Quantifying Hydrocarbon Saturation in Cased-hole — A Case Study

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Abstract

Drilling complication and/or in economizing the cost of a development well often forces E & P companies to lower casing without wire-line services. In such situation, C/O ratio method is relied upon in finding prospective zones and to evaluate them. The principle is based on Induced neutron gamma ray spectroscopy and induced capture gamma die-away responses against formations. By off-setting and adjusting parameters emanating from these responses against shale and water bearing zones, the potential layers are highlighted as well as their saturations quantified. In the absence of this vital supplementary information, a greater challenge is imposed upon analyst for rational interpretation. A challenge of this nature was faced in one well of Gujarat State in India where the data was recorded in 4 1/2″ casing using 2.125″ OD RMT[**] (Reservoir Monitoring Tool) without any input from open-hole log response. The problem has been addressed by modeling C/O ratio curves in association with Ratio of Near/Far Inelastic values (RIN) and Ratio of Near/Far Capture values (RNF).

Introduction

Southern part of Cambay basin is gas prone. Gas is confined in shallower clastic sediments of Miocene. Drilling through these sediments is not easy, because the sediments are less compacted and loose, and often create near blowout conditions. Gas occurrences being shallow, the environment create chances for the gas to seep to nearby cultural habitation through fissures, fractures, joints or unconformity surfaces. Safety and stricter environmental compliance therefore put pressure to the drilling community, case the well at the earliest without venturing for open-hole logging services. Moreover, in certain instances, E & P companies may prefer economizing cost and time of development wells by not recording open-hole logs. In such a situation, petrophysicist has to rely only on cased-hole logs which are relatively more susceptible to environmental effects due to casing and cement behind casing. RMT in cased-hole is found quite handy in formation evaluation, and is in practice for quite sometime now.

RMT principle relies on C/O ratio method and is based on the characteristics of the inelastic gamma ray signatures principally due to C and O reactions, present in the formation, with externally induced high energy (fast) neutrons. The distinction

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[**] *Trade Mark of Halliburton*

between hydrocarbon (C+H) and water (H+O) makes C/O ratio a potential indicator of hydrocarbon bearing layers. The other elements, besides C and O, contributing to inelastic spectra are: Ca, Si, Fe, S, and Mg.

The outcome from second nuclear reaction in capture mode is normally employed for supplementary information support e.g. porosity, identifying gas bearing, high saline water bearing and shale layers. These are vital information source required to workout present status of the well, identify and quantify potential hydrocarbon bearing layers. In the event inputs from open-hole logs are absent, they work as guidelines that help in superposition, offsetting and adjusting responses suitably to bring out new and leftover potential hydrocarbon bearing layers to target upon, and quantify hydrocarbon saturation.

This technique has successfully been employed in notifying shallow gas bearing layers through RMT service where only cased-hole gamma ray and Neutron log is available as supplementary support. Absence of open-hole logs and laxity of information about lithological disposition (e.g. shale, sand & silt from other sources) made the interpretation a challenging task. This is probably the first case in Cambay basin that has been resolved successfully through cased-hole services alone, saving rig time and money. Several gas bearing layers have been identified. One among these layers eventually put under commercial exploitation.

Data Acquisition and Processing

Two passes in C/O (inelastic) mode and one up and down passes in capture mode were made at a very low speed to control statistical variation and maximize the total count. The logs were then processed for gain stabilization by adjusting the spectrum to the desired channel numbers and were subjected to environmental corrections to condition the data for quantitative porosity and saturation estimation.

Shale layers have been identified and Vshale values were quantified from cased-hole gamma ray log. Total porosity is obtained from RCAP (capture ratio) and RIN (inelastic ratio) and is plotted like rhob–nphi (density-neutron porosity). These two inputs together provide the desired effective porosity values. The hydrocarbon saturation is then computed using Delta C/O saturation equations as mentioned below, and the delta offset is adjusted to match zero S_O (hydrocarbon saturation) in water bearing zones and shale layers to highlight present status of the formation. In the present case the adjustment has been done against shale layers only.

$$\text{Soil} = \frac{(1.82\,(2.69 - \Phi_T)\,\Delta C/O)}{(\Phi_T(1 + 3.07\,\Delta C/O))}$$

$$\Delta C/O = C/O - 0.21\,Ca/Si + 0.088\,\Phi_T$$

Observation

Sigma log against interval ‘A’ indicates the layer as gas bearing. Porosity of the layer is in the range of 12 to 18 pu and hydrocarbon saturation is 20 to 50%.

Interval ‘B’ is also gas bearing as indicated by sigma log. In this case, porosity is ~18 pu and hydrocarbon saturation is ~40%.

Similar sigma log response is seen against interval ‘C’ making it gas bearing. Here the porosity is in the range of 10 to 30% and hydrocarbon saturation is 35 to 60%.

Besides these, there are many zones which appear to be gas bearing with lesser saturations.

Conclusions

RMT record identified several gas bearing layers in this well. Interval 655.5-657.5 m was tested and was successfully put on commercial production which helped in increasing the productive life of the field.

This example establishes the robustness of the RMT tool in the present geological environment.

It has saved valuable rig time and made up for the data gap lost due to non availability of open-hole logs.

Acknowledgements

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References

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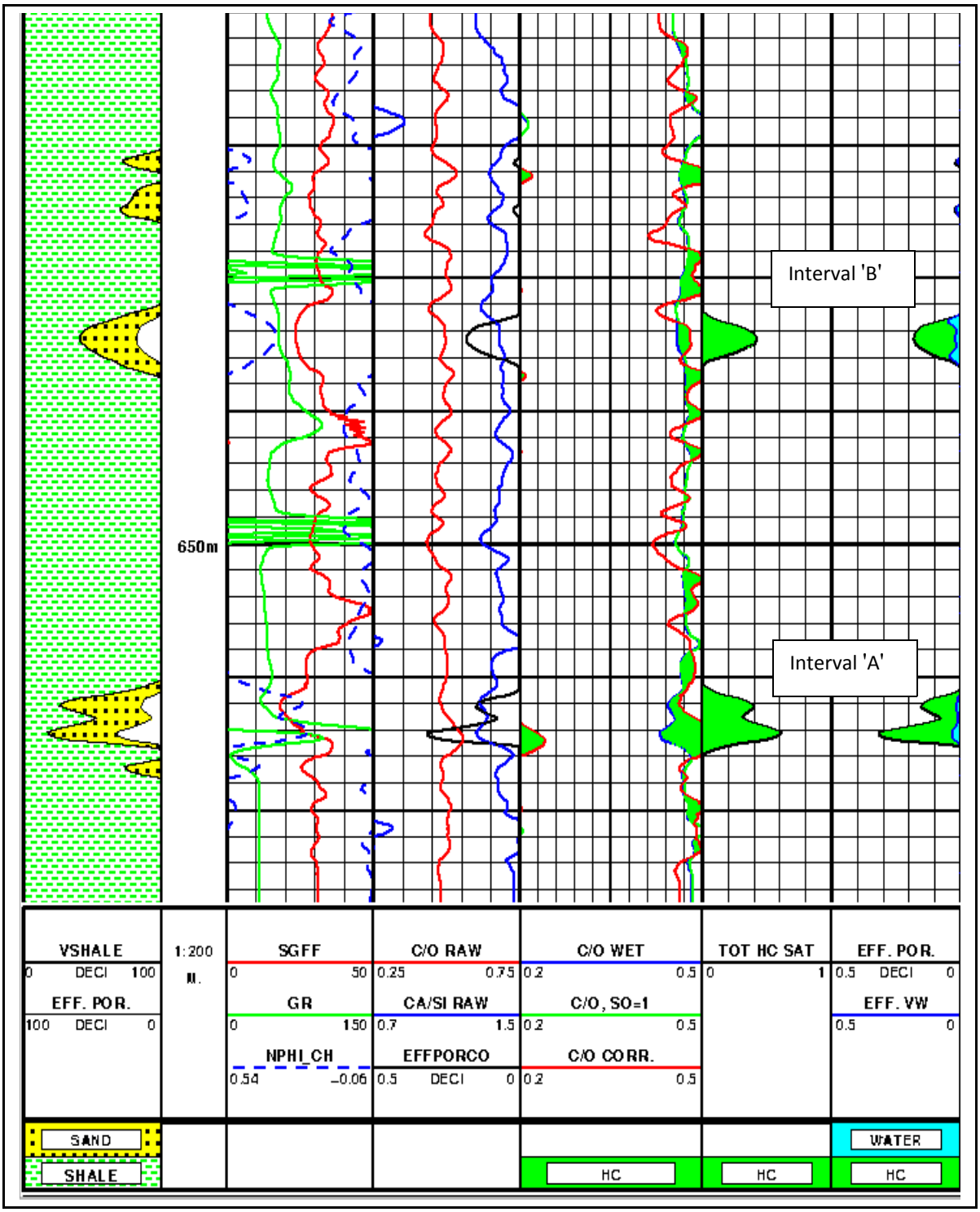

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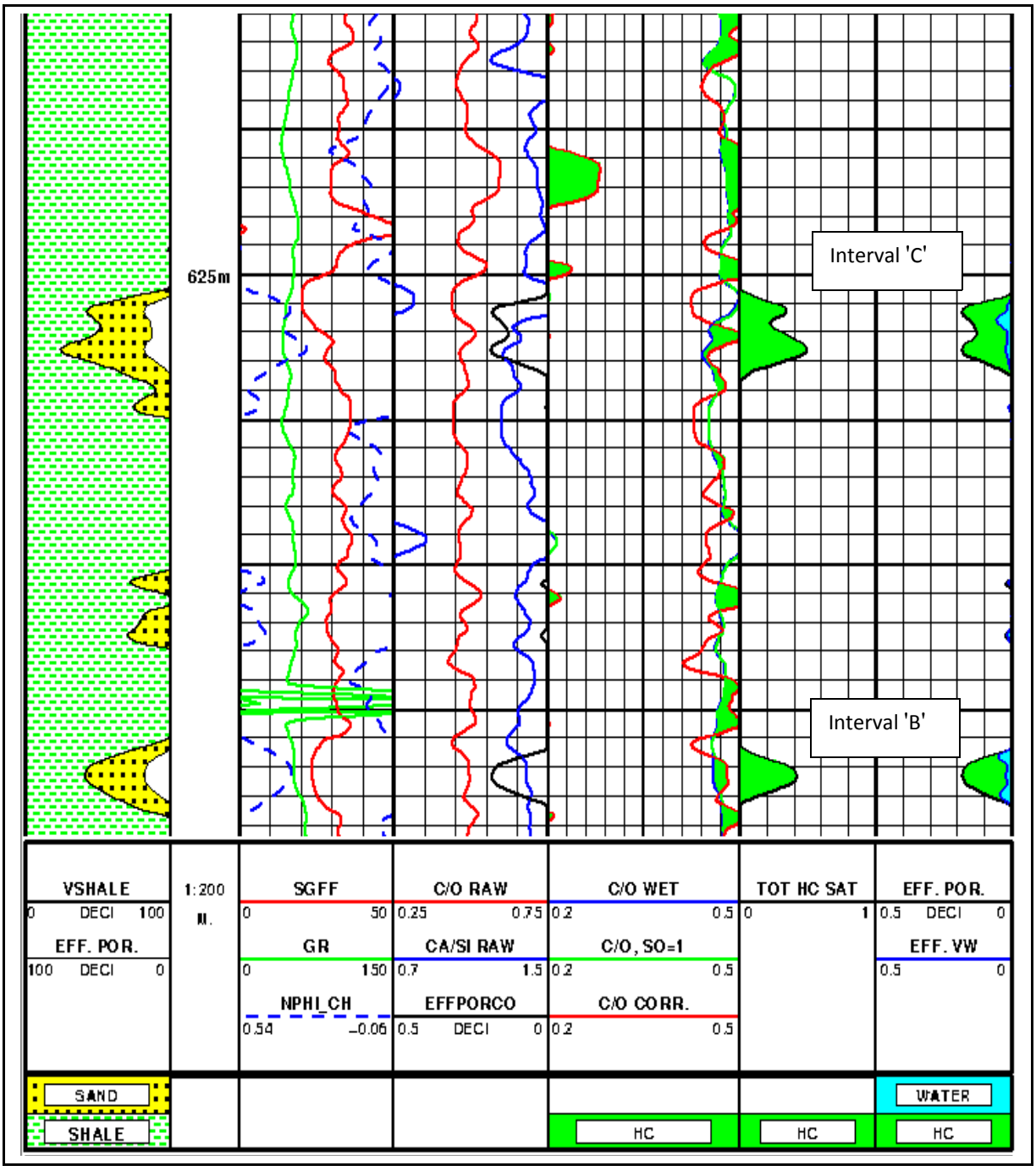

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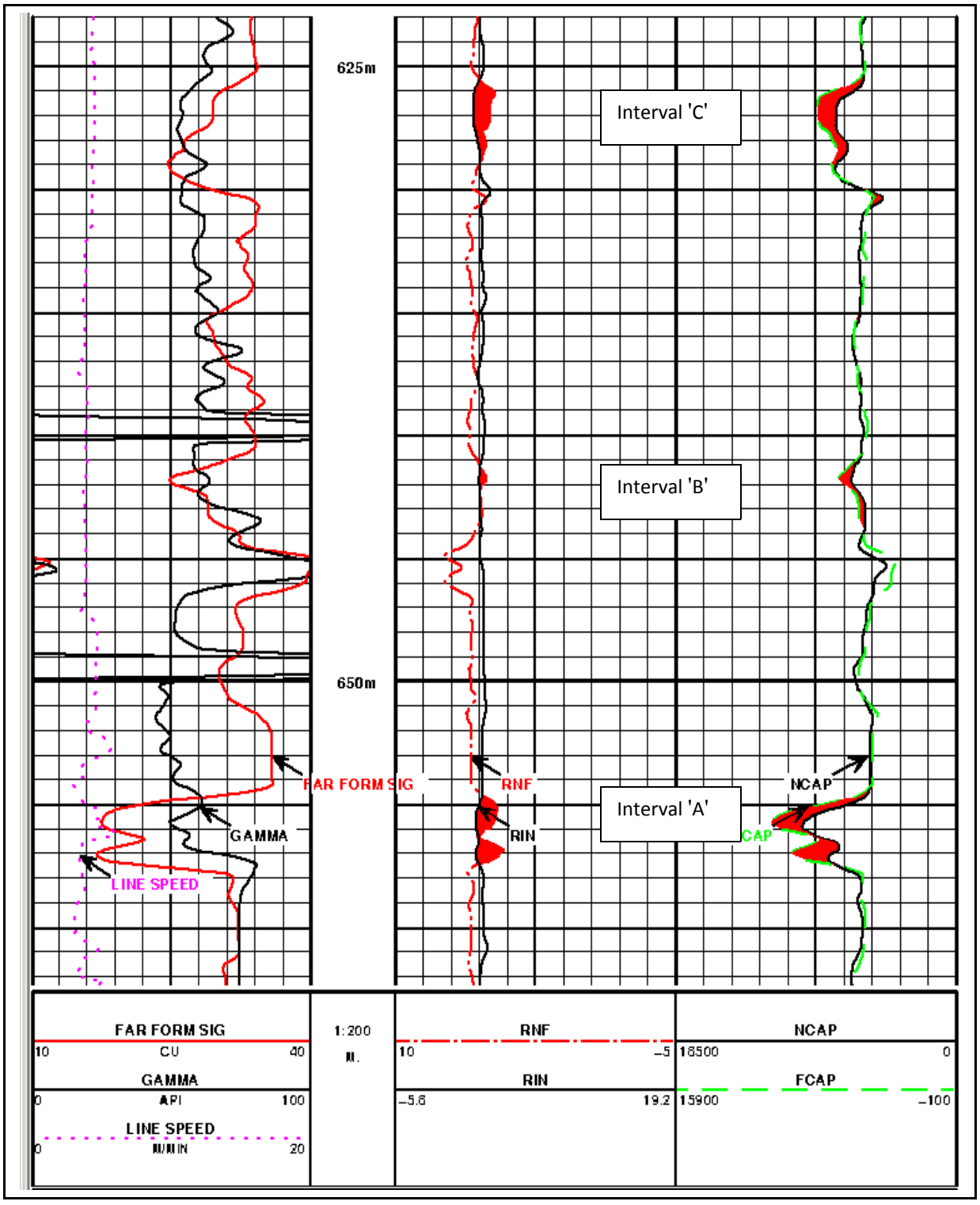
625m
650m
Interval 'C'
Interval 'B'
Interval 'A'
FAR FORM SIG
GAMMA
LINE SPEED
RNF
RIN
NCAP
FCAP
FAR FORM SIG
10
CU
40
GAMMA
0
API
100
LINE SPEED
0
M/MIN
20
1:200
M.
RNF
10
-5
RIN
-5.6
19.2
NCAP
18500
0
FCAP
15900
-100