Unlocking the Hydrocarbon Potential of a Marginal Field Through Advance Data Integration - De Risking Reservoir Uncertainty & Phased Field Development Planning.

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Abstract

Marginal field development is always strategized in conservative approach. Integration of multifaceted subsurface data, aptly supported by long term production result, is the key to further unlocking true potential of the field. However, a broad level of uncertainty always kick-in any oil field development & their capture and mitigation is well known strategy to keep the net present value (NPV) high for field. Data acquisition & fruitful integration always pave a path to mitigate reservoir uncertainties. Our current study of a heterogeneous reservoir of Saraswati - a marginal field- in the south -central part of the Barmer Basin - shows considerable number of possibilities after successful integration of advanced core, seismic, geological & engineering analysis and further unlock the potential of phased field development planning.

Introduction

Saraswati Field, located in the southern central part of hydrocarbon prolific Barmer Basin (Figure 1) was discovered in 2001 and were further appraised with three wells which are all located in the main central part. Lately the surrounding fault blocks were also appraised with different wells. The field has hydrocarbon presence at multiple stratigraphic levels.

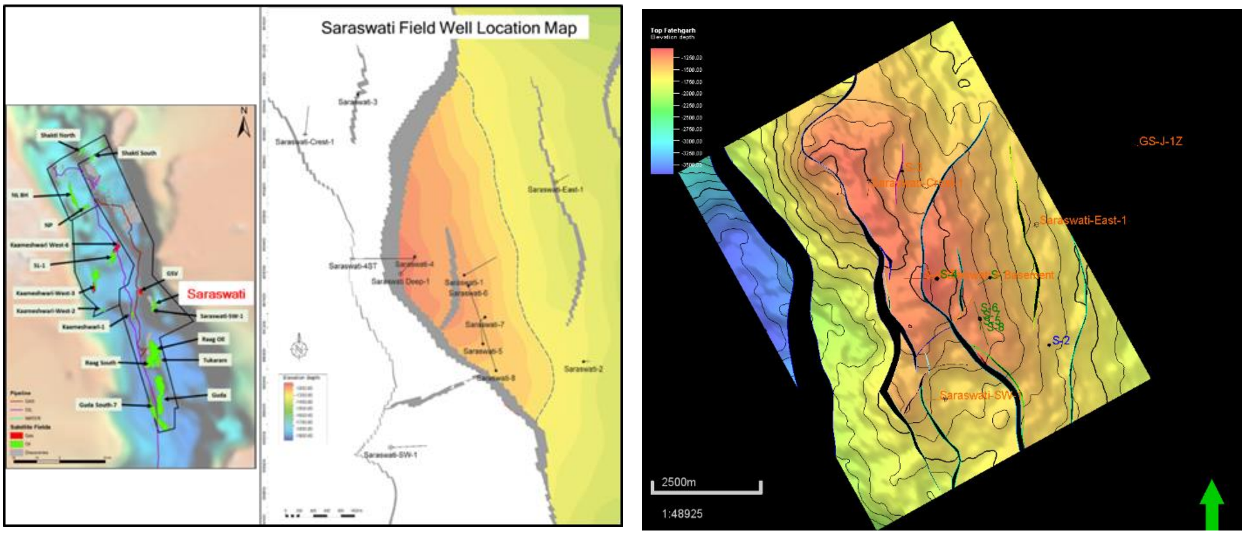


Figure 1: Saraswati field & Top Fatehgarh depth structure map

In the light of reconditioned seismic data, detailed core study (detail sedimentological analysis, SCAL, MICP) of acquired core, there has been substantial improvement in the overall understanding of geological attributes and reservoir potential of the field. Accordingly, a fresh static model has been prepared incorporating all the studied and conceptual updates of the field. This new static model not-only captures the potential upside in the STOIIP estimation but also highlights case for further development plan in northern part of field.

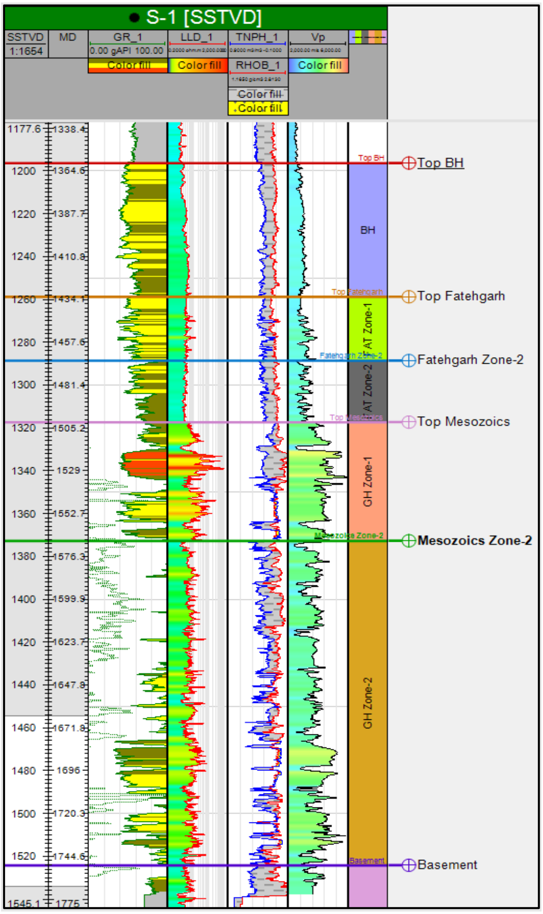
This paper aims at capturing the recently concluded G&G studies & associated uncertainties that have provided critical inputs for the preparation of an integrated static model. Further, this paper presents an overview of integration of workflow and phase wise field development plan for Saraswati field.

Geology

The Saraswati Field is structurally interpreted as a terrace which is described as a rotated fault block positioned between the east central Barmer basin margin and a western bounding fault (approximately 2 km throw) separating the field from adjacent Field. The main Saraswati Field is bounded by 3-way fault closure; however, multiple intra-field faults with variable throws have been interpreted across the Saraswati Field (Figure 1).

Major markers are co-relatable across the wells from the logs as well as tying to the seismic data. Fatehgarh (Paleocene) and Ghaggar Hakra (Cretaceous) constitute the main reservoirs of this field. Ghaggar-Hakra Formation has been sub-divided into two zones. GH Zone 1 is a comparatively high NTG system dominated by fluvial sands, while GH Zone 2 is intercalated by channel margin & fluvial sandstones, mudstones. The volcanic facies can be identified from the cores as well as from wireline logs which are interbedded with fluvial channel and lacustrine sediments of the Ghaggar Hakra formation. Shallower Palaeocene age Fatehgarh sits unconformably above the GH Formation. Fatehgarh has been further sub divided into two zones (Fatehgarh Zone 1 & Zone 2) based on the depositional facies definition. Fatehgarh Zone 1 is a high NTG system dominated by fluvial channel facies, lake margin facies and slope channel facies whereas Fatehgarh Zone 2 is mud dominated system with very little reservoir rocks.

As mentioned earlier, the above-mentioned stratigraphic understanding has been revised and is discussed in detail in the coming sections



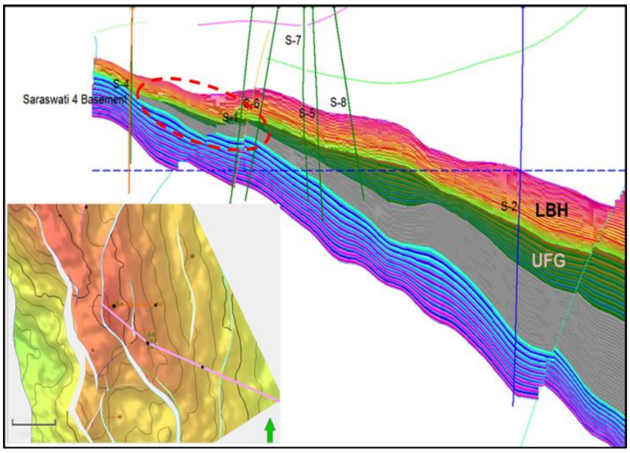


Figure 2.1: Type Log and Stratigraphic column

Figure 2.2: Cross Section of Saraswati Field showing crestal part erosion and pinch out

Workflow

Recent studies have significantly changed the understandings of reservoir continuity and correlation, properties as well as the in-place estimates.

Updated Stratigraphic Understanding & Well Correlation, Core Analysis

A. Well Data: The existing model incorporates the initial E&A wells and development wells drilled as a part of Phase-1 FDP. However, subsequently few E&A wells have been drilled in the vicinity of the Saraswati main field area to appraise different fault blocks. All these wells have been accounted in the current studies and modelling exercise.

B. Updated Stratigraphic Correlation: Detailed studies of the Saraswati core data, drill cutting samples and outcrops results to classify the stratigraphic correlation, using a combination of facies association mapping, a pragmatic re-appraisal of the biostratigraphy and the identification of key unconformities. Based on the basin-wide understanding, depositional environments for each of the formations have been considered for broader stratigraphic correlation. The

C. Core Analysis: Cores are available in Fatehgarh and Ghaggar Hakra reservoirs. The updated understanding of lithofacies from core sedimentological studies have been captured in the current static model. Relative Permeability studies have been carried along with MICP and permeability estimations on core plugs from cored wells and form the basis of revising the petrophysical interpretation for new static model.

Seismic Study: The existing static model is based on the interpretation carried out on 3D PSTM data set re-processed in 2007-08. The existing data quality has been a matter of consideration with very low frequency and very low S/N ratio especially in crestal part of the field. To improve this poor dataset, the data has been conditioned in-house (Vintage IHC'18) to improve S/N ratio, event continuity and frequency content. This re-conditioned and significantly improved data set has been used to revise the interpretation and rebuild the static model.

A. Structural Interpretation: The fault and horizon interpretations have been carried out over in-house conditioned seismic (PreSTM'18) data across the Saraswati main block and different adjoining blocks. Four major horizons viz: Barmer Hill (BH), Fatehgarh (Fat), Mesozoic / Ghaggar Hakra (GH) and Basement have been interpreted in time. Structural Framework Modelling (SFM) using volume-based modelling (VBM) has been used to obtain fault constrained time structure map and fault surfaces as input to static model (Figure 3.2).

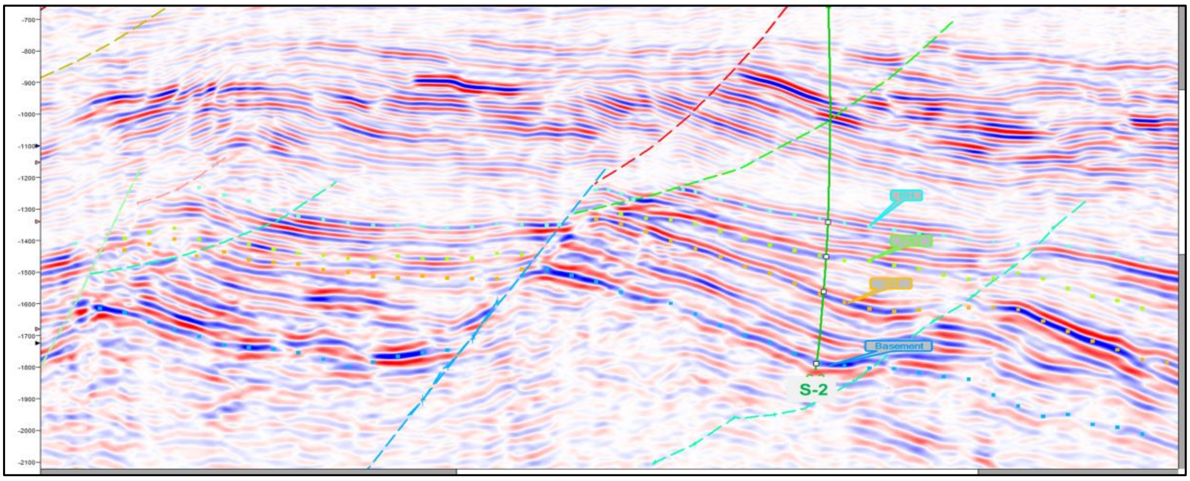
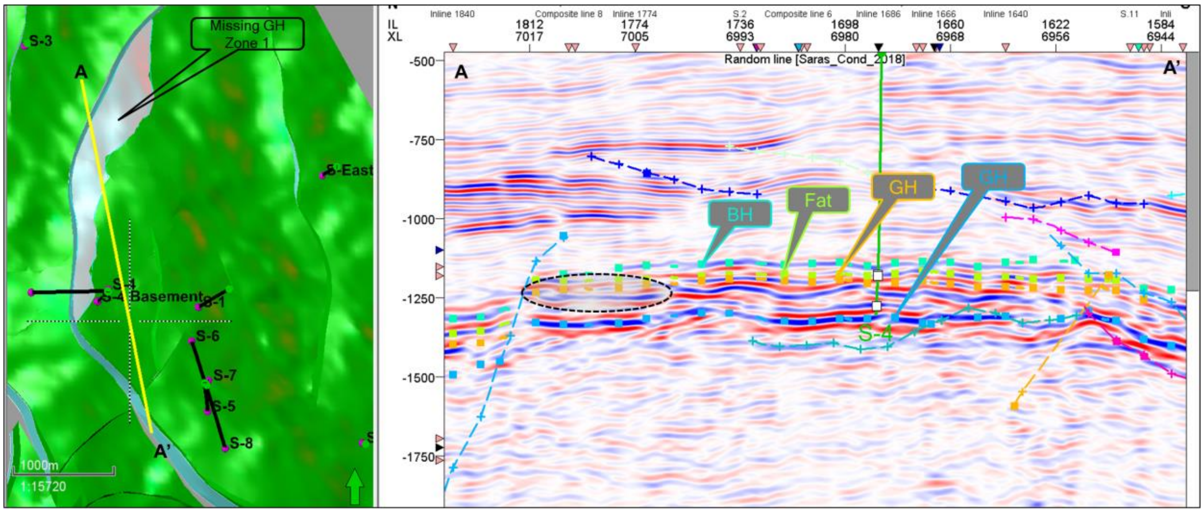


Figure 3.2: Seismic cross-section showing horizon and fault interpretation

B. Velocity Modelling & Depth Conversion: Seismic constrained velocity modelling approach was used for time to depth conversion. During this process, seismic velocity cube was calibrated with well velocities at different levels and used as main input for velocity modelling while well tops and well-tied depth surfaces were used as correction elements in different versions of velocity modelling. The well calibrated seismic velocity model was used to convert the volume based structural framework model in depth and depth converted model was used for volume base static modelling.

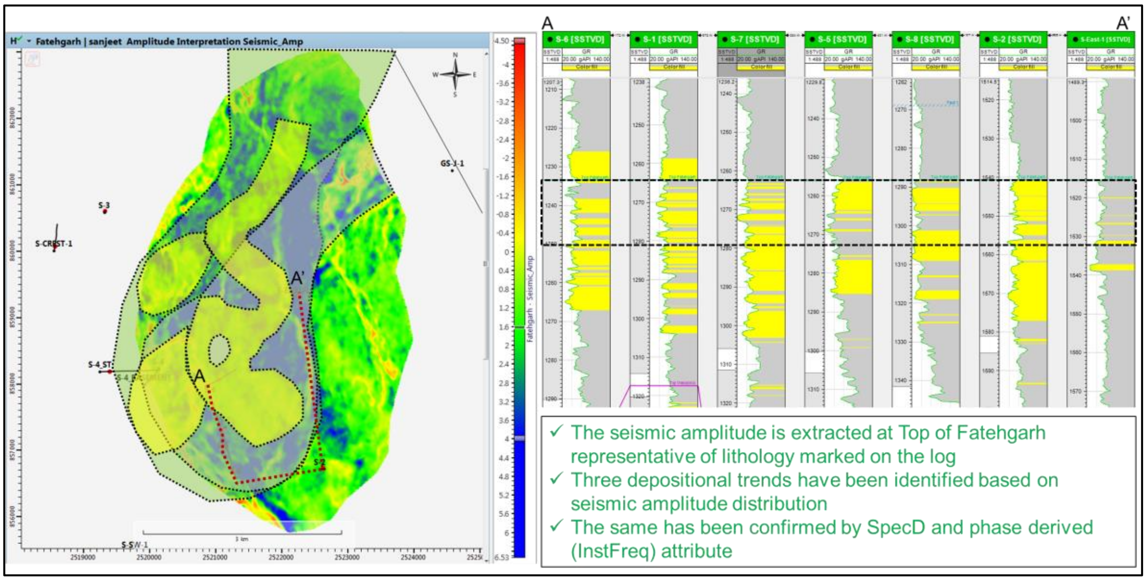
C. Erosional Unconformity at Ghaggar Hakra (GH): Unconformity (KT Boundary) is present between GH and Fatehgarh across the basin while KT boundary acts as erosional unconformity in crestal region of Saraswati which is very much evident in seismic as well. Well based interpretation of missing section (GH Zone-1) in northern crestal area of Saraswati Main Block has been validated by thinning of GH zone towards northern crestal area as envisaged in the seismic interpretation (Figure 3.3).



- ✓ *The grey area present in the panel (left) represent the area of missing GH-Zone 1 which can be explained by the thinning of GH member in crestal part*
- ✓ *The probable missing area have been highlighted on the seismic section (right panel) taken parallel contour of the structure*

Figure 3.3: The grey area (left panel) represents the erosion of GH Zone 1 as validated in seismic (right panel)

D. Seismic Attribute Studies: Seismic attribute study has been carried out for both the reservoir zones namely Fatehgarh & Ghaggar Hakra. For Fatehgarh, horizons were extended till the basin margin and extensive amplitude studies have been carried out to understand the GDE The sand prone zone was characterized by low amplitude (Reflectivity/RMS) and confirmed by low instantaneous frequency and low amplitude in Spectral-Decomposition results. The different depositional lobes originating from eastern margin was the possible interpretation of amplitude distribution which is in line with basin GDE at Fatehgarh level. RMS amplitude within 24ms was extracted and provided as input to populate reservoir facies within upper zone of Fatehgarh formation (Figure 3.4).



- ✓ The seismic amplitude is extracted at Top of Fatehgarh representative of lithology marked on the log
- ✓ Three depositional trends have been identified based on seismic amplitude distribution
- ✓ The same has been confirmed by SpecD and phase derived (InstFreq) attribute

Figure 3.4: Fatehgarh Zone 1 depositional fairway (left panel) based on amplitude distribution

Similarly for GH, the attribute study has been carried out in order to characterize the distribution of volcanic elements embedded within GH members at different levels. The volcanic units are extracted as geobodies using RMS amplitude cube. Horizon probe between GH and Basement was taken and opacity curve was edited to reflect high amplitude volcanic elements and subsequently extracted as 3D cube. The 3D Volcanic cube was depth converted using existing velocity model and used as trend to populate volcanics within GH formation.

Petrophysical interpretation:

Petrophysical analysis for Saraswati Field has been re-visited in the light of new MICP data, revisiting of old pressure data with PVT compositional analysis, inclusion of production data. All the updates in petrophysical interpretation parameters and basic understandings are summarized below.

A. Porosity & Vshale: Deterministic approach was taken to estimate volume of shale & porosity. Further, these outputs were calibrated against available core and NMR data for validation. Average total porosity of Fatehgarh is ~20PU and for Ghaggar Hakra is ~ 14PU. The Neutron-Density combination along with Gamma Ray has given reasonably good VShale estimation whereas Gamma and Resistivity data has been used where hole conditions are poor (in E&A wells). The shale parameters were picked from the Density-Neutron cross plots, which also helped in the zonation of the logged section for the purpose of processing.

B. Facies: Core Data of Fatehgarh Zone-1 suggests presence of considerably more reservoir facies in the system compared to what is captured by wireline log. Drill cuttings data also indicates presence of more sand and silt than the percentage represented by wireline logs. Image Log data supports this fact indicating presence of “thin bed pay” which are beyond log scale resolution. Based on these considerations facies proportions are redefined and for practical purpose binary facies were used along with identification of separate volcanic facies to capture in the static model.

C. Water Saturation: An Indonesian equation was used to compute water saturations using analogue “a”, “m” and “n” values (Mangala and Aishwariya Fatehgarh core data) in the absence of FRF/FRI measurements in Saraswati Field. The Rw used is based on a salinity value of 19000 ppm (0.27 @ 30degC).

D. Permeability: Permeability was established by using Coates-Dumanoir transform, calibrated with well test & core permeability by changing co-efficient. Permeability was calculated for each rock typing created from cluster analysis.

E. Saturation Height Function: MICP capillary pressure measurements were performed on core plugs of Fatehgarh & Ghaggar Hakra reservoirs and used for Saturation height function generation using Skelt Harrison Saturation Height function. Two different equations were prepared for Fatehgarh & Ghaggar Hakra zones and Sw was populated accordingly in the static model.

F. OWC / FWL: After careful consideration of Qc’ed pressure points along with log analysis, recent production data & PVT composition gradient, 1407mss is considered as base case free water level (FWL) for both Fatehgarh & Ghaggar Hakra zones. (Fig 3.5)

G. Cut Offs: Based on sensitivity analysis with hydrocarbon pore thickness, six wells were analysed to determine reservoir & pay cut-offs for Fatehgarh & Ghaggar Hakra zones.

The integrated Petrophysical analysis is captured in Figure 3.6

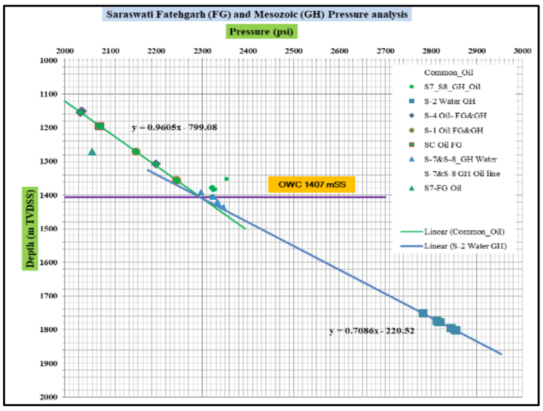


Figure 3.5: Saraswati OWC estimation

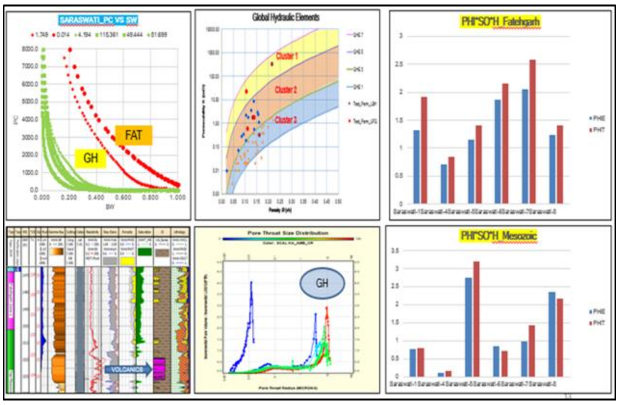


Fig 3.6: Integrated Petrophysical analysis

Conclusions

Integration of technology and subsurface understanding for Saraswati field reduces the uncertainty and further unlock a path of phased field development planning. Newly built static model also reduces the drilling uncertainties whilst developing additional resources and achieving target production. Wells are positioned to maximize production, and this has enabled smaller oil pools to be economically developed. This study also provides a model strategy for field development optimization and the integrated approach to the use of technology, well planning and sequencing in challenging environments, sets a benchmark for a heterogeneous reservoir development in the Barmer Basin. The clear value of these integrations was a reduced overall development cost and wells better placed for recovery and production.

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