

## Maximizing deeper hydrocarbon opportunity below producing Raageshwari-Deep-Gas field: a case study from Deccan Volcanics reservoir, Barmer Basin, India

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### Keywords

Barmer Basin, Raageshwari, RDG, Deccan Volcanics Reservoir, Deeper Hydrocarbon

### Abstract

Recent successful testing in some deeper Raageshwari wells from deep Volcanic reservoirs (shallow Basalt and deep Felsic zones) below the established Gas-Down-To (GDT, 3393m) have flowed light oil (API 48-50 deg) down to a depth of 3474mSS (Oil-Down-To or ODT). After the detailed study on testing data and subsurface understanding in terms of net reservoir distribution, both the technical and commercial merits were established to produce the oil rim along with existing shallow Gas leveraging the ongoing in-fill drilling campaign in the RDG field. This technical paper highlights the potential and the opportunities to produce the oil as commingle flow along with the Gas in the most cost-effective way. Also, it was envisaged that future production of oil would not be possible from these wells accessing the deeper zones due to subsurface complexities and cost implication. The monetization plan increased the reserve by ~1.3mboe with an additional average production of ~350boepd Oil.

### Introduction

The deepest oil found in Barmer Basin in India so far is situated within Deccan equivalent volcanic reservoirs below the Raageshwari Deep Gas (RDG) field. The hydrocarbon pool was discovered in 2015 in the northern fault block to the main Raageshwari high when Well-A (Figure 1), an exploration well flowed light oil (~45-48 deg API) with a rate of 100 bopd from a depth of ~3600mSS. Further appraisal activities proved the possible extent of this deeper oil in adjacent southern fault block through Well-B. Central fault block is currently the FDP area for Raageshwari Deep Gas field, producing from more than 80 wells and a few of these wells (Well-C, D, E in Figure 1) also flowed deeper oil below GDT of 3350mSS. Subsequent activities by deepening gas

development wells (such as Well-F) confirmed the vertical extend of oil column and presence of water further below the ODT. Despite the significant in-place oil volumes established from all these existing wells and current static model, the commercial deliverability as a standalone development concept of this deeper oil has not been found to be encouraging enough to drain maximum potential of the pool. In addition, the key uncertainty to monetize this opportunity is the variability in well deliverability with a long-term commercial flow rate.

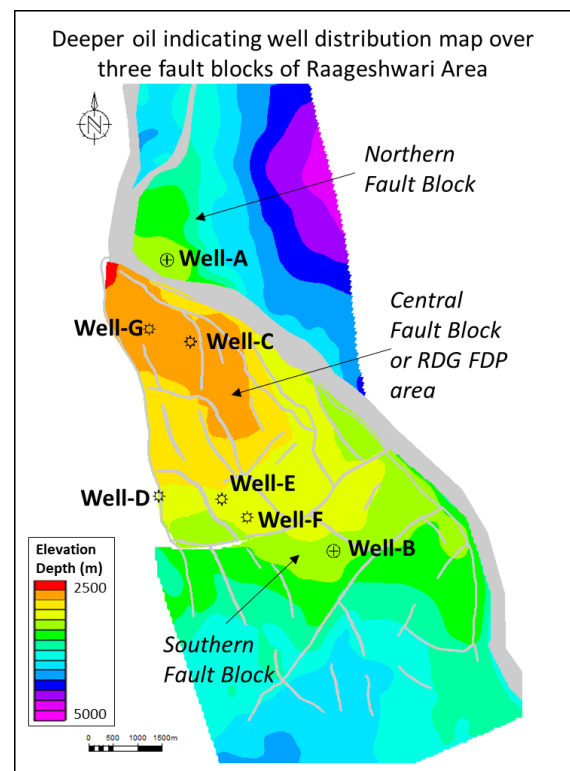
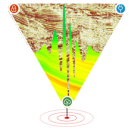


Figure 1: Deeper oil indicating well distribution map over three fault blocks of Raageshwari Area



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To address the uncertainties, a reservoir model calibrated to the limited test data was prepared predicting dynamic behavior based on vertical well and horizontal well concepts. The work concluded that the reservoir quality dominates the performance of the wells, and the decline behavior is very sensitive to contribution of natural fractures. In parallel to modelling work, feasibility of utilizing the ongoing infill gas wells was analyzed. The result suggested that commingle flow of deeper oil along with shallower gas would be a better approach with respect to reservoir performance and commerciality of the project. Additional frac and testing planned for oil zones could increase oil-condensate production without significantly impacting the gas production rate.

### Method

From subsurface point of view, the Central fault block is a tilted horst structure and shallowest of all fault blocks surrounded by shallower shale dominated source rock of Barmer Hill formation from which the hydrocarbon generated and migrated into the structure. In this horst block main reservoirs are Fatehgarh and Volcanics where volcanic unit are subdivided into shallow Basalt and deep Felsic subzones trapping both gas, condensate, and light oil hydrocarbon phases. Log motif in Figure 2 from a type well (Well-G) shows the vertical distribution of further subdivisions of Felsic units where it is clearly observed that both the zones are having range of volcanic facies intercalated as lava flows. NMR based facies classification approach was followed to establish basaltic, felsic, and intermediate types of lithologies and associated petrophysical properties. This log motif also indicates the net pay distribution over different zones where the shallow Basalt unit has laminated pay and deeper Felsic unit has thicker pay zones due to felsic facies dominance. For gas production, all the lithofacies proved to be potential targets but it has been observed from testing activities that oil felsic facies are more effective for better flow rate. Figure 3 depicts the seismic signature over all the stratigraphic unit, and it is to be notified that for deeper felsic zone seismic is very helpful for advance geophysical studies due to very low frequency and low amplitude coverage. Also, this figure show that Basalt zone is emplaced as a mound over the felsic unit, and it get pinched out in the crestal part of

Central fault block. Figure 4 is from existing static model and a N-S section through Well-F and Well-G shows the vertically distributed pay zones in the tilted horst structure. Static models are constructed from well based data and associated trend analysis of multiple petrophysical parameters.

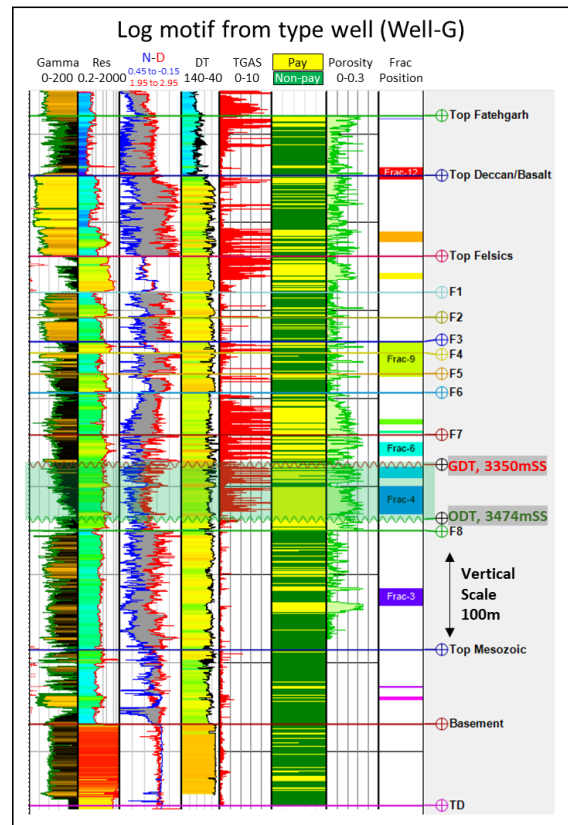


Figure 2: Log motif from type well (Well-G) showing the wireline log response in Volcanics and associated pay zone distribution

Within the potential oil rim of 125m between the GDT and ODT, deeper Felsic subunits (F7 to Top Mesozoic) are primary target in the crestal area of Central fault block whereas shallow Felsic subunit (F6 to F0) and subsequent Basalt zone are primary targets in the flank area. Figure 5 shows the spatial distribution of same net pay between GDT and ODT, indicating the dominance of pay zone in the northern crestal part and western region of Central fault block. Based on the detailed subsurface analysis, the “sweet



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spot” for the oil zone was mapped with a net reservoir of 60-100m and average porosity of 13%.

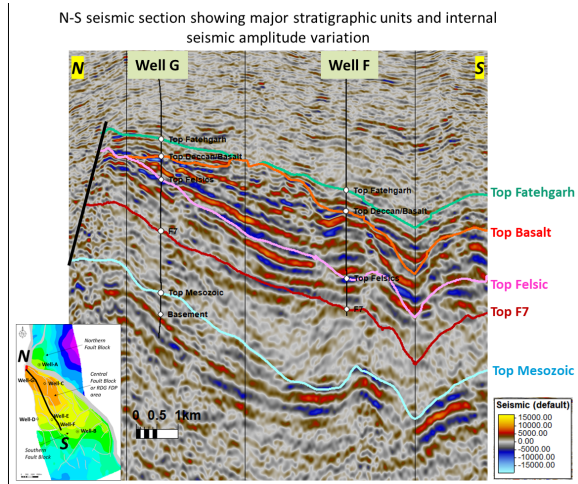


Figure 3: N-S seismic section showing major stratigraphic units and its internal seismic amplitude variation.

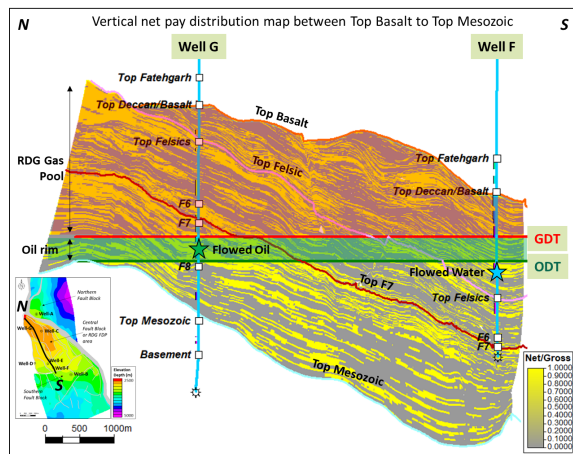


Figure 4: N-S seismic section showing vertical net pay distribution map between Top Basalt to Top Mesozoic

Previously based on the log evaluation and Tgas presence in development Well-G, a zone between 3400–3460mSS below GDT (3393mSS) was stimulated and tested separately. This zone flowed light oil (47.2–49.3°) on self with an average oil rate of 300-500 bopd at different chock sizes (12/64” to 24/64”). Our current understanding from NMR log

signature, Tgas presence, and reservoir zone distribution suggest that this light oil occurs as the oil rim in continuation of the large RDG gas column. A gas infill campaign was planned with more than 20 wells to enhance gas production. Based on static and dynamic model-based studies, these new wells were placed in available areas to chase un-depleted reservoirs and enhance the gas production. This opportunity was leveraged to test deeper oil zones throughout the Central fault block and establish the sustainable oil production rate as these wells are planned to drill up to 3525mSS.

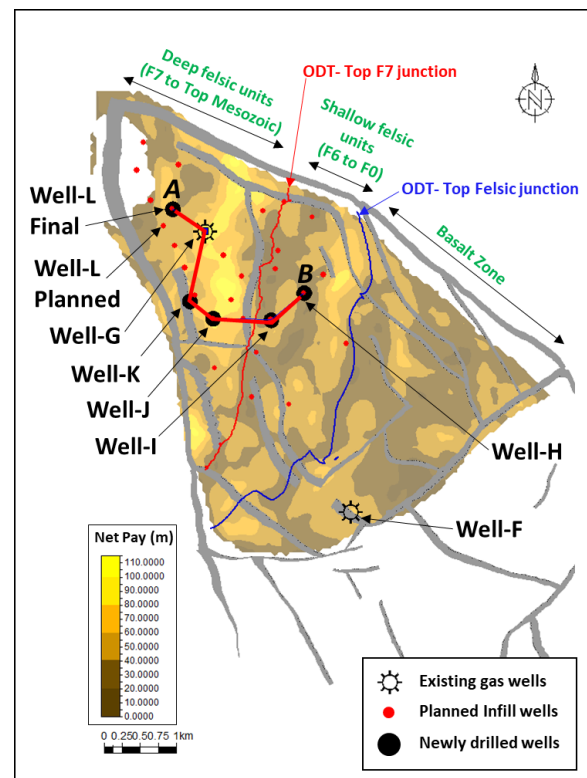


Figure 5: Base map showing lateral net pay distribution GDT and ODT for oil rim along with newly drilled infill well locations targeting oil zone.

### Result

Several existing wells have shown promising potential in the available PLT. For oil target, 2 infills wells from flank area were first to be tested (Well-H and Well-I in Figure-5) below GDT in F6-F0 units and resulted in oil flowrate of ~200 bopd.



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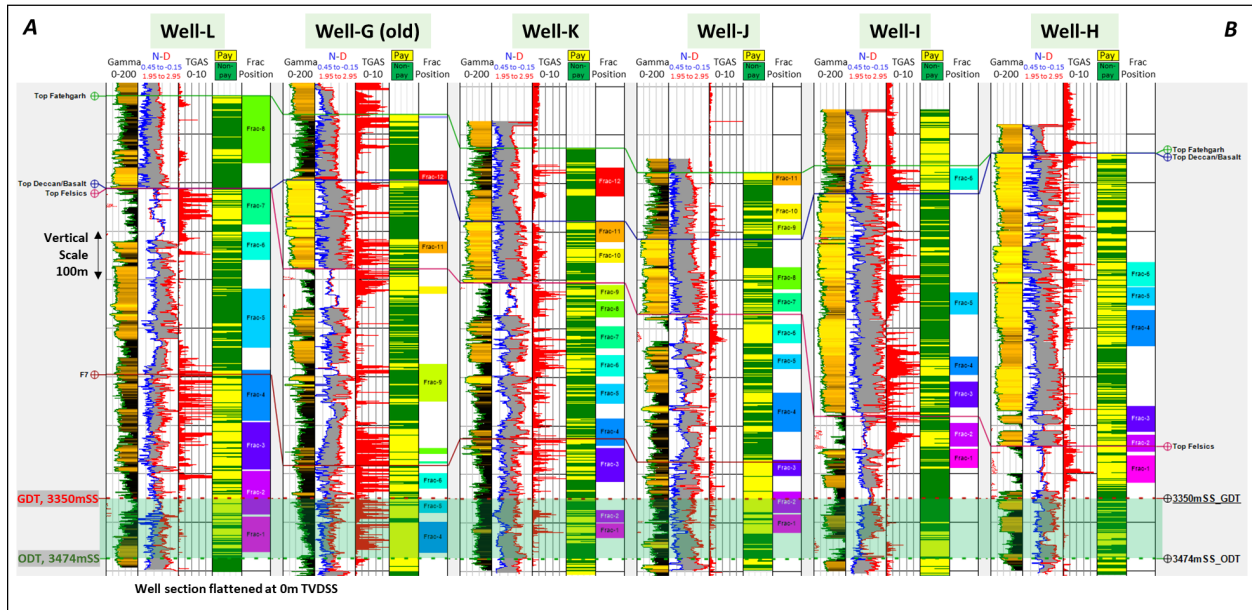


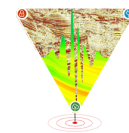
Figure 6: Well section A-B (nearly a North-South section, marked on Figure 5) is showing the vertical pay distribution in old well like Well-G and newly drilled wells like Well-H, -I, -J, -K and -L; Fracs were placed in these wells depending on the presence of pay zone and its position with respect to GDT.

As per the drilling schedule, subsequently more wells were selected in the Western corridor targeting the deeper Felsic zones (F7 and deeper) with predicted higher pay thicknesses as per the static model. Wells like Well-J and Well-K encountered good pay zones with elevated total gas in Felsic subunit, as well as the dynamic lateral facies variation within short distances. Deeper Felsic zones fraced, tested and flow-back was done in a commingled way with overlying RDG gas targets resulting higher oil flow rate of ~500 bopd. The static model was updated based on these newly drilled wells to enhance the reservoir predictability in the remaining areas, especially crestal and central parts as the best predicted pay zones were concentrated in those areas. Furthermore, the position of the remaining wells (such as Well-L) was adjusted laterally to chase the best reservoir as shown in Figure 5. Wells in the crestal area and western corridor became most promising in terms of oil flow rate reaching a peak rate of more than 1000 bopd without affecting the gas production target. Well-L provides a glimpse in the well correlation panel A-B (Figure 6, section marked in Figure 5) that prediction of higher pay zone was eventually successful to establish better production rate and enhance the overall hydrocarbon volume.

The static model is dynamically being updated as the new well results are incorporated in the model. New wells also indicated that deeper Felsic facies are more potential in terms of pay 3-dimensional distribution and require advance geophysical study. During the Frac and testing activity of each well, pay zones from both gas and oil were analyzed separately and fracs were placed in the zones nearest to GDT to boost the commingle flow. Well like Well-J has shown that if a continuous thick pay is distributed between both gas and oil zones then the oil rate can be much higher and sustainable.

**Conclusions**

The commingled flowback approach provided a potential solution to overcome the economical hurdle and monetize the deepest oil from the Volcanic reservoir. The initial flow test data suggested an average oil production of ~200 bopd from the first 3-4 wells additionally the complex reservoir heterogeneity. Finally, the key to success depended on the well selection and frac placement based on the net pay distribution.



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