

Geological and geophysical integrated interpretation and modelling techniques

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SUMMARY

Exploration is becoming harder, at depth or under cover and decisions need to be made in model rather than data space; supported by multiple data sets. Geophysics plays an ever increasing role and integration of information from various geophysical data sets in tight collaboration with geological control is required to maximise the return from the individual data sets.

In terms of integrating geological and geophysical data, the essential goal is to interpret the available geophysical data in terms of geological domains. The process requires a common sense approach to interpretation that is flexible, adaptive and objective driven. It is not an exact formula or procedure; particularly when multiple geophysical surveys are involved. Understanding the relationships between geology, geophysical responses and rock properties is the key to develop a geological basis for your integrated interpretation. Following this, rapid 3D geological modelling and geologically based forward modelling and inversion are essential for model validation and quantitative integration of data. An integrated interpretation is not necessarily the simplest approach, but does provide answers to geo-scientific questions that are stronger than individual elements interpreted on their own.

This paper presents a review of the mechanics involved in integrated interpretation and demonstrates the results with selected case study examples.

Key words: Integrated interpretation, forward modelling, geologically constrained inversion.

INTRODUCTION

The modern mineral exploration context is increasingly one of targeting at depth or under cover. This requires moving beyond traditional interpretation of data and its map representation towards interpretation of 3D models. In mineral exploration, the fundamental purpose of a model is to convert data, concepts and interpretation into an actionable construct.

Unequivocally, the concept of integrated interpretation is focused on minimising ambiguity and providing answers to geo-scientific questions that are stronger than individual elements interpreted on their own. The application of multi-disciplinary data integration directly in terms of exploration targeting has grown awareness in the industry (Joly et al, 2015; McCaughey, 2006; Michinson et al, 2014; Chalke & McCaughey, 2015). But integrated interpretation also has a place during the development of the geological models (Jevvel et al, 2014; Lindsay et al, 2015; Spornigato et al, 2015) that are a part of the multi-disciplinary targeting process (if not the common framework that links various data types). In terms of integrating geological and geophysical data, the essential goal is to interpret the available geophysical data in terms of geological domains.

Historically, 3D geological models have predominantly been utilised in a mining environment where interpretation is facilitated by large volumes of information obtained through dense drilling and pit/underground mapping. Models were typically built solely on the basis of direct geological observation. On the other hand, away from the mine site and its abundance of direct observation, 3D earth models have been based primarily on geophysical inversion. Often, these scenarios are addressed with unconstrained inversion to provide a first pass, smooth distribution of rock properties (Li and Oldenburg, 1996). Seldom is this model interpreted in terms of geological domains that can be attributed with rock property data and validated against the geophysical surveys.

The aim of this review is to reinforce the importance of integrated geological and geophysical interpretation and the mechanics involved, particularly in cases with limited sub-surface control. The aim is to highlight the geological information that can be drawn from geophysical survey data.

METHODOLOGY

It is important to recognise that the specific methodology for integrated interpretation of geological and geophysical data varies according to the geological objective and the data that is available. In a data rich environment, integrated interpretation of geological and geophysical data considers construction of a geological model from geological constraints, attribution of the model with petrophysical data, then validation and reconciliation of a model through forward modelling and inversion. This is essentially a model validation, but does still reveal new information and advance the understanding of the relationship between geology and rock properties.

A First Course In Geophysical Exploration And Interpretation

W.H. Fertl, R.E. Chapman, R.F. Hotz



A First Course In Geophysical Exploration And Interpretation:

First Course in Geophysical Exploration and Interpretation Robert E. Sheriff, 1979 *A First Course in Geophysical Exploration and Interpretation* Robert E. Sheriff, 1977 *Geophysical Exploration and Interpretation* Robert E. Sheriff, 1978 **An Introduction to Geophysical Exploration** Philip Kearey, Michael Brooks, Ian Hill, 2013-04-16 This new edition of the well established Kearey and Brooks text is fully updated to reflect the important developments in geophysical methods since the production of the previous edition The broad scope of previous editions is maintained with even greater clarity of explanations from the revised text and extensively revised figures Each of the major geophysical methods is treated systematically developing the theory behind the method and detailing the instrumentation field data acquisition techniques data processing and interpretation methods The practical application of each method to such diverse exploration applications as petroleum groundwater engineering environmental and forensic is shown by case histories The mathematics required in order to understand the text is purposely kept to a minimum so the book is suitable for courses taken in geophysics by all undergraduate students It will also be of use to postgraduate students who might wish to include geophysics in their studies and to all professional geologists who wish to discover the breadth of the subject in connection with their own work

Exploration Geophysics Mamdouh R. Gadallah, Ray Fisher, 2008-10-20 Many text books have been written on the subject Exploration Geophysics The majority of these texts focus on the theory and the mathematical treatment of the subject matter but lack treatment of practical aspects of geophysical exploration This text is written in simple English to explain the physical meaning of jargon or terms used in the industry It describes how seismic data is acquired in 2 D and 3 D how they are processed to convert the raw data to seismic vertical and horizontal cross sections that are geologically meaningful and how these and other data are interpreted to delineate a prospect Workshops are included after each chapter and are designed to reinforce learning of the concepts presented Key Features Written in simple easy to understand language Heavily illustrated to aid in understanding the text End of chapter Key words and workshop The text includes several appendices and answers for the selected workshop problems **Exploration Seismology** R. E. Sheriff, L. P. Geldart, 1995-08-25 This is the completely updated revision of the highly regarded book Exploration Seismology Available now in one volume this textbook provides a complete and systematic discussion of exploration seismology The first part of the book looks at the history of exploration seismology and the theory developed from the first principles of physics All aspects of seismic acquisition are then described The second part of the book goes on to discuss data processing and interpretation Applications of seismic exploration to groundwater environmental and reservoir geophysics are also included The book is designed to give a comprehensive up to date picture of the applications of seismology Exploration Seismology s comprehensiveness makes it suitable as a text for undergraduate courses for geologists geophysicists and engineers as well as a guide and reference work for practising professionals **A First Course in Geophysical Exploration** Robert E.

Sheriff,1978 **Applied Geophysics** W. M. Telford,L. P. Geldart,R. E. Sheriff,1990-10-26 This is the completely revised and updated version of the popular and highly regarded textbook Applied Geophysics It describes the physical methods involved in exploration for hydrocarbons and minerals which include gravity magnetic seismic electrical electromagnetic radioactivity and well logging methods All aspects of these methods are described including basic theory field equipment techniques of data acquisition data processing and interpretation with the objective of locating commercial deposits of minerals oil and gas and determining their extent In the fourteen years or so since the first edition of Applied Geophysics many changes have taken place in this field mainly as the result of new techniques better instrumentation and increased use of computers in the field and in the interpretation of data The authors describe these changes in considerable detail including improved methods of solving the inverse problem specialized seismic methods magnetotellurics as a practical exploration method time domain electromagnetic methods increased use of gamma ray spectrometers and improved well logging methods and interpretation

DOE/RA. ,1980 Handbook of Geophysical Exploration ,1987 Field Methods for Geologists and Hydrogeologists Fakhry A. Assaad,James W. LaMoreaux,Travis Hughes,2013-03-09 This book is designed for scientists and engineers who want practical information to plan manage write and review geologic and hydrologic projects and reports It provides step by step methods to prepare more timely readable and technically accurate reports Detailed guidelines are provided to prepare the different subjects included in this book Source references project proposals and checklists are included to assist authors The use of the techniques described in this book will result in less time spent in report writing editing rewriting and review which will save time and money This book is the result of nearly 50 years of experience in program and project development in the field of hydrogeology The two main authors P E LaMoreaux and Fakhry Assaad who submitted both the idea and the major subjects of the book have been closely associated during this period with the Geological Survey of Egypt the General Desert Development Organization in Egypt the u S Geological Survey USGS the Geological Survey of Alabama the University of Alabama and in a great variety of consulting projects in different States of America and over the world It is based on experience from the assignment and supervision of many professionals with a great variety of academic training and experience *Carbonate Reservoir Characterization: A Geologic-Engineering Analysis, Part II* S.J. Mazzullo,H.H. Rieke,G.V. Chilingarian,1996-11-22 This second volume on carbonate reservoirs completes the two volume treatise on this important topic for petroleum engineers and geologists Together the volumes form a complete modern reference to the properties and production behaviour of carbonate petroleum reservoirs The book contains valuable glossaries to geologic and petroleum engineering terms providing exact definitions for writers and speakers Lecturers will find a useful appendix devoted to questions and problems that can be used for teaching assignments as well as a guide for lecture development In addition there is a chapter devoted to core analysis of carbonate rocks which is ideal for laboratory instruction Managers and production engineers will find a review of the latest laboratory technology for

carbonate formation evaluation in the chapter on core analysis The modern classification of carbonate rocks is presented with petroleum production performance and overall characterization using seismic and well test analyses Separate chapters are devoted to the important naturally fractured and chalk reservoirs Throughout the book the emphasis is on formation evaluation and performance This two volume work brings together the wide variety of approaches to the study of carbonate reservoirs and will therefore be of value to managers engineers geologists and lecturers

Seismic Exploration Methods

Ray L. Sengbush, 2012-12-06 This book describes the seismic methods used in geophysical exploration for oil and gas in a comprehensive non rigorous mathematical manner I have used it and its predecessors as a manual for short courses in seismic methods and it has been extensively revised time and again to include the latest advances in our truly remarkable science I once called it Advanced Seismic Interpretation but the geophysicists who attended the courses always wondered when I was going to start discussing interpretation They discovered at the end that I never did discuss interpretation as they knew it No mention was made of reflection picking poststack time mapping contouring and things they already knew perfectly well Instead I discussed Fourier transforms sampling theory impulse responses distortion operators Wiener filters noise in $f-k$ space velocity spectra wave equation migration and direct detection of hydrocarbons as each of these topics appeared on the seismic scene I wanted the geophysicists to think beyond the routine of interpretation to develop a better understanding of why seismic sections look as they do to have a better feel for what digital processing is doing for good or evil to the seismic data I attempted to stretch their minds Whitehead said it best A mind once stretched by a new idea can never shrink to its former dimension May this book be a successful mind stretcher R L

Studies in Abnormal Pressures

W.H. Fertl, R.E. Chapman, R.F. Hotz, 1994-02-01 When Fertl's first book Abnormal Formation Pressures was published by Elsevier in 1976 the topic was relatively new in book form In the years that followed his book became the standard work for petroleum engineers and drillers The list of major petroleum provinces with abnormally high pore pressures has grown steadily over the years and with it has grown our knowledge and experience There have also been technological advances A new book was required but no longer could the topic be covered adequately by one person The problems of abnormally high formation pressures encountered in the subsurface while drilling for petroleum are very diverse involving geologists geophysicists reservoir engineers drilling engineers and borehole logging engineers The acute anticipation of such pressures before drilling has become possible with modern technology This book treats these developments and covers the following topics world occurrences the geology of abnormal pore pressures and the background theory reservoir engineering aspects of abnormally pressured reservoirs detection of abnormal pressures by geophysical methods before drilling and during drilling and their evaluation after drilling It examines the special problems of shallow hazards from shallow abnormal pressures and relief well engineering to control blowouts It also examines the generation of abnormal pressures from hydrocarbon generation in the Rocky Mountains and the distribution of abnormal pressures in south Louisiana USA The

topics are examined from a practical point of view with a theoretical background There is a glossary of terms and a relevant practical conversion table Both SI units and the conventional US oil industry units are used **Seismic Stratigraphy** R.E. Sheriff, 2012-12-06 Every little wiggle has a meaning all its own This is our underlying faith that details of seismic waveshapes can tell us the details of the nature of the earth But their voices are obscured by many irrelevancies They speak in a high noise environment and we have been able to decipher only a small portion However things are looking up better techniques are lessening the irrelevancies and we are learning to read In exploration of unknown areas determining the nature of the rocks present is often the difficult aspect Most of the properties of rocks that can be measured at a distance are not distinctive enough to identify the rock unambiguously Conventionally seismic data are used to determine aspects of the structure Stratigraphic pictures are inferred from the structure the nature of rocks exposed for examination in the surrounding area and regional concepts Three points make seismic stratigraphy feasible now 1 we have better data quality 2 we have begun to systematize analysis procedures and 3 we believe in the geologic significance of waveshape details

Tectonics Eldridge M. Moores, Robert J. Twiss, 2014-07-23 Deformation of the Earth's crust happens at a multitude of scales ranging from submicroscopic to planetary Tectonics explores structures and processes from regional to global differentiating itself from the material covered in most structural geology textbooks Moores and Twiss emphasize basic principles and methodologies of tectonics embracing the time honored perspective of using present processes to understand the past Comprehensive in scope and detail coverage includes the effects of plate motions and reconstructions and the resultant structures associated with active rift transform and subduction boundaries as well as triple junctions and collision zones deformations of both the ocean basins and the continents and orogenic belts Moores and Twiss present tectonics as an open ended field of study in which assumptions can be challenged and interpretations changed The authors emphasize the use of models as a means of understanding observations and putting them in context to maintain a distinction between what we know from observing the Earth and what we infer from interpretation **Geophysical Methods** Robert E. Sheriff, 1989

Sedimentary Geology Bernard Biju-Duval, 2002 In this work the reader will find the basic concepts and vocabulary of sedimentary geology along with a presentation of the new ideas that are in current use in petroleum exploration This abundantly illustrated book will serve as an excellent educational tool and remain a valuable resource and handy reference work in any petroleum geology library Contents 1 Basics of dynamic geology 2 Continental and oceanic basins 3 Sedimentary driving mechanisms and environments 4 Time evolution Sedimentary sequences stratigraphy 5 From sediments to sedimentary basin rocks and mountain chains 6 Petroleum systems Index State of Strain 2 State of Stress 3 Thermodynamics of Continuous Media II Mechanism of Material Strain 4 Linear Elasticity General Theory 5 Plane Theory of Elasticity 6 Behaviour of a Material Containing Cavities 7 Thermodynamics of Saturated Porous Media 8 Infinitesimal Thermoporoelasticity 9 The Triaxial Test and the Measurement of Thermoporoelastic Properties 10

Thermoporoelastoplasticity General Theory and Application III Mechanisms of Material Cohesion Loss 11 Fissuring 12
Introduction to Damage Theory 13 Appearance of Shearing Bands in Geomaterials **Seismic Reflection Processing** S.K.
Upadhyay, 2004-07-19 The author coherently presents the physical concepts mathematical details and methodology for
optimizing results of reservoir modeling under conditions of isotropy and anisotropy The most common form of anisotropy the
transverse isotropy is dealt with in detail Besides practical aspects in reservoir engineering such as interval isotropic or
anisotropic properties of layered media identifying lithology pore fluid types and saturation and determining crack fracture
orientations and density form the core of discussions This book incorporates significant new developments in isotropic and
anisotropic reflection processing while organizing them to improve the interpretation of seismic reflection data and
optimizing the modeling of hydrocarbon reservoirs The text contains exercises and problems and solutions are provided for
the exercises This book is written primarily for graduate postgraduate students and research workers in geophysics

Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems
, 1990

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