Application of the Coherence Cube Analysis Technology in Seismic Interpretation in X Oilfield

Yuxia Xin, Zuoji Tian, Zhizhang Wang and Tianwei Zhou

ABSTRACT

The coherence technology is an important means for analyzing spatial distribution discontinuity of data volumes and identifying fault distribution and micro-faults. With the coherence technology, stratigraphic structure features can be understood in detail, thus providing guidance to the interpretation work in the whole survey area. The paper describes the application of the coherence technology in X oilfield based on the coherence analysis principle and finally re-ascertains the faults in the study area according to the seismic information, logging information, production performance information, etc., thereby providing geologic bases for the study of the remaining oil distribution in X oilfield.

THE PRINCIPLE OF THIS TECHNOLOGY

There are very many methods for calculating seismic coherence cubes at present and their principle is virtually the same\(^{[1-4]}\). The paper uses the coherence coefficient method with strong resistance to interference. The calculation method is below:
Assuming that the cross-correlation function of two adjacent seismic channels x(n) and y(n) at time t is:

\[ C_{12}(t) = \sum_{i=-\frac{k}{2}}^{i+\frac{k}{2}} x(i)y(i) \]  

(1)

Where: k is time window length; in general the value of k is taken as 1/2~3/2 apparent periods. The autocorrelation function of the two channels is respectively as follows:

\[ C_{22}(t) = \sum_{i=-\frac{k}{2}}^{i+\frac{k}{2}} y(i)y(i) \]  

(2)

\[ C_{11}(t) = \sum_{i=-\frac{k}{2}}^{i+\frac{k}{2}} x(i)x(i) \]  

(3)

Then define the coherence coefficient of signals x(n) and y(n) at time t as follows:

\[ C_i(t) = \frac{C_{12}(t)}{\sqrt{C_{11}(t)C_{22}(t)}} \]  

(4)

\[ C_i(t, p) = \frac{C_{12}(t, p)}{\sqrt{C_{11}(t, p)C_{22}(t, p)}} = \frac{\sum_{i=-\frac{k}{2}}^{i+\frac{k}{2}} x(i)x(i)}{\left[ \sum_{i=-\frac{k}{2}}^{i+\frac{k}{2}} x(i)x(i - p) \right] \left[ \sum_{i=-\frac{k}{2}}^{i+\frac{k}{2}} y(i)y(i - p) \right]} \]  

(5)

Scan the value of p within 1/2~1/2 apparent periods and take the maximum of C1(t,p) as the coherence coefficient of signals x(n) and y(n) at time t considering dip angle:

\[ \overline{C_i(t)} = \max_{\frac{-1}{2} < p < \frac{1}{2}} C_i(t, p) \]  

(6)

In contrast to the coherence coefficient of 2D channels, the coherence coefficient of 3D channels considers a dip angle parameter q. Automatically search the value of p and q, and take the calculated maximum as the coherence coefficient value of this point. The calculation formula:

\[ \overline{C_i(t)} = \max_{\frac{-1}{2} < p < \frac{1}{2}} \max_{\frac{-1}{2} < q < \frac{1}{2}} C_i(t, p, q) \]  

(7)
Fault Interpretation Method for X oilfield

Fine interpretation of faults and that of horizons are an organic integral and an important link in structure interpretation. It is necessary to take full advantage of multiple kinds of seismic information to correctly identify faults. Multiple methods and means are needed to repeatedly recognize faults according to the attitude and location of fault planes and then the fault interpretation precision can be improved\[5\].

(1) Use the time slice plan view of coherence cubes and determine the planar assemblage of faults.

Coherence analysis is amplitude-based calculation. Taking advantage of multi-channel similarity, 3D amplitude data volumes are converted into correlation coefficient data volumes and discontinuity is highlighted on display by emphasizing non-correlation anomalies.

As shown in Figure 1, the coherence cube technology is used in fault interpretation and combination, thereby avoiding the randomness of the interpretation result and compensating for the result unreasonableness caused by insufficient experience of interpretation personnel. The result can be directly applied in 3D seismic data volumes, and taking advantage of the automatic tracking function, fine interpretation of faults is achieved, so the accuracy of the obtained interpretation result and planar assemblage has been greatly improved.

Faults are developed in the survey area. To ensure the precision of the interpretation result, firstly carry out coherence cube processing of the main target formation before fault interpretation. The planar extension and assemblage relation of faults on coherence cubes are reflected very clearly.

(2) Process sections using coherence data volumes, determine the assemblage of faults longitudinally, and correct and verify the correctness of fault assemblage.

(3) Prevent wrong fault assemblage, track lines one by one, and carry out mutual projection verification of crosslines and in lines.

(4) Select the seismic section of any line for interpretation and study the best fault point location of faults on plane and section.

(5) Determine the accurate position of fault disappearance through circumambient fault closure interpretation.

(6) Through the comparative analysis of regional fault systems, prove the consistency of fault assemblage and distribution with regional structure features.
(7) Identify small faults using the survey line in any direction vertical to the fault strike direction. Faults shall be interpreted mainly using the inline. Few faults diagonal with the inline shall be verified and corrected using any survey line vertical to the fault strike direction. Fault interpretation principle: Large faults are interpreted based on faulting of waves. Small faults are interpreted taking distortion of events as the main mark. Bifurcation, combination and distortion of events are another main basis for interpretation of small faults.

In order to meet the development needs of the oilfield, the target formation has been finely interpreted and faults have also been interpreted. After preliminarily completing fault interpretation, superpose the faults of the target formation and ensure the consistence of the fault assemblage schemes for different horizons. Reasonableness and reliability of fault interpretation have been ensured taking advantage of a series of technologies and means mentioned above.

**Fault Interpretation Result of X oilfield**

Finally, according to seismic information, logging information, production performance information, etc., the faults in the study area of X oilfield have been re-ascertained and 12 reliable faults have been determined, including 6 normal faults and 6 reverse faults. The two sides of 8 faults are not connected and those of fault F6 are partially connected. The property, strike direction and dip direction of these faults have been studied one by one. For details, see Table 1.
SUMMARY

(1) The coherence cube technology is used in fault interpretation and combination, thereby avoiding the randomness of the interpretation result and compensating for the result unreasonableness caused by insufficient experience of interpretation personnel. The result can be directly applied in 3D seismic data volumes, and taking advantage of the automatic tracking function, fine interpretation of faults is achieved, so the accuracy of the obtained interpretation result and planar assemblage has been greatly improved.

(2) According to seismic information, logging information, production performance information, etc., the faults in the study area of X oilfield have been re-ascertained using the coherence cube technology and 12 reliable faults have been finally determined, including 6 normal faults and 6 reverse faults. The two sides of 8 faults are not connected and those of fault F6 are partially connected.

Table 1. The study area’s fault table.

| Fault name | Property     | Strike direction | Dip direction | Comparison                        |
|------------|--------------|------------------|---------------|-----------------------------------|
| F1         | Normal fault | NE               | NW            | Original                          |
| F2         | Normal fault | Near-SN          | W             | Original                          |
| F3         | Reverse fault| Near-SN          | E             | Increase in the original length   |
| F4         | Reverse fault| Near-SN          | E             | Variation of the original location|
| F5         | Reverse fault| Near-SN          | E             | Variation of the original length  |
| F6         | Reverse fault| NE               | ES            | New fault                         |
| F7         | Normal fault | NE               | NW            | New fault                         |
| F8         | Normal fault | NE               | ES            | New fault                         |
| F9         | Normal fault | NE               | NW            | New fault                         |
| F10        | Reverse fault| Near-SN          | E             | New fault                         |
| F11        | Reverse fault| Near-EW          | S             | New fault                         |
| F12        | Normal fault | NE               | ES            | Variation of the original direction|

REFERENCES

1. Hou Bo-gang, Wuda Bala, Yang Zai-yan. “Seismic coherence cube technology and its application” [J]. Geoscience, 1999, 13(1): 121-124.
2. Li Yu-xin. “The application of the seismic coherence technique to the interpretation of faults and sedimentary facies in the Shengli Oilfield” [J]. Sedimentary Geology and Tethyan Geology, 2006, 26(3): 67-71.
3. Zhang Jin-miao, Wanf Chun-hong. “An application of coherence technique in full 3D seismic interpretation” [J]. China Offshore Oil and Gas, 2000, 14(4): 277-282.
4. She De-ping, Cao Hui, Wang Xian-bin. “Coherence cube with application to 3-D seismic interpretation” [J]. Geophysical Prospecting for Petroleum, 1998, 37(4): 75-79.
5. Bahorich M.S., Farmer S.L. “3-D seismic coherency for faults and stratigraphic features” [J]. The Leading Edge, 1995, 14(10): 1053-1058.