Study on fracture identification of shale reservoir based on electrical imaging logging

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Abstract. In recent years, shale gas exploration has made important development, access to a major breakthrough, in which the study of mud shale fractures is extremely important. The development of fractures has an important role in the development of gas reservoirs. Based on the core observation and the analysis of laboratory flakes and laboratory materials, this paper divides the lithology of the shale reservoirs of the XX well in Zhanhua Depression. Based on the response of the mudstone fractures in the logging curve, the fracture development and logging Response to the relationship between the conventional logging and electrical imaging logging to identify the fractures in the work, the final completion of the type of fractures in the area to determine and quantify the calculation of fractures. It is concluded that the fracture type of the study area is high and the microstructures are developed from the analysis of the XX wells in Zhanhua Depression. The shape of the fractures can be clearly seen by imaging logging technology to determine its type.

1. Introduction
In recent years, the research on fractured reservoirs has been paid more and more attention. With the huge demand for energy and the complexity of oil and gas exploration, fractured reservoirs have been continuously displayed in oil and gas exploration and development. Out of importance. Especially for the shale reservoir, the development of the shale fractures is an important factor in determining the quality of the shale oil and gas reservoirs. Generally speaking, the higher the fractures, the higher the enrichment degree of the reservoirs and the fractures more developed gas reservoir, its quality is relatively good.

In the exploration and development of shale oil and gas reservoirs, it is very important to study the shale fractures. At present, scholars at home and abroad have done a lot of research work, there are many ways to identify mud shale fractures, in theory and methodologies and other aspects have made important achievements, awareness and progress. It mainly includes the types and causes of fractures, the qualitative and quantitative identification methods of fractures, the characteristics of fracture development and the performance parameters of fractures and the distribution prediction of fractured reservoirs [1]. At present, foreign scholars have made important achievements in mud shale identification and characterization, genetic type and distribution law, basic parameters and physical
parameters research, reservoir performance evaluation and so on [2]. The fractures can be identified by geological methods, logging methods, seismic methods, drilling logging methods, and interrochonical interference pressure tests. The use of logging data to identify and evaluate the fractures is an effective method, in the oil and gas exploration work has been widely used. However, due to the uneven development of fractures and the characteristics of reservoir anisotropy, the evaluation of such oil and gas reservoirs is difficult. Imaging logging provides reliable and intuitive image data for accurate identification and evaluation of fractures, but is constrained by economic benefits. Imaging logging is not as extensive as conventional logging. In this paper, the core types of Zhanhua Depression in Shengli Oilfield are used to analyze the types of fractures and identify the shale fractures through the technical means of imaging logging technology.

2. Overview of the study area
Shengli Oilfield Zhanhua Depression is a tectonic unit in the Jinan depression in the Bohai Bay Basin. Depression in the north near the north east of Yihe Zhuang raised its south near the east and west to Chenjiazhuang raised. The study area as a whole constitutes a north-east direction of the open mountain basin-like basin [3]. The well XX is located in the western wing of the Luoqia Nose-shaped structural belt in Zhanhua Depression, Jiyang Depression. The Luo Nian-shaped tectonic belt is a large underwater uplift near the north-south, north of Bonan sag, south of Chenjiazhuang raised. The Luo-tang-shaped tectonic belt deposited several hundred meters of dark mud shale during the third trimester, and a thin layer of limestone and ointment was deposited in the upper part of the sand. The strata and the lower South super complex on the Paleozoic unconformity, north into the Bonansag [3]. At the same time, the Neoproterozoic Paleogene strata in this area are cut by several northeast or near-eastward extension of the basin.

3. Electrical imaging logging to identify mud shale fractures
In the process of oil and gas exploration and interpretation, it is necessary to identify the type of fractures, which can be divided into the fracture development section, so as to determine a better reservoir section, and then combined with laboratory core analysis data and field test data to determine Oil and gas layers. FMI imaging logging is an effective method for identifying fractures and is a new logging technique developed to accommodate complex heterogeneous reservoirs. The core analysis results are compared with the imaging log images, and the fractures can be accurately identified and evaluated. In the process of imaging comprehension, the data need to be processed to obtain the static and dynamic imaging of the borehole wall after the single well imaging logging data is processed, and the fractures around the wellbore are extracted. The emphasis is on the qualitative and quantitative identification of the electrical imaging logging Method of Fractures in Shale Reservoir.

3.1. Qualitative identification of fractures
The fractures are the rupture of the rock formation, and the rock is not obvious on both sides of the rupture surface. It is divided into natural fractures and induced joints by type. The natural fractures are usually formed by multi-stage tectonic movement, which is affected by precipitation, The fracture is usually less regular and the slit width changes greatly. The induced slit is due to the influence of the drilling and the formation is drilled to cause the formation stress to be released in the wellbore induced by the fractures. Therefore, the induced joints are neat and regular Strong, no change in the width of the slot, radial extension of small.

(1) Natural fracture electrical imaging response characteristics
According to the conductivity of the division, the natural fractures are divided into high-profile joints and high-resistance joints, high-profile joints are generally not filled with other substances to open the fractures in the drilling process by the mud intrusion, resistivity smaller than the surrounding rock Dark or black; and high-resistance joints are generally due to tectonic stress after filling the cementing of other minerals, the image shown as light or bright yellow sine lines.
According to the shape, the natural fractures are divided into five types: high angle seam, oblique seam, low angle seam, horizontal seam and irregular mesh seam. On the imaging chart, there are different side lines with different angle of inclination angle. And light-colored, mesh ically controlled generally appear in carbonate rocks, caused by a strong dissolution, different shapes of high-profile profiles shown in Figure 1 a-d, and high-resistance see Figure 1-e.

![Figure 1. Electronographic image interpretation template for natural fractures](image1)

(2) The characteristics of induced seam electrical imaging response

The induced joints are generally divided into drilling tools, vibrating geese, fractures, stress relief joints, respectively, described below in the imaging image on the characteristics of:

![Figure 2. Electronographic image interpretation template for induced fractures](image2)

Ge-like seam: fractures caused by drilling tools, the seam is very small and the extension is shorter, showing a geese or feathers, see Figure 2-a.

Fracture: Fractures caused by heavy mud or unbalanced geostresses, with shorter radial extensions, but with larger openness, longer longitudinal extension, and two dark vertical bars with 180 degree azimuths on the imaging image. Figure 2-b.

Stress release joints: generally appear in dense carbonate rocks, are produced by the release of paleo-tectonic stress and modern tectonic stress release. The stress relief slit is clearly visible on the borehole wall image, which is a group of rules close to the parallel seam High angle fractures, see Figure 2-c.
3.2. Quantitative evaluation of fractures

The basic parameters of the fracture are the important parameters of the reservoir, and the quantitative evaluation of the fracture mainly includes the orientation, inclination, fracture width, fracture length, fracture density, average hydrodynamic width and fracture porosity (fracture porosity).

(1) Fracture width (FVA)

Fracture width refers to the fracture as the opening degree. The fracture width in each direction of the fracture trajectory and the direction of the fracture is the single point fracture width, and the average of all the single point fracture widths on the fracture track is the fracture width. The accuracy of the calculation results of the fracture width quantitatively affects the calculation of other fracture parameters. In this paper, the calculation formula of the fracture width of Schlumberger's finite element method is adopted.

According to the finite element method, the anomaly of the conductivity at the fracture is related to the width of the fracture. The abnormal value of the conductivity can be expressed by the curve. The integral area $A$ of the curve is determined by the opening degree of the fracture and the resistivity of the intrusion zone near the borehole wall. The following calculation of the fracture width is given:

$$W = C \cdot A \cdot R_m^b \cdot R_{xo}^{(1-b)}$$  \hspace{1cm} (1)

In formula (1):

$W$ -- Fracture width, in units (mm);

$R_{xo}$ -- Flush with resistivity (LLS after calibration plate data instead), unit ($\Omega \cdot m$);

$A$ -- The area of the electrical conductivity caused by the fracture, the unit (mm/$\Omega \cdot m$);

$R_m$ -- mud resistivity, unit ($\Omega \cdot m$);

$C, b$ -- Instrument-related constants, $C = 0.004801$, $b = 0.863$, constants associated with instrument structure

(2) Fracture length (FVTL)

The length of the fracture is the sum of the length of the fracture seen per square meter of the borehole wall. The unit is m/m$^2$ or 1/m, the path of the fracture is picked up by means of human-computer interaction, and then the length of the fracture track is calculated by means of the method of elemental integration. Long range (0.6096m) statistics obtained fracture length.

(3) Fracture density (FVDC)

The fracture density is the number of fractures in the unit section.

(4) Average hydrodynamic width (FVAH)

The average hydrodynamic width is a measure of the width of each fracture in the unit section, and then the value obtained by opening the cubic is the fitting of the average hydrodynamic effect of the fracture in units of mm.

(5) Fractures Porosity (FVPA)

The apparent porosity of the fracture is the area of the fracture that can be identified on the 1m borehole wall image divided by the whole image of the 1m borehole wall. Since the imaging image mainly reflects the borehole wall feature, the fracture porosity can be expressed by the porosity,

$$\phi_f = \frac{S_{\phi_f}}{S}$$  \hspace{1cm} (2)

$$S_{\phi_f} = \sum(W_i \cdot L_i)$$  \hspace{1cm} (3)
In the formula (2): $\phi_f$ - the fracture surface rate, fraction, $W_i$ - the width of a single fracture, $L_i$ - the length of a single fracture, $S_{\phi_f}$ - the pore area of the fracture, $m^2$ and $S$ - the total surface area of the rock, $m^2$.

3.3. Application of fracture identification

Based on the qualitative identification of the fractures in the third sub-section of the XX wells, the microstructures of the microstructures with high angle are also developed, and the microstructures are also developed (Figure 3). The relative development of the total fractures is 2970-2971m, 2981-2983m, 3005-3013m, 3028-3032m, 3038-3058m, 3075-3077m, 3081-3082m, 3109-3111m, 3115-3122m, 3128-3132m, total 51m, 3005-3013 m, 3038-3058 m, 3075-3077 m, 3115-3122 m, 3128-3132 Thickness, high fracture parameters, is the most favourable fractured reservoir section, lithology is mainly gray matter mudstone, gray matter mudstone and Oil shale (Figure 4). Through the quantitative identification of fractures, it is concluded that the depth of the well is 2996-3060 m in the middle and low angle seam, mainly in the depth of 3060-3125 meters, the fractures in the high angle of the main, the overall direction of the fractures better. The poor oil layer appears in layers 1, 3, 4, 5 and 7, the oil layer appears in the layer 2, 6, the maximum number of fractures is 16, the minimum is 2; the maximum fracture density is 1.63, the lowest is 0.40; The maximum fracture width is 275.32μm, the lowest is 40.08μm, the porosity is between 0.010-0.078 (Table 1).

Figure 3. Electronographic image of the fracture of the well
Figure 4. The quantitative identification results based on electrical imaging

Table 1. Calculate the results of quantitative calculation of fractures

| Layer No. | Top deep (m) | Bottom deep (m) | Thickness (m) | FMI process result | Overview                      |
|-----------|--------------|-----------------|---------------|---------------------|-------------------------------|
|           |              |                 |               | No. of fracture | Fracture angle | FVDC, 1/m | FVAH, 1/m | FVPA, % |            |
| 1         | 2996         | 3019.7          | 23.7          | 13                 | Low-medium      | 0.78      | 82.15     | 0.021   | Poor oil layer |
| 2         | 3019.7       | 3042            | 22.3          | 8                  | Low-medium      | 0.58      | 105.9     | 0.022   | Oil dry layer    |
| 3         | 3042         | 3057            | 15            | 16                 | Low-medium      | 1.63      | 40.08     | 0.01    | Poor oil layer    |
| 4         | 3057         | 3067.2          | 10.2          | 2                  | Medium - high  | 0.4       | 66.98     | 0.012   | Poor oil layer    |
| 5         | 3067.2       | 3081.1          | 13.9          | 3                  | high            | 1.17      | 92.36     | 0.057   | Poor oil layer    |
| 6         | 3081.1       | 3123.8          | 42.7          | 14                 | Medium - high  | 0.65      | 118.86    | 0.024   | Oil dry layer     |
| 7         | 3123.8       | 3135.7          | 11.9          | 5                  | Medium          | 0.58      | 275.32    | 0.078   | Poor oil layer    |

4. Conclusion

(1) In general, the fractures of the wells in the XX wells are sporadic, and the microstructures are mainly developed. The fractures of the whole well are not developed, and the development of the fractures is 7.2 m. The direction of the high crevices and micro faults is mainly northeast and southwest.

(2) From the fractures identified in the imaging logging, the fractures of the wells in the XX well are sporadic, and the microfacies are mainly developed. The velocity of the high trough and microfractures is mainly northeast-southwest, the fracture line density is 0.04 ~ 1.63 / m and the width is 0.40 ~ 2.75 mm.

(3) Thickness between 10m-45m, more than 15m thick thickness of the shale accounted for more than 80%. The average porosity is between 1.0% and 6%, and the average porosity is 5.7% in the 3067.2m-2081.1m shale section. The overall average effective porosity is 4.6%. The effective porosity shows the characteristics of "middle high, top and bottom low".
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