Proceedings of the 3rd International Conference on Green Energy, Environment and Sustainable Development (GEESD2022), X. Zhang et al. (Eds.)

doi:10.3233/ATDE220385

Study on Factors and Characteristics of Qingshuihe Formation in Shinan Area, Junggar Basin

Wanchang ZHANG[a,1] and Yanju LI[b]
[a] *School of Engineering-Agriculture-Medicine, Gansu Open University, Lanzhou 730000, Gansu, China*
[b] *School of Energy and Engineering, Longdong University, Qingyang 745000, Gansu, China*

Abstract. Reservoir characteristics and influences by diagenesis and sedimentary environment of the Qingshuihe clastic formation of Shinan area, Junggar Basin, are studied in this paper by SEM, casting thin sections, X-ray diffraction, combining geology logging and well logging data, providing a theoretical guide for further exploration and development. The results show that the Qingshuihe Formation in the region of interest was developed in braided river front subfacies, of which the lithology includes grey medium-coarse-grained sandstone and medium-fine-grained sandstone with which some grey siltstone and grey silty mudstone were mingled. In the process of diagenesis, compaction caused about 60% of the primary pore loss, and cementation caused about 20% of the primary pore loss. The physical properties of Qingshuihe Formation are principally controlled by sedimentary environment, on which the influence of diagenesis is small.

Keywords. Reservoir characteristics, diagenesis, sedimentary environment, Shinan area, Junggar Basin

1. Introduction

The research on reservoir physical properties and prediction of high-quality reservoir is pivotal segment to cohere exploration and development of oil and gas. In the forming process of clastic reservoir, physical properties of clastic reservoir are affected by country rocks, sedimentary environment, and diagenesis in different stages. The nature of country rock determines the composition of reservoir and the transformation of reservoir by sedimentary environment and diagenesis lately [1]. The sedimentary environment controls constructure, size, grading, roundness, and content of matrix of the reservoir [2]. Diagenesis is divided into destructive diagenesis and constructive diagenesis [3], destructive diagenesis mainly includes compaction and cementation, constructive diagenesis mainly means late dissolution. The degrees of effect on reservoir properties of reservoir by country rocks, sedimentary environment and diagenesis are quite not the same in different basins or in different blocks of the same basin, even in different formations of the same block [4-7]. Shinan field in Junggar

[1] Corresponding Author, Wanchang ZHANG, School of Engineering-agriculture-medicine, Gansu Open University, Lanzhou 730000, Gansu, China; Email: 328041238@qq.com.

Basin was discovered by obtaining commercial oil flow from Shinan 4 well in 1996, of which the main formation includes Qingshuihe Formation in cretaceous, Toutunhe Formation and Xishanyao Formation in Jurassic. In recent decades, massive research has been carried out by scholars focusing on hydrocarbon accumulation and migration and sedimentary system [8-12], lacking studies on reservoir physical properties, diagenesis, and main factors of reservoir.

2. Geological Background

The Junggar Basin is in the northern Xinjiang Uygur Autonomous Region, between Altay Mountains and Tianshan Mountains, which is one of the most potential large-scale superimposed basins in western China. Shinan area is situated in hinterland of Gurbantunggut Desert in the center of Junggar Basin, about 130 km west from Karamay City, the main body of the tectonic area is the secondary tectonic unit Jidong Nose, which is in the Luliang Uplift, which was formed in the Late Hercynian Movement [13]. The Jidong Nose descended to the Southwest, reached North to the Sangequan Nose, of which the Southwest plunging end connected with Dabasong Nose stretching to the West hydrocarbon generating Sunken of Pen 1 well. In early Devonian-Carboniferous, a whole set of arc calc-alkaline volcanic suite was deposited in the region of interest, Because of the strong and long durating tectonic movement in this period, most of the Jiamuhe Formation (P_1j), Fengcheng Formation (P_1f), Xiazijie Formation (P_2x) and Wuerhe Formation (P_2w) in Permian above the Carboniferous in the structural high part were absent. The whole Junggar Basin declined until the late Triassic, entering the Pan-lake sedimentary period when the entire Lunan Uplift was generally covered by a dark lacustrine mudstone layer with a thickness of about 200 m, which was widely distributed and had a large thickness, becoming a stable regional cap rock. In the early-middle Jurassic, the tectonic movements in the region of interest were relatively less and stable, a set of river-lake- swamp facies coal-bearing sand-mudstone layers with a uniform thickness of nearly 800 m were deposited. Up to the early Yanshan Movement, the Luliang Uplift began to rise again, and unconformity and a few extension fractures appeared in Jurassic formation, the Cretaceous overlies the Toutunhe Formation in the middle Jurassic in the local structural high part of the uplift. In Cretaceous, the tectonic movements decreased, and the deposition was relatively stable, and the formation thickness is evenly distributed over a wide range. The main body of the Lower Cretaceous Tugulu Formation is an important regional caprock. Since the Tertiary, the overall tilting effect rising in the north and descending in the south of the Junggar Basin has become more intense, but the fault activity has basically ended, and the area with intense Himalayan Movement of the basin has moved to the piedmont depression of the North Tianshan, the tectonic activities of the Luliang were very weak, so that the early traps were preserved [14].

3. Physical Properties of Reservoir

3.1. Petrological Characteristics

The Qingshuihe Formation has a stable distribution in the region of interest and is

mainly comprised of gray and gray-brown fine-sandstone, medium sandstone, siltstone, argillaceous siltstone, fine sandstone and frequent gray, red-brown mudstone alternate layers., which is primarily characterized by widely spread red-brown mudstone, and mingled with gray, gray-white and varicolored conglomerate and glutenite (as shown in Figure 1). The Qingshuihe Formation contacts with the lower Toutunhe Formation uncomformably.

Figure 1. Petrological characteristics of Qingshuihe Formation.

3.2. Physical Characteristics of Reservoir

The porosity of the Qingshuihe Formation in Shinan area is mainly distributed between 1.4% and 29.1%, with an average of 13.57%, and the permeability is mainly distributed in the range of 0.02×10^{-3} μm^2 to 2860×10^{-3} μm^2, with an average of 7.53×10^{-3} μm^2, median 8.55×10^{-3} μm^2. According to the observation by microscope and scanning electron, combining with the research on diagenesis and intergranular cements, the Qingshuihe Formation is dominated by primary intergranular pores, remaining intergranular pores and intragranular dissolved pores.

3.3. Pore-throat Characteristics

The structure characteristics of sandstone pore-throat are classified by capillary pressure curves and image analysis, combining with scanning electron microscope, thin cast section and petrophysical properties. According to various parameters, combining with pore types, the pore structure of sandstone reservoir in the region of interest is divided into four types (as shown in Figure 2).

- Coarse pore-throat structure. The pore types are chiefly intergranular pores and intragranular dissolved pores, with a high degree of pore connectivity. The sandstone with this coarse pore-throat structure has a high degree of homogeneity, and its coefficient of variation and heterogeneity are smaller than others. The formation is mainly made up of medium-fine sandstone and coarse silt sandstone with structural

maturity, weak diagenetic compaction and cementation, and strong dissolution. So, these types of pores were formed in the sand body deposited in shallow buried or high energy environment.

- Medium pore-throat structure. The pore types are intergranular dissolved pores, intragranular dissolved pores and residual intergranular pores. The degree of correlation between porosity and permeability is relatively high, the correlation coefficient is generally greater than 0.7, and the degree of heterogeneity is strengthened. The formation is mainly composed of fine sandstone, siltstone, and argillaceous siltstone. The structural maturity from good to poor. The siliceous cementation is obviously strengthened. The accumulation of oil and gas and the existence of abnormal high pressure are conducive to the preservation of pores, which provides conditions for the formation of medium pore-throat structure.
- Fine pore-throat structure. The chief pore types are intergranular dissolved pores, intragranular dissolved pores, intergranular pores, and micro pores. The correlation between porosity and permeability deteriorated significantly, the correlation coefficient is generally less than 0.7, and the permeability decreases sharply with the decrease of porosity. The heterogeneity is strong.
- Micro pore-throat structure. The main types of pores are small residual pores, intragranular dissolved pores and incompressible intergranular pores, which are hydrophilic rocks and can store natural gas, but it is difficult to maintain stable production. The formation is mainly composed of siltstone and argillaceous siltstone with good to poor structural maturity.

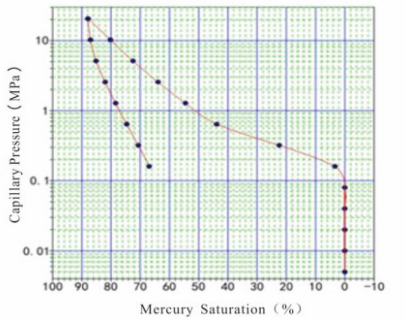

Figure 2. Capillary curves of the Qingshhuihe Formation in the region of interest.

4. Analysis of Main Controlling Factors of Reservoir

4.1. Analysis of Effect of Sedimentary Environment on Reservoir

The research of precipitation facies shows that the Qingshuihe Formation in Cretaceous mainly growed in braided river delta front subfacies, of which the lithology includes gray medium-coarse-grained sandstone and medium-fine-grained sandstone (belongs to the microfacies of underwater distributary channel of front subfacies, and the plate-like cross-bedding is common.), mingles with gray siltstone and grey silt mudstone (belongs to the microfacies of underwater distributary interchannel of front subfacies, and the ripple bedding was developed somewhere). So, for sandstones and conglomerates developed in the delta front, the reservoir properties are significantly

affected by the content of argillaceous matrix controlled by the hydrodynamic forces during deposition. The clastic rocks which were developed in underwater distributary channel with strong hydrodynamic force were strongly elutriated, so that the physical properties of reservoir are the best because of the lower content of argillaceous matrix, the well-developed intergranular pores and the relatively weaker compaction. On the contrary, the clastic rocks which were developed in underwater distributary interchannel with weak hydrodynamic force has higher content of argillaceous matrix, as a result the physical properties are poor because of the damage by compaction under the lubrication of muddy matrix.

4.2. Analysis on the Controlling Effect of Diagenesis on Reservoir

Although the Qingshuihe Formation in Shinan area is mainly influenced by sedimentary environment, the influence of diagenesis on physical properties of the reservoir still cannot be ignored. The figure of relationship between porosity and depth shows that the correlation between porosity and depth is strong, indicating that compaction has a greater impact on reservoir porosity (as shown in Figure 3). The evaluation of effect of compaction and cementation on the physical properties of reservoir indicated that cementation caused about 20% of the porosity loss, which varies greatly from sample to sample, and compaction caused about 60% of the pore loss.

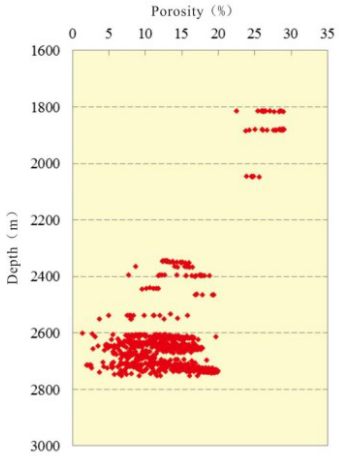

Figure 3. Relationship between porosity and depth.

4.3. Analysis of Main Factors of Physical Properties of the Reservoir

The Cretaceous Qingshuihe Formation in Shinan area which was composed of fine-grained clastic sediments such as fine sandstone, medium sandstone and medium-fine sandstone and experienced diagenesis, mainly developed in braided river delta front underwater distributary channel and braided river delta plain distributary channel belongs to medium porosity and medium-low permeability reservoir. The physical properties are mainly influenced by sedimentary environment, and diagenesis has little effect on it. The sand body developed in braided river delta front underwater distributary channel always has better physical properties.

5. Conclusion

The Qingshuihe Formation in Shinan area was developed in braided river front subfacies, of which the lithology includes grey medium-coarse-grained sandstone and medium-fine-grained sandstone with which some grey siltstone and grey silty mudstone were mingled. The grey medium-coarse-grained sandstone with tabular cross bedding belongs to the microfacies of front subaqueous distributary channel, and the grey siltstone and grey silty mudstone with ripple bedding belongs to front subaqueous distributary interchannel. The provenance come from the North of the region of interest. In the process of diagenesis, compaction caused about 60% of the primary pore loss, and cementation caused about 20% of the primary pore loss. The physical properties of Qingshuihe Formation are mainly controlled by sedimentary environment, on which the influence of diagenesis is small.

Acknowledgement

This research was supported by Gansu Province Fund for Youth Science and Technology (21JR7RM97), and Doctor Fund of Longdong University (XYBY1913).

References

[1] Luo JL, Wei XS, Yao JL, et al. Provenance and depositional facies controlling on the Upper Paleozoic excellent natural gas-reservoir in northern Ordos Basin, China. Geological Bulletin of China, 2010, 29(06):811-820.
[2] Liu F, Zhou W, Deng LZ, et al. Influential factors on physical property parameters of Paleozoic clasolite reservoir in the Southwest of Tahe oilfield. Computing Techniques for Geophysical and Geochemical Exploration, 2007, 29(04):317-321+277.
[3] Liu B, Huang Z, Long GQ, et al. Diagenesis and its effect on petrophysical property of low-permeability reservoir. Special Oil and Gas Reservoirs,2007,12(03): 317-321+277.
[4] Li HJ, Wu TR, Wu Bo, et al. A review of controlling factors of deep reservoirs in high-quality clastic rocks in China. Geological Science and Technology Information.2004,23(4):76-82.
[5] Liu BH, Zhang B, Guo Q, et al. Discovery and exploration inspiration of deep volcanic gas reservoirs in eastern sag of Liaohe depression. China Petroleum Exploration, 2020,25(3):33-43.
[6] Wang RY, Hu ZQ, Dong L, et al. Advancement and trends of shale gas reservoir characterization and evaluation. Oil&Gas Geology, 2021,42(1):54-65.
[7] Zhang YF, Dai X, Wang M, et al. The concept, characteristics and significance of fluvial fans. Petroleum Exploration and Development, 2020,47(5):947-957.
[8] Wang YT, Xu CS, Wang J. History of pool formation of Shinan oil-gas field, Junggar Basin. Petroleum Exploration and Development,1999,01: 48-51+5+14.
[9] Ren XJ, Yu XH, Li SL, et al. Sedimentary facies distribution and lithologic traps recognition of J1 S 21 Formation in the area of Shinan in Junggar Basin. Xinjiang Oil&Gas, 2009,5(01):8-12+102-103.
[10] Liu WF, Sun DQ, Yang CD, et al. Stratigraphic reservoir formation patterns and the favorable zones of stratigraphic/lithological reservoirs in central Junggar Basin. Natural Gas Geoscience, 2015, 26(12):2267-2274.
[11] Gao CL, Ji YL, Ren Y, et al. Sedimentary sequence evolution analysis of Qingshuihe formation in Shinan Area of Junggar Basin. Journal of China University of Ming&Technology,2016,45(05):1-14.
[12] Fu S, Ji BQ, Li JF, et al. Diagenesis of Middle Jurassic-Cretaceous reservoir in Shinan Area, Junggar Basin. Northwestern Geology. 2018,51(4):244-254.
[13] He DF, Chen XF, Kuang J, et al. Development and genetic mechanism of Chepaizi-Mosuowan uplift in Junggar Basin. Earth Science Frontiers. 2008, 15(04):42-55
[14] Qu GS, Ma ZJ, Chen XF, et al. On structures and evolutions in Junggar Basin. Xinjiang Petroleum Geology.2009,30(01):1-5.