Application of Well-Seismic Combined Fault Recognition Technology in Oil Field Development

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Keywords: Break Point, Logging Curve, Seismic Cross-section, Oilfield Development

Abstract. The advantage of fault identification by logging curves is high vertical resolution and can determine the location of the breakpoint of the well. The disadvantage is that the breakpoints on the surface can not be identified. The advantage of seismic interpretation is that it can identify points on the surface, and has high lateral resolution, while the disadvantage is low vertical resolution. Combining the two methods to identify faults is more real and reliable. In this paper, by well-seismic combined faults, the phenomena in oilfield development are explained， the injection-production relationship of target formation is initially established to guide the adjustment, and the measures to improve injection-production capacity are optimized.

Introduction

Fault research at home and abroad has gradually changed from single discipline and single means to multi-discipline and multi-angle [1][2][3]. Well-seismic combination technology has been widely used in describing sedimentary facies [4] [5] [6] and modeling [7] [8]. In recent years, well-seismic combined fault identification technology has developed rapidly [9] [10] [11] [12] [13].

There are 209 oil and water wells in XX block. From March 2003 to February 2013, the mining target is SII10-SIII10 horizon. Polymer injection began in December 2003, which took effect in March 2004 and reached the lowest water content in December 2005. August 2007 entered the follow-up stage of water flooding. From March 2013 to now, SII1-SII9 horizon has been recovered upward. Faults in Daqing Oilfield are normal faults. There are 13 faults related to the target horizon. Fault No. 100 is the longest, extending 1940m; Fault No. 98 has the longest breaking distance, with a breaking distance of 102 m. There are 101 wells (134 breakpoints) related to these 13 faults, accounting for 48% of the total wells in the whole block.

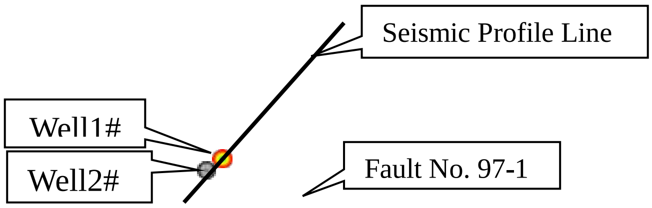
This paper explains the method of combining logging data with seismic data, identifies the location relationship between target formation and fault, and applies this method to oilfield development, and achieves good results.

Method of Combining Well Logging Data with Seismic Data

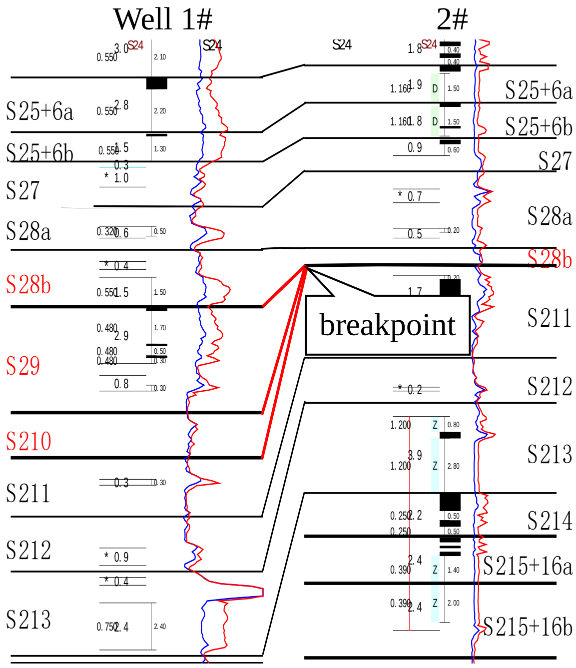
Well 1 # and well 2 # are 45 meters apart. Seen from the well location map, well 2 # is located on fault 97-1. It is impossible to determine whether it is located in the upper or lower wall of a fault. The first step is to select a well with no breakpoint near the well. It is best that the connection of the two wells can be perpendicular to or almost perpendicular to the fault. The second step is to find out the logging curves of these two wells and make stratigraphic correlation to find out the breakpoint of this well. Through comparison, it can be seen that the breakpoint of well 2# is located 1032.4m, and the loss horizon is from SII8 down to the bottom of SII10, and the loss distance is 9.2m. The third step is to draw seismic profiles along the line between the two wells to look at stratigraphic continuity. Through the above analysis, the following conclusions can be drawn: the strata below SII10 of well 2# belong to the lower wall of fault 97-1, and the strata above SII9 belong to the upper wall of fault 97-1. Therefore, when SII10-SIII10 reservoir is exploited, well 2# belongs to the lower wall of the fault, well 1# is located on the upper wall of the fault, so the formation of the two wells is discontinuous. In addition, the fault surface is smeared with mudstone, and the permeability is very poor, so the

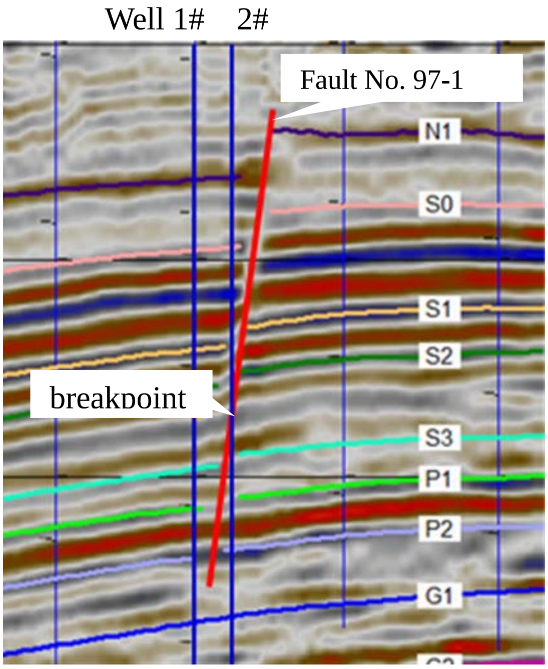
  DOI: 10.25236/iccem.2021.002

injection-production relationship between the two wells can not be formed. When SII1-SII9 reservoir is exploited, well 2# belongs to the upper wall of the fault, well 1# is located on the upper wall of the fault too, so the formation of the two wells is continuous. Therefore, a good injection-production relationship has been formed between the two wells.



(a) Well location map of XX block





(b) Logging curve comparison of the two wells (c) Two wells on seismic section

Fig.1. Figure of Combining Well Logging Data with Seismic Data

Applications in Oilfield Development

The horizontal and vertical distribution of faults is of great significance to the analysis of injection-production relationship, dynamic adjustments and measures to tap potential. Here are three examples.

First example: directing injection-production relationship analysis. When SII10-SIII10 horizons were exploited by polymer injection, the whole area took effect in March 2004, and the water cut reached the lowest point in December 2005. But there is a 3 # well, which took effect in September 2010 and reached its lowest water cut in April 2011. Compared with the whole region, the effective time was 6 years and 6 months later, and the lowest water cut was 5 years and 4 months later. Through analysis, a small fault which may affect injection-production relationship is found, named new-17. The injected energy flows around the end of the fault before reaching the production well, and is intercepted by other production wells in the middle. This explains why the effect is late. When mining the upper stratum S II1-S II9, the fault still forms an effective shield. Generally speaking, when the upper stratum SII1-SII9 is mined, all strata SII10-SIII10 injected with polymer below are blocked. Before recovery of SII1-SII9, the water cut of this well was less than 70%, and the remaining oil around it was enriched, so the SII10-SIII10 formation was not plugged.

Second example: application of perforation operation. The new mining strata S21-9 began to fill holes in March 2013 and ended in May 2016, lasting for 3 years and 2 months. During this period, it is necessary to consider the relationship between injection and production and rationally run the plan of hole filling. Otherwise, there is injection but no recovery which causes casing damage; there is production and no injection which results in low production. There is a production well named 4# whose fluid volume has been declining since the hole was filled in April 2013. Through analysis, the well is located on a narrow Horst formed by two faults. There are three injection wells on this horst. Two injection wells have been perforated to provide energy for this recovery well. However, according to the sedimentary facies zone diagram, there are phase transitions between the two injection wells and production wells, which can not form a good injection-production relationship. However, another injection well without perforation, well 5#, has no phase change with the produced well, which can form a good injection-production relationship. Therefore, in July 2013, the relationship between injection and production was improved by perforating 5# wells. After perforation of 5 # injection well, the daily fluid production of 4 # production well increased to 155 tons per day, and the daily oil production increased to 23 tons per day. Compared with before, the daily fluid production of 4 # production wells increased by 75 tons per day, and the daily oil production increased by 10 tons per day.

Third example: optimizing fracturing and plugging removal wells 6 # well produces about 15 tons of fluid per day, and the bottom hole flowing pressure is about 1 MPa. Preliminary analysis shows that formation energy is insufficient and fluid supply is seriously insufficient. According to this well group, the injection-production ratio of the well group is always greater than 2.6. According to this well group, it is contradictory to inject more and recover less. Based on the further analysis of sedimentary facies zones, some problems have been found. The injection wells are located in the middle of the channel facies, and the reservoir properties are good; while the production wells are located at the edge of the channel facies, the reservoir properties become worse and the connectivity is poor. Therefore, it is difficult for injection wells to advance to production wells. In order to change this situation, fracturing of 6 # production wells is carried out. At this time, there is a new problem. Well 6 # is close to the fault. It is possible that if the fracture extends to the fault plane, the fracturing fluid and fracturing sand will move along the fault plane. In this way, not only can not change the current situation of this well, but also cause casing damage in other wells. Through well-seismic analysis, the shortest distance between 6 # well and cross-section is 70m, and the distance between 6 # well and breakpoint is 155m. The length of cracks is generally 40-60 m. So this well can be fractured. The well was fractured in April 2016. After fracturing, the well produces 98 t of fluid per day, 3.5 t of oil per day, 96.5% of water cut, 6.5 MPa of bottom hole flowing pressure and 263 mg/l of polymer concentration. Compared with the former, daily fluid production increased by 83 t, daily oil production increased by 3 t, bottom hole flowing pressure increased by 5.5 MPa, polymer concentration decreased by 60 mg/l, and injection-production ratio of well group recovered to about 1.0.

The above three examples prove the accuracy and validity of fault identification by well-seismic combination. According to the need, 22 seismic profiles are drawn and 134 breakpoints are found by logging interpretation. On this basis, the whole block connectivity graph is drawn, which provides accurate basic data for dynamic analysis. In addition, the database of the distance between the target layer and the breakpoint and the distance between the target layer and the fracture surface is established to facilitate the well selection of fracturing measures.

Conclusion

The resolution ratio of seismic interpretation faults on the surface is high, and that of log interpretation faults on the point is high. The combination of the two improves the accuracy of fault identification. The application of the interpreted faults in the XX block confirms the advantages of this combination. Therefore, this method of fault identification provides accurate basic data for dynamic analysis and fracturing measures modification. This method is highly operable and can be used for reference in the development of other blocks in the oilfield.

Acknowledgement

When using seismic method to identify faults, we got the selfless help of Song Jie, senior engineer of our unit. When using logging curves to identify faults, I got the selfless help of Wang Shengnan, an intermediate engineer in our unit.

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