Application of Hydrocarbon Gas Abundance Log in the Rolling Exploration and Development of Offshore Extra-low Resistivity Oilfield: A Case Study of CFD Oilfield Group in Bohai Bay Basin*

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Abstract

Billion barrels of oil has been proved in low resistance reservoirs of CFD Oilfield Group in Bohai Bay Basin. In this region, oil zones are hard to distinguish from water zones as they have the same resistivity values. In the exploration stage, we identify extra-low resistivity oil zones based on nuclear magnetic logging, testing and cores. In the development stage, we adopt the previous knowledge about these extra-low resistivity oil zones to satisfy the production. However, we still face the problem that the development wells are not able to identify new encountered oil zones for lacking effective and economical methods. To solve this problem, in recent years we use gas logging data to identify extra-low resistivity oil zones and obtain good results.

Introduction

CFD Oilfield Group is located in the west of Bohai Bay Basin. Taking the representative CFD11-2 Oilfield as an example, its structure is mainly a low-amplitude draping anticline. The main oil bearing sequence of this oilfield is Neogene N1g strata while its sedimentary type is a braided river. There are three oil groups in N1g and the biggest one is characterized by extra-low resistivity. The low resistivity oil zone usually refers to the oil zone whose resistivity is less than two times of resistivity value of water zone in the same oil bearing sequence. In the Neogene strata of CFD11-2 Oilfield, as the resistivity of the Neogene low resistivity oil zone is quite even lower than that of the water zone, we cannot use resistivity logs to discriminant fluid type (Figure 1).

Preprocessing of Gas Logging Data

As a conventional method to identify formation fluids, gas logging plays an irreplaceable role. When accuracy of resistivity logging is negatively affected by a variety of factors in extra-low resistivity oil zones of CFD11-2 Oilfield, the accuracy of gas logging remained constant. Therefore, gas logging replaces resistivity logging as the main method to identify formation fluids in this oilfield.

The influence factors of gas logging include the geologic factor, the drilling factor, the operation factor and the logging factor. Due to the existence of these factors, in a strict sense, gas logging data represent the concentration of hydrocarbon gas detected by instruments when the bottom hole drilling fluid is circulated to the wellhead but not the actual concentration of hydrocarbon gas in the formation. In order to provide a criterion to the gas logging data for identifying formation fluid, we have to eliminate the influence of the above factors and correct the gas logging curve to be hydrocarbon abundance curve, which can mainly represent the actual concentration of hydrocarbon gas in the formation. Aiming at the mechanism and influence range of different factors, we take two steps to correct the gas logging curve.

The first step is single well correction. While drilling, geologic and drilling factors can cause varying degrees of influence at different depths. For example, The greater the pressure difference between the formation pressure and the drilling fluid pressure, the more hydrocarbon gas will get into the drilling fluid within a single unit time and the higher the gas measurement value is. The greater the drilling speeds, the more hydrocarbon gas will get into the drilling fluid within a single unit time and the higher the gas measurement value is. These both make certain deviations between the gas measurement value and the real concentration of hydrocarbon gas in formation. In order to eliminate the influences of such factors in a single well, we take division operation to the original total gas logging data with pressure, drilling speed, solution gas oil ratio and then get hydrocarbon abundance curve of single wells.

The second step is inter-well correction. While drilling, some of the drilling and logging factors make systematic errors between different wells. For example, the differences of the sensitivity and initial settings of different logging recording instruments will lead to different record values of gas logging in same circumstances. In order to eliminate the influences of such factors between different wells, we choose the large sections of water zone in N1g strata as the standard layer to eliminate the system error caused by bit diameter, drilling fluid density, drilling fluid viscosity, instruments and other systematic errors and then unify the base values of hydrocarbon abundance log of different wells.

Some operation factors like recirculating gas are difficult to eliminate. While applying hydrocarbon abundance logs to identify fluids, we should check through the curves' characteristics under the guidance of the reservoir model in this area. Testing the accuracy of corrected hydrocarbon abundance curves, we compare them with resistivity logs in normal oil zones. As Figure 2 and Figure 3 show, hydrocarbon abundance curves and resistivity logging curves have excellent correlation and synchronization in response to the abnormal fluids. In the circumstance that we adjust all wells' base hydrocarbon abundance values to 1000 ppm, the threshold value of the oil layer is >10,000 ppm.

Identifying Extra-Low Resistivity Oil Zone

On the premise of the hydrocarbon abundance curve having good recognition effect on the normal oil zone, we apply it to identify extra-low resistivity oil zone. As Figure 4 shows, in the depth range above the oil-water interface we have already known, there are abnormal high hydrocarbon abundance values, while there is no abnormal high hydrocarbon abundance value in the depth range below the oil-water interface. As Figure 5 shows, the hydrocarbon abundance log is able to identify extra-low resistivity oil zones and the adjacent water zones, and its effect is better than resistivity logging.

Based on extra-low resistivity oil zone threshold of hydrocarbon abundance logs in the N1g formation, we re-examine old wells in CFD11-2 Oilfield. Taking the production well A10 for example, hydrocarbon abundance logs show that there is an obvious abnormal high hydrocarbon abundance value in the sand layer below the two already known extra-low resistivity oil zones. It is preliminarily identified as a suspected extra-low resistance oil zone. After that, it is proved by production that this is an oil zone with a large scale of reserves and high productivity.

In recent years, in the identification of extra-low resistivity oil zones in CFD Oilfield Group, we reviewed older wells hydrocarbon abundance logs to find the suspected oil zones, and then proved them by the wells perforation. More than ten million tons of geological reserves in extra-low resistivity oil zones are found in and around the oilfields, which effectively alleviates the lack of replacement reserves in the middle and late period of CFD Oilfield Group development.

Conclusion

Hydrocarbon abundance curves can be obtained by preprocessing gas logging data. By statistical analysis, we can get extra-low resistivity oil zone thresholds of hydrocarbon abundance logs, which can replace resistivity-logging curves to identify fluids in CFD Oilfield Group. In the middle and late development stages of the extra-low resistivity oil zones in CFD Oilfield Group, hydrocarbon abundance log plays a key role in the practice of increasing reserves and production. In the context of the current low oil price, this method helps us to maximize the benefits of oilfield development, and lay the foundation for the sustainable development of oilfields. It also provides new ideas for the exploration of similar oil-bearing structures and development of similar oilfields.

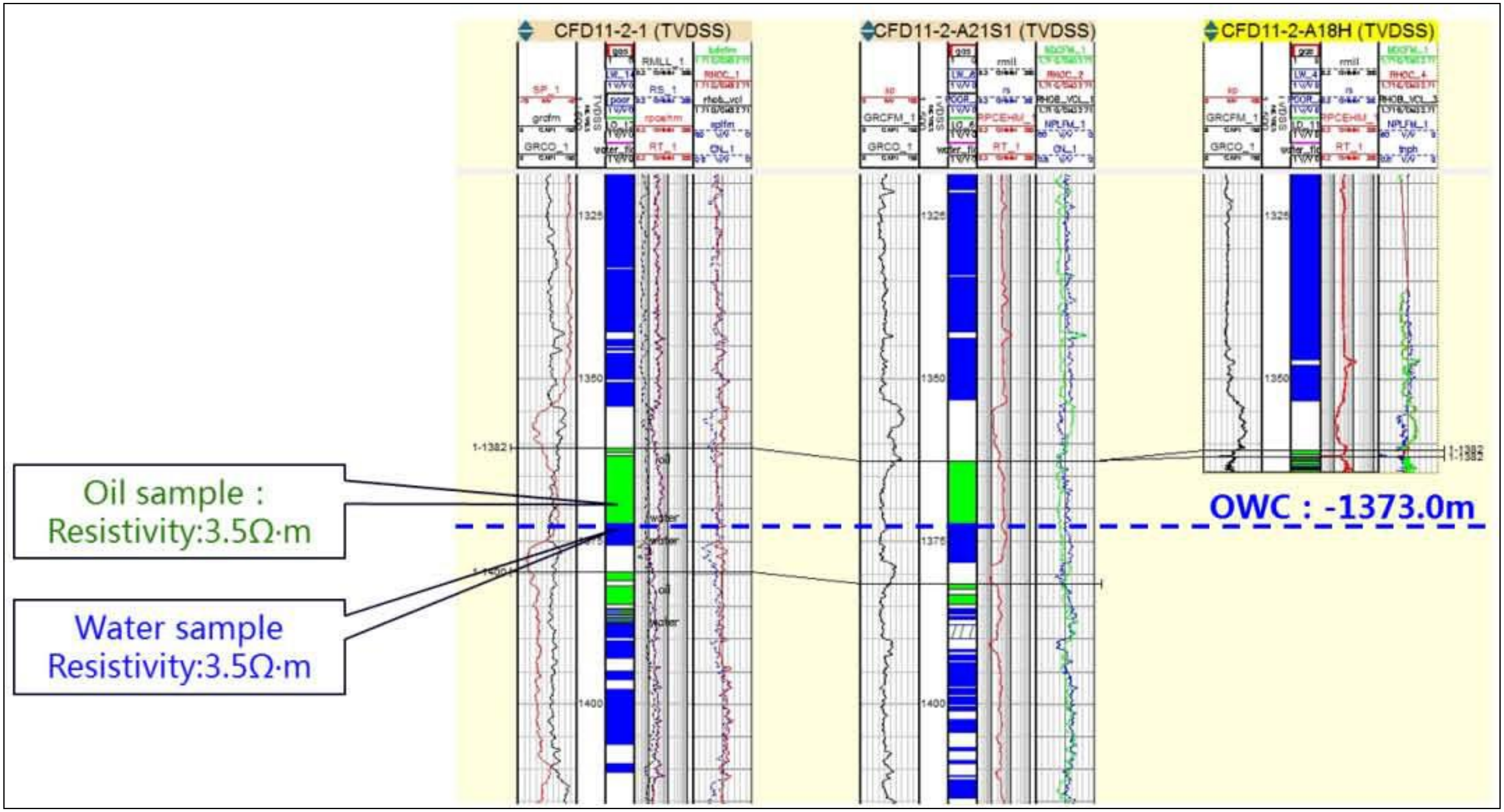

Figure 1. Correlation diagram of extra-low resistivity oil zones of CFD11-2 oilfield.

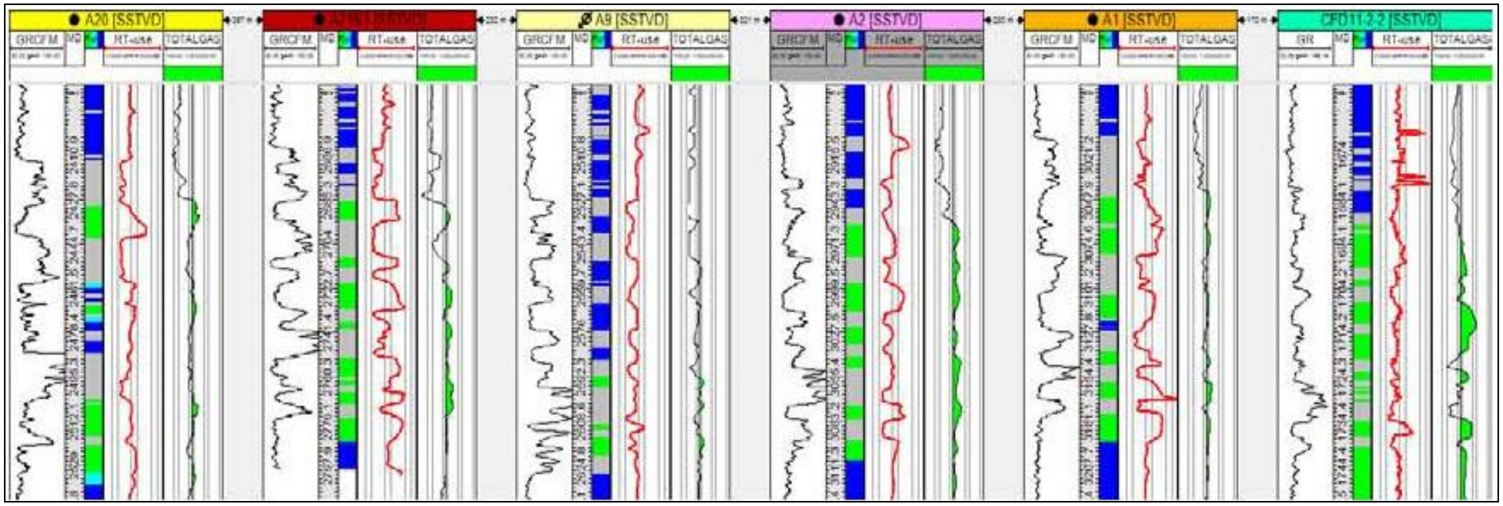

Figure 2. Correlation diagram of normal oil zones in CFD11-2 Oilfield.

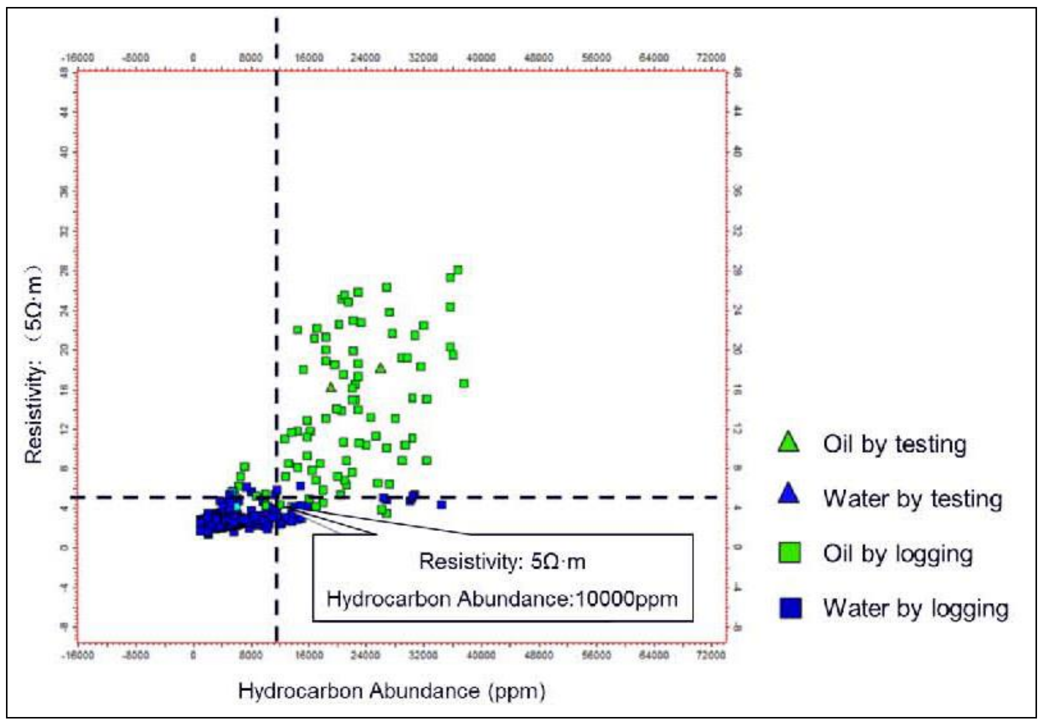

Figure 3. Resistivity and hydrocarbon abundance intersection diagram of normal oil zones in CFD11-2 Oilfield.

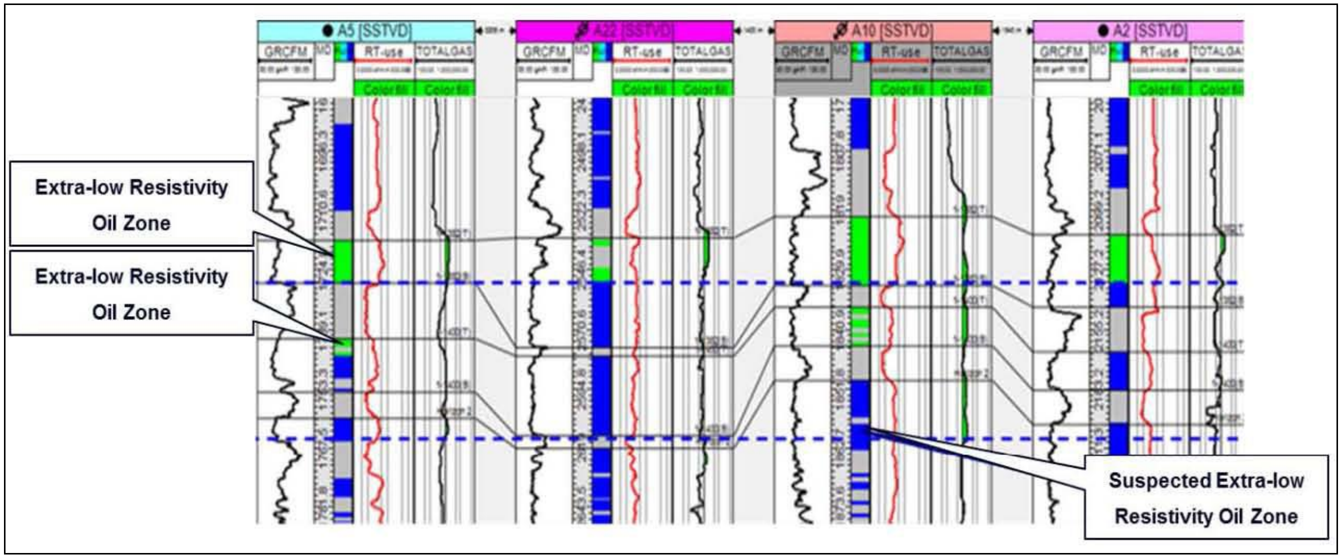

Figure 4. Correlation diagram of extra-low resistivity oil zones in CFD11-2 Oilfield.

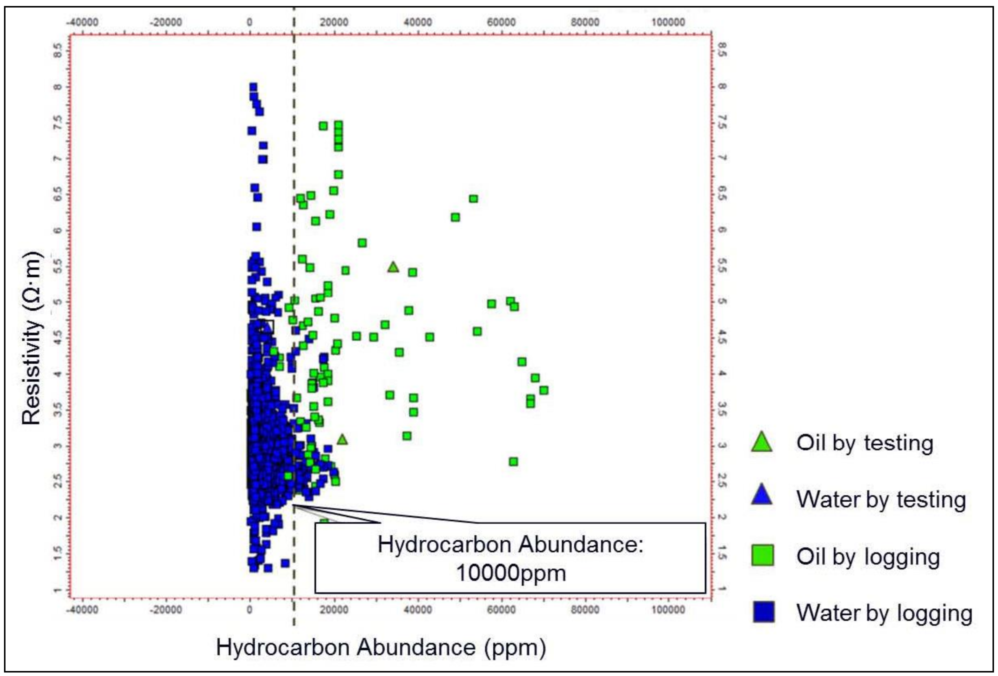

Figure 5. Resistivity and hydrocarbon abundance intersection diagram of extra-low resistivity oil zones in CFD11-2 Oilfield.