Abstract

The Mid-Continent Mississippian Limestone is an unconventional carbonate reservoir with different scales of mineralogical, lithological, and petrophysical heterogeneity. A complex depositional and diagenetic history of the Mississippian Limestone has resulted in a variety of lithofacies and a pore system with different shapes, pore sizes, and pore-size distribution. The heterogeneous lithofacies and pore-system properties play a significant role in controlling reservoir distribution, fluid storage, connectivity of the pores, and fluid flow in a reservoir. Despite its scientific and economical potential, little information on lithofacies and pore-structure characteristics of the Mid-Continent Mississippian Limestone in the state of Oklahoma is currently available.

This study focuses on lithofacies and pore-structure analysis of the Mid-Continent Mississippian Limestone from integrated core and digital image analysis. The Mississippian Limestone represents a distally-steepened ramp where seventeen (17) lithofacies ranging from mud-dominated to grain-dominated and chert breccia lithofacies were deposited. Multi-scale 2-D pore-structure characterization using digital-image analysis (DIA) reveals that the majority of pores in the Mississippian Limestone are within the nanopore ($1 \text{ nm}^2 < A < 62.5 \mu m^2$) to micropore ($62.5 \mu m^2 < A < 500 \mu m^2$) classification size. General pore types consist of interparticle and intraparticle, vuggy, channel, matrix, and micro-fracture pores. DIA-porosity quantification yields a reliable result to predict porosity in several lithofacies. However, for mud-dominated lithofacies, DIA-porosity quantification results in a relatively higher porosity as compare to core-measured porosity. Relationships among several pore parameters such as pore shape, pore size, circularity, convexity, and solidity with the petrophysical properties are also investigated in the Mississippian unconventional carbonate reservoir.
1. Abstract

The Mid-Continent Mississippian limestone and chert reservoirs are unconventional reservoirs with different scales of mineralogical, lithological, and petrophysical heterogeneities. A complex depositional and diagenetic history of the Mississippian limestone and chert reservoirs have resulted in a variety of lithofacies and a pore system with different scales of mineralogical, lithological, and petrophysical heterogeneities. Lithofacies and pore system properties play a significant role in controlling reservoir distribution, thermal maturity of the pore, and fluid flow in a reservoir. Despite its scientific and economical potential, little information on lithofacies and distribution, fluid storage, connectivity of the pores, and fluid flow in a reservoir is available. The Mississippian limestone and chert reservoirs in north-central Oklahoma was studied in the Mississippian limestone and chert reservoirs in the state of Oklahoma is currently available.

This study focuses on lithofacies and pore structure analysis of the Mid-Continent Mississippian limestone and chert reservoirs from integrated core and digital image analysis. The Mississippian limestone and chert reservoirs represent a distally-steepened ramp where seventeen (17) lithofacies ranging from mud-dominated reservoirs to grain-dominated and chert breccia lithofacies were deposited.

Lithofacies and Pore-structure Characterization of the Mid-Continent Mississippian Limestone and Chert Reservoirs, Grant County, Oklahoma

Fnu Suriain and Matthew J. Praner
ConocoPhillips School of Geology and Geophysics, University of Oklahoma, Norman, Oklahoma

2. Objectives

There are three main steps to accomplish the objectives of this study. First, data acquisition including core description and lithofacies analysis, this section preparation, optical microscopy and SEM photomicrography. Second, Digital Image Analysis was done in the schematic workflows below. Third, data integration, analysis, and interpretation. Lithofacies were identified from a detailed description of the Devonian 1-7 SWD core and its associated thin sections. The digital images, including high-resolution thin-section images and SEM photomicrographs, were manipulated and printed into either pore solid phase using photo editing and manipulation software, as well as image processing software. The HRTS images were partitioned by assigning pore phase to all solid containing blue color tones that represent impregnated blue epoxy. To enhance this process, SEM photomicrographs were first manipulated to increase the contrast between pore and solid phases.

3. Geologic Setting

The Mid-Continent Mississippian limestone and chert reservoirs in north-central Oklahoma was deposited in a carbonate ramp, which locally was exposed and eroded. The study area is located in the Ardmore basin, an upthrown block of the Ouachita basin.

In the study area, the Mississippian deposits show high-frequency transgressive-regressive cycles that result in a series of shallowing-upward cycles. The Mississippian stratigraphy is shown in Figure 1. The Mississippian limestone and chert reservoirs in the study area are subdivided into six (6) geologic intervals, the Northview and Compton Formations, the Meramecian, and the Kinderhookian Stages.

4. Data and Methodology

The data used in this study include Devonian 1-7 SWD Frieouf core that has penetrated nearly 528 ft (~161 m) of Mississippian age strata, marine core analysis of 57 core plug samples, 57 thin sections impregnated with blue epoxy, 26 high-resolution thin section images (HRTS) of selected samples taken using a fully automated system installed on an optical microscope, and 256 mm environmental scanning electron microscope (ESEM) photomicrographs taken from gold/palladium coated thin sections.

There are three main steps to accomplish the objectives of this study. First, data acquisition including core description and lithofacies analysis, this section preparation, optical microscopy and SEM photomicrography. Second, Digital Image Analysis was done in the schematic workflows below. Third, data integration, analysis, and interpretation. Lithofacies were identified from a detailed description of the Devonian 1-7 SWD core and its associated thin sections. The digital images, including high-resolution thin-section images and SEM photomicrographs, were manipulated and printed into either pore or solid phase using photo editing and manipulation software, as well as image processing software. The HRTS images were partitioned by assigning pore phase to all solid containing blue color tones that represent impregnated blue epoxy. To enhance this process, SEM photomicrographs were first manipulated to increase the contrast between pore and solid phases.

3. Geologic Setting

The Mid-Continent Mississippian limestone and chert reservoirs in north-central Oklahoma was deposited in a carbonate ramp, which locally was exposed and eroded. The study area is located in the Ardmore basin, an upthrown block of the Ouachita basin. In the study area, the Mississippian deposits show high-frequency transgressive-regressive cycles that result in a series of shallowing-upward cycles. The Mississippian stratigraphy is shown in Figure 1. The Mississippian limestone and chert reservoirs in the study area are subdivided into six (6) geologic intervals, the Northview and Compton Formations, the Meramecian, and the Kinderhookian Stages.

4. Data and Methodology

The data used in this study include Devonian 1-7 SWD Frieouf core that has penetrated nearly 528 ft (~161 m) of Mississippian age strata, marine core analysis of 57 core plug samples, 57 thin sections impregnated with blue epoxy, 26 high-resolution thin section images (HRTS) of selected samples taken using a fully automated system installed on an optical microscope, and 256 mm environmental scanning electron microscope (ESEM) photomicrographs taken from gold/palladium coated thin sections.

There are three main steps to accomplish the objectives of this study. First, data acquisition including core description and lithofacies analysis, this section preparation, optical microscopy and SEM photomicrography. Second, Digital Image Analysis was done in the schematic workflows below. Third, data integration, analysis, and interpretation. Lithofacies were identified from a detailed description of the Devonian 1-7 SWD core and its associated thin sections. The digital images, including high-resolution thin-section images and ESEM photomicrographs, were manipulated and printed into either pore or solid phase using photo editing and manipulation software, as well as image processing software. The HRTS images were partitioned by assigning pore phase to all solid containing blue color tones that represent impregnated blue epoxy. To enhance this process, ESEM photomicrographs were first manipulated to increase the contrast between pore and solid phases.
5. Result - Core Description and Lithofacies

The pores identified in this study are mainly within nanospaces (1 nm < A < 62.5 μm²/m) to micropores (62.5 μm²/m < A < 100 μm²/m) classification size. The major pore types are interparticle and intraparticle pores. Most of these pores are sealed by dissolution. The interparticle pore types consist of pores between crystals and pores between grains. The intraparticle consist of intracrystalline pores within pores, intraparticle pores within crystals, interparticle pore after crystal, and intraparticle pore after crystal. Two pore types are noted in this study, one is labeled as crystal-form pore, and the other is labeled as microfracture within crystal. These pore types are categorized as interparticle pores.

6. Result - Pore Types, Pore Morphology, Pore Size Distribution, DIA Quantitative Analysis

The 12 (12) of seventeen (17) observed lithofacies are represented by their routine core analysis data and thin sections. However, only seven (7) lithofacies have satisfactory data to draw conclusions. DIA porosity quantification generally yields a reliable result to predict porosity. Seven lithofacies have a strong positive correlation between laboratory-measured porosity and DIA porosity. Most of the porosity obtained from DIA, particularly for mud-dominated lithofacies, are higher as compared to core-measured porosity.

7. Summary


8. References

We thank the sponsors of the "Mississippian shale" Consortium at the University of Oklahoma.

Acknowledgements

We thank the sponsors of the "Mississippian shale" Consortium at the University of Oklahoma.