GeoPlanet: Earth and Planetary Sciences

Jerzy Sobotka

Reservoir Rock Diagnostics for Water or Hydrocarbon Exploration

Acoustic and Electric Fields Interaction Phenomena in Geophysical Research (Seismoelectric & Electroseismic Effect)

Springer

GeoPlanet: Earth and Planetary Sciences

The GeoPlanet series is a forum for presenting the latest achievements in the Earth and space sciences. It is published by the GeoPlanet consortium (Earth and Planetary Research Centre) formed by five institutes affiliated with the Polish Academy of Sciences: Institute of Geophysics, Space Research Centre, Institute of Geological Sciences, and Institute of Oceanology, and Nicolaus Copernicus Astronomical Centre. Its main objective is a multidisciplinary approach to link scientific activities in various Earth-related fields (geophysics, geology, oceanology) with Solar System research. Our publications encompass topical monographs and selected conference proceedings, authored or edited by leading experts of international repute as well as by promising young scientists. The GeoPlanet series aims to provide the stimulus for new ideas and discoveries by reporting on the state of the art and laying the foundations for the future development of the Geosciences.

More information about this series at http://www.springer.com/series/8821

Jerzy Sobotka

Reservoir Rock Diagnostics for Water or Hydrocarbon Exploration

Acoustic and Electric Fields Interaction Phenomena in Geophysical Research (Seismoelectric & Electroseismic Effect)

Springer

Jerzy Sobotka
Institute of Geological Sciences,
Laboratory of Geophysics
University of Wrocław
Wrocław, Poland

The GeoPlanet: Earth and Planetary Sciences Book Series is in part a continuation of Monographic Volumes of Publications of the Institute of Geophysics, Polish Academy of Sciences, the journal published since 1962 (http://pub.igf.edu.pl/index.php).

ISSN 2190-5193 ISSN 2190-5207 (electronic)
GeoPlanet: Earth and Planetary Sciences
ISBN 978-3-030-31048-6 ISBN 978-3-030-31049-3 (eBook)
https://doi.org/10.1007/978-3-030-31049-3

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Series Editors

Managing Editor

Anna Dziembowska
Institute of Geophysics, Polish Academy of Sciences

Advisory Board

Foreword

The monograph *Reservoir Rock Diagnostics for Water or Hydrocarbon Exploration: Acoustic and Electric Fields Interaction Phenomena in Geophysical Research (Seismoelectric & Electroseismic effect)* by Jerzy Sobotka is a compact compendium of theoretical and practical knowledge of electric and acoustic mutual interactions and suggestions how the discussed phenomena can be used in geophysical prospecting. The author showed the physical basis of phenomena recognized theoretically in the past which were now classified as useful in applied geophysics for the construction of modern measurement equipment.

The author presents the theory and practical solutions for laboratory and field measurements dedicated to hydrocarbons and water exploration. Common approach to methods determining petrophysical parameters for hydrocarbons (industry object) and water (life object) prospection is highly sensible because porosity and permeability are crucial properties in recognition storage and fluid flowability in reservoir rocks. Their determination from simple acquisition ways is the basis for hydrocarbons and water prospection and exploitation. Applicability of the presented solutions known from the theory of physical phenomena recognized during years in design and construction of modern, sophisticated equipment is a second important aspect underlined in the monograph.

Chapters contain the theoretical basis for mutual acoustic and electric fields interactions in rock formation, named seismoelectric and electroseismic effects. Modern technology of weak signals measurements and advanced processing software are able to increase the signal/noise ratio, so the identification of the above-mentioned effects and their measurements are useful tools in applied geophysics. Now, they form the base of advanced solutions in the field data acquisition which were not possible in the previous practice in natural resources prospection. Great progress observed in applied geophysics acquisition technology encourages constructors to use the known but not yet used physical phenomena. In applied sciences (applied geophysics), the progress is always based on the construction of new, advanced measurement tools or improvement of data processing technology. New solutions based on IT technology can be applied to process the old data to increase the practical ability of better understanding the rock formation and its

properties. In the monograph, the physical bases for the new measurement technology are presented. They are a good illustration of technological trends observed in modern applied sciences. Nowadays, prospection for natural resources (hydrocarbons, water) is a great challenge, because many deposits of high parameters have been earlier exploited. So, scientists and engineers need to focus their attention on difficult, challenging objects applying new technologies which can bring expected results. Physical phenomena described in details in the monograph and suggestions of using them in modern prospection approaches are the great value of the presented work.

Porous, geological formations with their complicated mineral composition, structure and texture, saturated with media of differentiated parameters are complicated objects for investigations of various physical interactions in heterogeneous media. Analysis of electric resistivity of electrolytes and hydrocarbons in ultrasonic field included in the monograph is an introduction for laboratory and field experiments and modeling of a borehole and artificial rock samples in ultrasonic field. Conceptual and physical experiments with ultrasounds acting on the electrical double layers in heterophase media proved changes in zeta potential, the most important part of the electrokinetic coupling in the filtration component of spontaneous potential measured in SP log related to mechanical stress. Diffusion and sorption processes were also influenced by elastic vibrations. So, finally measurable components of SP signals carrying new information useful from geophysical and geological viewpoint were selected. Such results are a success for the field measurements' simplicity and effectivity.

Transition induced polarization processes observed in sedimentary rocks are the sum of the fast interactions at the interphase boundary and the relatively slow processes associated with diffusion–adsorption in the pore liquid. Individual polarization signal components can be distinguished by acting with acoustic field whose nature is different from that of the original field. The induced polarization signal relaxation components of different duration are linked to the properties of the selected parts of a heterophase medium (liquid, solid phase, electrical double layer), so they carry specific information about the properties of the investigated formation. The seismoelectrical effect and the electroseismic effect (the reverse one) are observed in rocks influenced by seismic (elastic wave) field or electric field. Processes of electromagnetic radiation generation in sedimentary rocks are connected with the activation of diffusion–absorption processes and influence the SP potentials measured in boreholes.

Exemplary results of the applications of physical field interactions in geological formations in field investigations as vibrostimulated electromagnetic radiation and vibrostimulated SP potentials observed above deposits of hydrocarbons are tangible evidence of the practical use of the discussed physical phenomena. The examples are from the 1990–2000s. Now, the field equipment building technology is more advanced, so it is assumed that modern apparatus measuring the discussed effects will be more effective and provide interpreters with the better material.

This monograph, due to the author's scientific basis from his physical study and experience in field and laboratory geophysical measurements, provides the practical solutions based on sophisticated theory which can be the basis for new effective measurement methods providing geophysicists and petrophysicists with good acquisition results.

Kraków, Poland Jadwiga Jarzyna
May 2019

Introduction

During the last decades, the exploration geophysics has relied mainly on traditional prospecting methods. Such methods can be refined through improving measuring devices and of data processing technology as well as through combining different methods into integrated complexes.

Development of essentially new methods in exploration geophysics requires a non-traditional, innovative approach, chiefly at the stage of studying the physical properties of rocks. Particularly promising in this respect seems to be investigation of secondary effects brought about by stimulation of geological formation with one or more physical fields, interacting with one another. New diagnostic and exploration methods can be based on phenomena of such an interaction. Thus, we can induce one physical field, e.g., acoustic one, but then we monitor and measure the system reaction as reflected in the behavior of another physical field, e.g., electrical, or vice versa.

The study here reported was aimed at establishing a set of diagnostic parameters appropriate for characterization of the behavior of a geological medium stimulated by external fields and their interactions, in order to set up a physical basis for inventing new methods in exploration geophysics. The present volume contains a synthesis of laboratory and field investigations carried out by its author during the last several years. Described are theoretical principles (a physical/mathematical model) of applicability of interactions of various types of physical fields in geological media for the needs of exploration geophysics. A detailed description of the invented and then elaborated and developed investigation methods as well as of measuring gauges is given (including laboratory, field, and borehole devices). Experimentally, field and modeling work has been done on the interaction of mechanic/electromagnetic fields in reservoir rocks. An effectiveness of the methodology proposed has been evaluated and shown using case studies that solved certain geophysical diagnostic/exploration problems. The research results have allowed the present author for inventing a number of new geophysical prospecting methods and obtaining letters patents to protect them.