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LoggingTechnology Applied to Three-dimensional Geological Modelling

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Shixin DAI[1,2], Yufei GONG[2]*, Tianchun YANG [2]

[1]Clean Utilization of Coal Resources and Mine Environmental Protection of Hunan University of Science and Technology, Hunan Xiangtan 411201

[2]Resource Environment and Safety Engineering College of Hunan University of Science and Technology, Hunan Xiangtan 411201

*Corresponding author's e-mail: 1399663811@qq.com

Abstract. Reservoir geological modelling is indispensable to the fine description of reservoir. The geological models can be combined with related technologies such as spatial information management, geological interpretation, geostatistics, spatial analysis and prediction, and physical content analysis. It can quantitatively characterize the various characteristic parameters of the reservoir, the basic geometric shape of the geologic body and the distribution of the data. The application of logging technology is very extensive, and the analysis and processing of logging data are very important for stratigraphic division, lithology analysis, and oil-water layer identification. In this paper, the well logging data of the Huaziping area in the oilfield is used as the object, and the geological modeling and geologic characteristics and the evaluation of the oil and gas layers are studied through geological modeling. Thereby achieving the guiding role of further development and utilization of the reservoir.

1.Introduction

With the demand of reservoir development, it is very important to find out the geological characteristics and reservoir numerical simulation. Three-dimensional visualization fine geological model can provide reliable static model for reservoir numerical simulation. The established geological static model is more accord with the geological characteristics of the reservoir. It can quickly and accurately analyze the geological characteristics of the reservoir, and plays an important role in oil and gas exploration and development. The method of physical parameters is one of the applied geophysical methods (including gravity, magnetism, electricity, shock, nucleus)[1-3].

As a key technology in petroleum industry, it plays a more and more important role in oil and gas exploration and development. According to geological and geophysical conditions and reasonable selection of comprehensive logging methods, drilling geological profiles can be studied in detail, useful minerals can be detected, and necessary data for calculating reserves, such as effective thickness and porosity of reservoirs can be provided in detail. Research on oil and gas saturation and permeability, as well as other tasks in drilling technology. The establishment of 3D geological model in this study area is based on the conventional resistivity porosity series[4,5].

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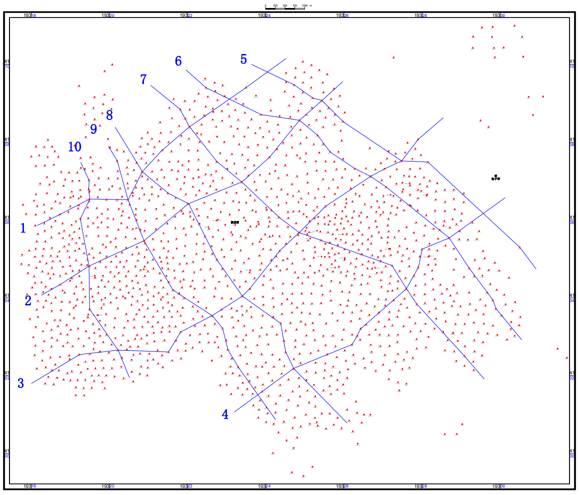

Figure 1. the area and well location of Huazaping oil region.

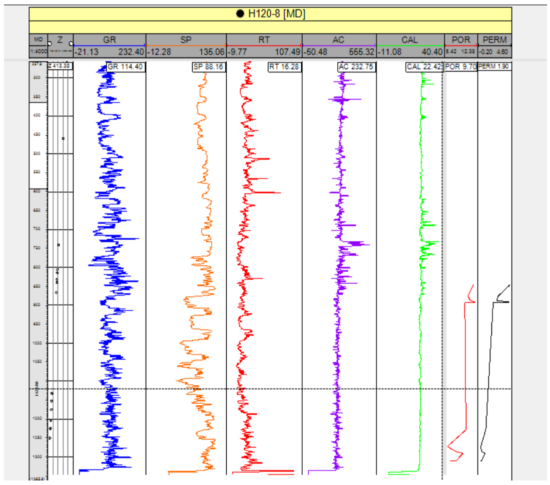

Figure 2. Schematic diagram of well Hua 120-8 logging curve.

This study covers the entire Huaziping oil area, which is located at both sides of the Hezhuang ditch area on the west side of Huaziping town in Ansai county. Figure 1 shows the area and well location of Huaziping oil region, with research scope: X: 4100000-4109500, Y: 36584500-36598000, with an area of about 140km^2. The surface is covered by loess, and the elevation difference of the ground can reach 150-120m. The Anze Huaziping Hezhuang area is the main block of the Xingzichuan oil production plant. At present, there are more than 1800 development wells, and the number of wells is large and dense. The main producing layer is the Chang 2 and Chang 6 oil layer groups. The main content of the study is the basic geological and reservoir description of the Chang 2 and Chang 6 oil layers in the Hezhuang area of Ansai-Huaziping oil area is the largest oil production area in Xingzichuan oil production plant. It mainly consists of four oil layers, namely Chang $2^{1-3,}$ Chang 6^{1-2}, Chang 6^{2-1},Chang 6^{2-2} and Chang6^{3}. The drilling-encounter rate of small reservoirs with Chang 2^{1-3} is 42%, 63.1% of Chang 6^{1-2}, 69.5% of Chang 6^{2-1} and 85.9% of Chang 6^{2-2}. The Chang 6^{3} substrata was 75.6%, while the rest of the substrata were only drilled in a few wells. The development well spacing is usually around 250 m, while some wells are about 200m and some wells are about 150m.

2. Matherial and methods

The 3D geological modelling is based on various original data to build a digital model that can reflect the geological structure form, the tectonic relationship and the change rule of the properties inside the geological body. The first data to be prepared for 3d geological modelling includes wellhead, fine stratigraphic stratigraphic data, wellpath, logging curves and lithologic description data of the research area. Log data contains natural gamma logging curve (GR), natural potential well logging curve (SP), acoustic logging curve (AC), the common resistivity logging curve (RT), the acoustic logging curve (ACL), caliper logging curve (CAL), porosity (POR) (PERM), oil saturation, permeability logging curve curve (SW), etc. Figure 2 shows an example of schematic diagram of well Hua 120-8 logging curve, and the data can be abjusted timely to correct errors according to the abnormal display.

Table 1. Hua120-8 Log interpretation result data.

Well name	Surveying depth		Vertical depth		Interval transit time(AC)	Formation resistivity (RT)	Porosity (POR)	Oil saturation	Permeability (PERM)	Shale content	Interpretation result
	Top depth	Bottom depth	Top depth	Bottom depth							
Hua120-8	845.6	849.8	809.1	812.9	248.2	13	11.5	0	4.2	26.4	water bed
Hua120-8	875.4	887.2	836.7	847.4	237.9	13.7	10.3	3.7	2.6	26	dry bed
Hua120-8	887.2	890.4	847.4	850.4	239.1	15.4	10.8	22.7	2.4	12.1	poor reservoir

Hua120-8	891.7	893.7	851.4	852.8	244.4	16.5	11.8	23.4	4.1	14.2	poor reservoir
Hua120-8	893.7	907.5	852.8	864.9	234	12.4	9.7	1.6	1.9	19.5	water bed
Hua120-8	1227.5	1247	1155	1173.5	234.6	20.8	9.9	4.8	0.9	19.9	dry bed
Hua120-8	1272.7	1275.4	1198	1200.5	218.2	29.8	6	5.9	0.2	20.7	dry bed
Hua120-8	1284.9	1288	1209.6	1212.5	226.7	29.4	7.7	21.4	0.3	19.2	poor reservoir
Hua120-8	1290.4	1294.6	1214.9	1218.9	234.5	25.3	9.3	4.8	0.8	17.7	dry bed
Hua120-8	1308.9	1310.9	1232.6	1234.5	226.7	35.7	7.9	22.3	0.3	15.3	poor reservoir
Hua120-8	1310.9	1316	1234.5	1239.5	217.4	31.9	6.7	5.6	0.2	19.9	dry bed

Table 1 shows the data of the Hua120-8 logging interpretation results. According to the basic data provided by the oil production plant, the basic data is loaded according to the software format requirements. The input and loading process of the modelling data is also the establishment process of the basic database [6]. The accuracy of the data is critical to building the right model. Data errors will make the final model meaningless, so the data preparation and processing phase is the key and foundation of the entire modelling project. The division criteria are: 1) the water content of the oil layer is <20%; 2) the oil and water layer: 20% ≤ water content ≤ 90%; 3) the oil-bearing water layer: 90% < water content < 95%; 4) the water content of the water layer ≥95%.

3.Results

The geological modelling is based on the database, and the precision of the model is determined by the richness and accuracy of the database. The main flow of this three-dimensional geologic modelling includes: well data input, building model, establishing phase model and establishing attribute model [7,8]. Figure 3 is a schematic diagram of the K9 mark layer. The post-modelling is based on the tectonic model, and the log data directly affects the spatial lattice of the later geologic model, the geometrical morphology of the sand body and the distribution of the three-dimensional space. and reservoir porosity, permeability, and water saturation and other attributes of the accuracy of the characteristics.

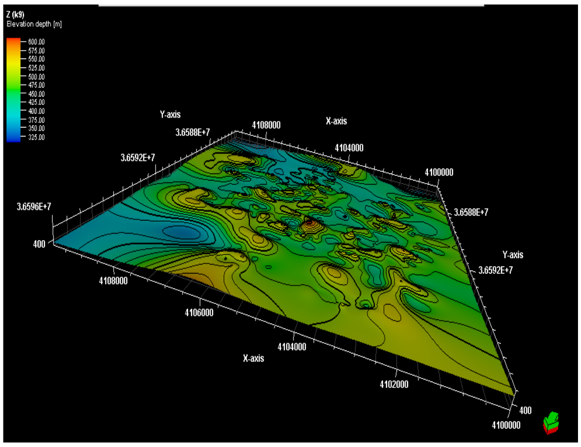

Figure 3. K9 logo layer schematic diagram.

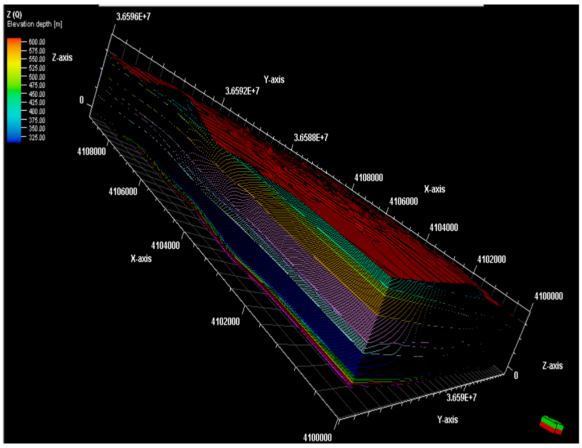

Figure 4. 3D Grid skeleton model.

3.1Logging information applied to structural stratification

Combined with the interpretation data of each logging curve the stratum can be divided and the lithology explained. Natural gamma ray logging GR (the Gamma Ray well logging) is used to measure the intensity of natural gamma rays in the formation, depending on the amount of radioactive material in the formation. In sedimentary rocks, the ability of the clay particles to absorb radioactivity is stronger than other skeleton particles, so the GR logging value is related to the rock mineral composition and mud content, which is mainly used in geological analysis to divide lithology and stratigraphic contrast, explain sedimentary environment and calculate mud content [9,10].

Natural potential well logging SP (Self Potential curve) is a well-logging method that is formed when the salinity of the drilling fluid in the well is different from the salinity of the formation water[11].

Sonic well logging AC (Acoustical log) is a variation of the acoustic wave time difference in the detection of a well log. The propagation time of the measurement can be used for stratigraphic comparison and calculation of porosity to identify lithology and cracks.

General resistivity logging RT (Resistivity Log) reflects the strength of the rock's electrical conductivity, can be used to classify lithologic profiles and identify oil and water layers, usually higher oil reservoir RT, low water level RT.

Well bore logging (Cal) reflects the lithology characteristics of strata and the permeability of reservoirs, often used in stratigraphic contrast, lithology judgment, selection of reservoirs.

Figure 4 shows the results of the results of the localization division in the model. According to the stratigraphic classification and comparison results, we prepared the top structure map of key marker layers, including Chang 63 (K3), Chang 2 (K9), and contour interval 5m. Through analysis, no fault was found in the study area, and the regional structure showed the monocline of east high and west low, with a slope of 7-10m. Due to the heterogeneity of sand body deposition and the difference of diagenetic compaction, the formation area of different target strata and the different structural elements of small nose-shaped uplift are different. The existence of these uplifts is related to the development degree of sandstone and the accumulation of oil and gas.

3.2 Logging information applied to lithology analysis

There are three methods for establishing facies model: drawing the sedimentary facies map by hand, replacing the sedimentary facies model with the lithofacies model, and modelling with the trend-plane constraint phase. Two constraint methods of sedimentary facies control and lithofacies control are commonly used in facies control modelling.

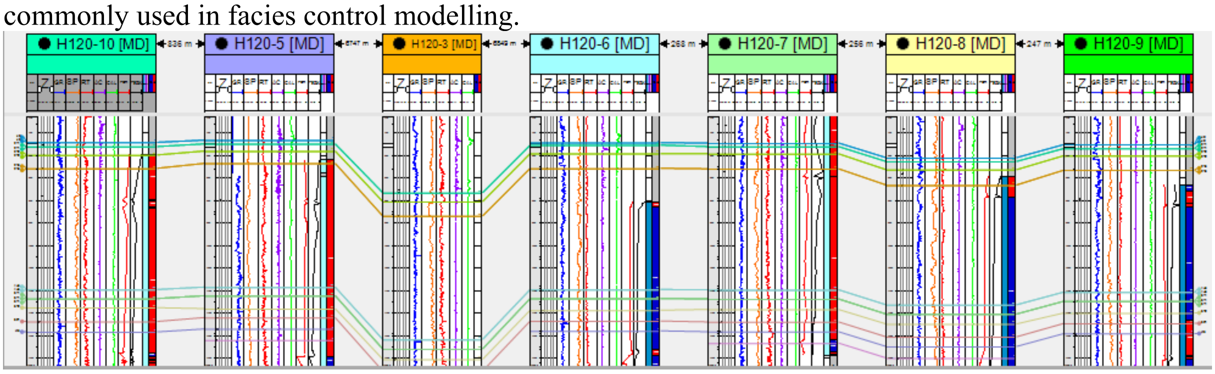

Figure 5. The sectional view of logging curve.

According to the logging curve, the lithology is mainly determined by the graphic intersection method, the statistical method and the neural network method. Dynamic identification of lithology. Figure 5 shows the sectional view of logging curve. The log curve amplitude is controlled by the lithology, thickness and fluid properties of the formation, which can reflect the grain size, sorting property and muddy content of the sediment. The study of sedimentary facies can guide the reasonable distribution of sand bodies, and the main basis of the study is facies marker and section sequence. Sedimentary facies mark is a sedimentary mark which can reflect sedimentary characteristics and sedimentary environment. The structural structure, mineral composition and granularity of sedimentary rocks are the typical characteristics of sedimentary facies. The sedimentary facies markers used in this study include the color, lithology, mineral composition, rock structure, sedimentary structure, paleontological fossils and logging facies [12-15].

3.3 Application of logging information to reservoir properties

The final purpose of 3D visualization geological modelling is to make reservoir attribute modelling part. The interpolation method or stochastic simulation method was used to predict the distribution of inter-attribute parameters, and a 3D spatial model was established for such parameters as porosity, permeability and oil saturation of the reservoir [16].

Reservoir Chang 6 in Huaziping Hezhuang area has poor physical properties, strong heterogeneity, relatively poor oil and gas information reflected by logging, and the reservoir experienced strong compaction and diagenetic changes during the burial process, and the geological factors affecting reservoir physical properties are complex. The reservoir heterogeneity is obvious, and the adaptability of log interpretation model is limited.

Table 2. Average porosity permeability of study area.

Horizon name	Chang 2^{1-3}	Chang 6^{1-2}	Chang 6^{2-1}	Chang 6^{2-2}	Chang 6^{2-3}
Average porosity(%)	12.5	10.9	9.1	8.8	8.8
average permeability(μm^2)	4.6×10^{-3}	1.53×10^{-3}	0.49×10^{-3}	0.71×10^{-3}	0.7×10^{-3}

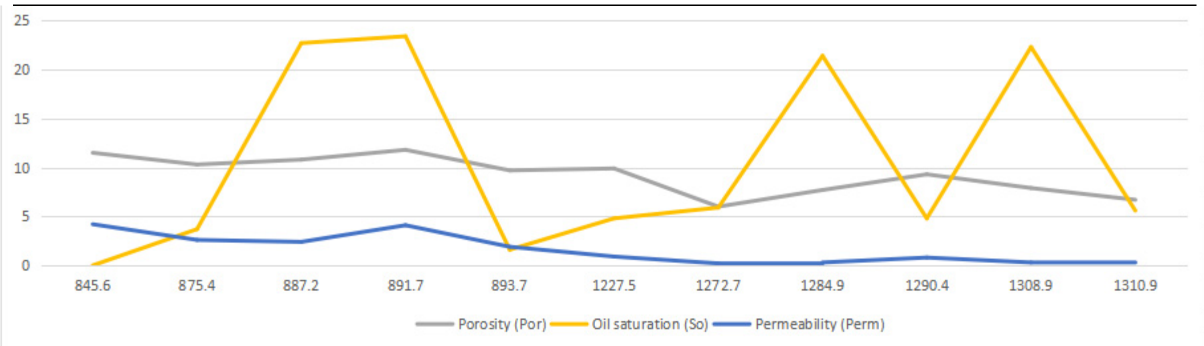

Figure 6. Porosity,permeability and oil saturation curves.

As shown in Table 2, the reservoir physical property of Chang 2 reservoir group in the study area of Huaziping is significantly better than of Chang 6 reservoir group. The porosity of small reservoirs with Chang 2^{1-3} is 17.4%, averaging 12.5%, mainly distributed between 10% and 15%. Logging interpretation maximum $16.37\times10^{-3}\mu m^2$, an average of $4.6\times10^{-3}\mu m^2$, mainly distributed in $1\sim10\times10^{-3}\mu m^2$, accounting for 94.3% of the total Chang 6 porosity are mainly distributed in between 7%~12%, average 9.4%, permeability mainly distributed between $0.1\sim5\times10^{-3}\mu m^2$, an average of around $0.94\times10^{-3}\mu m^2$ with classic grain size and by to siltstone and fine sandstone, Chang 6 reservoir porosity and permeability showed a trend of decrease. Figure 6 shows the porosity ,permeability and oil saturation curves of well Hua120-8.

Due to the difference of geological conditions and the nature of underground fluid in different regions, the relationship between lithology and logging information should be established on the basis of the study of core data. The main sandstone type of Chang 6 formation is feldspathic sandstone, followed by lithic feldspar sandstone, a small amount of feldspathic lithic sandstone, relatively low maturity of sandstone mineral composition, and Chang 6 oil formation is dominated by fine sandstone with poor grain roundness. Most of them are subangular, mainly linear contact. The main rock types of Chang 2 formation in the study area are lithic feldspathic sandstone, mainly fine sandstone, fine siltstone and siltstone, and a small amount of medium sandstone, mudstone is mainly deep gray and gray, and clastic composition is mainly feldspar and quartz.

4.Discussion

Acoustic time difference AC is a series of well logs that reflect the physical properties of the reservoir. The smaller the acoustic wave time difference, the denser the underground rock formation, represents the poorer physical properties of the reservoir until it becomes an invalid layer. On the contrary the greater the difference in sound wave time, the looser the underground rock formation,representing reservoir properties as possible.

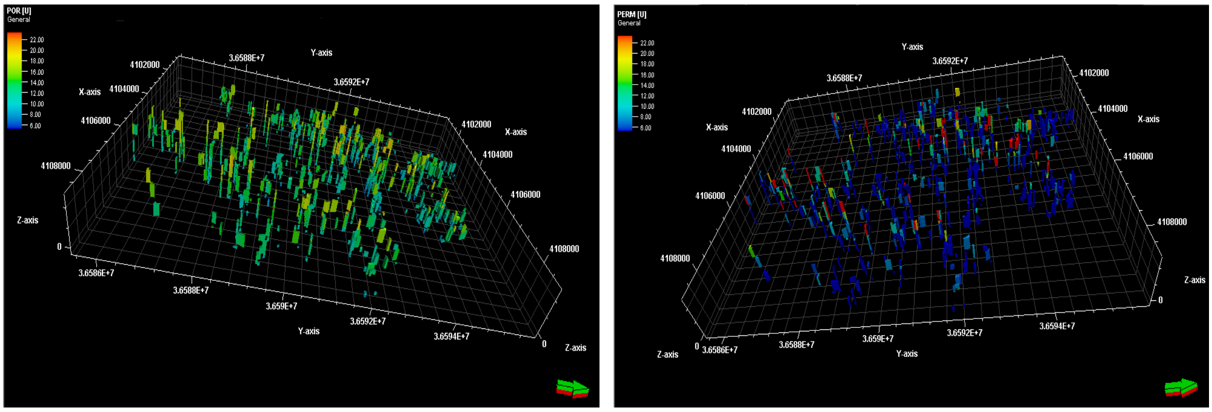

Figure 7. Porosity(a) and permeability(b) curve discretization model.

Figure 7 shows the porosity(a) and permeability(b) curve discretization model. In the study area, the area of oil content in small layers of Chang 2^{1-3}, Chang 6^{1-2}, Chang 6^{2-1}, and Chang 6^{2-2} gradually increased from top to bottom. It is 27.73 km^2 and 46.77 km^2. The area of the Chang 6^{2-1} layer is 52.26 km^2, and the oil-bearing area of the Chang 6^{2-2} is 70.22 km^2. The oil bearing area of the Chang 6^3 formation is larger, up to 59.43 km^2, but the deficiency is that the thick oil sands are relatively dispersed. Therefore, only from the distribution characteristics of oil-bearing area, it can be seen that Chang 6^{2-2} is the main target stratum that is most favorable for water injection development, followed by Chang 6^3, Chang 6^{2-1}, Chang 6^{1-2} and Chang 2^{1-3}.

5. Conclusion

The interpretation and analysis of well logging data by logging technique can be used to classify the stratigraphic structure, lithology characteristics and reservoir properties by synthesizing the geological meanings contained in various logging information. In turn, the establishment of a three-dimensional geological model of the oil reservoir in the Ansai-huaziping block of Yanchang oilfield was promoted. Accurate 3D geological model is helpful for quickly and accurately analyzing the geological characteristics of the reservoir, establishing the reservoir attribute grid, and clarifying the remaining oil distribution. It can provide strong support for exploration and development decisions [17,18].

Based on geologic modelling, the distribution and development law of reservoir is clear, which is suitable for the further development of oilfield, especially underground injection. CO_2 development provides the basis, on this basis, to make favorable prediction of exploration zone, to provide scientific basis for decision-making, and to provide reference for other similar areas of oil and gas exploration and development at the same time.

Acknowledgements

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