Original Research Article

Analysis and Evaluation of Reservoir Characteristics of Marine Gas Reservoirs in Tongnanba Area, Sichuan Basin

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Abstract: This article conducts in-depth research on marine gas reservoirs in the Tongnanba area of the Sichuan Basin. Through comprehensive analysis of geological data, core observation, thin section identification, and interpretation of logging data, the petrological characteristics, pore types and structures, physical properties, and heterogeneity of the reservoir in this area were elaborated in detail. On this basis, a comprehensive evaluation of the reservoir was conducted, and the main controlling factors affecting reservoir development were explored, providing important geological basis for further exploration and development of marine gas reservoirs in the region.

Keywords: Sichuan Basin; Tongnanba region; Marine gas reservoir; Reservoir characteristics

1. Introduction

The Sichuan Basin is one of the important oil and gas basins in China, and the marine gas reservoirs in the Tongnanba area have enormous exploration and development potential. Thoroughly studying its reservoir characteristics is of great significance for improving the exploration and development efficiency and benefits of gas reservoirs.

2. Regional geological background

2.1. Construct features

The Tongnanba region is located in a unique geological location in the northeast of the Sichuan Basin, and the division of its tectonic units presents significant complexity and diversity. From a macro perspective, it can be mainly divided into three major structural units: the northern fault fold belt, the central depression belt, and the southern slope belt.

The northern fault fold belt is characterized by a series of closely arranged and consistently trending faults and folds. These faults not only vary in size, but also have significant differences in activity intensity and properties. Some exhibit thrust overturning, while others show strike slip pull apart. Folds come in various shapes, including tight and wide, forming a complex structural pattern.

The central depression zone shows a relatively sinking trend as a whole, with a large thickness of strata and a relatively stable sedimentary environment. However, there are still some small local structures inside it, such as nose shaped structures, which have a certain impact on the accumulation and distribution of oil and gas.

The southern slope zone is a relatively gentle area with a small inclination angle of the strata and relatively weak structural deformation, but its extension range is wide and the transition with surrounding structural units is relatively smooth.

In the long process of geological evolution, the Tongnanba area has undergone rich and varied tectonic evolution. Since the ancient Caledonian period, the region has experienced basement uplift and folding, laying the foundation for subsequent tectonic development. In the Hercynian period, with the rise and fall of sea levels, the sedimentary environment underwent significant changes, accompanied by weak tectonic activity.

2.2. Sedimentary environment

The research area exhibits diverse sedimentary facies types, unique distribution of sedimentary systems, and complex sedimentary evolution processes during the marine sedimentary period.

In terms of sedimentary facies types, they mainly include platform facies, slope facies, and basin facies. The platform facies can be further subdivided into subfacies such as open platform, restricted platform, and platform margin. In the open plateau environment, the water has high energy and has deposited a large amount of coarse-grained and well sorted carbonate rocks; Due to limited water circulation, sedimentary rocks on restricted plateaus often have higher mud content. The edge of the plateau usually develops reef limestone and beach limestone.

Slopes are located in the transitional zone between plateaus and basins, where sediments consist of both carbonate rock debris from plateaus and mud and silt materials from basins, forming a mixed sedimentary characteristic.

From the distribution of sedimentary systems, in the early stage of marine sedimentation, platform facies were mainly distributed in the eastern and southern parts of the study area. Over time, the platforms gradually migrated and expanded towards the northwest direction. The slope phase is distributed around the edge of the plateau, and its range also varies with the changes of the plateau. The basin facies has always been located in the deeper waters of the northwest of the study area.

3. Reservoir petrological characteristics

3.1. Rock type

In order to accurately determine the main types of reservoir rocks, we conducted extensive core observations and thin section identification work.

The research results indicate that the main types of rocks in this reservoir include limestone and dolomite.

Limestone is mainly composed of calcite, and its mineral purity is relatively high. Calcite crystals vary in size and shape, with some exhibiting small microcrystalline structures and tightly arranged crystals, forming a dense rock structure; Some of the calcite crystals in the limestone are relatively large, exhibiting a medium or even coarse crystal structure, and the boundaries between the crystals are clearly visible. In terms of structural characteristics, limestone commonly has blocky structures, with uniform rock texture and no obvious layering or texture; In addition, there are layered structures, manifested as alternating distribution of rock layers of different thicknesses, reflecting the periodic changes in sedimentary environments; Biological reef structures are also a common type of limestone, typically formed by the accumulation of bones and remains of ancient organisms, with unique shapes and structures.

The main mineral component of dolomite is dolomite, and its formation process is relatively complex. According to their different origins, dolomite can be divided into primary dolomite and secondary dolomite. Primary dolomite is usually formed by direct precipitation in specific sedimentary environments. Its dolomite crystals are relatively large, mostly in a medium to coarse crystal structure, with relatively large pores between crystals. Secondary dolomite is formed on the basis of limestone through later diagenetic processes. Its crystal size and morphology are relatively irregular, and its mineral composition may also contain small amounts of impurities such as calcite and quartz. In terms of structure, secondary dolomite has a more complex and diverse structure, which may present pore like, honeycomb like, and other structures.

3.2. Rock texture

A detailed description and analysis of the structural characteristics of reservoir rocks is of great significance for a deeper understanding of reservoir properties.

The particle size of rocks exhibits significant differences in reservoirs. At the microscale, there are particles at the particle level, typically with a diameter of several micrometers or less. These particles are often tightly packed to form the matrix of the rock. At the same time, there are also distributions of medium and coarse particles. The diameter of medium particles is generally between 0.25-0.5 millimeters, while the diameter of coarse particles is greater than 0.5 millimeters. Their distribution in rocks is uneven, sometimes forming localized enrichment areas.

In terms of sorting, the overall performance of reservoir rocks is poor. The distribution of particle sizes is relatively mixed and lacks clear regularity. This may be due to the instability of water flow conditions during the sedimentation process, or the alteration caused by later diagenesis.

In terms of roundness, most particles exhibit a sub rounded to sub angular shape. This indicates that the abrasive effect experienced by particles during transport is relatively weak, possibly due to the short transport distance or low energy of the transport medium.

The types of cementation in reservoir rocks mainly include pore cementation, basement cementation, and contact cementation. Pore cementation refers to the main distribution of cement in the pores between particles, which can to some extent preserve the original pore space of the rock and facilitate the preservation of reservoir properties; Basal cementation refers to the widespread distribution of cement at the bottom of particles, tightly fixing them together and making the rock denser, thereby significantly reducing the porosity and permeability of the reservoir; Contact cementation refers to the distribution of cement mainly at the contact points of particles, and its impact on reservoir properties is between pore cementation and basement cementation.

These rock texture characteristics have a significant impact on reservoir properties. The uneven distribution of particle size and poor sorting result in irregularity and reduced connectivity of pore space, thereby affecting the fluid flow ability in the reservoir. The rounding degree from sub rounded to sub angular makes the contact between particles tighter, further reducing the pore space. The different types of cementation directly determine the degree of pore retention and connectivity. Pore cementation is conducive to the formation of better reservoir properties, while basement cementation often leads to a deterioration of reservoir properties.

4. Types and structures of reservoir pores

4.1. Pore type

In order to gain a more comprehensive and in-depth understanding of the pore characteristics of reservoirs, they have been finely divided based on their genesis and morphology.

Primary pores are pore types formed during the process of rock sedimentation. Among them, intergranular pores are one of the common forms of primary pores. Interparticle pores are pore spaces left between particles that are not completely filled during particle accumulation. These types of pores are usually polygonal or triangular in shape, with relatively uniform pore sizes, but their size is often limited by particle size and arrangement. Intragranular pores are pores that exist within particles, such as the pore space inside biological fossils. Their shape and size often depend on the type and preservation status of biological fossils, with a certain degree of randomness and complexity.

Secondary pores are pores formed through various later processes after the formation of rocks. Dissolved pores are an important type of secondary pores, usually generated by the dissolution of easily soluble substances in rocks by groundwater. The morphology of dissolution pores is irregular, with significant differences in pore size, ranging from microscopic small pores to larger pores. Intercrystalline pores are tiny pores formed between crystals, with generally smaller pore sizes and more uniform distributions. Cracks, as a special type of secondary pore, are fracture surfaces generated by the action of structural stress and other factors on rocks. The shape of cracks is usually linear or patchy, with significant variations in length and width, which can significantly improve the connectivity of reservoirs.

4.2. Pore structure

In order to accurately analyze the structural characteristics of reservoir pores, advanced techniques such as mercury intrusion experiments and scanning electron microscopy were used.

By conducting mercury intrusion experiments, information on the distribution of pore size can be obtained. The results show that the distribution of pore size in the reservoir exhibits significant heterogeneity. Micropores and small pores account for a large proportion in terms of quantity, but their contribution to the total pore volume is relatively small. The number of mesopores and macropores is relatively small, but they contribute significantly to the total pore volume. The non-uniformity of size distribution has a significant impact on the flow and storage of fluids in pores.

The observation results of scanning electron microscopy reveal the distribution characteristics of pores. The distribution of pores in rocks is not uniform, with some areas having denser pores while others have fewer pores. The unevenness of this distribution increases the difficulty of reservoir evaluation and development to a certain extent.

The connectivity of pores is crucial for the permeability of reservoirs. Research has found that some pores have good connectivity and form continuous fluid channels; However, there are also some isolated pores that have poor connectivity with surrounding pores, which can hinder fluid flow to some extent.

5. Conclusion

This article provides a detailed study of the characteristics of marine gas reservoirs in the Tongnanba area, comprehensively analyzing the structural background, sedimentary environment, petrological features, pore structure, physical properties, and reservoir heterogeneity. Through comprehensive evaluation of multiple factors, the main factors affecting reservoir development have been identified, providing a scientific basis for exploration and development in the region. In future work, it is necessary to further combine seismic data and actual drilling data to refine reservoir prediction, in order to improve the development efficiency and economic benefits of gas reservoirs. At the same time, it is particularly important to conduct technical research on reservoir transformation and enhanced oil recovery, in order to achieve efficient and sustainable development of marine gas reservoirs in the region.

References

[1] Stimulating Carbonate Formations Using a Closed Fracture Acidizing Technique. S.E. Fredrickson. SPE14654.1986