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Application of Seismic Attribute Optimization in Reservoir Prediction

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Abstract: Seismic attributes includes physical attribute and geometry attribute, which quantifies specifically the characters of geometry, kinematics, dynamics or statistics in seismic data. Although geometry attributes can be easily accepted and straightly identified by the sense organ of men, the physical attributes derived from abstract process and mathematics are better than geometry attribute in seismic reservoir prediction. Therefore, seismic attribute is mainly referred to physical attribute calculated by mathematical algorithm. Reservoir prediction by seismic attributes is widely used in geophysics. Since 1980s,pattern recognition technique is paid great attention to, and the reservoir prediction techniques ,such as a fuzzy pattern recognition, statistic pattern recognition, neural network pattern recognition and function approach ,have been successively developed .The predicted objects include hydrocarbon, reservoir thickness, lithology and reservoir porosity. In reservoir prediction, the selection of seismic attribute is accomplished by experience of interpreters, whose effect is subject to better geological conditions, simple predicted objects, and higher S/N in original seismic data. However, under the other conditions, the effect of prediction is worse. In fact, there exist complex relations between predicted objects and their seismic attributes. The seismic attributes sensitive to predicted objects are not totally the same in different areas and reservoirs. They are also somewhat different even for same reservoir and same area. The optimization technique of seismic attributes is an effective means for solving the above questions. The optimum methods of seismic attributes mainly include the dimension-reduced projected profile and cluster analysis etc. Its purpose is to optimize the minimum seismic attributes or seismic attribute esgroup, which are the most sensitive (or most effective, most representatives) to studied problem, in order to increase reservoirs prediction precision and to improve the effect of processing and interpretation related to seismic attributes. The obvious effect of reservoir prediction in CB31 area has been achieved by using the optimum method of seismic attributes. This area is located at the graben belt that is between the drape structures of CB30 buried hill and the drap structures of Changdi buried hill. Its main reservoirs are the sand bars, formed by mean deriver sediment, in Neogene Guantao Fm, with poor continuity and small distribution. Because the distribution of depositional sand bodies are unstable in lateral and vertical direction and because the drilled thickness of sand bodies is usually less than 10m, the sand bodies have no corresponding re-flection on seismic sections, resulting in the bigger difficulty in reservoir prediction and description. Therefore, the recognition of its pool-forming factors and hydrocarbon accumulation rules has been disputed for many years. With the help of the theory and methods of seismic attribute optimization, the seismic attributes of predicted reservoir are optimized. Meanwhile, one of the optimized seismic attributes, the wave peak number, is verified with seismic forward modeling, and demonstrating the reliability of the method. Based on the above works, the stratigraphy, reflected wave velocity, structure and electric property have been studied; the pool-forming factors and hydrocarbon accumulation have been analyzed; the areal distribution of sand bodies have been basically identified; more than 30 sand bodies have been described. As a result, the oil in place reserve in the CB31 well block is estimated to be 40 million tons.

Keywords: Reservoir Prediction; Seismic Attribute; Attribute Optimization; Forward Modeling.

Introduction

Because the relationship between seismic attributes and the predicted complex objects, different work area and the different reservoirs of the predicted target sensitive (or the most effective, the most representative) seismic attributes are not identical. Even in the same work area, the same reservoir, predict the object corresponding to different sensitive seismic attributes is different. At the same time, after all, it is secondary seismic reflection data, reflecting the complexity of reflection geological background underground geological conditions on seismic data alone ** Multiple Solutions. Currently oil yet to find an effective solution to the problem. Since the seismic attribute optimization technology can improve the prediction accuracy of seismic reservoir can be carried out more efficiently reservoir description, to further improve the success rate of drilling, with significant economic and social benefits, showing that the technology can solve these problems.

Theoretical Basis

Seismic attribute specific measurement geometry, kinematics, dynamics or statistical characteristics of

seismic data contained in [1], can be divided into physical properties and geometrical properties of two categories. Geometric attributes easy to be accepted by the senses, to facilitate visual identification. However, the seismic reservoir prediction ability of abstraction and Exporting Physical properties mathematically much stronger than people. Therefore, we studied seismic attributes mainly refers to the physical properties of the mathematical calculation method

Only post-stack seismic attribute extraction processing parameters obtained can be divided into five major categories of 39 kinds, the actual effect is as follows:

- The amplitude statistics class: a combination of amplitude characteristics of the fluid reservoir lithology and porosity rivers, deltas, some type of reef, unconformity strata tuning effect, stratigraphic sequence changes and other factors;
- Complex seismic trace statistical categories: complex seismic trace is actually a Hilbert transform of seismic signals, it helps analyze the gas, fluid characteristics, lithology, and the river delta, reef, unconformity, stratigraphic sequence, cracks, tuning and other effects;
- (frequency can) Spectral statistics class: it is the energy spectrum and the seismic signal characterization, reveals fracture zone, hydrocarbon absorption zone, tuning effect, lithology or sub-wave changes due to absorption;
- Sequence statistics class: to help characterize the sequence features, the main change is the energy, the polarity and amplitude comparison of critical analysis, to identify changes in lithology, hydrocarbon potential, depicts sequence stratigraphic features ,highlighting some amplitude anomalies;
- Relevant statistical categories: Road and Road for quantitative description of the similarities between help identify faults, pinch out, data quality, messy reflection.

Thus, the different attributes for different lithology sensitivity is different, in describing different objects the role is not the same.

Seismic reservoir prediction process, typically introduced various seismic attributes and reservoir prediction related. However, the increase in the property for an unlimited reservoir prediction will be adversely affected. Because: ① some seismic attributes may be relevant for the purposes layer itself, which reflects the change in shallow interference, if the properties entered uncritical, cause confusion; ② property will increase calculation difficult, too much data to take up a lot of storage space and computing time; ③ large amount of property will certainly contains many interrelated factors, resulting in duplication and waste information; ④ on pattern recognition is concerned, when the fixed number of samples, the properties will be too much the deterioration of the classification results. Therefore, specific issues, all from seismic attribute set to pick the best set of seismic attributes of multiple solutions to reduce and improve the reservoir prediction accuracy, which is the seismic attribute optimization problem.

Optimization

Use of human experience or mathematical method, optimized for solving the problems of the most sensitive (or the most effective representative), attributes the minimum number of seismic attributes, or a combination of seismic attributes, improve seismic reservoir prediction accuracy improvement and earthquake property-related processing and interpretation of results. This is the core of seismic attribute optimization.

- Axis mapping. Seismic attribute mapping dimension reduction method is more commonly used K-L transform [3], a lot of it is from the original seismic attributes
- Starting constructed few effective new seismic attribute [4].
- Select Properties. Seismic attribute selection can be optimized seismic attributes. In doing optimization operation, the objective function must be designed. Optimization objective function to determine flexible choice, different methods have different objective functions according to reservoir prediction method and seismic attributes. The simplest selection method is selected seismic attributes to reservoir prediction that the most influential property based on the knowledge of experts. Another possibility is to use mathematical methods to filter comparison [3,4], to identify properties with a maximum reservoir information.
- Cluster, intersection analysis. Cluster analysis, also known as point cloud analysis. It is in accordance with the object Relationships in nature or on the genesis of the object perform a quantitative classification of multivariate statistical analysis methods. Cluster analysis can be divided into polymerization and decomposition clustering analysis cluster analysis. Specific algorithms and formulas refer to the literature [5,6]. The basic principles of cluster analysis: a sample or variable ① if selected in the sub-group has never been good, put them to form a separate group; one pair of samples or variable ② if elected, there has been a appears in the group had good points, put another sample or variables are also included in this group; one pair of samples or variable ③ if elected are good points,

respectively, appear in the two groups, put the two groups link into a newGroup; ④ if one pair of samples or selected variables appear in the same group, then the sample is no longer the grouping.

EXAMPLE

Work area before

CB31 area is located graben CB30 buried hill drape structure and drape structural belt between the causeway, which is the main oil and gas series Tertiary Guantao reservoir meandering river deposits formed sand dam main difference between continuity of sand, small distribution range. Since the meandering river diversions frequently, so that the deposition of sand body in the transverse, longitudinal variations are larger [7], in addition to most of the wells drilled in the area of sand thickness in 10 m, and the reflection on the seismic section without a corresponding and difficult to explain tracking, reservoir prediction and description have greater difficulty, so many years of their accumulation of factors, understanding of hydrocarbon enrichment patterns of more controversial. Seismic attribute optimization of the formation, speed, construction, electrical and other areas were analyzed, and its accumulation factors of hydrocarbon enrichment patterns were studied to identify the basic distribution of sand bodies.

Predict reservoir distribution

The study, LANDMARK interpretation system RAVE (Reservoir Attribute Visualization and Extrapolation) software, the comprehensive utilization of all geological information including seismic, geological, logging, and other data, including engineering, math seismic attributes, clustering , regression analysis, similarity calculation, 2D / 3D mapping class group and cross plots, the final optimized seismic attributes and reservoir prediction is closely related to determine the distribution of reservoir

The basic idea of the sandstone reservoir seismic evaluation is: from the existing seismic data, analyzes development sandstone intervals to study the reflection characteristics, and to be compared with the drilling and logging data corresponding lithology, reservoirs using seismic attribute optimization technology, reservoir geometry description, determine reservoir depth, thickness, spatial distribution, an accurate description of reservoir evaluation. First, the practical significance of the 14 kinds of geological seismic attributes, use the intersection 2D array understand the relationship between various parameters. Depending on the size of the correlation coefficient can select or discard a particular property. If both attributes is very good, you can only choose one, the other can be discarded. By screening to optimize elected five major attributes: RMS amplitude (amplitude variation is very sensitive), reflecting the strength of the slope (reflection intensity regression analysis, fitting it in predetermined curve, the slope of output within the window), the energy half-life (describe the energy attenuation speed), the effective bandwidth (zero-delay auto-correlation values, the bandwidth becomes narrower, more similar signal, ground reflection characteristics simple, otherwise explain complex formation) and peak numbers (identification sandstone and mudstone inter bedded development band). Secondly, the use of 3D intersection, by the rotation of different angles, isolated clusters of multi-attribute characteristics, and more preferably meaningful on the clusters (Figure 1), through the delineation and choose, it will be mapped to the interpretation results base map finally, distribution of reservoir prediction based on multi-parameter clustering features known well.

Seismic Modeling

For this specific earthquake zone, geological conditions, given the low resolution of seismic data as well as sand and shale interbedded sedimentary characteristics, the need for forward modeling to determine the relationship between the study area and its sand sets of seismic attribute sand thickness, in this paper, the peak number and the thickness of the sand layer optimization of seismic attributes, one of the forward modeling. Figure 2a is a geologic model thin sand-shale interbedded design, since the income obtained synthetic seismograms (Fig. 2b) by self-excited, press attribute extraction control layer between H1-H2 to give the number of peaks, the peak number of a minimum of 9, up to 15, according to the peak corresponding to the number of accumulated sand thickness obtained Figure 2c.

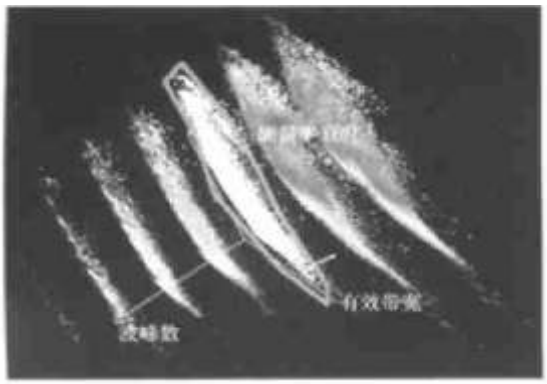
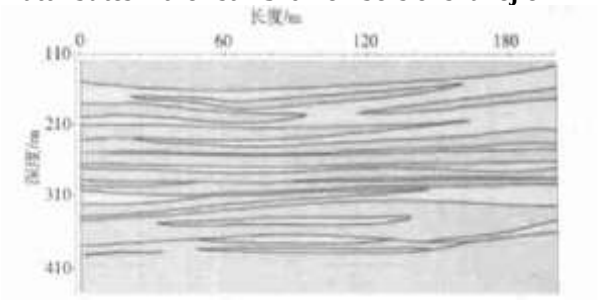
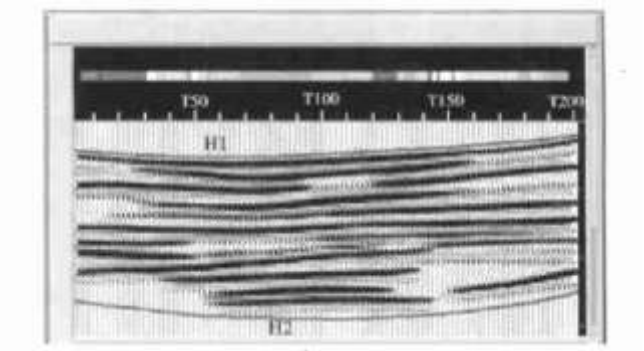


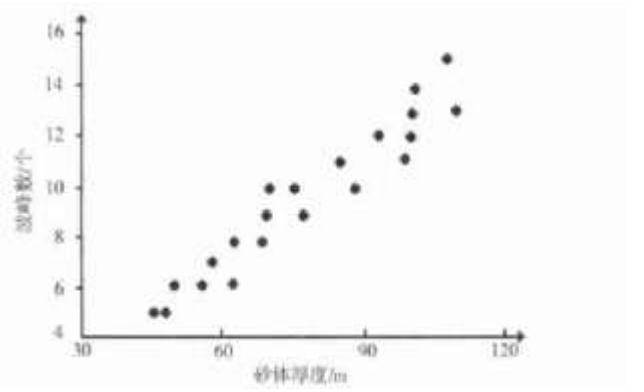
Fig-1:3D Correlation coefficients among seismic attributesin the 1st—3rdmembers of shahejie Fm



(a)



(b)



(c)

Fig-2: Forward modeling of sandy thickness a- geological model; b- Earthquake Response c- Peak numbers of the relationship between the thickness of the sand

Thus, the cumulative sand thickness and number of crests into approximate linear relationship. So, we can use the peak number of such seismic attributes to predict the development of sand and shale inter bedded with determining the lateral reservoir distribution.

Practical effect

By optimizing the seismic attributes will be mapped to the interpretation of the results of the base map, according to the well known multi-parameter clustering features Predictive Distribution reservoirs. FIG. 3 is the result of five kinds of left-attribute mapping along Chengbei 31 major reservoirs of the upper and lower 15 ms time window extracted in the end on the graph. By optimizing the seismic attributes, according to the number of peaks, the effective bandwidth, five kinds of clustering attribute parameters of the reflection intensity and rate of change, to make plane distribution area sandstone reservoirs (Fig. 3 right). As can be seen, the reservoir in the study area is mainly developed in two areas CB30-CB321 well area north and south of CB31-CB332 well region predicted results and drilling results agree well with the northern part of sand, now in development, and built several tons of production capacity. The CB31-CB332 well area south, only a few exploratory wells drilled, relatively low level of exploration. According to seismic attributes to predict the results described in this district a total of more than 30 sand, through overall analysis and evaluation, to provide drilling three wells, forecast oil reserves 4 000 × 104t

Conclusions and Recommendations

Relationship between seismic attributes and the predicted complex objects, different regions and different reservoir of sensitive seismic attributes are different; it is difficult to predict reservoir received satisfactory results with a single property. Seismic attribute optimization technique is an effective way to solve this problem, it can use a variety of effective earthquake prediction of reservoir properties, significantly improve the prediction accuracy.

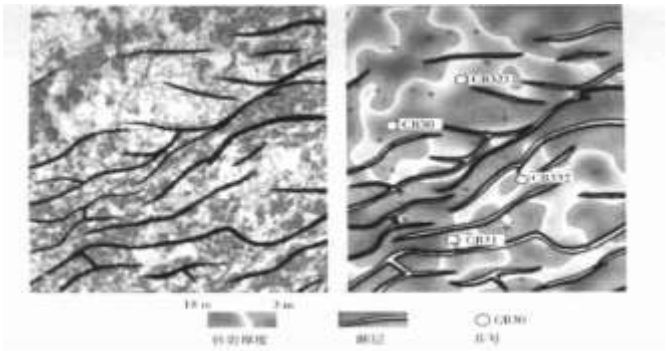


Fig-3: Optimizedmulti-attributes (the left) and reservoir prediction (the right) in Chengbei 31 wellblock

In the prediction of the various properties of reservoir, should be selected according to a combination of different properties and prediction target. In general, predict sand thickness selected amplitude and frequency of the class attribute class better predict when the hydrocarbon potential, the selected spectral type, the absorption coefficient and other properties will have good results. There can not be established to optimize seismic attribute libraries, only a single attribute joint interpretation thereof. If we can use the appropriate combination of seismic attributes from seismic attributes optimized library reservoir prediction, we will expand seismic reservoir characterization and optimization of range

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