Hydrocarbon generation and expulsion of Middle Jurassic lacustrine source rocks in the Turpan–Hami Basin, NW China: Implications for tight oil accumulation

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Abstract
In recent years, new oil reservoirs have been discovered in the middle Jurassic tight mixed rocks of the Turpan–Hami Basin. However, the generation potential of the J2q2 source rocks remains poorly understood. Petrographic, petrological, and geochemical analyses were carried out to assess the quality of the J2q2 source and reservoir rocks. The hydrocarbon generation potential method was utilized to evaluate the hydrocarbon generation and expulsion potentials. The results indicated that the rocks can be classified as high-quality source rocks with a relative lower degree of maturity. The hydrocarbon bearing zones are classified as tight reservoirs (average porosity of 5.90% and permeability of 0.18 mD) with an average pore throat radius > 150 nm, which is higher than the cut-off pore-throat radius. The source rocks start to expel hydrocarbons when Ro is 0.56%. Bulk hydrocarbon generation and expulsion intensities in the center of the study area were calculated with the values of 900 \times 10^4 t/km² and 400 \times 10^4 t/km², while the weights of

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these hydrocarbons were $48.8 \times 10^8$ t and $27.3 \times 10^8$ t, respectively. The tight oil reservoir-forming conditions are superior, and the hydrocarbon generation and expulsion intensities are more remarkable in controlling the tight oil distribution. This study provides an important example for the Jurassic source rocks in Western China, and indicates that middle Jurassic lacustrine source rocks deserve attention in future exploration.

**Keywords**
Tight oil accumulation, Resource potential evaluation, middle Jurassic lacustrine source rocks, second member of Qiketai formation, Turpan–Hami Basin

**Introduction**

The qualities of source rocks are the material factors that control petroleum generation and accumulation; furthermore, they are prerequisites in hydrocarbon exploration and prospect appraisal, especially for unconventional resources (Hu et al., 2018; Jia et al., 2016). More than 90% of the world’s recoverable hydrocarbon reserves are produced from six sets of source rocks, including Jurassic source rocks which account for about 25% of the total source rocks in the whole geological period, and Jurassic tight oil reserves account for 31.0% of the total tight oil resources (Klemmeetal, 1991; Ma et al., 2014; Wang 2016; Zou et al., 2015). In China, the tight oil resources of Jurassic system can reach $16.10 \times 10^8$ t, and economical production from the Middle–Lower Jurassic Formation in the Sichuan Basin has been documented (Li et al., 2017; Zheng et al., 2019). Moreover, the Jurassic source rocks in Qaidam Basin, Yabrai basin (The estimated resource of tight oil is $0.92 \times 10^8$ t) are of high quality and have potential for tight oil exploration (Fu et al., 2013; Gao et al., 2017; Liu et al., 2008). These examples showed that there are considerable tight oils in Jurassic stratum. The study on the quality of source rocks and tight oil resource potential of the second member of Qiketai formation will provide an important research example, which will be helpful to promote the exploration and research of tight oil in the Jurassic system.

Previous studies mainly focused on Permian Wutong, Triassic Karamay, Jurassic Badaowan, Xishanyao and the Cretaceous formations, (Gou et al., 2019; Ni et al., 2015; Sun et al., 2000; Shao et al., 2003; Wang et al., 2018). However, there was no systematic research about tight petroleum resources in the Turpan–Hami Basin. While the geochemical characteristics of the middle Jurassic lacustrine source rocks including the second member of Qiketai formation have been studied. However, previous investigations of source rocks were still not sufficient for full characterization. Thus, the tight oil resource prospects of the J$_2$q$_2$ reservoir remain unclear, which inhibits further exploration. Moreover, the hydrocarbon generation and expulsion characteristics of low-maturity source rocks are rarely studied. The aims of this study are: (1) examination of source rock characteristics, as well as the hydrocarbon generation and expulsion intensity, efficiency, and quantities, (2) determination of the J$_2$q$_2$ reservoir characteristics (petrological characteristics, porosity, and permeability, reservoir pore space, pore structure, the pore-throat diameter and porosity cut-offs), (3) determination and comparison of the potential of Jurassic source rocks. The findings are helpful for understanding the tight oil resource potential, and inform the Jurassic unconventional oil and gas exploration in petroliferous basins of Western China.
Geological background

The Turpan-Hami Basin (Figure 1(a)) is an intermountain basin extending from east to west, with a total surface area of $\sim 5.35 \times 10^4$ km$^2$, and the effective exploration area is $3.50 \times 10^4$ km$^2$ (Gou et al., 2019). The Permian, Triassic, Jurassic, Cretaceous, Paleogene and Quaternary systems with a thickness of nearly 10000 m were deposited on the folded basement (Wang et al., 2018; Yuan et al., 2002).

The Shengbei area is located in the western part of the Taibei Depression, Turpan-Hami Basin (Figure 1(b)). During Mesozoic, Shengbei area was mainly compressed by the North-South tectonic stress, resulting in a series of strike-slip and thrust faults, which provided conditions for hydrocarbon migration and accumulation (Xiao et al., 2016). At present, many sets of oil and gas bearing horizons such as Jurassic and Cretaceous have been found, and the Middle Jurassic is an important source rock development horizon (Wang et al., 2018; Yuan et al., 2002; Zhu et al., 2014). The Jurassic stratum (Figure 1(c)) can be divided upwards into the Badaowan, Sangonghe, Xishanyao, Sanjianfang (J$_2$s), Qiketai (J$_2$q), Qigu, and Kalazha formations (Feng et al., 2020; Ni et al., 2015). The thickness of the J$_2$q ranges from 100 to 250 m. The J$_2$q depth gradually increases from SE to NW. The source rocks are in contact with the

Figure 1. Comprehensive geologic map of the Shengbei area (modified from Feng et al., 2020). (a) Location of the Turpan-Hami Basin. (b) Geological map of the Shengbei area. (c) Generalized columnar section of the Shengbei area.
overlying tight reservoirs or alternates with tight reservoirs in the vertical direction, which is beneficial to the migration and accumulation of tight oil (Figure 2).

**Samples and basic geochemical information**

**Samples**

Samples have been collected for total organic carbon (TOC) content measurements, pyrolysis analyses, chloroform bitumen “A” content measurements, vitrinite reflectance measurements, elemental composition of kerogen measurements, and biomarker groups. Furthermore, the characteristics of the tight reservoir were elucidated using data from measurements of reservoir physical properties, mercury injection tests and nuclear magnetic resonance (NMR) analyses. The thin-section analyses, scanning electron microscopy (SEM) images, argon ionization-field emission scanning electron microscopy (AIP-FESEM) images, and X-ray diffraction were also carried out for samples.

![Figure 2. Stratigraphic column and its major source-reservoir-caprock association in the study area.](image-url)
Rock-eval pyrolysis results were obtained by the temperature-programmed method in the OGE-II oil and gas evaluation workstation. For the determination of chloroform bitumen “A”, the samples should be crushed to the particle size below 0.18 mm, then dried and weighed to 60 g for extraction. After the filtrate was concentrated, the content of chloroform bitumen “A” could be weighed and calculated. $R_o$ values were measured using an MPV-SP microphotometer. Elemental composition of kerogen results were determined by using a Elemental cube element analyzer, before the experiment, the kerogen was finely mixed and dried at 60°C for 4 hours. Gas chromatography-mass spectrometry (GC-MS) data were acquired using an Agilent 7890–5975C GC-MS instrument with a HP-5MS capillary column ($60\text{ m} \times 0.25\text{ mm} \times 0.25\text{ μm}$).

The porosity and permeability of the reservoir rocks were determined for a 3 cm long cylinder core using a PoroPDP-200 overburden pressure porosity and permeability measuring instrument, whose porosity and permeability measurement ranges were 0.01% – 40% and 0.00001 – 10 mD. Mercury injection values were obtained using a Conta PoreMaster-60 instrument, which is suitable for measurements of pore throat diameters between 2.8 nm and 50.0 μm. NMR data were obtained using a MesoMR23-060-H-I instrument with a frequency of 21 MHz and a magnetic field intensity of 0.5 T. The samples were prepared with a length and width of 3.0 cm and 2.3 cm.

**Hydrocarbon generation potential method**

Using the hydrocarbon generation potential methodology to construct the hydrocarbon generation and expulsion pattern. The source rocks original hydrocarbon generation
potential of the source rocks was recovered by the material balance method (Pang et al., 2005). GPI (GPI = 100 × (S1+S2)/TOC) is a parameter used to express the hydrocarbon generation potential of source rocks, which could evaluate the hydrocarbon generation ability (Peng et al., 2016, 2018). As shown in Figure 3, GPIo is the original hydrocarbon generation potential index, the remaining hydrocarbon generation potential index (GPIr) is defined as the hydrocarbon generation potential of the source rocks after hydrocarbon has been expelled (Peng et al., 2016). GPIo can be calculated by the following equations (1) and (2):

\[
GPI_o = \frac{GPI_r}{k}
\]

(1)

\[
k = \left(1 - 0.83 \times \frac{GPI_r}{1000}\right) / \left(1 - 0.83 \times \frac{GPI_o}{1000}\right)
\]

(2)

In the equation above, k is a restored coefficient and 0.83 is the average carbon content of hydrocarbons (Jarvie, 1991).

The hydrocarbon expulsion potential index (q_e) (mg HC/g TOC) indicates the hydrocarbons expelled per unit of organic carbon since the source rocks passed the hydrocarbon expulsion threshold (equation (3)). The hydrocarbon expulsion rate (r_e) can be calculated by equation (4).

\[
q_e(R_o) = GPI_o(R_o) - GPI_r(R_o)
\]

(3)

\[
r_e(R_o) = \frac{dq_e}{dR_o}
\]

(4)

The hydrocarbon generation intensity (I_g) and expulsion intensity (I_e) are the amounts of hydrocarbon generation and expulsion per area, which can be calculated by equations (5) and (6), respectively.

\[
I_g = \int_{R_o^t}^{R_o} q_g(R_o) \times H \times \rho \times TOC(R_o) \times d(R_o)
\]

(5)

\[
I_e = \int_{R_o^t}^{R_o} q_e(R_o) \times H \times \rho \times TOC(R_o) \times d(R_o)
\]

(6)

where \(R_o^t\) is the \(R_o\) value when the source rocks reach the hydrocarbon expulsion threshold, \(H\) is the thickness of the source rocks (m), and \(\rho\) is the bulk density of the source rocks (g/cm³).

**Specific surface area method**

The pore-throat radius can be obtained through high-pressure mercury injection experiments (Yan et al., 2017; Zhang et al., 2014). The surface area corresponding to different pore-throat radius can be determined via equation (7). And the cut-off pore-throat diameter
can be determined according to the inflection point where the specific surface area starts to increase rapidly.

\[ A_{qi} = \frac{2}{r_i \Delta V} \]  

(7)

where \( A_{qi} \) is the total pore surface area (cm\(^2\)), \( r_i \) is the pore-throat radius corresponding to the mercury intake pressure \( P_{ci} \) (\( \mu \)m), and \( \Delta V \) is the pore volume controlled by the radius \( r_i \) (cm\(^3\)).

**Results**

**Source rocks evaluation**

*Sedimentary environment.* The formation of high-quality source rocks is closely related to the sedimentary environment (Sun et al., 2019; Wang et al., 2020). The average value of the ratios of pristane/phytane is 0.82, according to the Pr/Ph ratio criterion (Li, 1999), the sedimentary environment is a freshwater to mildly brackish lake environment, the water medium is a reducing environment, and the main sediments are mudstone with high organic contents.

*OM abundance.* The OM abundance of the source rocks was evaluated using TOC and chloroform bitumen “A” content. The results show that most samples are considered with classification as a good source rock, with only a few samples being classified as poor or nonsource rock (Figure 4). These data indicate that the source rocks have high hydrocarbon generation potential.

*OM type.* The OM type of the source rocks was evaluated using organic elemental analyses and organic maceral analyses. The scatter diagram of H/C and O/C ratios of kerogen is established to assess the kerogen types. The average values of H/C and O/C atomic ratio of kerogen are 1.31 and 0.050, respectively and the ratios are different from J\(_{2s}\) and J\(_{2q1}\), which the organic matter types are type II and III kerogen (Figure 5). The organic macerals are

![Figure 4](image-url)  

*Figure 4.* The frequency chart of TOC and chloroform bitumen “A” of the source rocks in the Shengbei area (ranges from Hu and Huang, 1991).
dominated by sapropelite (Figure 6). These data show that the organic matter types are mainly type I and II kerogen.

**Thermal maturity of OM.** The OM maturity of source rocks was studied using the $R_o$ values, the odd/even predominance ratio (OEP), the carbon preference index (CPI) of $n$-alkanes, and sterane isomerization. The $R_o$ values are all higher than 0.5%. The CPI values vary from 1.22 to 1.39 and the OEP values vary from 1.09 to 1.33. These values indicate that the majority of source rocks are low-mature–mature. Furthermore, the $20S/(20S + 20R)$ isomerization ratios of the C$_{31}$ hopane are all less than 0.6, which also demonstrate low-mature source rock features.

**Hydrocarbon generation and expulsion characterization of source rocks**

The hydrocarbon generation and expulsion patterns were established with the source rocks pyrolysis data and the hydrocarbon generation potential method (Pang et al., 2005). The pattern shows that source rocks started to expel hydrocarbons when $R_o$ is 0.56%. The
hydrocarbon expulsion efficiency concurrently increases from 0 to 57.7% (average of 46.0%) (Figure 7).

The hydrocarbon generation potential curve of source rocks is a comprehensive reflection of the effects of different geological factors (Peng et al., 2016, 2018). Based on source rocks’ thickness, TOC, R_0 values, and the hydrocarbon generation and expulsion patterns, the hydrocarbon generation and expulsion intensities of the source rocks were calculated using equations (5) and (6), respectively. The intensities of hydrocarbon generation and expulsion of the hydrocarbon generation and expulsion centers can exceed 900 and 400°C/104 t/km2, respectively. The generated and expelled hydrocarbon amounts from the J2q2 source rocks are 48.8 x 10^8 t and 27.3 x 10^8 t, respectively.

Tight reservoir characterization

The reservoirs with porosities lower than 10% and permeabilities lower than 1 mD are classified as tight reservoirs (Hu et al., 2018; Jia et al., 2016; Peng et al., 2016). In this paper, we analyze the petrological characteristics, porosity, permeability, pore systems, and pore structure characteristics of the J2q2 reservoir and detail identifiable tight reservoir features.

Petrological characteristics. Among the minerals, silty quartz and feldspar grains account for 17.8%–65.0% of the total mineral content, and the proportion of carbonate minerals ranges from 9.0 to 56.1% while that of clay minerals range from 10.6 to 53.0%. The clay minerals mainly consisted of an Imon mixed layer, with an average value of 52.35%, while the contents of chlorite and kaolinite were low, with an average value of 10.62% and 10.53%. The average brittleness index of the reservoir is 68.43% based on the rock mineral composition method (Jin et al., 2015). The J2q2 reservoir shows the characteristics of mixed deposition, which can be divided into silty mixed rock, argillaceous mixed rock and carbonate mixed rock.

Reservoir physical properties. The porosity ranges from 0.6% to 10.8% (average of 5.90%) and the permeability ranges from 0.003 to 1.07 mD (0.18 mD on average), except for the samples

Figure 7. Simulation model of hydrocarbon generation and expulsion of the J2q2 source rocks in the Shengbei area, Turpan-Hami Basin.
with microfractures, indicating that the J2q2 reservoir is characterized by low porosities and low permeabilities. And silty mixed rocks have the best physical properties, with average values of 6.72% and 0.26 mD, respectively. The porosity and permeability of carbonate mixed rock are slightly lower than silty mixed rocks, with average values of 5.55% and 0.21 mD. The permeability of argillaceous mixed rocks is ultra-low, and the average permeability is only 0.05 mD (Figure 8).

**Pore systems.** There are four different types of reservoir spaces in the study area: intergranular pores (Figure 9(a) and (c)), intercrystalline pores (Figure 9(b) and (d)), secondary dissolution pores (Figure 9(e) and (f)), and fractures (Figure 9(g) to (i)). The intercrystalline and intergranular pores are irregular with pore radius ranging from 0.02 to 9.7 μm, and the porosity (obtained by point counting) varies from 0.2% to 3.6% with an average value of 1.7%. Dissolution pores are widely distributed, and the pore radius ranged from 0.01 to 6.7 μm, while the dissolution porosity ranges from the trace level (<0.1%) to 1.3%, with an average of 0.7%. The fractures and microfractures appear as linear, dendritic, and reticulated fractures with widths of 0.005 to 0.05 mm, and most of them are unfilled. Even if some fractures are filled, they can still contribute to inducing additional fractures, which is important for tight oil infiltration.

**Pore structure characteristics.** The pore radius of the reservoir range from 8.9 to 9700 nm (average of 150 nm), and the matrix pores are dominated by nanopores. The displacement pressure is mostly lower than 15 MPa, and the average efficiency value of mercury ejection is 40.92%. The saturated NMR T2 spectrum shows two main peaks, the shape of the left peak (T2 range from 0.1 to 1.0 ms) is similar, but the right peak (T2 range from 10 to 100 ms) of different types of reservoirs shows different characteristics, silty mixed rocks have the high right peak, and carbonate mixed rock have a moderate amplitude of right peak. It is also found that the samples with a high clay mineral content are mostly characterized by discontinuous double or triple peaks in the NMR T2 spectrum, which have a distinct the left

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**Figure 8.** The porosity-permeability analysis plot of the J2q2 reservoir in the Shengbei area (ranges from Jia et al., 2016; modified from Feng et al., 2020).
peak and a small right peak, indicating that the micropore size of the argillaceous mixed rocks is underdeveloped and that the pore structure is poor (Figure 10).

As shown in Figure 11, the specific surface increases rapidly when the pore-throat radius range from 20 to 50 nm. Thus, we consider that the cut-off pore-throat radius of the reservoir is 50 nm. The porosity has a good correlation with the pore-throat radius. With the increase in the pore-throat radius from 14 to 589 nm, the porosity increases from 0.99 to 8.4%; thus, the lower limit of the porosity can be determined to be 2.6%.

Discussion

Factors controlling the expulsion magnitude and efficiency are organic matter abundance, organic types and maturity of source rock. The high-quality source rocks should have high hydrocarbon generation and expulsion intensities, which are favorable for tight petroleum
Figure 10. The pore structure characteristics of the J2q2 reservoir in the Shengbei area.

Figure 11. The cut-off pore-throat value of the reservoir was evaluated using the specific surface area method.
accumulations and development potentials (Bowker, 2007; Chen et al., 2014; Liu et al., 2019; Lu et al., 2012; Peng et al., 2016, 2018). Compared with the Huilu area, the hydrocarbon generation and expulsion intensities in the Shengbei area are relatively low (Peng et al., 2016), because the thermal maturity of the source rocks is lower. However, low-maturity source rocks can also form large amounts of tight oil, such as the Permian Lucaogou Formation in the Santanghu Basin, the Shahejie Formation in the Shulu Sag and the Qingshankou Formation in the Songliao Basin, which have experienced geological conditions suitable for the formation of tight oil (Table 1) (Huo et al., 2020; Liang et al., 2017; Lin et al., 2019). The studies of lacustrine immature-low mature oil in China show that after algae die and were buried, their cellular organic matter and lipid aggregate into alginate and then incorporated into kerogen. As long as the reductive sedimentary-diagenesis conditions were available, hydrocarbon generation can happen at the early stage (Ge et al., 2016; Huang et al., 2003; Luo et al., 2012; Wang et al., 1995). The hydrocarbon generation capacity of low mature source rocks increases with the contents of sapropelite and exinite (Li, 2009). The J2q2 source rocks formed in reductive sedimentary environment having a high abundance of organic matter and the main kerogen macerals are sapropelite. Moreover, there is a positive correlation between major kerogen macerals and chloroform bitumen “A”, which favors the generation of low-maturity oil. In addition, the source rocks with good organic matter have a shallower hydrocarbon expulsion threshold, and its hydrocarbon expulsion peak will be earlier, which are conducive to the accumulation of low-mature oil (Chen et al., 2014; Guo et al., 2012; Jiang et al., 2016).

Widely developed reservoirs are an important prerequisite for the accumulation of tight oil, and the quality of a reservoir is crucial for the enrichment of lacustrine tight oil and its effective utilization (Hu et al., 2018; Zhang et al., 2018; Zhao et al., 2017). The distribution area of the J2q2 tight reservoir in the Shengbei area can reach 1025 km², and the thickness of the reservoir ranges from 30 to 130 m (Zhu et al., 2014). In addition, the source rocks are largely in contact with the overlying tight reservoirs or alternate with reservoirs in the vertical direction. These conditions correspond to the accumulation model of tight oil that refers to a self-source and self-reservoir with a near-source in the reservoirs, ensuring an efficient accumulation of tight oil (Hu et al., 2018; Qiu et al., 2016; Zhu et al., 2014; Zou et al., 2010). The micropore structure of the tight oil reservoirs is complex, and nano-scale-pores were mainly developed, so in the tight reservoirs only flowable crude oils can be exploited effectively (Feng et al., 2019; Hu et al., 2018). The J2q3 reservoir has a high content of brittle minerals, and the compression due to the NW to SE tectonic stress during the deposition of the Qiketai Formation has resulted in notable fracture development with a fracture density of up to 2.6 fractures/m (Wang et al., 2019; Zhu et al., 2014). The crude oils in the reservoirs are light oils and the pressure coefficients of the exploited J2q2 reservoirs in the study area are higher than 1.3 (Zhu et al., 2014). These conditions are conducive to the fluidity of the oil in the tight reservoirs. Moreover, the cut-off pore-throat diameter, the lower limit of the porosity, and the movable oil ratio are of great significance in predicting favorable tight oil areas (Hu et al., 2018; Li et al., 2018, 2019). The average radius of the pore throats is larger than 150 nm, with 73.5% of the pore-throat radius of the reservoir rocks larger than the cut-off pore-throat radius (50 nm). In planar view, almost the whole study area has reached the lower limit of the porosity. According to the classification of tight oil reservoirs in China by predecessors (Hu et al., 2018; Jia et al., 2016), the J2q2 tight reservoir in the Shengbei area has favorable conditions for tight oil accumulation.
| Research area     | Formation | TOC (%) | $S_1+S_2$ (mg HC/g TOC) | chloroform bitumen “A” (%) | Types of organic Matter | Ro (%) | Hydrocarbon expulsion intensity ($\times 10^4$ t/km²) | Reference                  |
|------------------|-----------|---------|------------------------|---------------------------|-------------------------|--------|---------------------------------------------------|---------------------------|
| Santanghu Basin  | Lucaogou  | 0.05–17.8 | 0.01–134.2              | 0.01–1.9                  | I–II                   | 0.5–1.0  | –                                                | Liang et al. (2017)       |
| Huilu area       | Wenchang  | 0.5–11.4 | 1.2–37.1               | –                          | II                      | 0.8–1.8  | 0–11000                                          | Peng et al. (2016)        |
| Shulu Sag        | Shahejie  | 0.06–8.0 | 0.04–60.8              | 0.01–0.4                  | I–II                   | 0.3–0.8  | 0–2000                                           | Huo et al. (2020)         |
| Songliao Basin   | Qingshankou | 3.14 (Avg.) | 29.3 (Avg.)              | 0.63 (Avg.)               | I–II                   | 0.5–1.0  | 0–600                                            | Lin et al. (2019)         |
| This study       | Qiketai   | 0.10–11.1 | 0.5–74.8               | 0.004–0.9                 | I–II                   | 0.5–0.8  | 0–1000                                           |                           |
For a tight oil reservoir, crude oil mainly accumulates in the source rocks and near-source reservoirs, with higher source rock requirements than those of conventional reservoirs (Xu et al., 2016). Source rocks have high hydrocarbon generation and expulsion intensities, and areas with micro-nanopore connectivity and flowable crude oil in tight reservoirs are favorable tight oil exploration areas (Hu et al., 2018; Lu et al., 2012; Zou et al., 2015). It is noteworthy that the reservoir porosity in the study area is generally higher than the lower limit of the porosity. Thus, the hydrocarbon generation and expulsion intensities are more remarkable in controlling the J 2q 2 tight oil distribution. According to the analytical results, it is considered that the strong hydrocarbon expulsion areas with hydrocarbon expulsion intensities higher than $400 \times 10^4$ t/km$^2$ can be the most feasible tight oil exploration target (Figure 12).

The Junggar Basin and the Tarim Basin are located in the Central Asia Orogenic Belt area. The Jurassic horizon is an important oil and gas bearing system in these basins. Jurassic coal-measure strata are widely developed in the Tarim Basin, in the Junggar Basin, and in the Turpan–Hami Basin. The Jurassic strata in the Junggar basin comprise a set of coal bearing sedimentary formations of braided river delta-limnetic facies (Chen et al., 2016; Chen et al., 2019). The main Jurassic sedimentary facies types in the Tarim Basin include fan delta facies, fluvial facies, and lacustrine facies, and the Jurassic strata can be divided into upper and lower parts. The lower part comprises coal bearing strata whereas the upper part comprises red strata (Liu et al., 2011). According to previous studies, the northwest of China featured a semi-arid and semi-humid climate in the late Middle Jurassic, under which river and lake facies developed (Deng et al., 2019). A combination of the tectonic setting, depositional environments, paleoclimates, and plant availability generally controls the accumulation of coal. Different from the Lower Jurassic (Badaowan Formation), the Qiketai Formation in the study area is mainly composed of lacustrine deposits owing to the intensity of the differential uplift and paleoclimatic conditions (Li et al., 1999; Liu et al., 2012). The early stage of the second member of the Qiketai Formation corresponds to the period with the deepest lake environment, it has a weak hydrodynamic condition and the water medium is a reducing environment, which is conducive to the preservation and enrichment of organic matter, and developed a set of extensive the sapropel-type kerogen source rocks with a high organic matter abundance. In the middle and late stages of the J 2q 2 Formation, with the continuous intensification of the drought process, the water depth of the lake became shallower, and the sedimentary environment gradually transformed from a semi-deep lake to a mildly brackish shore-shallow lake environment (Feng et al., 2020; Liu et al., 2012; Yuan et al., 2002). The sediments are rich in algae, which not only provides a good source material, but also creates a reductive condition conducive to the preservation of organic matter, which lays a foundation for the formation of high-quality lacustrine source rocks. This is consistent with the previous studies that the source rocks formed in freshwater to mildly brackish water environment are the most favorable in continental source rocks (Fang et al., 2019). Compared with the study area, the thickness of the Jurassic source rocks can exceed 300 m in the sedimentary center. The TOC contents indicate these two basins all have a set of good Jurassic source rocks, and the Jurassic kerogen type is dominantly type II and type III (Chen et al., 2019; Du et al., 2019; Gao et al., 2013; Qiu et al., 2008; Qian et al., 2018). Moreover, tight reservoirs are widely distributed in the Jurassic of these two areas, and fractures are generally developed, the source rocks are largely in contact with the overlying tight reservoirs or alternate with reservoirs in the vertical direction, which are conducive to the enrichment of tight oil and gas (Du et al.,
However, the maturity of the Jurassic source rocks in the two basins is higher than that in the study area. In combination with the maturity and production practice, the Jurassic source rocks in Junggar basin are rich in oil and gas, and the areas with low maturity are dominated by oil (Qian et al., 2018; Du et al., 2019), while the maturity of Tarim Basin is distributed in 0.5% – 3.0% (Gao et al., 2013). According to the calculation results of hydrocarbon generation and expulsion in important regions for oil-gas exploration in the Junggar Basin and in the Tarim Basin. The total amount of hydrocarbon generation from Jurassic source rocks in the southern margin of the Junggar Basin is $3973 \times 10^8$ t, the expelled amount oil and the expelled gas amount are $389 \times 10^8$ and $911 \times 10^8$ t, respectively. The expelled amount oil and the expelled gas amount are $85 \times 10^8$ and $802 \times 10^8$ t in the Kuqa depression (Guo et al., 2012). The unconventional oil and gas resources of the Tarim and Junggar basins are dominated by tight gas and shale gas. Nonetheless, there may be abundant tight oil resources in the favorable area of the low-maturity source rock (Zheng et al., 2019). This means that the tight oil resources in the petrolierous basins in Western China could have further exploration potential.

**Conclusion**

1. The source rocks have the characteristics of high organic matter abundance, good type and low mature stage. By comparing the characteristics of Jurassic source rocks, it is considered that Jurassic source rocks in Western China are of high quality and have further potential for tight oil exploration.
2. The J2q2 source rocks start to expel crude oil at R_o = 0.56%, while the hydrocarbon expulsion efficiency increases from 0% to 57.7%. The generated and expelled hydrocarbon amounts from the source rocks are 48.8 and 27.3 × 10^8 t, indicating that middle Jurassic lacustrine source rocks deserve attention in future exploration.

3. The J2q2 tight oil reservoir-forming conditions are superior, and the hydrocarbon generation and expulsion intensities are more remarkable in controlling the tight oil distribution.

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