An Integrated Approach Using High Resolution Logs and Advance Petrophysical Analysis to Establish the Production Ambiguity- A Case Study of Sand Stone Reservoir off the West Coast of India.

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Keywords

Image Log, Texture, Petrophysics, Sorting index, High Resolution, Production Log, Heterogeneity, Ambiguity

Summary

In this study advanced petrophysical analysis were performed to get the insight of the complex formation; which in turn has helped in understanding the flow dynamic of the reservoir sands. Oligocene clastic reservoir from Mumbai always poses immense challenge due to enormous variation in reservoir heterogeneity both laterally and vertically. Therefore, determining correct petrophysical property along with the geological uncertainties is of utmost importance.

Electrical Borehole Image log texture was used to qualitatively identify different reservoir sands as different facies. An enhanced processing on the Image log was performed to extract the synthetic resistivity and the sorting index. High resolution synthetic resistivity data clearly depicts the fine scale variation of lithology; which is beyond the resolution of normal resistivity log. Sorting index provides a very good idea about the grain size distribution based on the conductivity variation. Effective porosity and permeability was also computed to understand the reservoir dynamics. A detail lithology analysis was also performed to understand to rock mechanical properties around the borehole. The image log analysis was integrated with the advanced volumetric results; which produces a robust petrophysical model.

The derived petrophysical model was subsequently used to decide completion strategy for gas exploitation wells in Tapti field. Analysis revealed that the pay zones have strong sand production tendencies due to the unconsolidated nature of the reservoir rock. The completion strategy focused on preventing sand production. Well in the field are completed in multiple and commingled zones using the frac-pack technique to avoid any sanding issue. After certain period of production, it was decided to carry out production log in these wells. Sophisticated production logging reveals the lower thick sand unit is producing at much lower rate than what was expected, whereas the upper thin sand unit is producing with high potential. Integrated petrophysical analysis along with the completion plan reveals the production ambiguity. This case indicate that the sand in proximity wells can also produce with lower than the actual potential due to clogging of the flow conduits by microfine of the sand. According necessary action in the form of design the perforation strategy and subsequent stimulation will be developed to derive the maximum potential from the reservoir.

Introduction

Tapti-Daman is one of the major hydrocarbon-producing clastic sub basins situated in the northeast region of the Mumbai High structure in Western offshore India. Tapti-Daman sub-basin (Fig.1) hosts more than 6 Km of clastic dominated sediments ranging from late Paleocene to Recent underlained by basement rocks.

Borehole image logs provide azimuthal distribution of high-resolution resistivity data in a near-borehole environment capturing the internal fabric and texture of varying lithofacies. The technique described here illustrates how the textural heterogeneity can be extracted; quantified and used to differentiate sedimentary facies that can then be classified on the basis of their textural variability. Integration of image textural analysis with dynamic production log data validates the reservoir heterogeneity using sorting Index; thereby significantly improving petrophysical evaluation and reserve estimation. Two reservoir sand layers (e.g. Sand-A & Sand-B) were evaluated and further conclusion was drawn based on the integrated log analysis result.

General Geology

The Tapti –Daman block consists of Tertiary clastic from Paleocene to Recent. The depositional lows contain in excess of 5000m of sediments. The generalized Stratigraphic succession is shown in (Fig.1). The Cenozoic basin is floored by Late Cretaceous to Paleocene Deccan Trap Basalts which erupted as a consequence of the rifting of the Indian plate in the Late Jurassic-Early Cretaceous time. The Lower Oligocene is represented by the Mahuva Formation which can be subdivided into a lower shale unit and an upper unit with lenticular sands and thin limestone bands. This formation is a major target for exploration and a number of gas and occasionally oil bearing plays have been probed. The Upper Oligocene is represented by the Daman formation which has been deposited in a delta front environment. The Miocene basal sands are fluviatile sands in the northern part of the basin and are the shallowest targets (Parashar et.al., 2010) .

Challenges & Advancements

The two prolific pay zones (Sand -A & Sand –B) are encountered in the present section. Advanced production logs reveal ambiguity in terms of production. The lower thick sand was producing much lower than the upper thin sand; which was unexpected as per the petrophysical analysis.

Facies analysis was performed using the conventional open hole logs to understand fine scaled variation in facies. However, satisfactory answer was not obtained due to coarser resolution of open hole logs (Fig.3).

An innovative approach was taken to unveil the production uncertainty; high resolution image logs were used to derive the detailed picture of the formation. Image texture alone was not distinctive in both the sand units due to hydrocarbon masking .Therefore, an advance textural analysis was performed to derive the sorting index in clastic section based on image logs. The image log was calibrated with the conventional open hole logs to derive high resolution synthetic resistivity before textural analysis. The sorting index provides a very good idea about the grain size distribution based on conductivity variations. An attempt was made to derive better facies model based upon sorting index and synthetic resistivity (Fig.4).

Methodology

Borehole Electrical images have been utilized to visually evaluate textural changes for some time. However, visual understanding by an interpreter remains subjective and is difficult to quantify. The technique described addresses this problem. The workflow consists of multiple steps involving image log and spectroscopy log processing and interpretation followed by correlation with core data at different stages of data integration. The measure of rock texture and heterogeneity is carried out using a sandstone textural analysis program. The first step of this sandstone textural analysis involves the calculation of resistivity image spectrum circumferentially around the wellbore over a short interval (few inches to fraction of an inch). Then, an image “sorting index” or “heterogeneity index” (Fig.2) is calculated from the percentile distribution of the resistivity image histogram. The variation in image resistivity is similar to that seen in grain size sorting in clastic rocks and the resistivity distribution can vary from well sorted, poorly sorted, bimodal, and skewed either high or low(Fig.2). The heterogeneity index calculation used is a relatively simple function of the percentile distribution (Newberry et. al., 2004).

$$\text{Sorting Index} = \frac{\text{75th Percentile} - \text{25th Percentile}}{\text{50th Percentile}}$$

In this form, the heterogeneity index is independent of the absolute resistivity values and will have a similar response in low resistivity and high resistivity formations. The heterogeneity or sorting calculation of the resistivity measurements are the same methods used in distinguishing sorting from a core grain size distribution. Finally, the high-resolution image data acquired in the steps above is merged with the available log data to generate a facies description (Fig.4 & 5), which captures much of the textural content of the images.

The major lithological divisions are then divided into textural subdivisions based on the resistivity variation, e.g., well sorted and poorly sorted.

Image log texture was used to qualitatively identify different reservoir sands as different facies. Petrophysical results and net pay are up scaled as well as fine tuned at places by using high resolution micro-resistivity data to bring out the minor textural variation in the reservoir units.

Interpretation and facies analysis scheme requires key wells for core calibration to determine facies relationships, but, the core data in practical situation is not available in each study well. The most important assumption in sandstone textural analysis is that the resistivity distribution is considered to be analogous with sorting / heterogeneity and therefore texture. The resultant lithofacies thus can be merged with other geological elements from different sources to give the subsurface model a better shape. The results have been further authenticated with dynamic production log data.

Result and Conclusion

Advanced image log analysis provides the finest information about the formation heterogeneity, which conventional open hole log is unable to produce alone. Integration of the advanced image log analysis with the dynamic production log reveals a clear picture of the sand zones.

Two major hydrocarbon bearing sands are identified from the open hole logs in this section; Sand-A and Sand-B respectively. The integrated image log analysis reveals Sand-A is having lesser proportion of conductive and resistive events along with low sorting index as compared to Sand-B .This clearly indicates that sand-A is comparatively better sorted.

Advanced production log results add an insight to the production profile in this deviated well. Spinner velocity data along with cumulative flow rate (Fig.5) indicates higher gas entry from the thinner sand-A (196600 SCMD) than the lower thicker sand-B (21897SCMD) as per the Table1. This might be attributed due to the better sorting of the sand –A (Fig.5).

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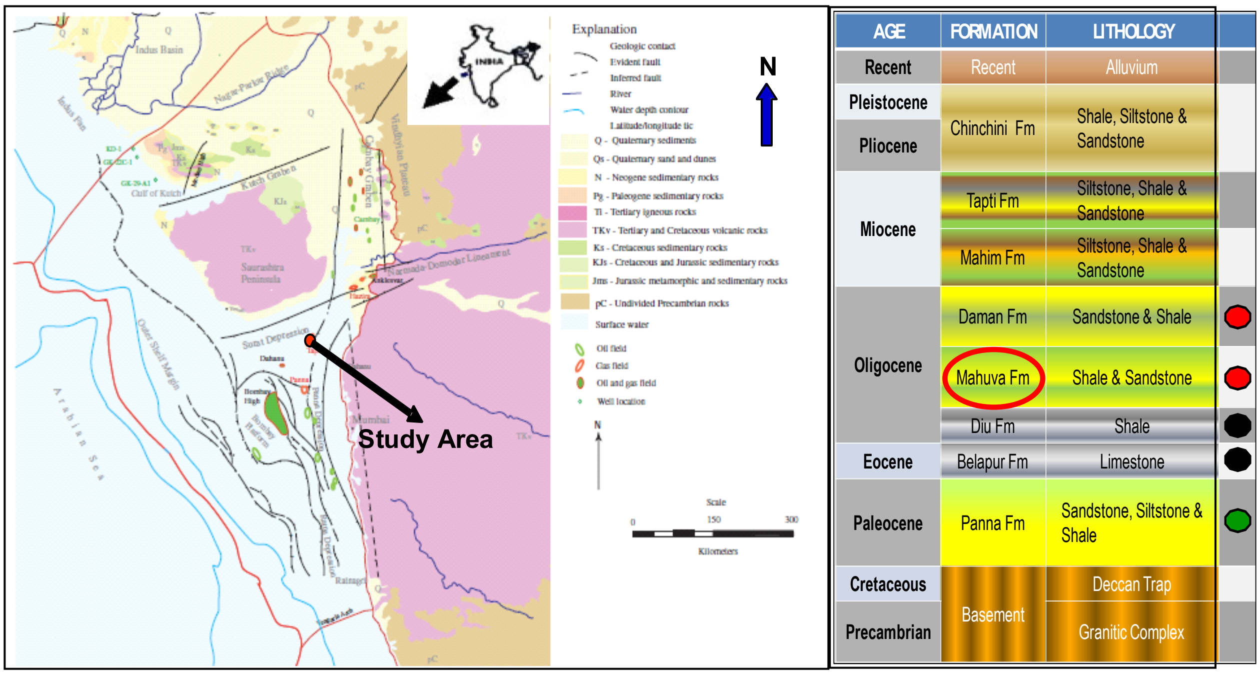

Figure.1 Area location (after Wandrey, 2004) and generalized Stratigraphy ofTapti –Daman field.

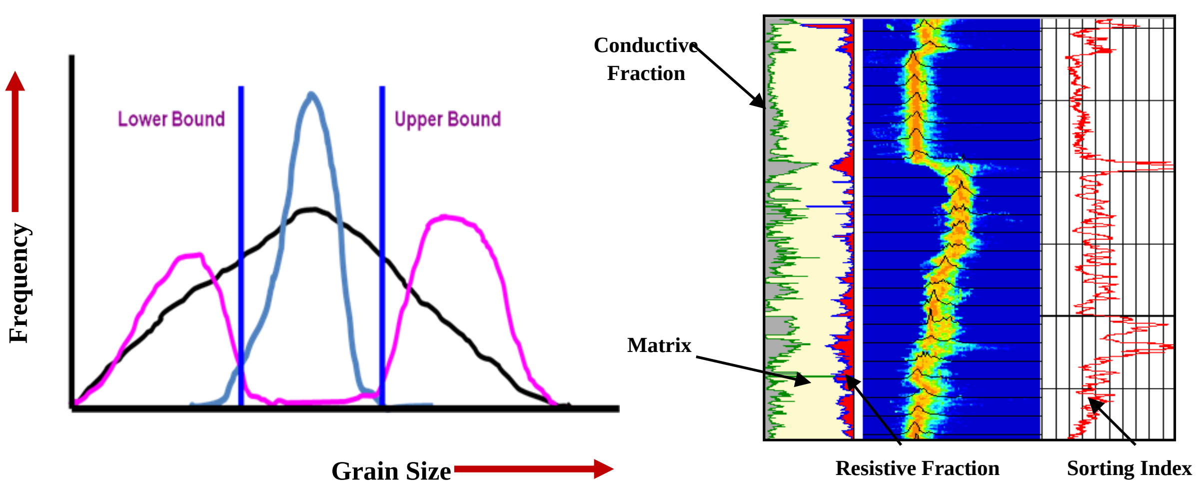

Figure.2 Principle of Sandstone Textural Analysis and textural classes (after Newberry et.al., 2004); User defined boundaries from poorly sorted to well-sorted distribution.

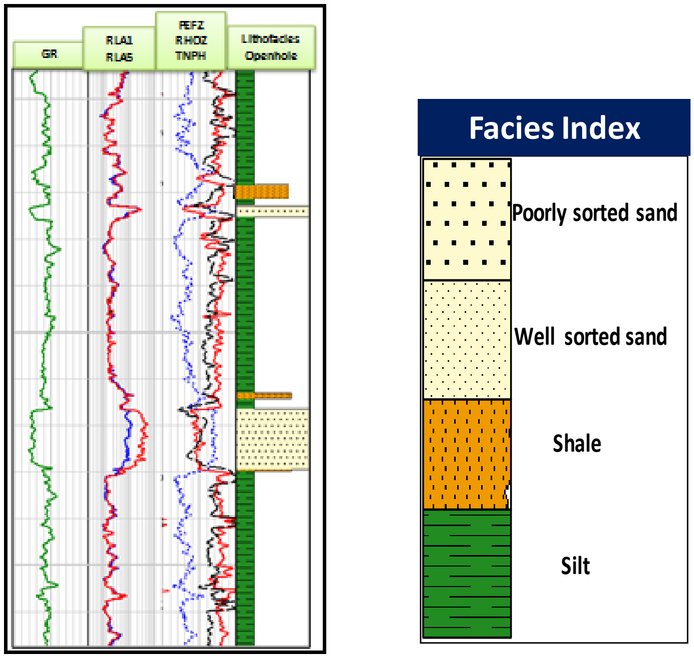

Figure.3 Facies classes from openhole log analysis.

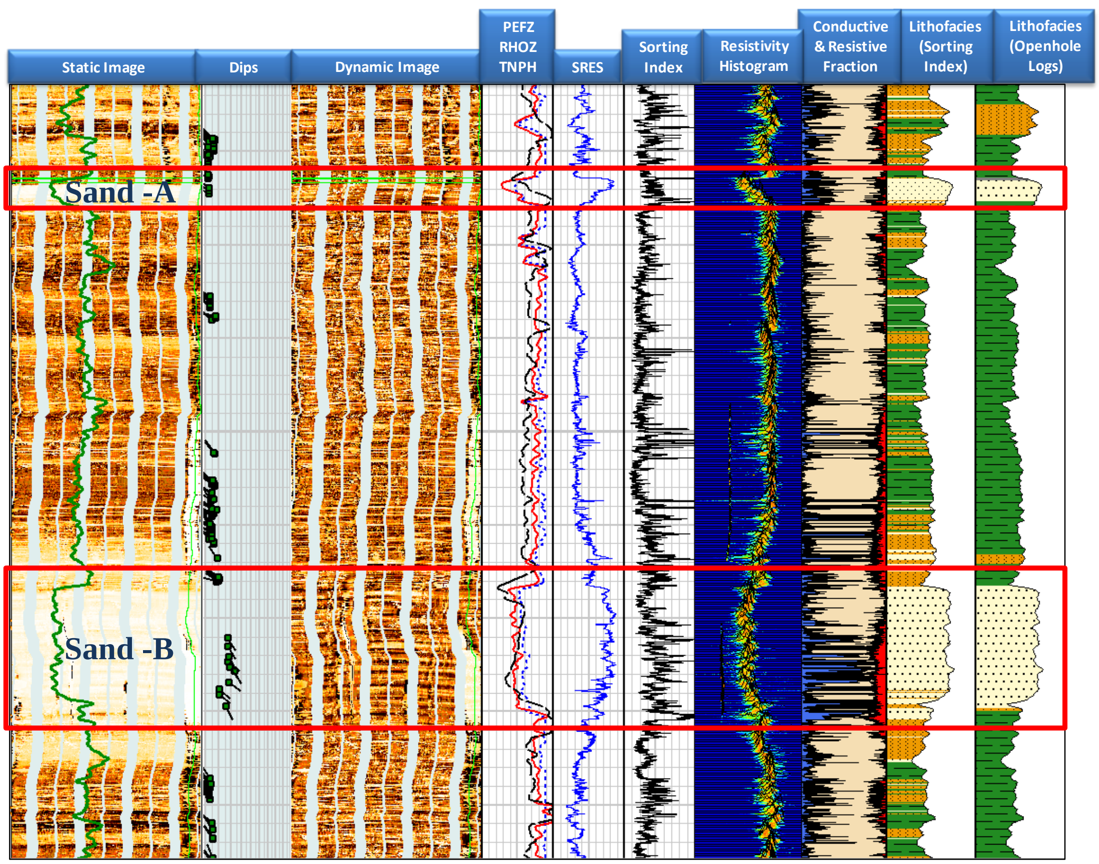

Figure.4 Heterogeneity Index and Textural facies as calculated based on image resistivity spectrum.

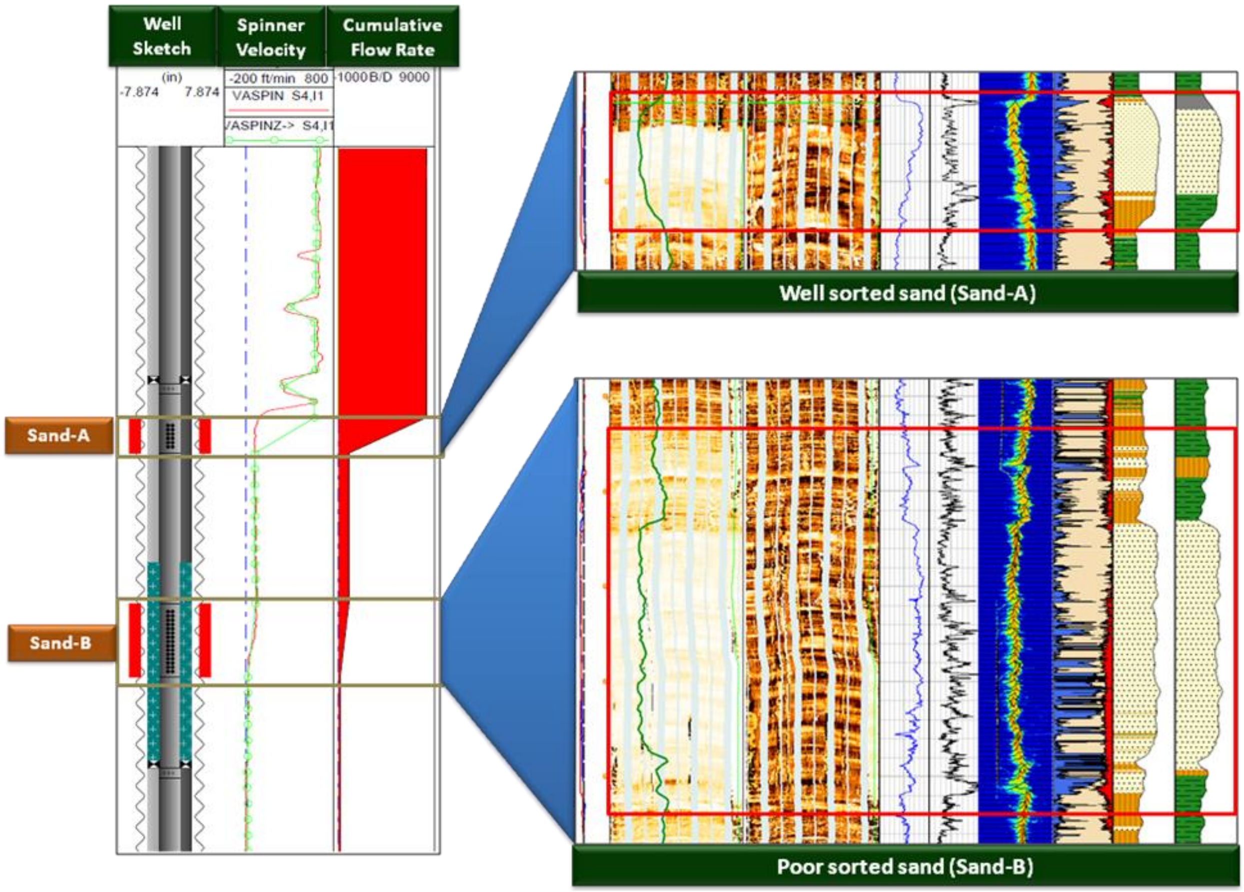

Figure.5 Validation of production profile with facies classification from sandstone textural analysis

Zones/Intervals	Gas	Condensate	Water
SCREEN	SCMD	BBL/D	BBL/D
Screen-1 (Sand-A)	196600	256	Traces
Screen-2 (Sand-B)	21897	37	Traces

Table1. Dynamic production log data for the two pay zones