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Reservoir characterization through standardization of minerals and petrophysical parameters and its utility in log property mapping. - A case study in North Cambay Basin.

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Abstract

Heterogeneous clastic reservoirs pose problems in formation evaluation due to variation in mineralogy and petrophysical parameters. Realistic reservoir characterization is necessary to understand complexity of these reservoirs. For this, the various minerals and petrophysical constants need to be standardized for that particular formation. Standardization of the petrophysical constants and minerals input helps in proper reservoir characterization, reducing uncertainty of estimated reservoir parameters and in deciding the field development programs. The present study aims to develop a standardized multi-mineral, petrophysical processing model through integration of open hole log data with core determined petrophysical parameters and mineralogical assemblage for realistic reservoir characterization. The study has been attempted for K-IX & K-X reservoirs of a field in North Cambay Basin in order to address the challenges of inconsistency in production behaviour vis-à-vis log character. Further, log property mapping has been carried out for bringing out the spatial distribution in porosity, thickness and saturation. These maps should be very useful in finalizing the strategic plan of hydrocarbon exploration and development in the studied area.

Introduction

The Cambay Basin, situated in north western part of Indian Peninsula in the state of Gujarat and part of Rajasthan, is one of the major on-land hydrocarbon producing basins across India. The field studied is located on the northern rising flank of Tarapur Depression in the Mehsana-Ahmedabad tectonic block of North Cambay Basin. The K-IX and K-X pays are two regionally distinct coarsening upward sequences ending with coal developed within the Formation and hydrocarbons accumulations have been established in the reservoirs. However, owing to heterogeneous nature of these reservoirs, processing and interpretation for fluid saturation and mineral volumes is not easy. Also there is inconsistency in production behaviour vis-à-vis log character. The present study focuses on developing a standardized multi-mineral, petrophysical processing model through integration of open hole log data with core determined petrophysical parameters and mineralogical assemblage for realistic reservoir characterization, in order to address the challenges of inconsistency in production behaviour vis-à-vis log character. Further, log property mapping has been carried out for bringing out the spatial distribution in porosity, thickness and saturation. These maps should be very useful in finalizing the strategic plan of hydrocarbon exploration and development in the studied area.

Methodology

In order to standardized minerals and petrophysical constants namely, ‘a’, ‘m’ and ‘n’, a sequence wise methodology has been adopted. Detailed sedimentological and petrophysical studies have been carried out in the respective labs on the available core samples. Integrating these studies with detail log analysis, minerals and petrophysical parameters have been standardized and these have been incorporated to develop a processing model for realistic reservoir characterization. To validate the model, key wells of the area have been reprocessed and the results have been compared with the initial production testing data. The minerals volumes are also validated with the minerals volume estimated from cores studies. The standardized multi-mineral processing model has kaolinite, chlorite as main clay minerals along with siderite as heavy mineral. Overall improvement has been noticed in hydrocarbon saturation (Sw) and effective porosity (ϕ_e) in the re-processed hydrocarbon bearing intervals with a good match with production data. Using these data, log property mapping has been carried out for bringing out the spatial distribution in porosity, thickness and saturation. These maps should be very useful in finalizing the strategic plan of hydrocarbon exploration and development in the studied area.

Results and Discussions

i. Petrophysical Parameters

Detailed petrophysical studies were carried out on core samples for the determination of petrophysical constants-'a', 'm', 'n' and parameters-porosity, permeability, grain density and bulk density.

The core derived 'a', 'm', 'n' constants for K-IX & K-X pay sands of the field A were found to be 0.71, 1.86 and 1.80 respectively. The core derived matrix density was 2.67 gm/cc.

The core derived porosity was in the range of 10.0 to 18.0%, while, the permeability was in the range of 0.5 to 3.0 mD. The grain and bulk densities were in the range of 2.5 to 2.69 gm/cc and 2.13 to 2.62 gm/cc respectively.

ii. Sedimentological studies

The objective of sedimentology core study is to find out the mineralogy and clay minerals which help in building the multimineral petrophysical model for better understanding of the reservoirs K-IX & K-X pay sands of field A . The SEM–EDX analysis and XRD studies were carried out for deciphering mineralogical and diagenetic impact on quality of reservoir rocks. Sedimentological study confirms the presence of Quartz, Kaolinite, Chlorite and Siderite minerals along with Coal.

iii. Integration of log analysis with core analysis

After analysing and integrating core data with log analysis, the petrophysical, mineralogical model has been standardized for evaluating K-IX & K-X pay sands of field A. The input parameters have been selected based on core derived sedimentological, petrophysical data and log attributes. Key wells have been evaluated through this standardized multi-mineral processing model. The example is shown in Fig.1.

The standardized mineral and petrophysical constants for K-IX & K-X pay sands of field A are as below:

Matrix: Quartz
Clay Minerals: Kaolinite, chlorite
Heavy mineral: Siderite,
Other mineral: coal
Petrophysical constants: a=0.71, m=1.86 and n=1.8

Formation water resistivity (Rw): 0.2 ohm.m at Formation Temperature

Fig. 1: Multi-mineral processed output with default and standardized parameters

Fig-1 shows the comparison of the processed results from default and standardized parameters. Processing with default parameters is unable to identify the exact minerals in the formation along with true fluid volumes. Reservoir characterization, therefore, is not realistic. Reprocessing with the standardized model is able to identify the minerals along with their volumes which match well with the core derived data. The standardized processing also shows an overall improvement in hydrocarbon saturation (Sw) and effective porosity (ϕ_e) in the hydrocarbon bearing intervals with a good match with the initial production testing data.

The technique also gives realistic reservoir picture and therefore, reservoir characterization through this methodology give accurate estimation of the reservoirs such as porosity, permeability, fluid saturation, minerals along with their volumes and the production profile of the reservoir.

Using this standardized data, log property mapping has also been carried out for bringing out the spatial distribution in porosity, thickness and saturation in the reservoirs.

iv. Property mapping of K-IX & K-X pay sands of field A and trend analysis:

Integrated reprocessing was carried out with the standardized multi-mineral, petrophysical model for fifteen wells. The generated outputs from processed log data viz. sand thickness, effective porosity and hydrocarbon saturation were used to generate maps and to establish a regional trend of variations across the field A. The top and bottom depths of K-IX & K-X pay sands were converted to TVDSS for all vertical and inclined wells for drawing the sand thickness map. Well-wise sand thickness, effective porosity and hydrocarbon saturation were estimated and noted in point data format with respect to depth from the

above processing. Corresponding values of effective porosity, hydrocarbon saturation in K-IX and K-X pays have been used for generation of maps. These log property maps have brought out the spatial distribution in porosity, thickness and saturation. These maps should be very useful in finalizing the strategic plan of hydrocarbon exploration and development in the studied area.

The maps of K-IX pay indicate that the sand has better thickness, effective porosity and hydrocarbon saturation towards the northern side. Area towards northern side might be promising from hydrocarbon point of view with better reservoir facies **(Fig. 2)**.

The maps of K-X show that the sand has good thickness, effective porosity and hydrocarbon saturation towards the northern and western sides of central part. Hence, area in the directions of northern and western sides appears to be interesting from hydrocarbon point of view in **(Fig. 3).**

Conclusions

The present study has developed a standardized multi-mineral, petrophysical processing model for K-IX & K-X pay sands through integration of open hole log data with core determined petrophysical parameters and mineralogical assemblage for realistic reservoir characterization. The standardized model has helped in better understanding of the hydrocarbon potential of K-IX & K-X pay sands of the field along with

realistic estimation of reservoir parameters besides showing improvement in hydrocarbon saturation against tested hydrocarbon bearing zones. Through standardization of parameters the study is also able to address the challenges of inconsistency in production behaviour vis-à-vis log character. Further, log property mapping has been carried out for bringing out the spatial distribution in porosity, thickness and saturation. These maps should be very useful in finalizing the strategic plan of hydrocarbon exploration and development in the studied area.

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