The lithofacies superposition patterns of oil-bearing reservoir of different productivity levels of the Lower Fourth Member of Eocene Shahejie Formation in Dongying Sag, Bohai Bay Basin

Ningning Xu*
Postdoctoral Scientific Research Station, Sinopec Shengli Oilfield Company, Dongying, Shandong, China
*Corresponding author e-mail: 418048012@qq.com

Abstract. Based on core observation and well logs, the paper reveals the lithofacies superposition patterns of oil-bearing reservoir of different productivity levels of the Lower Fourth Member of Eocene Shahejie Formation in Dongying Sag, Shengli Oilfield. The reservoir is divided to three types according to its productivity levels. Type A: natural productivity > 10 tons per day; Type B: 5 tons per day < natural productivity ≤ 10 tons per day and Type C: natural productivity ≤ 5 tons per day. Their corresponding lithofacies superposition patterns are “thin bedded sandstone + mudstone superposition model”, “multi-stage superposition of thick-bedded conglomerate and pebbled sandstone” and “superposition of medium thick pebbled sandstone, coarse-grained sandstone and medium-grained sandstone”.

1. Introduction
The study area is located in the northern fault step belt of Dongying Sag, Jiyang Depression, Bohai Bay Basin. The north is near the Chenjiazhuang uplift, the east is near the Qingtuozi uplift, the south is the central uplift zone. The provenance from the Chenjiazhuang Uplift rapidly accumulated in the Fourth Member of the Shahejie Formation (Es4) and formed the nearshore subaqueous fan and fan delta, which were dominated by gravity flow. Due to the action of east-west normal faults, the front of the fan is prone to collapse and be transported again, thus forming sedimentary forms such as clastic flow and turbidite. The lithology is mainly coarse-grained lithology of medium and fine gravel and coarse-grained sandstone-pebbled sandstone. In recent years, significant exploration breakthroughs have been made in the vicinity of fault step belts, and Well Fs10 and Fsx101 have obtained industrial oil flows in the Lower Member of the Fourth Member of the Shahejie Formation (Es4x), indicating a good exploration prospect.
2. Reservoir classification
The well data of the Lower Member of the Fourth Member of the Shahejie Formation were counted and screened, including oil test results, casting thin section identification, whole rock diffraction, etc., to clarify the existing data distribution of reservoirs with different oil test effects, and they were divided into three types of reservoirs according to daily oil production.

Type A: no measures taken, the self-injection liquid production is greater than 10t/d, such as Well Fs10; Type B: no measures taken, the self-injection liquid production is greater than 5t/d, less than 10t/d, such as Well Y22; Type C: no measures are taken, the liquid output of self-injection is less than 5t/d, such as Well F8.

3. Core observation
Core observation shows that the three types of reservoirs have different lithologic characteristics.

Type A (Fig. 2a, b) is mainly composed of black, grayblack pebbled sandstone and coarse-grained sandstone. The composition of the gravel is mainly massive or lacerated gravel, and the arrangement between the gravel is relatively orderly and imbricate. It shows that the laminar flow action of transporting water body is obvious, and the rock is the result of traction current action.

Type B (Fig. 2c, d) is mainly composed of white and graywhite pebbled sandstone, fine conglomerate and coarse-grained sandstone. There are obvious dissolution pores on the surface of the core with good porosity and permeability conditions. Common gravel is subcircular, the largest particle size up to 10 cm. The whole structure is mainly positive grain order, and some syngenetic deformation structures are common. The whole should belong to clastic flow-slump deposit.

Type C (Fig. 2e, f), mainly black and grayish brown pebbled sandstone and conglomerate. Gravel is mainly composed of carbonate rock. Gravel is imbricated and mainly composed of massive structure. The whole belongs to elastic flow-slump deposit.
Fig. 2 Typical core photos of different types of reservoir of Es4x in Dongying Sag
(a) FS10, 4263.5m; (b) FS10, 4260.0m; (c) FSX101, 4529.8m; (d) FSX101, 4532.8m; (e) YX228, 4230.6m; (f) YX228, 4239.8m.

4. Lithofacies superposition patterns

Based on core observation, well logs and other data, the paper reveals the lithofacies superposition patterns of different types of reservoirs.

Type A (Fig. 3 A) is “thin bedded sandstone + mudstone superposition model”. The burial depth of reservoirs in the study area is generally more than 4,000 m, and the rock fabric generally reaches the tight condition, so burial diagenesis is the key to improve reservoir quality. The effect of the diagenetic evolution of mudstone on the reservoir is that the organic acids produced by mudstone can promote the dissolution of unstable particles such as feldspar in the adjacent sandstone. Therefore, the superposition model of thin-bedded sandstone-pebbled sandstone and mudstone is a type of reservoir with the best reservoir performance in the study area.

Type B (Fig. 3 B) is “multi-stage superposition of thick-bedded conglomerate and pebbled sandstone”. In the absence of adjacent mudstones, relatively thick layers of conglomerate can effectively resist compaction, thus preserving some of the original pores within. This superposition model is considered to be the superior reservoir development model of the second stage in the study area.

Type C (Fig. 3 C) is “superposition of medium thick pebbled sandstone, coarse-grained sandstone and medium-grained sandstone”. This is the worst reservoir development pattern in the study area. First, the absence of mudstone interlayer makes it lack of organic acids needed for feldspar dissolution; second, the multi-stage single-layer sand body is more likely to be compacted and get tight in the later compaction process, resulting in the formation of poor reservoir.
Fig. 3 Lithofacies superpositional patterns of different types of reservoirs of Es4x in Dongying Sag

5. Conclusion
The reservoir of Es4x in Dongying Sag is divided to three types according to its productivity levels. Type A: natural productivity > 10 tons per day; Type B: 5 tons per day < natural productivity ≤ 10 tons per day and Type C: natural productivity ≤ 5 tons per day. Their corresponding lithofacies superposition patterns are “thin bedded sandstone + mudstone superposition model”, “multi-stage superposition of thick-bedded conglomerate and pebbled sandstone” and “superposition of medium thick pebbled sandstone, coarse-grained sandstone and medium-grained sandstone”. Whether there is mudstone interlayer or not and the thickness of single sand body are the key factors to determine the quality of reservoir.

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