Journal of Natural Gas Science and Engineering 50 (2018) 250–258

Contents lists available at ScienceDirect

Journal of Natural Gas Science and Engineering

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

Effects of early oil emplacement on reservoir quality and gas migration in the Lower Jurassic tight sand reservoirs of Dibei gas field, Kuqa Depression, western China

Hui Shi[a,*], Xiaorong Luo[a], Ganglin Lei[b], Hongxing Wei[b], Liqiang Zhang[c], Likuan Zhang[a], Yuhong Lei[a]

[a] *Key Laboratory of Petroleum Resources Research, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China*
[b] *Research Institute of Petroleum Exploration& Development, PetroChina Tarim Oilfield Company, Korla 841000, China*
[c] *School of Geosciences, China University of Petroleum, Qingdao, Shandong 266555, China*

ARTICLE INFO

Keywords:
Tight sand gas
Early oil emplacement
Sweet spots
Hydrocarbon migration
Lower jurassic
Kuqa depression

ABSTRACT

It is common for many tight gas sandstone reservoirs to have experienced an early oil charge before gas invading. To determine the effects of early oil emplacement on reservoir quality and gas migration has important role in predicting “sweet spots” of gas production in tight sand reservoirs. We investigated the palaeo and current fluids contacts accurately due to parameters from quantitative grain fluorescence in the Lower Jurassic Ahe Formation of Dibei gas field. The porosity and permeability values in palaeo-oil leg are totally higher than in palaeo-water leg, especially there being a wide gap of permeability with an order of magnitude. The variation of reservoir quality derives from the early oil emplacement, which restrained clay conversions from kaolinite or illite-smectite mixed-layer into fibrous illite that dramatically increasing flow-path tortuosity in sandstones, according to core analysis and X-ray diffraction. The early oil preserved penetrating quality of palaeo-oil leg, but the sandstones that never experienced early oil emplacement contains much more fibrous illite. It made most of early oil pathways subsequently act as the migration pathways for late gas and less than 50% of the migration pathways for gas were caused by microfractures due to quantitative grain fluorescence. Only the sandstones with medium early oil saturation did become sweet spots for gas in the tight sand reservoirs. Too much and too little oil once saturated in pores maybe adverse to the late gas migration and accumulation.

1. Introduction

The tight sand gas, as one type of unconventional resources, plays a significantly important part in the natural gas production of the world. Tight gas sand reservoirs are natural extensions of conventional sandstone reservoirs and are commonly referred to as low-permeability reservoirs, having in situ permeabilities lower than 0.1 md and no natural commercial hydrocarbon capacity (Holditch, 2006). Compared to shale gas reservoirs, they generally contain more brittle components and are easier to engineer for commercial gas flow (Ma et al., 2016). Although shale gas and shale oil have recently made revolutionary breakthroughs in the USA, more than 50% of all natural gas production is still from tight gas sand reservoirs (EIA, 2015). Since the discovery of two tight sand gas fields in the Ordos Basin (Sulige gas field) and the Sichuang Basin (Chuangxi gas field) (Zou et al., 2011; Hou et al., 2015), this type of reservoir has also played a significant role in China's total gas production.

It appears that the early oil emplacement before gas charging is common in the tight gas sandstone reservoirs. Law (2002) proposed two formation modes of basin-centered gas systems (BCGSs) based on the type of source rock. Direct BCGSs are characterized by gas-prone source rocks, while indirect BCGSs are based on liquid-prone source rocks, which initially produce liquid hydrocarbons that are then thermally cracked to form methane (Law, 2002). Some studies have investigated tight gas reservoirs in the Cretaceous of the western Rocky Mountain basins of the U.S. and in the Triassic of the western Canadian Basin, which had experienced early oil emplacement before gas invasion (Roberts et al., 2004; Tobin et al., 2010; Wood et al., 2015). Shanley and Cluff (2015) emphasized that sandstone porosities during the initial oil charge were 2–3 times greater than current levels, while permeabilities were 1–3 orders of magnitude greater in many tight gas basins of the western United States. In China, a large amount of pore migrabitumen was found in the Upper Triassic tight sand reservoirs of Chuangxi and in the Upper Palaeozoic of Sulige (Zhang et al., 2009;

* Corresponding author.
E-mail address: cupfidel@qq.com (H. Shi).

https://doi.org/10.1016/j.jngse.2017.12.004
Received 28 August 2017; Received in revised form 23 November 2017; Accepted 14 December 2017
Available online 21 December 2017
1875-5100/ © 2017 Elsevier B.V. All rights reserved.

Wang et al., 2011; Liu et al., 2012), suggesting that early oil emplacement in tight sand reservoirs may be common and pervasive before gas invading.

Oil emplacement was regarded as one mechanism for porosity preservation by inhibiting diagenesis in sandstones that exposed to high temperatures (Worden et al., 1998; Marchand et al., 2001; Worden and Barclay, 2003; Wilkinson and Haszeldine, 2011). However, there were some evidences to suggest that hydrocarbon-rich pore fluids do not significantly influence cementation rates and reservoir quality in sandstones (Walderhaug, 1996; Taylor et al., 2010). In fact, it is extremely difficult to accurately distinguish the palaeo oil–water contact only using logging and production data under conditions of multi-stage hydrocarbon emplacements and brine reinjections. In addition, strong reservoir heterogeneity also results in multiple oil–water contacts in low-permeability sand reservoirs (Luo et al., 2015). We believe that it is primary to demonstrably identify the palaeo oil-water contacts (POWCs) and current gas–water contacts (CGWCs) for acquiring the effects of early oil emplacement on the sand reservoir quality.

The quantitative grain fluorescence (QGF) technique (Liu and Eadington, 2005; Liu et al., 2014) was employed to detect both current (residual) and palaeo (encapsulated) oil in reservoirs with a single analytical procedure. It can precisely identify palaeo oil–water contacts, current gas–water contacts, and hydrocarbon migration pathways by detecting traces of hydrocarbon compounds trapped as inclusions (QGF) or absorbed onto grains (QGF-E). Fortunately, Liu et al. (2015) measured the QGF parameters for the Lower Jurassic tight sandstones of the Dibei gas field, where the reservoirs were regarded as typical tight sandstones (Zou et al., 2011). Although the POWCs and CGWCs were confirmed by the QGF technique, there was no deep work to investigate the differences between palaeo-oil legs and water legs, especially to find out whether early oil emplacement inhibiting diagenesis or not.

In this paper, we firstly compared the reservoir qualities and clay mineral, which was determined as one important factor controlling the reservoir quality in the Ahe sandstones of Dibei gas field in the Kuqa Depression (Zou et al., 2011; Zhang et al., 2015), between sandstones that had experienced early oil charge and ones that were never filled with oil. Secondly, the relationship between the early oil migration and late gas percolation was studied. The ultima goals of this study are to (1) determine the effects of early oil on reservoir quality of tight sandstones, (2) reveal the formation mechanisms of gas migration pathways, and (3) identify the main factors controlling production sweet spots.

2. Geologic setting

The Kuqa Depression in the Tarim Basin, western China (Fig. 1a), is dominated by four structural belts and three sags. The four structural belts include the Northern Monocline belt and the Kelasu, Yiqikelike, and Qiulitage Thrust Belts. The Baicheng, Yangxia, and Wushi sags are the main negative tectonic units (Zeng et al., 2010; Tang et al., 2014) (Fig. 1b). The Dibei gas field is in the central part of the Yiqikelike Thrust Belt (Fig. 1b). It borders the southern Tianshan Orogenic Zone to the north and the Qiulitage Thrust Belt to the south.

The study area was influenced by the Middle and Late Yanshan (approximately 135–23.3 Ma) and Himalayan (approximately 23.3–0.7 Ma) tectonic movements (Fig. 2) and exhibits typical foreland thrust deformation characterized by a series of north-dipping thrust faults (Zeng et al., 2010) (Fig. 1c). The Yiqikelike Fault in the north of the gas field is the most important fault, which began to form during the late Eocene (approximately 34 Ma) and intensified during the late Miocene and Quaternary (approximately 10–1.6 Ma) (Zhang et al., 2014).

The strata in the Dibei gas field are primarily Mesozoic and Cenozoic, consisting of terrestrial clastic rocks, coal seams, and salt layers (Fig. 2). Coal layers occur in the Upper Triassic Taliqike Formation (T_3t), Lower Jurassic Yangxia Formation (J_1y), and Middle Jurassic Kezilenuer Formation (J_3kz). Salt, gypsum, anhydrite, and dolomite are interbedded with thin mudstone layers and extend from the Paleocene Kumugeliemu Formation (E_1k) to the Miocene Jidike Formation (N_1j). Other strata are normal terrestrial clastic rocks with conglomerate, sandstone, and mudstone. This lithological assemblage indicates a lacustrine and evaporative swamp environment (Zhang et al., 2014; Yu et al., 2014).

The Dibei gas field, discovered in the 1990s, is a typical tight sand gas accumulation (Li et al., 2004). The main gas-bearing interval is the Ahe Formation of Lower Jurassic (Figs. 2 and 3), which is characterized by upward-fining deposits and represents a transition of braided river delta (Ahe Formation) to shallow lake (Yangxia Formation) (Liu et al., 2004). The sandstone reservoirs in Ahe Formation, which have been determined to be tight although some intragranular microfractures (Liu et al., 2004; Ju et al., 2013; Lu et al., 2015), are medium-coarse grained litharenites and feldspathic litharenites ($Q_{26.5\sim52.4}F_{6.0\sim35.3}R_{32.1\sim53.3}$) with igneous fragments dominating over metamorphic and sedimentary fragments. The mean gas porosity is approximately 7.3%, and the mean gas permeability is below 1.0 md (Li et al., 2004). Approximate 6.9%–10.9% of pores are primarily occupied by the clay matrixes, in which authigenic illite is the most common (Zou et al., 2011; Zhang et al., 2015). It indicates that the authigenic is one of the most important controls for reservoir quality.

Previous studies (Liang et al., 2003; Li et al., 2004; Zhu et al., 2015) documented that the source rocks for the gas in the Dibei gas field are located in the Yangxia Sag (Fig. 1). The Huangshanjie Formation (T_3h) and the Taliqike Formation (T_3t) are oil-prone lacustrine shales that consistently generated hydrocarbons from 35 Ma to 12 Ma. Gas-prone source rocks in the Yangxia Formation began to expel gas from 5 Ma. Multi-stage hydrocarbon charges into the Ahe Formation were confirmed by both micropetrography and microthermometry for hydrocarbon inclusions (Gao et al., 2002; Guo and Zhu, 2005; Li et al., 2013). Some attempts (such as Ju et al., 2013) were conducted to explain the distribution of natural fractures with the tectonic stress field and to predict production sweet spots in the study area. The results suggested that the locations with high fracture density were near wells YN4 and YS4 in the north. It is inconsistent with the gas exploration, because the two wells mainly produce water as well as a little gas (Guo and Zhu, 2005) (Fig. 3). Therefore, the fractures should not be responsible for the formation of sweet spots in the study area.

3. Samples and methods

QGF is a technique to test ancient and current hydrocarbon quantity by detecting traces of hydrocarbon compounds trapped as inclusions (QGF) and adsorbed onto grains (QGF on extract, or QGF-E). QGF index is defined as the average spectral intensity between 375 nm and 475 nm normalized to the spectral intensity at 300 nm and indicates hydrocarbon inclusion abundance. QGF-E intensity corresponds to the maximum spectral intensity normalized to 1 g of quartz sand in 20 mL of DCM solvent, which is used to estimate the concentration of residual hydrocarbon (Liu and Eadington, 2005; Liu et al., 2014). In general, the sandstones from palaeo-oil leg have high QGF index values and the QGF-E intensity values of current-gas leg are high; the distinguish of palaeo-water leg and current-water leg is the opposite. The two fluorescence parameters together with the waveform can be used to identify the POWCs and CGWCs. In the study area, eighty-six core samples were selected by Liu et al. (2015) for QGF analysis from four key wells, including wells YN2, YN4, YS4 and YN5 (locations showed in Fig. 1c). We adopted the data from QGF analysis to determine the POWCs and CGWCs for Dibei gas field, and then to investigate the relationship between early oil migration and late gas migration.

Furthermore, we selected a total of 1037 sandstone core samples from Ahe Formation of well YN4 for routine core analysis to analyze the variation of reservoir quality between the sandstones that experienced oil emplacement and the ones did not. These cores were firstly were

Download English Version:

https://daneshyari.com/en/article/8128426

Download Persian Version:

https://daneshyari.com/article/8128426

Daneshyari.com