

Analysis of elastic wave propagation in stratified fluid-filled porous media for interwell seismic applications

Jorge O. Parra

Southwest Research Institute, 6220 Culebra Road, P.O. Drawer 28510, San Antonio, Texas 78228-0510

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The analytical solution for seismic wave propagation associated with a point force in a fluid-filled porous medium is developed. The point force solution is applied to solve the boundary value problem of seismic wave propagation in a stratified poroelastic medium. The coupled Biot vector wave equations are expressed in cylindrical coordinates and expanded in Fourier series with respect to azimuth. The resulting equations are transformed to the wave-number domain using the Hankel transform method. Following this analysis, one set of three coupled partial differential equations associated with fast compressional, slow compressional, and vertically polarized shear waves is derived. The unknowns are the radial and vertical displacements associated with the solid frame motion as well as the fluid pore pressure. A separate partial differential equation associated with waves whose particle motion is polarized in horizontal planes (*SH* waves) is derived as well. The general solution of the three coupled differential equations is obtained by the Kupradze method. This solution of the Biot's motion equations in the wave-number domain leads directly to closed form expressions for the vector wave displacement and the pressure produced by a point force in a poroelastic unbounded medium. In order to develop the solution of a point force in the presence of a stratified porous medium, the displacement-stress matrix, the pressure, and the vertical component of the displacement of the fluid in its relative motion versus the solid for different regions are expressed in terms of upgoing and downgoing waves and unknown wave coefficients. The wave coefficients are determined by applying boundary conditions of continuity of displacements, pressure and stresses across each layer interface, and the radiation conditions at infinity. To determine the unknown wave coefficients, a method that consists in expressing the kernels of the Hankel transform integrals in terms of factorization of upgoing and downgoing wave amplitudes in each layer is used. These factorizations are based on the generalized reflection and transmission coefficient matrices, which are formed recursively, from one layer boundary to the next, including all of the reflection/conversion/transmission properties of the layered medium. Their factorization method allows the field within each layer above or below the source to be determined once the field in the medium containing the source is known. The final equations provide a complete description of the field throughout the layered medium. The particular form of the equations makes possible the simultaneous evaluation of the response at a number of detector locations for a number of different source positions in a borehole for interwell seismic applications. Numerical model results demonstrate the validity of this theoretical development for predicting spectral responses associated with porosity and permeability effects. The seismic pressure response of a thin gas-saturated porous layer was analyzed. The results inferred that the gas-saturated porous layer strongly attenuates the waveforms observed by detectors within the layer. Alternatively, large multiple reflections and converted waves from the layer are observed by detectors in the water-saturated porous formation.

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INTRODUCTION

Many sedimentary rocks consist of a porous skeleton saturated with water. This skeleton is made up of granular particles held together by some degree of cementation; the skeleton may be a continuous matrix containing connected solution channels and vugs, or the skeleton may be a mass of fractured rock where the porosity is confined to the cracks among slightly displaced blocks. Those less predominant cases where the pore space is filled with oil or gas are of

special interest, placing important emphasis on the effects of the pore fluids on seismic velocities and other properties of porous rocks.

To approach this problem with a minimum of simplifying assumptions, Gassmann¹ supposed that the properties of the skeleton could be measured in an independent way, and he derived expressions for the corresponding properties of the rock when saturated with any fluid of known properties. In this derivation, he assumed that any relative motion between the fluid and solid was negligibly small in compari-

Seismic Wave Propagation In Stratified Media

**Jaroslava Plomerova, Robert C.
Liebermann, Vladislav Babuska**



Seismic Wave Propagation In Stratified Media:

Seismic Wave Propagation in Stratified Media Brian Kennett, 2009-05-01 Seismic Wave Propagation in Stratified Media presents a systematic treatment of the interaction of seismic waves with Earth structure. The theoretical development is physically based and is closely tied to the nature of the seismograms observed across a wide range of distance scales from a few kilometres as in shallow reflection work for geophysical prospecting to many thousands of kilometres for major earthquakes. A unified framework is presented for all classes of seismic phenomena for both body waves and surface waves. Since its first publication in 1983, this book has been an important resource for understanding the way in which seismic waves can be understood in terms of reflection and transmission properties of Earth models and how complete theoretical seismograms can be calculated. The methods allow the development of specific approximations that allow concentration on different seismic arrivals and hence provide a direct tie to seismic observations. *Seismic Wave Propagation in Stratified Media* B. L. N. Kennett, 1985-09-12 The success of this book stems from its clear and concise yet detailed summary of the advances in seismic source studies during the past two decades. Dr Kennett presents a mainly theoretical account of the passage of seismic waves from source to receiver, linking the theoretical development to the nature of seismograms observed across a wide range of distance scales from a few kilometres as in shallow reflection work for geophysical prospecting to many thousands of kilometres for earthquakes. A unified framework is presented for all classes of seismic phenomena for both body waves and surface waves. Each topic is taken up systematically, including many topics not normally covered in discussion of propagator theory such as source representation theory, generalised ray theory, and the calculation of complete theoretical seismograms including all wave effects arising from the presence of the Earth's surface. *Seismic Waves* Masaki Kanao, 2012-01-25 The importance of seismic wave research lies not only in our ability to understand and predict earthquakes and tsunamis; it also reveals information on the Earth's composition and features in much the same way as it led to the discovery of Mohorovicic's discontinuity. As our theoretical understanding of the physics behind seismic waves has grown, physical and numerical modeling have greatly advanced and now augment applied seismology for better prediction and engineering practices. This has led to some novel applications such as using artificially induced shocks for exploration of the Earth's subsurface and seismic stimulation for increasing the productivity of oil wells. This book demonstrates the latest techniques and advances in seismic wave analysis from theoretical approach, data acquisition and interpretation to analyses and numerical simulations as well as research applications. A review process was conducted in cooperation with sincere support by Drs Hiroshi Takenaka, Yoshio Murai, Jun Matsushima, and Genti Toyokuni. **Propagation of Transient Elastic Waves in Stratified Anisotropic Media** J.H.M.T. van der Hijden, 2016-05-24 Seismic waves are one of the standard diagnostic tools used to determine the mechanical parameters: volume density, mass compressibility, elastic stiffness in the interior of the earth and the geometry of subsurface structures. There is increasing evidence that in the interpretation of

seismic data especially shear wave data the influence of anisotropy must be taken into account This volume presents a method to compute the seismic waves that are generated by an impulsive source in a stratified anisotropic medium Although written with the seismic applications in mind the method that is developed is not limited to solid earth geophysics In fact the methods discussed in this monograph are applicable wherever waves propagate in stratified anisotropic media The standard approach to this problem is to employ Fourier transformations with respect to time and with respect to the horizontal spatial coordinates To obtain numerical results the relevant inverse transformations then have to be evaluated numerically In this monograph the problem is in contrast to the standard approach solved by applying the Cagniard de Hoop method and by representing the wave field as a sum of generalized rays With this method the computational results can be obtained relatively easily with any degree of accuracy and with considerably less computation time For completeness analysis of acoustic waves in stratified isotropic media is included Furthermore for large horizontal or vertical source receiver separations very efficient approximations are derived Several examples and applications are given Wave Propagation in Drilling, Well Logging and Reservoir Applications Wilson C. Chin, 2014-09-19 Wave propagation is central to all areas of petroleum engineering e g drilling vibrations MWD mud pulse telemetry swab surge geophysical ray tracing ocean and current interactions electromagnetic wave and sonic applications in the borehole but rarely treated rigorously or described in truly scientific terms even for a single discipline Wilson Chin an MIT and Caltech educated scientist who has consulted internationally provides an integrated comprehensive yet readable exposition covering all of the cited topics offering insights algorithms and validated methods never before published A must on every petroleum engineering bookshelf In particular the book Delivers drillstring vibrations models coupling axial torsional and lateral motions that predict rate of penetration bit bounce and stick slip as they depend on rock bit interaction and bottomhole assembly properties Explains why catastrophic lateral vibrations at the neutral point cannot be observed from the surface even in vertical wells but providing a proven method to avoid them Demonstrates why Fermat s principle of least time used in geophysics applies to non dissipative media only but using the kinematic wave theory developed at MIT derives powerful methods applicable to general attenuative inhomogeneous media Develops new approaches to mud acoustics and applying them to MWD telemetry modeling and strong transients in modern swab surge applications Derives new algorithms for borehole geophysics interpretation e g Rh and Rv in electromagnetic wave and permeability in Stoneley waveform analysis and Outlines many more applications e g wave loadings on offshore platforms classical problems in wave propagation and extensions to modern kinematic wave theory These disciplines important to all field oriented activities are not treated as finite element applications that are simply gridded number crunched and displayed but as scientific disciplines deserving of clear explanation General results are carefully motivated derived and applied to real world problems with results demonstrating the importance and predictive capabilities of the new methods *Monitoring the Comprehensive Nuclear-Test-Ban Treaty: Surface Waves* Anatoli L.

Levshin, Michael Ritzwoller, 2012-12-06 On September 1996 the United Nations General Assembly adopted the Comprehensive Nuclear Test Ban Treaty CTBT prohibiting nuclear explosions worldwide in all environments The treaty calls for a global verification system including a network of 321 monitoring stations distributed around the globe a data communications network an international data center IDC and on site inspections to verify compliance Seismic methods play the lead role in monitoring the CTBT This volume concentrates on the measurement and use of surface waves in monitoring the CTBT Surface waves have three principal applications in CTBT monitoring to help discriminate nuclear explosions from other sources of seismic energy to provide mathematical characterizations of the seismic energy that emanates from seismic sources and to be used as data in inversion for the seismic velocity structure of the crust and uppermost mantle for locating small seismic events regionally The papers in this volume fall into two general categories the development and or application of methods to summarize information in surface waves and the use of these summaries to advance the art of surface wave identification measurement and source characterization These papers cut across essentially all of the major applications of surface waves to monitoring the CTBT This volume therefore provides a general introduction to the state of research in this area and should be useful as a guide for further exploration **Quantitative Seismology** Keiiti Aki, Paul

Richards, 2002-09-21 This book provides a unified treatment of seismological methods that will be of use to advanced students seismologists and scientists and engineers working in all areas of seismology This new edition of the classic text by Aki and Richards has at last been updated throughout to systematically explain key concepts in seismology Now in one volume the book provides a unified treatment of seismological methods that will be of use to advanced students seismologists and scientists and engineers working in all areas of seismology *Earthquake Microzoning* Antoni Roca, Carlos

Oliveira, 2012-12-06 In many past and recent earthquakes it has been shown that the local conditions and in particular the local geology have a great influence on the observed seismic ground motion and consequently on the damage distribution in housing industrial stock and life lines Seismic microzoning is the usual procedure to have these local effects taken into account for engineering design and land use planning being a useful tool for earthquake risk mitigation This volume presents a collection of papers mainly originated from a workshop on Seismic Microzoning organized during the 23rd General Assembly of the European Geophysical Society EGS in Nice France in April 1998 The workshop dealt with various geophysical tools for analysing the effects of the local soils of subsurface geology on seismic ground motion namely the methods using experimental data such as microtremors and the theoretical numerical 1 D and 2 D modelling methods Additional contributions discussing techniques for characterising soil properties microzoning applications to several urban areas and others were added to the volume to broaden this important topic **Geodynamics of Lithosphere & Earth's**

Mantle Jaroslava Plomerova, Robert C. Liebermann, Vladislav Babuska, 2012-12-06 Plate tectonics has significantly broadened our view of the dynamics of continental evolution involving both the processes currently active at the surface and those

extending deep into the interior of the Earth Seismic anisotropy provides some of the most diagnostic evidence for mapping past and present deformation of the entire crustmantle system This volume contains papers presented originally at an international workshop at the Chateau of Trest in the Czech Republic in 1996 This workshop brought together geophysicists and geologists who work in the field of observational and theoretical seismology mineral and rock physics gravity studies and geodynamic modelling Topics include large scale anisotropy of the Earth s mantle mantle heterogeneity vs anisotropy 3 D velocity and density structures and inferences on mantle dynamics mineral and rock physics studies and mathematical aspects of complex wave propagation

Variational Views in Mechanics Paolo Maria Mariano, 2022-02-08 This volume provides a timely survey of interactions between the calculus of variations and theoretical and applied mechanics Chapters have been significantly expanded since preliminary versions appeared in a special issue of the Journal of Optimization Theory and Applications 184 1 2020 on Calculus of Variations in Mechanics and Related Fields The variety of topics covered offers researchers an overview of problems in mechanics that can be analyzed with variational techniques making this a valuable reference for researchers in the field It also presents ideas for possible future areas of research showing how the mastery of these foundational mathematical techniques can be used for many exciting applications Specific topics covered include Topology optimization Identification of material properties Optimal control Plastic flows Gradient polyconvexity Obstacle problems Quasi monotonicity Variational Views in Mechanics will appeal to researchers in mathematics solid states physics and mechanical civil and materials engineering

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 Earths 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 Earths 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

Reflection Seismology Yang Wencai, 2013-09-18 Authored by a geophysicist with more than 50 years of experience in research and instruction Reflection Seismology Theory Data Processing and Interpretation provides a single source of foundational knowledge in reflection

seismology principles and theory Reflection seismology has a broad range of applications and is used primarily by the oil and gas industry to provide high resolution maps and build a coherent geological story from maps of processed seismic reflections Combined with seismic attribute analysis and other exploration geophysics tools it aids geologists and geo engineers in creating geological models of areas of exploration and extraction interest Yet as important as reflection seismology is to the hydrocarbon industry it s difficult to find a single source that synthesizes the topic without having to wade through numerous journal articles from a range of different publishers This book is a one stop source of reflection seismology theory helping scientists navigates through the wealth of new data processing techniques that have emerged in recent years Provides geoscientists and geo engineers with a theoretical framework for navigating the rapid emergence of new data processing techniques Presents a single source of reflection seismology content instead of a scattering of disparate journal articles Features more than 100 figures illustrations and working examples to aid the reader in retaining key concepts Arms geophysicists and geo engineers with a solid foundation in seismic wave equation analysis and interpretation

Elastic Waves in Solids, Volume 2 Tony Valier-Brasier, Daniel Royer, 2022-07-20 Elastic waves are used in fields as diverse as the non destructive evaluation of materials medicine seismology and telecommunications Elastic Waves in Solids 2 analyzes the radiation scattering and generation of these waves It studies the emission of bulk or surface waves from sources localized on the surface of an isotropic or anisotropic solid It then examines the scattering of a longitudinal or transverse elastic wave by one or more cylindrical or spherical heterogeneities Finally it explores the methods and devices used to generate and detect elastic waves using the piezoelectric effect or the interaction with a laser beam Accompanying figures illustrate these properties and the text provides the orders of magnitude of some characteristic parameters This book is intended for students completing a master s degree in acoustics mechanics geophysics or engineering as well as teachers and researchers in these disciplines *Introduction to Seismology* Peter Shearer, 1999-09-28 An approachable and concise introduction to seismology for upper division undergraduates and first year graduate students Mechanics of Elastic Waves and Ultrasonic Nondestructive Evaluation Tribikram Kundu, 2019-07-09 Summary This book presents necessary background knowledge on mechanics to understand and analyze elastic wave propagation in solids and fluids This knowledge is necessary for elastic wave propagation modeling and for interpreting experimental data generated during ultrasonic nondestructive testing and evaluation NDT E The book covers both linear and nonlinear analyses of ultrasonic NDT E techniques The materials presented here also include some exercise problems and solution manual Therefore this book can serve as a textbook or reference book for a graduate level course on elastic waves and or ultrasonic nondestructive evaluation It will be also useful for instructors who are interested in designing short courses on elastic wave propagation in solids or NDT E The materials covered in the first two chapters provide the fundamental knowledge on linear mechanics of deformable solids while Chapter 4 covers nonlinear mechanics Thus both linear and nonlinear ultrasonic techniques are

covered here Nonlinear ultrasonic techniques are becoming more popular in recent years for detecting very small defects and damages However this topic is hardly covered in currently available textbooks Researchers mostly rely on published research papers and research monographs to learn about nonlinear ultrasonic techniques Chapter 3 describes elastic wave propagation modeling techniques using DPSM Chapter 5 is dedicated to an important and very active research field acoustic source localization that is essential for structural health monitoring and for localizing crack and other type of damage initiation regions Features Introduces Linear and Nonlinear ultrasonic techniques in a single book Commences with basic definitions of displacement displacement gradient traction and stress Provides step by step derivations of fundamental equations of mechanics as well as linear and nonlinear wave propagation analysis Discusses basic theory in addition to providing detailed NDE applications Provides extensive example and exercise problems along with an extensive solutions manual

Advanced Mathematical Tools In Metrology - Proceedings Of The International Workshop Nicola Bellomo, Patrizia Ciarlini, Maurice G Cox, Roberto Monaco, Franco Pavese, 1994-05-18 Since its reform and opening up China has experienced unprecedented social and economic development It is important to understand the biggest and fastest growing economy s policy and strategy As a key director in Party School of the Central Committee of the Communist Party of China the author proposes a development path and reform strategies for China in the next three decades This book suggests reform strategies not only for the economic structure but also for the political system in China The author makes a sound analysis and exposition of Chinese dream which reflects the vision of a better life in the future and the main indicators of social change The book investigates China s development path political system economic structure people s livelihood etc and suggests long term strategies for China in this regard

Dynamics of Smart Structures Ranjan Vepa, 2010-03-10 Dynamics of Smart Structures is a practical concise and integrated text that provides an introduction to the fundamental principles of a field that has evolved over the recent years into an independent and identifiable subject area Bringing together the concepts techniques and systems associated with the dynamics and control of smart structures it comprehensively reviews the differing smart materials that are employed in the development of the smart structures and covers several recent developments in the field of structural dynamics Dynamics of Smart Structures has been developed to complement the author s new interdisciplinary programme of study at Queen Mary University of London that includes courses on emerging and new technologies such as biomimetic robotics smart composite structures micro electro mechanical systems MEMS and their applications and prosthetic control systems It includes chapters on smart materials and structures transducers for smart structures fundamentals of structural control dynamics of continuous structures dynamics of plates and plate like structures dynamics of piezoelectric media mechanics of electro actuated composite structures dynamics of thermo elastic media shape memory alloys and controller designs for flexible structures

Analysis of Piezoelectric Structures and Devices Daining Fang, Ji Wang, Weiqiu Chen, 2013-08-01 This edited work covers piezoelectric materials in the form of beams plates

shells and other structural components in modern devices and structures Applications are frequency control and detection functions in resonators sensors actuators oscillations and other smart and intelligent structures The products and technology are with us in our daily life through computers and communication devices The contributions cover novel methods for the analysis of piezoelectric structures including wave propagation high frequency vibration material characterization and optimization of structures Understanding of these methods is increasingly important in the design and modelling of next generation devices and micro structures with piezoelectric elements and effects *DPSM for Modeling Engineering Problems* Dominique Placko, Tribikram Kundu, 2007-07-09 This book is the first book on this technique it describes the theory of DPSM in detail and covers its applications in ultrasonic magnetic electrostatic and electromagnetic problems in engineering For the convenience of the users the detailed theory of DPSM and its applications in different engineering fields are published here in one book making it easy to acquire a unified knowledge on DPSM *An Introduction to Seismology, Earthquakes, and Earth Structure* Seth Stein, Michael Wysession, 2013-05-30 *An Introduction to Seismology Earthquakes and Earth Structures* is an introduction to seismology and its role in the earth sciences and is written for advanced undergraduate and beginning graduate students The fundamentals of seismic wave propagation are developed using a physical approach and then applied to show how refraction reflection and teleseismic techniques are used to study the structure and thus the composition and evolution of the earth The book shows how seismic waves are used to study earthquakes and are integrated with other data to investigate the plate tectonic processes that cause earthquakes Figures examples problems and computer exercises teach students about seismology in a creative and intuitive manner Necessary mathematical tools including vector and tensor analysis matrix algebra Fourier analysis statistics of errors signal processing and data inversion are introduced with many relevant examples The text also addresses the fundamentals of seismometry and applications of seismology to societal issues Special attention is paid to help students visualize connections between different topics and view seismology as an integrated science *An Introduction to Seismology Earthquakes and Earth Structure* gives an excellent overview for students of geophysics and tectonics and provides a strong foundation for further studies in seismology Multidisciplinary examples throughout the text catering to students in varied disciplines geology mineralogy petrology physics etc Most up to date book on the market includes recent seismic events such as the 1999 Earthquakes in Turkey Greece and Taiwan Chapter outlines each chapter begins with an outline and a list of learning objectives to help students focus and study Essential math review an entire section reviews the essential math needed to understand seismology This can be covered in class or left to students to review as needed End of chapter problem sets homework problems that cover the material presented in the chapter Solutions to all odd numbered problem sets are listed in the back so that students can track their progress Extensive References classic references and more current references are listed at the end of each chapter A set of instructor s resources containing downloadable versions of all the figures in the book errata

and answers to homework problems is available at <http://levee.wustl.edu/seismology/book> Also available on this website are PowerPoint lecture slides corresponding to the first 5 chapters of the book

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Seismic Wave Propagation In Stratified Media Introduction

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