Journal of Petroleum Science and Engineering 159 (2017) 853–868

Contents lists available at ScienceDirect

Journal of Petroleum Science and Engineering

journal homepage: www.elsevier.com/locate/petrol

Characterization of compact carbonate pore–throat network systems in the Xiagou Formation in Qingxi Sag, Jiuquan Basin, China

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ARTICLE INFO

Keywords:
Xiagou Formation
Micropore structure
NMR technique
Micrometer and nanometer CT techniques
Nanometer-scale pore–throat network system
Exploration and development

ABSTRACT

The Xiagou Formation is the main tight oil reservoir in the Qingxi Depression of the Jiuquan Basin; however, its poor physical properties have restricted tight oil exploration and development. Therefore, itis important to gain a better understanding of its micropore structure. The results show that the lithology of the Xiagou Formation reservoir is dominated by gray argillaceous dolomite and dolomitic mudstone. The pore types are primarily composed of elliptical and irregular intergranular pores. Intercrystalline and organic-matter-hosted pores are mostly isolated and have poor connectivity. Moreover, NMR spectroscopy results show that the T_2spectra of the rock samples in the study area are predominantly unimodal or bimodal in distribution, with pore sizes principally ranging between 0.01 and 0.69 μm. Using CT scanning, we obtained a three-dimensional (3D) pore–throat stereogram. At the micrometer scale, the pore throats differed in size and exhibited shelf-like, banded, and spheroidal shapes. At the nanometer scale, we observed a greater number of nanometer-scale micropores. These pores were shelf-like and spheroidal in shape and were distributed inside or at the mineral grain (crystal) surface. The nanometer-scale spheroidal micropores showed poor connectivity and were isolated in 3D space, with most serving as reservoir spaces. However, the nanometer-scale short-shelf-like micropores showed connectivity with the micrograde shelf-like micropores, were adjacent to the isolated spheroidal nanometer-scale micropores, and acted as both pore throats and pores. The larger throat-to-pore ratio coefficient indicates a greater correlation between the pore and throat, which further results in a higher concentration of pores. The larger average pore volume leads to higher porosity and, together with the higher average coordination number, enables better pore connectivity, thereby yielding a better potential reservoir and penetration capacity.

1. Introduction

Pore structure plays a major role in the physical properties of reservoirs and is a critical factor in determining their storage and hydrocarbon enrichment performances. Therefore, the investigation of pore structures in tight oil reservoirs has both theoretical significance and practical significance in reservoir evaluations (Law and Curtis, 2002; Higgs et al., 2007; Lin et al., 2011; Gao and Li, 2016).

A significant amount of geological data has been collected, and a valuable practical experience has been gained with the increasingly deep exploration of the tight oil reservoir in the Qingxi Depression of the Jiuquan Basin. However, new puzzles and challenges continue to emerge, such as characterization difficulties and the low accuracy of pore structure evaluations with respect to the tight oil reservoir in the Xiagou Formation (Perrin et al., 2006; Christian et al., 2006; Loucks et al., 2012; Adnan and Russell, 2013; Annapurna and Ganapathi, 2015; Stéphane et al., 2016). The purpose of this paper is to study the pore structure of carbonate rocks in the Xiagou Formation of the Qingxi Depression, Jiuquan Basin, clarify the carbonate pore–throat network system in the study area, and provide guidance for subsequent exploration and development.

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https://doi.org/10.1016/j.petrol.2017.09.070
Received 26 April 2017; Received in revised form 29 August 2017; Accepted 26 September 2017
Available online 5 October 2017

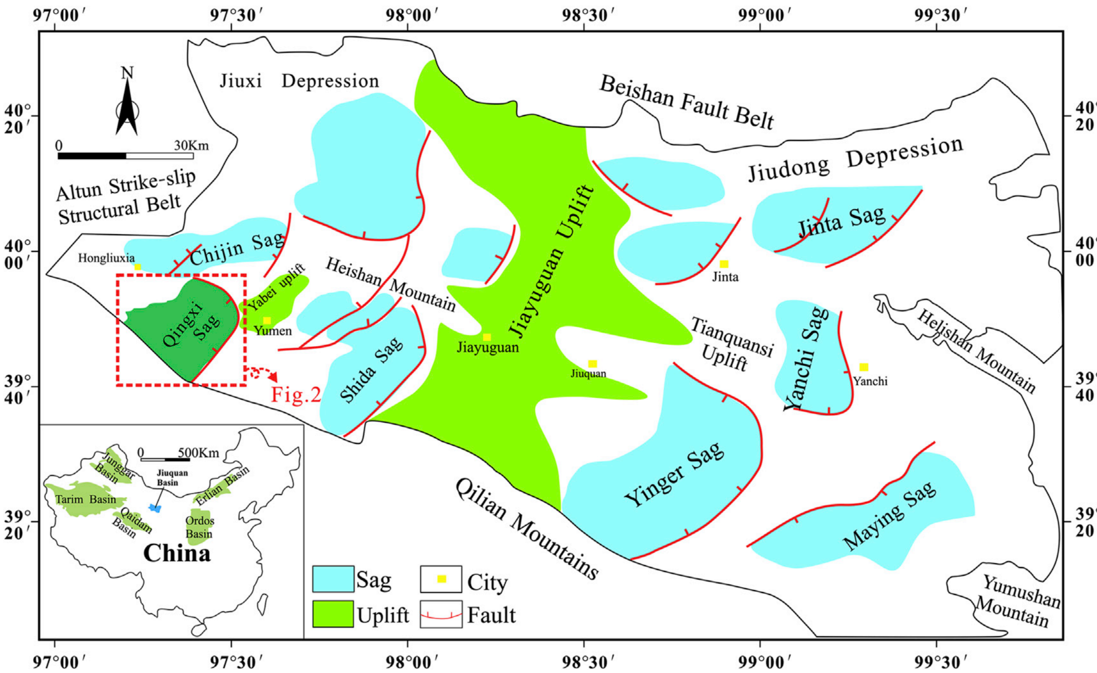

Fig. 1. Map showing the location of theQingxi Sag (Han et al., 2007; Pan et al., 2006; Sun et al., 2006; Wang et al., 2005a,b).

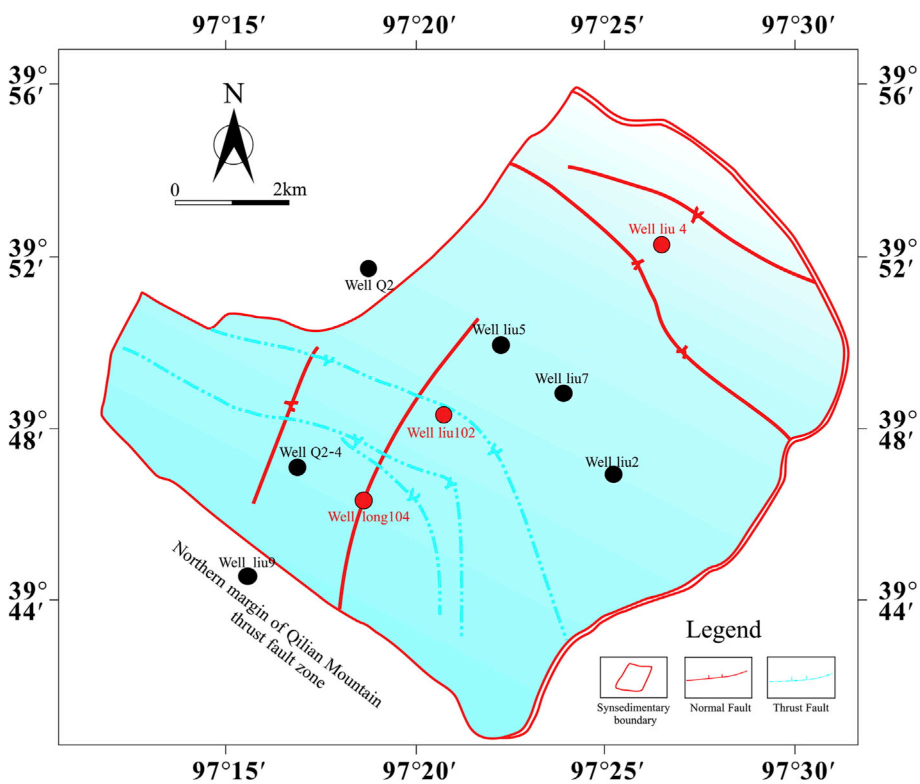

Fig. 2. Outline map of the Qingxi Sag.

2. Geological background

The Jiuquan Basin is located north of the Qilian orogeny. The Altun and Alxa plots are composed of the Jiuxi Depression, Jiudong Depression, and Jiayuguan Uplift (Chen et al., 2014; Zhang et al., 2015). The Qingxi Sag lies in the southwestern corner of the Jiuquan Basin, with an area of approximately 670 km^2 (Fig. 1) (Zhao et al., 2005). The Qingxi Sag is the depositional and subsidence center of the depression and is an asymmetrical dustpan-shaped fault that developed in the Late Mesozoic period on a Paleozoic basement (Vincent and Allen, 1999; Wang et al., 2005a,b). Since the Early Cretaceous period, Yanshan and Himalayan tectonic movements have played a decisive role in the formation and development of the depression, leading to depressions that were formed during the Early Cretaceous faulted period, the Late Cretaceous–Neogene uplift, and the flexural and depression periods since the Neogene (Fig. 2) (Tapponnier et al., 1990; Hendrix et al., 1992; Graham et al., 1993;