Analysis of micro amplitude structure along faults based on Fault Segmented Growth Pattern

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Abstract

In this article, taking the fault F278b in the north of the Songliao Basin as an example, based on the fine 3D seismic interpretation, the distance-displacement of fault curve are established. Preferred six kinds of interpolation methods of Surfer software and the structure counter map of the PI11 layer is constructed. Take the Formation mechanism of fault trap as a guide, match the relationship between the micro amplitude structures distributes nearby the faults and the faults' location. Statistical sand ratio of wells in micro amplitude structure position and sand ratio of wells nearby the segmented growth point position. The relationship between transverse section growth of fault location, the difference of the formation energy and the micro amplitude structure is systematically analyzed. The research results show that：(1)The deviation of minimum curvature method is the smallest of the six interpolation methods at the boundary of the fault line， the least and the boundary of the well control area with actual situation. (2) Influence of transverse section growth of faults, Micro amplitude structure of Footwall with the micro amplitude structure of upper wall, alternate distributes as the sine curve. (3) Along fault's upper wall negative micro range structural sandstone content higher, footwall forward micro range structure and fault's transverse section growth position the sand content is relatively low.

Keywords

Preference of interpolation method; Fault trap Formation mechanism; Fault transverse segmentation growth; Micro amplitude structure; Competency

1. Preface

At present, the Daqing oilfield has entered the high water cut stage, because of the role of water flooding, the distribution of residual oil is uncertain, "The whole is highly dispersed, and Local relative enrichment" state, but there are rules to follow，This makes it necessary to make a clear understanding of the micro structure in the study area. Meanwhile, the fault can not be underestimated. During the development of oil field, Relative enrichment of the residual oil in fault edge, Therefore, it is needed to consider the geological factors to carry out targeted deployment of directional well, so as to improve the production of oil field. Horizontal well is relatively high to the structural precision. Therefore, a comprehensive study on well-log and seismic combination is carried out by using 3D seismic data, provide support for fine directional potential tapping technical is necessary. As the work of structural description using well-log and seismic combination is moved forward, the description of micro amplitude structure is continuous fine, the accuracy of fault characterization is continuously improved. Therefore, it is necessary to carry out the research work of fault segmentation growth. Perfect the fine interpretation method of micro amplitude structure at the margin of faults. It is necessary to carry out the research of the fault segmentation growth and the fine interpretation of micro amplitude structure at the margin of faults. This has laid a solid foundation for the future development of oil field. In recent years, some scholars have made a deep research on the formation and evolution of the faults in Daqing placanticline, it is believed that the control of the deep deformationalterrain is eventually connected to Daqing placanticline of NNE strike 错误!未找到引用源。. Some scholars have carried out a lot of useful research on the Fault transverse segmentation growth and quantitative discrimination criterion. That the growth of the fault mainly experienced three stages: Isolated nucleation stage, “soft linkage” stage and “hard-linkage” stage, different stages growths with different types of fault traps.Some scholars put forward the method of quantitative recovery of fault formation and evolution.In the last few years, the method of identifying the micro amplitude structure is mainly:1) Structural trend surface analysis: application of multiple regression, generating surfaces to reflect the local variations of the remaining maps;2) Data isochronal sections: the direction of the reflection interface of all seismic events at a certain time;3) Coherent body technique: the image of the construction of hidden formation can be interpreted by the quantitative processing of seismic coherence properties;4) Well point data small grid mapping method: using dense grid method to draw contour, according to the change of contour lines, the micro amplitude structure is identified· But through literature survey found that literature had been published in the aspect of fault transverse segmentation growth and micro amplitude structure exist the following problems:①In China, the distribution of the micro amplitude structure and its microstructure along the segmented growth fault is not fine enough.②Lack analysis of the influence on fault segmentation growth and distribution law of the micro amplitude structure from formation competency this factor. In this paper, we propose a method of fine identify micro amplitude structure take combination of the formation mechanism of the fault trap and Well point data small grid mapping method as a guide. Using this method the fault transverse segmentation growth position and the micro amplitude structure along the faults is matched well, A comparative analysis of the lithology of the fault transverse segmentation growth position and the position of the micro amplitude structure, find the influence of lithology on the distribution of the micro amplitude structure at the margin of faults.

2. Regional profile

Daqing oilfield is located in the central depression of the Songliao Basin, the secondary structural belt placanticline. Xingshugang oil field, the study area is located in the northern Daqing placanticline Xingshugang structure. The West adjoin Qijia-Gulong depression, the east connect with Sanzhao depression, northern Daqing placanticline is Xingshugang structure, southern is Putaohua structure and northeastern is Taipingtun structure. Located in the central depression of the Songliao basin,on the third-class structural in the central section of the secondary structural belt in Daqing placanticline. Oil / water distribution is controlled by the secondary structural, reservoir burial depth is 800～1200m. Xingbei area is a third-class structural in central depression of Songliao basin, this structure is relatively flat, two limbs is basic symmetry, the structural long axis is 20.4km and the short axis is 7.33km, the deepest shut height is 94.4m, closure area is 80.8km2. high point of structure deflect to northwest. The northern part of the structure is cut into a plurality of North West striking fault block bands. The role of the north and south direction of the torsion, There are fourteen large-scale faults with northeast and northwest tension torsion develop in the study area, all of them is normal fault.

3. Fine identification of micro amplitude structure

3.1 Preference of interpolation method

Golden Software Surfer 12 (hereinafter referred to as Surfer) is a 3D map painting (contour, Image map, 3D surface) software, is one of American the Software Golden company's Series graphics softwares. The main function of Surfer is to draw the contour map, is a drawing software with interpolation function, so even if your data is unequal spacing, still can use it to plot. In addition, it can also draw a post map, classification of the post map, vector map, image map, surface map 3D, and other forms of graphics. There are twelve kinds of interpolation method in Surfer 12, commonly used six kinds of methods: Inverse Distance to a Power, Kriging, Minimum Curvature, Radial Basis Function, Nearest neighbor, Triangulation with liner interpolation. Among them method Inverse Distance to a Power can adjust the structure of the space interpolation contour by weight; method Kriging is a smooth interpolation method, the greater the amount of data, the higher the credibility of the results; Minimum Curvature method is used to generate the smooth surface of the data; Complex two function method of Radial Basis Function method is widely used; Nearest neighbor interpolation method has good effect on the area of evenly spaced data and the area filled with no value; Triangulation with liner interpolation uniform distribution of data within the grid, there are obvious differences in the triangle surface at dense and sparse regions. This work first preferred one interpolation method most consistent with the actual situation from six methods, the preferred process is as follows:

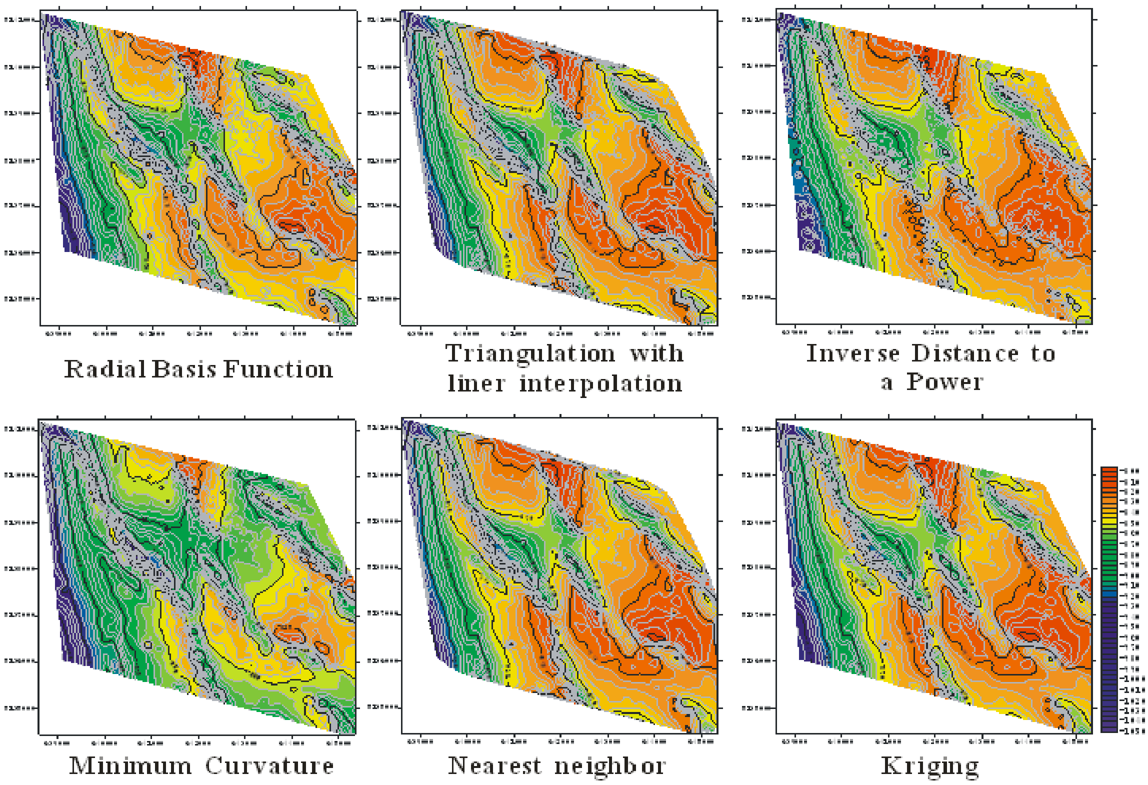


Fig. 1 Six interpolation methods' model chart

Test the six methods based on the available data (See Fig. 1). Select twenty straight wells at the edge of well control area, margin of faults and the area without the influence of faults, read the depth data generated by six interpolation method of every wells' and compare them with the actual depth data, statistics and analysis the error of the six methods. Computational characteristics of Surfer 12 can be seen in the above region by the above 6 methods. (See Table 1 and Fig. 2)

Table 1 Error value of six methods

Well name	Minimum Curvature (/m)	Kriging (/m)	Inverse Distance to a Power (/m)	Nearest neighbor (/m)	Triangulation with liner interpolation (/m)	Radial Basis Function (/m)
X5-32-P909	0.34	2.73	2.93	2.42	0.9	4.17
X5-40-709	0.11	8.84	4.2	7.43	7.84	7.49
X5-4-116	0.2	5.24	7.3	5.01	5.03	6.82
X5-41-619	0.16	0.75	1.77	0.73	0.59	0.16
X5-34-732	0.37	1.09	5.64	0.44	0.4	13.05
X6-11-617	0.01	0.39	0.84	0.22	0.33	0.89
X6-3-125	0.01	3.77	2.34	1.85	0.31	0.76
X6-3-19	0.32	2.23	1.64	0.83	0.1	1.49
X6-2-738	0.02	12.17	8.77	12.13	9.93	5.79

X6-D3-120	0.07	0.38	2.42	0.03	0.34	0.83
X7-20-618	0.03	7.09	8.33	7.41	8.46	7.03
X7-21-624	0.08	0.61	2.85	0.17	0.46	0.04
X7-2-28	0.03	2.14	4.33	2.34	1.83	1.49
X7-D2-134	0.21	19.03	10.97	16.07	19.86	18.65
X7-D4-126	0.15	5.56	1.01	4.08	3.81	5.61
X8-11-623	0.23	18.29	14.39	32.43	14.4	19.29
X8-11-627	0.27	9.24	9.51	16.15	16.58	12.43
X8-D1-129	0.01	3.47	0.36	3.87	2.34	4.15
X8-10-633	0.15	0.24	3.54	1.23	1.14	0.73
X8-D1-136	0.9	2.57	10.82	0.01	0.61	4.44

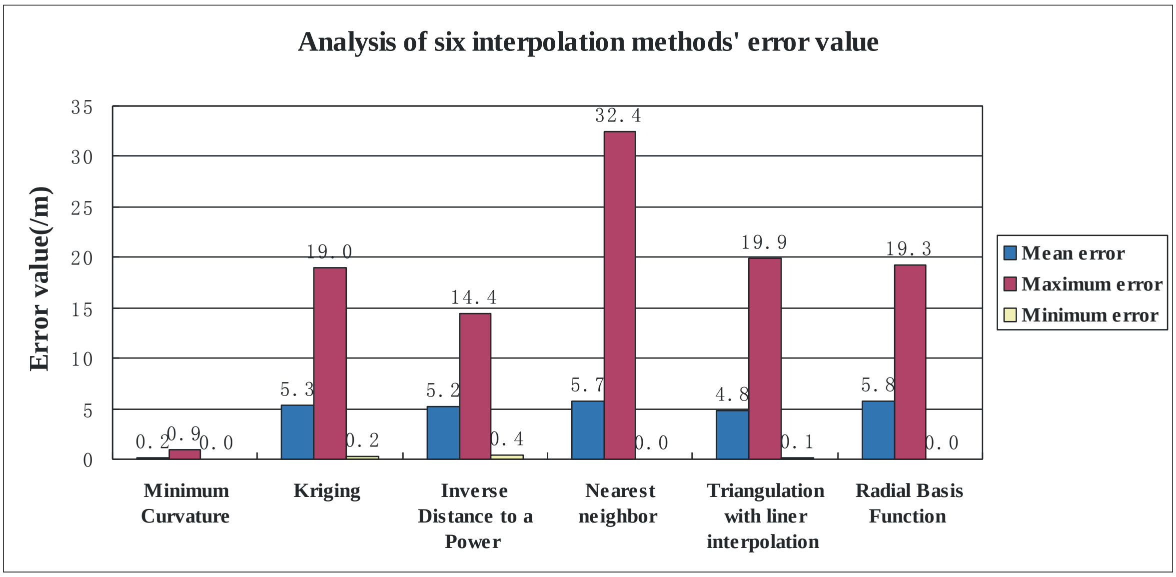


Fig. 2 Six interpolation methods' statistical bar chart

Through data statistics found mean error of Kriging, Inverse Distance to a Power, Nearest neighbor, Triangulation with liner interpolation and Radial Basis Function is all larger than the minimum curvature method's, at about 5 meters. In the area near the border delineation of Xingba, the error of the above 5 methods is relatively large, maximum value can reach 10 to 30 meters. The error of minimum curvature method at the well control area and the edge of it are relatively small. According to the above analysis, minimum curvature method is most in line with requirements, error is the smallest. So this work is done by the minimum curvature interpolation method, the grid precision of the structure chart is 10 * 10.

3.2 Fault trap Formation mechanism

From the distribution law of the transfer zone and the fault trap we can see clearly, fault block trap is controlled by the complete section of faults between transfer zones, and faulted anticlinal trap is controlled by transfer zone. So fault block trap develops at the footwall of antithetic fault and faulted anticlinal trap develops at the hanging wall of synthetic fault, this is closely related to the segmentation of the fault, mainly reflected in the change of fault separation in the direction of fracture strike. For the complete isolated fault, displacement is the biggest at the central section of fault, gradually reduced to zero for both sides to the end, therefore formation at the footwall of fault occurs tilted up pour, Along the fault strike formation from middle to side of the fault take shape into a transverse anticlines that long axis perpendicular to the fault strike (Fig. 3), the distortion of the hanging wall's formation is on the contrary, that is the formation along the fault strike from the middle to the sides of the fault formed by a bend in a syncline which is the long axis perpendicular to the fault strike, so footwall easy to form fault block trap, the essence is a kind of transverse anticlines. For sectional growth faults, at the connection points of segmentation growth fault, the fault separation are still small, but syncline formation of the hanging wall at the fault isolate section beside segmented growth points bending shape to anticline form at the segmented growth points, and the long axis direction is also perpendicular to the fault strike, also a kind of transverse anticlines. On the contrary, anticline formation of the footwall at the fault isolates section beside segmented growth points bending shape to syncline form at the segmented growth points. In addition, for transverse anticline at the hanging wall of synthetic fault, as the deformation process of the hanging wall's formation easy to occurs reverse drag transformation, so the transverse anticlines which is formed always have part of alone trap, but transverse anticlines is nevertheless large range to the boundary of fault block trap.

Fault block trap and faulted anticlinal trap are macro both local positive structures, are favorable directional zone of oil and gas migration and accumulation and residual oil convergence. For development block, the deployment of remaining oil wells In accordance with the developmental regularity of fault block trap and faulted anticlinal trap under dense well pattern condition is obviously not appropriate. Because the fault trap is relatively more macro, the range is relatively large, only search forward micro amplitude structure controlled by faults inside the fault trap further, in particular the forward micro amplitude in the margin of the fault is practical significance to guide the distribution of remaining oil. So considering fault segmentation growth controls developmental characteristics of local positive structures. Have been predicted local forward structure possible development in the margin of segmented growth fault F278b. In this direction, it is further to find the forward micro amplitude structure in the local forward structure.

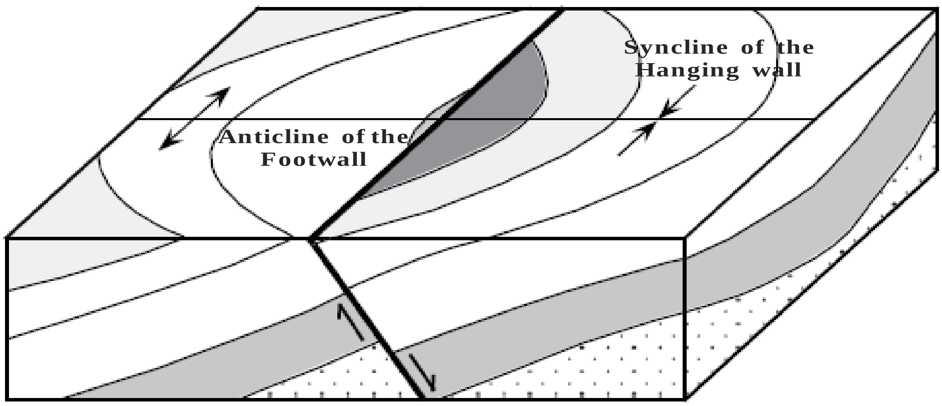
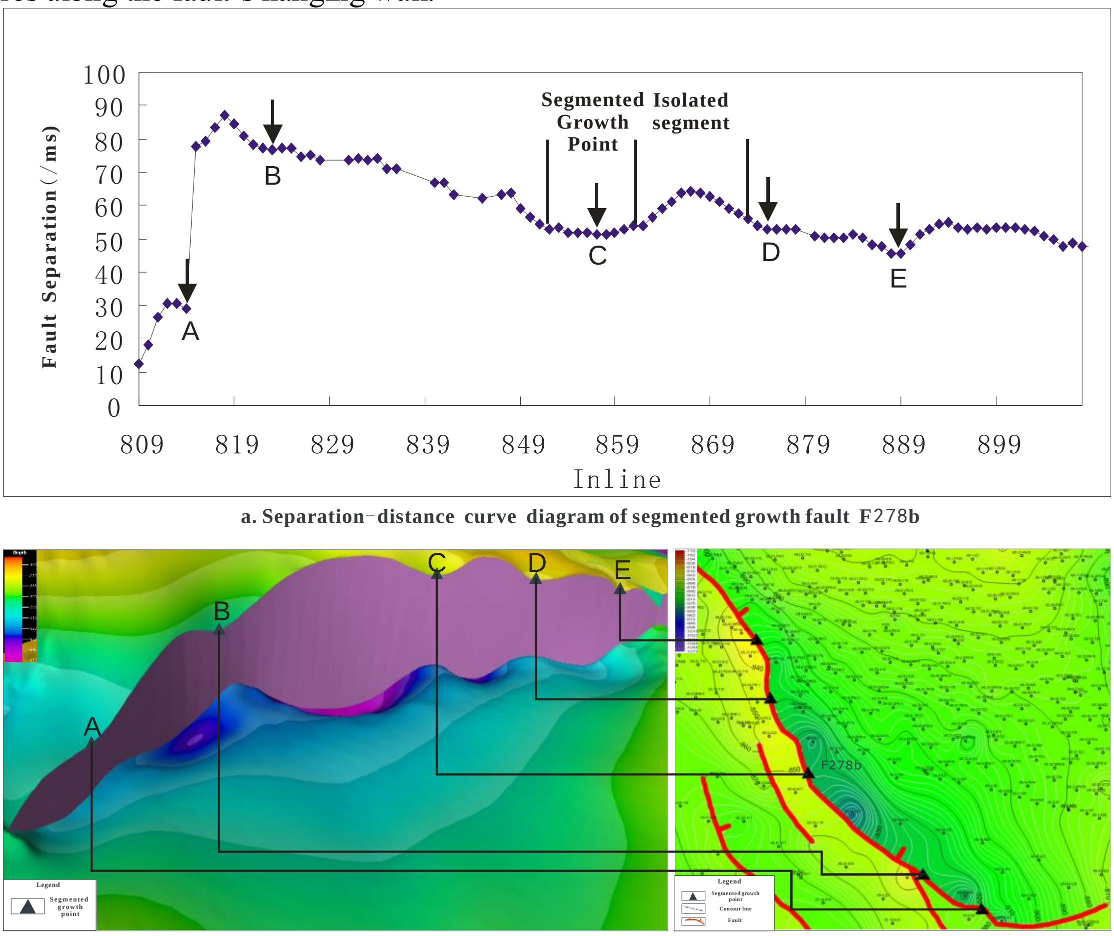


Fig. 3 Geometrical morphology of isolated normal fault's transverse fold

3.3 A method for identifying the micro amplitude structure under the control of fault trap

Seismic fine interpretation is a direct method to identify the micro amplitude structure, however, the accuracy of seismic interpretation is not able to identify the required scale of the micro amplitude structure requirements, and it is needed to find an effective method to predict the distribution of the micro amplitude structure. The development of the micro amplitude fault-nose at the edge of both the fracture of the hanging wall and footwall, these fault-nose are controlled by transverse fold formation mechanism and transverse segmentation growth mechanism, the formation mechanism of micro amplitude fault-nose and fault block trap at the footwall is similar, the formation mechanism of micro amplitude fault-nose and faulted anticlinal trap at the footwall is similar. Then there is a sine curve distribution between the micro amplitude structure at the footwall and the micro amplitude structure at the hanging wall. Based on the characteristics of the fault section growth mechanism, draw a fault separation-distance curve diagram (Fig. 4-a) for the fine seismic interpretation of fault F278b in formation PI11.

Contrasting the characteristic of the fault separation-distance curve of the corresponding interface (Fig. 4-a), F278b's fault plane three-dimensional display map (Fig. 4-b) and micro amplitude structure map (Fig. 4-c) for amplitude fault-nose on the both side of the fault draw by Surfer, forward micro amplitude fault-nose at the footwall and fault isolated section is corresponding, forward micro amplitude fault-nose at the hanging wall and the sectional growing area of fault is corresponding. Forward micro amplitude fault-nose at the footwall and the hanging wall along the fault strike distribute as a sine curve, it is further confirmed that the micro amplitude structure of the fault margin is the same as the fault trap, is also controlled by segmentation growth formation mechanism. Moreover, to further illustrate this problem, select the micro amplitude structure distinguished by interpolation method and the distribution of micro amplitude structure collated and stipulated by separation-distance curve diagram based on seismic interpretation for the target fault, fault F278b which is fine seismic interpreted engender five connection points of fault segmentation growth, is coincided with the segmented growth points which is collated and stipulated by separation-distance curve diagram, and from the separation-distance curve diagram we can see that there is more segmented growth points which is not interpreted out by seismic interpretation. Separation-distance curve diagram shows that fault F278b was growth by six stages, there are four positive structure likes fault anticline, fault-nose develop at the footwall, between them there are three obvious syncline structures along the fault's hanging wall.



a. Separation-distance curve diagram of segmented growth fault F278b

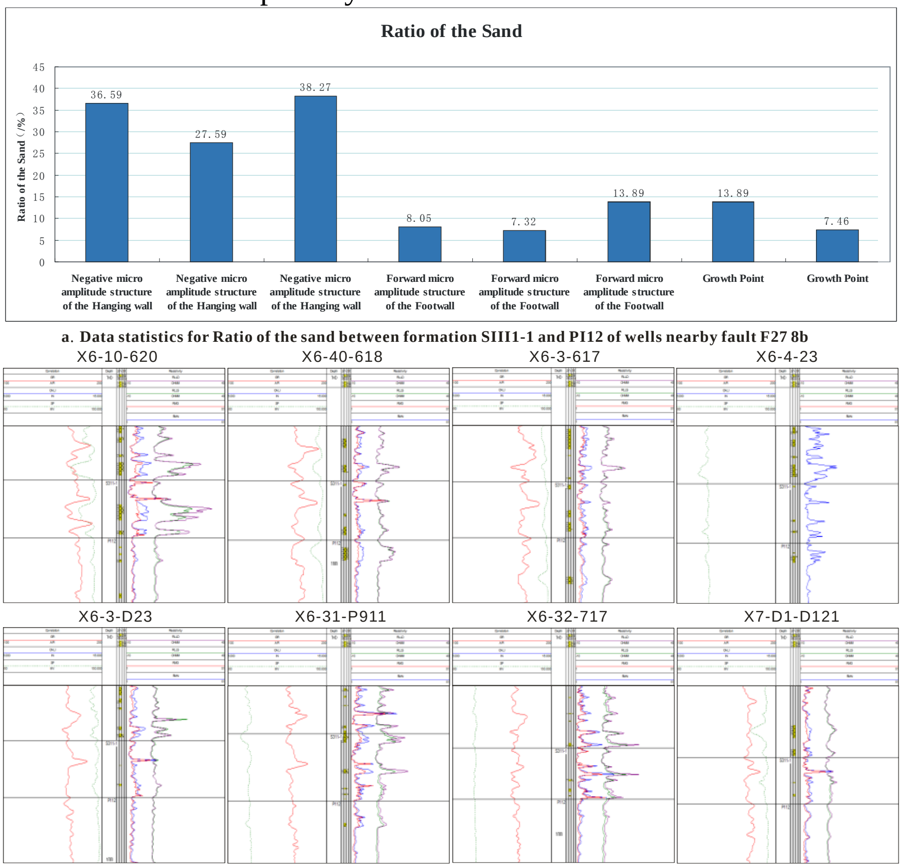
b. Three-dimensional figure of segmented growth fault F278b

c. Structural contour map of segmented growth fault F278b

Fig. 4 The structural map of fault the segmented growth fault F278b

4. Relationship between fault segmentation growth, microstructure and formation energy

There is a difference in the competency of rocks, the fault cores develops in the competent formation with the biggest displacement. Fault terminal develop in the incompetent formation, and the displacement gradually decreased from competent formation to incompetent formation, incompetent formation is typical parts of arrangement overlap belt. Along with the fault activity, fault displacement continuous accumulated, multiple small tails of faults is influenced by the formation competency, at the incompetent formation through "soft linkage" stage to "hard-linkage" stage turn in to a huge fault. According to the formation mechanism of the fault trap above hanging wall at the fault isolate section beside segmented growth points bending shape to anticline form at the segmented growth points, anticline formation of the footwall at the fault isolates section beside segmented growth points bending shape to syncline form at the segmented growth points. So under influence of formation competency segmented growth fault controls multiple micro amplitude structure. Through ratio of the sand statistics for wells nearby fault F278b between formation SIII1-1 and formation P112, we can see the relationship between micro amplitude structure, Fault transverse segmentation growth position and formation competency.



a. Data statistics for Ratio of the sand between formation SIII1-1 and PI12 of wells nearby fault F27 8b

b. Well-logging curve of wells nearby fault F278b between formation SIII1-1 and PI12

Fig. 5 Ratio of the sand for formation between SIII11-1 and PI12 of wells nearby fault F278b with corresponding lithology maps.

Statistical data is consistent with the law of the distribution of the micro amplitude structure controlled by the segmented growth faults. From the data we can see sandstone content in these formations is higher at the negative micro amplitude structure of footwall, and then is lower at the forward micro amplitude structure of hanging wall and position nearby the segmented growth points, basically, mudstone dominated (Fig. 5). It is showed that the negative micro amplitude structure develops at competent formation in the margin of faults, the forward micro amplitude structure develops at more incompetent formation , the segmented growth points develops at most incompetent formation.

5. Conclusion:

1) Through the statistical analysis of the data and the real data, errors of six kinds of interpolation methods, contrasting with the actual situation the minimum curvature method is found to be the minimum at the well pattern controls region, the regional boundary, in the margin of the fault. The

other 5 methods' average error are about 5 meters is greater than the minimum curvature method's, the maximum error can reach 30～10 meters.

2) Based on the accurate judgment of the fault growth's point location and the fine interpretation of the fault, it is found that the identification of the distribution of the micro amplitude structure in the margin of fault and the position of the segmented growth points is good. Micro amplitude structure of footwall with the micro amplitude structure of the hanging wall under the control of fault transverse segmentation growth develops into a sine curve distribution alternately.

3) The formation plane lithology difference and heterogeneity, sandstone content in these formations is higher at the negative micro amplitude structure of footwall, and then is lower at the forward micro amplitude structure of hanging wall and position nearby the segmented growth points. It shows that the negative micro amplitude structure develops at competent formation in the margin of faults, the forward micro amplitude structure develops at more incompetent formation , the segmented growth points develops at most incompetent formation.

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