagation in anisotropic conditions by means of slowness and wave surfaces It continues to explore the theory of elasticity the interaction of elasticity and material symmetry and conditions imposed by the stability of the medium Wave propagation in general anisotropic solids are discussed referring in particular to singular and longitudinal directions Slowness and wave surfaces in transversely isotropic media and in the planes of symmetry of orthorhombic media is presented and then moves on to wave propagation in orthorhombic media by means of squared slowness surfaces The latter part of the book deals with layer induced anisotropy showing how a particular internal structure of a medium leads to anisotropy and how much of this structure can be recovered by inversion of the modelling algorithm A few fundamental aspects of exploration seismology are also discussed The final chapter discusses how concepts which were developed by Kelvin but only recently understood can be utilised to determine the symmetry class and orientation of an elastic medium

Foundations of Anisotropy for Exploration Seismics Klaus Helbig, 1994 *Foundations of*

Anisotropy for Exploration Seismics K. Helbig, 2015-08-11 Over the last few years anisotropy has become a hot topic in seismic exploration and seismology It is now recognised that geological media deviate more or less from isotropy This has consequences for acquisition processing and interpretation of seismic data and also helps determine the cause of anisotropy and adds to our knowledge concerning the structure of the medium at scales beyond the resolution of the seismic method This volume addresses the theoretical foundations of wave propagation in anisotropic media at an easily accessible level The treatment is not restricted to exploration seismology The book commences with fundamental material and covers the description of wave propagation in anisotropic conditions by means of slowness and wave surfaces It continues to explore the theory of elasticity the interaction of elasticity and material symmetry and conditions imposed by the stability of the medium Wave propagation in general anisotropic solids are discussed referring in particular to singular and longitudinal directions Slowness and wave surfaces in transversely isotropic media and in the planes of symmetry of orthorhombic media is presented and then moves on to wave propagation in orthorhombic media by means of squared slowness surfaces The latter part of the book deals with layer induced anisotropy showing how a particular internal structure of a medium leads to anisotropy and how much of this structure can be recovered by inversion of the modelling algorithm A few fundamental

aspects of exploration seismology are also discussed The final chapter discusses how concepts which were developed by Kelvin but only recently understood can be utilised to determine the symmetry class and orientation of an elastic medium

Seismic While Drilling F.B Poletto,F. Miranda,2004-06-30 The purpose of this book is to give a theoretical and practical introduction to seismic while drilling by using the drill bit noise This recent technology offers important products for geophysical control of drilling It involves aspects typical of borehole seismics and of the drilling control surveying hitherto the sole domain of mudlogging For aspects related to the drill bit source performance and borehole acoustics the book attempts to provide a connection between experts working in geophysics and in drilling There are different ways of thinking related to basic knowledge operational procedures and precision in the observation of the physical quantities The goal of the book is to help build a bridge between geophysicists involved in seismic while drilling who may need to familiarize themselves with methods and procedures of drilling and drilling rock mechanics and drillers involved in geosteering and drilling of smart wells who may have to familiarize themselves with seismic signals wave resolution and radiation For instance an argument of common interest for drilling and seismic while drilling studies is the monitoring of the drill string and bit vibrations This volume contains a large number of real examples of SWD data analysis and applications *Basic Theory in Reflection Seismology* J.K. Costain,C. Coruh,2004-10-27 The material in this volume provides the basic theory necessary to understand the principles behind imaging the subsurface of the Earth using reflection and refraction seismology For reflection seismology the end product is a record section from a collection of wiggly traces that are recorded in the field from which information about the properties of subsurface structure and rock can be derived For the most part the principles of imaging are the same regardless of the depth to the target the same mathematical background is necessary for targeting a shallow water table as for investigating the base of the earth s continental crust at a depth of 30 50 km

Multi-component VSP Analysis for Applied Seismic Anisotropy Colin MacBeth,2002 The vertical seismic profile acquired with an array of 3C receivers and either a single source or several arranged in a multi component configuration provides an ideal high fidelity calibration tool for seismic projects involved in the application of seismic anisotropy This book catalogues the majority of specialized tools necessary to work with P P P S and S S data from such VSP surveys at the acquisition design processing and interpretation stages In particular it discusses 3C 4C 6C and 9C VSP marine and land surveys with near and multiple offsets walkways azimuths walkarounds or a combination of both These are considered for TIH or TIV flavours of seismic anisotropy arising from cracks fractures sedimentary layering and shales The anisotropic adaptation of familiar seismic methods for velocity analysis and inversion reflected amplitude interpretation are given together with more multi component specific algorithms based upon the principles dictated by the vector convolutional model Thus multi component methods are described that provide tests and compensation for source or receiver vector fidelity tool rotation correction layer stripping near surface correction wavefield separation and the Alford rotation with its

variants The work will be of interest to geophysicists involved in research or the application of seismic anisotropy using multi component seismic **Seismic Stratigraphy, Basin Analysis and Reservoir Characterisation** P.C.H.

Veeken,2006-11-13 The interest in seismic stratigraphic techniques to interpret reflection datasets is well established The advent of sophisticated subsurface reservoir studies and 4D monitoring for optimising the hydrocarbon production in existing fields does demonstrate the importance of the 3D seismic methodology The added value of reflection seismics to the petroleum industry has clearly been proven over the last decades Seismic profiles and 3D cubes form a vast and robust data source to unravel the structure of the subsurface It gets nowadays exploited in ever greater detail Larger offsets and velocity anisotropy effects give for instance access to more details on reservoir flow properties like fracture density porosity and permeability distribution Elastic inversion and modelling may tell something about the change in petrophysical parameters Seismic investigations provide a vital tool for the delineation of subtle hydrocarbon traps They are the basis for understanding the regional basin framework and the stratigraphic subdivision Seismic stratigraphy combines two very different scales of observation the seismic and well control The systematic approach applied in seismic stratigraphy explains why many workers are using the principles to evaluate their seismic observations The here presented modern geophysical techniques allow more accurate prediction of the changes in subsurface geology Dynamics of sedimentary environments are discussed with its relation to global controlling factors and a link is made to high resolution sequence stratigraphy Seismic Stratigraphy Basin Analysis and Reservoir Characterisation summarizes basic seismic interpretation techniques and demonstrates the benefits of integrated reservoir studies for hydrocarbon exploration Topics are presented from a practical point of view and are supported by well illustrated case histories The reader student as well as professional geophysicists geologists and reservoir engineers is taken from a basic level to more advanced study techniques Overview reflection seismic methods and its limitations Link between basic seismic stratigraphic principles and high resolution sequence stratigraphy Description of various techniques for seismic reservoir characterization and synthetic modelling Overview nversion techniques AVO and seismic attributes analysis **Information-Based Inversion and Processing with Applications** T.J.

Ulrych,M.D. Sacchi,2005-12-16 Information Based Inversion and Processing with Applications examines different classical and modern aspects of geophysical data processing and inversion with emphasis on the processing of seismic records in applied seismology Chapter 1 introduces basic concepts including probability theory expectation operator and ensemble statistics elementary principles of parameter estimation Fourier and z transform essentials and issues of orthogonality In Chapter 2 the linear treatment of time series is provided Particular attention is paid to Wold decomposition theorem and time series models AR MA and ARMA and their connection to seismic data analysis problems Chapter 3 introduces concepts of Information theory and contains a synopsis of those topics that are used throughout the book Examples are entropy conditional entropy Burg s maximum entropy spectral estimator and mutual information Chapter 4 provides a description of

inverse problems first from a deterministic point of view then from a probabilistic one Chapter 5 deals with methods to improve the signal to noise ratio of seismic records Concepts from previous chapters are put in practice for designing prediction error filters for noise attenuation and high resolution Radon operators Chapter 6 deals with the topic of deconvolution and the inversion of acoustic impedance The first part discusses band limited extrapolation assuming a known wavelet and considers the issue of wavelet estimation The second part deals with sparse deconvolution using various entropy type norms Finally Chapter 7 introduces recent topics of interest to the authors The emphasis of this book is on applied seismology but researchers in the area of global seismology and geophysical signal processing and inversion will find material that is relevant to the ubiquitous problem of estimating complex models from a limited number of noisy observations Non conventional approaches to data processing and inversion are presented Important problems in the area of seismic resolution enhancement are discussed Contains research material that could inspire graduate students and their supervisors to undertake new research directions in applied seismology and geophysical signal processing

Seismic Signatures and Analysis of Reflection Data in Anisotropic Media I. Tsvankin, 2005-06-13 Following the breakthrough in the last decade in identifying the key parameters for time and depth imaging in anisotropic media and developing practical methodologies for estimating them from seismic data Seismic Signatures and Analysis of Reflection Data in Anisotropic Media primarily focuses on the far reaching exploration benefits of anisotropic processing This volume provides the first comprehensive description of reflection seismic signatures and processing methods in anisotropic media It identifies the key parameters for time and depth imaging in transversely isotropic media and describes practical methodologies for estimating them from seismic data Also it contains a thorough discussion of the important issues of uniqueness and stability of seismic velocity analysis in the presence of anisotropy The book contains a complete description of anisotropic imaging methods from the theoretical background to algorithms to implementation issues Numerous applications to synthetic and field data illustrate the improvements achieved by the anisotropic processing and the possibility of using the estimated anisotropic parameters in lithology discrimination Focuses on the far reaching exploration benefits of anisotropic processing First comprehensive description of reflection seismic signatures and processing methods in anisotropic media

Coding and Decoding: Seismic Data Luc T. Ikelle, 2010-03-29 Currently the acquisition of seismic surveys is performed as a sequential operation in which shots are computed separately one after the other This approach is similar to that of multiple access technology which is widely used in cellular communications to allow several subscribers to share the same telephone line The cost of performing various shots simultaneously is almost identical to that of one shot thus the savings in time and money expected from using the multishooting approach for computing seismic surveys compared to the current approach are enormous By using this approach the long standing problem of simulating a three dimensional seismic survey can be reduced to a matter of weeks and not years as is currently the case Investigates how to collect stimulate and process multishooting data

Addresses the improvements in seismic characterization and resolution one can expect from multishooting data Aims to educate the oil and gas exploration and production business of the benefits of multishooting data and to influence their day to day surveying techniques Seismic Amplitude Inversion in Reflection Tomography Yanghua Wang, 2003-02-25 This is the first book of its kind on seismic amplitude inversion in the context of reflection tomography The aim of the monograph is to advocate the use of ray amplitude data separately or jointly with traveltimes data in reflection seismic tomography The emphasis of seismic exploration is on imaging techniques so that seismic section can be interpreted directly as a geological section In contrast it is perhaps ironic that in decades of industrial seismology one major aspect of waveform data that potentially is easier to measure and analyse has generally been ignored That is the information content of seismic amplitudes Perhaps the potential complexity has deterred most researchers from a more thorough investigation of the practical use of seismic amplitude data The author of this volume presents an authoritative and detailed study of amplitude data as used in conjunction with traveltimes data to provide better constraints on the variation of seismic wave speed in the subsurface One of the fundamental problems in conventional reflection seismic tomography using only traveltimes data is the possible ambiguity between the velocity variation and the reflector depth The inclusion of amplitude data in the inversion may help to resolve this problem because the amplitudes and traveltimes are sensitive to different features of the subsurface model and thereby provide more accurate information about the subsurface structure and the velocity distribution An essential goal of this monograph is to make the amplitude inversion method work with real reflection seismic data **Seismic Waves and Rays in Elastic Media** M.A. Slawinski, 2003-08-04 This book seeks to explore seismic phenomena in elastic media and emphasizes the interdependence of mathematical formulation and physical meaning The purpose of this title which is intended for senior undergraduate and graduate students as well as scientists interested in quantitative seismology is to use aspects of continuum mechanics wave theory and ray theory to describe phenomena resulting from the propagation of waves The book is divided into three parts Elastic continua Waves and rays and Variational formulation of rays In Part I continuum mechanics are used to describe the material through which seismic waves propagate and to formulate a system of equations to study the behaviour of such material In Part II these equations are used to identify the types of body waves propagating in elastic continua as well as to express their velocities and displacements in terms of the properties of these continua To solve the equations of motion in anisotropic inhomogeneous continua the high frequency approximation is used and establishes the concept of a ray In Part III it is shown that in elastic continua a ray is tantamount to a trajectory along which a seismic signal propagates in accordance with the variational principle of stationary travel time **Geodynamics of Lithosphere and Earth's Mantle** Jaroslava Plomerová, R. C. Liebermann, Vladislav Babuška, 1998 **Waves And Rays In Elastic Continua (Fourth Edition)** Michael A Slawinski, 2020-09-24 Seismology as a branch of mathematical physics is an active subject of both research and development Its reliance on computational and technological advances continuously motivates the

developments of its underlying theory The fourth edition of Waves and Rays in Elastic Continua responds to these needs The book is both a research reference and a textbook Its careful and explanatory style which includes numerous exercises with detailed solutions makes it an excellent textbook for the senior undergraduate and graduate courses as well as for an independent study Used in its entirety the book could serve as a sole textbook for a year long course in quantitative seismology Its parts however are designed to be used independently for shorter courses with different emphases The book is not limited to quantitative seismology it can serve as a textbook for courses in mathematical physics or applied mathematics

Waves And Rays In Seismology: Answers To Unasked Questions (Second Edition) Michael A Slawinski, 2018-05-04

In summary Professor Slawinski has written an engaging volume covering an unfamiliar topic in a highly accessible fashion Non specialists will gain a significant appreciation of the unique complexities associated with seismology Contemporary Physics The author dedicates this book to readers who are concerned with finding out the status of concepts statements and hypotheses and with clarifying and rearranging them in a logical order It is thus not intended to teach tools and techniques of the trade but to discuss the foundations on which seismology and in a larger sense the theory of wave propagation in solids is built A key question is why and to what degree can a theory developed for an elastic continuum be used to investigate the propagation of waves in the Earth which is neither a continuum nor fully elastic But the scrutiny of the foundations goes much deeper material symmetry effective tensors equivalent media the influence or rather the lack thereof of gravitational and thermal effects and the rotation of the Earth are discussed ab initio The variational principles of Fermat and Hamilton and their consequences for the propagation of elastic waves causality Noether's theorem and its consequences on conservation of energy and conservation of linear momentum are but a few topics that are investigated in the process to establish seismology as a science and to investigate its relation to subjects like realism and empiricism in natural sciences to the nature of explanations and predictions and to experimental verification and refutation In the second edition new sections figures examples exercises and remarks are added Most importantly however four new appendices of about one hundred pages are included which can serve as a self contained continuum mechanics course on finite elasticity Also they broaden the scope of elasticity theory commonly considered in seismology

Waves And Rays In Elastic Continua Michael A

Slawinski, 2010-09-09 The present book which is the second and significantly extended edition of the textbook originally published by Elsevier Science emphasizes the interdependence of mathematical formulation and physical meaning in the description of seismic phenomena Herein we use aspects of continuum mechanics wave theory and ray theory to explain phenomena resulting from the propagation of seismic waves The book is divided into three main sections Elastic Continua Waves and Rays and Variational Formulation of Rays There is also a fourth part which consists of appendices In Elastic Continua we use continuum mechanics to describe the material through which seismic waves propagate and to formulate a system of equations to study the behaviour of such a material In Waves and Rays we use these equations to identify the types

of body waves propagating in elastic continua as well as to express their velocities and displacements in terms of the properties of these continua To solve the equations of motion in anisotropic inhomogeneous continua we invoke the concept of a ray In Variational Formulation of Rays we show that in elastic continua a ray is tantamount to a trajectory along which a seismic signal propagates in accordance with the variational principle of stationary traveltime Consequently many seismic problems in elastic continua can be conveniently formulated and solved using the calculus of variations In the Appendices we describe two mathematical concepts that are used in the book namely homogeneity of a function and Legendre s transformation This section also contains a list of symbols

Waves And Rays In Elastic Continua (3rd Edition) Michael A Slawinski, 2014-12-15 The present book which is the third significantly revised edition of the textbook originally published by Elsevier Science emphasizes the interdependence of mathematical formulation and physical meaning in the description of seismic phenomena Herein we use aspects of continuum mechanics wave theory and ray theory to explain phenomena resulting from the propagation of seismic waves The book is divided into three main sections Elastic Continua Waves and Rays and Variational Formulation of Rays There is also a fourth part which consists of appendices In Elastic Continua we use continuum mechanics to describe the material through which seismic waves propagate and to formulate a system of equations to study the behaviour of such a material In Waves and Rays we use these equations to identify the types of body waves propagating in elastic continua as well as to express their velocities and displacements in terms of the properties of these continua To solve the equations of motion in anisotropic inhomogeneous continua we invoke the concept of a ray In Variational Formulation of Rays we show that in elastic continua a ray is tantamount to a trajectory along which a seismic signal propagates in accordance with the variational principle of stationary traveltime Consequently many seismic problems in elastic continua can be conveniently formulated and solved using the calculus of variations In the Appendices we describe two mathematical concepts that are used in the book namely homogeneity of a function and Legendre s transformation This section also contains a list of symbols

Computational Neural Networks for Geophysical Data Processing M.M. Poulton, 2001-06-13 This book was primarily written for an audience that has heard about neural networks or has had some experience with the algorithms but would like to gain a deeper understanding of the fundamental material For those that already have a solid grasp of how to create a neural network application this work can provide a wide range of examples of nuances in network design data set design testing strategy and error analysis Computational rather than artificial modifiers are used for neural networks in this book to make a distinction between networks that are implemented in hardware and those that are implemented in software The term artificial neural network covers any implementation that is inorganic and is the most general term Computational neural networks are only implemented in software but represent the vast majority of applications While this book cannot provide a blue print for every conceivable geophysics application it does outline a basic approach that has been used successfully

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

Review of Progress in Quantitative Nondestructive Evaluation Donald O. Thompson, Dale E. Chimenti, 2012-12-06 These Proceedings consisting of Parts A and B contain the edited versions of most of the papers presented at the annual Review of Progress in Quantitative Nondestructive Evaluation held at the University of Washington Seattle on July 30 to August 4 1995 The Review was organized by the Center for NDE at Iowa State University in cooperation with the Ames Laboratory of the USDOE the American Society of Nondestructive Testing the Department of Energy the National Institute of Standards and Technology the Federal Aviation Administration the National Science Foundation Industry/University Cooperative Research Centers and the Working Group in Quantitative NDE This year's Review of Progress in QNDE was attended by approximately 450 participants from the US and many foreign countries who presented over 375 papers The meeting was divided into 36 sessions with as many as four sessions running concurrently The Review covered all phases of NDE research and development from fundamental investigations to engineering applications or inspection systems and it included many important methods of inspection science from acoustics to x rays In the last several years the Review has stabilized at about its current size Most participants seem to agree it is large enough to permit a full scale overview of the latest developments but still small enough to retain the collegial atmosphere which has marked the Review since its inception The Proceedings are structured in a format to reflect the organization of the Review itself producing a more logical organization for both the meeting and the present volume

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