Field Examples Elucidate the Value Addition Through NMR Logging in Western Region of ONGC

K K Prasad
WLS, Baroda
E-mail : prasadkk@ongcl.co.in

Summary

Oil companies are using NMR measurements for an ever growing number and range of applications,such as characterising formation fluids during reservoir evaluation , assesing formation producibility,designing more effective stimulation etc.. These measurements are dramatically changing well- completion designs and reservoir development. ONGC by using state–of–the art NMR measurements has kept pace with other oil companies for different applications and has been deriving benefits by doing so.

NMR measurements are used in different applications as enumerated below :-

1. To determine porosity almost independent of mineralogy.
2. To evaluate reservoir producibility.
3. To discriminate hydrocarbons from water(Fluid Characterisation) in varying salinity and low resistivity, low contrast regimes.
4. To derive continuous permeability information which is anessential input in designing cost effective stimulation designs.

Present paper discusses 6 field examples from Western Region of ONGC , elucidating the value addition of NMR measurements.This imbues enough confidence in NMR that it can serve as a desired succour in similar difficult situations in WR of ONGC.

Introduction

In last 15 years or so , nearly everyone involved in exploration and production, including reservoir engineers, completion engineers, geologists and petrophysicists applauded the newly arrived pulsed nuclear magnetic resonance (NMR) logging tools for their ability to solve the impending problems..A fundamental advantage of the latest generation of NMR tools is the ability to provide a wider scope of information about reservoirs & formation fluid than ever before. Thus one can hope for an answer through NMR data for many of their key questions like :

1. How to determine porosity almost independent of mineralogy.
2. How to evaluate reservoir producibility.
3. How to discriminate hydrocarbons from water in fresh, unknown or varying formation water salinity and low resistivity,low contrast regimes.
4. How to get continuous permeability information as an essential input in designing cost effective stimulation designs.

NMR logging has been utilised for above mentioned applications in WR of ONGC and an appraisal of its value addition has been done through field examples, which shows positive trend.

Principle of NMR Logging

NMR logging measures the magnetic moment of Hydrogen nuclei (protons) in water and hydrocarbons. Protons have an electric charge and their spin creates a weak magnetic moment.NMR logging tools use large magnets to create a strong, static, magnetic polarising field inside the formation. The longitudinal- relaxation time, T1, describes how quickly the nuclei align, or polarise, in the static magnetic field..The rate at which the proton precession decays, or loses its alignment,is called the transverse – relaxation time, T2. Both , T1& T2 processes are affected predominantly by interaction between pore- fluid molecules, or bulk relaxation characteristics, and from pore fluid interactions with grain surfaces of the rock matrix, also known as surface –relaxation characteristics. In addition, in the presence of a significant magnetic- field gradient within the resonant zone, there is relaxation by molecular diffusion that influences only T2 process. The longitudinal relaxation time (T1) is usually evaluated in the laboratory but in the well bore the transverse relaxation time (T2) is measured instead, because T2 is easier to measure in a logging environment. NMR logging is done in depth mode as well as station mode. The main application of NMR measurements are to understand pore size distribution in reservoir zones, to determine bound fluid volumes and, from

this information, improve predictions of free fluids which will flow from any given zone.

In station mode attempt is made to discriminate the pore fluid type (oil/water).This is done by integrating the down hole data acquisition and well site inversion with a multifluid response model to determine: fluid saturations, fluid volumes & oil viscosities. The service provider uses the patented technique for accomplishing this.

Discussion of 6 field examples from Western Region of ONGC

Field Example-1 (Anklesvar well –A Fig. 1)
Problem : Porosity evaluation uncertain through N-D combination as it is shown as highly shaly reservoir with apparently poor producibility . However, uncertainty on matrix value(complex lithology) may also be responsible in shrouding the real producibility of the reservoir.
Anatomy of the figure:
Track-1……S.P. in milli volt.
Track-2……Resistivity in ohm-m , increasing R.H.S.
Track-3……PHIN , RHOB , DELRHO.
Track-4……Permeability derived from NMR measurements.
Track-5……Porosity compartmentalization :
(a) Brown band—Clay bound Porosity
(b) Yellow band—Capillary bound Porosity
(c) White band (encompassed by Yellow band)
—— Producible/free fluid Porosity
Track-6……T2(Transverse Time Distribution) in milli seconds.
Value addition : NMR log successfully yields matrix independent (not affected by complex lithology) porosity with producible component (white portion) in 5th track. Permeability thro' NMR is shown in 4th track .Testing results corroborate NMR information.

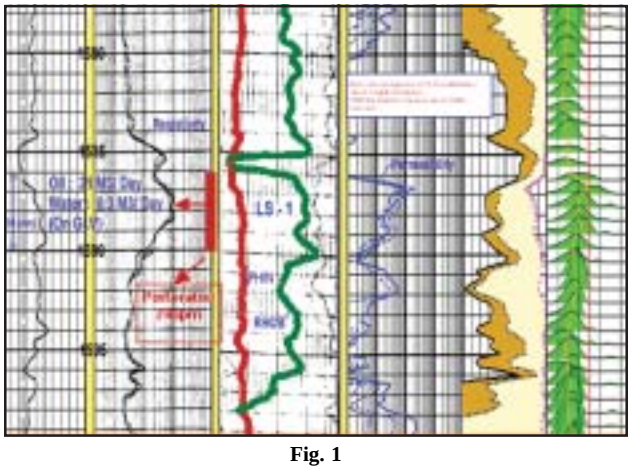

Fig. 1

Field example -2 (Gandhar well –A Fig. 2)
Problem : N-D separation shows good clean reservoir, however on account of bad hole it appears uncertain and the producibility of the rock is doubtful.
Anatomy of the figure:
Track-1……GR in API
Track-2……Resistivity in ohm-m , increasing R.H.S.
Track-3……PHIN in red , RHOB in green.
Track-4……BIN Porosity
Track-5…… Permeability derived from NMR measurements
Track-6…....Porosity compartmentalization :
(a) Brown band—Clay bound Porosity
(b) Yellow band—Capillary bound Porosity
(c) White band (encompassed by Yellow band)
—— Producible/free fluid Porosity
Track-7 …T2 (Transverse Time Distribution) in milli seconds.
Value addition : NMR logging shows extremely poor producibility. Luckily NMR has escaped facing the same bad hole as faced by density log . Testing results corroborate NMR information.

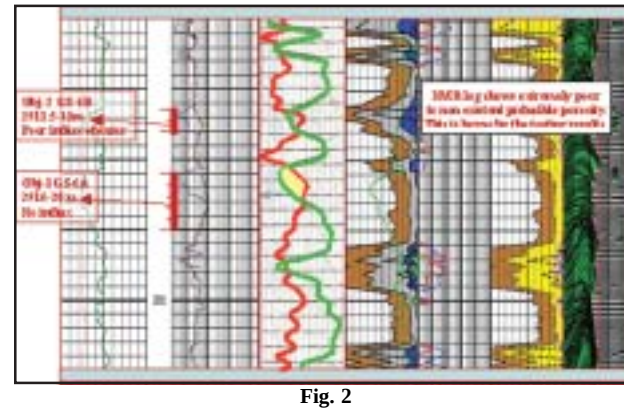

Fig. 2

Field example-3 (Limbodra well –A Fig. 3)
Problem: Ascertaining the type of fluid in the reservoir i.e. Fluid characterization.
Anatomy of the figure: Left half of the figure**:** Depth Log Mode.
Track-1…...GR in API
Track-2……Resistivity in ohm-m , increasing R.H.S.
Track-3……PHIN in red , RHOB in green.
Track-4……BIN Porosity
Track-5…… Permeability derived from NMR measurements
Track-6…… Porosity compartmentalization :
(a) Brown band—Clay bound Porosity
(b) Yellow band—Capillary bound Porosity
(c) White band (encompassed by Yellow band)
—— Producible/free fluid Porosity
Track-7……T2 (Transverse Time Distribution) in milli seconds.

Right half of the figure**:** Station Mode at a depth. Amplitude vs. T2 plot , showing water and oil components (Log mean as vertical st. line and amplitude signal as curve) in blue and green colors, respectively.

Value addition Presence of oil is indicated thro' green oilT2distribution and green vertical line corresponding to oil T2 log mean on x-axis on x-y plot towards RHS. NMR information is corroborated by testing results.

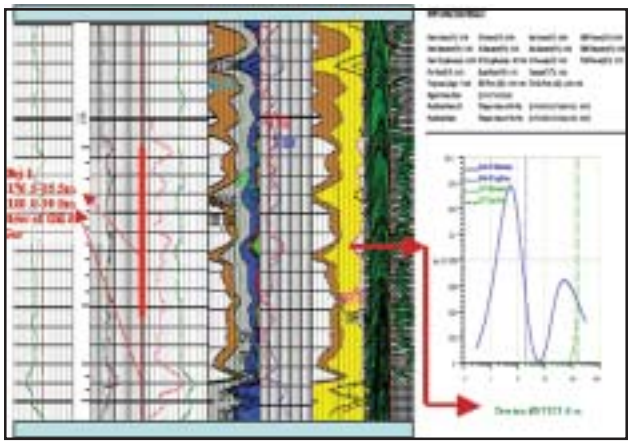

Fig. 3

Field Example- 4 (Mewad well –A Fig. 4)

Problem*:* Ascertaining the type of fluid in the reservoir i.e. Fluid characterization

Anatomy of the figure: Left half of the figure**:** Depth Log Mode.

Track-1……GR in API

Track-2……Resistivity in ohm-m , increasing R.H.S.

Track-3……PHIN in red , RHOB in green.

Track-4……BIN Porosity

Track-5…… Permeability derived from NMR measurements

Track-6…… Porosity compartmentalization :

(d) Brown band—Clay bound Porosity

(b) Yellow band—Capillary bound Porosity

(c) White band (encompassed by Yellow band) —— Producible/free fluid Porosity

Track-7……T2 (Transverse Time Distribution) in milli seconds.

Right half of the figure**:** Station Mode at a depth. Amplitude vs. T2 plot , showing water and oil components (Log mean as vertical st. line and amplitude signal as curve) in blue and green colors, respectively.

Value addition: Presence of oil is indicated through green oilT2distribution and green vertical line corresponding to oil T2 log mean on x-axis on x-y plot towards RHS. NMR information is corroborated by testing results.

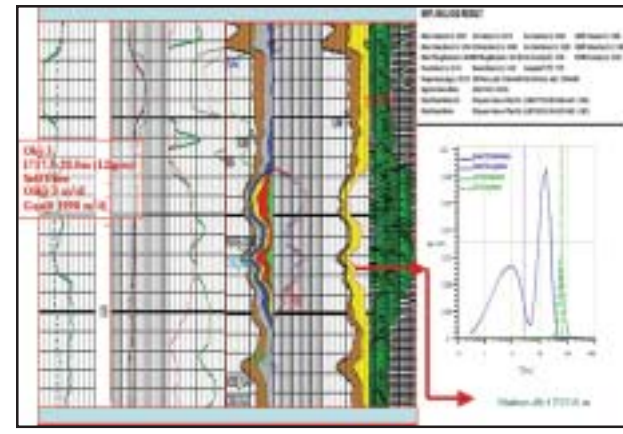

Fig. 4

Field Example- 5 (Sobhasan well –A Fig. 5)

Problem*:* Ascertaining the type of fluid in the reservoir i.e. Fluid characterization.

Anatomy of the figure: Left half of the figure**:** Depth Log Mode.

Track-1……GR in API

Track-2……Resistivity in ohm-m , increasing R.H.S.

Track-3……PHIN in red , RHOB in green.

Track-4……BIN Porosity

Track-5…… Permeability derived from NMR measurements

Track-6…… Porosity compartmentalization :

(e) Brown band—Clay bound Porosity

(b) Yellow band—Capillary bound Porosity

(c) White band (encompassed by Yellow band) —— Producible/free fluid Porosity

Track-7……T2(Transverse Time Distribution) in milli seconds.

Right half of the figure**:** Station Mode at a depth. Amplitude vs. T2 plot , showing water and oil components (Log mean

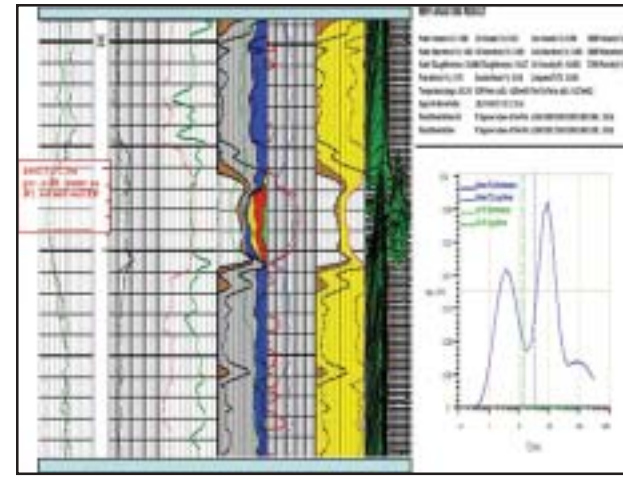

Fig. 5

as vertical st. line and amplitude signal as curve) in blue and green colors, respectively.

Value addition: Presence of oil is indicated through insignificant green oil T2distribution and green vertical line corresponding to oil T2 log mean on x-axis on x-y plot towards RHS. Oil indications are not so strong .NMR information is corroborated by testing results. Presence of oil is indicated , but not as strong an in earlier examples

Field Example- 6 (Gandhar well –A Fig. 6)

Problem*:* Ascertaining the type of fluid in the reservoir i.e. Fluid characterization.

Anatomy of the figure: Left half of the figure**:** Depth Log Mode.

Track-1……GR in API

Track-2……Resistivity in ohm-m , increasing R.H.S.

Track-3……PHIN in red , RHOB in green.

Track-4……BIN Porosity

Track-5…… Permeability derived from NMR measurements

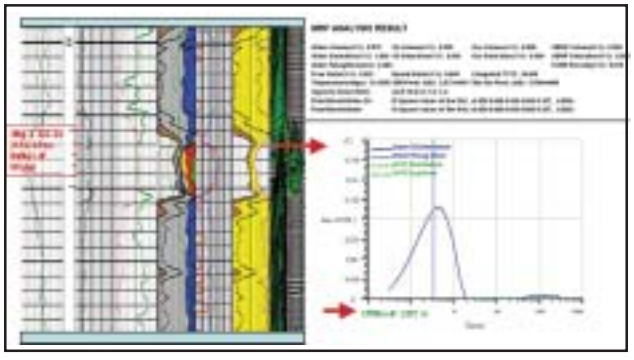

Fig. 6

Track-6…… Porosity compartmentalization :

(f) Brown band—Clay bound Porosity

(b) Yellow band—Capillary bound Porosity

(c) White band (encompassed by Yellow band) —— Producible/free fluid Porosity

Track-7……T2 (Transverse Time Distribution) in milli seconds. Right half of the figure**:** Station Mode at a depth.Amplitude vs. T2 plot , showing water and oil components (Log mean as vertical st. line and amplitude signal as curve) in blue and green colors, respectively.

Value addition: Presence of water is indicated through no green oil T2 distribution and no green vertical line corresponding to oil T2 log mean on x-axis on x-y plot towards RHS. It shows only blue water T2distribution and blue vertical line corresponding to water T2 log mean on x-axis on x-y plot towards RHS..NMR information is corroborated by testing results.

Conclusions

Field examples amply demonstrate that NMR tool in WR of ONGC has been quite successful in :

1. solving formation evaluation problems in complex lithology not amenable to N-D combination.
2. ascertaining the type of fluid present in the reservoir, which may be of great help In taking decisions whether to complete the well in target horizons or not.

Acknowledgements

Author is grateful to Sh.Chatar Singh, ED-Chief Logging for encouragement motivation and Mr. S.C. Choudhary, GM-Head Logging ,Baroda for his keen interest and discussions. Contribution of other colleagues is gratefully acknowledged.

Views expressed in this paper are those of the authors only and may not necessarily be of ONGC.

References

Brochures from service provider on NMR and fluid characterization.

Iskender S. Djafarov, Sergei F. Khfizov, and Pavel E.Syngaevsky, March-April 2004, NMR application in reservoirs with complex lithology: a case study, PETROPHYSICS.