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Lacustrine tight oil accumulation characteristics: Permian Lucaogou Formation in Jimusaer Sag, Junggar Basin

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ABSTRACT

The Permian Lucaogou Formation of Jimusaer Sag in the southeast region of the Junggar Basin is a typical area recently attracting tight oil reservoir research efforts in China. Commercial oil has been obtained from many wells in this region. The main lithological formation comprises thick mudstones; two sweet spots exhibiting high porosity and permeability are interbedded in the mudstones. The sweet spots comprise alternating thin layers of silt-fine sandstones, carbonatites, and mudstones.

Numerous core samples were analyzed to establish the hydrocarbon generation and storage potential of Lucaogou Formation's lithological units in this region. The test results indicate that although the tight sandstones have a certain hydrocarbon generation potential, mudstones are evidently higher-quality source rocks. The silt-fine sandstones' reservoir quality is best among the three rock types.

Biomarker evidence shows the difference between the upper- and the lower-section Lucaogou Formation oil, corresponding to the mudstone layer extracts within the upper and lower sweet spot, respectively. Despite its thickness, the thick-bedded mudstone (average thickness = 80 m) between the upper and lower sweet spots does not appear to contribute to the oil reservoirs. Since the distance between the thick mudstone and the sweet spot is quite large and the entire formation has generally low permeability, migrating from the thick mudstone to the sweet spot is difficult. Hence, oil in the sweet spots can be concluded to be from the adjacent mudstone. To our knowledge, this is the first study reporting this finding.

1. Introduction

The term "tight oil" first appeared in the 1940s when it was used to describe oil-bearing tight sandstones (Ledingham, 1947). The U.S. Energy Information Administration (EIA) defined tight oil in the Annual Energy Outlook 2012 as "oil produced from shale or other low permeability reservoir with the application of horizontal drilling and multistage hydraulic fracturing technology" and in Technically Recoverable Shale Oil and Shale Gas Resources as "oil produced from low permeability sandstone and carbonate formations that can often be found adjacent to shale oil formations." (EIA, 2012, 2013).The Natural Resources Canada (NRC) identifies tight oil as the oil discovered in low permeability reservoirs. Its migration to the well site is blocked by fine grained rocks. Thus, its exploitation requires the application of high-production techniques such as horizontal drilling and hydraulic fracturing (NRC, 2014). Some scholars define it as light oil plays where the source does not coincide with the reservoir, and the matrix permeability is low (<0. 1 md). These plays are analogous to tight gas plays and may include clastics or carbonates (Clarkson and Pedersen, 2011).

Actually, light tight oil refers to two different types of reservoirs: oil in shale or claystone rocks, and oil in other rocks (IEA, 2011; BGR, 2009). Oil in the first type of reservoir is still in the formation where it was generated, i.e. source rock = reservoir. Since these kinds of rocks normally consist of shales, crude oil produced from these formations is also called "shale oil" (BGR, 2009). In the second type of reservoir, oil has actually migrated (from its source rock) over a relatively short distance into another, usually low permeability, rock formations, such as sandstone and carbonate rocks, i.e. source rock ≠ reservoir (IEA, 2011; BGR, 2009). Crude oil from these kinds of formations is called "tight oil"

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(Wang et al., 2015). It is challenging to differentiate these two types of formations clearly due to the high degree of similarity (BGR, 2009).

With the successful exploitation of Bakken oil (Williston basin, North America) (Miller et al., 2008) and Eagle Ford oil (South Texas) (Mullen, 2010), tight oil has become a research focus in global petroleum geology (Johnstone, 2007; Zou et al., 2013) and was considered the most practical unconventional replacement for oil and gas besides shale gas (USGS, 2008; BP, 2011). In China, tight oil, especially tight sandstone oil, is widely distributed and explored (Jia et al., 2012).

Marine tight oil plays are well known due to the successful exploitation of Bakken Formation (Sonnenberg and Pramudito, 2009), whereas lacustrine tight oil plays are relatively unexplored and untested. The Lucaogou Formation was previously regarded as a source rock in Junggar Basin. Inspired by the commercial development of Bakken tight oil, significant tight oil reservoirs were recently discovered in the Lucaogou Formation and commercial oils are obtained from many wells. The present study focuses on exemplifying this lacustrine tight oil system and analyzes the hydrocarbon accumulation pattern.

2. Geological setting

Junggar Basin is a large typical intracontinental superimposed basin located at the intersection of the Kazakhstan, Siberian, and Tarim plates. Jimusaer Sag, in the southeastern part of Junggar Basin (Fig. 1a and b), experienced multiperiod tectonic movements. The characteristics of the sag boundary are evident, the internal structure is gentle, and the terrain hardly changes (Fig. 1c). The sag extends over 1278 km^2 and is bordered by Guxi Uplift to the east, Beisantai Uplift to the west, Fukang

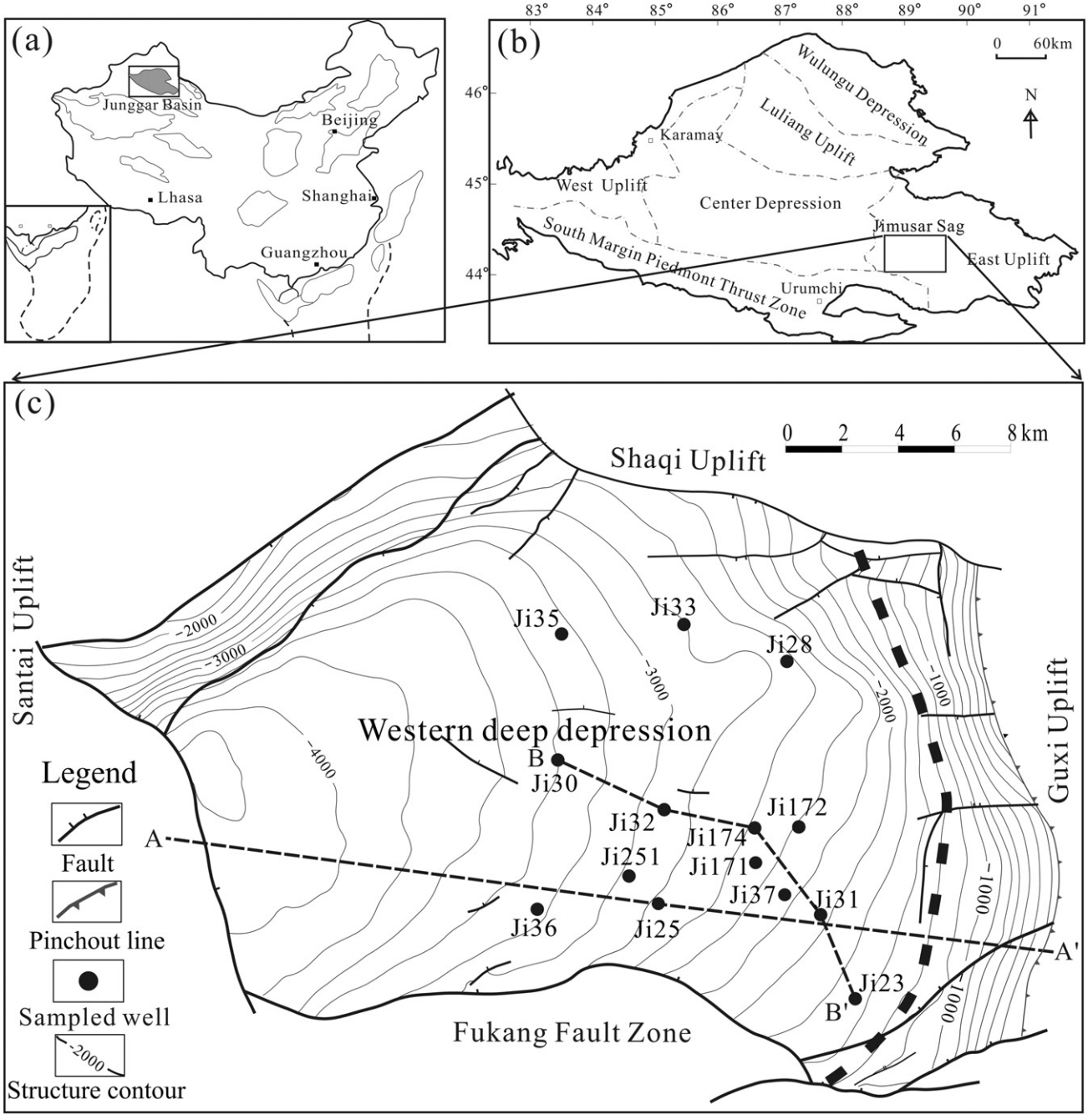

Fig. 1. (a) Location of Jimusaer Sag in Junggar Basin and (b) Jimusar Sag, with (c) structure contour on top of Lucaogou Formation of the Jimusar Sag. Sampling well locations are shown in (c).