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# 611. Fracture Characterisation and its Significance in Production from Unconventional Fractured Deccan Trap Reservoir, Padra Field, Cambay Basin , India.

## Introduction

Padra field, located in eastern margin of South Cambay basin, is famous for oil and gas production from unconventional fractured Deccan trap reservoir. More than 70 wells are drilled in the field, and oil gas production is contributed from trap, Olpad and Ankleshwar Formations. It is well established fact that the reservoir porosity, permeability and hydrodynamic behaviour in trap are attributed to natural fractures present in it. Almost all the wells producing from trap are barefoot completions (100-150m) and are average to poor producers, and except few wells, all are on SRP. A wide variation in well performance is observed in near by wells in the field, and it is the primary issue for development programme and exploration.

In this article relationship existing between production character of wells and natural fracture systems is studied. Natural fracture analysis is done by utilizing field level faults, FMI logs recorded in recent wells and few conventional cores from trap section.

## Geological Setting and Stratigraphy

Padra structure lies in the north eastern rising flank of the late Tertiary Broach depression. The structure shows a series of NNW –SSE trending normal faults almost parallel to one another forming successive horsts and grabens and thus resulting in series of fault blocks and many fault closure within it. There are also some major transverse normal faults trending ENE-WSW to E-W cross cutting the main longitudinal faults (Figure1.).

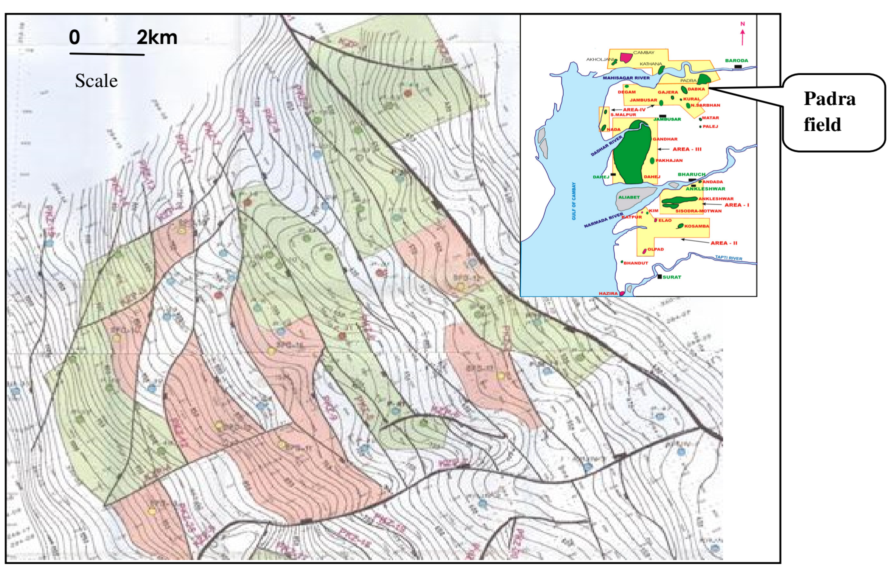
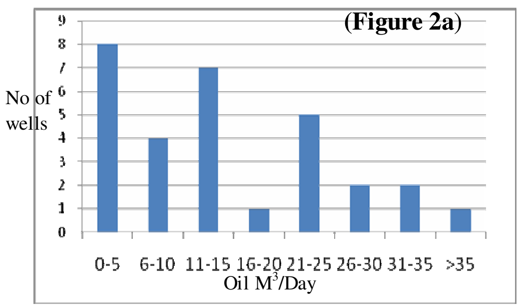



**Figure1.** Time Structure map near the top of Deccan Trap, Padra

Stratigraphically, the area is covered by Tertiary and Quaternary sediments of about 600-700m overlying Deccan trap unconformably. The Olpad Formation belonging to Paleocene age are the first sediments deposited on Trap. They consist of trap conglomerate with red and variegated claystone, Trap wash and in lower part predominantly sand. Cambay shale Formation is very thin to almost absent in the area. Ankleshwar Formation deposited in an upper deltaic environment, directly overlies the Olpad Formation and it cannot be differentiated into Members in the area. In the north eastern part of the field Post Dadhar sediments directly overlie the Trap and the entire Paleogene section is pinching out in this direction.

## Production Characteristics

The performance of the wells in trap is mapped over the history of the field and particularly two production parameters, initial production potential i.e. initial production rate (IP) and cumulative production (CP) are used to understand the significance of fractures. The frequency diagrams of IP and CP for the wells in the field display a highly skewed frequency (Figure 2.). The frequency distribution has many wells with low IP and CP and few wells with high IP and CP. This feature is characteristic of a fractured reservoir worldwide. The cross plot diagram of IP Vs CP for the trap reservoir shows a poor correlation between IP and CP as depicted by correlation coefficient of 0.23. This aspect signifies the smaller pools with few wells and their drainage area strongly controlled by localised fracture networks. These fractures are generally more dense and interconnected near the major faults zones or reservoir block limiting faults.



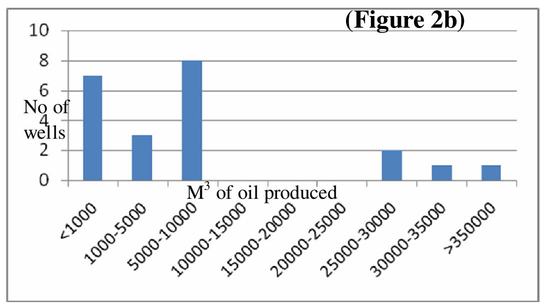




**Figure 2a.** Frequency distribution diagram for initial production show skekwness towards low production rate wells. **Figure 2b.** Frequency distribution diagram for cumulative production shows similar distribution

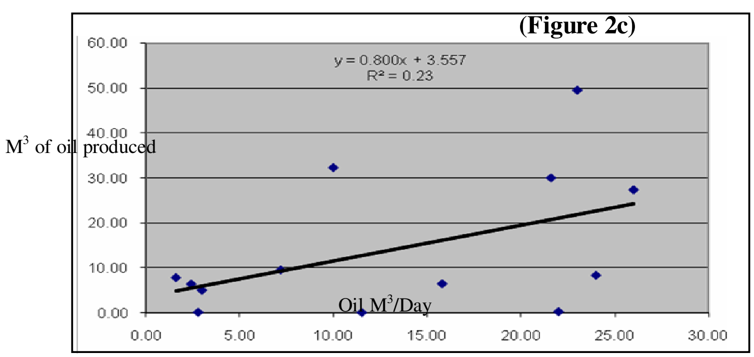



**Figure 2c:** Cross plot between initial production rate and cumulative production show poor correlation coefficient

The IP and CP production parameters when represented in map form, they depict the control of major faults and reservoir block limiting faults (Figure 3.). The bubble maps and contour maps for the IP and CP display the strong influence of NNW- SSW faults in the north eastern and central part of the field. In the western part of the field higher IP and CP contours are influenced by E-W trending normal faults. More specifically areas with closely spaced faults are the best IP and CP blocks.

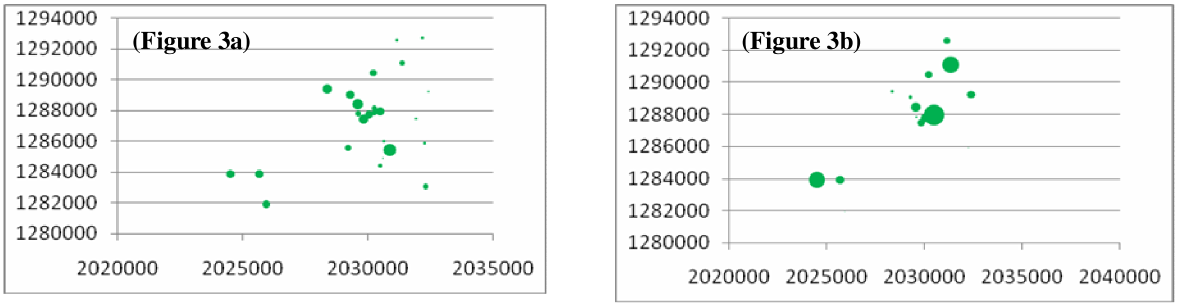



**Figure 3**. Bubble maps for initial production and cumulative production. **a)** Map shows the high production rate wells along NW-SE direction. **b)** No clear cut trend is seen for cumulative production.

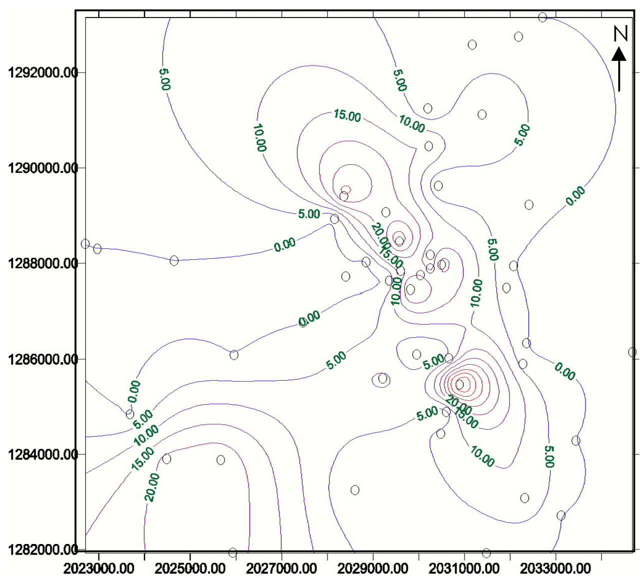



**Figure 3c.** Contour map for initial production rate shows NNW-SSE and ENE-WSW trends. It is the result of influence of faults oriented in these directions.

## Fracture Analysis from FMI

The image logs (FMI and Acoustic image logs) have become very important tool for fracture analysis as they provide vital information like azimuth, dip, density aperture etc. of the fracture systems. This information is now widely used for geomechanical modelling of fields. In this study FMI log from three wells with totally different productivity behaviours are used for natural fractures and borehole failures analysis.

### Natural Fractures

The FMI logs show the presence of two broad categories of trap images, one highly resistive and another conductive occurring in multiple alternate depth intervals. These two FMI characters are interpreted as fresh trap and weathered/altered trap respectively. They may also represent the different flows of Deccan volcanism. This observation is also corroborated with cutting samples and cores from trap in the field (Figure 4.).

The maximum development of conductive natural fracture is observed in high resistivity zones of fresh trap, where as the fracture development is very poor to negligible in low resistivity conductive zones the weathered trap. The weathering/alteration in trap might have obliterated the fractures in weathered zones.

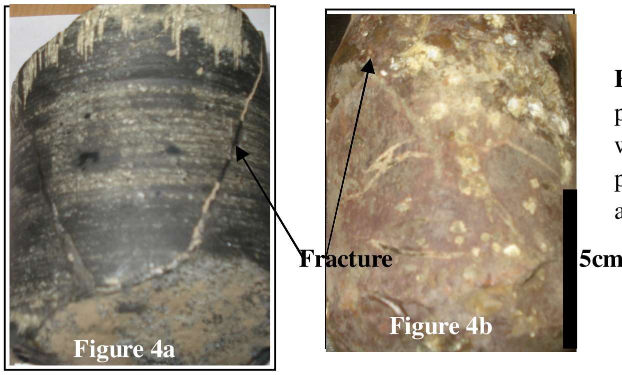



**Figure 4.** Core pieces of trap. **a)** A fresh basaltic trap piece showing sub vertical open fracture. **b)** A highly weathered and altered basaltic piece from trap. Poorly preserved fractures and powdery calcite in vesicles are also seen .

The fractures occur in minor to mesoscopic to mega sizes, and are open as well as partially to fully filled with high resistive minerals. They are oriented in NNW-SSE and in E-W directions with true dip of $5^0$ to $85^0$. The smaller fractures are less dipping and occur as clusters of interconnected fractures. Larger scale fractures are isolated to few cross cutting fractures with sub vertical dips (Figure 5a &b). The fracture density is in the range 5-15 fractures /metre, the fracture aperture is in range 0.01-0.1cm on image log and true porosity is up to 0.1%.

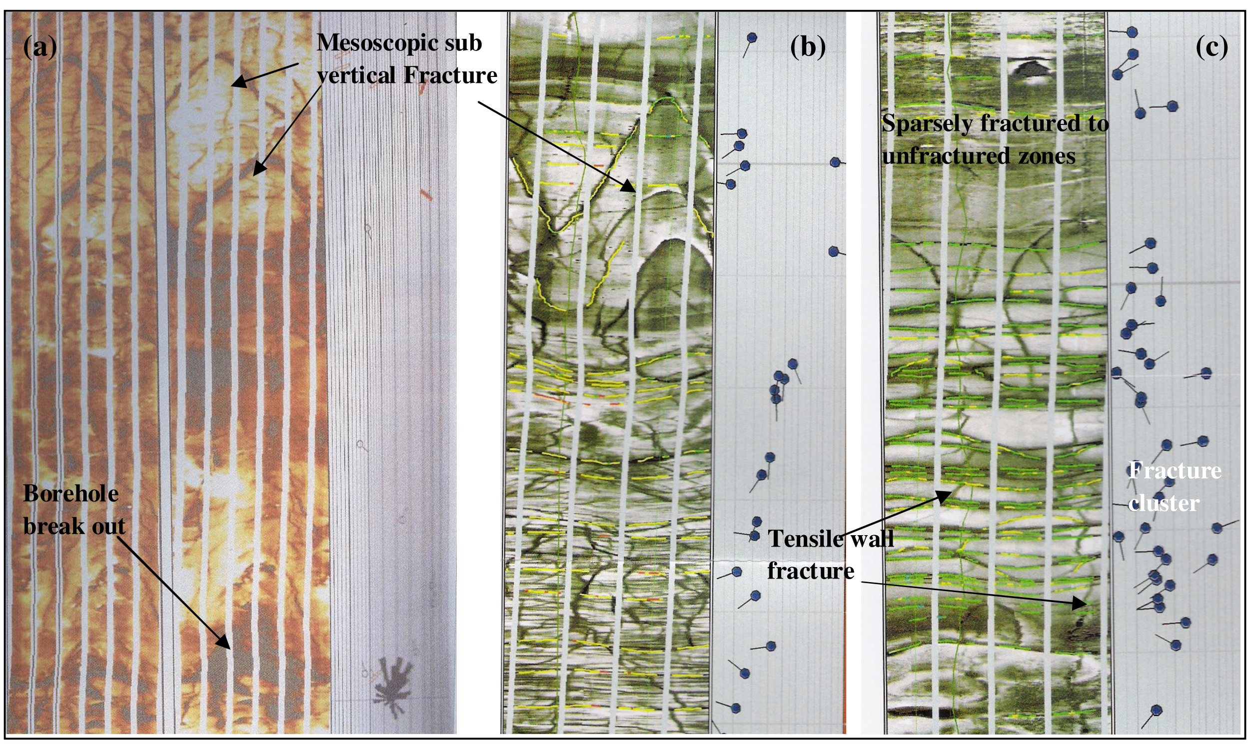



**Figure 5.** Examples of natural fractures imaged in two wells from trap. **a)** Static and dynamic images showing mesoscopic and minor fractures. Borehole breakout is also seen due to intersection of more than one mesosccopic fractures. **b)** Subvertical fractures and low dipping to sub horizontal fractures observed in dynamic image. **c)** Fracture cluster, sparsely fractured and unfractured zones are seen. Drilling induced tensile fractured developed vertically is also seen.

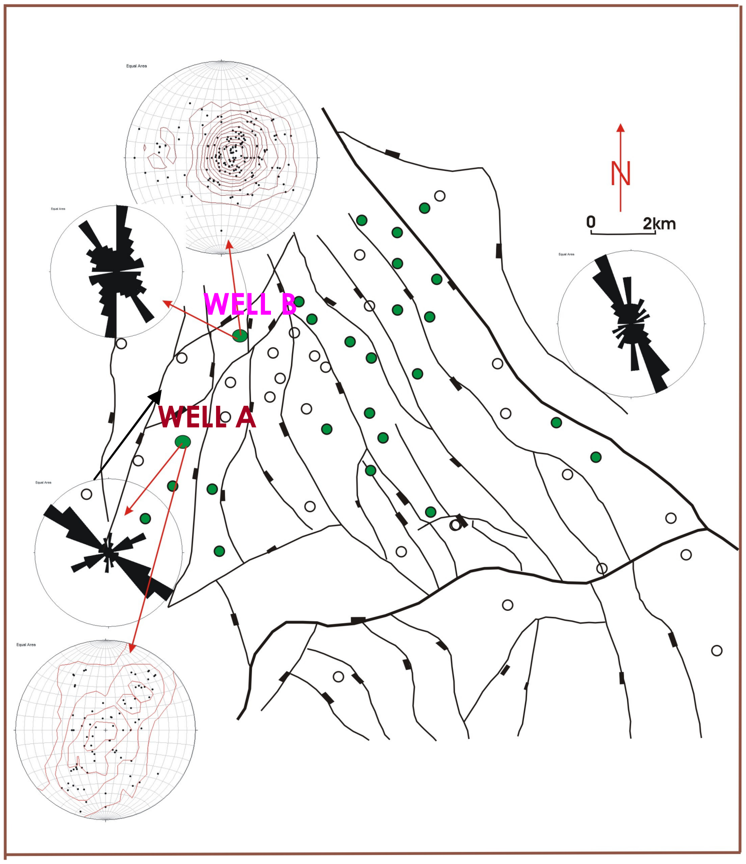



Figure 6. Rose diagram for azimuth of all fractures from wells A&B and azimuths of field level faults show more or less show similar trend. Kamb contour of all fractures measured in theses two wells suggest that these two wells intersect distinct fracture populations, indicating a highly compartmentalised faulted basement reservoir. .

## Discussion

The occurrences and fracture density of minor and mesoscopic fractures apparently do show some influence on the well performance. But, the proximity of few mega fractures/faults seems to control the hydrocarbon occurrence and increased production rates as inferred from the production characteristics of the field. The mega fracture/fault systems might be the main conduit for hydrocarbon charging of the trap reservoir block. The smaller scale natural fracture system observed on FMI logs provided porosity and permeability to the reservoir. Hence, both mega fractures/fault system and natural fracture system are prerequisites for an ideal condition for hydrocarbon accumulation and production. The azimuth of natural fracture sets interpreted from FMI is dominantly NNW-SSE, N-S and E-W and they more ore less follow the trend of the faults in the area (Figure 6). This means the faults and natural fractures are genetically related and were developed under same stress conditions. The related swarms of fracture system of greatest fracture intensity and permeability will be expected around fault planes and fault offset zones. These zones of high porosity and permeability can be optimally utilized by planning wells cross cutting the fault planes constituting the reservoir blocks at an angle of 25-45$^0$ from foot wall side to hanging wall side (Figure 7).

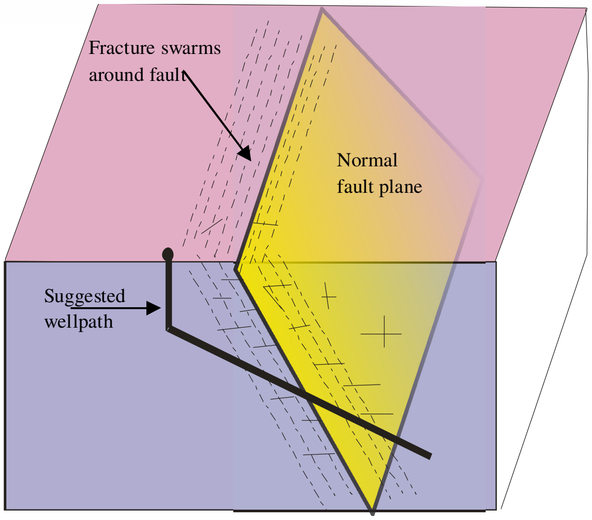



Figure 7. A schematic diagram showing suggested well path for maximum no. of fracture intersection utilisation around a hypothetical normal fault plane dipping.

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## Conclusion

Padra field is unique for its oil and gas production from unconventional fractured Deccan trap reservoir. It has very critical hydrocarbon accumulation and production behaviour greatly controlled by faults and natural fracture system. So, both mega fractures/fault system and natural fracture system are prerequisites for an ideal condition for hydrocarbon accumulation and production. Fracture analysis of Deccan trap reservoir in few wells from FMI log data suggests that a wide variation in fracture population across the field exists due to highly compartmentalised and faulted reservoir. A genetic relationship between field level fault system and natural fractures also exist as they were formed in the same state of stress. This relationship between them can be utilized for planning infill development well locations with optimum well path for maximum fracture intersection and further exploration in the area in trap.