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Effect of Natural Fractures on Shale Gas Reservoir Reconstruction

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Abstract. Natural fractures have great influence on shale gas reservoir reconstruction. In order to find out the law of influence, comprehensive analysis of the characteristics of geological natural fracture and fracturing fracture before fracturing is carried out. Firstly, natural cracks are identified by using coherence and maximum relief attributes of ground seismic data. Secondly, the characteristics of hydraulic fracturing cracks and the response characteristics of natural cracks are analyzed by using the results of microseismic monitoring and positioning and the data of hydraulic fracturing construction. Finally, the influence of natural fracture on the effect of fracturing reconstruction is summarized. The results show that the response characteristics of natural cracks predicted by surface earthquakes are different in the results of microseismic monitoring. According to the response characteristics of natural cracks, they can be divided into active and inactive natural cracks. Combining with the fracturing data, it is found that both active and inactive natural cracks will affect the fracturing construction to varying degrees. Active natural fractures are prone to abnormal construction conditions such as sand plugging, casing deformation and fracturing fluid leakage. Non-active natural fractures play a role of stress shielding under certain conditions, which can affect the fracturing fracture morphology and the effect of fracturing reservoir reconstruction. The research results provide a basis for shale gas horizontal well trajectory optimization and adjustment of hydraulic pressure construction parameters.

1. Introduction

The low porosity and permeability of shale gas reservoirs bring great challenges to the economic and efficient development of shale gas. Volume fracturing is an important means to develop shale gas. During hydraulic fracturing, a large number of high-viscosity and high-pressure fluids are injected into shale reservoirs. When the bottom hole fluid pressure is greater than the rock fracturing, it will cause rock breakage and vibration. Microseismic monitoring technology uses geophones in wells or on the ground to record seismic waves generated by rock fracture. Based on the results of microseismic monitoring, the fracture propagation pattern of hydraulic fracturing is analyzed, and the effect of reservoir fracturing is evaluated.

The activity of natural fractures is an important factor affecting the effect of hydraulic fracturing on shale gas reservoir reconstruction. Many scholars at home and abroad have done relevant research. Maxwell et al [1]. According to microseismic monitoring in Sandy and mudstone strata, the signal characteristics produced by fracture activity and hydraulic fracturing are different. Rich et al [2]. analyzed the influence of geological factors and stress distribution on the geometry of hydraulic fracturing in shale gas development. Li Hongmei et al [3]. Analyzed the response characteristics of microseismic events of hydraulic fracture and natural fracture.

In recent years, with the large-scale development of shale gas, microseismic monitoring technology, as one of the key technologies in fracturing design, implementation and evaluation, has developed



rapidly. It is urgent to carry out a detailed analysis of the spatial distribution of natural fractures on fracturing fractures in order to achieve the optimal design of fracturing construction and oil and gas development programs.

Well H is located in Yanggaosi structure of low fold zone in South Sichuan. It relies on Tanziba structure in the east, Lichitan structure in the west, Jiukuishan structure in the north and Naxi structure in the south. The target layer of Well H is the Lower Paleozoic Longmaxi Formation. The high-quality shale section is buried in the depth of 3661.86-3722.05 m and the thickness of the high-quality shale section is about 60.19 M. This fracturing observation adopts microseismic ground monitoring mode. A total of 10 surveying lines are laid out with H well as the center. The number of geophone channels is 931, the distance between channels is 45m, and the total length of surveying lines is 41445m. Well H has designed 27 fracturing sections. The microseismic event signals during perforation and fracturing have been collected by microseismic monitoring. From the collected signals, the perforation signal has strong wave field energy, clear wave group characteristics and is easy to track. The wave field characteristics of microseismic event signal are similar to perforation signal and easy to identify. In the process of data processing, the processes of preprocessing, static correction, dedrying, event recognition, velocity model establishment and focal location processing are established. The method of energy scanning and full waveform energy superposition is used to locate the effective event signal accurately. A total of 1809 microseismic events were located.

By synthesizing ground seismic, microseismic monitoring and fracturing construction data, the influence of natural fractures on shale gas reservoir reconstruction is analyzed. Firstly, natural fractures are identified by using seismic attributes of ground seismic data. Secondly, the distribution characteristics and activity of natural fractures are analyzed by combining the high-precision positioning results of microseismic monitoring and the data of hydraulic fracturing construction. Finally, the effect of natural fracture on shale gas reservoir reconstruction is summarized. It is found that natural fractures will have different effects on fracturing construction, and play an important guiding role in the design of next fracturing parameters, guiding fracturing production and improving the effect of fracturing reconstruction in H well area.

2. Methods

2.1 Natural Fracture Prediction Technology

The development of natural fractures has a great influence on the effect of hydraulic fracturing. In seismic exploration, coherence, curvature and maximum likelihood are used to detect faults, fractures and geological boundaries. This paper mainly uses coherence and maximum relief attributes to predict natural fractures.

The coherence property is a measure of the degree of similarity between multi-channel seismic data. The magnitude of the coherence reflects the degree of similarity between the seismic trace and its neighboring seismic traces. The greater the degree of coherence, the higher the degree of similarity; The less similar the degree of similarity.

The basic principle of maximum relief fracture prediction is [4]: the original seismic data contains dip and azimuth information, calculates the similarity of each sampling point containing dip and azimuth information, and then only retains the minimum similarity (called maximum relief body) and the corresponding dip and azimuth values, and normalizes the whole area. So that it can reflect the linear relationship of faults.

Figure 1 shows a comparison of natural fracture predictions for coherent properties and maximum relief properties. (a) For the coherent property slice, the blue color in the figure is a low coherence anomaly, representing the natural fracture development zone. (b) For the maximum likelihood attribute slice, the red color in the figure is the maximum release property anomaly, representing the natural fracture development zone. It can be seen from the slice of these two properties that the crack in the study area is very developed. The B point of the horizontal well, the middle of the horizontal section, and the crack near the A point are all developed.

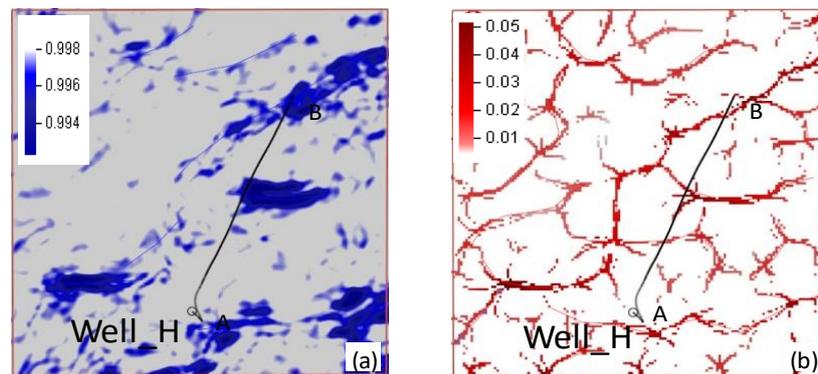


Figure1. Comparison chart of natural fracture seismic attribute prediction

Where there is low coherence value, the prediction of maximum release fracture shows the location of fracture development, but the coherence attribute can only reflect the information of large-scale fracture, and the maximum release attribute can not only reflect the large-scale fracture, but also clearly represent the small and medium-scale fracture. The maximum release attribute value can represent the probability of fracture development. The greater the value, the greater the possibility of fracture development; on the contrary, the more the value, the less the possibility of fracture development. In plane, the prediction accuracy of maximum release attribute is higher than that of coherence attribute.

2.2 Hydraulic fracturing fracture monitoring

2.2.1 Microseismic Monitoring Technology for Hydraulic Fracturing Fractures

In the process of hydraulic fracturing, a large number of high-viscosity and high-pressure fluids are injected into shale reservoirs, and rock fracturing induces micro-earthquakes. Microseismic monitoring is to locate the spatial position of each fracture signal by using geophones to record the seismic signals generated by rock fracture in wells or on the ground, after filtering, noise suppression and spatial positioning. The magnitude of a microseismic event represents the relative energy of the source vibration. The occurrence and development of fracturing fractures can be described by the spatial geometric characteristics of microseismic events.

Microseismic events are projected into different coordinate planes to obtain the top and side views. The extension direction of microseismic event points on the top view is the strike of fracturing fracture network, the length of extension direction is defined as the length of fracturing fracture, the length of vertical extension direction is defined as the width of fracturing fracture, and the extension length of lateral microseismic event in the vertical direction is defined as the height of fracturing fracture. From these four parameters, the occurrence and development dynamic characteristics of fracturing fractures can be described intuitively.

Micro-earthquakes triggered during fracturing are quite complex. The number of microseismic events detected is not only related to the sensitivity of geophone, but also to the distance between fracturing wells and monitoring wells. The spectrum of microseismic events is much higher than that of conventional seismic exploration. Conventional seismic exploration spectrum is generally 30-40 Hz, but microseismic events are usually between 200-1500Hz, sometimes higher. The duration of microseismic events is less than 15 seconds, and the energy of microseismic events usually ranges from M-3 to M+1. Well condition and geological stratigraphic characteristics of construction blocks will affect the reception effect of microseismic signals and the spatial distribution characteristics of microseismic events.

Fracture monitoring technology can effectively evaluate the fracturing effect. Through the crack monitoring, we can better understand the fracturing construction, get the roughly size of the crack, and judge whether the fracturing has produced multiple cracks. The results of microseismic monitoring can

help us to understand the post-compression production, judge whether the cracks cover the target layer, and analyze whether the cracks and natural cracks intersect. The results of microseismic monitoring can also be used for fracturing optimization and economic evaluation of production. With the increase of construction scale, how many crack lengths and heights can be obtained, and the optimal fracturing design can be obtained. At present, the accurate fracture monitoring method is an effective means to understand fracture propagation in shale gas wells.

2.2.2 Microseismic Response Characteristics of Natural Fractures

According to the experimental study of acoustic emission of shale gas-hydraulic fracturing fracture characteristics, Fracture energy of microseismic events at different scales is different.[5] Combined with the results of large data of hydraulic fracturing microseismic monitoring, natural fractures can be identified according to the abnormal characteristics of microseismic events in waveform energy, spatial distribution characteristics and time response.

1. Waveform energy characteristics of microseismic events (i.e. magnitude). The single channel amplitude energy of natural fracture events will be larger, and the average energy of natural fracture event points is far greater than that of micro-seismic events caused by hydraulic fracturing.

2. Spatial distribution characteristics of microseismic events. The microseismic events caused by hydraulic fracturing extend to both sides of the wellbore along with the progress of construction, and the direction of extension is basically consistent with the direction of the maximum principal stress in this area. Hydraulic fracturing process results in stress response of natural fractures, which will produce a large number of microseismic events. The fracture propagation speed is faster than that of hydraulic fracturing, and the spatial distribution is more concentrated. There is no obvious relationship between the direction of fracture extension and the direction of maximum principal stress in this area.

3. Time response characteristics of microseismic events are used to distinguish natural fracture from hydraulic fracture. Natural fracture event is a response to natural fracture activation for a long time, which has nothing to do with whether the fracturing operation is carried out or not.

3. Effect analysis

Natural fracture has obvious influence on hydraulic fracturing. In the process of hydraulic fracturing, the activity of natural fractures may change due to the change of stress field near wellbore, which is usually reflected intuitively in the results of microseismic monitoring. The criterion for identifying the activity of natural cracks is that when the magnitude of the microseismic event point increases obviously, the distribution is concentrated and there is a corresponding relationship with the natural fracture zone, the natural fracture is considered to be an active fracture; when the microseismic event is evenly distributed, the energy level does not change significantly, and does not constitute a specific corresponding relationship with the natural fracture zone, it is considered that the natural fracture zone is a natural fracture zone. However, the fracture is an inactive fracture.

3.1 Effect of Natural Fractures on Geometric Shape of Hydraulic Fracturing Fractures

By superimposing the results of microseismic monitoring and fracture prediction (Figure 2.), it can be seen from the superimposed graph that the response of natural fractures monitored by microseismic monitoring can basically correspond to the area of natural fractures predicted by ground earthquake, and the degree of coincidence is relatively high. Areas I, II and III are consistent with the natural fracture results predicted by seismic attributes; the microseismic event points in red circle are continuously responding in clusters, which may be due to the influence of faults in the middle of wellbore. During the fracturing process, due to the change of stress, strong energy events occur in the formation fracture near the faults. Points form fractured zones. The natural fracture zone in area IV has no active characteristics.

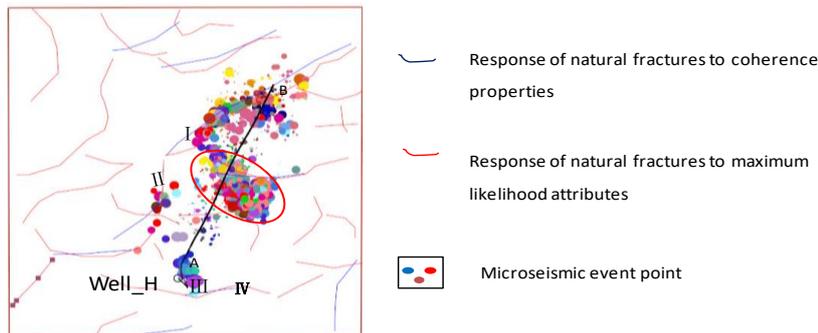


Figure 2. Composite diagram of microseismic monitoring results and fracture prediction results

3.2 Effect of Natural Cracks on Fracturing Construction

During the construction of the project, the construction pressure of Y well varies greatly, which is mainly manifested by the difficulty of sand filling and sand plugging in the process of fracturing. According to the distribution characteristics of microseismic events during the construction of this project, there are some corresponding relations between the fluctuation of construction pressure, the difficulty of sand adding and the uneven expansion of cracks and natural joints.

In order to deal with the difficulties of sand filling and sand plugging, real-time adjustment of construction was carried out according to the results of microseismic monitoring and prediction of natural cracks.

In the fracturing process of the seventh stage, different displacement combinations are adopted. In the fracturing curve of Figure3, the displacement is reduced from 17.6 to 16.2, and the difficulty of sand filling is alleviated or solved by reducing the displacement. However, the effect of microseismic mapping is not obvious and the fracture propagation is uneven.

In the seventh paragraph, temporary plugging agent (Figure4.) is used to optimize fracture propagation. After adding temporary plugging agent, the eastern microseismic response increases, and the temporary plugging steering effect is obvious.

In the process of fracturing in the 9th stage, there are fewer microseismic events and uneven fracturing fracture propagation (Figure5). In the 10th stage, the number of perforations is optimized in the field, and the number of perforations is reduced (48 to 36). The result of microseismic monitoring shows that the effect of optimization is obvious: the influence of the NE-SW natural fracture zone is weakened and easy to expand.

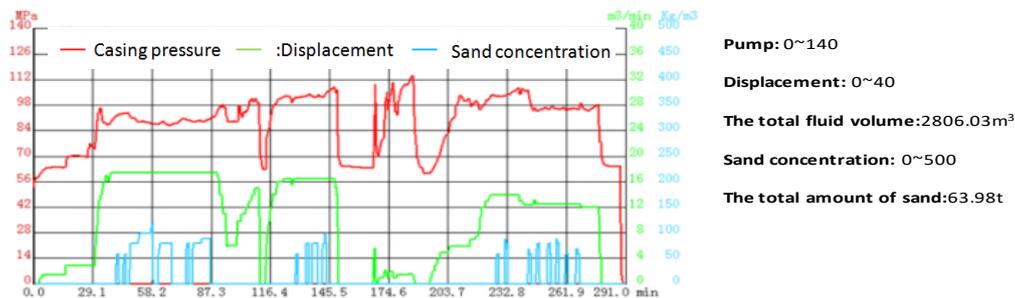


Figure3. Fracturing operation curve of stage 7 of well H

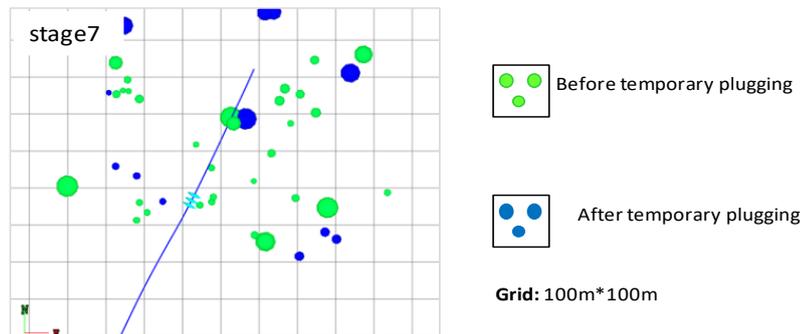


Figure4. Analysis of temporary plugging effect in stage 7 of well H

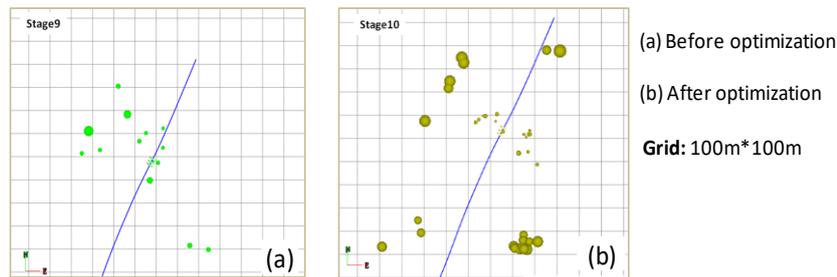


Figure5. microseismic monitoring results before and after perforation number optimization

4. Conclusions

Post-stack coherence and maximum release attributes can be used to identify natural fractures. In identifying micro-fractures, maximum release attributes have higher resolution.

Active natural fractures have different effects on the geometry of fracturing fractures and fracturing construction, and are prone to abnormal construction conditions such as sand plugging, casing deformation and fracturing fluid leakage.

Inactive natural cracks play a role of stress shielding under certain conditions, which can affect fracture morphology and fracturing construction.

Based on the influence of natural fracture on shale gas reservoir reconstruction effect, it is suggested that in hydraulic fracturing engineering, natural fracture distribution should be predicted according to three-dimensional seismic data before fracturing, and natural fracture activity should be analyzed and judged in real time by using microseismic monitoring and positioning results during fracturing, so as to pay close attention to fracturing construction and avoid fracturing. It avoids unnecessary engineering damage and provides reference for adjusting hydraulic fracturing parameters and evaluating shale gas reservoir reconstruction effect.

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