Identification Method and Effect of Dongjiagang's Alluvial Fan*

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Abstract

The study area is a continuously developed large nose-like structure belt of Paleogene sediments, located in the middle of the west slope of the eastern sag in the Liaohe depression. The early stage of exploration mainly found fault block reservoirs and fault-nose reservoirs in the complex fault terrace, in the south and north of the study area, the exploration degree is relatively high, certain amount of proven reserves have been found in the third member in Shahejie Formation (Es3). The early three exploratory wells in Dongjiagang did not drill the reservoir or drilled the thin red layer, so the exploration was once stagnated. We consider that under the control of palaeotopography, multistage of superimposed fan bodies may develop in the study region. In the slope and nose-like structure periclinal parts, there are good conditions for forming lithologic oil reservoir and great potential for exploration.

For a detailed study of the sedimentary characteristics of lower Es3, we applied analysis techniques of Paleo-geomorphic restoring, waveform clustering properties, velocity analysis and amplitude properties to confirm the fan body's boundary and shape. In identifying the fan body's physiognomy of southern Dongjiagang, we found that Dongjiagang fan body was more obviously controlled by three ancient valleys, in the lower step of western slope belt, sediment source deposited along the valleys, formed four alluvial fans. In the southern Dongjiagang, Dong 15 well obtained low-yield oil flow, Dong 6 well failed. The result showed the accumulation factors were complex. We established reasonable accumulation mode and identified advantageous reservoir forming assemblage to guide well deployment.

Based on comprehensive analysis, we suggested O58 well in the main channel in Dongjiagang, The well precisely drilled sandstone of Es3 as predicted, and acquired industrial oil flow in the third stage glutenite rock. Deepened the overall understanding of lithologic reservoir accumulation principle, and effectively promoted the lithologic oil gas reservoir exploration in eastern sag. After the research, we achieved three points: (1) Paleo-geomorphology analysis technique is the key to guide fan body prediction; (2) comprehensively apply multiple geophysical technologies to identify fan body will makes prediction result more reliable; and (3) reasonable accumulation analysis will increase the success ratio of lithologic oil and gas reservoirs exploration.

Introduction

The study area is a continuously developed large nose-like structure belt of Paleogene sediments, which is located in the middle of the west slope of the eastern sag in the Liaohe depression. The region is where the central deep subsag's hydrocarbon migrates to the slope area. The condition of oil source is good, the early stage of exploration mainly found fault block reservoirs and fault-nose reservoirs in the complex fault terrace, in the south and north of the study area, the exploration degree is relatively high, certain amount of proved reserves have been found in the 3rd member in Shahejie Fm (Es3).

The Dong area has a relative low exploration degree, there are only five wells drilled in this region. The reservoir mainly in the lower Es3 formation varies greatly. The three early exploratory wells ran into the basement, either did not drill the reservoir or drilled the thin red layer. D14 well drilled sets of reservoir and D15 well only met a thin layer of low-yielding reservoir, so the exploration was once stagnated.

After comprehensive consideration of exploration strategies, we conclude that under the control of palaeotopography, multistage of superimposed fan bodies may develop in the study region. The alluvial fan body in lower Es3 (Es_3^3) and large set of dark mudstones in middle Es3 (Es_3^2) can form a good source-reservoir-seal assemblage. In the slope and nose-like structure periclinal parts, there are good conditions for forming lithologic oil reservoir and great potential for exploration.

Prediction Methods of Fan Body

Taking into account the difficulties and characteristics of the exploration of this kind oil and gas reservoirs, we used these methods:

1) Paleo-geomorphic restoring technology
2) seismic facies analysis and multi-wells controlled wave impedance inversion technology
3) velocity analysis along the specified layer technology
4) fan body fine depiction technology.

For a detailed study of the sedimentary characteristics of Es_3^3, we analyzed characteristics of exploration wells seismic facies, applied ancient landform analysis technique and waveform classification technique for studying the sedimentary characteristics. Based on fine structure interpretation, we flattened the top of Es_3^3, restored the ancient landform when Es_3^3 was deposited, then we could clearly divide Dong slope into three fan bodies controlled by ancient depression: Northern of Dong fan body, Dong fan body and Southern of Dong fan body (Figure 1). Dong fan body was more obviously controlled by ancient depression. Sediment source was controlled by three ancient valleys (Figure 2), in the lower step of western slope belt, deposited along the valleys, formed four alluvial fans (Figure 3).

The seismic section perpendicular to the main fan body showed lenticular reflection characteristics, and wave impedance section showed strong wave impedance characteristics. We used velocity analysis techniques in the area showing lenticular reflection. Through the original velocity profile and velocity plane analysis, in the seismic profile, the fan body showed velocity increasing phenomenon, plane velocity was higher than the surrounding stratum, which further validated the sandstone and conglomerate developed there.

We applied analysis techniques of waveform clustering properties and amplitude properties to further confirm the fan body's boundary and shape, identify the fan body's physiognomy of southern Dong, then combined with the single well facies and multiple well correlation analysis. Finally, the fan body could be divided into root fan, middle fan and fan edge. Source moved from northwest to southeast. In order to precisely depict Dong fan body, we combined well correlation with wave impedance inversion results, then finally divided the fan body into three stages, and predicted the fan body reservoir stage by stage (Figure 4).

Accumulation Conditions

In Dong's alluvial fan, D15 well obtained low-yield oil flows. D6 well failed. The result showed the accumulation factors were complex. In the middle of eastern sag, there was a large set of lacustrine dark mudstones in Es_3^2, that was the main source rocks of the reservoir in Es_3^3 and they could serve as regional cap rock. D6 well drilled root fan with poor physical properties. D15 well drilled middle fan with better physical properties. However, the well was located in the flank of the fan body, so the reservoir was thin. Combining inversion profile with seismic facies features, we predicted the boundary of the lacustrine facies mudstone of Es_3^2. D15 well was inside of it, covered by lacustrine facies mudstone, while D6 well was outside of it. Under the favorable structural background, Dong fan body accumulation was mainly affected by the sedimentary facies and regional mudstone that serve as a cap rock.

Exploration Effect

Based on the research results above and combined with the tectonic location, we had suggested the well O58. The well precisely drilled fan body's top surface, and drilled sandstone of Es_3^3 as predicted. Multiple sets of sand body obtained good oil and gas shows, and acquired industrial oil flow in the third stage glutenite rock.

Under the background of west slope, the success of well O58 proved the glutenite rock's oil-bearing condition of eastern sag, and further proved that the alluvial fan body's middle fan sub-facies had good accumulation conditions. Because of lateral sealing of the root fan and cap sealing of lacustrine mudstone, middle fan sub-facies formed an "upper generation, lower storage" lithologic oil reservoir. Our research has deepened the overall understanding of lithologic reservoir accumulation principle, and effectively promoted the lithologic oil gas reservoir exploration in eastern sag.

Conclusions

Based on our research, we arrived at three points:

1) Ancient landform is important for controlling the sediment system type and its spatial distribution, paleo-geomorphology restoration technique is the key to guide fan body prediction;
2) Comprehensively apply multiple geophysical technologies to identify fan body as far as possible, than authenticates mutually that will makes prediction result more reliable;

3) Reasonable accumulation analysis will increase the success ratio of lithologic exploration.

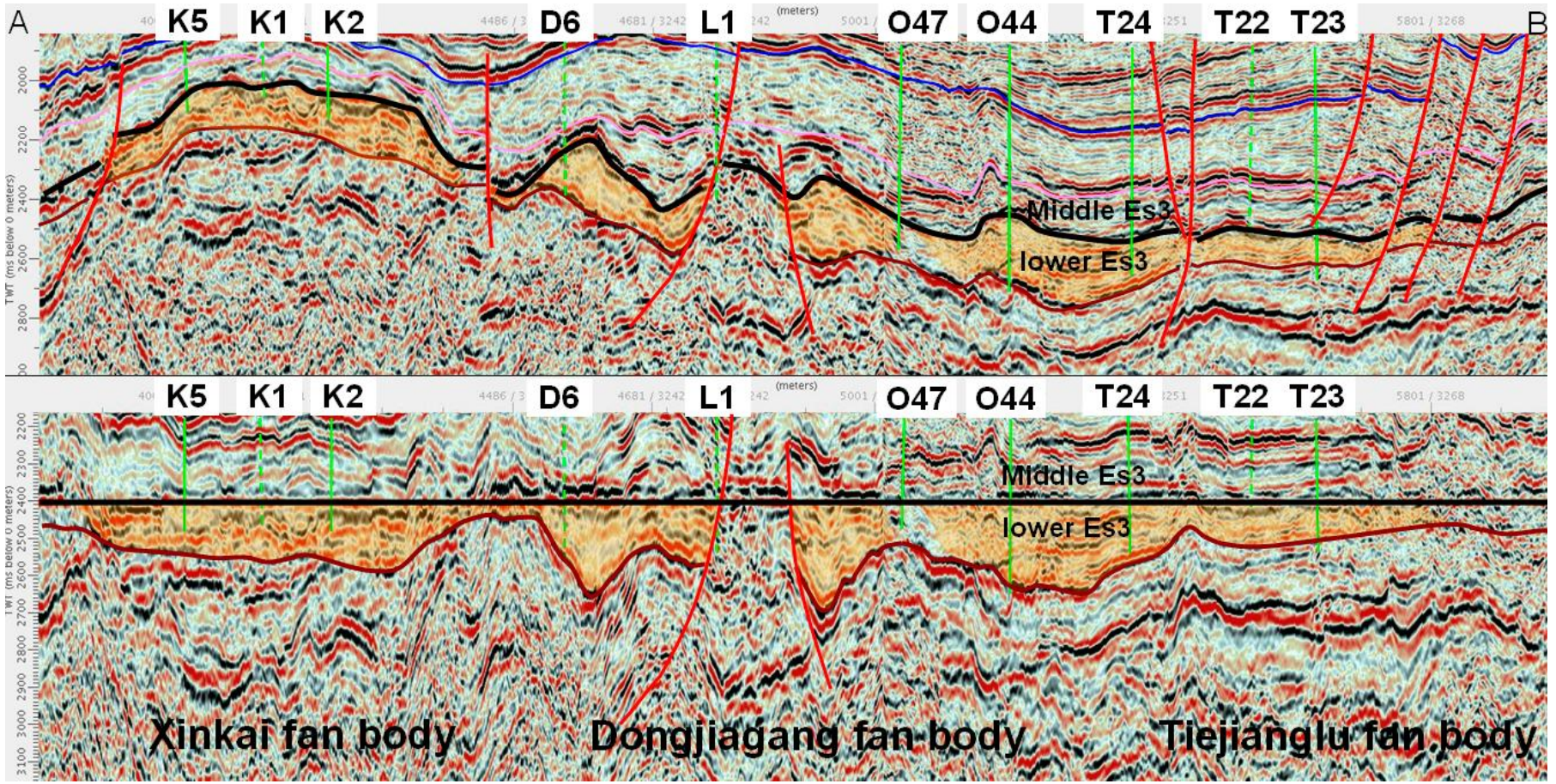

Figure 1. The flattened seismic profile of the western slope zone.

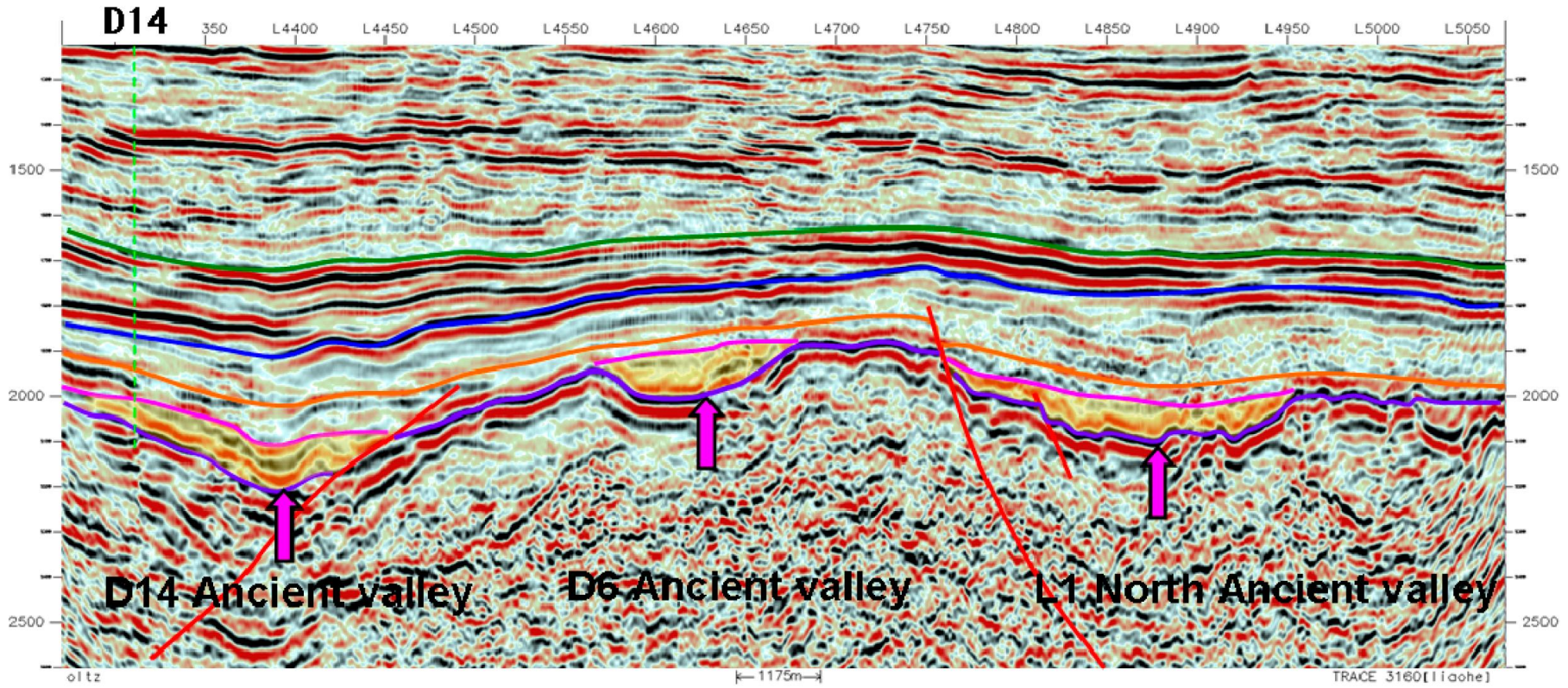

Figure 2. Source supply ancient valley map in Dongjiagang area.

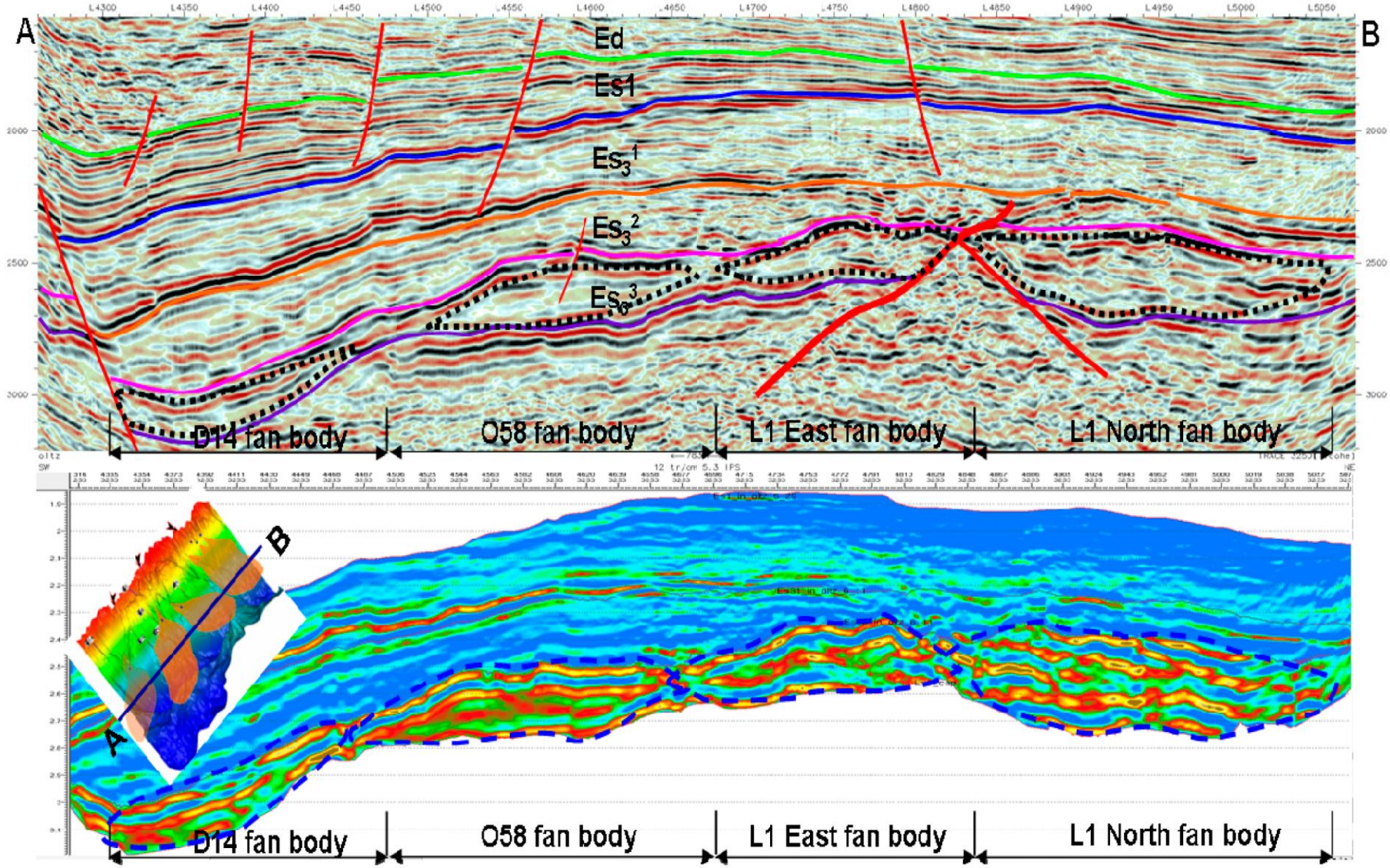

Figure 3. The seismic and AI inversion of Dongjiagang's alluvial fan.

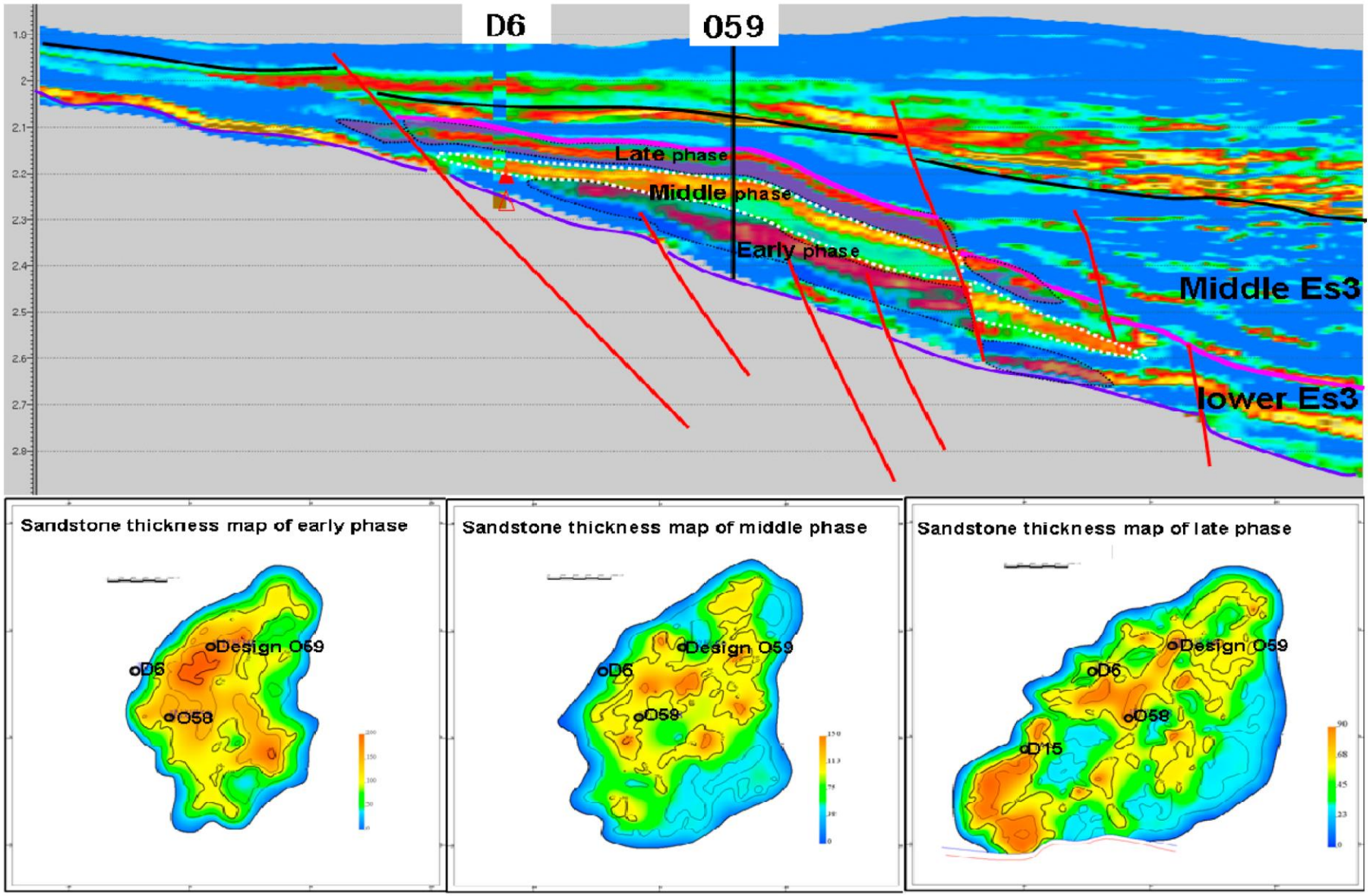

Figure 4. The reservoir prediction of Dongjiagang's alluvial fan.