Application of Rapid Trend Fracture Prediction Technology in Feixianguan Reservoir

Qiancheng Xu*, Lei Chen, Yan Zhang

Geological Exploration & Development Research Institute of CCDC, CNPC, Chengdu, China

*xuqc_dyy@cnpc.com.cn

Abstract. The main reservoir spaces of Feixianguan carbonate reservoirs in the eastern Sichuan region are various types of pores, caves, and fractures. Common reservoir types include fracture-pore type, pore type, and fracture type. From core analysis and testing, it can be seen that the reservoir type of the Feixianguan Formation oolitic beach reservoir in this area is of the fracture-pore type. Therefore, the prediction of the occurrence and development zones of cracks is the basis for the prediction of favorable sweet spot areas. In response to the multi-scale and heterogeneity of cracks in this area, based on rock density theory, the rapid trend crack technology is used to study the distribution pattern of cracks in this area, and the dominant crack development zones are ultimately selected. The prediction methods are compared and evaluated. This method has achieved good results in predicting the fracture zone of Feixianguan reservoir in the eastern Sichuan region.

Keywords: carbonate rock, Feixianguan, rapid trend, residual analysis, crack prediction, discontinuity detection.

1 Introduction

The prediction of small-scale fractures in carbonate reservoirs has always been difficult in academic research, and many universities and research institutes are committed to seismic description research for fracture prediction, and have made certain progress.

The geological methods for predicting fractures include geological analogy method, stratigraphic curvature method, and geological genesis method based on structural strain [1]. The geological analogy method requires similar tectonic evolution backgrounds and significant errors [2]. The results of the stratigraphic curvature method are greatly influenced by the thickness of the strata, and it is difficult to effectively predict the distribution position of fractures during geological evolution for structural fractures generated by multiple tectonic activities. The numerical simulation method has strict requirements for boundary and rock physical parameters, and the calculation results often have multiple solutions due to multiple tectonic evolutions [3]. Geophysical methods that utilize the anisotropy of seismic waves and the differences between seismic traces can predict fractures at different scales[4]. However, due to the complexity of

A. E. Abomohra et al. (eds.), *Proceedings of the 2023 9th International Conference on Advances in Energy Resources and Environment Engineering (ICAESEE 2023)*, Atlantis Highlights in Engineering 29,
https://doi.org/10.2991/978-94-6463-415-0_72

guaranteed, and the prediction results are too subtle to accurately predict the overall distribution trend of fracture development zones [5].

The fractures in the Feixianguan carbonate oil and gas reservoir in eastern Sichuan include diagenetic fractures, pressure solution fractures, and structural fractures, with throats including porous throats and intergranular throats. However, due to the poor reservoir function of common vertical seams, inclined seams, dry shrinkage seams, and throat seams, they are more believed to serve as channels for oil and gas infiltration.

On the basis of using inter channel differential fracture prediction, this article applies the principle that the development of fractures in fractured and vuggy reservoirs is jointly affected by structural deformation and lithological differences. Under the same tectonic stress, the difference in rock density results in different degrees of fracture development. By comparing the high and low density differences with the deformation amplitude of homogeneous rocks, the distribution range of dominant zones for fracture development is well defined, It compensates for the shortcomings of conventional methods in identifying the distribution of fracture zones and provides a technical basis for efficient exploration and development of carbonate oil and gas.

2 Regional crack characteristics

2.1 Geological Overview of the Study Area

The latent structure of G gas field(Figure 1) is a latent structure located at the foot wall of the northwest wing fault of the Wenquanjing structure. The regional structure is located at the northern edge of the eastern Sichuan fault fold belt in the Sichuan Basin, southeast of the Wubaochang (structure) depression, and the structural relationship is at the intersection of the northwest and northeast Sichuan fold belts of the Daba Mountains. On the south side, it is adjacent to the main body of the hot spring well structure, separated by a fault depression; The northeast side is separated from the Eagle Rock structure by a fault depression; The southwest direction is separated from the Luojiazhai structure; The northwest direction faces the Zishuiba structure.

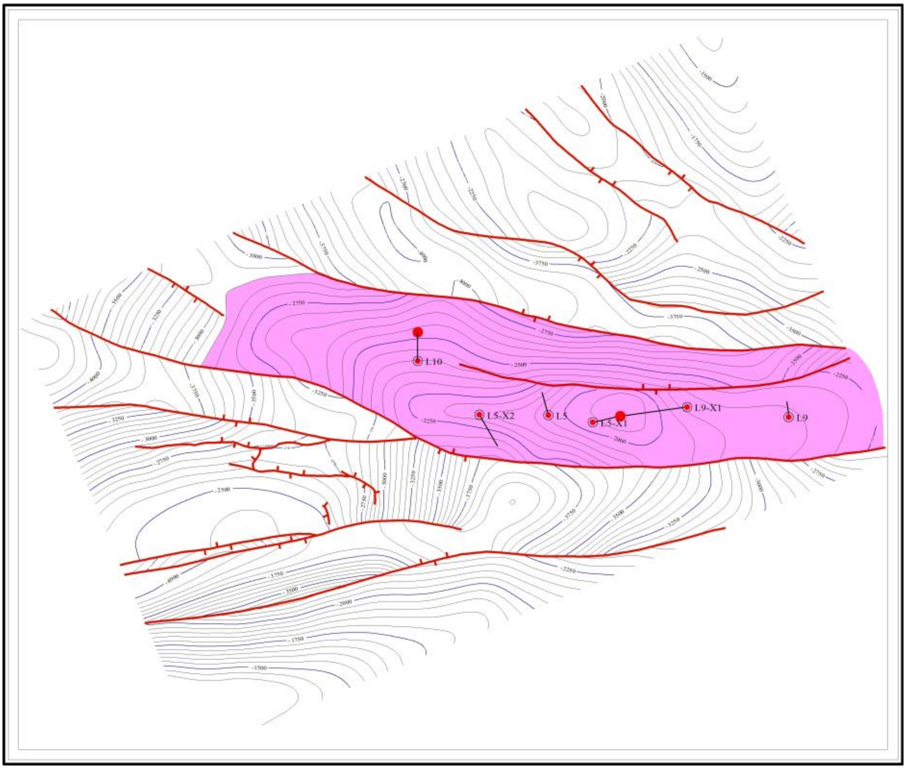

Fig. 1. Top Boundary Structure of Oolitic Beach Reservoir in Feixianguan Formation of Gas Field G

2.2 Characteristics of Single Well Microfractures

According to the core statistics of the Feixianguan Formation in Gas Field G, the L5 well has a core footage of 72.08m, a core length of 70.26m, a total of 1155 fractures, 862 effective fractures, and an effective fracture density of 12.27 fractures per meter; The drilling footage of L9 well is 48.57m, with a core length of 46.42m. There are a total of 1014 fractures and 622 effective fractures, with an effective fracture density of 13.40 fractures per meter. Comparing the effective fracture density of the cores of the two wells, L5 well and L9 well are basically equivalent. However, from the thin section observation, the dissolution fractures, structural fractures, and pressure dissolution fractures of L9 well are mostly filled with gray, cloud, silica, gypsum, and asphalt. Microcracks are generally thin and short in shape, with few open cracks. They are mainly caused by the Yanshan and Himalayan tectonic movements that caused rock fractures to form structural cracks, and local dissolution along the structural cracks forms dissolution cracks, most of which are filled. Structural joints generally extend smoothly and are locally connected to intergranular dissolved pores(Figure 2).

Fig. 2. Crack Types in the Coring Well Section of Block H

Observation of cast thin sections shows that microcracks are visible on most of the thin sections. Some of the microcracks on the thin sections are subjected to dissolution, resulting in irregular surfaces that improve the porosity and permeability of the cracks. Some microcracks on the thin sections are completely filled with calcite, dolomite, and asphalt, becoming ineffective microcracks; In addition, microcracks can also be seen in gypsum rock, but due to the strong plasticity of gypsum, the cracks are prone to forming bell shaped openings, which are characterized by seepage sand and are mostly ineffective microcracks (Figure 3).

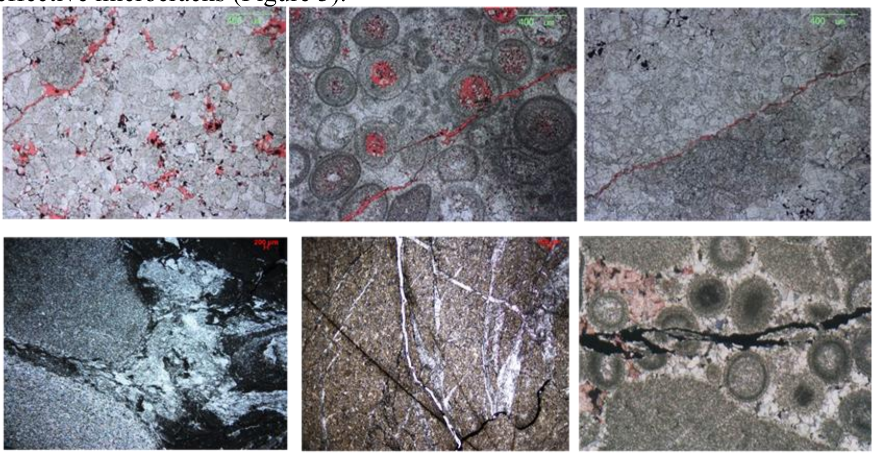

Fig. 3. Microscopic Crack Characteristics of Feixianguan Section

3 Rapid trend crack identification technology

The rapid trend crack identification technology is mainly based on the rock density theory (Figure 4), and it's using the rapid trend residual analysis method to predict the development of rock fractures and caves. The density of rocks is determined by their structure and pore fissures. In relatively stable carbonate sedimentary areas, the density of pore fissures in rocks is lower, while in contrast, the density of dense rocks is higher.

Under the action of tectonic stress, the deformation degree of low-density rocks is greater than that of theoretical rocks (which can be considered homogeneous rocks). Similarly, the deformation amplitude of high-density rocks is smaller than that of theoretical rocks. If the defined fast trend residual value is equal to the difference between the theoretical rock deformation amplitude and the actual rock deformation amplitude, then in the negative value area of fast trend analysis, it is the distribution area of low-density rocks, which is the crack development area; On the contrary, in the positive area of rapid trend analysis, it is a high-density rock distribution area and an underdeveloped crack area.

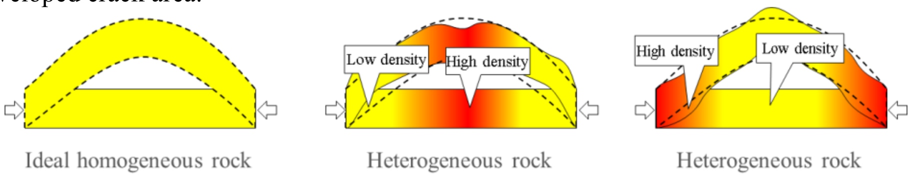

Fig. 4. Schematic diagram of the principle of rapid trend crack identification technology

A surface can be seen as a spatial graph composed of countless curves, each with its corresponding curvature value. In theory, it can be proven that the tangents of the curves corresponding to two principal curvatures are perpendicular to each other. The average value of these two curvatures is called the mean curvature or medium curvature H, and its product is the total curvature or Gaussian curvature K. In previous geological applications, the surface curvature taken was the average curvature H, but if the point is saddle shaped, it is possible that k1+k2=0. At this point, regardless of the absolute value of curvature, the average curvature H=0; On the other hand, the curvature value of the anticline point k1=0, k2<0, and the average curvature H=k2/2 are reduced by half, which is obviously unreasonable. Therefore, in geological applications, the mean curvature H and Gaussian curvature K cannot be used for surface curvature, but the curvature with the highest absolute value in k1 and k2 is called extreme curvature. The favorable exploration area for fractured gas reservoirs is the area with a large negative absolute curvature value. The magnitude of the negative curvature value can quantitatively represent it's degree of development of structural cracks. For a certain research area, based on the actual situation of crack development, the curvature value k0 can be determined. When the calculated curvature value k<k0, it is considered that the crack at that point is developed, and vice versa, it is considered that the crack is not developed. If all points that meet the criteria of k<k0 are distributed in patches, it is considered a fracture development area and is called a favorable exploration area. K0 is referred to as the classification standard for favorable exploration areas.

The standard k0 for dividing favorable exploration areas varies for different regions, which can only be obtained by combining the geological reality of the study area or applying the results of other similar study areas. The area with a large degree of curvature on the rock surface is the most prone to cracks, so curvature is a parameter that measures the degree of curvature on the rock surface. The larger the absolute value, the greater the curvature on the rock surface. When applied to geology, it indicates that the larger the curvature, the more likely it is to produce cracks. Therefore, the distribution of structural cracks in the later stage of renovation can be evaluated by the magnitude of curvature values.

For curve y=f (x), the definition of curve curvature is:

$$k = \frac{\mathrm{d}\alpha}{\mathrm{d}s} = \frac{\mathrm{d}\alpha}{\mathrm{d}x} \cdot \frac{\mathrm{d}x}{\mathrm{d}s} = \frac{\mathrm{d}}{\mathrm{d}x}(artgy') \div \frac{d}{dx}\sqrt{dx^2 + dy^2}$$

$$= \frac{y''}{1 + y'^2} \cdot \frac{1}{\sqrt{1 + y'^2}} = \frac{y''}{(1 + y'^2)^{1.5}}$$

Due to the fact that the normal direction of a surface determines the positive or negative curvature, and the degree of curvature of the surface determines the absolute value of curvature, when taking the maximum curvature, the curvature with the highest absolute value should be taken instead of the curvature with the highest numerical value.

4 Prediction of the occurrence of fracture development zones in the 4 study areas

The differences in rapid trend analysis indicate differences in the degree of crack development. Figure 5 shows the predicted plane distribution of fractures in the G gas field in the eastern part of Feixianguan, East Sichuan. The development of cracks is represented by four colors: red, green, yellow, and blue. The darker the color, the more advanced the crack development is the lower the degree. As can be seen in the figure, the fault cuts the fracture development zone into multiple blocks, and the degree of fracture development decreases from south to north. The cracks in the main structural area are distributed in strips, and the development degree weakens from the middle to the two wings of the structure. The high point of the structure is the concentrated development area of cracks, which forms a double platform with high development degree of cracks in the southwest of the high point. From the prediction of single well fractures, the trend of the fracture development zone is distributed in the northwest southeast direction, and the distribution characteristics are consistent with the imaging logging and core characteristics. The line from Well L-5 to Well L5-X1 is a zone with strong fracture development, while Well L9 has a slightly lower degree of fracture development, which is in good agreement with the drilling results. At the same time, the central fault distance to the north of Well L5 is large, while the east-west fault distance is small. The maximum fault distance near Well L5 in the middle is nearly 200 meters, while the fault distance near Well L9 in the southeast is only about 20 meters. The distribution characteristics of the fracture plane are consistent with the trend of the fault fault distance change, which also proves the reliability of the fracture prediction results. The relatively well-developed fractures in the large well free areas in the south and north indicate that the G gas field has good exploration and development potential, and is an important target area for the next step of tapping deep natural gas. Overall, the in-situ stress in the current research area is controlled by a nearly north-south compressive stress field, and local folding and bending have a transformative effect on the fractures. The application of rapid trend analysis method to the fracture prediction results of G gas field can explain the fracture development characteristics of G gas field, providing an important basis for the next step of oil and gas prediction.

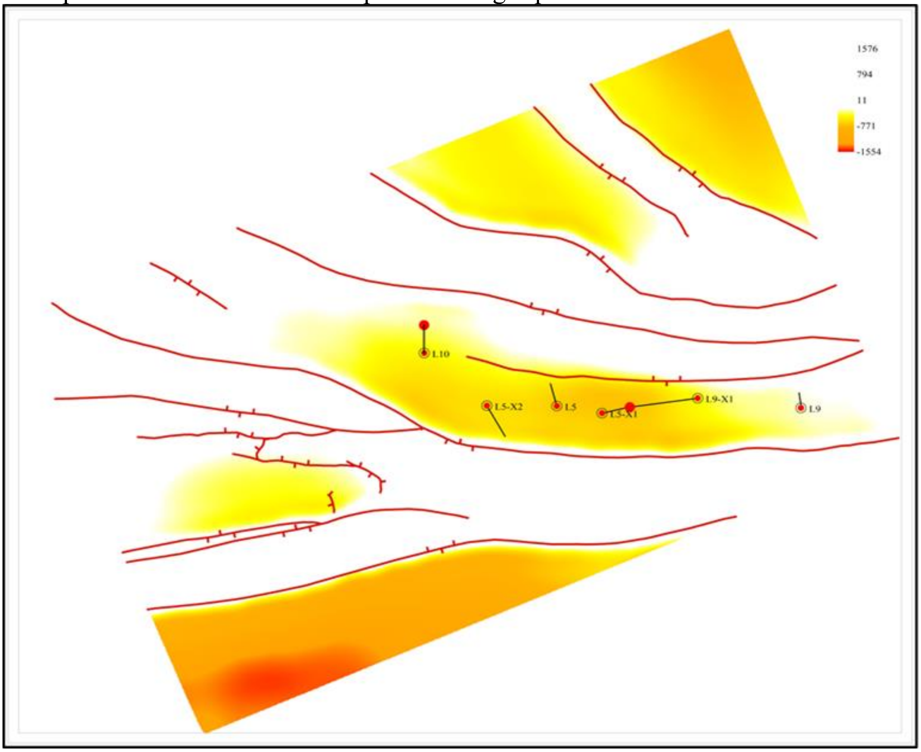

Fig. 5. Prediction Plan of Fracture Development in Gas Field G

5 Conclusion

Due to the small scale of cracks, small differences between seismic data channels, and low seismic resolution, cracks are not easily identified in the original 3D seismic data. However, the rapid trend analysis technology based on the variation characteristics of rock brittle deformation differences determines the development of cracks based on the strength of the non plastic bending degree of the formation, which is highly consistent with the actual situation and can meet the needs of oil and gas field exploration and development.

(1) The rapid trend analysis method can detect small linear structural differences and compensate for the shortcomings of conventional interpretation and prediction.

(2) The rapid trend analysis method can avoid the disadvantage of average curvature and Gaussian curvature in identifying cracks in saddle shaped complex fault areas during the process of identifying crack development zones, and reduce the multiplicity of solutions in identifying crack zones.

(3) Due to the need to calculate the difference in the degree of formation curvature when using rapid trend analysis methods to identify fractures in the target layer, precise three-dimensional structural interpretation of the layers is required.

(4) Due to the influence of multiple factors such as structure, lithology, and weathering degree, it is difficult to horizontally predict the fractures in the bedrock formation. It is not possible to rely solely on attributes as the sole tool for determining fracture development zones. It is necessary to combine other seismic attributes and data such as logging, logging, testing, and oil reservoirs to improve the accuracy of the results and verify the accuracy of the results.

By combining multiple disciplines and methods for verification, the multiplicity of predicted results for fracture development zones can be reduced.

References

1. Dorigo M, Maniezzo V, Colorni A, et al. Positive feedback as a search strategy. Milan: Milan Politecnico di Milano,1991:99-106.
2. Richard J Lisle. Detection of Zones of Abnormal Strains in Structures Using Gaussian Curvature Analysis. AAPG Bulletin, 1994, 78(2): 185-200.
3. J J Muňóz2pérez, Tejedor L, Medina R. Equilibrium beach profile model for reef2protect beaches [J]. J. Coastal Res., 1999 ,15 (4).
4. Wang Zhenqing, Wang Hongbin, Gong Honglin. Development of seismic coherence technology and its application in predicting carbonate fractured reservoirs [J]. Petroleum and Natural Gas Geology and Exploration, 2009:35-38.
5. Su Peidong, Qin Qirong, Huang Runqiu. Current Status and Prospects of Reservoir Fracture Prediction Research [J]. Journal of Southwest Petroleum Institute, 2005, 17:14-17.