Jurassic tight oil in Sichuan Basin is chiefly distributed over the central basin with an area of about 4.2 × 10^4 km^2. Since the first drilling in 1953, it has experienced four stages, including the Central Sichuan Basin Brought under Exploration and Development, Progressive Exploration and Development, Setting A Goal of 30 × 10^4 t/a, and Adjusting and Keeping A Stable Production. More than sixty-year exploration and development history demonstrates that there are five sets of oil zones and four sets of source beds with a better association, which belong to self-sourcing self-storing and near-source oil charging patterns; there are two tight reservoirs composing of shelly limestone and sandstone which are accumulated by plenty of unconventional tight oil. Since 2000, many strata of Jurassic in Longgang area, central Sichuan Basin, have made new progress. Oil show often emerged from Shaximiao 1 Member, Lianggaoshan Formation, and Daanzhai Member; and industrial oil flow was gained from most wells. These all prove that the Jurassic tight oil in Sichuan Basin has a bright exploration prospect. Moreover, supporting by the PetroChina Major Scientific and Technological Project, the PetroChina Southwest Oil and Gasfield Company has entered on a five-year research of the Jurassic tight oil from 2011 by means of resource reassessment, comprehensive evaluation of reservoir geology, along with study on accumulation pattern and corresponding technology. Finally, some favorable targets or blocks have been put forward, which can attempt to form a large-scale and effective development.

1 Tight Oil Distribution Affected by Jurassic Tight Sandstone (or Shoal) Distribution

As Jurassic tight-oil reservoirs, either shelly shoal of Daanzhai Member or sandstone of both Lianggaoshan Formation and Shaximiao 1 Member are extensively developed in central Sichuan Basin. So, there is plenty of tight oil. In this study, six profiles of Jurassic depositional framework (three transverse ones and three longitudinal ones, respectively), and the standard profiles of Daanzhai Member and Lianggaoshan Formation in six blocks of central basin are established at first; and then, the depositional system of every Jurassic formation or member, and the sedimentary microfacies are analyzed; thirdly, the sedimentary-facies maps are made for the upper, middle, and lower Daanzhai Member, as well as Lianggaoshan Formation and Shaximiao 1 Member; fourthly, a favorable sedimentary-facies belt is selected; at last, the distribution of either shelly shoal of Daanzhai Member or sandstone of both Lianggaoshan Formation and Shaximiao 1 Member are make clear.

2 Several Pore-Throat Systems (mm-μm-nm) Developed in These Jurassic Reservoirs with a μm-nm Level as the Soul

Different from a previous view that Daanzhai Member belongs to a fractured reservoir, our study deems that in this member, both shelly limestone and argillaceous shelly limestone have a better storage property; there are three types of reservoir space containing solution cave, matrix pore, and fracture, in which the second is dominated by pore and throat with a μm-nm level; in horizontal some reservoirs with relatively high porosity may be often found whereas in vertical they are distributed in part or are comparatively centralized, which may affected by multiple factors of high-energy shoal, low-energy shoal facies, fracture, and dissolution. Sandstone reservoirs of both
Lianggaoshan Formation and Shaximiao 1 Member belong to fractured-porous and porous ones, respectively. The relatively high-quality reservoir is mainly controlled by beach-bar facies (for example Lianggaoshan Formation, and the bottom of Shaximiao 1 Member), channel facies (such as the middle and lower Shaximiao 1 Member), and secondary dissolution.

3 Lower Limit of Tight Reservoir Attaining a nm Level

For Jurassic limestone and sandstone reservoirs, their pore-throat system is fully investigated by means of FE-SEM, nanoCT, and NMR. A new opinion about the lower limit of conventional pore has been gained. And it is supposed that pore-throat diameter is the key factor to confirm whether oil from Jurassic tight reservoirs is charging or not. The lower limits calculated are 32 nm (0.032μm) for limestone, and 26 nm (0.026μm) for sandstone, individually. Integrated thin-section identification with well dynamic performance, it is affirmed that in Daanzhai Member at a near-source area, for the limestone with porosity less than 2%, the matrix pore is often oil bearing, and oil may be produced from certain reservoirs with permeability more than 0.01 mD.

4 Migration and Accumulation Mechanism: Pore-Fracture Compound Conduction Pattern with Non-Darcy Percolation

There are different lithologies in Daanzhai Member, Lianggaoshan Formation, and Shaximiao 1 Member. And several approaches, including fluid-inclusion analysis, relative-permeability and percolation experiments, reservoir-forming model, CT scanning of digital core, and migration-accumulation numerical simulation, are used to explore the migration and accumulation pattern of Jurassic tight oil. Results show that Daanzhai limestone reservoirs emerged a densification in late J3p. From this time, oil was filled with these reservoirs (for example, late J3p for reservoirs in the north, and K1 for ones in the south, respectively); two sandstone reservoirs of Lianggaoshan Formation and Shaximiao 1 Member occurred the densification also in late J3p. Since then, oil was filled with these sandstone reservoirs; oil charging was dominantly forced by hydrocarbon-generating pressurization and capillary-pressure difference; migration mechanism was non-Darcy percolation which could be subdivided into quasi-linear, non-linear, and retention ones; and pore-fracture compound conduction was the main migration-accumulation pattern.

5 Main Influencing Factors: Source, Reservoir, and Source-Reservoir Association

After the study on Bajiaochang, Zhongtaishan, Jinhua, Gongshanniao, and Longgang oil blocks, it is demonstrated that source, reservoir, and source-reservoir association are the essential factors for tight-oil accumulation; high-yield wells are closely related to microfracture development; there are three self-sourcing and near-source accumulation patterns developed for Daanzhai Member, Lianggaoshan Formation, and Shaximiao 1 Member.

6 Accumulation Patterns

After the study on source, reservoir, source-reservoir association, and migration-accumulation mechanism and pattern, it is believed that Jurassic tight oil is featured by controlling oil within source area, near-source charging, continuous distribution, and sweet-spot accumulation. Both horizontal and longitudinal distribution of oil was affected by source. Oil charging often just occurred at some reservoirs close to source. Tight oil presents an extensive and continuous distribution in Daanzhai Member. And rich tight oil can be found in some high-quality reservoir belts (for example sweet spot). So, three factors of source-reservoir association, fracture development, and relatively high-porosity reservoir are critical to maintain a high and stable production.

7 Favorable Blocks: a Reservoir Development Area Immediately Adjacent to Source Centre

In terms of geological feature, accumulation condition, resource potential, and migration-accumulation mechanism, an evaluation on Jurassic tight oil was carried out. Results show that the Jurassic is not only rich in oil, but also has a large exploration and development potential. Moreover, a viewpoint, one target block with $1\times10^8$ t reserves, is proposed. In addition, some suggestions are made on the basis of seismic prediction, such as four favorable blocks, one pilot-test block, and twelve wellsites, which may provide geological evidence for further exploration.

8 Further Research on Jurassic Tight Oil with a Bright Prospect

8.1 Large amount of source with high maturity

There are four source beds, containing Lianggaoshan Formation, Daanzhai Member, Dongyuemiao Member, and Zhenzhuchong Member. Their cumulative thickness:
110 m (TOC > 1%); mature-high maturity; hydrocarbon-generating intensity: 2×10^4~8×10^4 t/km².

8.2 Multiple reservoirs presenting a stack in longitudinal and extensively horizontal distribution
There are five reservoir beds, including Shaximiao 1 Member, Lianggaoshan Formation, Daanzhai Member, Dongyuemiao Member, and Zhenzhuchong Member. In which Shaximiao 1 Member, Lianggaoshan Formation, and Daanzhai Member are the chief ones. They are featured by large cumulative thickness and widely horizontal distribution.

8.3 Favorable source-reservoir association belonging to self-sourcing or near-source charging
For both Lianggaoshan Formation and Daanzhai Member, the main source beds, their source center is located at the north and northeast of central basin, individually. In carbonate-rock reservoir of Daanzhai Member, the favorable shelly shoal facies which are close to source center are distributed in a zonal pattern; whereas in clastic-rock reservoirs in Shaximiao 1 Member and Lianggaoshan Formation, the favorable beach-bar and channel facies appear in the east and north. An area that is located at or adjacent to source center is just a migration oriented region, which is available for oil migration and accumulation.

8.4 Better preservation conditions
Above many reservoirs of Shaximiao 1 Member, Lianggaoshan Formation, Daanzhai Member, there is the middle Jurassic sandstone and mudstone as regional caprock besides direct caprock. Poor preservation may only occur at the edge of basin due to fault and fracture development. So, better preservation appears in the Jurassic other than the edge of basin.

8.5 Multiple favorable zones resulting in a large area for drilling
Besides three main oil zones (including Shaximiao 1 Member, Lianggaoshan Formation, and Daanzhai Member), both Dongyuemiao and Zhenzhuchong members should also be selected as targets. So, there is a large oil-bearing area.

8.6 Great difficulty in exploration and development
Jurassic tight oil is characterized by low accumulation degree and relatively low production (commonly 1~3 t/d) due to its reservoirs with strong heterogeneity and large horizontal variation. It’s difficult to finish an economic exploitation through conventional tools. However, after our study, 10 wells which were used by horizontal-well volumetric fracturing obtained a good effect. High-yield industrial oil flow was from Daanzhai Member of GQ1H well, and Shaximiao 1 Member of both G117H and G003-H16 well, individually. From now on, we should have a further study on this Jurassic tight oil by means of more innovative technologies at home and aboard in order to make breakthrough in its exploration and development.

References

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