Evaluation of Nandigama formation producibility by integrating facies & poro-perm transform

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Keywords

Reservoir facies, Poro-Perm transform, RQI (reservoir quality index), NPI (normalized porosity index), FZI (flow zone indicator)

Summary

In the present study the methodology adopted for identification and characterization of hydraulic units is based on empirical relationship between the log of permeability versus porosity. The adopted technique is based on modified Kozeny-Carmen equation and the concept of mean hydraulic radius.

Introduction

Nandigama field is situated in between the Kaza-Kaikalur horst in the west and Tanuku horst in the east of west Godavari sub basin (fig-1). The Nandigama formation is the oldest stratigraphic unit in this field and the presence of hydrocarbon has been established from this formation. Lithologically this rift fill sequence contains lithic wacke sandstone with clay rich matrix intercalated with clyastone/shale. This formation appears to be deposited under medium to high energy conditions within a fluvial system. The Nandigama formation is subdivided into Argillaceous and Arenaceous based on the log characters. The Arenaceous unit overlies on the Basement.

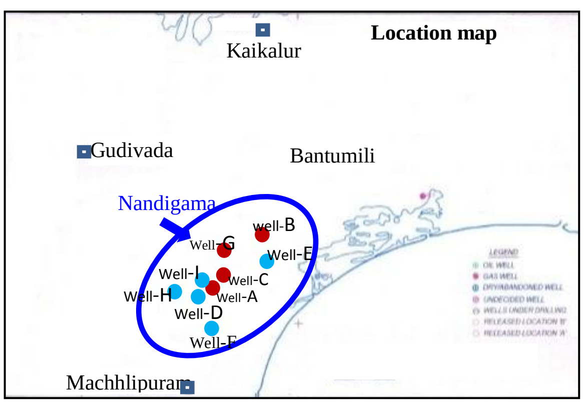


Figure 1: location map of the study field.

The reservoirs in this formation are of relatively low porosity and low permeability and are at high pressure and relatively high temperature (ranges in between 155-165 deg C).
Being low porous & permeable nature of reservoirs, HF jobs are carried out for hydrocarbon production. Identification of reservoir facies is an important aspect for successful HF job. This paper shows the methodology for demarcating producible zones by integrating deduced reservoir facies & testing/production results.

Study Approach

Reservoir facies analysis is an integral part of proper reservoir characterization to identify producible intervals especially in low porous & low permeable reservoirs. To understand petrophysical characters of producible interval's, petrophysical facies are generated using conventional log curve and are integrated with reservoir facies which are generated through porosity –permeability crossplot.
As reservoir facies are product of depositional and digenetic processes which alter the porosity and permeability of formations. Thus, the reservoir facies exhibit most importantly the petrophysical characters that control the fluid behavior and the flow potential of the reservoirs.

In the present study the methodology adopted for identification and characterization of hydraulic units is based on empirical relationship between the log of permeability versus porosity. The adopted technique is based on modified Kozeny-Carmen equation and the concept of mean hydraulic radius. The equation indicates that for any hydraulic unit, a log-log plot of a reservoir quality index ($RQI=0.0314 \sqrt{k/ø}$) versus normalized porosity index {NPI=ø/(1-ø)}, which should yield a straight line with a unit slope. The intercept of the unit slope line is defined as flow zone indicator (FZI) and it is a unique parameter for each hydraulic unit.

Estimation of Permeability

k-lamda or geochemical permeability has been computed using volumes of the various minerals of the processed output and their specific surface-to-volume-ratio. The general expression is:

$$k = \frac{A\,\phi^{m+2}}{(1-\phi)^2\,(\rho_{ma})^2\,(6W_{Cla} + 0.22W_Q + .2W_F)^2}$$

Where A = constant, ϕ = porosity, m=cementation exponent, ρ_{ma} = maxtrix density, and W's are the weight fractions of different minerals. The weight fractions of different minerals are computed from their respective volumes. The co-efficients associated with the weight fractions are related to the surface-to-volume-ratio that being maximum for clays. The constant A can be adjusted by core calibration.

Reservoir facies generation

To demarcate the reservoir flow efficiency of Nandigama field, computation of FZI (flow zone indicator) value has been carried out. Based on log-log cross plotting of RQI versus NPI for the wells of Nandigama field, total five types of rock facie have been discriminated. The identified rock types are named as rock type - I, II, III, IV & V and the reservoir facies associated with these are non-reservoir, very poor, poor, moderate & good reservoir respectively. The sample cross plot of one facie is depicted in fig-2 which represent interaction of generated reservoir facies with corresponding petrophysical evaluation as well as production testing details of these reservoirs.

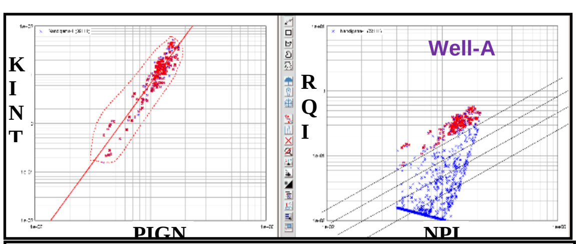
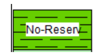
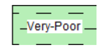
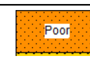
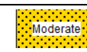


figure-2: For good type of reservoir facies, Curve itting equation: Y = pow(10, 4.0850 + (3.2649) * log10 (X)) : Goodness of fit = 0.861678.

Criteria	Rock Type	Reservoir Facies	Colour Coding
FZI<=0.2	Rock Type - I	No-Reservoir	
FZI between 0.2-0.45	Rock Type – II	Very Poor	
FZI between 0.45-0.85	Rock Type – III	Poor	
FZI between 0.8 -1.8	Rock Type – IV	Moderate	
FZI > 1.8	Rock Type - V	Good	

Transform generation

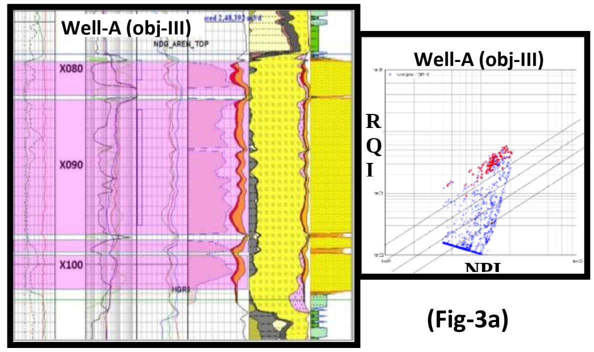
The log-log cross plot of ELAN derived permeability (KINT) versus porosity (PIGN) has been prepared and various Regression curves have been generated for Good, Moderate, Poor & Very Poor type of reservoir facies for Nandigama formation in all the drilled wells of Nandigama field.

The cross plots between permeability & porosity are generated and used to get regression equations of each facie to compute permeability in other wells. Each facie is also linked with clay volume which can be used to compute permeability with the generated transform in newly drilled wells in the area. A good fit has been observed for different facies amongst the individual wells with high correlation co-efficient. Regression equations for each facie with average coefficients/constants are listed below.

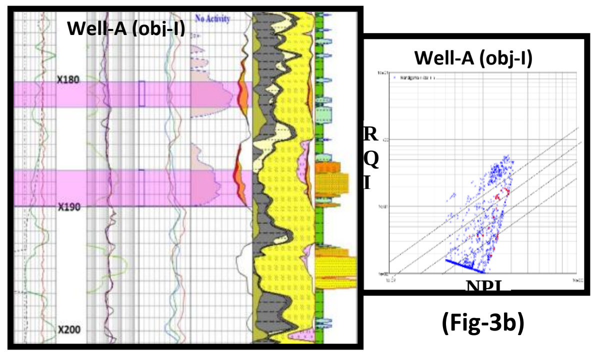
Good Reservoir Facie: Curve fitting equation: Y = pow (10, 4.6992 + (3.7061) * log10 (X)); Vcl <10%
Moderate Reservoir Facie: Curve fitting equation: Y = pow (10, 3.9466 + (3.4051) * log10 (X)); Vcl ~10-20%
Poor Reservoir Facie: Curve fitting equation: Y = pow (10, 3.2586 + (3.2497) * log10 (X)); Vcl ~20-40%
Very Poor Reservoir Facie: Curve fitting equation: Y = pow (10, 2.8962 + (3.3736) * log10 (X)); Vcl ~40-60%

Conclusions

- Approach using permeability & porosity to know flow zone indicator is helpful to identify producible intervals in low porous & permeable reservoirs.
- The computed volume of clay percentage variations are in tandem with the identified Flow Zones/Hydraulic Units with clay content increasing from Good, Moderate, Poor to Very Poor type of reservoir facies.
- Integrating clay volume from petrophysical evaluation with deduced facie and generating transform between porosity & permeability for each facie may be used in newly drilled wells for permeability computation.
- The methodology adopted for permeability and reservoir facies computation is getting calibrated with the testing data of Well-A in which Obj-III with very good reservoir facies and permeability gave commercial gas production while the Obj-I with very poor reservoir facies and very low permeability did not show any activity fig-3a & 3b.



(Fig-3a)



(Fig-3b)

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