

Fracture identification using conventional open hole logs in tight carbonate reservoirs of Vindhyan Basin, India.

Chaudhary Manisha*, Verma Jyoti, Gorhe R.P.
KDMIPE ONGC, INDIA

Chaudhary_manisha@ongc.co.in

Keywords

Fractures, tight carbonate, open hole logs.

Summary

Understanding fractures is a key factor in developing exploitation strategy, especially in tight carbonate reservoirs. Considering the limitations of coring and recording image logs, the present study attempts to use open hole logs to identify fractures in Rohtas Limestone Formation of Vindhyan Basin, which is a characteristically tight reservoir with porosity ranging from 1 - 5%.

Introduction

Identifying fractures in reservoir rocks is important because they provide conduits for the flow of oil and gas into the wellbore. Since fractures add to the complexity of the reservoir behavior and its productivity potential (Minne, J.C., 1979), it is desirable that such zones be recognized and evaluated. The primary source of information on presence of fractures so far is based on core data and image logs, while well tests describe its production potential. The present study focuses on identifying fractures using regular suite of open hole (OH) logs.

To demonstrate the robustness of the hypothesis, a tight formation (Rohtas Limestone) with porosity values mainly between 1% to 5% was used. Historically, it has been established that the only source of production from this reservoir is through open fractures. So, it becomes important to find readily available methods to identify fractured interval in such reservoirs.

Theory

Well data of ten wells from Vindhyan Basin, has been studied for developing and validating the hypothesis that OH logs can be used as a proxy to

identify fractures. Based on behavior of the conventional open hole logs in known fractured reservoirs (Jun Yan, et al., 2009) and considering various possible methods, two techniques using a suitable open hole log combination have been finalized. The first one is based on neutron and sonic log responses in fractured zones (DELTA_NDT technique) (Arango, S., 2004), which gives satisfactory results in clean (non-shaly) limestone and the second is based on the ratio of deep and shallow resistivity in the formation (RR technique) (Feng Cuiju, 2013), for the relatively shaly intervals of the formation. The two techniques have been integrated using an algorithm to get the desirable results in tight limestone formations having both clean and shaly horizons. The results have been further validated using resistivity image logs and available core data. The OH logs have benefit over image logs as their vertical and horizontal resolution is more than image logs (vertical/horizontal resolution of laterolog and image logs are 80cm/150cm and 2cm/3cm respectively) thus, they can give information for larger area within the formation as compared to image logs. Detailed flow chart of the technique is given below (Fig-1).

The stepwise approach for development of the technique to identify fractured zones is as follows:

1. Pre-calculations and environmental corrections for LLS, LLD, DT and NPHI curves for generation of new set of environmentally corrected log curves.
2. Overlay of NPHI_COR (corrected neutron porosity) and DT_COR (corrected sonic). The two curves should be overlain in tight, non-fractured clean limestone having a minimum thickness of 5m. The

identification of fractured zones is made by appreciable separation in the overlay of the above-mentioned curves. This method works well in clean formations but it is seen to provide overestimates in shaly formations.

The method has been quantified by normalizing these two curves (Eq-1 & Eq-2) and taking their difference (Eq-3). The deviation of DELTA_NDT from baseline which is set in non-fractured clean limestone, gives the fractured intervals (Fig-2).

$$DT_NOR = \frac{(\Delta t - \Delta t_{min})}{(\Delta t_{max} - \Delta t_{min})} \dots \text{Eq-1}$$

$$NPHI_NOR = \frac{(NPHI_COR - NPHI_COR_{min})}{(NPHI_COR_{max} - NPHI_COR_{min})} \dots \text{Eq-2}$$

$$DELTA_NDT = NPHI_NOR - DT_NOR \dots \text{Eq-3}$$

3. However, the above technique was discovered to have limitations in shaly limestones as the total porosity calculated by NPHI increases in the shaly part and DELTA_NDT value gives overestimated secondary porosity. Therefore, to identify fractures in shaly parts, another technique, the Resistivity Ratio (RR) technique, was used, and the results obtained are satisfactory (Fig-3). This method uses the relation between shallow and deep resistivity to give the output (Eq-4).

Calculation of Resistivity Ratio from Deep and Shallow Resistivity:

$$RR = \frac{(R_t - LLS_COR)}{LLS_COR} \dots \dots \text{Eq-4}$$

Rt= True resistivity of the formation

By determining shale volume from GR logs (Eq-5) and applying a cutoff to differentiate between shaly and clean parts, either of the two techniques are

selected on the basis of shale volumes and applied respectively to clean and shaly horizons within the formation under study.

4. Calculation of Shale Indicator from GR :

$$V_GR = \frac{(GR_COR - GR_COR_{min})}{(GR_COR_{max} - GR_COR_{min})} \dots \dots \text{Eq-5}$$

5. Integrating the above two techniques, Fracture Flag (FF) is generated for fracture identification from Porosity, Resistivity and GR logs:

$$FRAC_NDT_RR_GR = \max (RR - 0, 0) \text{ for } V_GR > 0.1$$

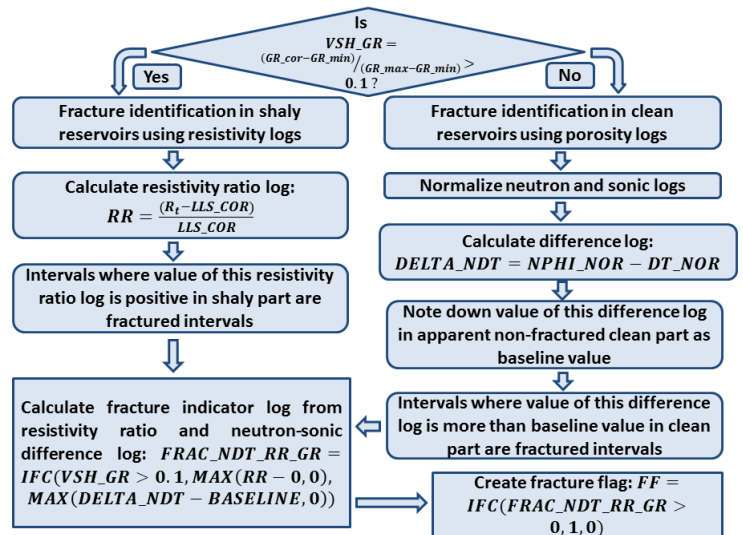
$$FRAC_NDT_RR_GR = \max (DELTA_NDT - BASELINE, 0) \text{ otherwise}$$

$$FF = 1 \text{ if } FRAC_NDT_RR_GR \text{ is positive}$$

$$FF = 0 \text{ if } FRAC_NDT_RR_GR \text{ is otherwise}$$

The fracture flag (FF) combines the two techniques to yield the final output in clean and shaly horizons (Fig-4).

Figure 1: flowchart of the technique



The technique has also been attempted in Sylhet limestone of Bengal Basin, where the limestone has same characteristics as that of Rohtas limestone of

Fracture Identification Using Conventional OH logs in Tight Carbonate Reservoirs of Vindhyan basin, India

Vindhyan basin and the technique gives reasonably accurate results in the Sylhet formation as well.

Examples

Figure 2: Fracture identification using DELTA_NDT technique.

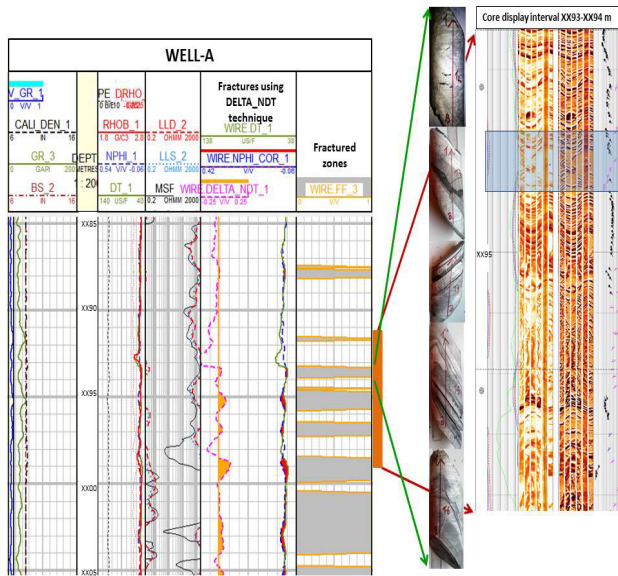


Figure 3: Fracture identification using RR technique.

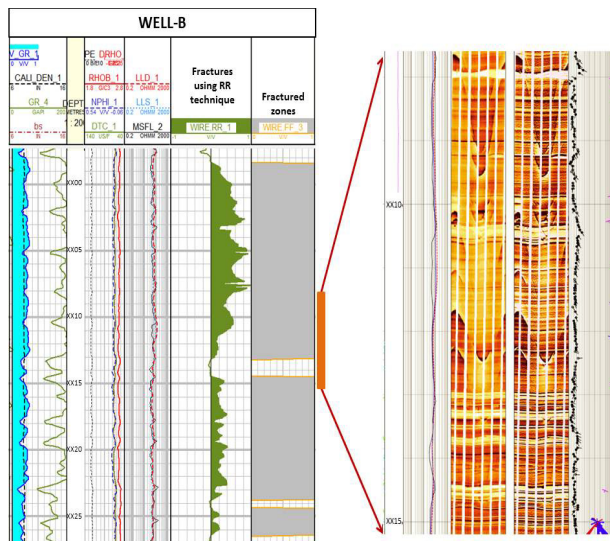
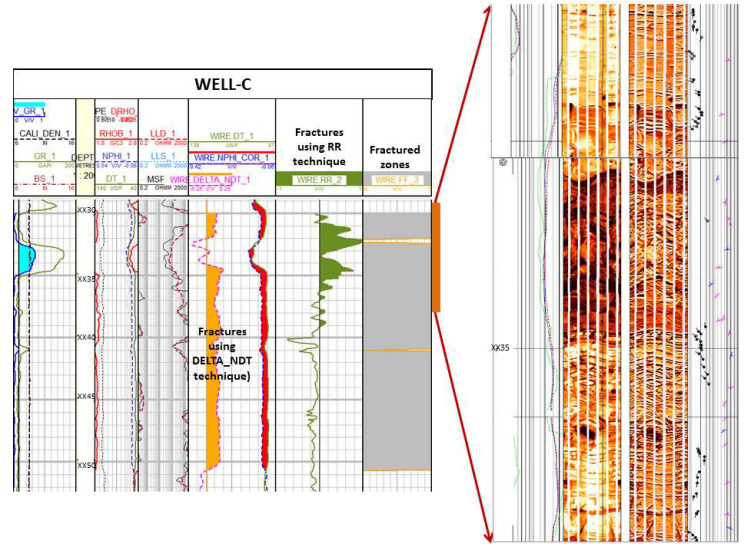


Figure 4: Fracture identification using both the techniques.



Conclusions

The study shows that fractured zones in tight carbonate formations can be identified using conventional OH log data. The conventional OH logs have an advantage over image logs as they have more depth of investigation, are less affected by the borehole rugosity and help in determining the connectivity of fractures away from the bore hole. The present study proposes two: DELTA_NDT and RR technique for identification of fractures in tight carbonate formations. The first technique provides satisfactory results in case of clean limestone Formation while the second technique is more helpful in case of increasing shaly content in the limestone formation. A method for integrating both of these techniques for achieving accurate results in mixed zone situations is described with case study from the

Rohtas Limestone Formation of Vindhyan Basin, India.

The technique has also been successfully applied in Sylhet limestone of Bengal basin, which has same characteristics as that of Rohtas limestone. The techniques have limitations in limestones with high porosity values (>7%) and in siliciclastic formations as well.

Acknowledgements

The authors express their sincere gratitude to Dr. D.N. Singh, ED-HOI-KDMIPE for his kind permission to undertake this study and for providing necessary infrastructure.

Useful interaction and discussion with geoscientists of KDMIPE has added value to the study. The authors wish to acknowledge and thank them.

References

Arango, S., Eduardo A. Idrobo, Hector H. Perez., 2004, A New Methodology to Estimate Fracture Intensity Index For Naturally Fractured Reservoirs. SPE.

Feng Cuiju & Yan Weilin., 2013, Fracture Qualitative Identification Using Conventional Logging Data; Applied Mechanics and Materials,.

Jun Yan, Liwei Lu, Rudi Lubbe and Simon Payne., 2009, Petrophysical fracture identification for rock physics studies; EAGE conference & Exhibition.

Minne, J.C., Gartner, J., 1979, Fracture detection in the Middle East; SPE.