Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 15, No. 2, 2025

Study on Reservoir Characteristics of the Fourth Member of Shahejie Formation in Zhanhua Sag, Jiyang Depression

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Abstract: The Huxiang carbonate rocks in the upper sub-member of the fourth member of the Shahejie Formation in the Zhanhua Sag are widely distributed, and the buried depth span is large. They have good exploration potential and can be used as important high-quality reservoirs. However, the horizontal and vertical changes of reservoirs are fast, the accumulation is complex, the difference of rock characteristics and the unclear distribution of favorable reservoirs in each facies zone limit the exploration and development of oil fields. Comprehensive utilization of casting thin sections, core physical properties, scanning electron microscopy, and other test analysis, the carbonate reservoir space structure, pore throat structure, and microscopic pore structure were systematically studied. The research shows that the Huxiang carbonate reservoir in the upper sub-member of the fourth member of the Shahejie Formation in the study area is dominated by limestone, which is a set of medium-low porosity-low permeability tight reservoir. The primary pores are basically not developed, and the reservoir space types are mainly fractures, intergranular pores, intergranular dissolved pores, and matrix pores. The porosity ranges from 0.4 % to 35.7 %, the average porosity is 7.41 %, and the permeability ranges from 0.100 mD to 597.000 mD, with an average permeability of 9.121 mD. The pore throat separation is good, mainly micro pore-micro throat.

Keywords: Lacustrine carbonate; Reservoir characteristics; Sha-4 Upper Sub-section.

1. Introduction

Carbonate rock is an important oil and gas reservoir in continental lacustrine basin, which is complex and changeable. It is one of the difficulties and hotspots in the field of carbonate rock research in the world today. Due to the limited distribution of lacustrine carbonate rocks in geological history, people pay less attention to it[1,2], which is a weak link in the field of sedimentology[3,4]. In recent years, with the deepening of oil and gas exploration, great breakthroughs have been made in the oil and gas exploration of lacustrine carbonate rocks at home and abroad[5]. Lacustrine carbonate rocks are the most widely distributed terrestrial carbonate rocks. Compared with clastic reservoirs, the characteristics of carbonate reservoirs are more complex, and the influence of sedimentation, rock type and diagenesis on reservoir physical properties is more significant. Compared with marine carbonate rocks, the lithological characteristics of lacustrine carbonate rocks are complex and changeable, which are not only formed in the coastal shallow water environment, but also obviously developed in deep-water fine-grained mixed rocks. Therefore, the study of lacustrine carbonate reservoirs is of great significance to the exploration and development of conventional and unconventional oil and gas reservoirs.

In recent years, high yield has been obtained in the exploration of lacustrine carbonate rocks in many areas. Huxiang carbonate rocks are widely developed in Jiyang depression. In this area, although some scholars have carried out research on reservoir characteristics, the complex lithology transformation of lacustrine carbonate rocks and the strong heterogeneity of reservoirs have led to unclear understanding of the sedimentary law of lacustrine carbonate rocks. In general, the research understanding is relatively weak, and the research needs to be further strengthened. In view of the above problems, this paper will use thin section identification, core observation, logging data and measured physical properties to analyze in detail, and discuss the reservoir characteristics of lacustrine carbonate rocks in the upper submember of the fourth member of the sand in the Zhanhua sag of the Bohai Bay Basin, which has reference significance for oil and gas exploration and development in similar areas.

2. Overview of the Study Area

Zhanhua sag is located in the northeast of Jiyang depression. It is a secondary tectonic unit of Jiyang depression. It is a fault basin extending northeastward and steep in the north and gentle in the south[6]. The north and the Yihezhuang convex are bounded by the Yinan fault, separated from the Chezhen sag, and the south is connected to the Chenjiazhuang convex[7](Fig.1). Since the Indosinian movement, it has undergone multiple tectonic evolution stages, forming multiple secondary basins and uplift structures. The total thickness of the fourth member of the Shahejie Formation in the study area is 1730.50 m, which is in unconformable contact with the underlying lower sub-member of the fourth member of the Shahejie Formation and the overlying third member of the Shahejie Formation. The fourth member of the Shahejie Formation is subdivided into the upper sub-member of the fourth member of the Shahejie Formation and the lower sub-member of the fourth member of the Shahejie Formation. The upper sub-member of the fourth member of the Shahejie Formation is the target layer of this study. The sedimentary period of the upper sub-member of the fourth member of the Shahejie Formation is the tectonic transition period from the initial fault depression to the rapid rifting in the Zhanhua sag. Controlled by the complex structural features and pattern, it

not only forms a variety of clastic rock sedimentary types such as gentle slope subaqueous fan, nearshore subaqueous fan, fan delta and clastic rock beach dam, but also develops gray beach dam in the southern gentle slope. It is often mixed with argillaceous, sandy and other clastic components and gypsum components to form mixed rocks. The overall mixed characteristics are obvious, and dark gray mudstone, glutenite and sandstone are locally developed. This kind of reservoir has strong heterogeneity.

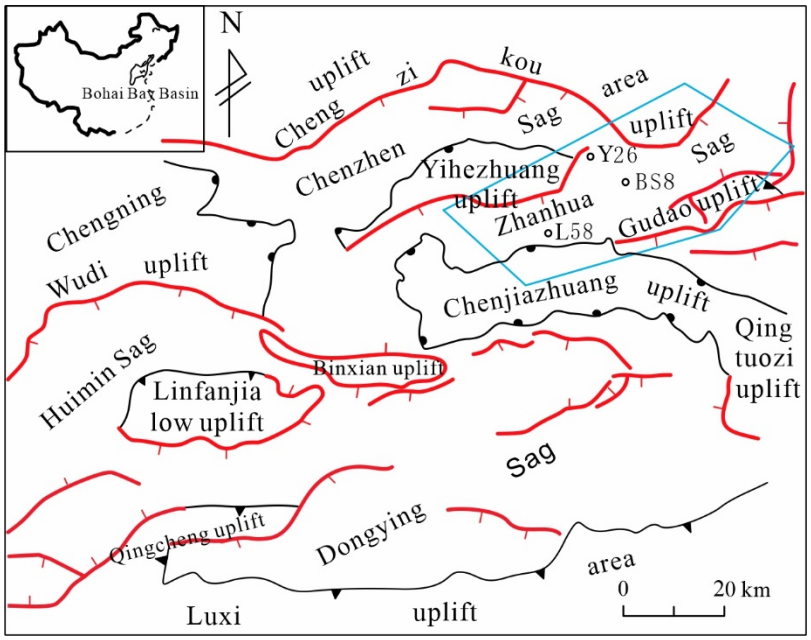

Figure 1. Geographical location of Zhanhua sag

3. Characteristics of Lacustrine Carbonate Reservoir

3.1. Petrological characteristics

Abundant lacustrine carbonate deposits are developed in the upper submember of the fourth member of the Shahe Formation in the study area, and the rock types are diverse. Based on the core of 29 coring wells in the study area, the analysis of cast thin sections of 20 rock samples, combined with the data of whole rock X-ray diffraction and scanning electron microscope analysis, the reservoir rock types of the upper fourth member of the Shahejie Formation in the study area are mainly divided into three categories: limestone, dolomite and mixed rock.

Limestone mainly includes granular limestone, bioclastic limestone and micritic limestone. (1) The particles in the granular limestone are mainly composed of internal debris and biological particles. Most of the internal debris particles are (powder) sand, with a particle size of 0.07-0.62 mm, and a small part contains ooids. The particles are in point contact or non-contact, most of which are floating and generally formed in a high-energy shoal environment. (2) Biological limestone is largely composed of biological debris cemented by calcium carbonate. Usually, the content of biological debris is more than 50 %, and the species are different. There are mainly algae, mollusks, corals, ostracods, etc., among which snails and ostracods are more common. The core is bioclastic structure, massive structure, and the cement is mainly micrite or sparry calcite. Generally, the water body is relatively shallow, the water quality is light, the sun is abundant, and the environment suitable for biological reproduction is suitable. It mainly includes snail limestone, shell limestone, algal framework limestone, etc. The morphology of various biological particles is relatively intact, and some biological particles are broken.(3) The micritic limestone is widely distributed in the study area. The core is layered, and the particle content is small, generally less than 10 % or no particles. The main component is micritic calcite. The structure is compact and single, containing a small amount of argillaceous and biological shell debris. When the argillaceous content increases, the phase becomes marlstone, and the type of biological debris is mainly smooth Nanxingjie, indicating that the hydrodynamic conditions are weak, the water body is relatively deep, and the water quality is light-brackish water.

The distribution of dolomite is relatively small, mainly gray dolomite and biological dolomite. The limestone dolomite is mainly dominated by grain structure, pore space is relatively developed, containing a small amount of bright crystal calcite) or (hard) gypsum, and mainly penecontemporaneous dolomitization. Due to the decrease of lake level or the salinization of arid water or the increase of temperature, it is probably developed after the reef or during the decline of semi-deep lake / deep lake. The organisms in the biodolomite are mainly branched algae and ooids. The particles are dark in color. The intergranular is mainly filled with micritic calcite. The intergranular dolomite is developed, which may be penecontemporaneous dolomitization. The ooids are mainly concentric ooids. The thickness of the concentric layer is less than the core diameter, and the particle size distribution is between 0.3 ~ 1.80 mm. It is caused by the decrease of lake level or the salinization of arid water or the increase of temperature.

The mixed rock is a transitional layer between the internal clastic source and the carbonate deposition. It is more developed in the upper and lower parts of the fourth member of the Shahejie Formation in the study area. The core is generally a layer of small thickness. The common rocks include marl, calcareous sandstone, gypsum limestone,

calcareous gypsum rock, and sandy limestone, which are more than carbonate mixed deposits. It is generally located in a relatively deep water area, and gypsum and ash mixed deposits are easily developed in semi-deep lakes or local depressions. The gypsum and limestone components in the gypsum limestone are interbedded or distributed in clumps. The gray matter in sandy limestone is mostly in the state of sand debris and agglomerates. The detrital minerals are mainly fine sand. In addition to quartz, feldspar and debris, dolomite debris is also seen.

In addition, a small amount of gypsum rock is developed in the study area, and it is found that the gypsum rock particles are directional under the microscope.

3.2. 3.2 Physical characteristics

The reservoir of upper Es4 in Zhanhua sag is a set of medium-low porosity and low permeability tight reservoir (Fig.2). The porosity of rock samples is 0.23 % -47.7 %, the average porosity is 7.41 %, the peak porosity is 0.00 % - 5.00 %, accounting for nearly 56.44 % of the total number of samples, followed by 12.00 % -15.00 % and 15.00 % - 20.00 %, accounting for about 30 % of the total number of samples. The permeability is 0.300 mD-456.000 mD, with an average permeability of 9.121 mD, and more than 75.76 % of the samples have a permeability of less than 0.8000 mD.

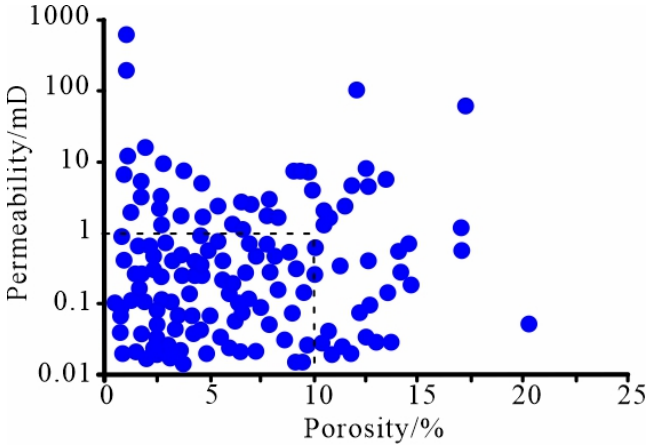

Figure 2. Reservoir physical property characteristics of lacustrine carbonate reservoirs in the Es4s in the Zhanhua Sag

3.3. Reservoir space characteristics

The reservoir space types of lacustrine carbonate rocks in the upper fourth member of Shahejie Formation in Zhanhua Sag mainly include two types of fractures and pores. The pores include primary pores and secondary pores, and the fractures mainly include structural fractures and non-structural fractures.

The types of primary pores in the study area include intragranular pores, intergranular pores, and biological body cavity pores. The primary pores in the study area are basically not developed, and only a small number of intergranular pores and biological body cavity pores are developed, which cannot be used as the main reservoir space in the study area.

Secondary pores include intragranular dissolved pores, intergranular dissolved pores, mold pores, etc. Intergranular dissolved pores and intragranular dissolved pores are more developed, and the pore size of intergranular dissolved pores is mostly 50.00-300.00μm. Intergranular dissolved pore C is commonly found in grain limestone such as calcarenite and oolitic limestone. Intergranular cements or matrix are partially or completely dissolved to form pore types, and residual calcite particles can often be seen. This type of pore has good porosity and permeability, and belongs to a better reservoir space type. Intragranular dissolved pores are common in biological limestone and calcarenite in the study area. The dissolved pore space will be filled with calcite organic matter, or not filled to form intragranular dissolved pores. The pore types in the study area are mainly intragranular dissolved pores, filling calcite, dolomite, etc. ; the mold hole is a pore type formed by the complete dissolution of the particles and the retention of the original particle profile under the selective dissolution of the underground fluid, which is easy to identify. This pore type mainly appears in the biological limestone, mainly including the ostracod mold hole. In addition, dolomite intergranular dissolution micropores are developed in the reservoir of the fourth member of the upper submember of the sand, and the pore size is very small and irregular.

The fractures in the study area are divided into two categories : structural fractures and non-structural fractures. The existence of fractures connects the tiny pores with the more isolated dissolved pores in the particles, which greatly improves the permeability of carbonate rocks and is particularly important for reservoir space. The non-structural fractures are mostly sutures produced by pressure solution. In the rock samples, it can be observed that the sutures are mainly parallel to the plane distribution, and the development is obvious. The fracture shape is irregular, mostly serrated, and the fracture is filled with asphaltene. Structural fractures are widely distributed in micritic limestone in the study area.

4. Summary

The porosity range of lacustrine carbonate reservoir in Zhanhua sag is 0.4 % -35.7 %, the average porosity is 7.41 %, the permeability range is 0.100 mD-597.000 mD, and the average permeability is 9.121 mD. The reservoir space is mainly secondary pores and fractures, and three types of pore throat structures are developed. The pore throat is well sorted, mainly coarse and fine pores-micro throats.

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