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Compression Related Deformational Features in Aishwariya Field, Barmer Basin- Impact on Subsurface Understanding and Production Performance

Abstract

The implication and influences of structural models on hydrocarbon production has been continuously looked at various stages of field life. As a result of a recent study, strike slip movement related deformational faults are identified in Aishwariya field, Barmer basin, NW India. The objective of this study is to understand impact of fault on stratigraphy and wells' production behaviors and finally, update the reservoir model with updated fault understanding.

Barmer basin has been predominantly a rift basin hence majority of the fault interpreted in the basin are normal in displacement. The basin has been in compression since Himalayan orogeny which can be seen in the resultant uplift and erosion of 800-1200m of sediments in different parts of the basin. As per current understanding, faults interpreted in the Aishwariya field are normal. The field is bounded by two set of faults N-S and E-W trending called Main Bounding Faults (MBFs). The recognition and impact of crossing conjugate faults is the Aishwariya field has been underestimated or not properly interpreted basically due to limitation of quality of seismic data and lesser well density which leads to the simplification of seismic interpretation. Another factor was at fault intersection areas normally not properly imaged therefore leaving room for misinterpretation. Recent beam-migrated 3D seismic data has improved imaging; which helped to map faults in more detail. Understanding production data in this part of the field is also a challenge.

Each drilled well is looked carefully for any fault cuts which could be integrated with structural understanding. Fatehgarh reservoir has been subdivided into five units in Aishwariya field (FA1 to 5). As per previous interpretation, the lowermost unit (FA-5) is missing at the area of interest; however, the production data contradict the missing lowermost unit. As per new understanding, wells penetrated in this part have missing sections of some of the lower Fatehgarh units. The fault cuts can be integrated with arms of positive flower structure which is better imaged at shallower stratigraphic section. The updated stratigraphic correlation and fault placement has significantly improved understanding of production behavior in this part of the field.

Introduction

Aishwariya field is located in northern part of the Barmer basin, NW India. The field was discovered in 2004. Fatehgarh formation of Paleocene age is the main reservoir, which has been deposited in continental fluvial environment (Crompton, P.). The Fatehgarh formation is subdivided into five sub-units FA1 to FA5; upper units FA1 and FA2 comprise Upper Fatehgarh and FA3 to FA5 units called Lower Fatehgarh. Younger units (FA1 -2) are deposited in low energy fluvial and lake margin settings; lower units (FA3-5) are dominated by multistory braided channel facies.

Reservoirs deposited in fluvial environments commonly contain significant heterogeneity in facies association; ranging from channel sands, point bar deposits, flood plain mud and crevasse splay deposits The field is tilted fault block dipping towards east and bounded by normal faults in west and north. The Barmer basin opened as narrow, elongate, roughly NS trending graben partially overstepping into Jurassic rocks of Jaisalmer basin in the north. The inverted Barmer basin has a maximum length of about 100km; while the width is about 50km. The field is tilted fault structure bounded towards west and north by faults called main bounding faults (MBFs). It is tilted towards east approximately 12 degree. Crestal part of the field is affected by gravity collapse faulting; which has scooped upper Fatehgarh units.

Figure 1: Location map of Aishwariya field and Fatehgarh reservoir units

The field has been developed with 71 wells in edge linedrive waterflood and has been in oil production since 2013. There are dedicated wells in upper and lower Fatehgarh. Multiple reservoir units in each zone being flowed commingle.

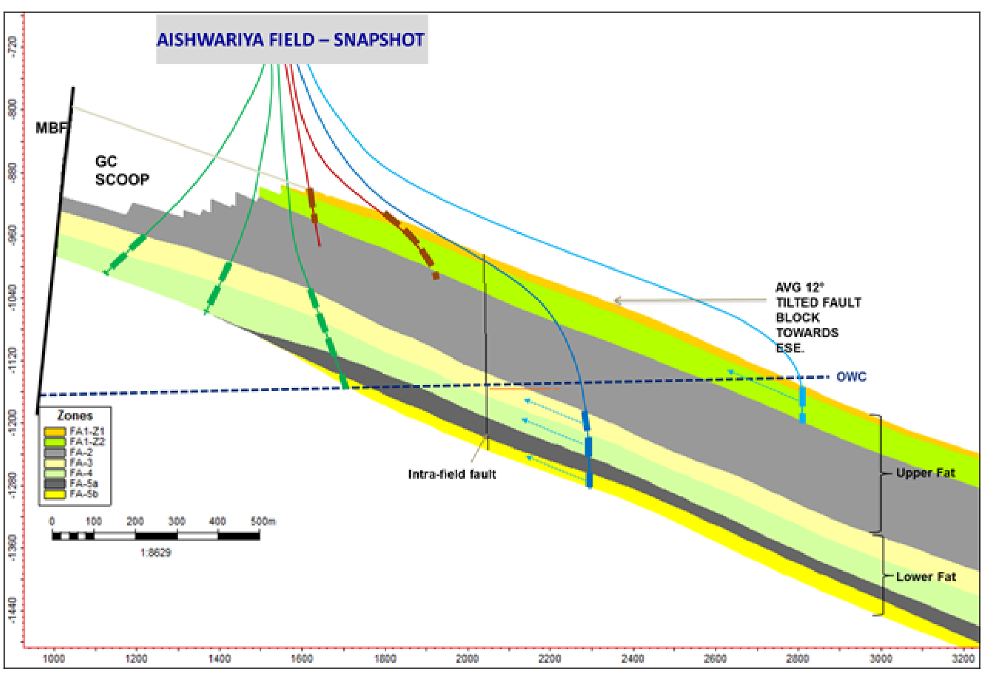

Figure 2: E-W cross-section through field showing major reservoir units and production mechanism

Methodology: Updated Structural Understanding

The Barmer basin is essentially a Tertiarry basin, formed over the basement comprising a variety of older rocks viz Pre-Cambrian granite and metamorphic rocks, Mesozoic sediments and Deccan trap volcanics. Older fault trend NE-SW also can be interpreted in the field; figure-3 shows major structural elements which could be interpreted in the field area. The earliest deposition in the basin constituted the Fatehgarh formation of Paleocene age which is believed to be deposited as early rift sediments in NW-SE trending rift basin. Fatehgarh formation is overlain by Barmer Hill formation of Upper Paleocene age.

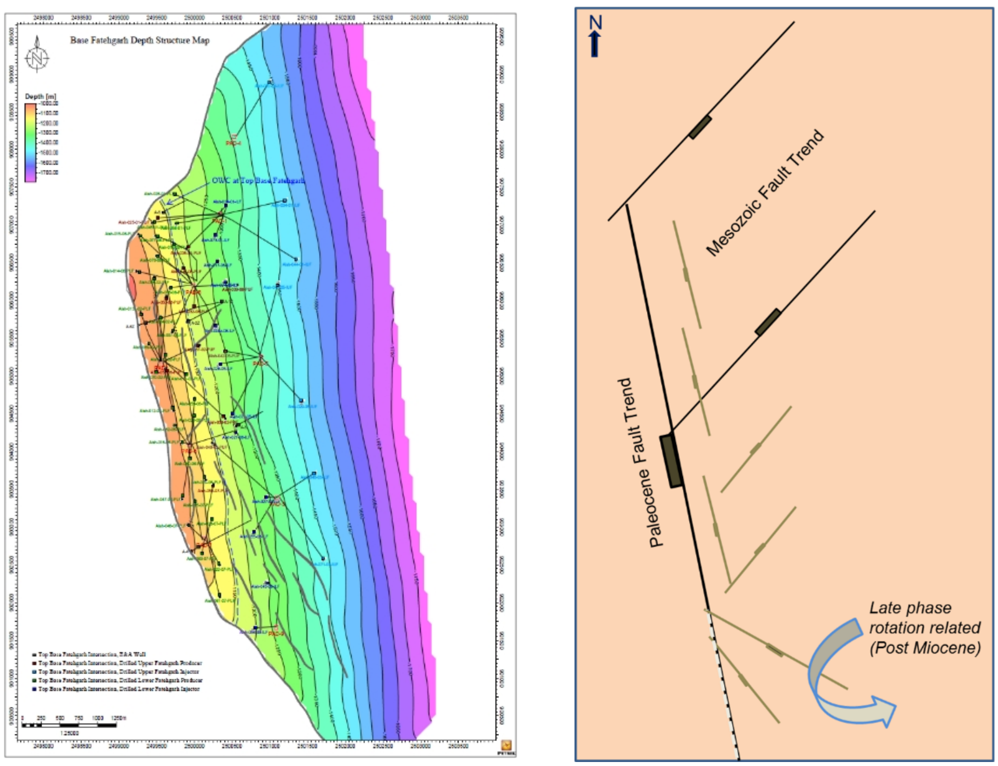

Figure 3: Depth structure map at basement (left) and major structural elements identified in Aishwariya field.

Maximum rift subsidence occurred during deposition of Dharvi Dungar formation which is clearly marked by higher thickness in hanging wall. The crestal part of the field is affected by series of low angle gravity collapse faults which are believed to be formed during late phase of Dharvi Dungar deposition.

The Barmer basin has undergone uplift and erosion of 800-1200m during Late Eocene- Miocene (V. Kothari et al), as estimated from apatite fission track analysis. The uplift is associated with compression related to Himalayan orogeny. Compressional forces has steepened the fault dip and reactivated some of the faults. Major structural events in the field are explained in figure 4; both extensional phase deformation and compressional phase deformation are explained with resultant fault geometries. At present, Barmer basin is in strike slip stress regime. As a result, strike slip related compressional feature- a positive flower structure can be interpreted at junction of two structure bounding faults (Figure 5); which is uplifting the crestal part of the field steeper than initially thought. Strike slip related deformation features also interpreted in other part of the basin.

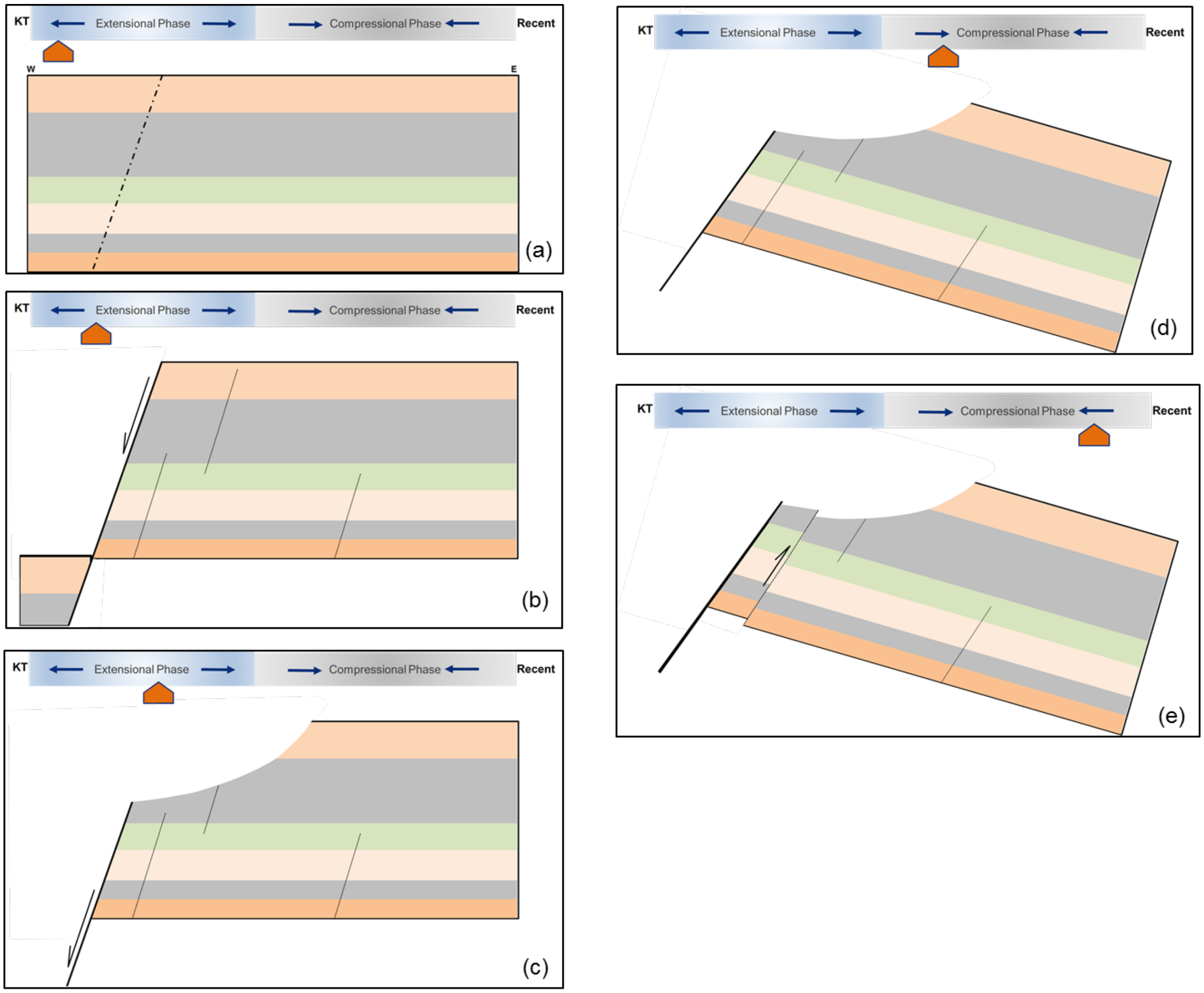

Figure 4: Major structural events in the field (a) Early to Late Paleocene (b) Late Paleocene (c) Late Paleocene- Early Eocene (d) & (e) Late Eocene to Recent

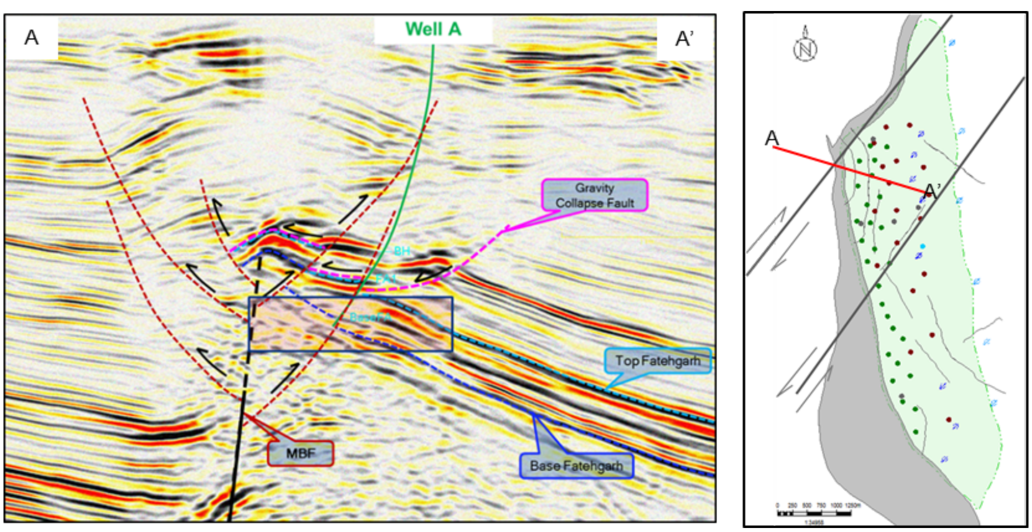

Figure 5: NW-SE seismic section sowing positive flower structure in the crestal part (left) and reinterpreted faults with arrows showing strike slip movement.

Implications

1. Stratigraphic Correlation

Fatehgarh formation is composed of sand, silt and shale intercalation, deposited in intra-continental rift setting. Primarily deposited in fluvial environment, youngest units of the formation indicate lacustrine margin clastics. As per previous interpretation FA5 was not deposited in north crestal part of the field. Lithological correlation has been a tricky, as no consistent shale unit could be correlated in wells, various conceptual understanding was considered for correlating individual sand-shale units. With new correlation, part of blocky sand at bottom of the FA4 unit is correlated as FA5b. An example correlation section and structural setting is shown in figure 6. Hydrocarbon volumes is redistributed into better reservoir facies which increases inplace volumes in this part.

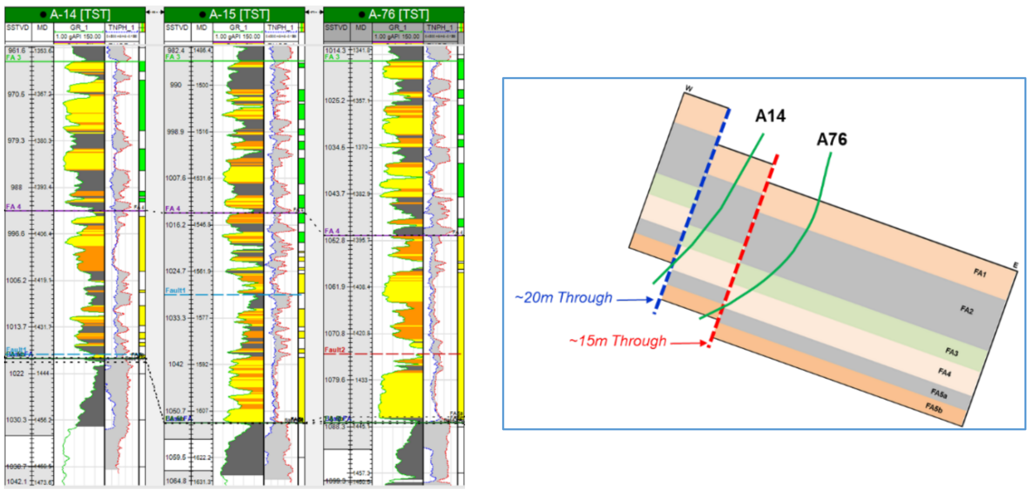

Figure 6: Well correlation with missing section identified and fault interpretation.

2. Structural Model

Missing sections identified in wells are looked carefully in seismic data. Updated fault are incorporated into structural model. A comparison of E-W cross-section of previous and updated model is shown in figure-7; as per previous model FA5 zones pinches towards crestal part. Updated model shows FA5 was faulted-out in the particular well shown in cross-section.

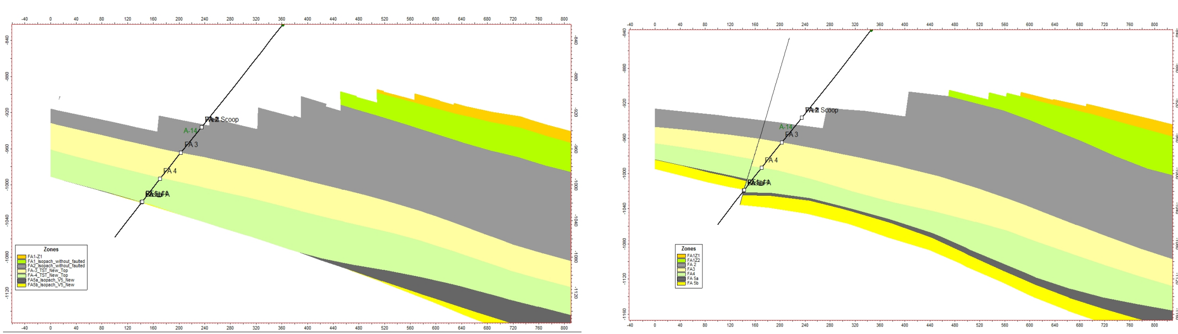

Figure 7: E-W cross-section comparison; previous model (left) vs updated model

3. Field Production Understanding

Lower Fatehgarh has excellent reservoir properties and has relatively better net-to-gross than Upper Fatehgarh. Among the lower Fatehgarh units FA5b has best reservoir properties and sands are blocky in nature. As per previous understanding, this part of the field has no FA5.

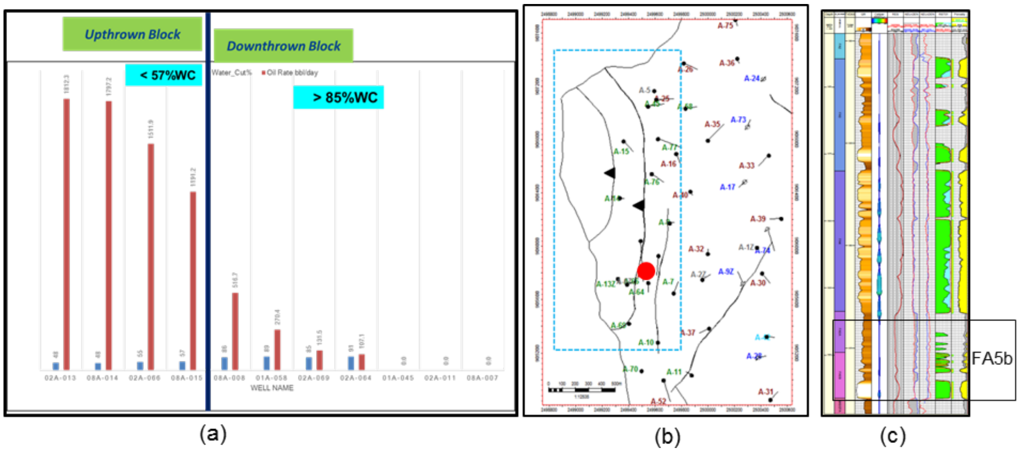

Figure 8: (a)Well performance with water cut ranges, (b) area of interest (blue rectangle), (c) latest time lapsed saturation (RST) taken at red colored well.

However, with new fault understanding and updated correlations, FA5 is deposited in this part of the field. As per previous simulation model, well encountered FA5b in the downthrown part of the area shows high water saturation. But, with new fault interpretation FA5b is juxtaposed against basement towards uplifted part, which making baffle for injected water into this zone and resultant high water cut in downthrown block (Figure 8a). Based on updated understanding, production optimization opportunities being worked out to produce hydrocarbon from FA5B sands which were initially thought as high water saturated zone.

Conclusion

The updated stratigraphic correlation and conceptual model has identified faults at the junction of two structure bounding faults (MBFs). Most of the identified faults in wells can be interpreted in seismic data. The interpreted fault pattern can be explained by current stress field in the basin and a positive flower structure can be seen in seismic data. Strike slip movement related deformations are also seen elsewhere in the basin. The updated litho-stratigraphic model shows FA5b is deposited at crestal part which was thought to be non-deposition. Production data also support faults in this part of the field. The updated structural model explains the crestal wells' production and high water cut in downthrown block. Initial production optimization activities based on current understanding indicate a significant FA5b potential left in this part. Further, this updated fault understanding will help to mitigate drilling risk and well planning in future.

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