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Study on formation fracture prediction of FuYu oil layer in Xingshugang area, central Songliao Basin, China

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Abstract: Fuyu oil layer exploration is potential and its reservoir type is complexed. Due to its poor of porosity and permeability, its production capacity depends mainly on oil and gas reservoir fractures situation. Fractures can not only provide reservoir space, improve matrix permeability, but also be the main migration path and the key factor for low permeability sandstone reservoir capacity. Thus, the rule of fractures distribution has become the most important issue to improve the efficiency of exploration and development. Since the fracture is affected by many factors, which requires a comprehensive method of geological, logging, geophysics, experimental analysis, production test data to describe. The history of construction and development is employed to analyze the times of fracture formation. The late Qingshankou formation was the major period when fractures were formed, with high angle and vertical fractures being the dominant. NW trending and NNE trending tension vertical fractures oriented, NW trending and NE trending conjugate shear fracture followed in Fuyu oil layer in Xingshugang area. The result of this study is significant to efficient development of similar reservoirs.

Key words: *Xingshugang oil field; present geo-stress; numerical simulation*

I. INTRODUCTION

The research of fracture, stress is one of the most important geological research of the development of low permeability oilfield. From the mid-1980s, people have been making unremitting exploration and research in this field[1-5]. Fracture is an important influence on the output performance of the reservoir so that study of the reservoir fracture has a special significance. According to statistics, fractured reservoirs of worldwide oil and gas production account for more than half of the world's oil and gas production, therefore exploration potentiality of fractured reservoir is very large and is an important succeeded type of resource[6-8]. With further exploration and development of oil and gas, fractured reservoirs (such as most bedrock hill reservoirs) and reservoirs impacted by fracture (such as some low-permeability reservoirs) are increasing in the proportion of oil and gas reservoirs discoveries, reserves and production has gradually increased in the proportion. The situation is particularly prominent in our country, and the research of reservoir fractures has been received increasing attention. Reservoir fracture early identification and reservoir fracture accurately describe and predict is the key to effective development of fractured reservoirs[9]. From the perspective of oil and gas exploration, with the end of simple structural traps of oil and gas exploration having been dominated, and fractured reservoirs being constantly found, which expands the field of exploration. From the perspective of oil and gas field development, with the continuous energy extraction and rapid exhaustion, making oilfield Enhanced Oil Recovery become the primary means to increase production and the amount of energy development. While the existence of fracture impacts on the effect of the reservoir development. So fracture has become an important part of reservoir evaluation, as well as the urgent need for effective development of oil fields. Currently, the research of fracture and stress distribution is almost in a blank stage in Xingshugang oilfield. Effective development of research on this type of reservoir fractures therefore carry out reservoir characteristics and distribution of Xingshugang oilfield has an important role in guiding.

1. FRACTURE CHARACTERISTICS

Xingshugang oilfield natural fractures can be divided into tectonic fractures and non-structural cracks. Non-structural cracks are in the mainly interlaminar fractures. Tectonic fractures can be divided into significant fractures and microfractures according to the size. Significant fractures can be identified naked eye, microfractures are visible only with a microscope. Through core observation, the major are tectonic construct caused of the structural joints (75%). Non-structural cracks mainly developed in mudstone, which are small in size and poor in connectivity. Construction fractures include tensile fractures and shear fractures. And shear fractures are developed seam, cut surface smooth and straight sewing, occurrence stable obvious scratches (Figure 1a). Tensile fractures are developed surface roughness, irregular and shorter extension(Figure 1b). The angles of tectonic fractures are mainly greater than 75°high-angle joints and standing seam based(Figure 2), which are more than 85% of the total cracks of this area, low angle seam is less developed.

a Shear fracture G431 1641.17m b Tensile fracture X76 1644.50m

Figure 1 Xingshugang oilfield Fuyu Reservoir fracture characteristics

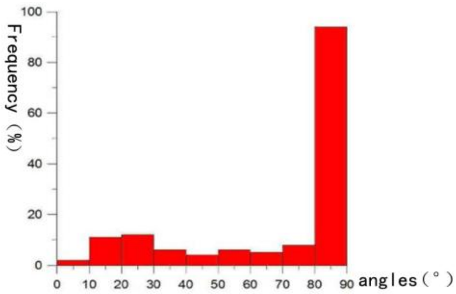
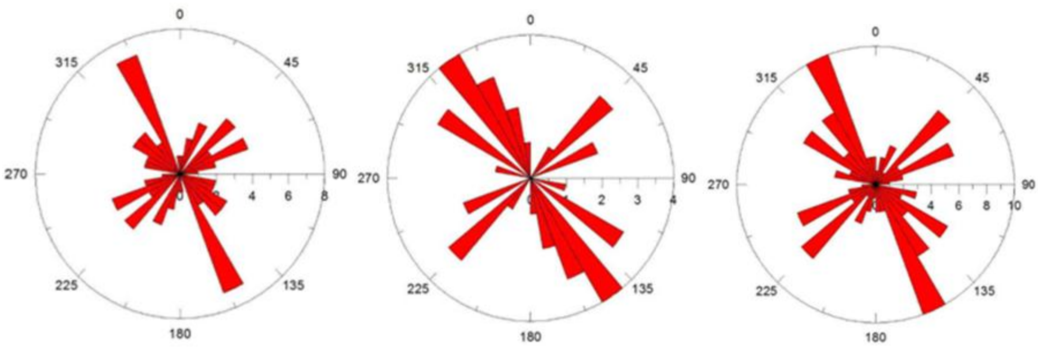


Figure 2 Frequency distribution of fracture angles

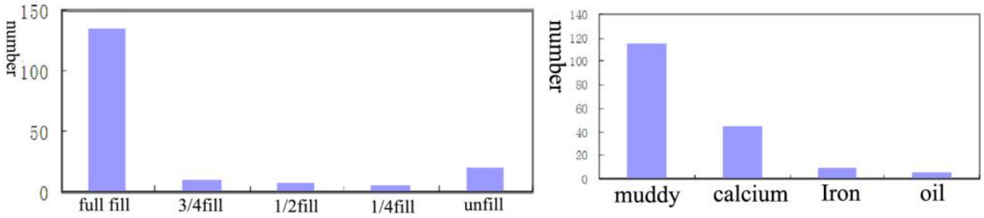
Conductivity anomaly detection, statistical analysis of borehole deviation and rock dynamic experiment including paleomagnetic experiment, differential deformation experiment and acoustic emission experiment are employed to analyze fracture distribution. The results prove that the trends of tensile fracture are major oriented north-west, followed by north-east and the trends of shear fracture are mainly north-east and north-west two group in the area (Figure 3). The trends of faults are substantially northwest in this area and fractures are developed into two group shear cracks under NEE stretch stress, and a set of tension cracks which show consistency with faults in trend.



(a) tensile fractures (b) shear fractures (c) all fractures

Figure 3 Xingshugang oilfield Fuyu Reservoir fracture trend rose diagram

The vast majority of fracture opening between 0-2mm, individual fractures with the opening of a large, but not more than 4mm; fractures are filled with a full fill-based, unfilled second, less half-filled of the amount. Most Fillings are muddy, mostly tensional fractures are filled with muddy, secondly calcium, shear fractures are mostly filled with calcium, of which five fractures full of oil, a number of high angle fractures and standing seam see traces of oil (Figure 4). Description of tectonic fractures within the reservoir in this area has a significant impact on migration and reservoir percolation of hydrocarbons.



(a) Filling rate (b) Fillings

Figure 4 fracture filling rate and fillings

II. ANALYSIS OF FRACTURE FORMATION CAUSE AND TIMES

2.1 Regional Tectonic Activity

Xingshugang area is located in the middle Daqing Changyuan of Central Depression of Songliao Basin, east Sanzhao depression, west of Qijia - Gulong depression; its reservoir type as anticline reservoirs, the anticlinal axis structure is relatively flat , east Wing constructed moderate, west Wing steeper; structural feature whereby the area is divided into east gentle slope belt, central and western steep anticline with three tectonic zones. Northern Songliao Basin experienced three stages evolution a Late Jurassic - Early Cretaceous stretch graben, the Early Cretaceous cooling depression, the late Cretaceous inversion fold[10-11]. The Basin has extension, compression duality in the development process, manifested as early rift, mid depression and late fold characteristics[12]. For Fuyu reservoir, the tectonic deformation mainly occurred in depression period(Qingshankou period- Nenjiang period) and Tectonic inversion period (Nenjiang period end-Mingshui period). Fractures accompanied with tectonic activity, after Quantou deposition undergone two strong tectonic movement in Songliao Basin, therefore regional extension and inversion construction were possible period when fractures of Fuyu reservoir were formed(table 1).

Regional tectonic evolution in Xingshugang area was similar with the process of tectonic evolution in Songliao Basin since the late of Early Cretaceous, mainly through two stages of extension construction phase and inversion construction phase. Meanwhile, Nenjiang period end as the dividing line, before the line mainly experienced extensional vertical settlement, after the line experienced reversal tectonic compression. Quantou Formation mainly experienced tension vertical subsidence in Xingshugang area at the Quantou end and Nenjiang end, experienced regional tectonic inversion at the period between Nenjiang end and Mingshui end.

Table 1 Songliao basin tectonic profile

Basin evolution		Period	Structural Features	Fault trend and nature	Tectonic stress field
Faulted period	Early stage	Jurassic end-Early Cretaceous	Heat dome-way stretch, A large area of volcanic activity	NNE,NNW,SN trending strong stretch	Biaxially stretched，NNE trending priority
	Late stage	Early Cretaceous	Crustal extension detachment, Lithospheric thinning	NNE trending extensional detachment fault-based	NWW-SEE trending horizontal tension
Depression period		Late Cretaceous	Cooling settlement, Overall Depression	Small-scale NE,NW,SN trending normal faults	NW-SE trending weak tension
Tectonic inversion period		Cretaceous end	Extrusion reversal, Local uplift and erosion	NNE-NE trending Reverse rift activity of normal faults	NWW-SEE trending Horizontal compression
		Cenozoic era	Basin atrophy, Overall Uplift	Faulting weak	NE-SW trending compression or stretching

2.2The main deformation of times

Usually, faults are fractures to continue, while promote a new fault and fracture formation. Thus the period of fault strong activity is the main period of fracture formation. There are plenty of small normal faults in Fuyu oil layer, these normal faults have characteristics of small-scale, intensive development and obvious stratabound, mostly formed in Quantou formation - Qingshankou formation deposition. The period of Qingshankou formation deposition is the period of most intense fault activity in Quantou and Qingshankou formation, with a relatively large amount of stretch.

Statistics and analysis through the sample of acoustic emission test, Quantou formation experienced two stages of tectonic evolution: which includes extension from the end Qingshankou to the end Yaojia period, the structural inversion from the end Nenjiang to the end Mingshui. There are the largest number of acoustic emission were detected in the end Qingshankou and the end Nenjiang, and therefore the two period the strongest tectonic activity period(Figure 5).

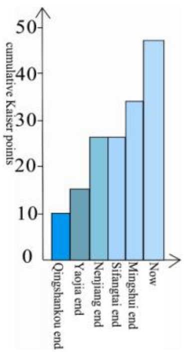


Figure 5　　acoustic emission determine the tectonic movements of the times

Furthermore, in particular the development of Qingshankou horizontal seam, line density is large, tectonic inversion of Qingshankou mudstone may be used as bedding detachment, resulting in a lower portion of Quantou reversal rate, anticline dip very slow, so there are poor possibility of making fracture.

2.3 Cracks Cause mode

On the basis of the analysis on the fracture trending, determine fracture forming in Qingshankou under stretch stress, only a small amount of shear extrusion forming in inversion construct period. Fuyu reservoir fracture patterns can be summarized as: the stress exceeds the yield strength of the crystal along the mineral grain sometimes weak surface shear displacement sliding cross to form an X-type conjugate shear fracture network distribution grid. When the force continues to increase, the further development of deformation, shear stress exceeds the shear strength of the material, the form of a pair of X-shaped cross conjugate shear and fracture surface in shear fracture grid basis. As stress increases again, then burst to continue to develop, and alternately accommodate X-type shear plane, having become jagged sheets of rupture. Shear fracture formed in the initial sheet joints continue to develop, tensional fracture tracking initial tensional joints and the continued development of the formation of larger tension cracks, when the crack to continue development and displacement obvious when they formed a fault, this time faults and fractures to the same two tectonic stress displacement under different products, with similar direction and distribution(Figure 6).

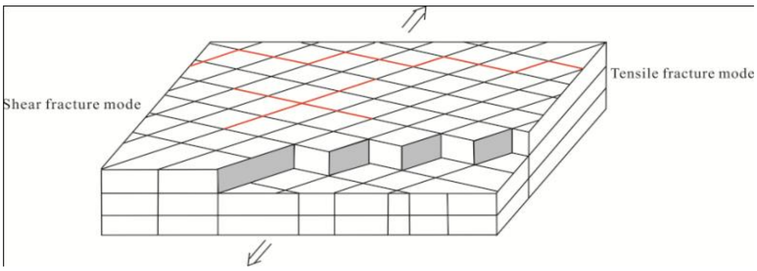
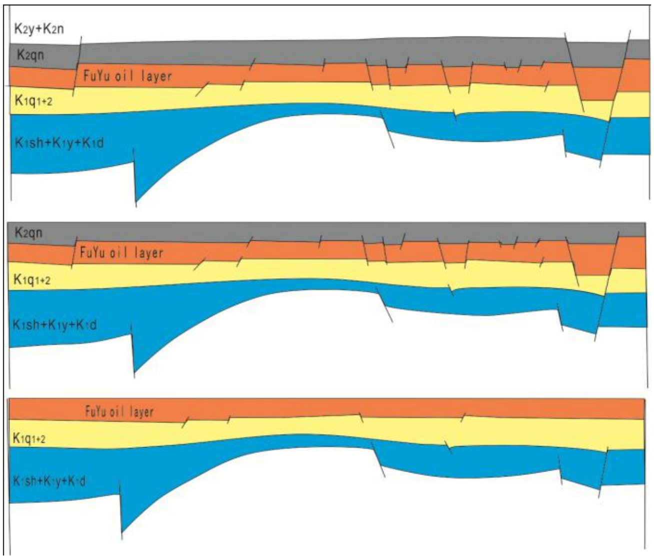


Figure 6 The mode of Fuyu reservoir fracture

2.4 Fracture sequence

By constructing the history of phylogenetic analysis, fracture development has gone through three stages (Figure



7).Figure 7 Fracture sequence of Fuyu reservoir in Xingshugang area

(From bottom to top, respectively：before Qingshankou deposition, before Yaojia deposition, before Sifangtai deposition)

Phase Ⅰ:Before Qingshankou deposition, tectonic movement was weak after intense stretching rift, producing a small amount of normal faults, fracture not being formed in this time.

Phase Ⅱ: Before Yaojia deposition is the period of making stretch fracture. Stretching effect produced a large number of synsedimentary faults during depression, accompanied by intense activities fault fracture formation, mainly to tension fractures, shear fracture second.

Phase Ⅲ: Tectonic inversion of the basin depression ended, structural inversion occurs, early normal faults absorbed major deformation of the basin, Qingshankou weak mudstone layer slippage occurred along, producing a very large number of horizontal seams balance the reverse deformation , Fuyu reservoir deformation was small, only a few obvious scratches of cut slits were produced in mudstone.

III. CONCLUSION

(1) NW trending and NNE trending tension vertical fractures oriented, NW trending and NE trending conjugate shear fracture followed in Fuyu reservoir in Xingshugang area. Extensional fractures are more developed in siltstone, with high fracture porosity, shear fractures are more developed in mudstone, with low fracture porosity.

(2) Most crack opening in 0.5-2mm, mostly full filling, nearly one-fifth as effective seam, multiple fractures of oil, a few cracks see oil spots, traces of oil.

(3) Qingshankou period is the main period of building fractures of the Fuyu oil layer and main reason of building fractures is weak stretch tectonic movements of the period. Due to the effect of slippage bedding of Qingshankou mudstone in the period of late structural inversion, deformation was weak and a few obvious scratches of cut slits were produced in mudstone.

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