NMR AND ULTRASONIC STUDIES IN CORE PLUG SAMPLES FROM CARBONATES AND SANDSTONES' TIGHT FORMATIONS

Romero P. and Montoya N.
PDVSA-Intevep, romeropxi@pdvsa.com

ABSTRACT

Core plug samples of carbonates and sandstones tight formations have been studied using ultrasonic P waves, analysed in frequency domain, and low field NMR transversal relaxation, in order to find information about lithology, presence of fractures and petrophysical properties. The main production mechanism of these formations is due to fractures. The Fast Fourier Spectra of P waves indicate higher amplitudes in the samples presenting microfractures than in non-fractured ones, because of less energy lost into S waves when open fractures are present. The T2 distribution times show characteristic behaviour determined by the grain size in sandstone samples and additionally by the presence of vugs in carbonates with complex lithology.

INTRODUCTION

Principle of ultrasonic evaluations

The core plug samples of one-inch diameter and two inches length were tested with an ultrasonic pulse of about 1 MHz main frequency. The P wave is captured in time domain and analysed in frequency domain using Fast Fourier Transforms (FFT). The FFT amplitude spectra is influenced by the presence of microfractures.

Principle of NMR evaluations

The low field NMR measurements have been performed with a 2 MHz spectrometer in order to determine petrophysical values as porosity, permeability, mobile and irreducible fluid volumes and to obtain information regarding lithological properties of the samples [1]. All this information is generated from the analysis of the transversal relaxation time distribution (T2-distribution) after applying an inverse Laplace Transform to the transversal magnetic relaxation decay curves. The samples were measured at both 100% and irreducible water saturation (after drainage in porous plate) at normal conditions of pressure and temperature. In order to assure the quality of the measurements, the NMR-porosity and NMR-permeability were compared with values from the conventional measurements.

Sandstone samples

These samples are from the Orocual field, "San Juan Medio" formation in East Venezuela. The geological age is cretaceous. The samples present lithological sequences of well sorted fine, medium and coarse grains, with sequences of cross laminations with variable angles. Typical porosity values are between 2% and 12%, the permeability is lower than 60 mD and the irreducible water saturation varies from 56% for fine-grained samples down to 10% for coarse-grained.

back to contents

Carbonate samples

These samples are from the Barinas field, "Escandalosa O" formation, which has a complex lithology, with eight depositional cycles containing sandstone mixed with dolomite and calcite (Figure 1). The porosity is about 20%, the upper part presents secondary porosity and some vugs are found in the bottom. The permeability is of the order of 1 mD. The geological age of the formation is cretaceous.

RESULTS

Ultrasonic measurements

In time domain is not easy to see any differentiation in the P wave between fractured and non-fractured samples. However, after applying FFT the frequency spectrum of a non-fractured sample shows higher amplitudes than for a fractured one. This is due to the lower amplitude disperse in the S waves direction, when open fractures are present (Figure 2). A similar tendency is observed in carbonates, where beside fractures the complex lithology may also influence the ultrasonic waves .

NMR measurements in sandstones

The T2 distribution depends on the ratio of pore surface over pore volume. But due to the relationship between pore size and grain characteristics as sorting and surface roughness, the T2 distributions in sandstones have been found to be very good correlated with the grain size [1,2]. Figure 3 shows the corresponding distributions for very fine to fine and for fine to medium grain sized samples with open fractures. After drainage the sample in a porous plate at about 100 psi (pressure of irreducible water saturation) the water saturated the NMR response was measured. The area under the T2 distribution curve for a drained sample corresponds to a porosity value for a T2 cut-off on the cumulative T2 distribution for a 100% water saturated sample. The average T2 cut-off for 23 samples was determined for the minimum in the average deviation, comparing the irreducible water saturation volume and the cumulative porosity along the distribution. Probably because of the presence of fractures, the best agreement was found for 6 ms. This value lies far below the 33 ms usually taken from the literature for petrophysical evaluations of this reservoir, leading in this case to an underestimation of the free fluid volume. The correlation's coefficient of the NMR-porosity vs. buoyancy porosity is 0.99.

NMR measurements in carbonates

In contrast to [3], the NMR behaviour of these samples implies a complex, non-typical carbonate lithology in each depositional cycle because of the variations in the positions of the maximum T2. In depositional cycle 1' (at the bottom) a characteristic sample shows high porosity (26%) and high T2 maximum at almost 90 ms, indicating the presence of a vuggy porosity with 80% dolomite content (Figure 4). In cycle 5 the quartz, dolomite and calcite content are near 30% each, the porosity is much lower (11%) and the T2 maximum lies around 12 ms (see fig. 4). The correlation's coefficient of the NMR-porosity vs. buoyancy porosity is 0.98. The average T2 cut-off for the depositional cycles is about 66 ms much less than the 90 ms to 110 ms usually taken for carbonates [3].

CONCLUSIONS

1. The intensity frequency spectra of the ultrasonic waves can be correlated qualitatively with the presence of fractures, using the P wave in sandstones and carbonates lithology.
2. For sandstones and carbonates with complex lithology, the T2 distribution is determined by the grain size, where very short main T2´s are correlated with very fine grains and large main T2´s with coarse grains or even vugs.
3. The T2 distribution in the studied very tight sandstone formation yields a very short T2 cut-off of about 6 ms, probably due to the presence of open fractures. A petrophysical evaluation using the standard value of 33 ms would lead to an underestimation of the free fluid volume.
4. The complex lithology with presence of dolomite, calcite and sandstone can not be evaluated as a carbonate reservoir then the T2 distributions give T2 cut-off values of about 66 ms, significantly lower than the 90-110 ms usually taken for carbonates.

REFERENCES

[1] Romero, P; Golindano, Y; Cedillo, I.; Azpiritxaga, I and Perernau, A., "NMR as a tool for reservoirs' characterization and lithofacies recognition", AAPG, New Orleans, 17-19 April 2000.

[2] Romero P.; Rodrigues P. and Alcócer Y.: "Use of Magnetic Resonance for Hydrocarbon Characterization". Journal CODICID, Vol. 2, No. 1, Dec. 2000.

[3] Salazar, J. and Romero, P.: "NMR measurements in carbonates samples and core-log correlations using artificial neural nets", SPE Annual Technical Conference and Exhibition, paper SPE 71701, New Orleans, 2001.

FIGURES

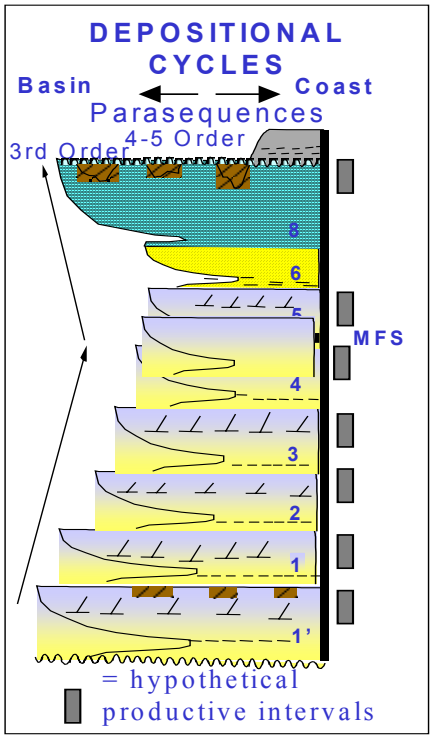

Fig.1 Schematic representation of depositional cycles in Escandalosa O formation of Barinas field

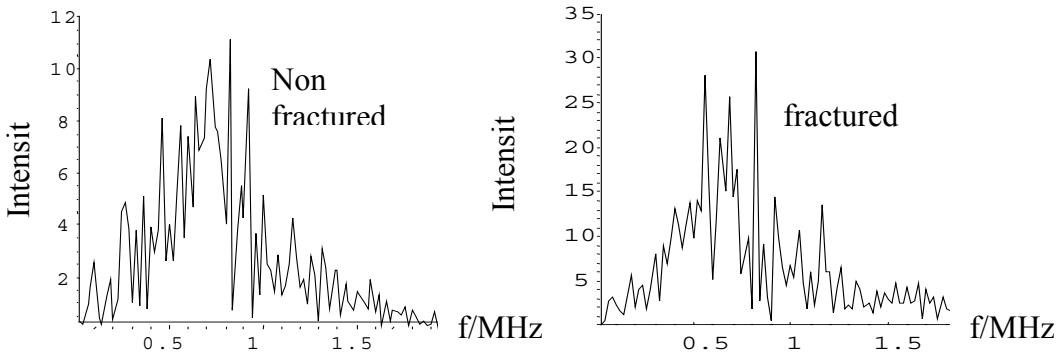

Fig. 2 Fourier spectra of the P wave for non-fractured and fractured sandstones samples

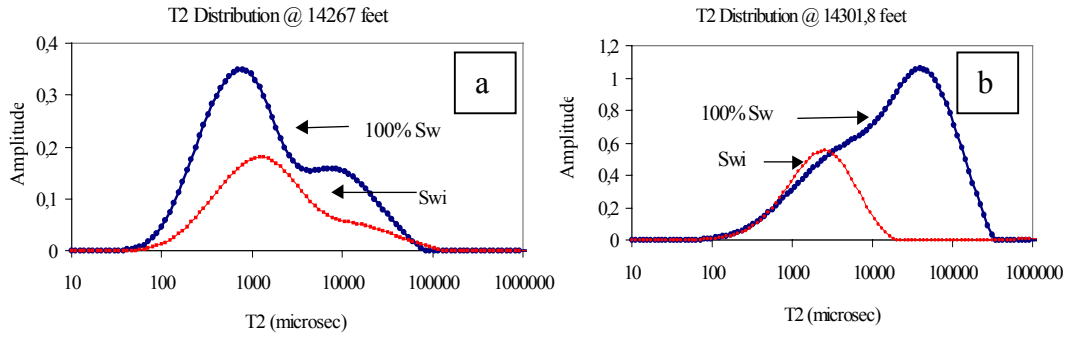

Fig. 3 T2 distribution of very fine to fine grained sandstone sample (a) and fine to medium grained sample (b)

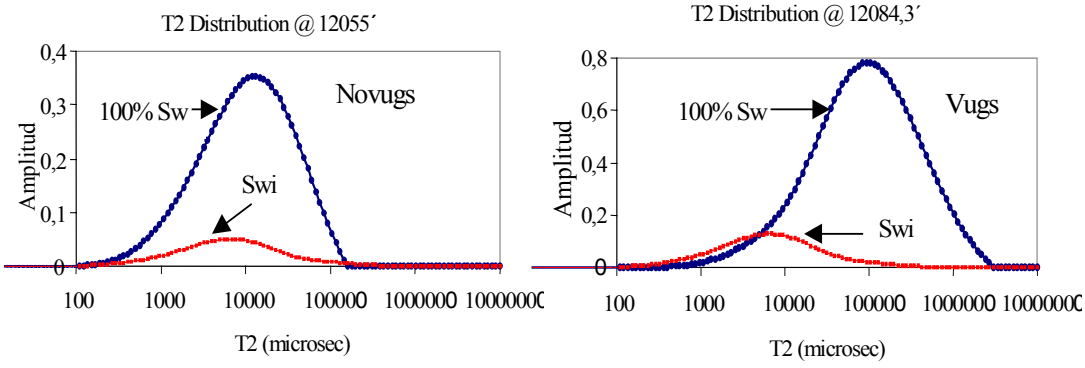

Fig. 4 T2 distributions of samples from complex lithology with no vugs and vugs

back to contents