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The Shakti Field Narrative: A Successful Decision Based Modelling Approach

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Abstract

Characterizing clastic reservoirs within a nascent hydrocarbon accumulation with limited well penetrations necessitate a comprehensive understanding of sedimentological heterogeneity, stratigraphic framework, petrophysical variability, and the structural complexities intrinsic to such depositional environments. Constructing a robust static reservoir model hinges on capturing these geological uncertainties to the best possible extent. Quantifying these uncertainties is pivotal for enhancing subsurface interpretation and evolving an effective field development strategy. The Shakti Field in the Barmer Basin, India, exemplifies the application of a Decision-Based Modeling (DBM) approach, which integrates facies distribution, diagenetic alterations, fluid flow dynamics, and structural variability to simulate the intricate geological architecture of clastic systems.

Shakti field is an onshore field and lies in the intra-cratonic rift of the Barmer Basin of Rajasthan, India (Figure 1) which has two closely spaced hydrocarbon closures (Shakti North & Shakti South). These fields are 3-way dip closure having been discovered in 2004. The initial exploratory and appraisal wells in the field targeted the clastic reservoir of the Fatehgarh Formation. The field area is covered primarily by 2D and partially by 3D seismic data having good core coverage and advanced logs acquired along with production testing history. Shakti Field depositional setting and reservoir quality is analogous to the high producing fields of Barmer Basin.

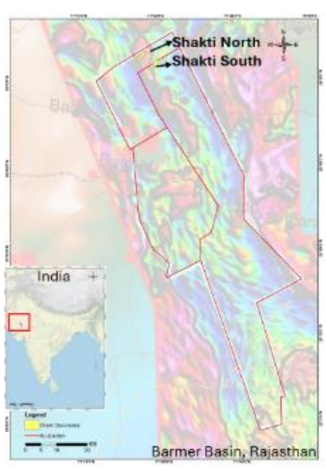

Figure1. Barmer basin showing location of Shakti fields. Inset map of India highlighting location of Barmer basin, Rajasthan

Due to the limited seismic coverage in the field on the 2D lines, the top structure is poorly interpreted, and this is addressed by establishing several scenario-based interpretations ranging from high to low case. Similarly, the bounding fault positioning uncertainty due to poorer seismic resolution was captured by mapping high and low case fault interpretations and capturing impact in gross rock volume numbers. In addition, considering the sparse well data presence in field, the reservoir characterization and heterogeneity is still underrepresented. Owing to these uncertainties, a decision-based modelling approach was attempted at each critical step, capturing the uncertainties and corresponding forward step for maturing development plan of Field.

Petrophysical evaluation of subsurface rock units was carried out within the Global Hydraulic Elements (GHE) framework using Flow Zone Indicator (FZI) cutoffs. These cut-offs were derived from core-based porosity–permeability (ϕ–k) relationships, to quantitatively classify Hydraulic Flow Units (HFUs) and assess corresponding reservoir quality zones. Several scenarios were made to understand optimal numbers of zonation and layering scheme to best represent these rocks in the model. The depositional environment shifted from a braided to a meandering fluvial one in the shallower reservoirs and due to the sparse well density populating the facies (Figure2) appropriately in the model was critical. Multiple iterative characterization and population scenarios were considered, and decisions were made based on consideration of a good representation of geology as well as dynamic understanding. Similar sensitivities were attempted on porosity, permeability and saturation population while calibrating these with core-based measurements and the depositional model. The resulting static model reasonably represents reservoir heterogeneity, supporting improved volumetrics estimates, well planning and dynamic simulation.

Several development scenarios were studied to best develop these reservoirs. The early production performance and pressure behavior indicated lower than expected inter well communication and this was captured in the geo-cellular model through the above workflow. This shallow seated reservoir contains oil with API gravity between 14-16, average permeability of ~1-1.5Darcy but significantly higher oil viscosity (~500centipoise) than other similar fields producing in Barmer Basin. So, a specific strategy for development of this reservoir was required to be evaluated & proposed. Concepts from low angle wells, highly inclined horizontals to multi-lateral wells were assessed. The modeling studies suggested combination of horizontal and multi-lateral wells is a good option for production from these reservoirs along with few low inclination wells for structural understanding in certain parts of the field.

Multiple realizations using stochastic methods and iterative quantification helped quantify geological uncertainty and reduce bias in flow simulations. The decision-based modelling approach underscores the importance of iterative modelling and geological realism in static model building, particularly in data-constrained fields. It highlights that incorporating geological uncertainty and calibrating depositional assumptions are critical for reliable production history matching and accordingly establish an appropriate field development planning.

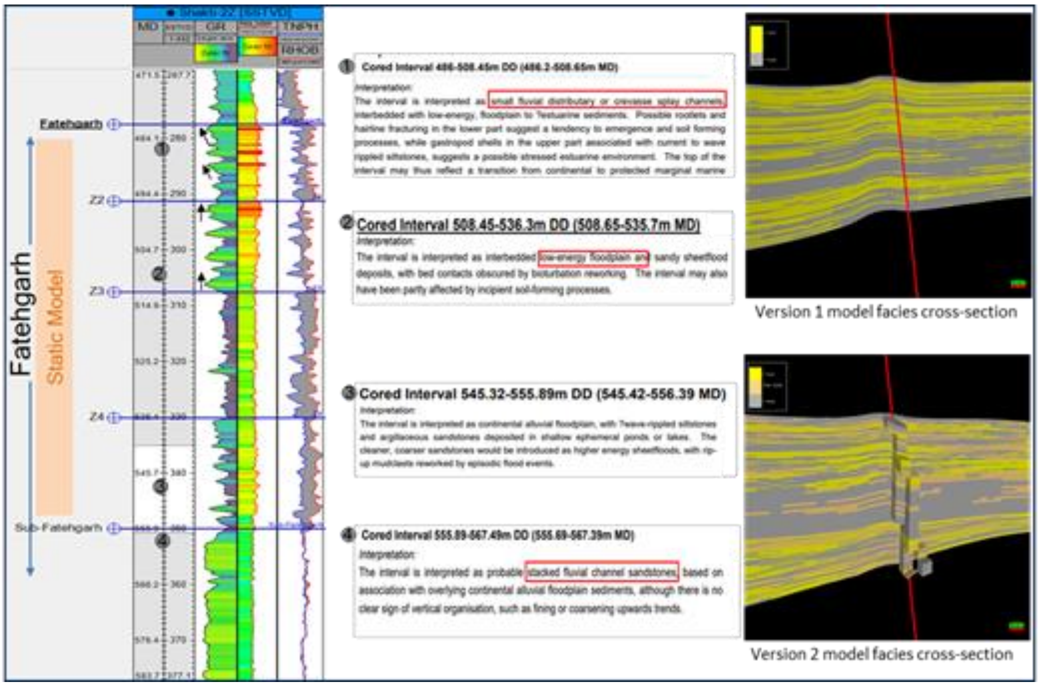

Figure 2. Integration of core characterization to log scale data to reach a most realistic facies geometry in geo-cellular model.