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Arriving at base case static model from multiple deterministic scenarios: Vijaya & Vandana Field, Barmer Basin, India

Abstract

This paper highlights the usefulness of building a robust base case model from discrete, deterministic, scenario-based outcomes representing the range of sub-surface uncertainties for Vijaya and Vandana (V&V) Field in the Barmer Basin, NW India. The V&V field consists of two mound shaped channel complexes; comprising of laterally migrating network of turbidite channels with individual beds upto 3-4 metres thick.

Difficulties in delineating the channel sands extensions and resolving their geometries through standalone seismic warranted the iteration of the facies model into different scenarios, with varying combinations of channel dimensions, trends and concepts. Individual scenarios were further iterated with other key high impact subsurface uncertainties resulting in *ca* 50 deterministic realizations, capturing wide uncertainty range in STOIIP through a PDF.

Ultimately, a single base case model is built from one of these deterministic realizations with expectation value for individual uncertainties, many of which are considered to have been mitigated through the ongoing appraisal campaign. This method is a dynamic one and allows the flexibility to adopt the model and update it from a range of discreet deterministic scenarios depending on appraisal/well testing results.

Introduction

Difficulties in defining reservoir continuity, owing to internal complexities make lacustrine turbidites a good candidate for sub-surface uncertainty management through the application of multiple deterministic method in the construction of static model. Studies on hydrocarbon bearing lacustrine turbidite reservoirs in East Brazil (Carozzi and Fonseca, 1989), West Africa (Teisserenc and Villemin, 1990) and China (Wagner et al., 1988; Xi-Jiang, 1988), show that reservoir dispositions in lacustrine turbidites are dominantly controlled by rapid and spatially variable extensional tectonics (Lezzar et al., 2002), the number of source points, provenance and climate. Resultant turbidites in rift settings thus ranges from hyperpycnites (deposits related to sediment-laden fluvial discharges, aided by seasonal precipitation or flood, entering a standing, lower-density water, Zavala et al.,2006) on one end of spectrum to typical episodic high energy turbidites on the other, each member being affected by inherent lateral heterogeneity and compartmentalization (Kothari et al., 2016). This variability of sedimentary set-up within a particular tectonic regime warrants an effective uncertainty management within the static model framework which incorporates multi-disciplinary inputs for efficient appraisal and development in these kinds of reservoirs.

Field Geology

The Vijaya and Vandana (V&V) area is located to the south east of the Aishwariya field in the northern Barmer basin in NW India along the eastern margin fault consisting of deep lacustrine turbidite sands within the Barmer Hill Formation. Twelve wells drilled in the area confirm seven stratigraphically trapped oil pools viz., BHT 1, 2, 10, 20, 30, 40 and 50 (Figure 1).

A perceptible change from high amplitude, continuous seismic reflectors of layered porcellanites of adjacent Aishwariya field to low amplitude, chaotic ‘mounded’ seismic facies in V&V area is observed in 3D seismic data of V&V Area. The BHT-10 unit, holding nearly 60% of the estimated STOIIP, primarily represents these mounds which exhibit several key turbidity-flow depositional elements, including channel complexes, associated channel elements and depositional lobes. The present shape of the mound is attributed to a complex interaction between differential compaction and sand remobilization; caused by slumping, channel switching, presence of additional fluid and other soft sediment deformation processes (Jenssen et.al, 1993).

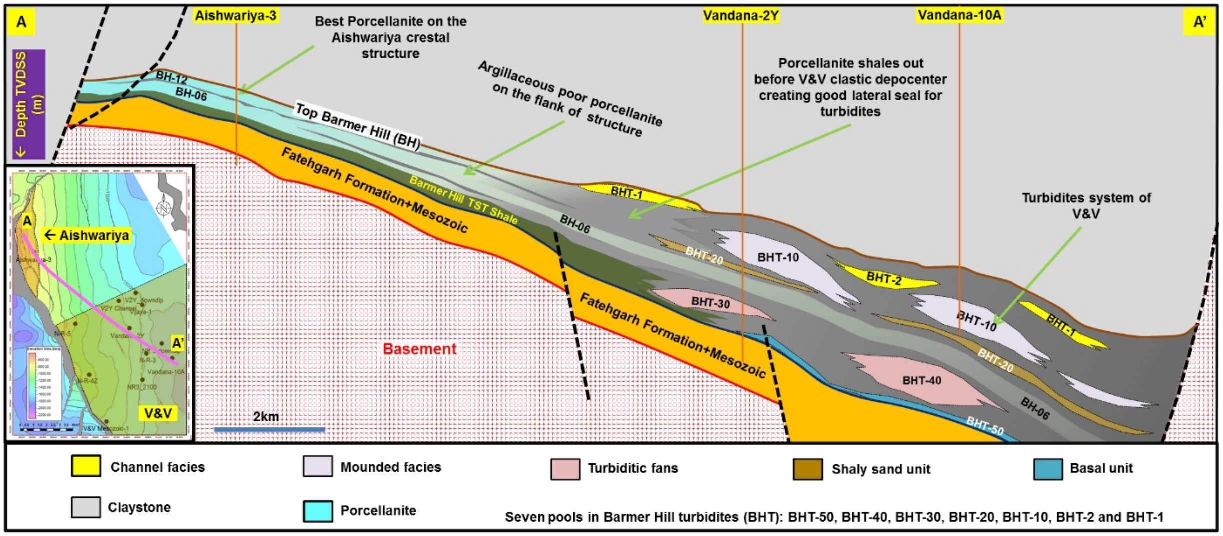

Figure 1: Schematic cross section through V&V area showing different reservoir pools

Sub-surface Uncertainties

Connectivity of the channel sands within the mounded complex stands out as the most prominent and impacting sub-surface uncertainty in the V&V field. The connectivity, controlled by amalgamation and linking of the individual channels encased within a shaly envelope, has an influence on the well deliverability, thereby impacting project economics. The linking of channels, in turn, is perceived to be guided by the channel geometries (length, width, sinuosity) and facies distribution, the latter having a direct effect on the resource base.

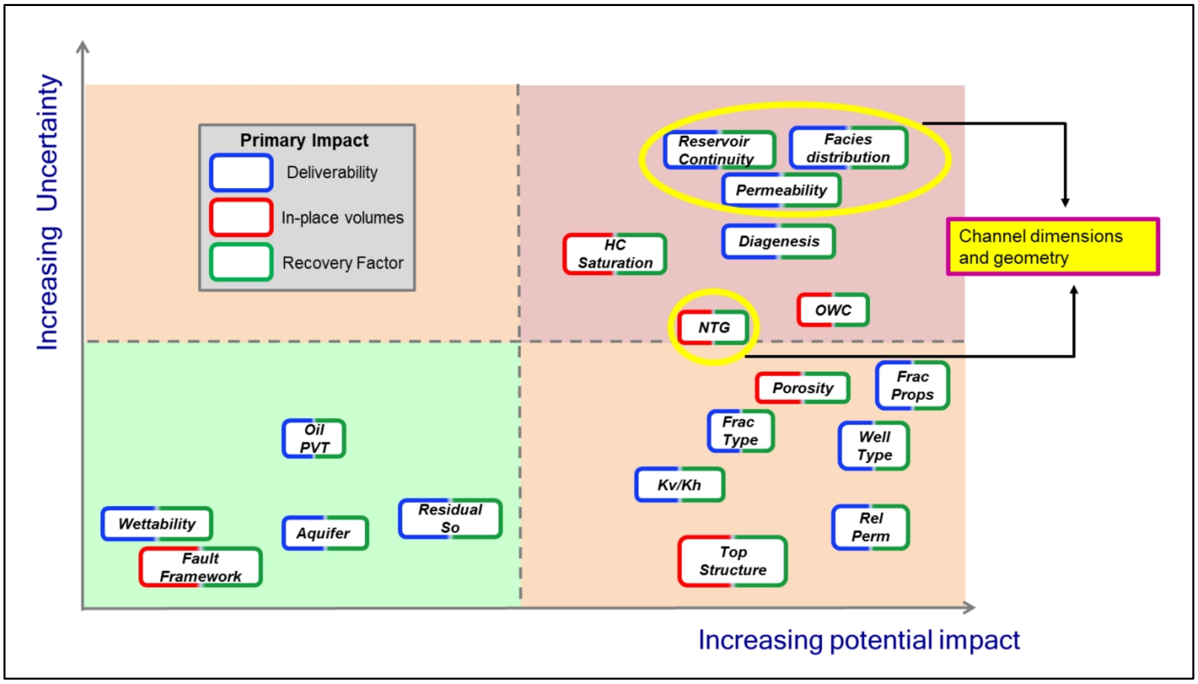

Figure 2: Boston plot showing high impact subsurface uncertainties affecting associated volumes in V&V

Reservoir quality within individual lithofacies is also quite variable due to intense post depositional alterations. Sandstone is the main reservoir rock in this field and its permeability is vastly impaired by intense cementation. Within a narrow porosity range (10-20%), order of magnitude difference in permeability (0.01-200mD) is typical of V&V sands.

The primary sub-surface uncertainties and their controlling factors (causative uncertainties) are depicted in the Boston Matrix Plot (Figure 2). The details of these uncertainties have been described by Konar et al. (2018).

Capturing uncertainties: Static model realizations

Reservoir continuity, facies distribution, system NTG, permeability, hydrocarbon saturation and OWC have been identified as the most impacting uncertainties for Vijaya and Vandana Field. These high impact uncertainties have been captured in static model through a host of deterministic realizations. As discussed earlier the dimension of the channel sands stands out as the most prominent sub-surface uncertainty.

To capture this uncertainty range the facies model was iterated into five different scenarios, based on varying combinations of channel dimensions, trends and concepts. Each of the facies model scenarios was further iterated with other key subsurface uncertainties (discussed earlier) assessed as high impact in the current study viz. hydrocarbon contact, saturation, NTG and porosity (Figure 3). This resulted in 50 deterministic static realizations and corresponding in-place volumes.

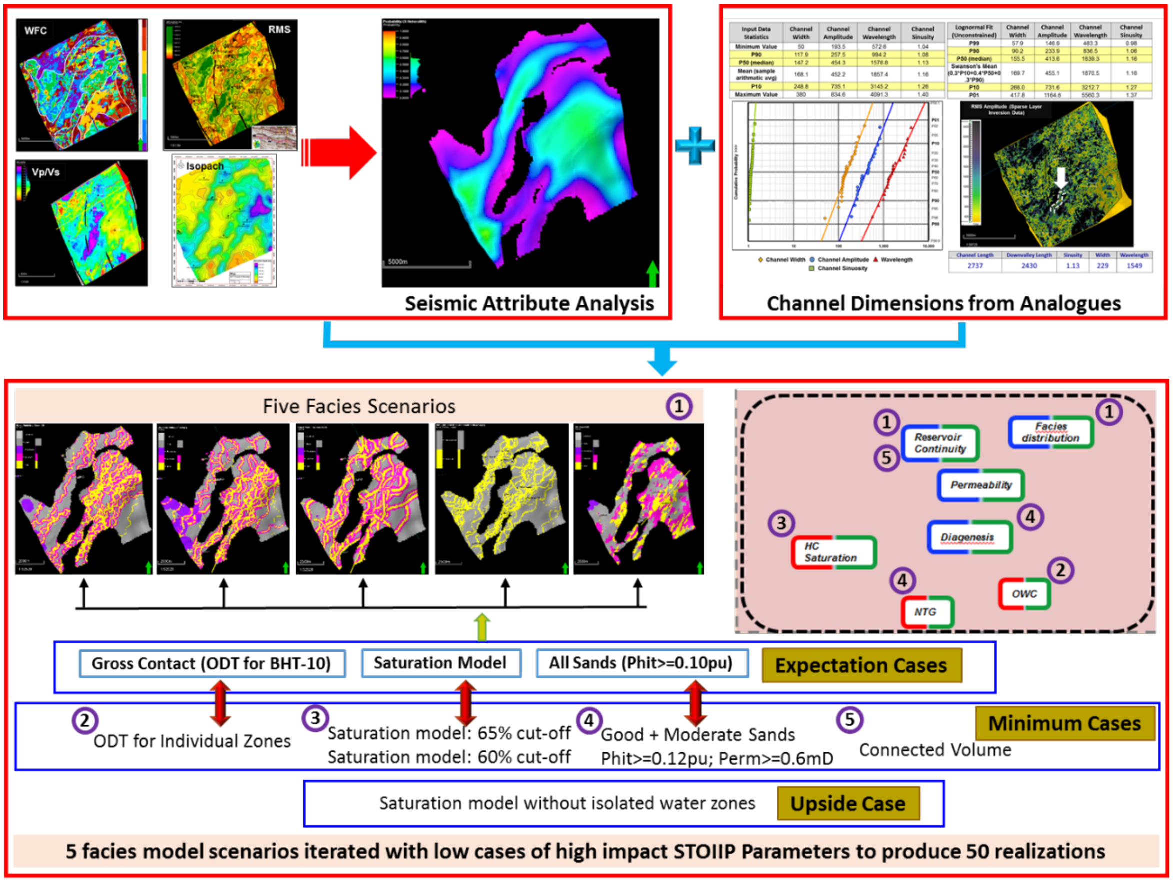

Figure 3: Process workflow for volume realizations taking into account the high impact uncertainties

50 realizations were simulated through log normal distribution (mean and standard deviation were calculated from the input realizations) by Monte Carlo analysis (done in @RISK) to generate spread of volumes in the form of a probabilistic distribution curve (Figure 4). The P10, P50 and P90 volumes of the field were chosen from this spread.

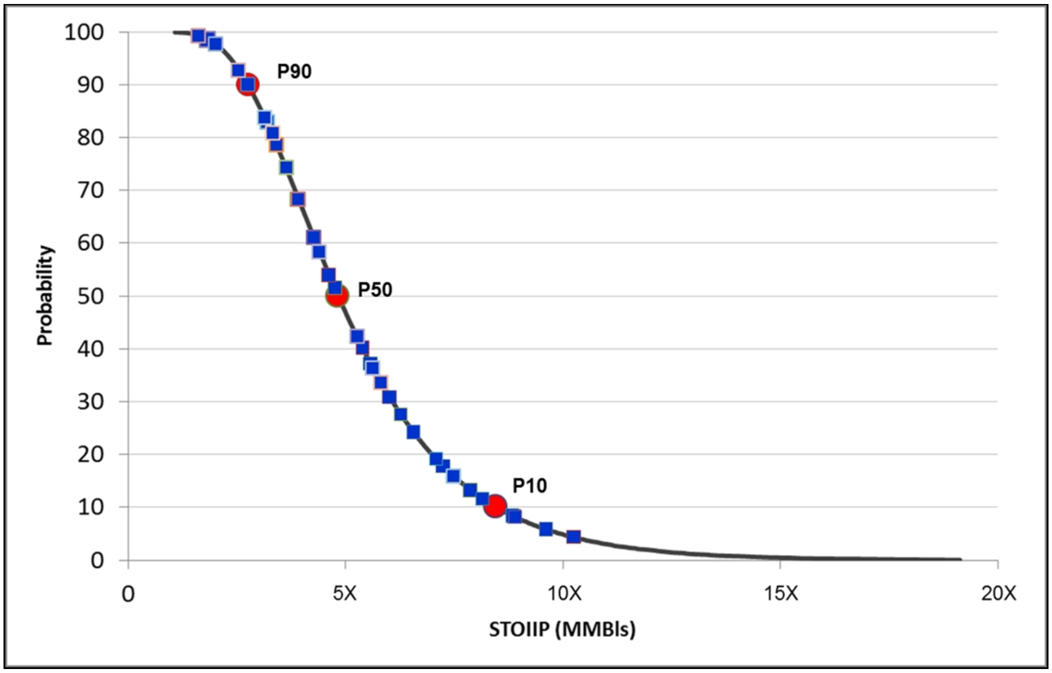

Figure 4: PDF curve of calculated in place volumes associated with 50 different realizations. Red circles mark the P90, P50 and P10 volumes

Base Case Model

Building a first pass base case model from a range of deterministic model scenarios primarily depends on the method of "omission and commission" wherein a number of scenarios are eliminated and /or tweaked depending on the mitigation of the uncertainties based on results of appraisal and development.

In the present study the well test data indicates a connected volume of ~30 acres around each well which corresponds to a drainage radius of ~ 200m. This translates to a channel width of 400 metres which fall beyond the range of channel width (90-170-270m channel width), inferred from log-normal fit of analogous data base and used in the model. Of the deterministic model realizations plotted in the PDF (Figure 4) the ones falling close to P50 value of STOIIP in the curve are those with low channel width of 90 metres. It is thus evident that, in reality, the levees/overbank deposits modelled in the form of non-net heteroliths in the 4 facies system are contributing to the well bore STOIIP. Studies on spatial relationship between channel and overbank lithofacies in a gravity flow deposit (Kilhams et al., 2011) show that channels are flanked by levees/overbank whose width on either side of the channel could be 80-110% of the channel core width.

In the present model, for a channel core width of 90 metres and 170 metres (the low and mid case channel width modelled), the width of the channel overbank pair could be ~260 and 500 metres corresponding to 13 and 47 acre drainage area. For a low energy system as V&V, the propensity of non-development of massive levee/overbank system notwithstanding, we do expect development of some reservoir facies beyond the channel core area, although it is difficult to evaluate the percent share of contribution of well bore STOIIP from channel core and overbank deposits.

In order to give credence to well test data and to do away with the complexities of allocation 2 facies reservoir system (Sand: Core & Heterolith: Overbank), a two system (reservoir/non-reservoir) model has been constructed as a base case model. The channel (reservoir) width assigned is 270 metres, which takes into account a 100 metres overbank width in addition to 170 metres mean width (the latter from analogues), but at the same time does not go beyond a P10 width (Max) of the assumed range from analogue log-normal fit curve.

Two different contacts are considered for both the mounds based on the lowest known oil (ODT) seen at the both Vijaya and Vandana mound separately. The saturation height function is calculated based on these contacts.

The well test data also indicated the water bodies to be small bodies with limited extent as opposed to large connected channels. The base case model has these water bodies statistically distributed with a small variogram within the reservoir facies, keeping the final percentage of the water sands equal to the percentage seen at the wells (Figure 5).

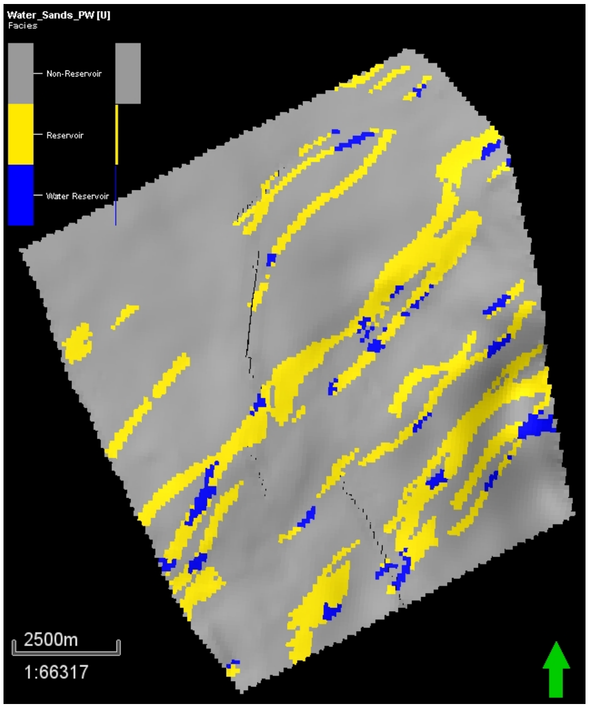

Figure 5: Small isolated water bodies statistically populated within the reservoir sand facies modelled as channels

Conclusions

The present study of V&V field, which is at an appraisal stage of project lifecycle, reveals that the high impact uncertainties of the V&V mounds, in terms of volumes and producibility, are facies distribution, reservoir continuity and overall NTG variation of the mounds. The most prominent causative sub-surface uncertainty behind the parametric uncertainties mentioned above is the delineation of the channel sands (which represent the reservoir), controlled mainly by the channel geometries.

Difficulties in delineating the channel sands in such chaotic package of low energy lacustrine hyperpycnites and resolving their geometries through standalone seismic warranted the iteration of the facies model into different scenarios, with varying combinations of channel dimensions, trends and concepts. Individual scenarios was further iterated with other key high impact subsurface uncertainties resulting in *ca* 50 deterministic realizations, capturing wide uncertainty range in STOIIP through a Cumulative Distribution Function plot.

Construction of a single base case model from one of these deterministic realizations are guided by the results and inferences from well test analysis data which have yielded considerable insight into lateral extent (width) of the channel sands. This method is a dynamic one and allows the flexibility to update a model from a range of discreet deterministic scenarios depending on appraisal / well testing results.

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