Application of 3D AVO Interpretation Technique to Lithological Reservoir in the Hongze Area

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Abstract: In the Hongze Area, the reservoirs vary rapidly laterally and are controlled by many factors, such as structure, lithology, oil source, and so on. S-wave well log curves are calculated from an equation derived from multiple-attribute regression analysis of RT, DT, GR, and DEN logs. Representative P- and S-wave velocities and Poisson's ratio are statistically computed for oil and water bearing reservoir rock, shale, and calcareous shale in each well. The averaged values are used for AVO forward modeling. Comparing the modeling results with actual seismic data limit the possible AVO interpretations. Well and seismic data are used to calibrate inverted P-wave, S-wave, Poisson's ratio, and AVO gradient attribute data sets. AVO gradient data is used for lithofacies interpretation, P-wave data is used for acoustic impedance inversion, S-wave data is used for elastic impedance, and Poisson's ratio data is used for detecting oil and gas. The reservoir and hydrocarbon detections are carried out sequentially. We demonstrate that the AVO attributes method can efficiently predict reservoir and hydrocarbon potential.

Keywords: S-wave, Poisson's ratio, gradient, modeling, attribute calibration.

Introduction

AVO technology has been used widely over the past 20 years, from 2D to 3D (Lee et al., 1998) and from P-wave to S-wave or converted waves to carry out reservoir studies (Hu, 1995). Attribute research developed from the calculation of single amplitude variations to anisotropy and reservoir research using comprehensive multiple attribute analysis. Then the distribution of reservoir can be predicted (Li, 1994). The study data varies from single volumes to multiple data sets. In this study, four AVO attribute volumes, including P-wave (P), S-wave (S), gradient (G), and Poisson's ratio (σ), were computed from inversion using the Shuey (1985) formula during the processing of the 3D AVO data. The purpose of the study is to find a useful and effective AVO interpretation method.

The Hongze Depression is characterized by different oil sources from deltas in north to fans in south. A series of faulted noses and faulted anticlines have developed on the steep slope of the depression and the depositional system mainly consists of nearshore subaqueous fans. Reservoirs are controlled by both tectonic setting and depositional system. The deep parts of the depression mainly consist of lacustrine shale and marlite interbedded with sand lens bodies of slump fans, ends of subaqueous fans, and delta fronts. These sand bodies form many updip and lateral pinch-out reservoirs. The influence of tectonic setting and oil and gas migration on the northwest slope has superimposed many delta sand bodies that form structural-stratigraphic pools with source rock in lower position and reservoir in upper position. The depositional system changes frequently in the Hongze area, so reservoirs are all small in thickness, trap area, and reserve scale. It is difficult to identify those stratigraphic reservoirs with traditional technologies, so AVO technology may be a critical method to improve the success rate of exploration in this region.

AVO Interpretation

Calculation of the S-wave curve

In AVO analysis, Poisson's ratio can be computed from the S-wave curve. Also, the S-wave data can be used in
the inversion of elastic impedance. But the cost of acquiring an S-wave log is expensive, so generally S-wave curves do not exist in the common log sets. In this local area, only the Guan3 well has three S-wave curve sections. In general, the S-wave curve is computed using the empirical relationship from Castagna, et al. (1993) statistics. However, a prerequisite of this method is the determination of lithology, so the application is limited. In addition, the method has a defect if the lithology is not pure. In this study, the S-wave curves of the entire well and the other wells are computed using single and multiple attribute regression of the three sections of Guan3 data. The specific steps are as follows:

**Curve edit**

Generally the Resistivity (RT) log and the lithology logs (GR, SP, DEN, and etc.) are absent in shear wave log series and the routine combination log series do not contain the S-wave slowness (DTSM) curve. The common curve in these two log series is P-wave slowness (DTCO). With the DTCO curve as a bridge, the two log series can be combined, the abnormal data removed, and the depth repositioned. In well Guan3, there are three discontinuous sections of S-wave curves with a total length of 740 m. After removing the abnormal data, the three sections were joined together (the sampling rate is the same as the common curve) and a new curve is formed (see Figure 1).

**Single attribute regression**

The S-wave curve is the dependent variable and RT (reflecting permeability), GR (reflecting lithology) and Density and P-wave slowness (reflecting lithology and physical properties) are taken as the independent variables. Many routine transformations are taken with the dependent and independent variables (reciprocal, square, root, logarithm, and etc.). Correlation coefficients and absolute errors between dependent variables and independent variables are calculated and the results are sequenced by correlation coefficients.

Table 1 displays the 12 dependent variables with good correlation coefficients. From the table, we can see that the S-wave curve has good relationships with RT and DEN and the best relationship with the reciprocal of RT (Figure 2). The correlation coefficient is 0.8829 and the absolute error is the minimum. This demonstrates that the resistivity curve not only contains abundant information of lithology

![Fig.1 Lithology of the target formation in well Guan3 and the well log characteristics.](image-url)