Identification and Exploration of Lithologic Traps in Block M of South Turgay Basin

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Abstract: The Jurassic formation in block M of South Turgay Basin is located in the gentle slope zone of the rifted lake basin where structural traps are not developed, so it is important for explorers to find lithologic traps. They are mainly located in the Jurassic system and the main control factor of forming reservoirs is the reliability of lithologic traps. The sedimentary characteristics of Jurassic system in this area show that reservoirs with sands up-dip pinch-out in front of slope zone are formed in formation Doshan in the Middle Jurassic. The spatial distribution and oil-bearing properties of the anomalous body in Doshan formation which forms the lithologic trap because of sands up-dip pinch-out are described by the techniques of automatic interpretation based on the global stratigraphic framework model, sub-volume coherence, S-Transform of spectral decomposition and low frequency enhancement. This lithologic trap which has favourable reservoir forming conditions was drilled to prove that it contains industrial oil and gas.

1 OVERVIEW OF THE STUDY AREA

The South Turgay Basin which is located in the central part of Kazakhstan and in the transitional shear zone of the Ural-Tianshan suture is the Mesozoic fault depression basin above the Hercynian period. It has experienced the Early-Middle Jurassic fault depression period, the Late Jurassic transitional period and the Cretaceous depression period (Shi et al. 2016; Liu and Jiang, 2013; Zhang et al., 2012; Sun et al., 2008). It is accompanied by a strike-slip tectonic movement along the western edge of the basin, forming a near-north-south Karatau crush-strike-slip fault, creating the structure pattern of a convergence in the southeastern and diverging in the northwest of the basin. The formation and distribution of oil and gas of the basin is controlled by the tectonic zoning of the basin (Zheng et al., 2009; Allen et al., 2001; Kong et al., 2007; Yin et al., 2012) (figure 1). The exploration of the basin began in the 1960s. It has been into the high mature -rolling stage of exploration for 50 years, so it is very difficult for further to find the large-scale structural oil and gas reservoirs (Tian et al., 2010; Yin et al., 2011; Sheng et al., 2014). The current exploration of the basin focuses on the lithology traps of the depressions and slopes.

The block M is located in the south of Aryskum graben and in the context of regional tectonics, the pattern of fault depression in the east and overlapping upward in the west are formed. The block M is the eastward slope on the whole and the Karatau strike-slip fault is developed in the east. Drilling results have shown that the lithology reservoirs in this area are mainly located in the Middle and Lower Jurassic. They can be divided into three sets of strata from the bottom to top (figure 2): the Ablin Formation(J1ab), the Doshan Formation(J2ds), the Karagansai Formation(J2kr). The Middle and Lower Jurassic periods correspond to the lake basin depression. The deep to semi-deep lake mudstone and source rock were developed in the J1ab. Based on the deposition of shallow lake, the delta sediment was developed in the J2ds and the underwater distributary channel, frontier sand and beach dam which were beneficial reservoirs were adjacent to source rocks and easy to form lithology reservoirs. The J2kr corresponded to a large-scale flood period. The thick mudstone which was the effective regional cap rock of J2ds was developed in the J2kr. It is an effective play of reservoir and cap.

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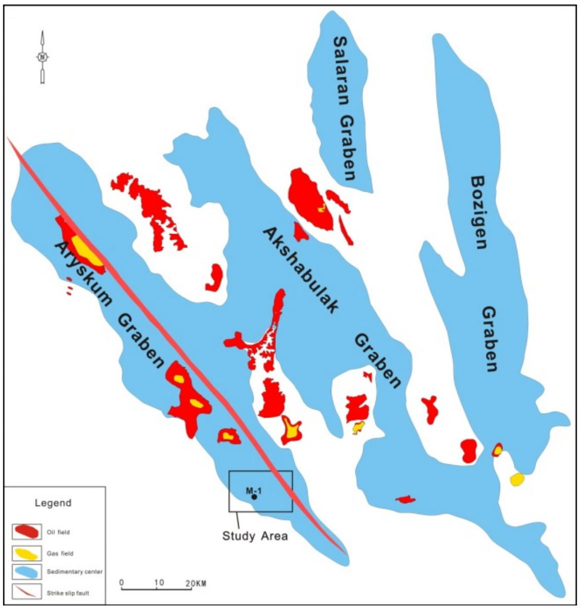

Figure 1: Structural framework and oil and gas distribution map of the South Turgay Basin.

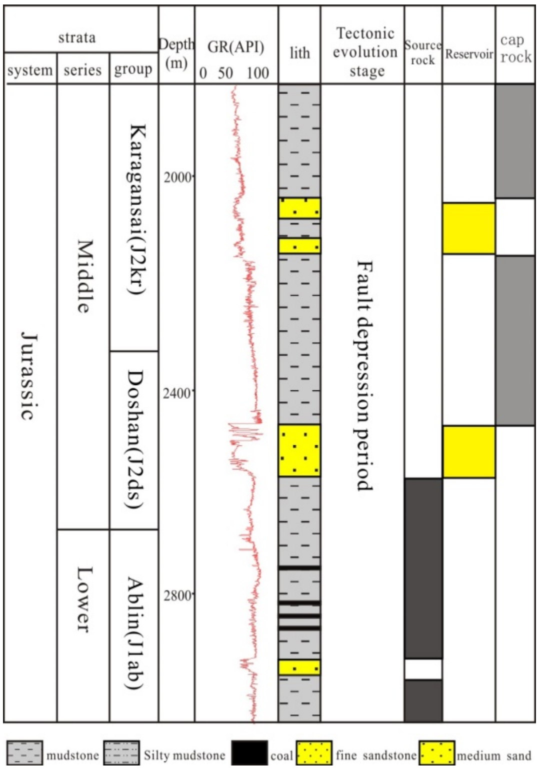

Figure 2: Jurassic geologic column of block M.

2 CHARACTERIZATION OF LITHOLOGIC TRAPS

Firstly, the stratigraphic model is calculated from the post-stack seismic data volume by using the automatic seismic interpretation method based on the global stratigraphic framework model. Then, the horizons are extracted from the model and the seismic attributes are calculated. Finally, the global search and tracking of the anomalous body and the research of sedimentary evolution are made by using the seismic attributes of many horizons.

On the basis of considering the seismic reflection characteristics, stratigraphic sedimentary global consistency, sedimentary thickness, formation inheritance and other integrated geophysical factors, the automatic seismic interpretation method based on the global stratigraphic framework model regards 3D seismic data as the show of the present underground geological bodies. The global stratigraphic framework model is established based on the seismic geologic information contained in the whole 3D seismic data and the global isochronous deposition sequence. And then the optimal stratigraphic model is selected in a large number of possible geological frameworks by the cost function based on seismic data similarity and geological consistency. On this basis, the application of drilling data, seismic data, multi-attribute and multi-directional integrated interpretation mode can greatly improve the interpretation accuracy of the structure. The isomorphic stratigraphic model, which contains all the geological information such as tectonic deformation, sedimentary sequence, sedimentary evolution and so on, can be used to reconstruct palaeogeomorphology and study the restoration and evolution of the sedimentary history. The realization process mainly includes two steps: first, a model grid consistent with the stratigraphic model is calculated based on seismic data. The stratigraphic model is calculated by using the cost function minimization algorithm and connects the seismic samples according to the wavelet similarity and the relevant distance. This process automatically tracks each horizon in the seismic data to constrain the grid and a relative geological age value is calculated at each grid point. Second, the model is refined by modifying the connection relationship between the automatic tracking horizons. Each operation has an effect on the node connection relationship in the model grid. Under the preview function, the quality of the model compared to the original seismic data can be evaluated until an optimized model is obtained.

Based on the pre-stack migration seismic data of block M, the Jurassic stratigraphic model was established by this method (figure 3-I). Then, 200 horizons were extracted from the J2ds stratigraphic model and the corresponding RMS amplitude and dessert attributes were calculated. The horizons extracted by this method were the isochronous surface (figure 3-II) and better than the time slices, the slices along horizons and the stratigraphic slices, because these three kinds of slices cannot be the isochronous due to the impaction of the attitude of stratum and the structural relief. It was concluded that the large-scale anomalous body was developed on the slope of J2ds formation by analysing the sedimentary evolution according to the animation of the dessert attributes corresponding to 200 horizons (figure 3-III).The anomalous body was isolated because its western upside is obliquely pointed out. The seismic amplitude of anomalous body was significantly enhanced and the frequency was lower. And then the top and bottom surfaces of the anomalous body were tracked by the three-dimensional visualization of the automatic tracking technology and its time isopach map was drawn. The plane of this anomaly which covers 13 square-kilometers is oval in the direction north-south. It is about 6300 meters long from north to south, and 3770 meters in width from east to west. On the whole, it is thicker in the east side than that in the west side and the maximum thickness of main part is up to 120ms (about 180 meters).

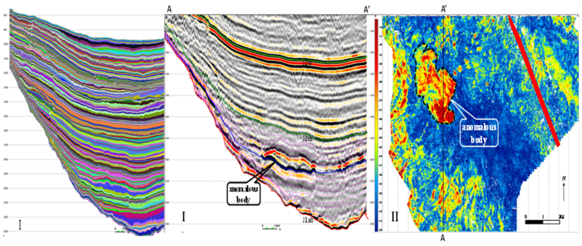

Figure 3: Jurassic stratigraphic model(I) and plane characteristics of J2ds anomalous body of block M(The pink lines in II is the part horizons extracted from I. III is the dessert attribute of the blue horizon in II).

3 HYDROCARBON DETECTION

This study has applied the spectral decomposition of four algorithms, such as Discrete Fourier Transform (DFT), Continuous Wavelet Transform (CWT), Time-Frequency Continuous Wavelet Transform (TFCWT) and S-Transform. The principle of the algorithm and the actual effect show the S-Transform method is optimal. The spectral decomposition profiles of the wells M-2 and M-3 are shown in figure 4, where the left side is the spectral decomposition profile of the wells with the gamma curve projected and the right side is the spectrum decomposition profile of the seismic trace at the well point. In figure 4, there are strongest energy of 20-25Hz and weak energy of 40Hz or more at the gas zone of well M-2. The anomalous body of J2ds deployed the new well M-3 is predicted gas zone where the frequency is concentrated at 5-15Hz and the high frequency attenuation is obvious.

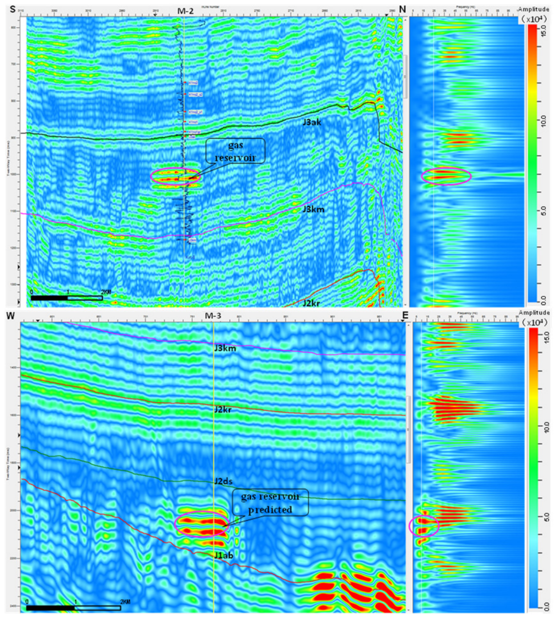

Figure 4:.Spectral decomposition profiles through wells M-2 and M-3.

Based on the spectrum decomposition 10Hz seismic data, the top and bottom surface of anomalous body were tracked firstly by the three-dimensional automatic tracking technology. Then its inner RMS amplitude was extracted, range more than 1.0×10^5 was selected and sculptured. Gas-bearing area of about 11.27 square kilometres was predicted (the pink line range in figure 4) and a higher degree of gas saturation area with about 100 meters thickness was 5.88 square kilometres (the black line range in figure 5).Well M-3 was deployed in conjunction with the structural features of the J2ds layer in the range of high gas saturation of the J2ds anomalous body. This well was drilled in 2016 and tested in the J2ds layer for obtaining high-yield oil and gas flows. This well is the first discovery well for the lithological trap in the J2ds formation, located in the southern Turgay Basin. The above technical approach is also promoted in the lithological traps of other blocks in the basin.

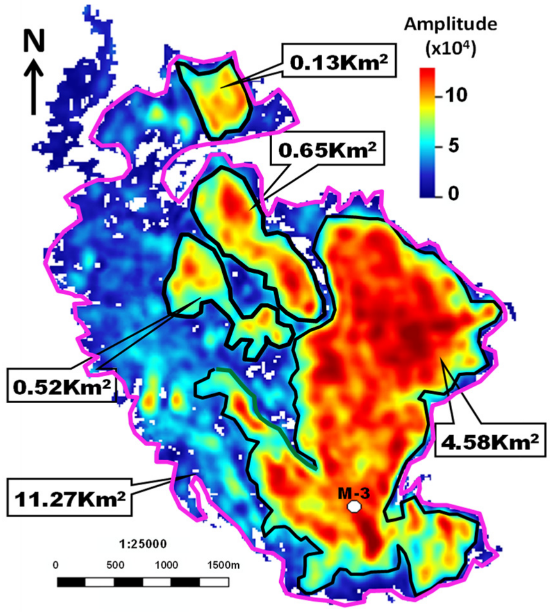

Figure 5: 10Hz seismic RMS amplitude of J2ds anomalous body of block M.

4 CONCLUSIONS

By using automatic interpretation technology based on global stratigraphic framework model, J2ds anomalous body in block M is identified, which is an up-dip pinch-out lithological trap on the slope. Its area is about 13 square kilometres with 180 meters maximum thickness of main part. Then, the spectral decomposition technique of S-Transform method is selected for spectrum decomposition. According to the dynamic characteristics of "low frequency enhancement, high frequency attenuation", hydrocarbon-bearing possibility of lithological trap was predicted based on the spectrum decomposition 10Hz seismic data. The predicted gas-bearing area is about 11.27 square kilometres and a higher degree of gas saturation area is around 5.88 square kilometres.

Based on 3D visualization of lithological trap and accumulation condition analysis, well M-3 has been deployed for obtaining high-yield gas flow. The first scale breakthrough of lithological reservoir was realized in block M and a new prospect of lithological reservoir exploration in this area was opened up. At the same time, the series of technology has been widely used in lithological exploration in other areas of the basin and achieved good practice results.

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