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Full Length Article

Quantitative characterization on shale-hosted oil reservoir: A case study of argillaceous dolomite reservoir in the Jianghan Basin

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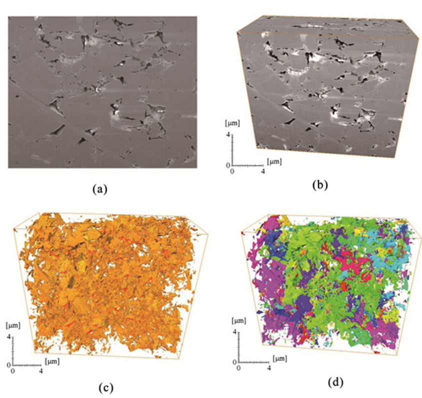
HIGHLIGHTS

- Characterization of the inorganic porosity in terms of areal porosity method.
- Reconstruction of the three dimensional pore structure of the argillaceous dolomite.
- The pore connectivity of the argillaceous dolomite and mudstone were revealed.
- The contribution of the inorganic pore radius to the porosity of the argillaceous dolomite.

GRAPHICAL ABSTRACT

FIB-SEM images were used to reveal the configuration and connectivity of the pores in the argillaceous dolomite. It shows that plenty of intercrystalline pores as well as some dissolved pores are widely distributed in the dolomite minerals, the spatial distribution of the pores is concentrated and most pores have better connectivity. The FIB-SEM images suggest that the connectivity of the pores is associated with dolomite mineral content.



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ABSTRACT

This article quantitatively investigated the microscopic pore structure of the Eocene argillaceous dolomite reservoir from the Jianghan Basin in China to further the understanding of shale oil and gas storage mechanism in these rocks, considering that extensive studies have been conducted on the shale reservoir but seldom focused on argillaceous dolomite reservoir. Image analysis technology (containing Areal porosity method, CT reconstruction calibration method and focused ion beam-scanning electron microscope) and intrusive method including mercury intrusion porosimetry were used to discuss the size, spatial distribution and connectivity of the pores, as well as to reveal the contribution rate of the pores to porosity. Dolomite and clay minerals are the main minerals in the samples (including mudstones, argillaceous dolomite and dolomite mudstones), with the average values are 27.8% and 28.5% respectively. Inorganic pores (mineral-associated pores) rather than organic pores (organic matter-hosted pores) are dominant in the argillaceous dolomite reservoir, which contain intercrystalline pores, intergranular pores and dissolved pores. The inorganic porosities calibrated by SEM range from 7.82% to 18.58%, close to the measured porosities. The argillaceous dolomites mainly develop intercrystalline pores in the dolomite mineral with good connectivity, while mudstones or dolomite mudstones mainly contain intergranular pores in the clay minerals with poor connectivity. Large throats always distribute in the parts where pores are well developed and connected. The connectivity of the pores in the argillaceous dolomite

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improves with the increase of the dolomite mineral content. The argillaceous dolomites have relatively high porosity containing more macropores while mudstones have lower porosity occupied by much more micropores. Pores with relatively larger throat radii contribute a larger fraction of the porosity of the argillaceous dolomite, while pores with smaller throat radii mainly contribute to porosity in the mudstones. These characteristics may be beneficial for understanding reservoir mechanism of argillaceous dolomite reservoir.

1. Introduction

Shale is widespread in China making it a focus for shale oil and gas exploration and development. Fortunately, shale oil and gas exploration on argillaceous dolomite and dolomite mudstones has been successful in the Jianghan Basin, Juggar Basin and Santanghu Basin, which has further expanded the domain for shale oil and gas exploration [1,2]. However, attention has seldom been paid to argillaceous dolomite or dolomite mudstones.

Previous studies show that pores in the shales are mainly micron or nanometer-scaled, and the latter is much more common [3–7]. Currently, there are mainly two methods to characterize pore features, which are image analysis and intrusive methods. Image analysis such as scanning electron microscopy (SEM), μm or Nano CT and focused ion beam-scanning electron microscope (FIB-SEM) can not only provide direct visual observation of pore structure, but also can achieve a resolution of several nanometers [8–14]. In recent years, more and more scholars began to use CT or other technologies to discuss the core digital network [15–17]. Han et al. [18] proposed the computational models and the numerical simulation results through direct mapping of the CT-scanned images. Intrusive methods can record the injecting amount and calculate the pore size distribution and surface area by injecting non wetting fluid (mercury, nitrogen or carbon dioxide) under different pressures [19–26]. Because mercury intrusion porosimetry, nitrogen and carbon dioxide adsorption methods have their own detection scopes, these methods were commonly combined to reveal the distribution of macropores, mesopores and micropores in shales [27–29]. Besides image analysis and intrusive methods, nuclear magnetic resonance (NMR) is also used to interrogate pore size distribution [30,31]. However, NMR cannot directly give pore size distribution, thus it is hard to study micropore structure without combining other methods [24,30,32]. In addition, Ultra Small Angle X-ray Scattering and Neutron Scattering (USAXS/USANS) combined with Small Angle X-ray Scattering and Neutron Scattering (SAXS/SANS) are also used to characterize the porosity in rocks [33,34]. Pore structure has some effect on the producibility of the shale or tight reservoir [35,36]. They classified the pore spaces into intergranular dominant, intermediate, and intragranular dominant and considered that more hydrocarbon is recoverable from intragranular porosity (inside the grains) than intergranular porosity (between the grains) using ultimate recovery from cyclic mercury intrusion and withdrawal based on mercury intrusion capillary pressure measurement.

Breakthrough has been achieved on shale oil exploration in the argillaceous dolomite in Eocene Xingouzui Formation rather than shales in the Jianghan Basin. To understand the reservoir mechanism of argillaceous dolomite, this article combined the image analysis and intrusive methods to discuss the microscopic pore structure, considering that image analysis can not entirely reflect shale characteristics owing to the limited vision while intrusive methods can only reflect interconnected pore features. This paper aimed to provide reference for better understanding microscopic pore structure of argillaceous dolomite reservoir in the field of unconventional oil and gas in view of that little work has been focused on argillaceous dolomite.

2. Data and methods

The samples were collected from the Xingouzui Formation in the Yajiao-Xingou Uplift and the Chentuokou Sag of the Jianghan Basin. Fig. 1A and B respectively show the distribution of the sampled wells and the comprehensive stratigraphic column of the Xingouzui Formation. The micro-pore structures were imaged by the field emission scanning electron microscopy (FE-SEM) using a FEI Quanta 200F analyzer with a resolution ratio of 1.2 nm. The image can be analyzed through secondary electron imaging (SE),

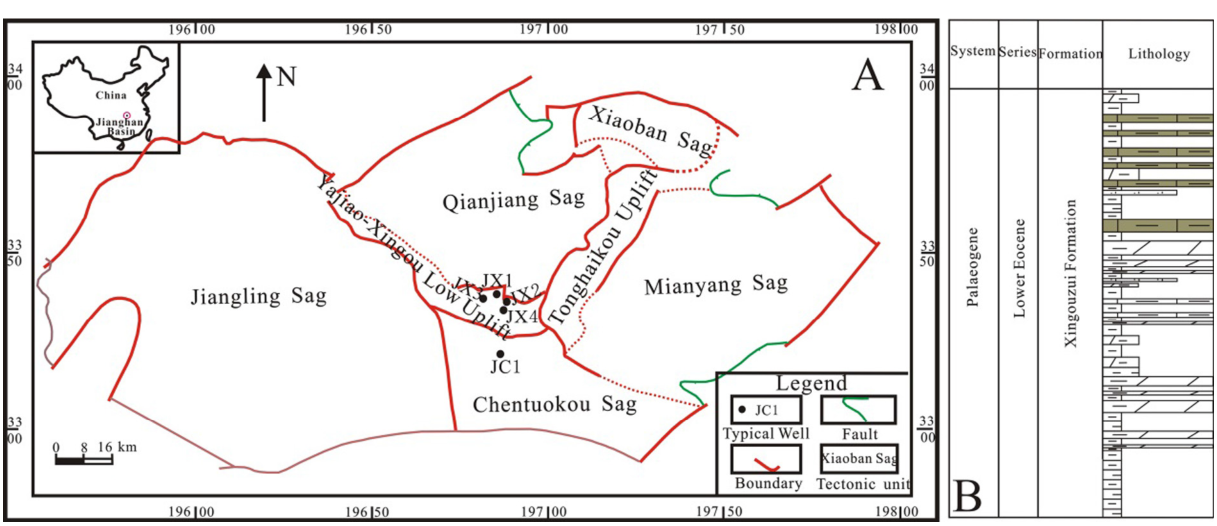

Fig. 1. The location of the structural belts and sampling wells in the Jianghan Basin.