Characteristics and Influence Factors of Es3 Reservoirs in Gubei Sag

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Abstract. There are many provenance systems in Gubei sag of Es3. Es3 is one of the main oil-bearing horizon of oil and gas exploration in gubei sag. Because of the great depth, the reservoir property is relatively poor. Influenced by factors such as sedimentary type and diagenesis, the reservoir characteristics of different provenance systems are different. The sedimentary type not only restricts the original physical properties, but also influences the late diagenesis. In the same diagenetic stage, there are differences in the physical properties of different sedimentary types, in the same sedimentary type there are also many differences between different sedimentary microfiches. The fan delta is the best, and the second is the underwater fan; the best part of the fan delta is the river channel and estuary sand bar in the front of the fan delta. The influence of different provenance system by depth, rock characteristics, the moving distance of different factors, in the stage of diagenesis, diagenetic types and other aspects are different, these factors continue to transform the reservoir. Ultimately these factors lead to the Kendong and Gudao provenance systems have the best reservoirs, Changdi second, Chengdong worst.

1. Introduction

Exploration in gubei sag began in the late 1970s, the exploration degree was relatively high. At present, several sets of oil-bearing strata such as paleogene series and neogene series have been found, among which the paleogene Es3 is one of the main oil-bearing strata [1-3], accounting for 70% of the discovered reserves in the whole region. The gubei sag has several sets of reservoirs with rapid lateral change and poor connectivity. So far, the distribution law of reservoir is well understood, but the physical characteristics and influencing factors of different source systems are not clear. In view of this, this paper analyzes the sedimentary background of different provenance in order to provide some guidance for oil and gas exploration in the Es3 of the study area. (Figure 1)
2. geological survey
Gubei sag is structurally located in the northeast of Zhanhua sag, Jiyang depression. It is adjacent to the buried hill of changdi in the east, the chengdong uplift in the west, the gudao uplift in the south, and the west buried hill of pile in the north. The east, west and north margins are all steep slope fault step belts, while the south is gentle slope fault step belts [4-6]. The depression is composed of three secondary structural units, two secondary depressions in the east and west, and a nasal structural belt in the middle. Under the influence of tectonic movement, the overall appearance of the third sand segment is bottom overtop stripping, with an area of about 400Km$^2$.

3. Reservoir characteristics
The three tectonic belts in the study area correspond to four provenance systems: the eastern depression zone is dominated by the changdi-kendong dual provenance system, the central nasal structural belt is mainly controlled by the gudao provenance system, and the western depression zone is controlled by the chengdong provenance system. Different provenance systems have different reservoir characteristics, which are embodied in the following aspects:

3.1. petrological characteristics
The petrological characteristics of reservoirs are different from different source systems [7-8]. The reservoir in the study area is mainly composed of clastic rocks, and the average content of clastic components in various source systems is different: Chengdong provenance’s quartz 18.6%, feldspar 31.7%, cuttings 49.2%. Changdi provenance’s quartz was 25.5%, feldspar 44.6% and cuttings 28.5%. Gudao provenance’s quartz 29.7%, feldspar 45.4%, cuttings 24.7%. The content of interstitial matter in each source system is different: Among them, the highest content of shale hetero - group in chengdong is 8.26%, Changdi and Chengdao is 6.6% and 5.9%, and the lowest content in Kendong is 5.8%.

3.2. pore type
The pore types in the study area are mainly secondary pores, including intergranular pores, intragranular pores, cuttings pores and cementitious pores. There are a few primary pores in the shallow part. With the increase of buried depth, secondary pores gradually increase and primary pores decrease. Primary pores below 3,200m are rare and mainly secondary pores.
Figure 2. Secondary porosity type of Es3 reservoir in gubei sag
A. Zhuang55, Dissolved pores between feldspar grains, 3287.2m, 100× (-)  
B. Zhuang80, Feldspar granule dissolved hole, 3573.77m, 400× (-)  
C. Bo991, Lithic dissolved pore, 2873.25m, 100× (-), D.Zhuang241, Cement solution hole, 3212.45m, 200× (-),  
E. Zhuang55, Mold hole, 3284.9m, 100× (-), F.Zhuang33, microfracture, 3164m, 50× (-)  

3.3. distribution law of reservoir physical properties
Longitudinally, the reservoir can be divided into four concentrated development stages according to depth (as shown in FIG. 3). Different provenance systems have different burial depth, developmental strata and sedimentary types. Chengdong source depth range in 3090-4300 meters, Changdi-Kendong buried depth range in 2700-3800 meters; Gudao reservoir of provenance system between 2800-3500 meters.

Figure 3. Concentrated development zone map of reservoir

According to the statistics of the relationship between reservoir physical properties and depth of different matter sources in gubei depression, it can be seen that the reservoir in the Es3 is buried deep and its physical properties are generally poor. The porosity shows a decreasing trend with the increase of buried depth. Due to the abnormal high value of secondary pores, the types of secondary pores are mainly intergranular and intratranular dissolved pores, the types of secondary pores are mainly intergranular and intratranular dissolved pores. To approximate average depth of reservoir porosity under comparison: reservoir II concentrated development period, for example, system average
porosity Chengdong source was 10.86%, Changdi, Gudao, Kendong source system average porosity of 16.4%, 12.6% and 12.9% respectively.

On the plane, the porosity of different source systems shows differences. From the perspective of the porosity distribution range (figure 4), the porosity distribution range of the source from Kendong and Gudao is 15-20%, Changdi is 10-15%, and the minimum porosity of the source from Chengdong is 5-10%. It can be seen that the reservoir physical property of Kendong and Gudao source is better than that of long dike source, Chengdong source is the worst.

![Figure 4: Histogram of porosity distribution of Es3 reservoirs](image)

4. Physical factors
Clastic particles from different sources are different in rock composition, particle size, sorting and transport distance due to different deposition types. These differences lead to different original porosity at the beginning of deposition, and late diagenesis also has a certain impact on pore transformation, resulting in different reservoir physical properties [9].

4.1. Sedimentation
On the one hand, sedimentation controls the quality of the original porosity and permeability of rocks; on the other hand, it controls the type, strength and evolution of the post-formation lithogenesis, which is one of the main factors influencing the physical properties of the reservoirs in this area. The factors influencing the physical properties of the reservoirs are as follows:

First, influenced by different provenance systems, the types of sedimentary facies are different. The physical properties of different sedimentary facies are obviously different under the influence of transportation distance and other factors. Through on the depth of the same period of comparing different types of sedimentary facies, reservoir II paragraphs concentrated development, for example, found that from Chengdong source system of the nearshore subaqueous fan facies sediment transport distance, low textural maturity, poor physical property; On the contrary, the fan delta physical properties of Changdi, Gudong and Kendong provenance systems are better as a whole.

Secondly, different sedimentary microfacies, clastic rock particle size, filler content, sorting and other aspects are also different. (Figure 5)
4.2. Diagenesis

Sedimentation, which controls the original physical properties of the reservoir, is the premise and foundation of later diagenesis. In the process of diagenetic epigenesis, the primary pores are transformed and secondary pores are formed, which have a certain influence on the present physical properties of the reservoir (figure 6).

Reservoirs of different source systems experience different diagenesis stages at different burial depths and different types of diagenesis, which ultimately affect the physical properties of reservoirs. Chengdong provenance: the diagenesis stage is from early diagenesis B to middle diagenesis A2. The cementation action is various, the dissolution action has the feldspar cuttings grain dissolution and the calcite dissolution two kinds. Dissolution of buried depth is deeper, and reservoir development period of II, IV corresponds. Changdi-Kendong provenance: the whole buried depth, the diagenesis stage is from the early diagenesis A to the middle diagenesis A1. The cementation of calcite and dolomite and the dissolution of feldspar clastic particles occur mainly, while the dissolution of calcite is rare. Source of isolated island: the diagenesis stage is early diagenesis B stage. The cementation is dominated by calcite cementation and ferric calcite cementation. Reservoir development period of I, II correspond to feldspar debris particles denudation depth, calcite dissolution. The four provenance systems all
experienced compaction in different diagenesis stages. Different provenance systems, different diagenesis stages and different diagenesis types have different effects on physical properties.

4.2.1. Effects of compaction on reservoir physical properties. With the increase of buried depth, the compaction is strengthened and the physical property is worse. With the increase of the buried depth, the elastic particles gradually changed from point-line contact to line contact and concave-convex contact.

With the increase of buried depth, the effect of compaction on reducing holes decreased (table 2). The porosity of reservoir above 3200 m is over 70%, and the decrease of primary pores is the main reason for the decrease of porosity. The porosity reduction rate of each source system is different, and the factors related to deposition, such as the composition, sorting, particle size, grinding, etc. of the clastic material have influence on the compaction effect. Chengdong provenance system in the same depth (such as reservoir development section), compacting hole rate significantly higher than the other three source reduction system, times, Changdi-the lowest east source. Based on the above reasons, it can be seen that under the joint action of deposition and compaction, the reservoir property of Chengdong provenance system is relatively poor.

For different sedimentary types of reservoirs, the compaction strength varies due to the transport distance. The fan delta facies reservoir, represented by Changdi-Gudao-Kendong provenance system, is affected by sedimentary transport. Compared with Chengdong provenance, unstable components in clasts are relatively few, and the rock composition is relatively mature with strong compressive resistance, which is conducive to the preservation of primary pores. The near-shore subaqueous fan sediments from the Chengdong provenance system are more likely to be compacted in the burial process due to their short transportation distance, rapid accumulation, low structural maturity, high content of argillaceous complexes, strong mobility of particles, and low interparticle support. The physical properties of the two types of sedimentary facies and the reservoirs with different microfacies of the same sedimentary facies become worse as the depth increases.

4.2.2. Effects of cementation on reservoir physical properties. Cementation generally has negative effects on reservoir. Early cementing ACTS as a consolidation and support to the rock, preventing further compaction, which reduces porosity for a period of time but provides a material basis for the formation of later secondary pores. The existence of secondary pores is to some extent the result of the combined action of cementation and dissolution. Reservoir cementation in the study area is mainly carbonate cementation, followed by siliceous cementation and occasionally pyrite cementation. Carbonate cementation includes calcite, dolomite, ferric calcite and ferric dolomite cementation. According to the statistics of the relationship between the content of carbonate cementite and porosity, it can be seen that with the increase of the content of carbonate cementite, the porosity decreases obviously, which shows that cementite inhibits porosity. The distribution of carbonate cement in the study area is uneven. Influenced by the composition of the source and the sedimentary environment, the content of cement in each source system is different.

The degree of cementation of different types of cementation varies at different depths, which reflects the control of deposition. With the increase of depth, the more carbonate cement content, the stronger the cement degree. For example, the buried depth of chengdong provenance system is larger and the degree of cementation is higher, while the buried depth of Gudao-Kendong provenance system is shallow and the degree of cementation is weak. Due to the difference of particle size, mud content and mineral composition, the cementation of different sources in the same depth section is different. Take Gudao and Kendong source systems as an example (as shown in figure 7): the reservoir is intensively developed in section I. The content of iron calcite cement in Gudong source is relatively high, with an average porosity of 16.1%. In the same depth range, the content of various types of cement in Kendong source is relatively low, with an average porosity of 18.4%. The reservoir is intensively developed in section II. The content of calcite cement from the two sources increases simultaneously, the content of
iron calcite cement from the island source decreases, and the degree of dolomite cement increases. The average porosity of the two sources is 12.6% and 12.9%, respectively.

4.2.3. Effect of dissolution on reservoir physical properties. Dissolution plays an important role in improving reservoir properties. The organic matter in the study area enters the threshold of hydrocarbon generation at 2500 meters, and reaches maturity with the deepening of the depth through thermal evolution, generating oil and gas and forming a large number of organic acids at the same time. Although there is carbonic acid dissolution in the study area, the dissolution is mainly organic acid. The organic matter in the early diagenetic stage is low mature and the organic acid content is high. The diagenetic stage enters the peak of oil generation and the concentration of organic acids decreases. For well-sorted sandstones with low hetero content and coarse grain size, organic acids tend to enter the reservoir and dissolve strongly. The organic acid in the reservoir with strong compaction and cementation is difficult to enter and the dissolution is weak. The dissolution of feldspar and some cementite is generally developed in the study area. In addition, calcite dissolution is also developed in Chengdong.

The dissolution of different matter sources is controlled by deposition. If the detritus is carried close, it has more unstable components and is more likely to be dissolved. After late dissolution, the chengdong provenance system improved the physical property of the reservoir to some extent, but the damage degree of compaction and cementation to the reservoir physical property was far greater than the improvement degree of dissolution, resulting in the poor physical property of the provenance system.

The comprehensive comparison shows that the particle separation of chengdong provenance system is poor and the hetero content is high. Although there are many unstable components, the organic acids are not easy to flow into the reservoir for dissolution, which ultimately leads to the worst physical property in this area. The reservoir of the source system of Changdi, Gudao and Kendong have strong dissolution effect, and a large number of intergranular and intracellular dissolution pores of feldspar were observed under the microscope. As the depth deepens, the compaction becomes stronger, and the concentration of organic acid decreases, the dissolution is weakened.

5. Conclusion
1) the reservoir in the third member of the gubei sag is mainly composed of clastic rocks. Vertically, there are four zones of concentrated reservoir development, which can be divided into four source systems: Changdi, kendong, Gudao and chengdong. The content of clastic components and fillings of each provenance system were different, and the physical properties were different: kendong and Gudao had better physical properties, Changdi followed, and chengdong are worse. The pore types are mainly secondary pores.

2) sedimentation and diagenesis jointly affect the physical properties of reservoirs: sedimentation not only controls the types of sedimentary facies, but also makes the physical properties of different
Sedimentary facies different. At the same time, the physical properties of different sedimentary microfacies are different due to the influence of transport distance and other factors. Diagenesis modifies the physical property, and with the increase of depth, compaction is strengthened, which is the main factor for the deterioration of the physical property in the study area. Meanwhile, carbonate cementation can also make the physical property worse. The secondary pores generated by the dissolution of feldspar and cement by organic acids in the studied area can improve the reservoir physical properties to some extent. In addition to the rock composition structure, chengdong provenance system has a short transportation distance, relatively low component maturity and weak compressive resistance, which results in relatively poor physical properties.

References
[1] BEARD D C, WEYL P K. Influence of texture on porosity and permeability of unsolidated sand [J]. AAPG Bullet in, 1973, 57(2): 349-369.
[2] RACHEL A D. Origin, distribution, and diagenesis of clay minerals in the albian panda formation, offshore Cabinda, Angola [D]. Reno: University of Nevada, 2001.
[3] READING H G, RICHARDS M. Turbidite systems in deep-water basin margins classified by grain size and feeder system [J]. American Association of Petroleum Geologists Bulletin, 1994, 78 (5): 792-822.
[4] Dickinson. W. R, Suczek. C. A. Plate tectonics and sandstone compositions [J]. AAPG Bulletin, 1997, 63 (12): 2164-2182.
[5] Salem A M, Morad S, Mato L F, et al. Diagenesis and reservoir quality evolution of fluvial sandstones during progressive Burial and Uplift: evidence from the upper Jurassic Boipebamemember, recncavo Basin, Northeastern Brazil [J]. AAPG Bulletin, 2000; 84, (7): 1015—1040.
[6] Amthor J E, Okkerman J. Influence of early diagenesis on reservoir quality of rotliegendes sandstones, Northern Netherlands [J]. AAPG Bulletin, 1998; 82 (12): 2246—2265.
[7] Morad S, Ramadan K, Ketzer J M, et al. The impact of diagenesis on the heterogeneity of sandstone reservoirs: a review of the role of depositional facies and sequence stratigraphy [J]. AAPG Bulletin, 2010; 94 (8): 1267—1309.
[8] Grant N T, Middleton A J, Archer S. Proxity trends in the Skagerrak Formation, Central Graben, United Kingdom Continental Shelf: the role of compaction and pore pressure history [J]. AAPG bulletin, 2014; 98(6): 1111—1143.