Faults Delicate Description Technology by Well-to-seismic Integration is applied to the Sabei Development Area of Daqing oil field

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Abstract. Due to the effect of faults, there are some problems such as the high oil wells ratios, and the partial incomplete injection-production relationship which effect the yield of the development in the west of Sabei Development Area that has a high content of oil. The effective method to improve the water-flooding control degree in densely faulted area is to further study the developmental morphology of fault area and improve the injection-production relationship. This passage combines the advantages of interpret ation seismic data with high resolution and vertical plane strong data continuity, forming a technology of the description of well seismic combined with fault by breakpoint data logging boot, seismic trace, identify the properties of body, and carry out the verification of the interpretation results of well seismic combined with fault by dynamic analysis methods, implement the fault’s shape in the top surface of each reservoir group of the study area, and applied the guidance of research to guide the adjustment of injection-production system in the West of oil area, improve the injection-production relationship of complex fault zone, achieving a good effect of tapping the potential.

1. Introduction
The technology of fault description based on logging breakpoint data mainly relies on 3D space display, to clarify the spatial configuration relationship of breakpoints, preliminary determination of the attribution of breakpoints, according to the attribution of breakpoints the fault plane is established, the overlapping relationship between faults is determined, and the optimal combination of breakpoints is realized, according to the principle of hierarchical control, the distribution pattern on the plane of the breakpoint, the rule of the change of the fault distance, the tendency of the fault plane and the two sides of the fault plane are defined[1]. In view of the fact that the description of faults only depends on the data of logging breakpoints, there are some problems, such as the inaccurate description of the head and tail changes of large faults and the shape of small faults, especially the unconfirmed trend, tendency and extension length of faults controlled by isolated breakpoints and faults between wells. By introducing the control of seismic data, the synthetic seismic records of wells covering the whole area are made, is established. The time-depth relationship has been established, and the accurate speed model has also been established, complete the time-depth relationship conversion of the breakpoint, use the guidance of logging breakpoint, carry out the fault tracking of the seismic ininline and the crossline, combine with the comprehensive identification of the seismic attribute date, carry out the spatial location of the breakpoint, the spatial combination of the fault and the implementation of the fault occurrence. Using the above technology to carry out the fine interpretation of the well seismic
combination fault in the study area, to clarify the development form of the fault and the top structure characteristics of each oil layer group in the study area, and to guide the injection production system adjustment in the complex fault area by using the well seismic interpretation results, to improve the injection production relationship in the study area.

2. Geologic aspects
The western part of the pure oil area of Sabei Development area is located in the West of the anticline structure in the north of Daqing placanticline Saertu oilfield, the oil-bearing area is 34.95km². The regional structure is relatively gentle with a dip angle of 1-3° and many faults. According to the research results of well-to-seismic integration with structural fine interpretation in 2008~2011, there are 49 faults in the reservoir, all of which are normal faults. The strike direction is mostly North-North and West, the fault dip angle is 60~70°, the fault extension length is 0.2 ~ 2.9km, the maximum fault distance is 93.2m, and the minimum fault distance is 0.8m.

3. Fault description method and result verification based on well-to-seismic integration

3.1. 3D Space combination of logging breakpoints
There are 275 breakpoints interpreted by logging curves in the study area, in order to maintain the integrity of the fault and effectively combine the isolated breakpoints, the method of controlling the location of the fault as a whole and combining the local breakpoints of the oil layer is adopted. Take the No.75 fault as an example. Firstly, all breakpoints data is added to the computer professional software project to clarify the fault shape, and then check whether the breakpoints of the target layer are in a trend plane, which is displayed in 3D space. The breakpoints in the middle are relatively scattered, most of them are outside the section, so adjust the section position to make it fall in the middle of the breakpoint, at the same time two No.55 fault breakpoints and an isolated No.30 fault breakpoint falling in No.75 fault plane are added to computer professional software project too, 29 breakpoints are combined in 2D seismic data, however, the actual 39 breakpoints are combined in 3D seismic data. Through the above methods, 22 faults in the study area are implemented, and the 3D combination of all breakpoints in the study area is completed, and the overlapping relationship between the faults is preliminarily determined.

3.2. Research methods and achievements of well-to-seismic integration fault description
The introduction of seismic data through the traditional geological modeling process for control, based on the fault of seismic interpretation, advanced fault detection techniques such as Coherence cube, horizontal slice and dip angle analysis are used. Realize the spatial regression of breakpoints, the spatial combination of faults and the implementation of fault occurrence. First of all, the research on the precise time-depth relationship and the 3D space-time velocity field, realize the same domain analysis of well and seismic data[3]. Seismic attribute extraction based on ant colony algorithm edge detection technology, adjusting the occurrence of large fault section and the change of its head tail extension according to the breakpoints, the identification of unexplained faults and the establishment of spatial association of faults, then, the data of breakpoints, seismic Slice, fault trend surface and ant body are synthetically used. The combination of multi windows and fault modeling can realize the spatial distribution characteristics of faults and faults.

3.2.1. Spatial variable velocity model by dense well pattern
The purpose of establishing the spatial variable velocity model is to transform the breakpoint in time domain and the reservoir group level construction into the depth domain. By extracting the average velocity point of the first target layer and the velocity point of the top surface of the remaining oil formations in the synthetic seismogram and interpolating the velocity surface, the spatial variable velocity model is established. In order to ensure the accuracy of the velocity model, it is necessary to
carry out multi-well consistency correction and reinterpret the marker layer near the fault to ensure that the velocity model has no distortion.

3.2.2. Seismic layer labeling combining with logging curves

Through the time-depth relationship transformation, the data of the two observation systems work together in the same domain, verifying and checking each other. The main reason for the unification of logging and seismic data into the time domain is that the accuracy of seismic revealed tectonic trend is higher than that of logging in the tectonic research stage, so the original appearance of seismic data should be kept as much as possible[4]. When the seismic time domain data is converted to the depth domain through the time-depth relationship, the error increases due to the large amount of data, and some seismic details will be lost. However, the conversion of logging stratification point belongs to point-to-point, and the relative error is much smaller. So will well layered, breakpoint and seismic data in time domain is studied.

After the well-seismic information is accurately combined with the synthetic records, in the seismic horizon tracking process, the interpretation density of the measuring network is gradually closed from sparse to dense, and the interpretation density is locally encrypted in the complex fault area to elaborate the structural characteristics of the top surface of each oil layer group, and the reserved well behind and combined well profiles are used to verify the seismic horizon interpretation results[5].

3.2.3. Fine fault interpretation by well-to-seismic integration

The fault characteristics in the study area are implemented by means of seismic interpretation and logging verification. According to the principle of seismic control shape and space location. The local amplification of seismic profiles can explain small faults and tectonic changes, and the overall reduction of tracing the shape of large faults. The spatial location of the fault is accurately determined by means of a high longitudinal resolution breakpoint, and the precise matching of the breakpoint, seismic section and seismic attribute body is realized[6]. The effective combination of breakpoints completes the recombination of breakpoints and fault repositioning in the study area, and forms the technique of well shock combined with fault description for data guidance of breakpoints, seismic profile tracking and comprehensive identification of attribute bodies[4].

For large faults identified by the eye on the seismic profile, the interpretation can be directly traced on the seismic interpretation data body. For large fault edges, the fault length is determined according to the dislocation of the same phase axis of the seismic, and the fault profile is accurately described with the breakpoint data of 3D optimization combination. For small faults difficult to be recognized by the eye, the distortion, bifurcation and merger of the same phase axis are reflected by faults or caused by lithologic changes. By means of dip detection technique, the time rate of change between sample points is calculated one by one along the layers[7]. At the same time, the seismic attributes were extracted, and the sectional shape of the fault and the changes of its head and tail extension were adjusted according to the breakpoint of the deep-time relation transformation. The seismic dip Angle, azimuth Angle and coherence block superposition display were used to guide the seismic data of the breakpoint to implement the small fault shape in the research area.

Firstly, the seismic data in the study area were smoothed to highlight the strong reflection, the spectrum of post-stack seismic data is adjusted, The 50Hz to 70Hz response is suppressed to filter out noise interference, the seismic data makes the fault shape more prominent[4]. At the same time, the seismic attribute data was extracted, the fault was manually tracked in combination with the seismic profile, and the time domain breakpoint was projected on the seismic profile to verify the well-seismic data[7]. The fault elements and the top surface fault distribution of each reservoir group were determined by well seismic combination. Fine interpretation by well-to-seismic integration make the combination rate of breakpoint increased from 87.2% to 96.3%. Compared with the original results, the fault strike and dip Angle change little, and the combination relationship and extension length change greatly. In the saertu reservoir, 26 faults were originally explained, 47 faults were explained by the well-to-seismic integration, 13 faults were newly combined, 4 faults were written off, and 8 faults
were broken into 20 faults. In the putaoahua reservoir, 26 faults were originally explained, 38 faults were explained by the well-to-seismic integration, 8 faults were newly combined, 3 faults were written off, and 5 faults were broken into 12 faults. In the gaotaizi reservoir, 18 faults were originally explained, 29 faults were explained by the well-to-seismic integration, 10 faults were newly combined, 4 faults were written off, and 2 faults were broken into 7 faults.

4. Analysis and verification of the research results of well-to-seismic integration

As an example of the reservoir of sa II formation with the most obvious seismic reflection characteristics, through well-to-seismic integration, 26 faults originally explained are determined to be 47 faults, and the fault strike and dip angle change little, and the combination relationship and extension length change greatly, the faults are more broken, and the new combination and write-off faults are mostly small faults.

The analysis of fault newly combined: Due to the improper combination of log breakpoints, the fault has not been explained separately, by means of seismic profile and fault detection of ant body, combined with fault modeling of well-to-seismic integration, the fault points which are not combined or do not fit the fault model after recombination are recombined.

As an example of the No.781 fault, the breakpoints of Wells N2-352-P49, N2-D5-30, N2-352-P50 and N2-D5-P31, located near the small No.781 fault, were originally assigned to the section of No.78 main fault, from the 3D sections and seismic profiles, it can be seen that the breakpoint of these four Wells is obviously not the No.78 main fault, therefore, it can be recombined as No.781 small fault, as a derivative of No.78 fault. The small fault No.781 was verified by pulse well test. Well N2-351-P49 and well N2-351-SP48 were located on the same side of fault No.781, and well N2-351-P49 and well N2-352-P49 were located on both sides of fault No.781. The test results show that the fluid volume of well N2-351-SP48 rises and falls in a stepped manner with the open-shut of well N2-351-P49, indicating that there is connectivity between the two Wells. The fluid volume of well N2-352-P49 does not rise and fall in a stepped manner with the open-shut of well N2-351-P49, indicating that the two Wells are not connected. The disconnection of Wells on both sides of No.781 fault verifies the rationality of the existence of No.781 fault. (Figure 1)

![Figure 1. 3D display of No.78 fault plane, seismic profile](image)

The analysis of fault written off: Through well-to-seismic integration, four faults were written off in the sa II formation, which were known as No.55, No.72, No.791 and No.801, the logging interpretation of these four faults in the sa II formation has no breakpoint, the original recognized fault is the projection of the lower fault and part of the stratum in this oil formation, the following is an example of No.72 fault to analyze the writes-off fault with well-to-seismic integration.

No.72 fault was identified in combination with seismic profile and ant tracking, after the well shock combined, it was verified that the breakpoint of No.72 fault below the putaoahua oil layer was No.724 fault extending downwards, Therefore, the breakpoints below the putaoahua oil layer of this fault were merged into the No.724 fault, then the breakpoints were recombined and canceled the No.72 fault.

Fault analysis of length variation after well-to-seismic integration: The extension length of the head and tail of most faults changes after well-to-seismic integration, among them, the extension of the
head of No.78 fault varies greatly. The original understanding directly projected the formation breakpoint encountered at the head of the fault to the oil layer, resulting in the original understanding that the head of the No.78 fault existed in the oil layer. After the re-implementation of well-to-seismic integration, the seismic section combined with the coherence block section analysis shows that the head of the No.78 fault has no fault loss, and the original 10 formation breakpoints at the head of the No.78 fault belong to a reasonable group after recombination, so the head of the No.78 fault does not exist in the oil layer.

Split fault analysis: Compared with the original known faults, more faults are disassembled after well-to-seismic integration, For example, the original length of No.76 fault is 3.1km, and it is divided into two parts after well-to-seismic integration, the extension length is 1.2km and 1.8km respectively. In order to verify the rationality of the explanation, the dynamic data of oil and water well near No.76 fault were analyzed. Well N2-D5-29 in the fault zone is a production well of the primary infill series, and the target layer is putaohua II oil layer, which belongs to the high, medium and low permeability oil layer. Since the production started, the fluid yield has been maintained at about 40t/d, with the flow pressure of 4.0MPa and the total pressure difference of 0.3MPa. In 2001, after the loss shut-in of injection Well N2-5-138 in the the same area, the fluid production of this well decreased to the minimum of 7t and the flow pressure decreased to 2.62MPa, in 2004, after the Well N2-5-138 was overworked and slanted, the fluid production volume of the Well N2-D5-29 rose to 40t again, and the flow pressure reached 4.0MPa. At present, the fluid production volume remains at 35t and the flow pressure is 4.32MPa, formation energy is abundant, it indicates that the well is well connected with well N2-5-CS138 in the primary infill injection well, forming an injection-production relationship, this proves the rationality of No.76 fault split after well-to-seismic integration, and the fault in the middle area is written off.

5. The design and application of well-to-seismic integration in fault study area
Two development and adjustment methods for complex fault area after well-to-seismic integration: For the area where the fault changes and the original well pattern injection and production are not perfect after well-to-seismic integration, the injection-production relationship is improved by the combination of new well drilling, Oil well injection and water well production; For the area where the fault changes and the original well pattern injection and production are perfect after well-to-seismic integration, the remaining oil potential is explored by means of hole filling and fracturing.

According to a new understanding of fault development characteristics after well-to-seismic integration, combined with the development characteristics of each reservoir in the pure oil area in the west and the current status of exploitation, On the basis of the original pattern production method, the injection-production relationship of each series is improved by drilling new Wells and transferring some oil Wells in the area with dense faults between faults 71# ~ 81#, after the adjustment, a total of 184 adjustment Wells were deployed in the injection-production system, including 69 new Wells (25 injection Wells, 44 production Wells) and 9 transferred Wells in the fault area with well-to-seismic integration. After the adjustment, 48 Wells have been put into production, with the average daily fluid output of a single well at the initial stage of 48.9t, daily oil output of 7.2t and comprehensive water content of 85.4%, in the fault area with well-to-seismic integration, 13 Wells were put into production, In the initial stage, the average daily fluid output of a single well was 46.0t, daily oil output was 9.3t, and the comprehensive water content was 79.8%, Compared with the new Wells in the adjustment area of the injection and production system, the daily oil production increased by 2.1t and the water cut was 5.6 percentage points lower, which achieved a better development effect.

6. Conclusions
(1) Good longitudinal accuracy of logging breakpoints can determine the exact depth of breakpoints and identify faults with small fault displacement. But the finiteness of the number and location of well breakpoints on the same fault makes it difficult to accurately describe the 3D fault plane; The combination of longitudinally accurate logging breakpoints and transversely continuous seismic data,
can improve the accuracy of structural interpretation and describe the spatial morphology of fault more accurately.

(2) With the upgrading of fault interpretation in the study area, the fault morphology is more accurate from 2d planar breakpoint combination, 3d spatial breakpoint combination, seismic fault interpretation to well-to-seismic integration, at the same time, the well-to-seismic integration based on the trend surface of seismic interpretation, makes the structure approach to the real underground situation.

(3) Comprehensive verification of fault description of well-to-seismic integration and dynamic analysis, which are formed by data guidance of logging breakpoint, seismic profile tracing and comprehensive identification of attribute body, provides reliable technical support for the application of interpretation results into actual production, and obtains better application effect.

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