CARBONATE RESERVOIR ROCKS

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Scrivener Publishing

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Co-published by John Wiley & Sons, Inc. Hoboken, New Jersey, and Scrivener Publishing LLC, Salem, Massachusetts. Published simultaneously in Canada.

Cover design by Kris Hackerott

Library of Congress Cataloging-in-Publication Data:

ISBN 978-1-119-08357-3

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

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Beverly, MA 01915-6106

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This book is dedicated to the Academician George V. Chilingar (Chilingarian), one of the foremost experts of carbonate rocks in the World. His studies on carbonate reservoir rocks were indeed invaluable. He was the first American Petroleum Geologist elected to the Russian Academy of Sciences, and an oil field in Iran was named after him: "Chilingar".

Introduction

Any improvement of the mineral resource base is only possible if the nature of the emergence, evolution, parameter estimation of high grade reservoir rocks at great depths is known and a theory of their forecast is developed. Over 60 percent of world oil production is currently associated with the carbonate reservoir rocks. The exploration, appraisal and development of these fields are significantly complicated by a number of factors. These factors include the structural complexity of the carbonate complexes, variability of the reservoir rock types and properties within a particular deposit, many unknowns in the evaluation of fracturing and its spatial variability, and the preservation of the reservoir rock qualities with depth.

The main objective of the present-day studies is discovering patterns in the reservoir rock property changes of carbonate deposits of different genesis, composition and age. A short list of the unsolved issues includes: the role of facies environment in the carbonate formation; the major geologic factors affecting the formation of high-capacity reservoir rocks and preservation of their properties; recommendations as to the use of the new techniques in studies of the structural parameters; and establishing a correlation between the major evaluation parameters.

A poorly developed knowledge domain is still the evaluation of the role of fractures in the capacity and hydrocarbon filtering of the different-type carbonate reservoir rocks. The author devoted a great deal of attention to the development of methodologies and techniques, which improve the reliability of evaluating the vugginess, fracturing, and void (pore, fracture, cavity and vug) space structure.

The author perfected an earlier developed new methodology in studies of the void space structure (Bagrintseva's method, 1982). This methodology is based on carbonate rock saturation with luminophore and on special techniques in processing of photographs made under UV light. The luminophore technique was combined with the raster electron microscopy and its variation, the studies under the cathode luminescence regime. This combination enabled a more detailed study of the reservoir void space, the nonuniformity in the open fracture evolution, their morphology, length and variability of openness. Over recent years these techniques have found wide application.

The book devotes special attention to describing techniques for improving reliability in the identification and evaluation of the reservoir rocks with complex void space structure. These new techniques proposed and meticulously developed by the author enable the evaluation of the void space structure, the reservoir rock type, the identification of vugs, cavities and fractures, their morphology, interconnectivity, openness and

the differentiation of fractures in terms of their importance to the fluid filtering. The book includes a number of photographs obtained with the UV-light source after the rocks were saturated with luminophore. These illustrations show significant variability and diversity of the fractures in carbonate rocks of different composition and genesis.

Among the poorly developed but important issues is the study of the carbonate rock surface properties. New methodological studies conducted by the author and her assistant (K.I. Bagrintseva and T.S. Preobrazhenskaya) came up with the wettability study technique based on the wettability contact angle. The technique opened a possibility of identifying the nonuniform wetting of porous and fractured carbonates as well as the differentiated and integral characteristics of certain core samples, which allowed for the rock wettability identification within certain intervals.

The empiric correlation between the wetting contact angle and the type of the rock-saturating fluid was established. This correlation allows to identify the rock productivity, the boundaries of intervals with different hydrocarbon composition in the carbonate sequence, and to fine-tune the oil-water and gas-oil contacts' location.

Some other issues were theoretically substantiated. They include the patterns in the spatial positions of different type reservoir rocks within sequences and the forecast and identification criteria of the reservoir rock types and properties within multi-facies intervals. The 45-year-long carbonate reservoir studies allowed the author to solve a number of theoretical issues, to develop the Evaluation-Genetic Classification, and to suggest the new methodological studies for better understanding the fluid filtering mechanisms through complex porous-fractured media. Fundamentally new data were obtained, which show the importance of the interconnection between the filtering-conducting elements. These studies were conducted by I.V.Shershukov and enabled the merger of singular indications into a system. Dr. Shershukov authored the Chapter devoted to the processing of porometric curves.

The studies of particular oil fields were directed toward identifying the effect of lithogenetic and structural specifics, composition and stratigraphic age of deposits on the lithophysical properties, and toward establishing the role played by the pore space geometry on rock capacity and permeability. For this purpose, beside the defining parameters, a number of structural parameters were also determined: the range and share fraction of the rock pore radiuses, the average radius of the entire pore population, the average radius of the filtering-controlling pores, and the threshold value for a system of interconnected fractures. The determination of the structural parameters enabled the analysis of the correlation between the structural parameters and reservoir rock properties, and the derivation of empirical correlations. Special attention was devoted to fractures, which play a major role in the filtering processes.

In a lengthy reservoir formation process, the nature and direction of the effect on the soluble carbonate rocks continually changes, the structural features of the void space change in space and time, numerous reservoir rock types emerge, which are different in their complexity and have substantially different major parameters.

The author believes that currently used carbonate rock reservoir terminology is highly confusing and ambiguous, including the understanding of the reservoir rock types, the residual water saturation, and the terms of vugularity sand fractureness. So the author developed her own approach and pays special attention to properly naming different type reservoir rocks, reflecting their genesis, properties and roles.

The book includes three major sections. The first one deals with the carbonate rock sedimentational environments and void space formation in carbonate rocks of different genesis. The books shows that the specific formation conditions of complex void space in carbonates of different lithofacies composition predetermine the direction and intensity of postdepositional alterations.

The second section presents the new techniques, methods developed by the author for evaluation parameters, void space structure, and especially fracturing studies. New methodologies are described allowing for taking into account the connectivity of the conducting elements in the estimation of theoretical permeability of the fractured-porous media. A brief description of the reservoir rock types and properties in the Paleozoic carbonates of the largest oil and gas fields on the East-European Platform and in the Siberian Riphaean is provided. The integrated comprehensive studies of the lithophysical properties of productive deposits were used to summarize the actual data about the value, nature of changes of the capacity/porosity, permeability, and void structure carbonate rock parameters. The data shows the variability of properties in the well sections of a number of large fields in the Pre-Caspian Depression and Timan-Pechora Province. The principal correlations between the evaluation parameters are included, the correlations typical for individual fields (Tengiz, Karachaganak, Korolevskoye and others) are checked, and the spatial reservoir rock variability in the natural reservoirs of the Pre-Caspian and Timan-Pechora provinces is established.

The reservoir rock description of the North Khosedayu field is based on the data obtained by Dr. P.V. Shershukov. Geology and properties of the Yurubchenskoe gas-oil field Riphaean reservoir rocks are briefly described.

The third section is theoretical. It deals with the main pattern in carbonate reservoir rock changes. It emphasizes the role of the major factors facilitating the formation of favorable void space and the preservation of high-capacity reservoir rocks at great depths. It shows the similarity of the parameters' correlations and similar trends in their changes. The Evaluatiion-Genetic Classification is developed for carbonate reservoir rocks of different types and classes.

Based on the theoretical considerations, the author proposed the Conceptual Scheme reflecting the sedimentation environment role in the reservoir rock types and properties evolution. This scheme allows for the reservoir rock potential forecasting.

Acknowledgements

The author acknowledges the contribution to the experimental and theoretical studies by Dr. G.E. Belozerova, N.V. Lysak, T.S. Preobrazhenskaya, T.G. Kuts, N.N. Potapova, V.B. Rabutovsky, E.N. Gadalina, E.V. Ovcharenko, R.S. Sautkin, without whose help and participation the book would not have materialized.

Special thanks to Grigoriy I. Shershukov for his software development, which allowed computer processing of luminophore capillary saturation photo images.

The author appreciates the assistance in the English language book preparation by Dr. I.V. Shershukov and G.I. Shershukov.

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