Evaluation of Shaly Sand Reservoirs with Anomalous Log Response In Kamlapuram Field -A Case Study

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Summary

Nagapattinum sub-basin of Cauvery Basin hosts many important hydrocarbon bearing structures viz. Kamalapuram, Vijayapuram, Kovilkaloppal, Narimannam etc. Evaluation of low resistivity reservoirs developed within Kamalapuram formation in Kamalapuram field is difficult with conventional interpretation techniques because of their complex nature. The pay sands within Kamalapuram formation are characterized with low formation resistivity, erratic GR response and higher Neutron porosity. The SP response is also not quite consistent with production profiles of respective wells. The analysis of various logs and lithological cross-plots suggest sand-silt-shale composition of these reservoirs. The same is corroborated by geological descriptions also. The conventional deterministic techniques do not yield realistic results as computed shale volumes are higher and computed porosities are pessimistic. The present paper discusses the development of suitable interpretation technique for realistic evaluation of such reservoirs with complex log responses and applies the same for evaluation of entire field. The computed results are consistent with production data.

Introduction

Cauvery Basin, on the East coast of India extends from Pondicherry in the North to Tuticorn in the South, stretching into offshore waters of Bay of Bengal, Palk Street and Gulf of Mannar. The basin is bound on the West by the Indian Craton, whereas on the East, the Srilankan massif and its subsurface continuation define its limits. The basin is thus an intercratonic down wrap. Nagapatinam sub basin of Cauvery Basin hosts many of important hydrocarbon bearing structures viz. Kamlapuram, Vijaypuram, Kovikalappal etc. The Kamlapuram field is located in the southwestern plunge of Karikal ridge at the trijunction of Tanjore, Tranquelar Nagapatinam sub-basins. The sequences encountered in Kamlapuram field range from Early Cretaceous to post Eocene.

Kamlapuram Formation is the main hydrocarbon producing formation in the field. This formation is present in almost entire basin with two major depocentres in the Arycalur-Pondicherry Sub-basin and the other along Karikal ridge area. It is unconformably underlain by Protonova Shale while the overlying Karikal Shale has the conformable contact with the formation. Kamalapuram Formation has discreet sand bodies encased within thick shales and can be easily distinguished from shales above and below it. The environment of deposition of Kamalapuram Formation is outer shelf to upper Bathyal. Thickness of the Formation ranges from 600 to 1000(+)m. The age of Formation ranges from Paleocene to lower Eocene as deduced from faunal assemblage.

Kamlapuram Formation has been further subdivided into lower Kamlapuram and upper Kamlapuram. The hydrocarbon bearing sand bodies occur at different levels in different wells within Kamlapuram Formation. These sand bodies have mostly limited aerial extent. Sedimentological studies indicate that these sands have been deposited as discreet isolated submarine fan lobes having East-West alignment. The conventional cores, SWC and cuttings describe the formation having sands-silt–shale composition. The lithological crosssplots generated for some wells also suggest the data points falling in the sand-silt-shale trend. Hence both geological description and cross plot analysis indicate the formation comprising of sand – silt – shale.

Anomalous log responses and interpretation model

The Kamlapuram Formation is characterized with anomalous log responses, which complicate the evaluation process.

The hydrocarbon producing zones are having low resistivity. The resistivity of water bearing section is less than 1.0 ohm indicating formation water to be highly saline. The shale resistivity is higher than resistivity of water bearing sections. (Plate No3). In general there is good SP development against clean sections indicating that reservoir facies are good. Neutron-Density logs also support the inferences based on SP log. However there are some sand bodies, which have poor SP development but good production rates. In such cases the SP development is masked by the presence of silt/ clay and hydrocarbons. Thus it is very difficult to correlate SP with good permeability against such reservoirs. Hence SP log is not diagnostic in most cases although it is helpful in arriving at important

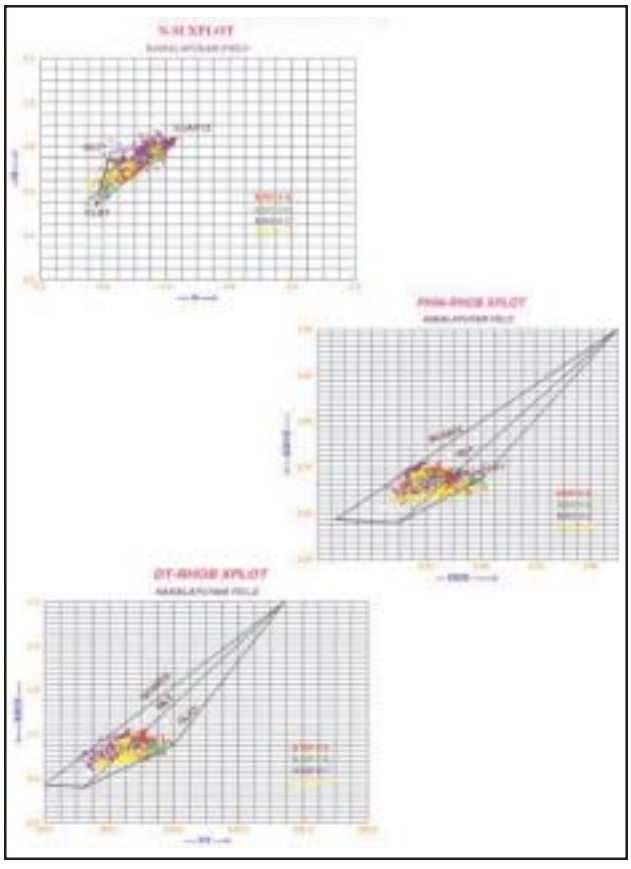

Plate1: Lithology cross plots Kamlapuram field

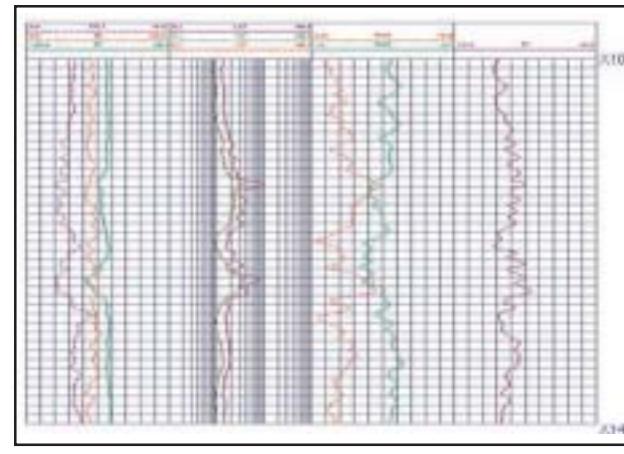

Plate 2: Flat GR Response Well KMP-A

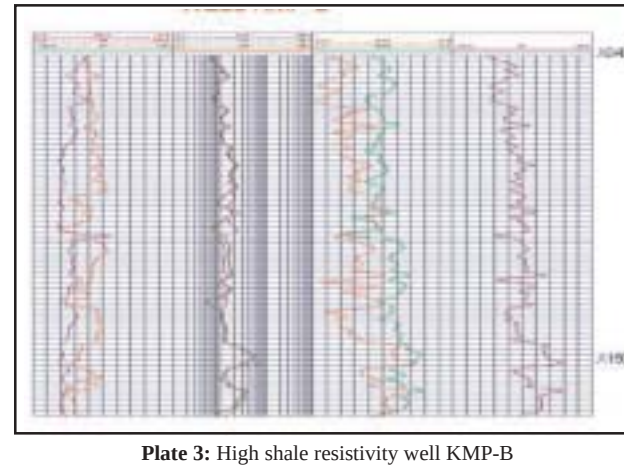

Plate 3: High shale resistivity well KMP-B

conclusions in some cases (Plate No. 2). GR response is quite erratic because of presence of radioactive sands in Kamlapuram Formation. In some cases sand bodies are associated with higher radioactivity than adjacent shales. Whereas in certain cases there is not much change in GR although SP log indicates the variation in reservoir facies (Plate-2). In general sand sections have good porosity. Most of the sand sections are having higher neutron porosity, which may be due to presence of micaceous silt. The same is also confirmed from cross plots of RHOB-PHIN. Most of the sand sections comprise of thin sand/shale alternations and log responses especially the resistivity log response is affected by side beds leading to misleading inferences.

The silty nature of reservoir, erratic GR response, thin sand/shale alternations and generally higher neutron porosities make the deterministic interpretation techniques unsuitable for the realistic computation of water saturations. The computed shale volumes are higher and inconsistent with production profiles of wells. The computed effective porosities are pessimistic because of higher shale volumes. Discussion of various log responses clearly indicate that multi-mineral model with quartz, silt and clay as the major constituents of the formation will be most suitable interpretation model for evaluating such reservoirs. M-N, RHOB-PHIN and RHOB-DT cross plots were generated for representative wells of the filed and data points were merged to obtain composite set of cross plots for the field. (Plate-1). The analysis of these cross plots indicate silt-sand -shale trend. After analyzing all the cross plots and excluding points corresponding to tight zones and caved borehole, the range of different matrix parameters for different constituents have been established as follow

RHOB (Quartz) = 2.65 gm/cc, PHIN (Quartz) = -0.03 p.u. and DT (Quartz)= 55.5 usec/ft.

RHOB (Shale) = 2.35-2.45 gm/cc, PHIN (Shale) = 0.50-0.54 p.u. and DT (Shale)= 110-120 usec/ft.

RHOB (Silt) = 2.68 gm/cc, PHIN (Silt) = 0.20-0.25 p.u. and DT (Silt')= 60-65 usec/ft.

There is no ambiguity regarding formation water resistivity in this field. A number of wells have produced formation water of salinity around 90,000 ppm. The formation water resistivity computed at formation temperature from this salinity is 0.04 ohm/m. The standard petrophyical parameters have been used for evaluation. The matrix parameters obtained from cross-plots have been used for processing of well log data by in-house software "APTWEL" based on inverse modeling technique. Various input parameters used for evaluation and interpretation model has been validated against known water bearing sections.

Out of 35 wells drilled in this field, 25 wells are oil wells and well log data of 23 wells has been processed. Processed data for two wells P & Q has been is presented in form of paralogs (Plate 4 & 5).

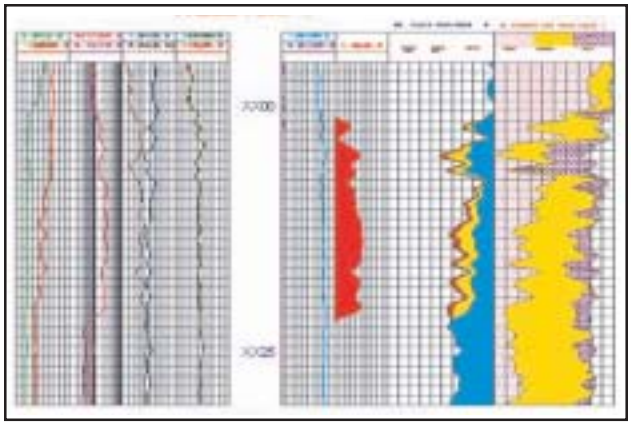

Plate 4: Reservoir evaluation well KMP-P

Discussions of results

The pay sands developed within Kamlapuram formation are characterized with low formation resistivity, erratic GR response and higher Neutron porosity. Evaluation of Kamalapuram pay sands with this model has resulted in higher effective porosities and lesser shale volume as compared to earlier evaluations. There is increase in porosity

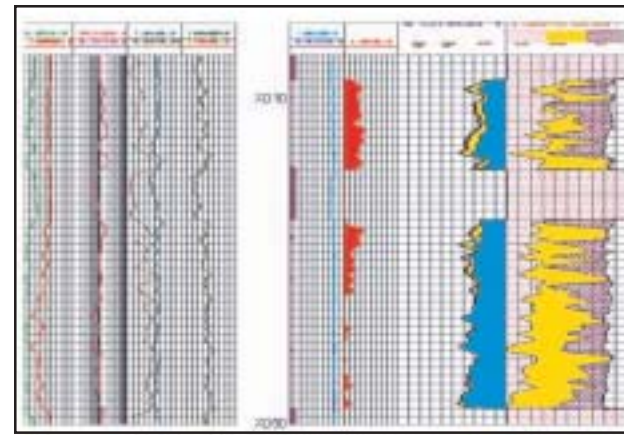

Plate-5 Reservoir evaluation well KMP-Q

ranging from 2 to 5 porosity units and decrease in shale volumes from 5 to 10 %. Computed effective porosity and shale volumes are consistent with core data and production profiles of the wells. Hydrocarbon bearing sands in Kamlapuram field occur at different levels in different wells as discontinuous sand bodies with limited areal extent. Among all the sand bodies only sand-2 developed within lower Kamlapuram formation has large areal extent.

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References

WORTHINGTON.P.F. 1982. The influence of shale effects upon the electrical resistivity of reservoir rocks. Geophys. Prospect. 30, 673-687.

POUPON, A. and LEVEAUX, J. 1971. Evaluation of water saturation in shaly Formations. Trans. SPWLA 12th Ann Logging Symp., 01-2.