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Effective Fracture Network Analysis Based on Micro Seismic

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Abstract Summary

Drawing on the successful experience of the North American Hydraulic Fracturing Test Site (HFTS), Changqing Oilfield established China's first shale oil hydraulic fracturing test site (HFFL) with the goal of further increasing single-well shale oil production. The project systematically deployed 16 well tests across 10 technologies including fiber optics, micro seismic monitoring, downhole televiewer, tracers, and coring. These tests were designed to conduct detailed evaluations of artificial fracture morphology, multi-cluster initiation, and fluid production contribution rates. Among them, micro seismic technology served as the primary method for assessing hydraulic fracture geometry and spatial patterns. By adopting a dual-well micro seismic monitoring approach, the impact of observation distance on results was mitigated. The project also integrated core well artificial fracture interpretation results and fiber optic strain monitoring data to conduct effective micro seismic event screening. Based on seismic moments inverted from dual-well micro seismic data, proppant distribution ranges were inversely modeled. This process ultimately calculated the geometric dimensions of the stimulated, effective, and propped fracture networks. The optimized regional micro seismic interpretation model enabled more accurate characterization of fracture network morphology, providing precise monitoring data for subsequent analysis.The template may not be changed; header and footer should remain the same, including the horizontal line above the event name. The logo or name of companies may not be added.

Introduction

Changqing Oilfield is the first to construct the Hydraulic Fracture Field Labs (HFFL) in China, in which micro seismic, optical fiber, TV logging and other tests are systematically carried out during fracturing, and the fine characterization and evaluation of artificial fracture morphology, fracture network range, fracture proppant range, and multi-cluster fracture propagation equilibrium degree are comprehensively carried out. Through the coring observation of 2 coring test wells, supporting dyeing proppant and cuttings while drilling analysis, the fracture morphology and proppant characteristics are evaluated, and the HFFL test scheme distribution is shown in Figure 1.

The fracture complexity index, fracture network morphology and coverage mainly relies on micro seismic analysis. In this paper, double well micro seismic monitoring was carried out in HFFL, and the results were combined with the two coring wells results, combined with the source mechanism, combined with the optical fiber DSS monitoring results in adjacent wells, the screening of effective micro seismic events and the calculation of the size of the effective fracture network, the regional micro seismic interpretation model was optimized.

Method

●Use micro seismic monitoring result to optimize the target of the coring well.

By calculating the density of micro seismic events and hot maps, the density and high-value areas of micro seismic events are delineated, and it is suggested that the trajectory of the coring well can pass through the high-density area of micro seismic events as much as possible, and the micro seismic events themselves are generated by rock dislocation and fracture in the process of hydraulic fracturing, which is generally located at the tip of artificial fracture activities. Coring through the high-density area of micro seismic events can have a greater chance of taking artificial fractures.

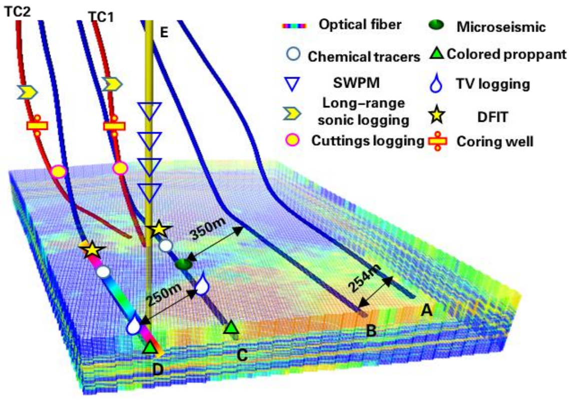

Figure 1: Changqing oil field HFFL test deployment diagram

●Screen different types of micro seismic events based on a variety of test data.

Based on the situation that the micro seismic event extends to the adjacent well, combined with the background noise level wells arranged by the geophones in the adjacent wells, combined with the DSS monitoring results of the optical fiber strain in the adjacent wells, the real fracture extending to the adjacent wells is judged, and there are micro seismic waves, strain responses, and the background noise of the adjacent wells rises, which is judged to be a real and effective frac-hit, and the micro seismic events induced by stress conduction are screened based on this. By matching the fracturing fractures taken from the coring well with the density of micro seismic events around the coring well, the optimal screening threshold was selected, so that the density of the fracturing fractures along the coring well and the density of micro seismic events around the coring well were fitted optimally, and the effective micro seismic events were screened based on this threshold.

Direct and indirect measurements were used to calculate the DFN geometry and orientation of the fractures (e. g. McKenna and Toohey (2013). The seismic moment reflects the displacement of the source slip, correlates the detected total seismic activity with the injection volume, and inverts the proppant distribution by combining the fluid effect and the filtration coefficient. Seismic moment and magnitude are measured for each micro seismic event and the focal mechanism for each event is used to determine the prientation of each fracture based on the event moment tensor of the double-well monitoring inversion.

●Simulate fracture network based on effective micro seismic events.

Based on the sequence of effective micro seismic events, combined with the results of the artificial fracture network of the coring well, and the frac-hit position of the optical fiber strain of the adjacent well, the continuous fracture network modelling based on micro seismic events is carried out, and the fracture network simulation is carried out from the perspective of micro seismic events.

Examples

The target well for the HFFL is Well C, with Wells B and D serving as micro seismic monitoring wells. Well C did hydraulic fracturing in 23 stages with 85 clusters, with the core target stage being stages 17 to 23, which correspond to the coring well. During the fracturing of stages 1 to 10, single-well monitoring was conducted using Well A. However, the micro seismic monitoring results from this single well were asymmetric and did not align with the frac-hit result of the DSS monitoring in Well D. Considering the impact of monitoring distance, the right-wing monitoring of the horizontal well was incomplete. Subsequently, another geophone array was deployed under Well D to do double-well monitoring (Figure 2).

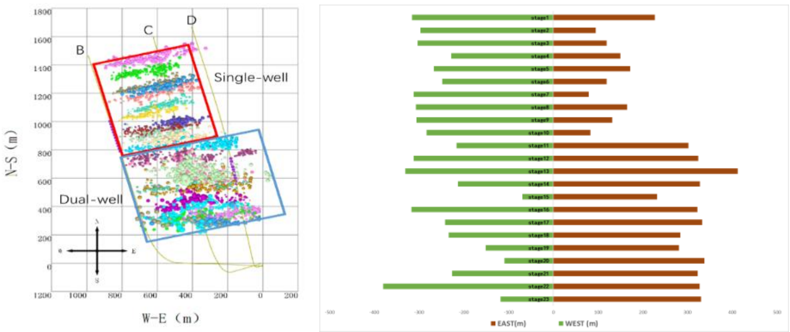

Figure 2: The monitoring results of HFFL and due to the single well monitoring of stage 1-10, the east wings were less than west wings (left), the east and west wing length statistics (right) .

Results

The density of micro seismic events within 50m around the coring well was calculated and the unit number density of fractures of the coring well was fitted (Figure 3), and the screening density of micro seismic events with the highest fitting degree was selected as the screening threshold value of effective events.

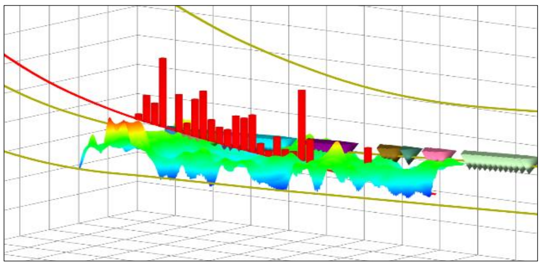

Figure 3: The density of micro seismic events within 50m next to the coring well matched the density of the artificial seam (histogram) of coring.

For the main test stage 17-23, the effective micro seismic events were finally obtained by combining the selected micro seismic events, combined with the artificial fracture positions of the two coring wells, and the Frac-hit positions monitored by DSS of the D wells, and the effective micro seismic events were calculated (Figure 4).

The seismic moment reflects the displacement size of the source rupture sliding, correlating the detected total seismic activity with the injection volume, combining fluid effects and filtration coefficient, the proppant distribution of the same dataset is simulated. Based on the distance tensor, the fracture network with proppant was inverted, combined with the early effective mesh size, and the initial micro seismic interpretation was optimized, and the average effective fracture network length was 455m, the fracture length with proppant was 133m, the effective fracture width was 58m, the effective fracture height was 39m (Figure 5), all are less than the initial monitoring results. The interpretation model for regional micro seismic monitoring has been optimized.

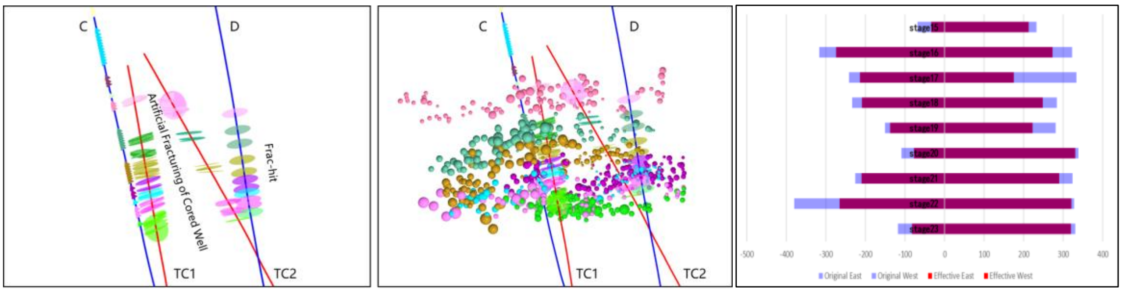

Figure 4: The artificial fracture location of the two coring wells and the Frac-hit location of the D well (left), and the correspondence between the screened micro seismic events and the artificial fracture and the Frac-hit (middle). Comparison of fracture network length (right)

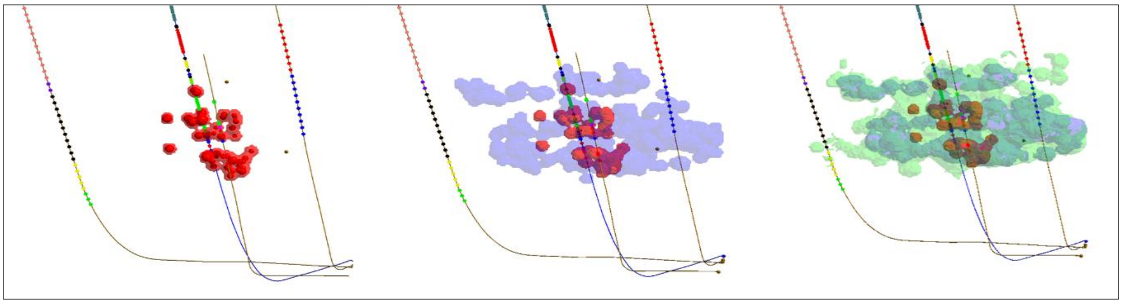

Figure 5: Proppant range (red), effective fracture range (purple), original fracture range (green)

Conclusions

Through comprehensive analysis of micro seismic with different testing methods in the HFFL, the effective micro seismic events have been screened, and the morphology of effective fracture networks has also been depicted based on this. Based this understanding, the hydraulic fracturing scheme can be further optimized.

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