Geomechanical And Petrophysical Properties Of Mudrocks

This book offers a practical reference guide to soft rock mechanics for engineers and scientists. Written by recognized experts, it will benefit professionals, contractors, academics, researchers and students working on rock engineering projects in the fields of civil engineering, mining and construction engineering. Soft Rock Mechanics and Engineering covers a specific subject of great relevance in Rock Mechanics – and one that is directly connected to the design of geotechnical structures under difficult ground conditions. The book addresses practical issues related to the geomechanical properties of these types of rock masses and their characterization, while also discussing advances regarding in situ investigation, safety, and monitoring of geotechnical structures in soft rocks. Lastly, it presents important case histories involving tunnelling, dam foundations, coal and open pit mines and landslides.

A comprehensive overview of the key geologic, geomechanical and engineering principles that govern the development of unconventional oil and gas reservoirs. Covering hydrocarbon-bearing formations, horizontal drilling, reservoir seismology and environmental impacts, this is an invaluable resource for geologists, geophysicists and reservoir engineers.

A surge of interest in the geomechanical and petrophysical properties of mudrocks (shales) has taken place in recent years following the development of a shale gas industry in the United States and elsewhere, and with the prospect of similar developments in the UK. Also, these rocks are of particular importance in excavation and construction geotechnics and other rock engineering applications, such as underground natural gas storage, carbon dioxide disposal and radioactive waste storage. They may greatly influence the stability of natural and engineered slopes. Mudrocks, which make up almost three-quarters of all the sedimentary rocks on Earth, therefore impact on many areas of applied geoscience. This volume focuses on the mechanical behaviour and various physical properties of mudrocks. The 15 chapters are grouped into three themes: (i) physical properties such as porosity, permeability, fluid flow through cracks, strength and geotechnical behaviour; (ii) mineralogy and microstructure, which control geomechanical behaviour; and (iii) fracture, both in laboratory studies and in the field.

Covering a wide range of topics involving both research developments and applications, resulting from the 10th International Conferecne on Computer Methods and Advances in Geomechanics (IACMAG) held in January 2001 in Tucson, Arizona, USA. The theme of the conference was Fundamentals through Applications. The up-to-date research results and applications in this 2-volume work (> 1900 pages) should serve as a valuable source of information for those engaged in research, analysis and design, practical application, and education in the fields of geomechanics and geotechnical engineering.

The study of reservoir and repository performance requires the integration of many different fields in Earth sciences, among them rock physics and geomechanics. The aim of this book is to emphasize how rock physics and geomechanics help to get a better insight into important issues linked to reservoir management for exploitation of natural resources, and to repository safety assessment for hazardous waste storage in geological environment. The studies presented here deal with the hydromechanical coupling in fractured rocks, the key experiments in safety assessment of repositories, the development of damaged zones during excavation in a shaley formation, the influence of temperature on the properties of shales, the poroelastic response of sandstones, the development and propagation of compaction bands in reservoir rocks, imaging techniques of geomaterials, the characterization and modelling of reservoirs using 4D seismic data, the mechanical behaviour of fractured rock masses, the petrophysical properties of fault zones, models for rock deformation by pressure solution and the elastic anisotropy in cracked rocks.

GeoProc2008 collects the proceedings of the International Conference on Coupled T-H-M-C (thermal, hydraulic, mechanical, chemical) Processes in Geosystems.

For many years, the Waipawa and Whangai formation mudstones have garnered considerable interest as petroleum source rocks. More recently, the Waipawa Formation has attracted attention as a potential unconventional reservoir and has even been likened to the Bakken and Barnett shales in North America. However, at present there is a paucity of information on the petrophysical and geomechanical properties of the Whangai and Waipawa formation mudstones. Understanding how the rock properties control the elastic behaviour of these mudstones is essential for accurate geophysical interpretation and reservoir characterization. Five preserved cores from Orui–1A and Te Mai–2 wells in the East Coast Basin have been analyzed in order to understand the compositional and textural controls on the propagation of elastic waves, the dynamic elastic moduli and their use in interpreting the geomechanical properties of the rocks. High density and directional P–wave velocity scans on large cores and subsampled plugs was undertaken using non-contacting laser-based ultrasonics. Additional P and S–wave data were acquired on core plugs using contacting ultrasonic transducers. Composition was determined with X–ray diffraction, X–ray fluorescence and Source Rock Analysis, and rock texture was characterized via thin section petrography. This study finds that composition is the dominant control on the wave velocities observed in these mudstones. Rocks which are higher in clay and kerogen composition have lower wave velocities, with kerogen exerting a stronger influence. Velocity anisotropy ranges from 2% to 15% within the samples with no apparent relationship between overall composition and the degree of anisotropy. High density elastic data acquired with a laser-ultrasonic system shows for the first time how sample heterogeneity (e.g. fractures or lateral changes in mineralogy/porosity) and layering affect the P-wave velocities. Anisotropy appears to be influenced by the alignment of minerals and variation in composition with respect to the orientation of the scans. The presence of fractures and veins have been found to enhance anisotropy. However, veins and open fractures have also been found to diminish the effects of laying induced anisotropy if the vein is approximately in the same plane as layering. Estimations of brittleness based on Young’s modulus and Poisson’s ratio indicate that the Whangai Formation may be well suited to hydraulic fracturing, with brittleness values as high as 63%. The Waipawa Formation is less brittle and maybe less well suited than the Whangai Formation.

This thesis presents an important step towards a deeper understanding of naturally fractured carbonate reservoirs (NFCRs). It demonstrates the various kinds of discontinuities using geological evidence, mathematical kinematics model and computed tomography and uses this as a basis for proposing a new classification for NFCRs. Additionally, this study takes advantage of rock mechanics theory to illustrate how natural fractures can collapse due to fluid flow and pressure changes in the fractured media. The explanations and mathematical modeling developed in this dissertation can be used as diagnostic tools to predict fluid velocity, fluid flow, tectonic fracture collapse, pressure behavior during reservoir depleting, considering stress-sensitive and non-stress-sensitive, with nonlinear terms in the diffusivity equation applied to NFCRs. Furthermore, the book presents the description of real reservoirs with their field data as the principal goal in the mathematical description of the realistic phenomenology of NFCRs.

From driverless cars to vehicular networks, recent technological advances are being employed to increase road safety and improve driver satisfaction. As with any newly developed technology, researchers must take care to address all concerns, limitations, and dangers before widespread public adoption. Transportation Systems and Engineering: Concepts, Methodologies, Tools, and Applications addresses current trends in transportation technologies, such as smart cars, green technologies, and infrastructure development. This multivolume book is a critical reference source for engineers, computer scientists, transportation authorities, students, and practitioners in the field of transportation systems management.

The Longmaxi Formation, in the Middle and Upper Yangtze region of China, has much potential for exploration and commercial resource development. This thesis characterizes the Longmaxi marine shale using well logs from two vertical wells and three horizontal wells in the southern Sichuan Basin, China. Geomechanical properties were determined by log data. The maximum permissible hydraulic fracturing net pressure with respect to the maximum fracture height was predicted. According to the log curves in the two vertical wells, there are two apparent boundaries in the Longmaxi Formation. Above the first boundary, the upper lime mudstone and limestone zone are located at the top of an organic shale layer. Below the organic shale zone is a limestone zone. The well logs show low porosity (average 6%) in the organic gas-bearing shale layer. Free gas accounts for about 50% of the total gas. The layer is high in quartz content (50%) and low in clay content (20%). These percentages indicate that the Lower Silurian Longmaxi Formation is brittle, and the lower mechanical moduli of the organic shale layer compared to the adjacent rock layers suggests the ability of this interval to contain the induced fractures. This constrains fracture propagation within the gas-bearing shale layers with respect to the fixed production rate and treatment pressure. According to my results, the maximum permissible net treatment pressure of vertical Well 1 in the fracture is 12.9 MPa, whereas in vertical Well 2 the maximum permissible net pressure is 4.5 MPa because of its thinner shale layer thickness compared to conditions in vertical Well 1.

CO_2 capture and geological storage is seen as the most effective technology to rapidly reduce the emission of greenhouse gases into the atmosphere. Up until now and before proceeding to an industrial development of this technology, laboratory research has been conducted for several years and pilot projects have been launched. So far, these studies have mainly focused on transport and geochemical issues and few studies have been dedicated to the geomechanical issues in CO_2 storage facilities. The purpose of this book is to give an overview of the multiphysics processes occurring in CO_2 storage facilities, with particular attention given to coupled geomechanical problems. The book is divided into three parts. The first part is dedicated to transport processes and focuses on the efficiency of the storage complex and the evaluation of possible leakage paths. The second part deals with issues related to reservoir injectivity and the presence of fractures and occurrence of damage. The final part of the book concerns the serviceability and ageing of the geomaterials whose poromechanical properties may be altered by contact with the injected reactive fluid.

The accelerated growth of the world population creates an increase of energy needs. This requires new paths for oil supply to its users, which can be potential hazardous sources for individuals and the environment. Risk Analysis for Prevention of Hazardous Situations in Petroleum and Natural Gas Engineering explains the potential hazards of petroleum engineering activities, emphasizing risk assessments in drilling, completion, and production, and the gathering, transportation, and storage of hydrocarbons. Designed to aid in decision-making processes for environmental protection, this book is a useful guide for engineers, technicians, and other professionals in the petroleum industry interested in risk analysis for preventing hazardous situations.

The key driver for both the Hedberg conference and this publication was the recognition that knowledge of risk in the estimation of sealing capacity and fault-seal potential is important in making judgments at the exploration, appraisal, and development stages of the petroleum business. In addition, incorporating seal risk in the overall assessment of hydrocarbons in place can affect decisions to drill prospects and the location of appraisal and development wells, as well as reserve estimation.

This book covers a range of topics that are of increasingimportance in engineering practice: natural hazards, pollution, andenvironmental protection through good practice. The first half of the book deals with natural risk factors, ofboth natural and human origin, that should be considered:subsidence, accidental infiltration, soil instability, rockslidesand mudslides, debris flow, and degradation of buildings andmonuments due to pollution and climactic effects, for example.These problems are highlighted and it is shown that a combinationof sophisticated numerical techniques and extensive experimentalinvestigations are necessary in order to effectively tackle theseproblems. The second half of the book is devoted to the use of pollutedsites and associated problems, a topic of growing significancegiven the increasing reclamation of land from abandoned industrialsites for urban development over the last 20 years. Different typesof oil pollution and decontamination methods are described,followed by a discussion of waste management and detailed coverageof confinement liners used in surface waste disposal.

Effective measurement of the composition and properties of petroleum is essential for its exploration, production, and refining; however, new technologies and methodologies are not adequately documented in much of the current literature. Analytical Methods in Petroleum Upstream Applications explores advances in the analytical methods and instrumentation that allow more accurate determination of the components, classes of compounds, properties, and features of petroleum and its fractions. Recognized experts explore a host of topics, including: A petroleum molecular composition continuity model as a context for other analytical measurements A modern modular sampling system for use in the lab or the process area to collect and control samples for subsequent analysis The importance of oil-in-water measurements and monitoring The chemical and physical properties of heavy oils, their fractions, and products from their upgrading Analytical measurements using gas chromatography and nuclear magnetic resonance (NMR) applications Asphaltene and heavy ends analysis Chemometrics and modeling approaches for understanding petroleum composition and properties to improve upstream, midstream, and downstream operations Due to the renaissance of gas and oil production in North America, interest has grown in analytical methods for a wide range of applications. The understanding provided in this text is designed to help chemists, geologists, and chemical and petroleum engineers make more accurate estimates of the crude value to specific refinery configurations, providing insight into optimum development and extraction schemes.

Geomechanics investigates the origin, magnitude and deformational consequences of stresses in the crust. In recent years awareness of geomechanical processes has been heightened by societal debates on fracking, human-induced seismicity, natural geohazards and safety issues with respect to petroleum exploration drilling, carbon sequestration and radioactive waste disposal. This volume explores the common ground linking geomechanics with inter alia economic and petroleum geology, structural geology, petrophysics, seismology, geotechnics, reservoir engineering and production technology. Geomechanics is a rapidly developing field that brings together a broad range of subsurface professionals seeking to use their expertise to solve current challenges in applied and fundamental geoscience. A rich diversity of case studies herein showcase applications of geomechanics to hydrocarbon exploration and field development, natural and artificial geohazards, reservoir stimulation, contemporary tectonics and subsurface fluid flow. These papers provide a representative snapshot of the exciting state of geomechanics and establish it firmly as a flourishing subdiscipline of geology that merits broadest exposure across the academic and corporate geosciences.

"Although carbonate reservoirs hold a wealth of hydrocarbon, they are among the most difficult types of reservoirs to be characterized. Carbonate reservoirs by nature have complex depositional environments and diagenetic processes in which brittle, ductile, fractured rocks, and vugular pores may all exist within small interval. This huge variance in the rock mechanical properties can cause challenges in the reservoir's development, especially in applications related to geomechanics. The main objective of this research is to geomechanically characterize and correlate the carbonate mechanical properties with their petrophysical properties. A comprehensive review for the geomechanical-petrophysical properties of carbonates was conducted from previous studies. Data from offset well have also been used to develop an integrated methodology that examines the uncertainty of carbonate wellbore integrity. The results present a new engineering classification to evaluate the carbonate drillability and deformability. Additional developments regarding the relationships between the carbonate compressive strength and confining pressure, maximum shear stress and mean stress, and internal friction angle and unconfined compressive strength (UCS) are systematically investigated based on the compiled database. New correlations to predict the UCS and Young's modulus of each carbonate type have been developed from the petrophysical properties. Applying P90 as a threshold on the estimated minimum mud weight proved to be conservative. For fracture mud weight, the field data showed that the P50 threshold did not prevent fluid losses. This study contributes toward better methods to predict shear wave velocities exemplified with field cases in Southeast Iraq"--Abstract, page iv.

Gas shale is a fine grained clastic, fissile sedimentary rock of gray/black color formed by consolidation of clays and silts. Successful petrophysical evaluation and stimulation treatments with horizontal drilling and hydraulic fracturing enable economic shale gas production. Shale gas development has contributed about 35 % of natural gas supply in US in 2013.Detailed evaluation of gas shales before and after stimulation treatments is a prerequisite to optimize gas production. Complex pore network in gas shales may result in inaccurate evaluation of petrophysical properties with traditional petrophysical models. Therefore, in this research we proposed a new methodology comprising a new understanding of evaluation of porosity, maturity analysis, geomechanical properties and initial gas in place calculations of gas shale via well logs and core analysis based on a new petrophysical model. We applied the methodology in a case study to investigate a Marcellus shale well in evaluating maturity, porosity and geomechanical properties to calculate initial gas in place and reserves and optimize stimulation designs. In the second part of this study, we conducted acoustic travel time measurements of Green River shale samples parallel and perpendicular to bedding plane before and after interaction with water to observe how shale interacts with water at different interaction times and bedding planes by analyzing change in acoustic velocity and mechanical properties before and after treatment to optimize stimulation designs. X-Ray diffraction analysis, scanning electron microscope imaging and horizontal and vertical permeability measurements of Green River shale samples using helium are conducted to characterize the samples by observing mineralogy, pore network and how permeability changes at different in-situ conditions. Therefore, the first and second parts of this research relate with utilization of well logs and core analysis to evaluate petrophysical properties of different gas shale formations.Maturity analysis, porosity evaluation and initial gas in place results of field case study of Marcellus shale show that total organic carbon content directly relates with porosity and adsorbed gas in place occupied in organic matter. Comparison of young's modulus and minimum in-situ stress values between Marcellus shale zone and adjacent boundaries are used for determination of stimulation interval in Marcellus Formation. An effective hydraulic fracturing treatment can be applied within the upper Marcellus Formation because of relatively higher minimum in-situ stress contrast between Stafford Limestone and upper Marcellus Formation. Closer porosity results of Marcellus shale when compared to that in literature and sufficient reserves suggest that density/resistivity separation method is more reliable than sonic/resistivity separation method. X-Ray diffraction and SEM images suggest that Green River Formation samples are dominantly comprised of carbonate minerals. Permeability measurements indicate that Green River Formation samples having very low permeability at various confining stresses needs to be stimulated effectively. Acoustic travel time measurements of Green River shale before and after interaction with water show that compressional and shear velocities increase as confining stress increases. Shear, young's and bulk modulus of Green River shale increase resulting in more rigid samples having more fracture conductivity as confining stress increases. Compressional and shear velocities decrease as Green River shale is exposed to water since minerals are dissolved by water solution and salinity of the samples decrease so that shear, young's and bulk modulus of the samples slightly decrease resulting in less rigid samples having lower fracture conductivity.The new methodology of petrophysical evaluation of gas shale based on the new petrophysical model serves a new understanding of evaluation of maturity analysis, porosity and mechanical properties and initial gas in place calculations of gas shale by utilizing well logs in field and core analysis in laboratory. Wireline formation testers are widely used to measure in-situ fluid pressure, to retrieve reservoir fluid samples, and to estimate formation mobility. However, formation-tester measurements are invariably influenced by mud-filtrate invasion due to drilling overbalance pressure, thereby affecting the acquisition of uncontaminated fluid samples and the estimation of in-situ petrophysical properties. Moreover, in cases of stress-sensitive formations, rock mechanical deformation may take place due to the combined effects of in-situ stress, wellbore stress imposed by mud overbalance, and wellbore pressure exerted by the formation tester itself. The latter deformation causes near-borehole perturbations of porosity and permeability that are evidenced by pressure transients measured during build-up and shut-in stages of formation testing, especially when using dual-packer pressure probes. If unaccounted for, such perturbations can also bias the estimation of in-situ fluid and petrophysical properties. Conversely, the detection and quantification of elastic mechanical deformation effects on measured pressure transients can be used to infer the underlying rock elastic and petrophysical properties of the stressed formation. The purpose of this dissertation is twofold: (a) to quantify the relative effects of mud-filtrate invasion and geomechanical deformation on pressure-transient measurements acquired with dual-packer formation testers, with special emphasis on the appraisal of near-borehole porosity and permeability enhancement due to elastic mechanical deformation, and (b) to develop a new method to estimate elastic and petrophysical properties of rock formations from dual-packer pressure transients acquired in mechanically deformable rocks. Numerical simulations of

mud-filtrate invasion are performed with an axialsymmetric two-phase (water-oil) method that enforces the specific boundary and source conditions of a wellbore that penetrates horizontal layers. Simulations are performed in a cylindrical system of coordinates using finite differences together with an implicit-pressure, explicit-saturation time-marching approach that also incorporates the dynamic conditions of immiscible mudcake growth due to filtration of solids at the wellbore. Laboratory experiments are conducted to further study pressure transients due to formation testing in the presence of invasion with water-base mud. Experiments include the effects of both mud circulation and mudcake on pressure-transient measurements and are performed on a variety of rock-core samples. Measurements are successfully validated with both the developed simulator and a commercial simulator, thereby lending credence to the assumed model of dynamic solid filtration. The developed mud-filtrate fluid-flow simulator is coupled with a finite-element code that assumes 2D axial-symmetric linear elasticity to quantify geomechanical deformation. Coupling of mechanical deformation with variations of porosity and permeability assumes a staggered-in-time, iteratively coupled volumetric model. We assume a dual-packer formation tester to quantify elastic deformation effects in stress-sensitive formations as a preamble to estimating in-situ elastic and petrophysical properties. It is shown that near-wellbore spatial variations of porosity and permeability due to mechanical deformation can bias the corresponding pressure-transient measurements acquired with the dual-packer formation-tester. The degree of biasing depends on the rigidity of the stressed formation. Finally, we develop a method to estimate in-situ petrophysical and elastic rock properties from pressure-transient measurements acquired with formation-testers in mechanically deformable rocks. Petrophysical and elastic properties will change in both time and space depending on the time evolution of the conditions that influence mechanical deformation. We use a commercial reservoir simulator to calculate pressure transients due to fluid pumpout in the presence of both invasion and mechanical deformation. A pre-stressed initial condition due to mud overbalance is assumed with incremental deformation due to surface force applied by the packers or probes, and active flow imposed by the formation-tester. In so doing, we consider pressure data sets acquired with both flow and observation probes during draw-down and build-up periods. For cases where a-priori information can be sufficiently constrained, our estimation method provides reliable and accurate estimates of petrophysical and elastic properties in the presence of moderate levels of random noise.
This book is one out of 8 IAEG XII Congress volumes, and deals with the theme of applied geology, which is a critical theme for the global economy. In the international, multidisciplinary approach to major engineering projects (either to macro- or mega-scale), the application of geological investigation techniques is fundamental for properly selecting the location sites, planning the construction and maintaining the infrastructures. The contributions in this book include not only engineering constructions but also case studies related to large projects on geo-resources exploration and extraction

(minerals, petroleum and groundwater), energy production (hydropower, geothermal, nuclear and others), transportation (railway and highway) and waste disposal as well as the environmental management of these and other activities. The Engineering Geology for Society and Territory volumes of the IAEG XII Congress held in Torino from September 15-19, 2014, analyze the dynamic role of engineering geology in our changing world and build on the four main themes of the congress: Environment, processes, issues, and approaches. The congress topics and subject areas of the 8 IAEG XII Congress volumes are: 1. Climate Change and Engineering Geology 2. Landslide Processes 3. River Basins, Reservoir Sedimentation and Water Resources 4. Marine and Coastal Processes 5. Urban Geology, Sustainable Planning and Landscape Exploitation 6. Applied Geology for Major Engineering Projects 7. Education, Professional Ethics and Public Recognition of Engineering Geology 8. Preservation of Cultural Heritage.

Core Analysis: A Best Practice Guide is a practical guide to the design of core analysis programs. Written to address the need for an updated set of recommended practices covering special core analysis and geomechanics tests, the book also provides unique insights into data quality control diagnosis and data utilization in reservoir models. The book's best practices and procedures benefit petrophysicists, geoscientists, reservoir engineers, and production engineers, who will find useful information on core data in reservoir static and dynamic models. It provides a solid understanding of the core analysis procedures and methods used by commercial laboratories, the details of lab data reporting required to create quality control tests, and the diagnostic plots and protocols that can be used to identify suspect or erroneous data. Provides a practical overview of core analysis, from coring at the well site to laboratory data acquisition and interpretation Defines current best practice in core analysis preparation and test procedures, and the diagnostic tools used to quality control core data Provides essential information on design of core analysis programs and to judge the quality and reliability of core analysis data ultimately used in reservoir evaluation Of specific interest to those working in core analysis, porosity, relative permeability, and geomechanics

A comprehensive textbook presenting techniques for the analysis and characterization of shale plays Significant reserves of hydrocarbons cannot be extracted using conventional methods. Improvements in techniques such as horizontal drilling and hydraulic fracturing have increased access to unconventional hydrocarbon resources, ushering in the “shale boom” and disrupting the energy sector. Unconventional Hydrocarbon Resources: Techniques for Reservoir Engineering Analysis covers the geochemistry, petrophysics, geomechanics, and economics of unconventional shale oil plays. The text uses a step-by-step approach to demonstrate industry-standard workflows for calculating resource volume and optimizing the extraction process. Volume highlights include: Methods for rock and fluid characterization of unconventional shale plays A workflow for analyzing wells with stimulated reservoir volume regions An unconventional approach to understanding of fluid flow through porous media A comprehensive summary of discoveries of massive shale resources worldwide Data from Eagle Ford, Woodford, Wolfcamp, and The Bakken shale plays Examples, homework assignments, projects, and access to supplementary online resources Hands-on teaching materials for use in petroleum engineering software applications The American Geophysical Union promotes discovery in Earth and space science for the benefit of humanity. Its publications disseminate scientific knowledge and provide resources for researchers, students, and professionals.

A symbiosis of a brief description of physical fundamentals of the rock properties (based on typical experimental results and relevant theories and models) with a guide for practical use of different theoretical concepts.

This book is intended as a reference book for advanced graduate students and research engineers in shale gas development or rock mechanical engineering. Globally, there is widespread interest in exploiting shale gas resources to meet rising energy demands, maintain energy security and stability in supply and reduce dependence on higher carbon sources of energy, namely coal and oil. However, extracting shale gas is a resource intensive process and is dependent on the geological and geomechanical characteristics of the source rocks, making the development of certain formations uneconomic using current technologies. Therefore, evaluation of the physical and mechanical properties of shale, together with technological advancements, is critical in verifying the economic viability of such formation. Accurate geomechanical information about the rock and its variation through the shale is important since stresses along the wellbore can control fracture initiation and frac development. In addition, hydraulic fracturing has been widely employed to enhance the production of oil and gas from underground reservoirs. Hydraulic fracturing is a complex operation in which the fluid is pumped at a high pressure into a selected section of the wellbore. The interaction between the hydraulic fractures and natural fractures is the key to fracturing effectiveness prediction and high gas development. The development and growth of a hydraulic fracture through the natural fracture systems of shale is probably more complex than can be described here, but may be somewhat predictable if the fracture system and the development of stresses can be explained. As a result, comprehensive shale geomechanical experiments, physical modeling experiment and numerical investigations should be conducted to reveal the fracturing mechanical behaviors of shale.

Praise for Reservoir Geomechanics: --

Special emphasis is given to the constitutive behaviour of rock material, including rock mechanics and partial saturation, chemo-mechanics, thermo-hydro-mechanics, weathering and creep. Theoretical concepts, laboratory and field experiments and numerical simulations are discussed. Multiphysics coupling and long-term behaviour has practical applications in a number of areas. In oil engineering (enhanced oil recovery, CO_2 injection, and well stability); in underground waste storage, post-mine behaviour and the long-term behaviour of railway and road infrastructures. This book will be useful to professionals and academics working in a variety of fields related to rock mechanics and environmental geotechnics. .

Hardcover plus CD

Geomechanical processes occurring during steam assisted gravity drainage (SAGD) thermal recovery influence petrophysical and

rock mechanical properties of both reservoir and caprock formations. While geostatistical techniques provide multiple equi probable geological realizations for petrophysical properties, rock mechanical properties are traditionally considered as homogenously in reservoir geomechanical simulations of the SAGD process. This research has shown that consideration of heterogeneous facies and rock mechanical properties will result in a larger range of possible outcomes, such as vertical displacement within the reservoir, than simulation models that adopt homogeneous facies and property distributions. Typically, only a select number of geological realizations are selected for simulation. Randomly selecting geological realizations will not accurately represent uncertainty and they should be selected based on appropriate ranking criteria. A ranking criterion, which is in good correlation with expected elastic deformation of reservoir, has been developed in this research. The developed ranking technique is based on expected elastic deformation of each cell considered in numerical simulation of SAGD. Geometrical calibration parameters are adopted within the developed ranking technique. Upscaling of geological models and moving from high resolution geological models to coarse scale simulation models results in reduction of number of cells and accordingly reduction of computational cost. A new numerical technique for upscaling of elastic properties has been proposed. Two major advantages of the new geomechanical upscaling technique include the ability to consider transversely isotropic deformation and independence from coarse scale properties with respect to facies configuration. The ranking and upscaling approaches were applied to a McMurray Formation field case study dataset. In comparison to upscaling techniques based on averaging, the numerical upscaling technique provided a reduction in simulation error. In addition, application of the upscaling technique to real field data confirmed the reduction in computational time for reservoir geomechanical simulations.
Due to its lower cost, the cold heavy oil production with sands (CHOPS) method is a common primary production recovery technique, not only in Canada where it originated, but also in many other countries including Venezuela, Kuwait, Russia, and China. However, this method has several practical limitations. It continuously changes the geomechanical and petro-physical properties of the reservoir due to the sand produced, resulting in high permeability channels known as wormholes. In addition, this method has a low oil recovery factor (5-15 %) and this entails further recovery techniques. Thermal methods after CHOPS are not usually favourable due to heterogeneity and reservoir instability. In addition, CHOPS wells are not completed for thermal (steam) operations. The CHOPS method is typically applied in thin formations in which heating by injected steam is characteristically inefficient. Solvent injection possesses similar problems caused by heterogeneity and cost. An option could be the hybrid application of steam/solvent. Assessment of this technique first requires a realistic modeling of the CHOPS process. Due to dynamic changes in reservoir properties, no valid model was available to accurately simulate field-scale CHOPS production. Therefore, a part of this thesis presents a quick workflow for CHOPS modeling to investigate efficient EOR/IOR (Enhanced/Improved Oil Recovery) methods after CHOPS. To achieve this, we first propose a partial-dual porosity approach coupled with algorithms for wormhole generation to create realistic static reservoir models. After generating fractal wormhole patterns of different kinds using a diffusion limited aggregation (DLA) algorithm, they were introduced into a reservoir model.

Based on fractal analysis, novel upgridding procedures for wormhole network in partial-dual porosity models were introduced. After validation of the models using data obtained from a field in Alberta, several preliminary post-CHOPS scenarios including thermal, solvent, and thermal/solvent hybrid applications were simulated. In addition, a 3D geomechanical model was used to calculate the stress distribution in the history matched field. The hydro-geomechanical model was then used for field development planning, reservoir management and assessment of near wellbore regions during cyclic injection and production. The field-wide deformation and stress changes were analyzed in deep overburden, cap rock, and reservoir to show the influence of local stress orientations in soft and stiff layers. Next, an experimental set-up consisting of a sand-pack with different configurations of complexity of wormhole patterns was designed. The experiment was aimed to mimic cyclic solvent stimulation at reservoir conditions. The sand-pack experiments were numerically simulated and effective diffusion coefficients were obtained. To generate accurate predictions in field-scale simulation, an up-scaling procedure from laboratory results of the cyclic solvent injection process was suggested. The overall findings suggest that an improved heavy oil recovery could be achieved using combined light and heavy solvents in CHOPS reservoirs. Steam (or hot-water) was found to play a positive role in solvent retrieval. Finally, an uncertainty screening procedure was performed to assess the feasibility of cyclic solvent stimulation as a post-CHOPS method. An economics model was developed and after-tax NPV (Net Present Value) of the field at the end of cyclic solvent stimulation process was calculated. Such calculations have the priority to oil recovery factor or cumulative oil production as it could incorporate costs and sales simultaneously by performing continuous discounting and allow the asset holder to maximize NPVs and select the best development strategy.

A detailed introduction to the study of crustal geomechanics, particularly the seismogenic crust, with exercises, solutions, and field-based datasets.

The Middle and Upper Devonian Horn River Shale, comprising the Evie and Otter Park members and the Muskwa Formation, northeast British Columbia, Canada is recognized as a significant shale gas reservoir in the Western Canada Sedimentary Basin. However, many aspects of this shale formation have not been adequately studied, and the published geochemical, petrophysical and geomechanical data are limited. This work aims to document the controls of geochemical composition variation on petrophysical and geomechanical properties and the relationship of rock composition to lithofacies and stratigraphic sequences. A detailed core-based sedimentological and wireline log analysis was conducted by my colleague Dr. Korhan Ayranci as a parallel study, in order to classify lithofacies, interpret depositional environments and establish sequence stratigraphic framework across the basin. Major and trace elements concentrations, key trace element ratios and Corg-Fe-S relationships were used to understand the effect of sea level fluctuation on detrital flux, redox conditions, productivity and therefore organic carbon enrichment patterns. Detrital sediment flux indicated by the concentration of aluminum and titanium to the basin was found to be higher during transgressions than regressions. Redox conditions, exhibiting strong correlation to TOC content, were the primary controls on the organic carbon deposition. The bottom water conditions are more anoxic during transgressions than regressions.

The presence of biogenic silica, identified by crossplot of silica versus zirconium concentrations, makes the use of total silica problematic as a detrital proxy; biogenic silica concentrations may be useful as a proxy for productivity. The depositional environments for the Evie and Muskwa intervals, depositing during high sea level, represented favorable conditions for organic matter accumulation, including anoxic bottom water conditions, high primary productivity and less clastic dilution. The Otter Park Member, deposited during sea level falling stage, has relatively low organic matter concentrations, which may have been due to high clastic dilution and dysoxic to oxic bottom water conditions. Geochemical controls on petrophysical properties (porosity, permeability, pore morphology, pore size and pore throat size distribution) within Horn River shale reservoirs were investigated by an integrated analysis of porosity and permeability measured by helium pynconometry and GRI method, nitrogen adsorption analysis, mercury injection analysis, scanning electron microscopy (SEM) and transmission electron microscopy (TEM). Porosity ranges from 0.62% to 12.04%, and the measured matrix permeability values increase with increasing porosity, ranging between 1.7 and 42.8 nanodarcy. Among the organic matter and inorganic components, TOC content exerts the strongest control on porosity and permeability. Pore size and pore throat size distribution are strongly associated with TOC content, decreasing with increasing TOC content. SEM and TEM images suggest that several kinds of sites for porosity development are present, including organic matter, pyrite framboids, clay platelets, quartz rims, carbonate grains and microfractures. High porosity and permeability are associated with specific depositional facies. Massive and pyritic mudstones, which are rich in TOC and quartz, have relatively high porosity and permeability. Laminated mudstone, bioturbated mudstone and carbonate, which are rich in clay and carbonate content, have relatively low porosity and permeability. Rock mechanical properties were evaluated by hardness measurements and Young's modulus, Poisson's ratio and brittleness calculated from dipole sonic and density log data. Clay content is the most significant factor controlling the brittleness of shale rocks. The effect of quartz content on rock mechanical properties depends on the type of the quartz present in the rock. Authigenic quartz is positively correlated with brittleness, but detrital quartz has little or no effect. Factor analysis indicates that carbonate increases brittleness, while no obvious correlation between TOC content and brittleness was observed in this study. Brittleness in Horn River Shale shows both geographic and stratigraphic variability. Increasing brittleness in the northwest part of the basin largely results from greater distance from the sediment source and decreased clay content. The Otter Park member represents a period of major relative sea level fall and is more ductile than the underlying Evie Member and the overlying Muskwa Formation because of its high clay content.

This thesis presents five studies of a gas shale reservoir using diverse methodologies to investigate geomechanical and transport properties that are important across the full reservoir lifecycle. Using the Barnett shale as a case study, we investigated adsorption, permeability, geomechanics, microseismicity, and stress evolution in two different study areas. The main goals of this thesis can be divided into two parts: first, to investigate how flow properties evolve with changes in stress and gas species, and second, to understand how the interactions between stress, fractures, and microseismicity control the creation of a permeable reservoir volume during hydraulic fracturing. In Chapter 2, we present results from adsorption and permeability experiments conducted on Barnett shale rock samples. We found Langmuir-type adsorption of CH_4 and N_2 at magnitudes consistent with previous studies of the Barnett shale. Three of our samples demonstrated BET-type adsorption of CO_2, in contrast to all previous studies on CO_2 adsorption in gas shales, which found Langmuir-adsorption. At low pressures (600 psi), we found preferential adsorption of CO_2 over CH_4 ranging from 3.6x to 5.5x. While our measurements were conducted at low pressures (up to 1500 psi), when our model fits are extrapolated to reservoir pressures they reach similar adsorption magnitudes as have been found in previous studies. At these high reservoir pressures, the very large preferential adsorption of CO_2 over CH_4 (up to 5-10x) suggests a significant potential for CO_2 storage in gas shales like the Barnett if practical problems of injectivity and matrix transport can be overcome. We successfully measured permeability versus effective stress on two intact Barnett shale samples. We measured permeability effective stress coefficients less than 1 on both samples, invalidating our hypothesis that there might be throughgoing flow paths within the soft, porous organic kerogen that would lead the permeability effective stress coefficient to be greater than 1. The results suggest that microcracks are likely the dominant flow paths at these scales. In Chapter 3, we present integrated geological, geophysical, and geomechanical data in order to characterize the rock properties in our Barnett shale study area and to model the stress state in the reservoir before hydraulic fracturing occurred. Five parallel, horizontal wells were drilled in the study area and then fractured using three different techniques. We used the well logs from a vertical pilot well and a horizontal well to constrain the stress state in the reservoir. While there was some variation along the length of the well, we were able to determine a best fit stress state of Pp = 0.48 psi/ft, Sv = 1.1 psi/ft, SHmax = 0.73 psi/ft, and Shmin = 0.68 psi/ft. Applying this stress state to the mapped natural fractures indicates that there is significant potential for induced shear slip on natural fracture planes in this region of the Barnett, particularly close to the main hydraulic fracture where the pore pressure increase during hydraulic fracturing is likely to be very high. In Chapter 4, we present new techniques to quantify the robustness of hydraulic fracturing in gas shale reservoirs. The case study we analyzed involves five parallel horizontal wells in the Barnett shale with 51 frac stages. To investigate the numbers, sizes, and types of microearthquakes initiated during each frac stage, we created Gutenberg-Richter-type magnitude distribution plots to see if the size of events follows the characteristic scaling relationship found in natural earthquakes. We found that slickwater fracturing does generate a log-linear distribution of microearthquakes, but that it creates proportionally more small events than natural earthquake sources. Finding considerable variability in the generation of microearthquakes, we used the magnitude analysis as a proxy for the "robustness" of the stimulation of a given stage. We found that the