Research Progress of Seismic Data Processing in Fault Interpretation and Recognition

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***Abstract*— Fault is the main factor to control the formation and distribution of oil and gas field. It is important to find out the shape and distribution of the fault. The traditional fault interpretation method is easy to be influenced by subjective factors, the reliability and the accuracy is not high, and the work efficiency is low. Therefore, it is hoped that the interpretation of the seismic data in the construction of the potential to improve the accuracy and speed of interpretation. For a long time, people have made a lot of efforts to accurately describe the fault system, put forward and applied a lot of description methods, and successfully extracted from the 3D seismic data of many outstanding fault information discontinuity attributes, such as slice technology, coherent body belongs to the technology, the variance of the technology, the angle of the angle of the property and edge enhancement technology, etc.. Along with the continuous improvement of the fault description method, the automatic identification of the fault becomes possible. In this paper, the following contents are discussed in detail: firstly, the characteristics of 3D seismic fault are introduced, and the performance of fault in time profile is summarized as 6 kinds, and a practical method of semi automatic fault interpretation is obtained. Secondly, several seismic fault interpretation methods and the extraction method of the fault enhancement attributes are introduced. The former includes the conventional fault interpretation analysis method and the fault slice interpretation method. At last, the automatic extraction technology of fault, the method of semi automatic fault recognition of artificial neural network and automatic extraction of the ant colony algorithm are introduced.**

***Keywords*—**Seismic data interpretation; Fault; Automatic fault recognition technology; Seismic coherence cube technique

I. INTRODUCTION

In seismic exploration, seismic data interpretation is a very important link, and it is one of the most important information to understand the structure of the crust. When the stress exceeds the strength of rock, the fracture is one of the most common geological phenomena, and the whole process of the exploration and development of oil and gas field. There are two kinds of common faults, such as joint (joint) and fault (fault). Fault in the process of oil and gas migration may play a role, it may play a role in sealing. With the theoretical exploration to the deep development, quantitative study of transportation system has become oil and gas reservoir research is an important part, among which the fault is one of the three carrier systems and difficult to study. The conventional fault interpretation method is that the vertical section and horizontal slice of the 3D seismic data is interpreted by the vertical and horizontal slices, which is usually along the main direction or the vertical line by line. Then the fault interpretation is achieved by the discontinuity of the visual identification. And when the system fault in this area is complex and fault trend is unknown, explaining the combination of fault is facing great difficulty, therefore to explain the staff hope that through the extraction of seismic data of potential structural information, to improve the speed and accuracy of fault interpretation. In the oil and gas exploration in the late development stage, explain and clarify the fault distribution to implement recoverable reserves, capacity building and management of the reservoir and its potential and has very important significance. Therefore, the fault identification in seismic image is very important to study the structure of the earth layer, and is an indispensable part of the oil and gas exploration industry.

II. D-SEISMIC FAULT FEATURE ANALYSIS

A. Characteristics of fault in seismic image

In the earth's crust, the formation of the rock is broken up to a certain intensity, and it is called a fault, which is obviously relative moving along the fracture surface. Fault often breaks the horizon, causing a shift in the horizon. The type of fault is a wide variety of types, and the performance

of the time section is also varied, but it can be concluded that there are several [1]:

(1) The reflected wave is in phase with the same event. The characteristics of the geological fault is the fault of the strata, and sometimes it can be reflected in the seismic section.

(2) The number of reflected waves in the event of a sudden increase or decrease or disappearance of a sudden change in the wave group interval.

(3) The reflection interface of the occurrence of mutations, or "blank with scattered reflection".

(4) A group of reflected wave groups is obviously strong phase transitions or torsion, which may be a reflection of a small fault. However, due to the change of the lateral lithology also caused strong phase transition, in this case, it should be a concrete analysis of the problem.

(5)In addition to the strong phase transition, there are also the lateral seismic facies of the catastrophe, it may be a reflection of the fault.

(6) The emergence of special waves.

B. Image feature extraction and recognition of 3D seismic tomography

At present, the high resolution seismic profile can reflect the fault 3M, which is about [2], and it can be used for the seismic exploration. The fault in seismic time section can be identified by the change of the reflection wave phase axis, and the linear feature of the fault can be seen in the original section of the fault line.

According to the result of above difficulties analysis, due to the influence of fault zone, seismic data in the adjacent seismic traces horizon is not stable, in the time section, using the reflection wave phase axis staggered, phase transformation, inphase axis branch and annihilate, the interpreter used to determine the breakpoint location characteristics determine the breakpoint, and then according to the interpretation of the breakpoint fault line. Although this is the most reliable method to deal with the 3D seismic data by the method of two-dimensional interpretation, it is the most reliable method to join the interactive processing. It is very difficult to realize the 3D automatic interpretation because of the particularity of the seismic interrupt layer data. Therefore, based on the characteristics of the present two-dimensional fault interpretation, a practical method for the interpretation of the semi automatic fault is obtained.

First, the use of the method of structural orientation of the image enhancement of the line of the image, the information of the line is obtained by the structural orientation of the line. The method of identifying the horizon line. The main point is that the breakpoint is located in the seismic profile. The analysis is made on the basis of the analysis. The analysis is obtained from the point. When The forward or backward rolling seismic profile of the seismic profile, which is based on the interpretation results of the fault lines, the fault line is carried out by the triangulation.

III. SEISMIC FAULT INTERPRETATION METHOD

For a long time, a lot of research work has been carried out on the accurate description and interpretation of fault system, and a lot of interpretation methods have been proposed. From the initial conventional fault interpretation analysis to fault section analysis method, with the further development of computer technology and further integration with other subjects, the lateral continuity of seismic data is weakened.

A. Conventional fault interpretation and analysis

In seismic data, the fault is mainly reflected by the displacement or interruption of the reflection horizon, and the lateral amplitude is not continuous. There are obvious differences between the two sides of the fault. Therefore, the conventional method is to analyze and explain the fault system. The conventional method is to follow the direction of the main line, or to pick up the fault line from the vertical direction of the fault. The 3D seismic data body is a favorable condition for accurate identification and tracing of faults. In the 3D data volume, the interpretation of the spatial extension and contrast of the fault is caused by time slicing or cutting along layer. However, the spatial extension of the fault in the control layer is the first to be affected by human factors, and the reliability is lower in the case of poor quality of seismic data. Therefore, the conventional fault interpretation and analysis method has the disadvantages of long period and strong subjectivity, and the fault system is more complex, or the fault occurrence is parallel to the formation and can not be formed.

B. Fault slice interpretation method

A..R.Brown first proposed the method of fault section in 1987, and used this method to explain the fault accurately, and analyze the small and small faults of the main faults. Interpretation of the tomograms of specific practices: first,

along the fault hanging wall and footwall, in parallel to the section of the spatial amplitude extraction section, forming a series of fault section, and put the slice projection to CDP or survey line direction on, become a conventional vertical profile, and then the conventional interpretation method to explain. This reason is due to the fault section in the space business only to cut fault hanging wall and footwall strata, so there is no fault footwall strata faulted interference, therefore sequence characteristics and stratigraphic relations remain unchanged, horizon lateral continuity, relatively easy to contrast. Moreover, the farther from the fault plane, the more clear that the layer is close to the fault plane, and the continuity of the slice is gradually changed. Therefore, starting from away from the broken level fault section can be the exact interpretation of footwall strata has been extended to the position as close as possible to the fault plane. It can be inferred by adjusting to determine the optimal fault plane position. This analysis method, makes full use of the strata in fault plane in the hanging wall and footwall of lateral continuity, used this method to explain the fault location and fault on both sides of the formation of the relative fault broken relationships than the conventional method accurately. In addition, the level sections along the fault can also directly explain footwall and the main fault intersecting plumes of small faults, provide good conditions for the use of seismic data to study the fault sealing. But due to the limit of the migration velocity precision, it is very difficult to all diffracted wave are convergence fault plane, so in practical application is difficult to accurately determine the fault plane and slice fault interpretation method essentially just a data representation techniques, it must be based on results of preliminary fault interpretation. Therefore, the traditional interpretation method cannot be found Shun layer fault. The method is also unable to identify, and the fault level adjustment of the position of the explanation requires repeated generation of fault sections, so its workload even than the conventional method.

IV. Extraction method of fault enhanced properties

The 3D seismic data contain abundant information of stratum and lithology. However, the interpretation method of conventional 3D seismic data is very difficult to be hidden in the 3D seismic data. In order to avoid the random, the result is more intuitive and clear. Because the 3D seismic data is extracted from the 3D seismic data, the fault property is the basis of automatic fault tracing, which directly affects the effect of the tracking. In this paper, the basic principle and calculation process of the first generation of the first generation to the third generation of coherent body algorithm are briefly introduced in this paper.

A. Seismic coherence cube technique

Seismic coherence cube technique is using seismic data to calculate the correlation, not related to the data highlight. It is generally believed that the strata in the original strata are continuous in the horizontal, even if there is a slight change in the process, so the seismic waveform has a horizontal similarity. The noise, lithology, fault and fracture development in seismic data processing can affect the correlation between seismic traces. In reflection seismic exploration, excited by the source of pulse wave in the downward propagation process, encounter wave impedance interface, based on the theorems of reflection and transmission, reflection and transmission. The form of seismic waves. When the seismic wave propagates in the horizontal uniform layer, the transmission path and the difference of the reflection wave are very close to each adjacent channel. Therefore, the reflection wave of the same reflection layer is close to that of the reflection wave. The coherent data body technique is used to describe the lateral heterogeneity of the formation and lithology by using the similarity of the adjacent seismic signals. In particular, when there is a fault in the earth, the reflection wave of the adjacent channel will have different degrees of change in the transmission, the amplitude, frequency and phase, which is completely irrelevant and coherent. For the formation of the local deviation, the reflection wave between adjacent channels is a part of the above two cases. According to the coherence cube algorithm, the coherent values are calculated for the occurrence of the offset data volume, and the corresponding data body [3] is obtained. Coherent body technique is a powerful feature of seismic attribute interpretation, which is developed in recent years. It is realized by the calculation of the similarity between the word and the like. In the interpretation of seismic data processing, multi-channel correlation technique has been successfully applied to static correction, velocity analysis, and automatic 3D data layer. However, this technique has been used as a numerical algorithm for the estimation of seismic coherence.

B. Other techniques for enhancing discontinuities

Since the coherent body technology has been widely used, many of the properties, such as the angle of inclination and azimuth, the property of chaos and the variance of the angle, have been used. The initial dip angle and azimuth angle are the effects of the interpretation of the horizon, and the second generation of coherent body algorithm can give out the true dip angle and azimuth angle, with the appearance and improvement of coherent body technology. Has the special significance of small fault structure dip and azimuth attributes to identify the coherence is difficult to identify; chaos is a kind of texture attributes, chaos is a measure of the value of amplitude and regularity of chaos, and the fault zone due to various scattering and diffraction of mutual influence, in the seismic record usually the reflection amplitude be an important parameter, so chaotic property is also used to identify the fault attributes using local variance; the variance value of inconsistency to measure the reflection amplitude signal, calculating method of variance in 3D seismic data body cut is a very thin layer level, and then calculate the local variance the amplitude of each point value. In the reflection layer, the amplitude of the amplitude is small, so the corresponding variance value is small. If the change of the amplitude is near the fault zone or the change of lithology, the corresponding values of the variance are larger. At the same time, in the calculation of variance, the dip angle estimation is used to guide the formation of the local estimation. It can be used to overcome the influence of the slope or the fluctuation of the horizon, and the lateral variation of the layer is also used to identify the important parameters of the fault. The properties of these properties are in common, which is to weaken the layered characteristics of the strata, and to change the layer between the layers. The extraction of these attributes are implemented in a certain time window or space, and there is a certain width of the discontinuous interface, which can be used to eliminate the influence of the formation and the effect of the application of these properties are affected by the different degrees of the parameters.

V. AUTOMATIC FAULT RECOGNITION TECHNOLOGY

Since the coherence of a series of reinforced attributes of continuity have emerged, in order to shorten the cycle of interpretation, fault interpretation to overcome the subjectivity, automated or semi automated identification technology of fault gradually aroused the attention of scholars and researchers, the fault recognition method is the use of early data driven strategy, to identify the fault location by local continuity constraints, since 2000, many fault automatic or semi automatic identification methods have been proposed, which are quite famous: Randen（2010）[4] proposed "artificial ants" to suppress the noise in the continuous attributes; Gibson [5] in 2003 proposed to measure non coherent body continuity, then determine the fault plane model by highest confidence first (HCF), extraction method of extraction of fault surface; Do RN and James[6] used the signal processing technology of the and Tingdahl to achieve automatic fault extraction (AFE).In the following, the paper introduces the automatic extraction of fault automatic extraction and artificial neural network, and the automatic extraction of ant colony algorithm.

A.Automatic Fault Extraction，AFE

This technique is proposed by Dorm and James in 2005, which uses signal processing technology of the fusion of geological prior knowledge to realize automatic extraction of fault. The specific process of its realization is as follows: firstly, using coherent data volume calculation of intrinsic coherence algorithm based on structural analysis, the coherence using classical destriping operator at each level were estimated and the residual acquisition footprint; due to the faults in the space has a certain length, in which every time or depth slice through enhanced linear features to achieve the purpose of fault enhancement; linear feature enhancement data, then the data of fault enhancement, to eliminate some non fault response, such as river boundary, pinchout and unconformity, the response and fault is different in vertical direction. No extension, on this basis can be strengthened through the vertical vector method to achieve fault enhancement purposes; and then get the fault enhancement body of data respectively. The vector of fault line is extracted along the vertical direction and horizontal direction. Finally, the optimal and combination of the fault line is obtained. The main features of the automatic fault extraction technology are: the fault extraction of the coherent body before the full preprocessing, according to the characteristics of the fault in the coherence cube and the change of the angle, combined with three-dimensional visualization technology to complete the automatic extraction and combination of fault. This technology is also integrated into the commercial software Epos, which has

been widely used. But such technology from nature to see just a coherence enhancement techniques, it enhances the coherent body of fault response, weakening the impact noise and other like fault response, but it did not enhance the fault in response to a coherent body of continuity, therefore use this method to extract the fault plane are relatively small pieces, mix up more difficult.

B. Semi automatic fault identification method for artificial neural network

The first use of the method of fault of semi automatic identification, this method is using the method of seismic attributes and artificial neural network to recognize the objects, the earliest application to identification and cylindrical ore body in 2005. With a number of steps: the first step in the seismic record of the vertical section of the vertical section and time slices on the record of a few vertical sections and time slices on the other hand, and in the other part of the seismic data, this step can be done on a single attribute of the seismic data. The second step is to calculate a single attribute of the seismic attributes. The third step is to calculate a single attribute of the seismic attributes. The step is to calculate the single attributes of the seismic attributes. The value of the output value of the non fault is lower, required To point out, the training process needs to have 10% to 25% of the overall data as training sample, to ensure the reliability of training; finally, the entire seismic data to calculate all the selected attribute values, and then the trained neural network is applied to the seismic data and seismic attributes, the final output of a representative of the reliability of the data body. This method can realize the semi automatic identification of the fault, and explain the higher level of interpretation to some extent. However, this method is based on the preliminary interpretation of the results, still with a certain subjectivity, and this method to calculate a large number of seismic attributes, the amount of calculation is very large, time-consuming, strong anti noise is not strong, due to the lack of spatial characteristics of the fault, the response of similar faults can not be effectively suppressed.

C. Three dimensional seismic fault identification method based on ant colony algorithm

In this method, the seismic coherence cube is considered as a gray image, and the clustering center is determined according to the histogram distribution of gray image. This method does not take into account the spatial geometry of the fault, but only completed the simple clustering analysis. The noise in the original coherent body is not processed. In 2010, the paper proposed the direction constrained ant colony tracking algorithm, which is based on the application of ant colony algorithm in the image edge detection, and the problem of the automatic recognition of seismic fault attributes is proposed. Ant colony algorithm has several characteristics as follows:

(1)Parallel distributed computing ability of all the ants are independent, unsupervised and all the points of the search solution space, in essence, is an efficient parallel search algorithm.

(2)The strong global optimization ability algorithm uses the random probability transfer rule instead of the deterministic rule, which can avoid the convergence to the local optimum.

(3) It is easy to combine with other algorithms in the process of constructing the solution to construct the ant colony algorithm, which can be easily combined with some effective prior knowledge. And it can be convenient to handle constraints. At present, the improvement of the algorithm is based on the idea of other optimization algorithms.

(4) Adaptive ant colony algorithm has no special requirements for the search space, which can be easily applied to various research areas without the need to adjust the algorithm to a great change.

To sum up the above fault automatic or semi automatic identification technology, it can be seen that the first step of all these techniques is to calculate the discontinuity of the fault enhancement attributes, and then use a variety of means to enhance the response of the fault, to suppress noise, to achieve automatic identification of fault. Therefore, the fault enhanced attribute can be considered as the basis of automatic fault recognition technology.

VI. CONCLUSION

Fault automatic recognition technology is a hot research problem, which is often involved in many subjects. In this paper, the methods of seismic fault interpretation, fault identification and automatic extraction are discussed, and the corresponding conclusions are drawn:

(1) Research and summarize the research status of this paper and the characteristics of 3D seismic fault, the fault on

the time profile of the performance of the 6 types, according to the characteristics of two-dimensional fault interpretation, a practical method of semi automatic fault interpretation. Several seismic interpretation methods are summarized, including conventional fault interpretation analysis method and fault interpretation method.

(2) The automatic extraction technology of fault, automatic recognition method of artificial neural network, automatic extraction of ant colony algorithm is summarized. The shortcomings of the method of automatic fault identification are pointed out.

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