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Uncertainty in fractured basement reservoir: A case study from Madanam area of Cauvery Basin

Abstract:

The paper aims to address the uncertainty in fractured basement reservoir of Madanam area in Cauvery Basin. The study aims to understand the probable reasons for water productions in the recently drilled wells in the area under study. FMI data of drilled wells were analysed to decipher the fracture orientation, dip and intensity at well positions. Further, CRAM processed 3D seismic data was used to generate ant track volume to understand fracture distribution and intensity away from the well positions. Water producing zones in drilled wells which have been identified through PLT data were calibrated to fractures deciphered through FMI & Ant track data. The sediments of shallower sequences are predominantly water bearing near flank areas of Madanam high. The study suggest that fractures connecting to aquifers in the shallower sedimentary sections are likely conduits for water influx. Precautions are to be taken before drilling further wells in this area to avoid similar set of water bearing fractures.

Keywords: FMI, PLT, Ant track, Basement

Introduction:

The Cauvery basin is one among the major pericratonic rift basin along the east coast of India that have developed during the rift-drift events associated with the breakup of India from Gondwanaland. The Precambrian rocks of the Southern Granulite Terrain (SGT) and Eastern Ghat Mobile Belt (EGMB) limit the basin in the west. While the Chingleput high separates the Palar basin from Cauvery basin in the north, the Sri Lanka massif limits the basin in the south and towards east the basin extends into offshore and open to deep Bay of Bengal. The Basin covers an area of 1.5 lakh sq.km comprising onland (25,000 sq.km), shallow offshore areas (33,000 sq km) up to 200 m isobaths and about 95,000 sq km of deep-water offshore areas in the Cauvery Basin (Rangaraju et al. 1993; Bastia and Radhakrishna 2012). According to Prabhakar and Zutshi (1993), the basin is characterized by Jurassic–Early Cretaceous pattern of normal faults along NE–SW trending horsts and graben and these trends are in conformity with the Eastern Ghats trend.

The study area lies to the northern part of Cauvery Basin. Exploration in the area was targeting structural closures for mainly Tertiary and the first exploration well was drilled in 1960 followed by few wells probing potential of for Upper Cretaceous and Paleocene for structural and pinch out prospects during 1990s. The area recently attained important for unconventional fractured basement play after discovery of oil in 2012 followed by discovery of free gas in adjacent fault block in a major basement high in the area. A well drilled in 2012 was tested barefoot in fractured basement high which flowed oil @ 115 m3/d and gas @11500 m3/d in the interval 1505-1430m. Subsequently two appraisal wells W#5 and W#6 were drilled to know the extension of fractured basement reservoir. The first appraisal well in the adjacent fault block flowed only gas @ 51500m3/day along with condensate @6m3/day and the second appraisal well W#6, on barefoot testing in the interval 2060-1600m in Basement ,flowed oil @ 64m3/day and gas @ 2400m3/day initially. These wells were followed by development wells W#7,W#8,W#9,W#10 and W#10S. The wells W#7,W#8 and W#9 on testing basement section ,flowed oil @116m3/day,@33m3/day and @82m3/day respectively. But well W#10 gave surprise by flowing water during testing basement section on barefoot which could not be immediately explained prompting the analyses for the probable reasons.

Geology of the area in brief:

The study area falls in the eastern part of Ariyalur – Pondicherry sub Basin(Fig.1) where Kumbakonam-Madanam Horst forms an important subsurface morpho-tectonic feature. The Horst divides Ariyalur-Pondicherry low in the NW and Tranquebar low in the SE. The axis of the Horst is aligned in an NE – SW direction in the Central part of the block and changes to NW – SE in the N – Eastern part of the block . The Horst is bounded by opposite hading NE-SW faults. These faults are offset by cross faults which are trending in NW – SE direction. The arcuate nature of the horst gives rise to major low to the NW of this horst which can act as a major kitchen area for charging the reservoir.The Kumbakonam-Madanam Horst remained as a paleo-high during the deposition of older sediments within the rift basin continued till Turonian time. Thin sediments of upper Cretaceous drape over the Madanam horst except on the crestal part of the cross faulted horst, to the north of well W#1. The Tertiary sedimentation deposited in the passive margin setup had shore line to the west of the study area draping over the entire area of the horst. Stratigraphic succession of Ariyalur-Pondicherry sub-basin is shown in figure no.2.

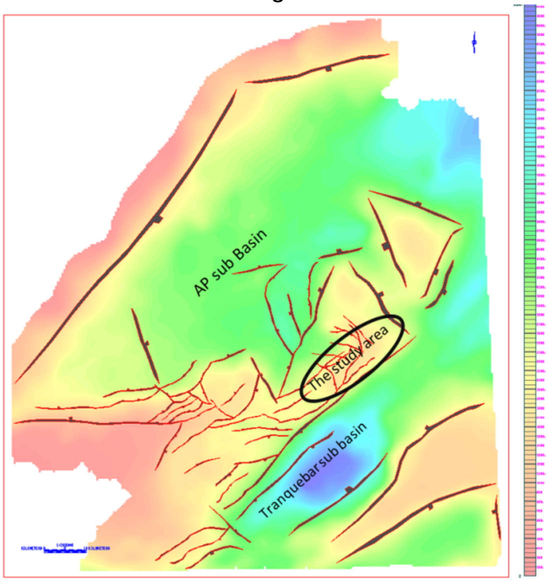

Fig.1 Structure map close to Basement top

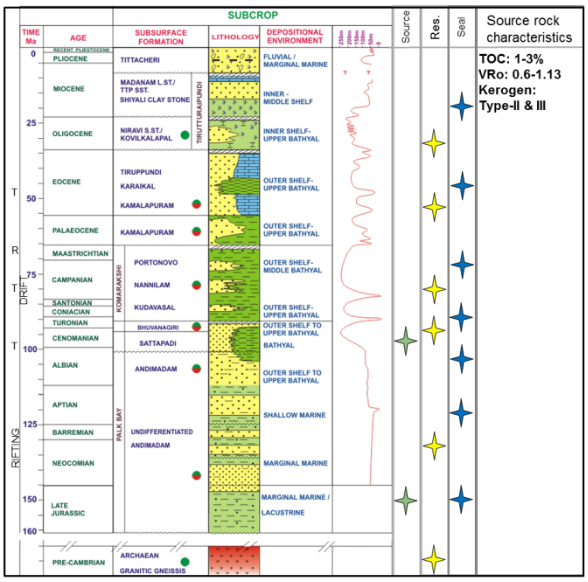

Fig.2 Generalized stratigraphy of Cauvery Basin

Envisaged petroleum system and hydrocarbon plays

Source rock: Shales within Andimadam Formation is considered as the major source having average TOC value of 2.38 %, HI value of 108mg HC/g . These source sequences have good to very good organic matter richness with varying organo facies of an admixture of pure Type III and Type II, with proclivity to generate both liquid and gaseous hydrocarbons in varying proportion. The source rock sequence especially Andimadam Formation is wedging out against Basement outside the Block boundary.

Entrapment: Turonian shale followed by Kudavasal shale of Conacian-Santonian age forms the regional seal. The shale within Tertiary sequence also acts as seal and the structure plays an important role for HC entrapment.

Reservoir: The fractured Granitic basement is the reservoir rock in Madanam area. In addition sands within Tertiary with a porosity range of 20-24% are also very good reservoirs in this area.

The hydrocarbon generated within in the Andimadam sequences is envisaged to have migrated through the fractures and entrapped in the highs (Fig.3)

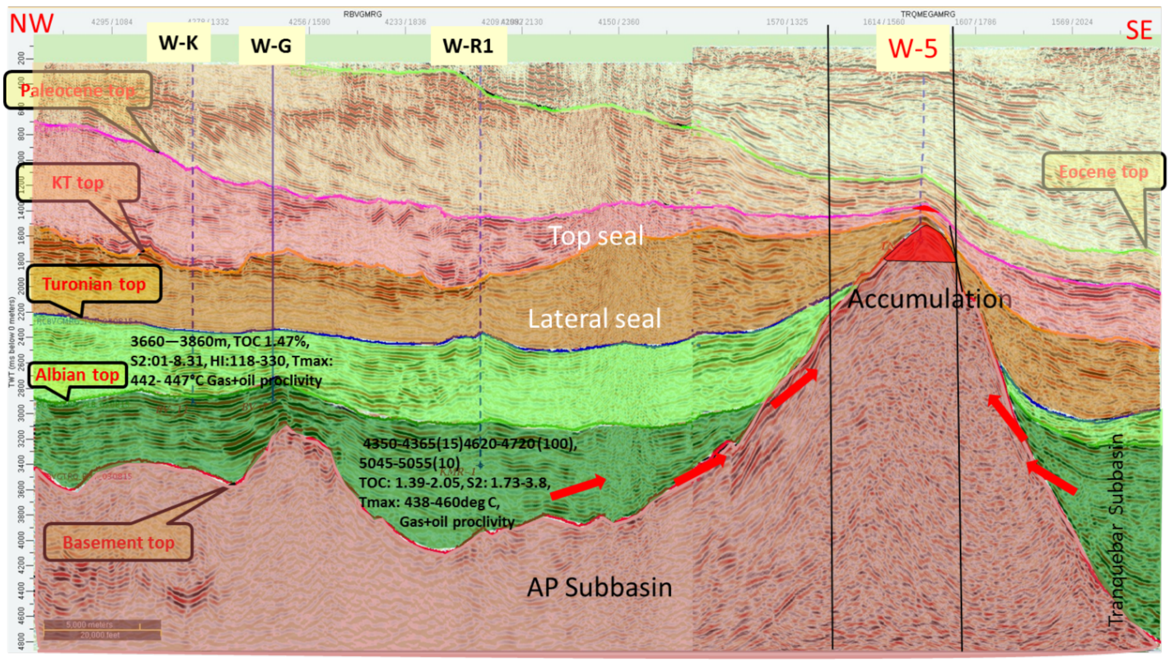

Fig3. Seismo-geological section across Ariyalur Pondichery Subbasin, Madanam High and Tranquebar Subbasin depicting Petroleum System of Madanam Field.

Present study:

The area is having 3D seismic data which was processed by Paradigm® 3D Common Reflection Angle Migration (CRAM®) method. The data was loaded in Petrel® software for the present study. Ant track study was carried out with the following work flow.

Ant track work flow:

By populating a preprocessed 3D seismic volume with computer agents coded to follow discontinuities, swarm intelligence is used to identify, track and sharpen faults (Pedersen et al., 2002). In the general ant tracking workflow, preprocessing can involve preparing the seismic with structural smoothing, filtering or other attributes, followed by discontinuity attributes such as chaos (Randen et al., 2000) or variance (Van Bemmel and Pepper, 2000). The resultant volume(s) are tracked by the "ant" agents, which are tuned to follow the desired faults and fractures.

The time scaled CRAM processed seismic data was conditioned with Gaussian smoothening using Structural Smoothening method. The Relative Acoustic Impedance (RAI) was applied on conditioned data to improve vertical resolution. The results from RAI volume was used as input for generating Variance volume and chaos volume for edge detection. The discontinuities in the reflector beds were identified through Variance volume and Chaos volume. Out of these two volumes variance volume found good and hence this variance volume has been used as input for generation of ant track volume (Fig.4).

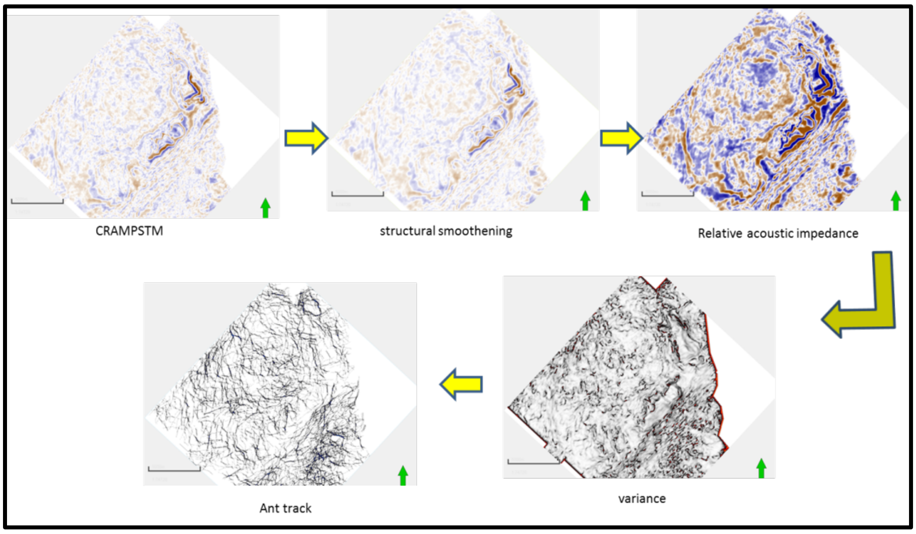

Fig.4. Workflow followed for generation of Ant track volume

FMI data analysis:

FMI data is recorded in 6 wells in the study area and the same data loaded in petrel for analysis. Fracture dip distribution diagrams were generated in wells W#5,6,7,8,9 &10 (Fig.5) to find out any relation between dip, hydrocarbon flow and water influx zones. In well W#10, fractures dip distribution is from 10º to 90º. Where as in other wells dip distribution is from 25º to 90º. It is observed that low angle fractures are connected to the water bearing shallower sedimentary sections and the high angle fractures remain with in the basement reservoir section.

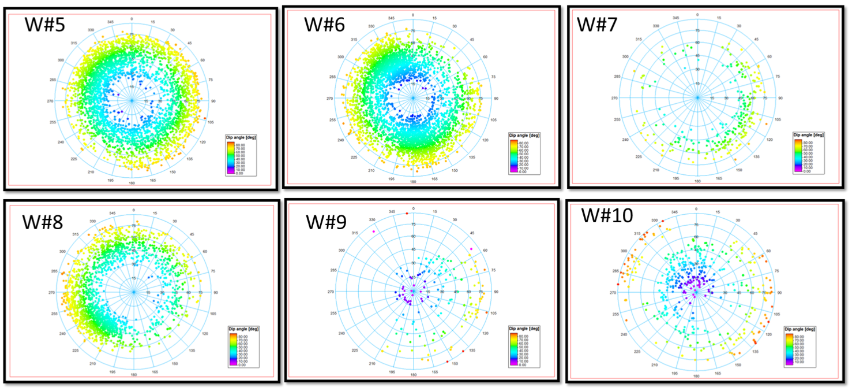

Fig5. Fracture dip distribution in wells W#5,6,7,8,9 & 10

Polar frequency diagrams (rose diagrams) were prepared to know the fracture orientation and dip. In wells W#5, W#6 and W#7most of the fractures are orienting in NE-SW direction and in well W#8 most of the fractures orienting in NW-SE direction. Where as in wells W#10 and W#9, orientation of fractures is in NE-SW & NW-SE (Fig.6).

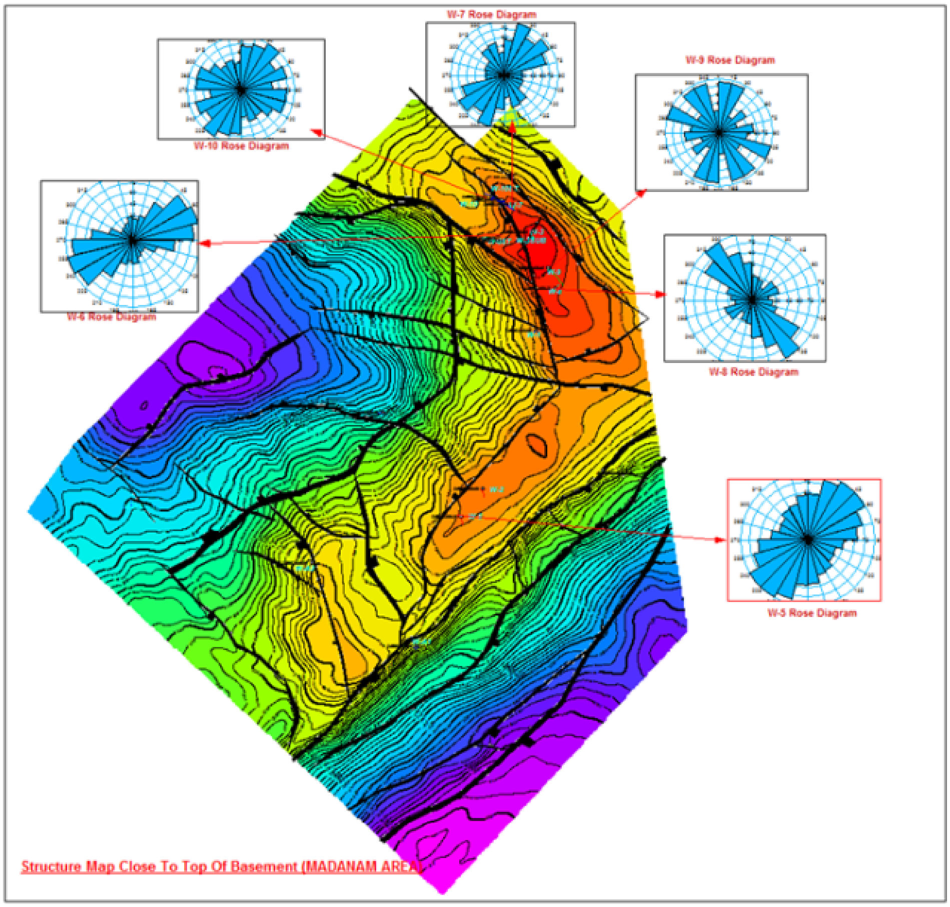

Fig6. Structure map close to top of Basement overlaid with well rose diagrams

PLT data: Production logging was recorded in 6 wells. The results were given in the following table

WELL	**Basement in (m)**	**PLT Result**
W#3	1430-1505 (-1421-1496)	Not attempted
W#3sub	1451-1519 (-1426-1494)	Major flow from 1460-97m
W#6	1600-2061 (-1591-2052)	PLT could not be attempted (Well Ceased during testing, side tracked)
W#6S	1586-1615 (-1557-1584)	PLT could not be attempted due to closed end tubing completion
W#7	1542-1844 (-1511-1813)	Major Flow from 1559-62m, 1571m, 1590-94m, 1645-51m, 1659-63m, 1704-13m, **1720-1725(-1694m)**
W#8	1523-2032 (-1494-2003)	Major flow from**1524-1590(-1561m**) Completion fluid below 1952m**.(-1923m)**
W#9	1628-1694 (-1430-1483.5)	Major flow outside slotted Çasing. completion fluid lying below 1656m.**(-1453m)**
W#10	1915.5-2358 (-1682-2045)	PLT indicating water incursion below **1925m(-1689.5m)**
W#10S	1708-1800 (-1603-1683.5)	Water producing interval **1747-1751m(-1637-1641m) & 1768-1772m (-1656-1659)**

Table1.PLT data of wells in the study area

Discussion:

From PLT study, the fractures below 1925m in well W#10 and in intervals 1747m-1751m,1768m-1772m in W#10S are producing water @7.2m3/day and 26m3/day respectively. And also small water cut has been observed in wells W#7 and W#8. The water incursion zones in wells were calibrated with ant track volume to see the lateral extension of the water contributing fractures. On Ant track volume data, water producing fractures are observed to be connecting to the shallower sedimentary sections which are in general natural aquifers (Fig7 & 8). Whereas fractures connected to source facies are responsible for hydrocarbon production.

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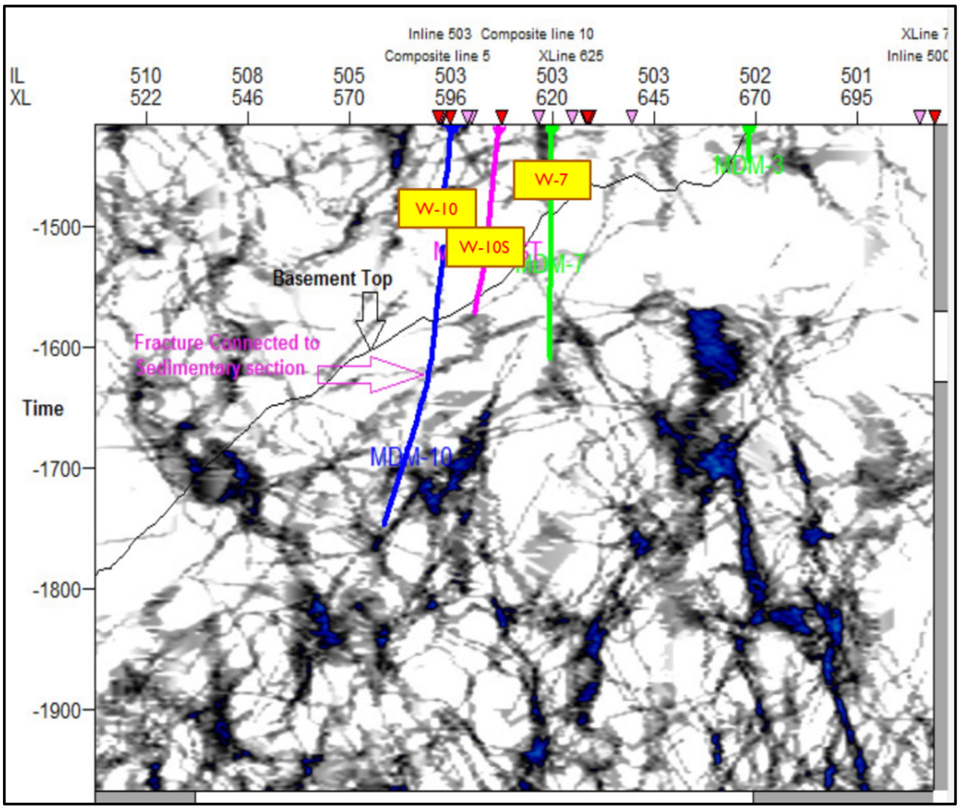

Fig7: Fractures connecting to sedimentary sections to well W#10 & W#10S partly extending up to W#07

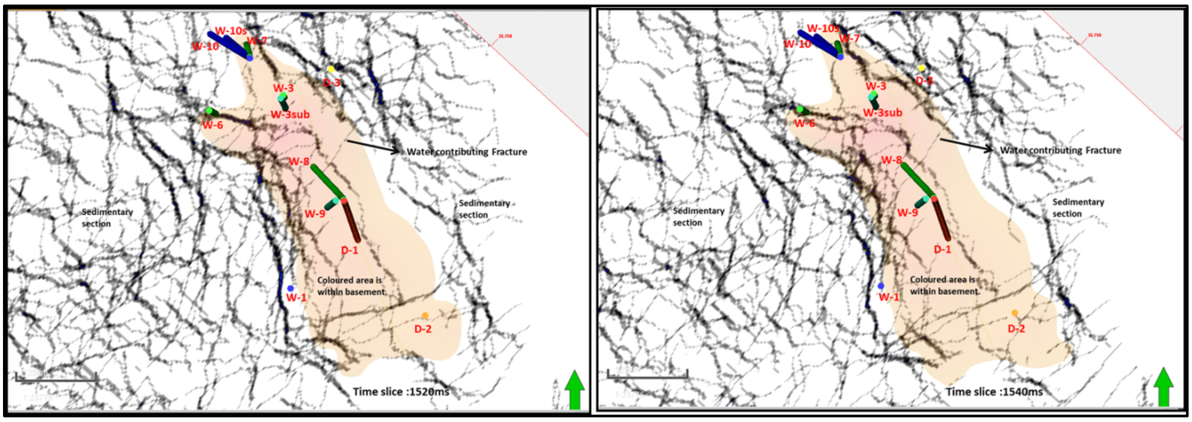

Fig.8 Time slices showing identified water contributing fracture in well W#8

Conclusion:

- Hydrocarbon producing fractures connected to source facies were identified through FMI, ant track and PLT data
- Fractures connected to shallower sedimentary sections (probably natural aquifers) could act as water conduits.
- It can be inferred that High angle fractures are likely to connect with deeper sedimentary source facies whereas low angle fractures are likely to terminate in shallower sedimentary sections which are juxtapositioned against Basement..
- The relation between hydrocarbon production and fracture orientation could not firmly established as the observed fractures are oriented in both NE-SW and NW-SE directions.

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