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Fluid Characterization Using Two Dimensional Nuclear Magnetic Resonance Logging - Case Studies in Oil Field of Mehsana Asset. Western Onshore - India

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Abstract

One-dimensional nuclear magnetic resonance (1D NMR) logging technology has some significant limitations in fluid typing. However, not only can two-dimensional nuclear magnetic resonance (2D NMR) provide some accurate porosity parameters, but it can also identify fluids more accurately than 1D NMR. Recent advances in 2D NMR technologies have extended the NMR logging applications to perform *in-situ* fluid typing, oil saturation, and oil viscosity determination. This paper presents a variety of field applications that illustrate recent advances in NMR logging fluid characterization methods. The main concepts of NMR logging and the principles underlying NMR diffusion measurements, which form the basis for all standalone NMR fluid characterization methods, are briefly reviewed. Fluid characterization methods are presented to demonstrate the separation of oil and water signals, saturation measurements and oil-viscosity determination.

The MRF method has been used to characterize fluid types and saturation measurements. The application of 2D NMR maps of relaxation times and molecular-diffusion rates to identify fluids and determine their properties in complex multi-fluid environments is illustrated with field examples from Mehsana, Cambay basin. We have recently deployed such 2D NMR technology to various oil fields. 2D NMR logging was performed in real open-hole wells by CMR stationary logging. Using a set of CPMG echo train data with different echo spacing and wait time acquired by commercially available NMR logging tools and a global inversion algorithm for relaxation-diffusion (GIRD), we were able to obtain a relaxation-diffusion 2D NMR map as a function of depth. This is a map which represents the hydrogen population as a function of both T2 relaxation time and diffusion coefficient.

Three candidate wells have been selected for current study where MRF station reading has been acquired. From our field test results, it is concluded that 2D NMR techniques greatly increase the accuracy of fluid typing and saturation determination in oil fields in western onshore of India. The T2-diffusion correlation information can be used to determine pore size distribution, perform fluid saturation typing, and estimate in-situ oil viscosity simultaneously. These techniques can also be applied to explore internal magnetic field gradient and characterize the droplet size distribution of emulsion, measure the gas/oil ratio and determine the properties of heavy oil.

Introduction

Cambay Basin

The Cambay rift Basin, a rich Petroleum Province of India, is a narrow, elongated rift graben (1), extending from Surat in the south to Sanchor in the north. In the north, the basin narrows, but tectonically continues beyond Sanchor to pass into the Barmer Basin of Rajasthan. On the southern side, the basin merges with the Bombay Offshore Basin in the Arabian Sea. The basin is roughly limited by latitudes 21˚ 00' and 25˚ 00' N and longitudes 71˚ 30' and 73˚ 30' E (Fig.1). Mehsana is a area of North Cambay Basin which has got well established oil fields which are producing for last four decades from multiple plays at different stratigrapic levels from Older Cambay shale to Kalol. The basin is in a very mature state of exploration and of late it is observed that though the success rate is good but sizes of the discoveries are small. Hence there is need to shift focus of exploration to deeper plays below Older Cambay Shale (OCS) and in this respect exploration of Olpad Formation is important. Present study has been carried out in Mansa field of Mehsana.

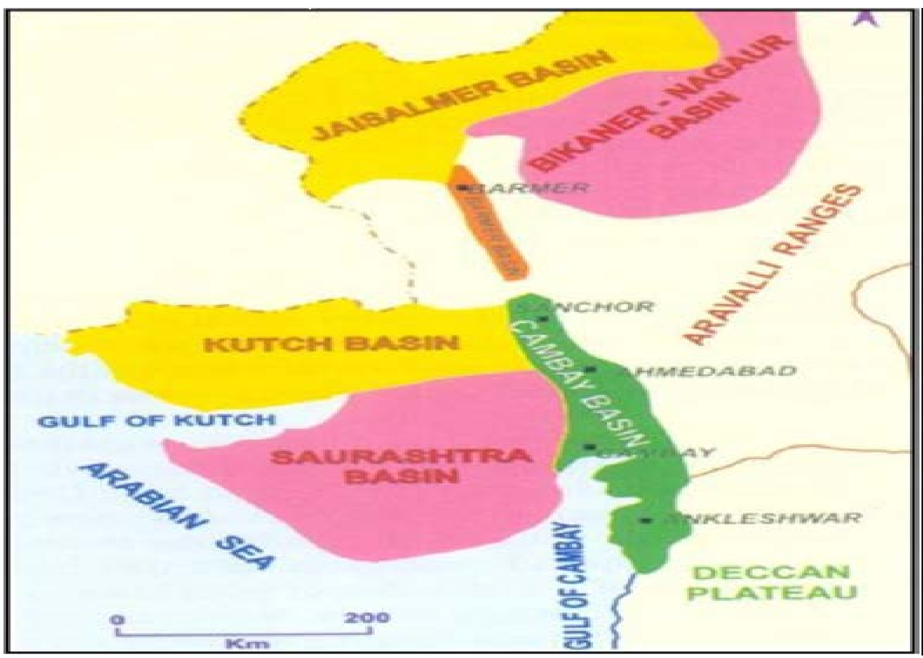

Fig.1 Geological Map Showing Cambay Basin

MRF Analysis

The T2 spectrum measured by an NMR logging tool is a composite (Fig.2) of the constituent components (2) of the reservoir fluids in the pore space. If there is no T2 contrast between the fluids, it is impossible to determine the type of fluid and the quantity of each fluid based solely on T2. In the event that 1D NMR, or T2 logging, is insufficient to differentiate fluids, alternative techniques must be used to determine reservoir fluid type and quantity. A common technique employed in other industries using NMR is two-dimensional 2D NMR imaging (3). With recent advances in borehole NMR technology, 2D NMR techniques now are available for reservoir fluid identification and quantification. While seemingly much more complex, 2D NMR is similar in concept to conventional log data crossplot techniques.

2D NMR plots are similar to conventional crossplots in that one NMR fluid property is plotted versus another NMR fluid property (Fig.3), and patterns in the data are used to identify and quantify the reservoir fluid.

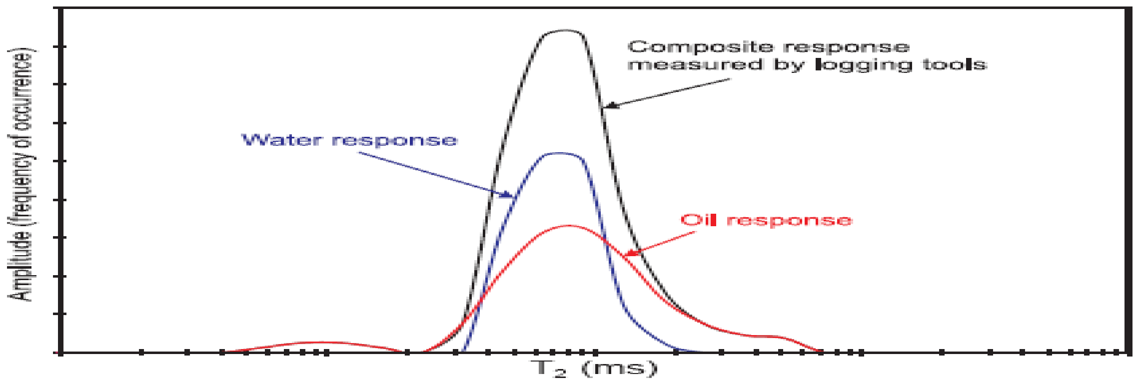

Fig .2 Moveable water and viscous oil, same T2

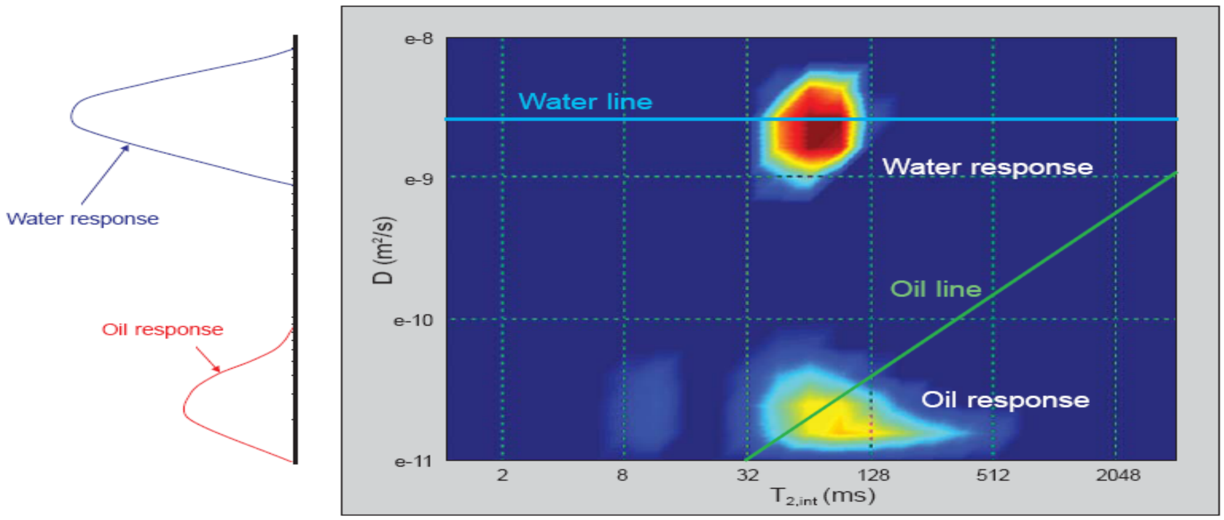

Fig .3 D vs. T2, 2D NMR image, crossplot of D spectrum and T2 spectrum

The MRF method (4) has been used to characterize fluid types and saturation measurements. The MRF method exploits molecular diffusion (5) in the field gradient generated by the tool magnet. This process leads to an additional NMR decay proportional to the square of the echo spacing and to the diffusion constant of each fluid component governed by the simple equation

$$\frac{1}{T_{2D}} = \frac{D(\gamma G)^2 TE^2}{12}$$

where TE – Echo Spacing, D – Diffusion Coefficient, G – Tool Gradient.

Because water molecules are typically smaller and more mobile than the hydrocarbon molecules in crude oils, the water signal decays faster than the oil signal for long-echo spacings. By inverting a specially designed suite of NMR measurements with different echo spacings, the MRF method separates brine and oil signals (Fig. 3-5) even when the T2 distributions completely overlap.

Field Examples

Three examples of field logs from Mehsana, Western Onshore processed using the MRF method are presented. These examples show brine and oil T2 distributions, saturations, and oil viscosities from MRF analysis of station logs acquired at different depths. MRF station readings have been at taken at depths 816.5 m, 857.5 m and 872.5 m.

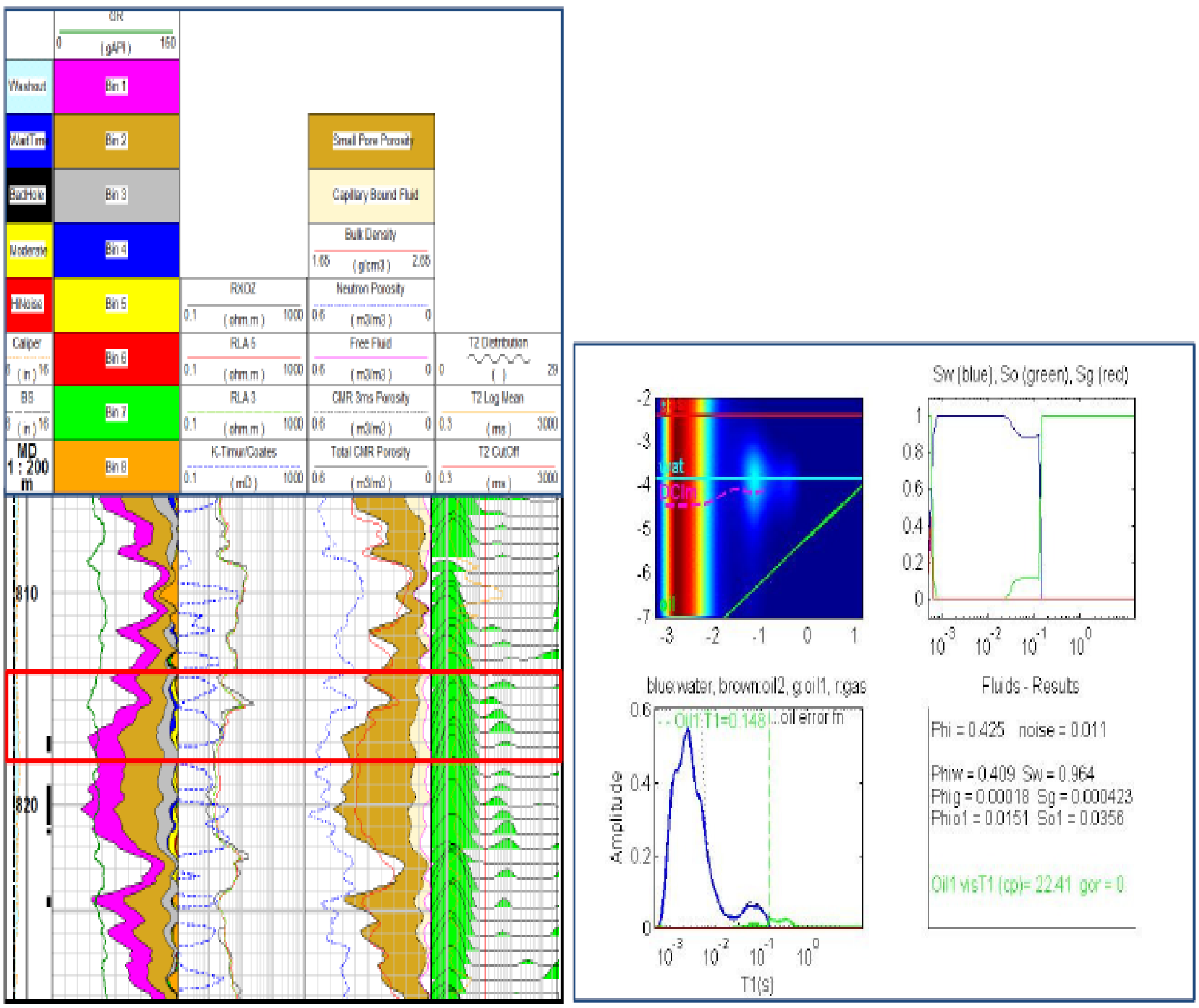

Fig.4 MRF analysis of the data acquired by the CMR tool @ 816.5 m

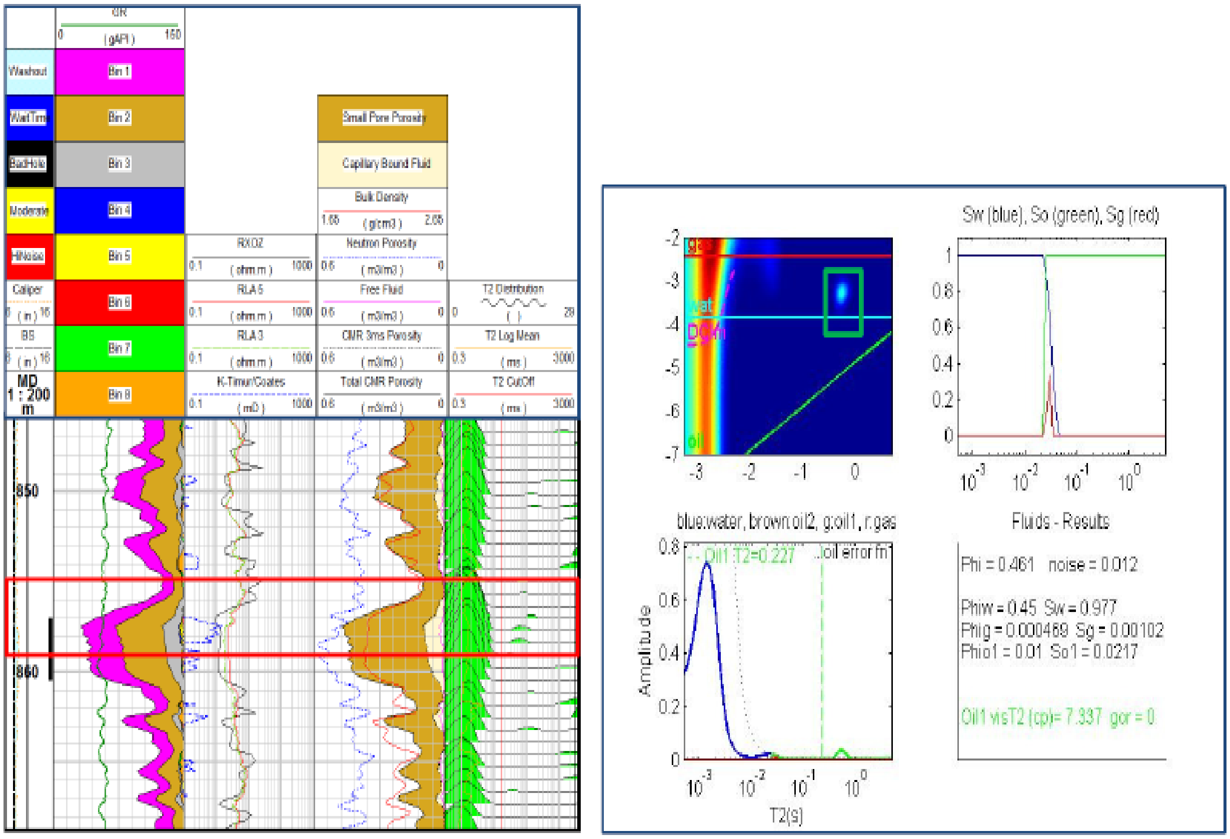

Fig.5 MRF analysis of the data acquired by the CMR tool @ 857.5 m

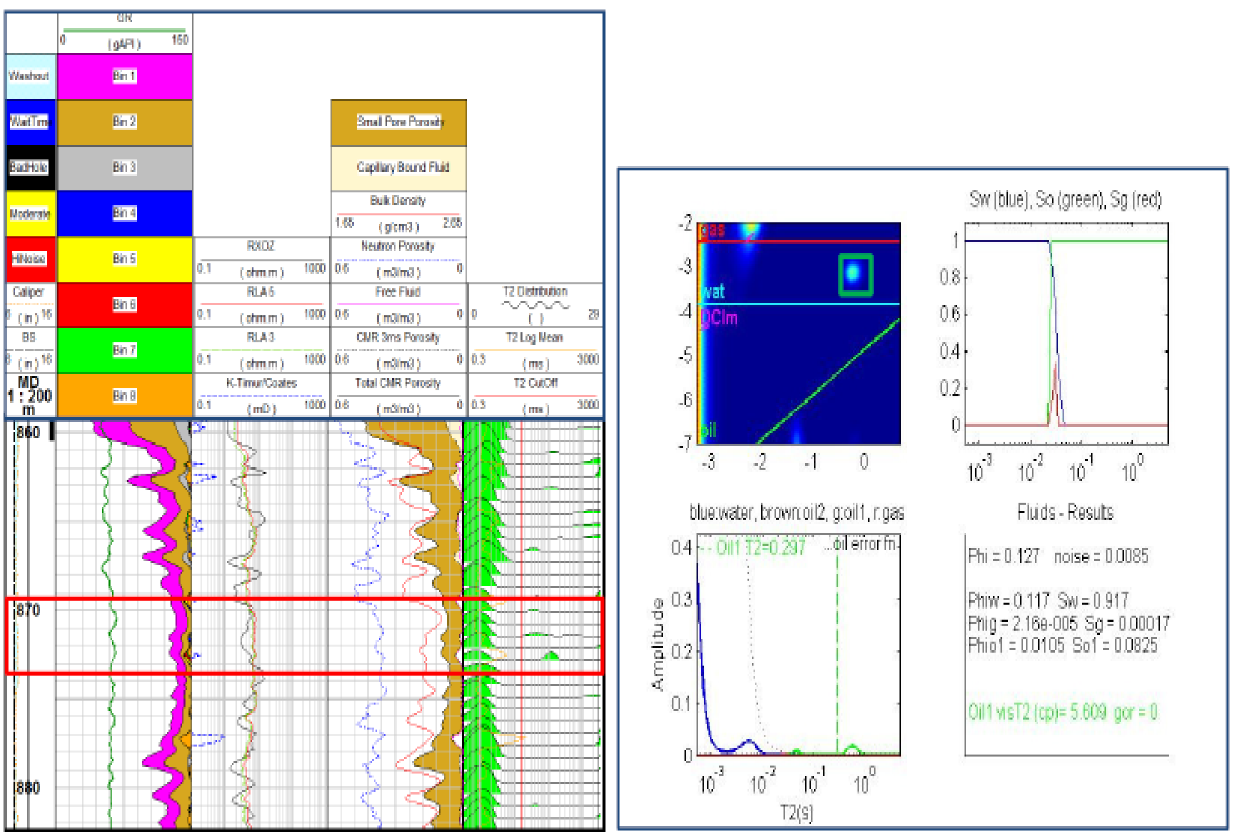

Fig.6 MRF analysis of the data acquired by the CMR tool @ 872.5 m

Results and Discussion

The analysis provides accurate results even though the brine and oil distributions completely overlap. At 816.5 m, the points are falling on water line (Fig.4) and no hydrocarbon signal has been observed. This seems to be a water bearing zone. Faint hydrocarbon signals have been seen above the water line at 857.5 m (Fig.5) and 872.5 m (Fig.6). It gives an indication of possible light hydrocarbon.

MRF technology can also provide solutions in fresh or varying formation waters, where Archie resistivity analysis is difficult. Using direct hydrocarbon characterization, pay intervals can be identified even in zones with low resistivity. The MRF method can over- come problems associated with Archie analysis, such as varying cementation exponent; dipping, thin or laminated beds that affect resistivity tools and unknown or varying water resistivity. This method also overcomes incorrect permeability calculations caused by hydrocarbon effects. The MRF method works in viscosities from less than 1 cp to more than 200 cp. For viscosities below this range, the DMR* Density-Magnetic Resonance method should be used because hydrocarbons that are very light (such as gas and condensate) result in porosity deficits. Above 200 cp there is a lack of diffusion sensitivity.

Conclusion

Based Upon the present studies and from our field test results, it is concluded that 2DNMR techniques greatly increase the accuracy of fluid typing and saturation determination in oil fields in western onshore of India. It has been found that the analysis provides accurate results even though the brine and oil distributions completely overlap.

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