Journal of Geoscience and Environment Protection, 2024, 12, 48-56
https://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

Application of Secondary Logging Interpretation—Taking Yan 9 Reservoir in X Area as an Example

Jiayu Li[1,2]

[1]School of Earth Science and Engineering, Xi'an Shiyou University, Xi'an, China
[2]Shaanxi Key Laboratory of Petroleum Accumulation Geology, Xi'an Shiyou University, Xi'an, China
Email: 1046767299@qq.com

How to cite this paper: Li, J. Y. (2024). Application of Secondary Logging Interpretation—Taking Yan 9 Reservoir in X Area as an Example. *Journal of Geoscience and Environment Protection, 12,* 48-56.
https://doi.org/10.4236/gep.2024.126004

Received: May 6, 2024
Accepted: June 14, 2024
Published: June 17, 2024

Abstract

Logging data and its interpretation results are one of the most important basic data for understanding reservoirs and oilfield development. Standardized and unified logging interpretation results play a decisive role in fine reservoir description and reservoir development. Aiming at the problem of the conflict between the development effect and the initial interpretation result of Yan 9 reservoir in Hujianshan area of Ordos Basin, by combining the current well production performance, logging, oil test, production test and other data, on the basis of making full use of core, coring, logging, thin section analysis and high pressure mercury injection data, the four characteristics of reservoir are analyzed, a more scientific and reasonable calculation model of reservoir logging parameters is established, and the reserves are recalculated after the second interpretation standard of logging is determined. The research improves the accuracy of logging interpretation and provides an effective basis for subsequent production development and potential horizons.

Keywords

Secondary Logging Interpretation, Reserve Recalculation, Yan 9 Reservoir

1. Introduction

The rapid development of oil reservoirs in the Ordos Basin in recent years, most oil fields have entered the middle and late stages of development, as well as the oil fields in the Hujianshan area (Wang, 2019; Zhang, 2020). At this time, the secondary interpretation of logging is an important part of this period. Usually, the logging interpretation model is established by integrating logging curves and core data, so as to guide the reservoir development and reserve estimation in the study area. For the problems existing in the study area, the secondary interpretation of logging can correct the previous logging interpretation results (Xie et al., 2020), and can also obtain more accurate logging data through secondary interpretation. At the same time, combine between with logging data and geological information of the study area, more and more abundant geological data are obtained, which plays a vital role in the exploration of the study area and the identification of potential layers (Zhang et al., 1998).

The research area is located next to the Tianhuan sag in the Ordos Basin. The geographical location of the area is excellent. In the proven area, it is found that the Yan 9 oil layer group has good content and has a good prospect for exploration and development. However, the overall reservoir scale in the study area is small, and the reservoir physical properties are controlled by many factors (Xiao et al., 2023; Wang et al., 2023), and the relationship between various factors is complex. If only a simple prediction is made in the study area, there will be great errors, which brings great difficulties to the determination of potential horizons. In order to effectively solve these difficulties, it is necessary to deeply explore the physical properties, lithology, electrical and oil-bearing characteristics of the reservoir in the study area and the relationship between them (Zhen, 2022). Taking the "four properties" relationship as the breakthrough point, the interpretation parameters are determined, the interpretation model is established, and then the reserves are predicted (Bu et al., 2010). Therefore, it is of great significance for the secondary logging interpretation of the Jurassic in this area (Liu et al., 2012; Zhang, 2020).

2. Logging Data Standardization

Logging data standardization means that in the same logging section as the target layer, the layer with stable distribution, similar physical properties or regular changes in the whole area is selected as the standard layer, such as dense limestone and pure mudstone; Sandstone with stable porosity distribution and not affected by fluid properties can be selected as the apparent standard layer. In this study, the Zhiluo large water layer with relatively stable distribution and a certain thickness was selected as the standard layer in this area. Mainly based on the following considerations: This section is relatively stable in the study area, and the thickness is large, which is 20 - 60 m. The logging curve characteristics are obvious and easy to distinguish. The exploration wells and development wells of this secondary interpretation are drilled through the Zhiluo large water layer, so the logging data standardization selects the Zhiluo large water layer as the standard layer in this area.

In this paper, the frequency histogram is used to standardize the logging data in the study area. The basic idea of this method is: The histogram of the logging data (such as acoustic time difference) of the key well standard layer after environmental impact correction is used as the scale mode of logging data standardization. By analyzing the frequency distribution of the logging data of each well standard layer, and comparing with the standard mode of the study area one by one, the reliability of each logging data is checked and the correction value is determined.

3. Exegetical Mode

3.1. Four Parameters' Characteristics

3.1.1. Reservoir Lithology and Electrical Characteristics

The main oil layer in the study area is Yan 9 reservoir, and its lithology is mainly gray black, dark gray shale, silty mudstone and gray green sandstone interbedded with coal seam, and the lower part is gray yellow thick massive pebbly sandstone. Because of the difference between the thickness of the rock particles and the mineral composition, the logging curves show different electrical characteristics.

For sandstone reservoirs, the natural potential shows obvious negative anomalies, and the natural gamma curve value is relatively low. With the increase of shale content, the negative anomaly amplitude of the natural potential logging curve is relatively reduced, and the natural gamma value is relatively gray.

3.1.2. Reservoir Physical and Electrical Characteristics

The reflection of electrical logging curve on reservoir performance is mainly reflected in acoustic time difference, natural potential and microelectrode. For reservoirs with good porosity and permeability, the spontaneous potential curve reflects obvious negative anomaly amplitude value, higher acoustic time difference, micro-potential and micro-gradient obvious amplitude difference.

Based on this, the reservoir acoustic time difference of Yan 9 is generally 240 - 266 μs/m, and the acoustic time difference of most reservoirs is 245 - 269 μs/m. The acoustic time difference of the reservoir has a good correspondence with the porosity. The most relevant electrical logging curve to the physical properties is the acoustic time difference, followed by natural gamma and natural potential. The physical properties are generally positively correlated with the acoustic time difference. The acoustic time difference is large, the reservoir physical properties are good, and the natural gamma is low, and the natural potential negative anomaly becomes larger. The relationship between acoustic time difference and porosity in the reservoir of the study area is good, so the porosity can be calculated by acoustic time difference in logging interpretation.

3.1.3. Reservoir Oil-Bearing and Electrical Characteristics

The identification of oil and water layers is mainly based on the resistivity curve. The resistivity curve is the most important curve for identifying oil and water layers. Under reservoir conditions, the resistivity shows a high value, indicating good oil content. The larger the acoustic time difference curve, the larger the reservoir space and the better the physical properties. The formation resistivity of the oil-water layer is generally greater than 11 Ω·m, the acoustic time difference is greater than 245 μs/m, and most of them are between 245 - 269 μs/m. Figure 1 is the analysis of porosity and permeability histogram.

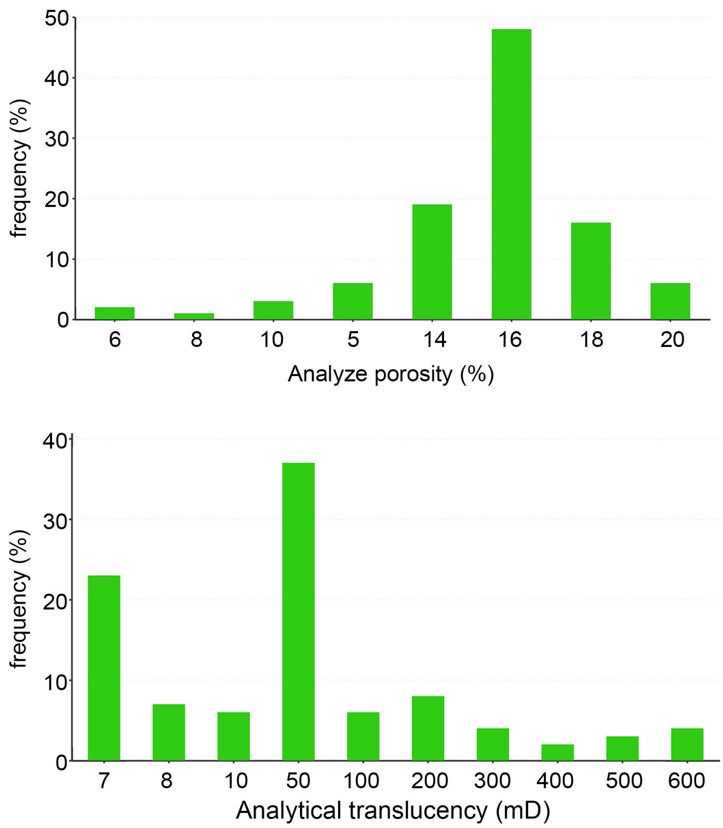

Figure 1. Analysis of porosity and analysis of permeability distribution histogram.

3.2. Reservoir Parameter

3.2.1. Porosity and Permeability Logging Interpretation Model

The characteristics of reservoir porosity in logging data are mainly reflected in the logging response values of acoustic time difference, density and compensated neutron. The acoustic time difference logging data in the study area are the most complete, so the acoustic time difference curve is used to calculate the formation porosity in the porosity study. Based on the porosity analysis of reservoir core experiments in the study area (68 samples from 14 wells), the acoustic time difference curve of the corresponding logging interpretation section was found, and the corresponding data were read, the relationship between the two was analyzed and the interpretation model was established. After linear regression analysis, the formula is:

$$\Phi = 0.22980*AC - 41.776R^2 = 0.7869 \text{ (Figure 2)}$$

The size of permeability is affected by porosity. Therefore, studying the relationship between permeability and porosity is an important part of characterizing reservoir physical properties. The porosity model data and the corresponding core permeability data are cross-plotted, and the logarithmic relationship between the two is analyzed. The permeability calculation model is:

$$LgK = 0.0004e^{0.7314\varphi} \quad R^2 = 0.6276 \text{ (Figure 3)}$$

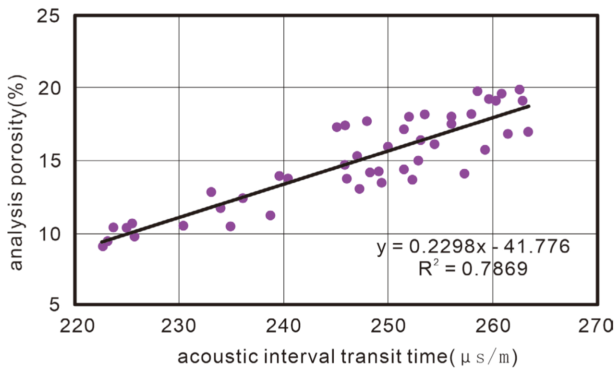

Figure 2. Acoustic time difference-analysis porosity relationship diagram of Yan 9 reservoir.

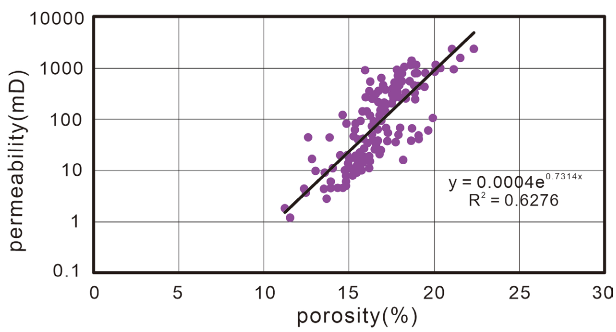

Figure 3. Relation diagram of porosity and permeability.

3.2.2. Oil Saturation Modeling

The volume method is used to estimate the oil and gas reserves in the study area, and the mercury injection data of 43 samples from 4 representative wells in the study area are used. According to the conversion, the relationship between J ~ Shg (**Figure 4**) is obtained. After fitting, a representative average J function graph is obtained. Then, through the relationship between J function and capillary pressure P_c:

$$J = \frac{P_c}{\delta \text{COS}\theta}\sqrt{K/\varphi}$$

Quorum: $\frac{1}{\delta \text{COS}\theta}$ The mercury-air experiment can be obtained as a constant 0.086.

Note: J = Is a function value, dimensionless quantity

P_c = capillary pressure, MPa

K = air permeability, $\times 10^{-3}$ μm^2

φ = porosity, %

According to the J function curve, the average capillary pressure can be calculated by P_c = J/C relationship (**Figure 5**). At the same time, using the relationship between throat radius and porosity, the porosity is 12.7%, the corresponding median radius is 17.2 μm, and the corresponding median pressure is 0.056 MPa. The mercury saturation value corresponding to the median pressure is 52%, that is, the oil saturation can be approximately regarded as 52% (**Figure 6**).

3.2.3. Secondary Interpretation Conclusion and Lower Limit of Oil Layer

By analyzing 126 data points of oil test, logging and coring in 103 wells in the study area, the crossplot of apparent resistance increase rate and acoustic time difference is made, among which 10 points are mistakenly entered and 3 points are mistakenly out. The accuracy of the plate is about 89.68 % (Figure 7). At the same time, the results obtained by combining the above interpretation model. The lower limit of the obtained parameters is: porosity ≥ 14.8%, acoustic time difference ≥ 238 μs/m, water saturation ≤ 49%, and apparent resistivity index ≥ 1.5.

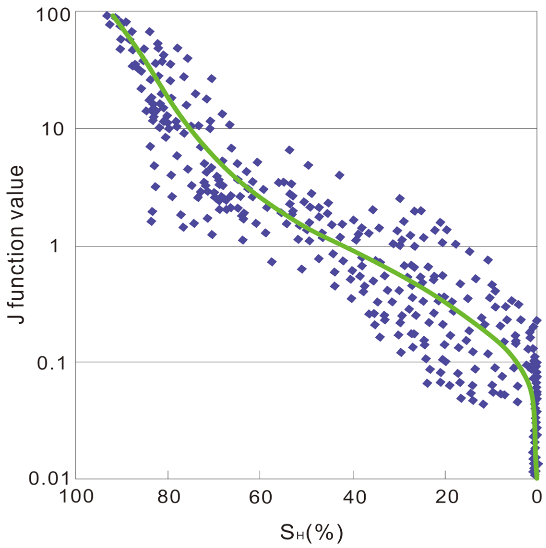

Figure 4. The average J function curve of Yan 9 reservoir.

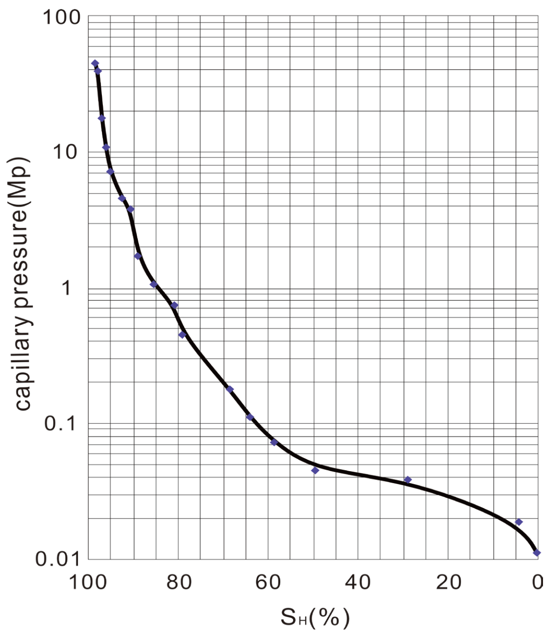

Figure 5. The average capillary pressure curve of Yan 9 reservoir.

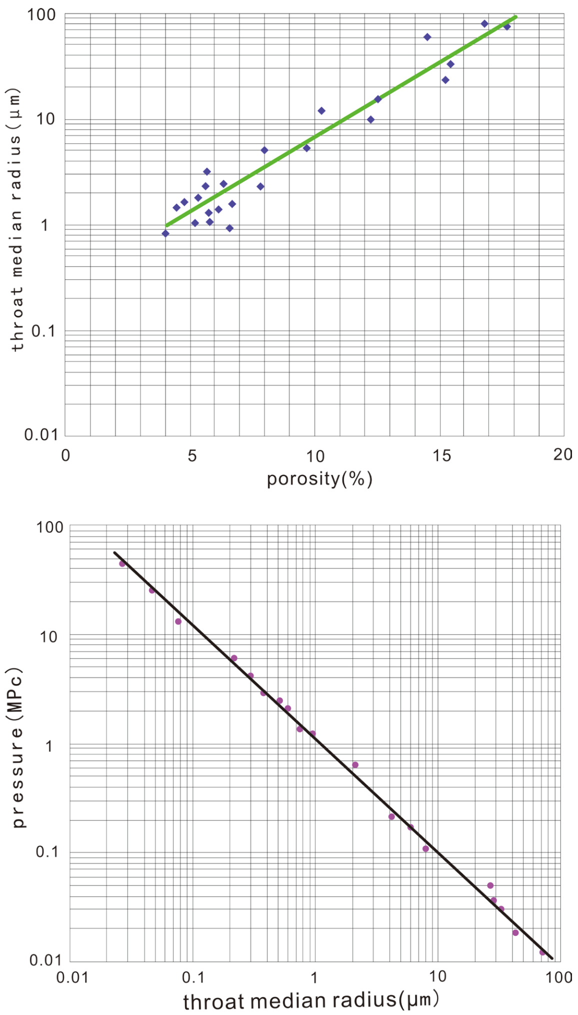

Figure 6. Yan 9 reservoir roar median radius and porosity and capillary pressure relationship diagram.

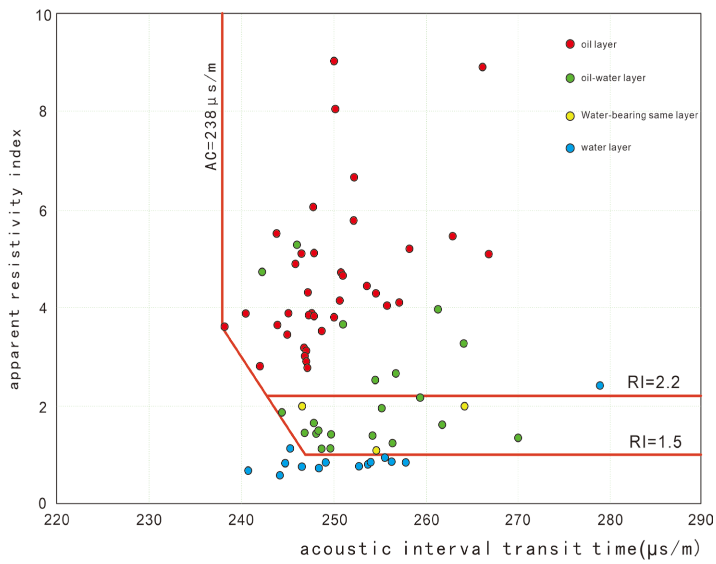

Figure 7. Intersection diagram of acoustic time difference-apparent resistance increase rate of Haotanyan 9 reservoir.

4. Reserve Recalculation References

The volume method is used to estimate the oil and gas reserves in the study area, and the formula is:

$$N = 100 \times A \times h \times \varphi \times S_{oi} \times \frac{\rho_o}{B_{oi}}$$

According to the above formula, the reserve parameters are calculated, where A is the oil-bearing area, h is the average effective thickness, φ is the effective porosity, S_{oi} is the oil saturation, ρ_o is the average density, and B_{oi} is the average original crude oil volume coefficient. The oil and gas reserves in the study area are 1077.81×10^4 t.

5. Conclusion

Based on the standardization of logging data, the logging interpretation model established by combining the four-property relationship and considering its influencing factors will be more in line with geological characteristics. At the same time, the porosity logging interpretation model, permeability logging interpretation model and oil saturation interpretation model established in this study are the most suitable methods for the geological law and application effect of the study area from the perspective of regression accuracy, which can meet the subsequent reservoir evaluation requirements.

Comprehensive analysis of the characteristics of the logging curve, in the secondary interpretation of more consideration of the late production dynamics, combined with the development of the study area, this approach makes the secondary interpretation has more feasibility and effectiveness, for the next step of the proposed potential layer provides an effective basis.

The recalculation of reserves has been revised on the original results, and the development index has been updated, which provides a reliable basis for future planning.

This paper only discusses the situation of Yan 9 reservoir in the study area, and it can be found that the reservoir physical properties and oil-bearing properties of Yan 9 in this area are better. At the same time, for the exploration of reservoirs in other periods in the region, further research is needed to obtain results.

Acknowledgements

This paper is a demonstration of some results of Shaanxi Haotan reservoir evaluation project. Thank you to all the colleagues involved in the project!

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

Bu, J., Li, W. H., Zeng, M., Sun, D., Fan, M. M., & Bi, L. (2010). Reservoir Diagenesis and

Its Influence on Porosity of Yan 9 Reservoir Group of Middle Jurassic in Longdong Area of Ordos Basin. *Petroleum Geology and Engineering, No. 3,* 24-27.

Liu, P., Cheng, L. X., Zhang, G. J., Mao, Z. J., Zhao, G. R., & Liu, X. L. (2012). Secondary Interpretation and Evaluation of Logging Data in High Water Cut Oilfield and Its Effect. *Science and Technology Innovation Bulletin, No. 10,* 82.

Wang, L. J., Wang, F., & Guo, C. L. (2023). Comprehensive Classification and Evaluation of Yan 9 Reservoir Group in Jingbian Laozhuang, Ordos Basin. *Energy and Energy Conservation, No. 12,* 53-57.

Wang, Y. C. (2019). The Application of Fine Logging Secondary Interpretation Model in L Oilfield. *Journal of Sichuan Geology, No. 3,* 490-495+502.

Xiao, F., Wu, D., Zhu, L. X., Huang, Y. M., Ji, S. W., & Song, J. W. (2023). Secondary Interpretation of Logging in Chang 7 Ultra-Low Permeability Reservoir in A Area. *Journal of Sichuan Geology, No. 3,* 450-456.

Xie, X., Tian, F., Bai, Y., & Zhang, C. T. (2020). The Application of Secondary Logging Interpretation in Chang 2 Reservoir of JB Oil Area. *Petrochemical Technology, No. 8,* 94-95.

Zhang, L. J., Li, T. H., Zhang, C. G., Geng, L. F. (1998). The Application of Multivariate Trend Surface Analysis in Improving the Accuracy of Oilfield Logging Interpretation. *Inner Mongolia Petrochemical, No. S1,* 62-63+115.

Zhang, W. Q. (2020). Reservoir Characteristics and Logging Secondary Interpretation of Paleogene in Subei Basin. *Liaoning Chemical, No. 7,* 783-786.

Zhen, Y. M. (2022). *Reservoir Distribution Characteristics of Yan 9 Reservoir in X1 Well Area of Ordos Basin*. Master's Thesis, Xi'an Petroleum University. https://kns.cnki.net/KCMS/detail/detail.aspx?dbcode=CMFD&dbname=CMFDTEMP&filename=1023021260.nh