Research on Application of Density Curve in Thickness Interpretation

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Abstract: Some error partition and leakage partition of effective thickness layers had been found in the new drilling interpretation program in the second district of northeast block. Through analysis, the main reason was that general density interpretation standard (density less than 2.20g/cm³) for the integrally formation in Lamadian Oilfield, which could not completely fill the interpretation need in the current development period, was added in the effective thickness interpretation standard by the logging department in the research institute in 2010. In order to guarantee and improve the precision of effective thickness data interpretation, this research improved and refined the original density interpretation standard, using the lithological and electrical characters of hermetic core holes after 2010. Based on the reservoir development characteristic, the improvement formed an auxiliary criterion of effective thickness interpretation, according to the specific condition such as oil bearing group, oil layer type and the depth of 1100m. The new criterion was based on the lithological and electrical characters and density curves of hermetic core holes, and improved the partition precision of reservoir thickness.

1. INTRODUCTION
There could be found a direct correlation between reliability of the reservoir thickness interpretation results and the applied method of logging curves, which directly reflects the stratum information, but needed to be supported by the hermetic core holes data. A general density interpretation standard (density less than 2.20g/cm³) for the integrally formation in Lamadian Oilfield, which could not completely fill the interpretation need in the current development period, was added in the effective thickness interpretation standard by the logging department in the research institute in Daqing Oilfield in 2010. So this research mainly studied on the refined improvement of the original density interpretation standard, based on the reservoir development characteristic, using the lithological and electrical characters of hermetic core holes after 2010. The improvement formed an auxiliary criterion of effective thickness interpretation based on the lithological and electrical characters and density curves of hermetic core holes, according to the specific condition such as oil bearing group, oil layer type and the depth of 1100m. The auxiliary criterion ensured the precision of effective thickness data interpretation and could provide more precise results for related works such as later reserve calculation, geologic modeling and development adjustment.
2. MATERIAL AND METHODS

2.1. Adaptability of the density standard to reservoir thickness interpretation
Thicknness from reservoir interpretation is the comprehensive reflection of lithology, physical property and oil-bearing ability. The showing thickness is larger when the rock coarse granularity and good sorting, and porosity, pore throat radius, permeability and the rank of oil and gas bearing of reservoir are higher. Under normal conditions, the changes of the lithology, oil and gas bearing ability, physical property and electric property show the same trends. But the logging curve of the extremely high water-cut stage is extremely complex due to the different sedimentary environment, development depth, watered out degree of reservoir and other factors. Therefore, a general density interpretation standard (density less than 2.20g/cm³) for the integrally formation aim at the Lamadian Oilfield was added by the logging department in the research institute in Daqing Oilfield in 2010. But the single standard could not offer a complete explanation of the differences between the lithology, physical property and oil-bearing ability of different reservoirs on the extremely high high water-cut stage which made it increasingly difficult to interpret thickness. So this research analyzed the results of the new drilling reservoir thickness data interpretation program in the second district of northeast block and studied the adaptability of reservoir classification to the density curve standard.

2.1.1. Density curve Characteristics of different oil bearing groups
Lamadian Oilfield is divided into three oil bearing groups: Saertu group, Putaohua group and Gaotaizi group, each of which has different sedimentary environment.

- Sa-I group belongs to delta front facies sedimentation and develops branched–lump transition sand body from delta front facies and sheet sand body from delta front facies outside. The average effective thickness is 4.1m and the peak values of density curve ranges from 2.00g/cm³ to 2.35g/cm³.

- Sa-II group sedimental unit belongs to fluvial sedimentation and mainly develops distributary channel sand body of different sizes. The average effective thickness is 15.3m and the peak values of density curve ranges from 1.95g/cm³ to 2.23g/cm³. Sa-III group develops distributary channel sand of different sizes as well and the average effective thickness is 12.3m and the peak values of density curve ranges from 1.90g/cm³ to 2.25g/cm³.

- Pu-I 1-2 oil layer in Pu-I group develops large braided fluvial sand body and large compound meander zone sedimentation sand body, the average effective thickness is 12.6m and the peak values of density curve ranges from 1.90g/cm³ to 2.20g/cm³. Pu-I 1 and Pu-I 4-7 oil layer is 17m~23m, which both mainly develop low-sinuosity distributary channel sedimentation sand body, the average effective thickness is 16.2m and the peak values of density curve ranges from 1.90g/cm³ to 2.20g/cm³. Pu-II group mainly develops low-sinuosity distributary channel sand body and branched delta sand body, the average effective thickness is 9.8m and the peak values of density curve ranges from 2.00g/cm³ to 2.35g/cm³.

- Gaotaizi oil bearing group which including G-I, G-II and G-III oil layer develops delta front sub-facies sedimentation sand body. The average effective thickness of G-I, G-II and G-III oil layer is 10.6m, 12.3m and 9.1m and the peak value of density curve is 2.00g/cm³—2.35g/cm³, 2.10g/cm³—2.35g/cm³ and 2.10g/cm³—2.35g/cm³, respectively.

Through the investigation above this research found that the uniform density standards for reservoir (density less than 2.20g/cm³), after being divided according to oil bearing group, could not completely fill precision need of thickness interpretation, except P-I 1-2 oil layer.

2.1.2. Characteristic of density curves of different types of oil layers
Lamadian Oilfield is divided into four types: Class I oil layer, Class II oil layer (IIA and IIB) and Class III oil layer, the physical properties of which are obviously different, according to the different sedimentation environment. Class I oil layer: Pu-I 1-2 oil layer mainly develops braided river flood plain facies and meander fluvial sedimentation, the average effective thickness is 12.6m, the flattening-out effective thickness of single layer is not less than 4.0m, and the peak value of density
curve ranges from 1.90g/cm³ to 2.20g/cm³. Class II oil layer (IIA) mainly develops fluvial sedimentation, the average effective thickness is 17.9m, the flattening-out effective thickness of single layer is not less than 1.5m, and the peak value of density curve ranges from 1.90g/cm³ to 2.25g/cm³. Class II oil layer (IIB) mainly develops fluvial sedimentation, the average effective thickness is 22.5m, the flattening-out effective thickness of single layer is not less than 0.7m, and the peak value of density curve ranges from 2.00g/cm³ to 2.30g/cm³. Class III oil layer: Gaotaizi oil bearing group mainly develops sheet sand body and untabulated reservoirs (sand drilling rate≥60%), which belongs to delta front facies sedimentation, and partially develops sub-sea distributary channel sand and bar sand (sand drilling rate<25%). The average effective thickness is 34.8m, the flattening-out effective thickness of single layer is less than 1.0m, and the peak values of density curve ranges from 2.10g/cm³ to 2.35g/cm³.

Through the investigation above this research found that the uniform density standards for reservoir (density less than 2.20g/cm³), after being divided according to the types of oil layers, could not completely fill precision need of thickness interpretation, except Class I oil layer.

2.1.3. Characteristic of density curves of different reservoir properties
Crude property of Lamadian Oilfield changes with depth, but is not obvious above 1100m well depth, the relative density varies between 0.86g/cm³ and 0.87g/cm³, and the surface oil viscosity is 18.0cP~20.0cP. The crude capability declines under 1100m depth to 1208m oil-water interfaces, which called viscous oil interval, the relative density increases from 0.86g/cm³ to 0.90g/cm³, and the viscosity increases from 23.8cP to 57.0cP. It is discovered from correlation with oil test data that the production index of reservoir is different around 1100m well depth, it is two times less of viscous oil reservoir than that of reservoir above 1100m. Compaction of reservoir becomes more apparent with depth, reservoir physical property changes, oil density increases, which case the obviously changes of the electric logging curve, while the density curve won’t change under the same lithology in theory.

Sa-II group sedimental unit belongs to fluvial sedimentation and mainly develops distributary channel sand body of different sizes, the average effective thickness is 15.3m and the peak value of density curve ranges from 1.95g/cm³ to 2.23g/cm³. Pu-II group mainly develops low-sinuosity distributary channel sand body and branched delta sand body, the average effective thickness is 9.8m and the peak value of density curve ranges from 2.00g/cm³ to 2.35g/cm³. Through the investigation above this research found that the uniform density standards for reservoir (density less than 2.20g/cm³), after being divided according to crude oil property, could not completely fill precision need of thickness interpretation.

2.2. Research on meticulous improvement of density curve standard
After fully consideration of the environment of coring well, this research adopted the density curve of Pu-I 1-2 oil layer where homogeneous blocked and the effective thickness was larger than 2.0m as a standard, using the lithological and electrical characters of hermetic core holes after 2010. Subtracted the density curve sample data of all formation from different reservoirs with the standard, this research could determine the density curve eigenvalues of different oil bearing groups, different types of oil layers and oil layers around 1100m, respectively, to establish the density curve interpretation standard accordingly.

2.2.1. Improvement of density curve standards of different oil bearing groups
By extracting the density curves and thickness interpretation data and analyzing the corresponding relationship, after being divided according to oil bearing group, this research established a plate about that relation above of Saertu, Putaohua and Gaotai oil bearing group.
The effective thickness density curve value of Saertu, Putaohua and Gaotai oil bearing group increased 0.23g/cm³, 0.20g/cm³ and 0.30g/cm³, respectively, according to the plate. S-I oil layer in Saertu oil bearing group and Gaotai oil bearing group both developed underwater sediment-deltaic environment. After the research it was found that when the density difference of Saertu oil bearing groups was between 0.20g/cm³ and 0.25g/cm³, the sample point must be from the S-I oil layer. Therefore, the density difference of Saertu oil bearing groups increased entirely.

2.2.2. Improvement of density curve standards of different types of oil layers

This research established a related plate by contrasting and analyzing the relationship of the differences of density curves and the thickness interpretation results, after being divided according to the differences data of Class I oil layer, Class II oil layer (IIA and IIB) and Class III oil layer.

The effective thickness density curve value of Class I oil layer, Class II oil layer and Class III oil layer increased 0.19g/cm³, 0.21g/cm³ and 0.30g/cm³, respectively, according to the plate.
2.2.3. Improvement of density curve standards of different reservoir properties

By extracting the density curves and thickness interpretation data and analyzing the corresponding relationship, after being divided into two sections according the depth: the viscous oil interval above 1100m and below, this research established a plate about that relation above of different types of oil layers.

This research got an increasing standard of difference value of density according to the plate. The increasing standard of Class I oil layer, Class II oil layer and Class III oil layer was less than 0.20g/cm³, 0.21g/cm³ and 0.30g/cm³, respectively, when the viscous oil interval was at depth above 1100m, while it was less than 0.20g/cm³, 0.21g/cm³ and 0.23g/cm³, respectively, below 1100m depth. The physical properties of oil layers are relatively poor with depth under the same sedimentation condition, due to the compaction of reservoir becomes more apparent with depth. So the lower limit values of the Class III oil layer above 1100m depth was relatively small under the prerequisite of guaranteeing physical properties of oil layers.
3. RESULTS

This research took a density curve value A.00g/cm³ of homogeneous blocked reservoir thicker than 2.0m, from P-I 1-2 oil layer as a criterion, when tested the standard in production wells practical application. Then the uniform density standard of thickness interpretation of Lamadian Oilfield must be A.30g/cm³. This research subdivided the density curve standard, according to three kinds of reservoir classification, and got a new standard. The new standard of Class I oil layer, Class II oil layer and Class III oil layer was less than A.20g/cm³, A.21g/cm³ and A.30g/cm³, respectively, when the viscous oil interval was at depth above 1100m. And the new standard of Class III oil layer was less than A.23g/cm³ when the viscous oil interval was at depth below 1100m. For example, take the density curve value 2.00g/cm³ of a new well in homogeneous blocked reservoir thicker than 2.0m, from P-I 1-2 oil layer as a criterion, then the uniform density standard of thickness interpretation of Lamadian Oilfield must be 2.30g/cm³.

Take the density curve value A.00g/cm³ of the well in homogeneous blocked reservoir thicker than 2.0m, from P-I 1-2 oil layer as a criterion first. Then this research subdivide the density curve standard based on the criterion, according to three kinds of reservoir classification, and get a new standard. The new standard value of Class I oil layer, Class II oil layer and Class III oil layer increases 0.20g/cm³, 0.21g/cm³ and 0.30g/cm³, respectively, when the viscous oil interval is at depth above 1100m. And the value of Class I oil layer, Class II oil layer is less than 0.20g/cm³ and 0.21g/cm³ and that of Class III oil layer increases 0.23g/cm³ when the viscous oil interval is at depth below 1100m.

4. DISCUSSION

This research got secondary interpretation to the core holes L6-JSM2601 chosen, using the new density curve standard. Take the density curve value 2.05g/cm³ of homogeneous blocked reservoir thicker than 2.0m, from P-I 1-2 oil layer as a criterion. Then this research divide the density curve standard based on the criterion, according to three kinds of reservoir classification, and get a new standard. The new standard of Class I oil layer, Class II oil layer and Class III oil layer increases 0.20g/cm³, 0.21g/cm³ and 0.30g/cm³, respectively, when the viscous oil interval is at depth above 1100m. And the value of Class I oil layer, Class II oil layer is less than 0.20g/cm³ and 0.21g/cm³ and that of Class III oil layer increases 0.23g/cm³ when the viscous oil interval is at depth below 1100m.

5. CONCLUSIONS; ACKNOWLEDGEMENTS; REFERENCES

Conclusion (1) The researcher cannot use the uniform density standards, due to the different sedimentary environments, hydrodynamic environments and other factors of Saertu group, Putaohua group and Gaotaizi group, so as not to affect the precision need of thickness interpretation. (2) The density curve standards are different of different reservoir types. Taking the density A.00g/cm³ as a criterion, the standard of Class I oil layer, Class II oil layer and Class III oil layer is less than A.20g/cm³, A.21g/cm³ and A.30g/cm³, respectively, when the viscous oil interval is at depth above 1100m. And the standard of Class III oil layer is less than A.23g/cm³ when the viscous oil interval is at depth below 1100m. (3) The increasing value of the new density interpretation standard mainly aims at the Class III oil layer; the maximum increasing value of the effective thickness of single well got is above 0.5m and the thickness ratio increases overall by 12.85%.

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