

CARBONATE RESERVOIR ROCKS

Ksenia I. Bagrintseva

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Scrivener Publishing
100 Cummings Center, Suite 541J
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Publishers at Scrivener
Martin Scrivener(martin@scrivenerpublishing.com)
Phillip Carmical (pcarmical@scrivenerpublishing.com)

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 and 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 book 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 Rhiphaean 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 Rhiphaean 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 Evaluation-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.

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Contents

Introduction	xi
Acknowledgements	xv
1 Carbonate Reservoir Rock Properties and Previous Studies	1
1.1 Brief Review of the Previous Studies	1
1.2 Major Terminology	4
2 Major Sedimentational Environments of Carbonate Rocks in Sedimentary Basins	13
2.1 Types of Carbonate Buildups	13
2.2 Open Shelf Edges	15
2.3 Genetic Types of Limestones and Dolomites	20
2.4 Effect of Post-Depositional Processes on the Void Space Formation	25
3 Conditions of Void Space Formation in Carbonate Rocks of Various Compositions and Genesis	29
3.1 Carbonate Rock Solubility and the Effect of Certain Factors on the Calcite and Dolomite Solubility Relationships	29
3.2 Pore Space Formation in Carbonate Rocks of Various Genesis	33
3.3 Formation of Fracture Capacity Space and Fluid Filtering in Fractured Rocks	37
4 Reservoir Rock Study Techniques	43
4.1 Major Evaluation Parameters and Laboratory Techniques of Their Determination	43
4.1.1 Porosity	43
4.1.2 Residual Water Saturation	44
4.2 Method By Bagrintseva: The New Technique of Fracturing and Vugularity Evaluating through the Capillary Saturation of the Carbonate Rocks with Luminophore	47
4.3 Determination of Fracture Openness	52
4.4 Method By Bagrintseva-Preobrazhenskaya: The Evaluation Technique of Rock Hydrophobization By Wetting Contact Angle	54

4.5	Method By Shershukov: New Methodological Approach to the Theoretical Permeability Calculation from Mercury Injection Porometry	60
5	Natural Oil and Gas Reservoirs in Carbonate Formations of the Pre-Caspian Province	71
5.1	Brief Review of Geology and Major Oil and Gas Accumulation Zones in the Pre-Caspian Province	71
5.2	Karachaganak Oil-Gas-Condensate Field	77
5.2.1	Field Geology and Lithology of the Productive Sequence	77
5.2.2	Major Reservoir Rock Types	77
5.2.3	Specifics of the Void Space Structure	81
5.2.4	Carbonate Deposits Fracturing	92
5.2.5	Correlations of the Major Parameters	93
5.2.6	Reservoir Rock Types	96
5.3	Zhanazhol Oil-Gas-Condensate Field	99
5.3.1	Field Geology and Lithology of the Productive Sequence	99
5.3.2	Major Reservoir Rock Types	109
5.3.3	Specifics of the Void Space Structure	111
5.3.4	Carbonate Deposits Fracturing	118
5.3.5	Correlation of the Major Parameters	120
5.3.6	Reservoir Rock Types	126
5.3.7	Major Conclusions	129
5.4	Tengiz Oil Field	129
5.4.1	Field Geology and Lithology of the Productive Sequence	129
5.4.2	Major Reservoir Rocks Types	132
5.4.3	Specifics of the Void Space Structure	138
5.4.4	Carbonate Deposits Fracturing	142
5.4.5	Correlations of the Major Parameters	148
5.4.6	Reservoir Rock Types	151
5.4.7	Major Conclusions	153
5.5	Korolevskoye Oil Field	153
5.5.1	Field Geology and Lithology of the Productive Sequence	153
5.5.2	Major Reservoir Rock Types	156
5.5.3	Specifics of the Void Space Structure	159
5.5.4	Carbonate Deposits Fracturing	160
5.5.5	Correlation of the Major Parameters	165
5.5.6	Reservoir Rock Types	165
5.6	Astrakhan' Gas-Condensate Field	167
5.6.1	Field Geology and Lithology of the Productive Sequence	167
5.6.2	Major Rock Types	168
5.6.3	Specifics of the Void Space Structure	170
5.6.4	Carbonate Deposits Fracturing	174
5.6.5	Reservoir Rock Types	179

6	Natural Oil and Gas Reservoirs in the Timan-Pechora Province	181
6.1	North Khosedayu Oilfield	181
6.1.1	Production Deposits Lithology	181
6.1.2	Limestone Vugularity and Fracturing	189
6.1.3	Reservoir Rock Types	190
6.1.4	Specifics of the Carbonate Rocks' Pore Space Structure	193
6.1.5	Main Conclusions	206
7	Types and Properties of the Rhiphaean Carbonate Reservoir Rocks	209
7.1	Yurubchenskoe Gas and Oil Field	209
7.1.1	Lithology of the Rhiphaean Productive Sequence	209
7.1.2	Void Space Morphology of the Rhiphaean Carbonates	212
7.1.3	Vugularity of the Rhiphaean	216
7.1.4	Pore Space Structure	218
7.1.5	Fracturing of the Rhiphaean Carbonate Rocks	220
7.1.6	Rhiphaean Carbonate Rocks Filtering-Capacity Reservoir Properties	223
7.1.7	Main Conclusions	230
8	Theoretical Fundamentals of the Reservoir Rock Evaluation and Forecast	231
8.1	Void Space Structure of Various Genesis Carbonate Deposits	231
8.2	Residual Fluid Saturation in the Carbonate Reservoir Rocks	237
8.3	Evaluation-Genetic Classification of the Carbonate Reservoir Rocks By Bagrintseva	249
8.3.1	Distinctive Features of the Pore-Type Carbonate Reservoir Rocks.	252
8.3.2	Distinctive Features of the Fracture Type and Complex-Type Carbonate Reservoir Rocks.	253
8.4	Distribution Models of Different-Type Reservoir Rocks	253
9	Major Factors Determining the Formation and Preservation of High-Capacity Carbonate Reservoir Rocks	259
9.1	Conditions for the Formation of High-Capacity Reservoir Rocks	259
9.2	Evaluation of the Fracturing Role in the Development of the Complex-Type Reservoir Rocks	263
9.3	Correlations between Major Reservoir Rock Evaluation Parameters	268
9.4	Criteria of the Reservoir Rock Forecast and Evaluation	276
	Conclusions	285
	Attachments	287
	References and Bibliography	319
	Index	329

