[PS]A Sequence Stratigraphic Framework for the Tide Dominated Lower Tarkeshwar Reservoir in the Lakshmi Field (Gulf of Cambay, India) to Enhance Field Understanding and Production Potential*

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Abstract

The offshore Lakshmi Field in the southern part of the prolific Cambay Basin, Western India, is an inversion fold structure generated during the Late Miocene. The main reservoirs in the lower Tarkeshwar Formation of the field were deposited during the early Miocene in a global sea level overall transgressive system following a late Oligocene major low-stand event. The present day satellite images of the Gulf of Cambay provide an effective analogue for the complexities and geometries of a tide-dominated estuarine environment. Flooding surfaces recognized in electro-log motifs from 12 wells in the Lower Tarkeshwar Formation enabled sequence boundaries to be interpreted and facies distribution patterns identified, including forced regressive units and associated complex valley-fill sequences. Analysis of the vertical stacking patterns in the well logs revealed a series of para-sequences through time. Electro-log driven seismic attributes were grouped into four primary geomorphic elements namely large estuary systems with channels, tidal creeks, muddy tidal flats and migrating tidal bar complexes. These geomorphic elements were analyzed in detail to establish realistic geometrical parameters including shape, size, orientation and thicknesses. Tidal bar geometries were obtained from quantitative data and satellite images of the present day Gulf of Cambay coupled with outcrop analogues of the Sego Sandstones in the Book Cliffs of Utah. Depositional trends were defined and aerial facies distribution maps were generated at key levels. The aerial facies distribution maps and electro-log stacking patterns were integrated to develop a 3D facies model, which honored the geometries of the geomorphic elements. Petrophysical property distributions biased to the facies model enabled characterization of the hydrocarbon fluid flow and addressed uncertainties in reservoir connectivity and continuity.

This integrated sequence stratigraphic approach to incorporate electro-facies, quantitative seismic geomorphology and modern day analogues has enabled the Lakshmi asset team to quantify the production potential of these Lower Miocene sands and open up future development opportunities. The result is a success story of transforming a depleting gas field to an economic low-cost oil-producing asset.

AAPG 2012 ANNUAL CONVENTION & EXHIBITION, 23-25 APRIL, LONG BEACH, CALIFORNIA

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Abstract ID: 1236310 PANEL 1

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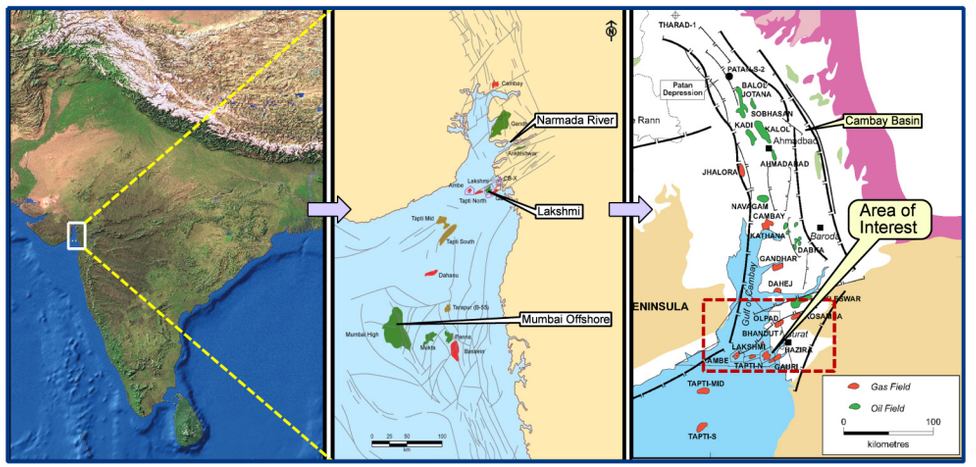
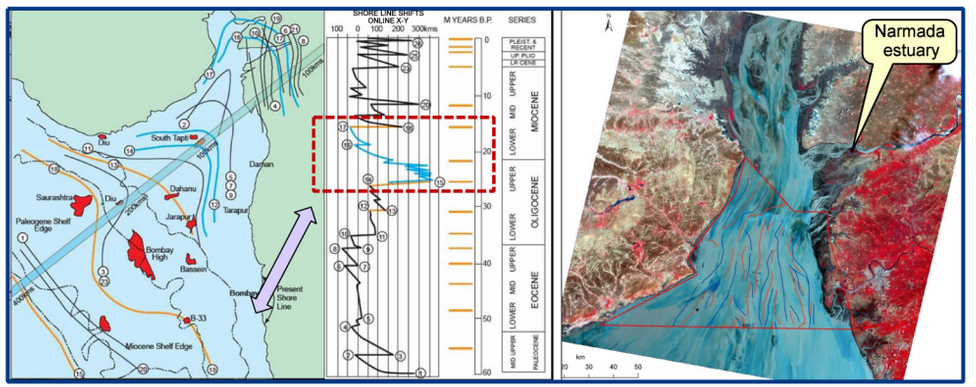
Location and tectonic setting of the Lakshmi Field , Gulf of Cambay



Indian sub-continent | Gulf of Cambay | Cambay Basin

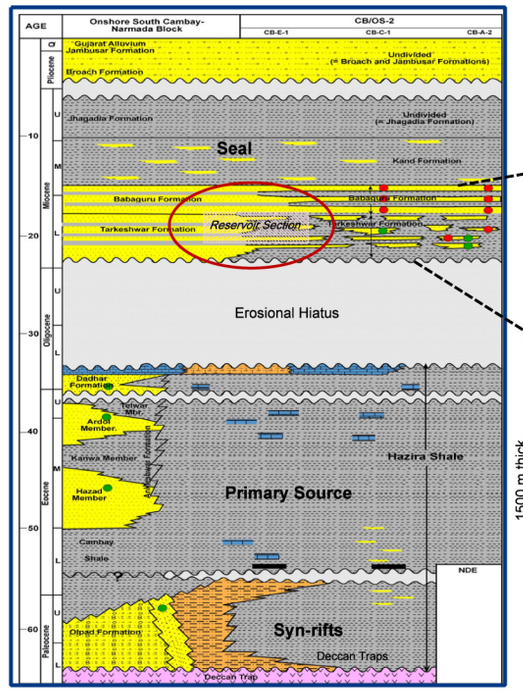
The Lakshmi field is situated in the Cambay Graben,one of the number of failed rifts in the Gulf of Cambay,West Coast of India.The rifts have undergone subsidence, transpression and transtension and partial inversion due to the Northward movement of the Indian Plate during the Late Miocene time. A structural inversion of the rift sequence occurred between the Miocene and Pliocene times resulting in four-way dip closures as the primary hydrocarbon trapping mechanism.



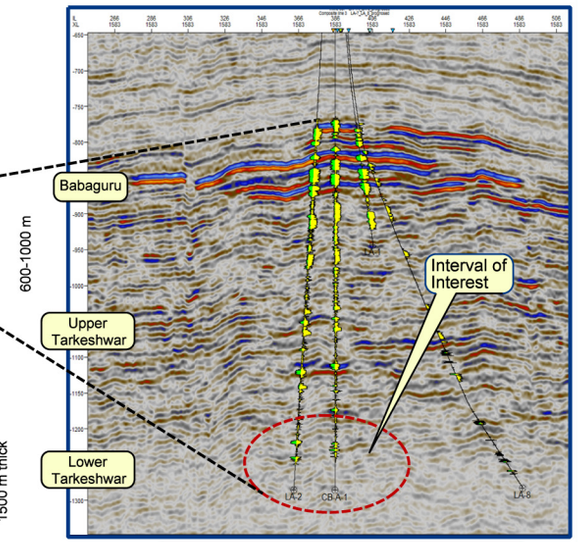
Shoreline shifts during Oligo-Miocene times | Present day macro-tidal Gulf of Cambay

The major oil bearing reservoirs of Lower Tarkeshwar Formation were deposited during the Oligo-Miocene time. Significant fluctuations in sea-level gave rise to a mixed-energy sediment deposition under an overall transgressive limb of global sea-level and comprising of highly heterogenous reservoir facies.

Chronostratigraphic framework and depositional setting of the Lower Tarkeshwar Formation



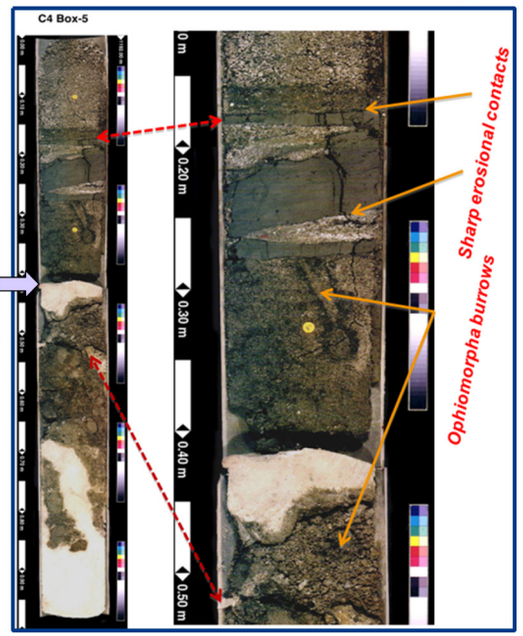
Stratigraphic succession of Lakshmi Field



Seismic data masked by shallower gas sands

- Brackish water trace fossils:Ophiomorpha,Planolites, Arenicolites and Planolites
- Core facies associations support tide dominated estuarine setting for the incised valley systems
- Highly complex valley fills
- Ichnological records display evidence of salinity fluctuations, episodic deposition, high aggradation rates and variable substrate consistency

Core sedimentology



Limited core data from off-set well, 7 km away

The idea is to incorporate a sequence stratigraphic framework for the reservoir interval to capture the uncertainties in the reservoir connectivity and also build a predictive 3D reservoir model for understanding the full potential of the reservoir and an optimized field development.

Why do we need a sequence stratigraphic framework?

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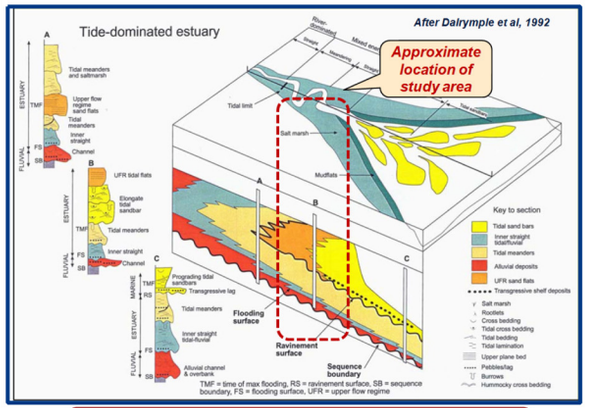
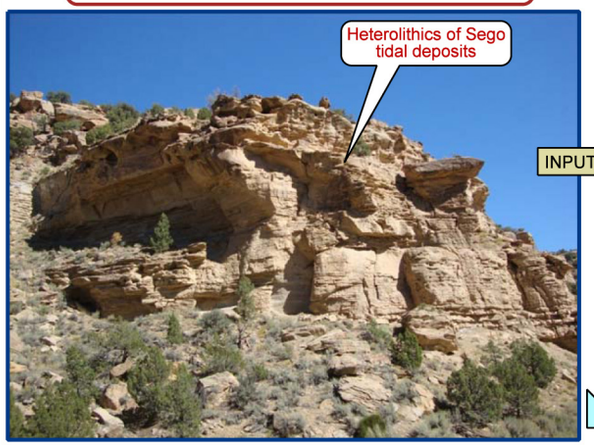
Joint Venture Partners: CAIRN, ONGC, TATA

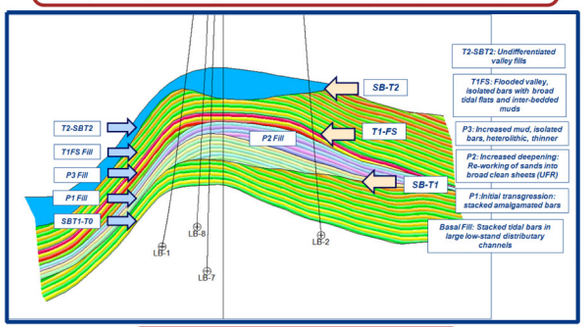
From concept to reality: The integrated workflow to characterize the Lower Tarkeshwar oil bearing formation in Lakshmi



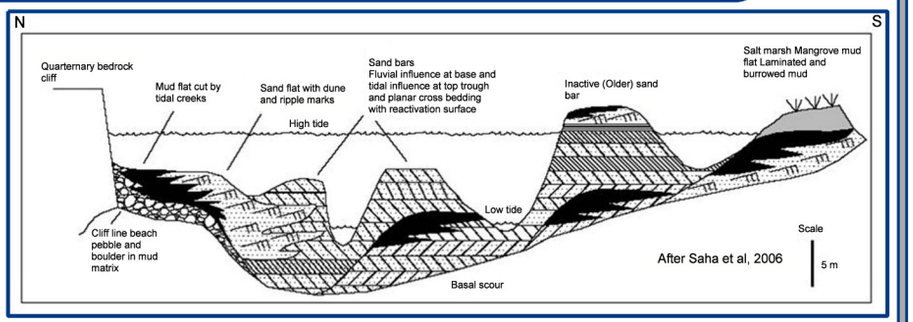
Conceptual depositional framework: Tide dominated estuary



Outcrop analogues: Sego Sandstone tidal deposits, Bookcliffs, Utah



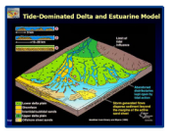
Structural framework of the modeled area

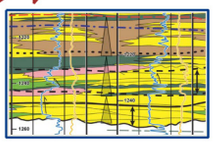


Schematic cross-section of Narmada Valley (GOC) displaying complex valley fill

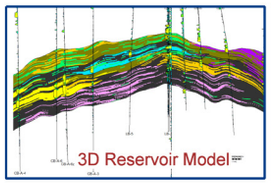
INPUT

Conceptual Sequence Stratigraphic Model and Analogue Data

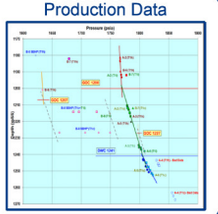


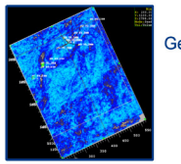


Well Log Motif Facies and Core Data from Offset Well



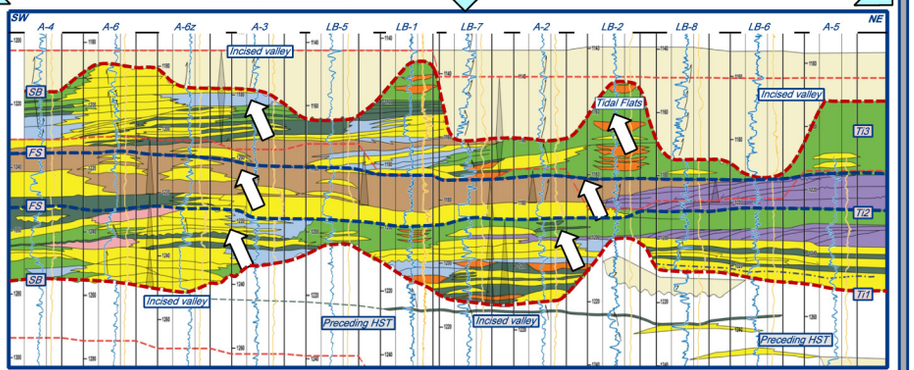
Pressure and Production Data





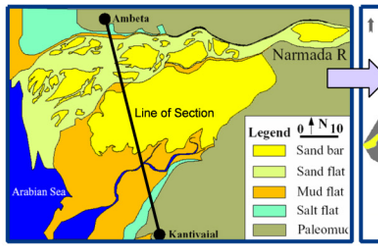
Seismic Geomorphology

OUTPUT

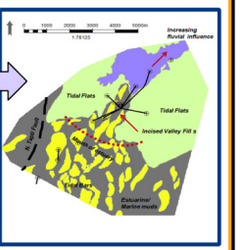


Sequence stratigraphic framework of the study area

Reservoir modeling based on a sequence stratigraphic framework



Narmada River sand bars

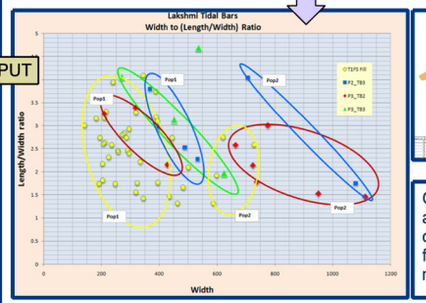


Facies distribution map of representative interval

Seismic attributes generated: RMS Amplitude, Spectral Decomposition, Coherency

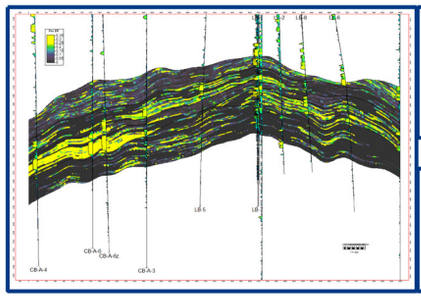
QC sizes of the morphologic bodies using modern observations

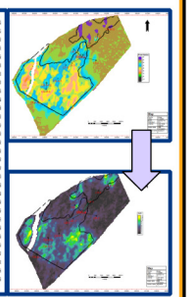
Representative interval slice interpreted and integrated with well observations



Geobodies were analyzed in detail to obtain parameters for object based modeling

Geobody dimensions were derived from analogues and facies maps





3-Dimensional petrophysical model (Effective Porosity)

Conceptual facies and sand maps