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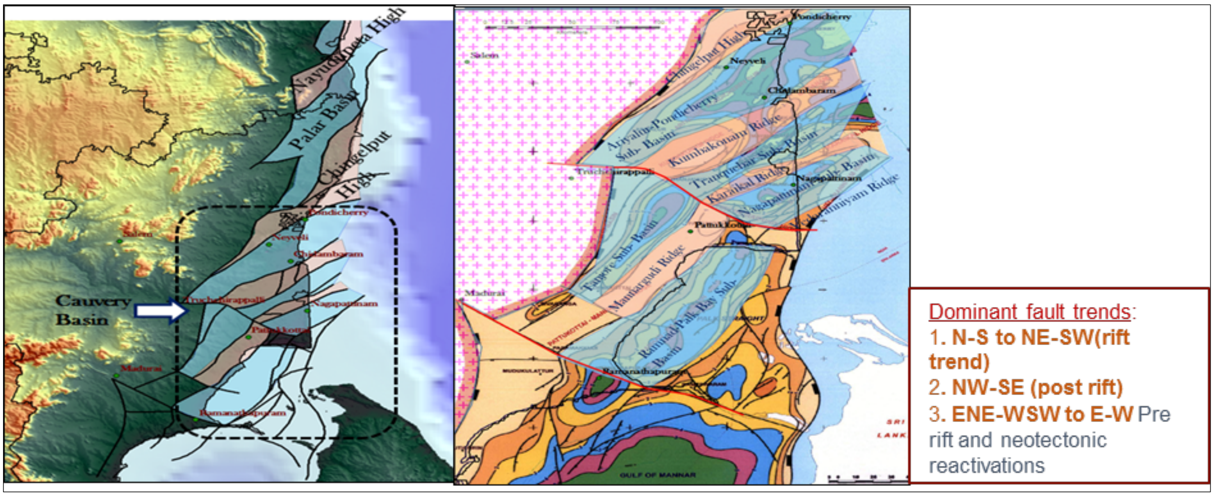
Highlighting role of fracture in storativity & migration using seismic & petrophysical tool: A case study from Mattur & Pundi basement reservoirs

Abstract

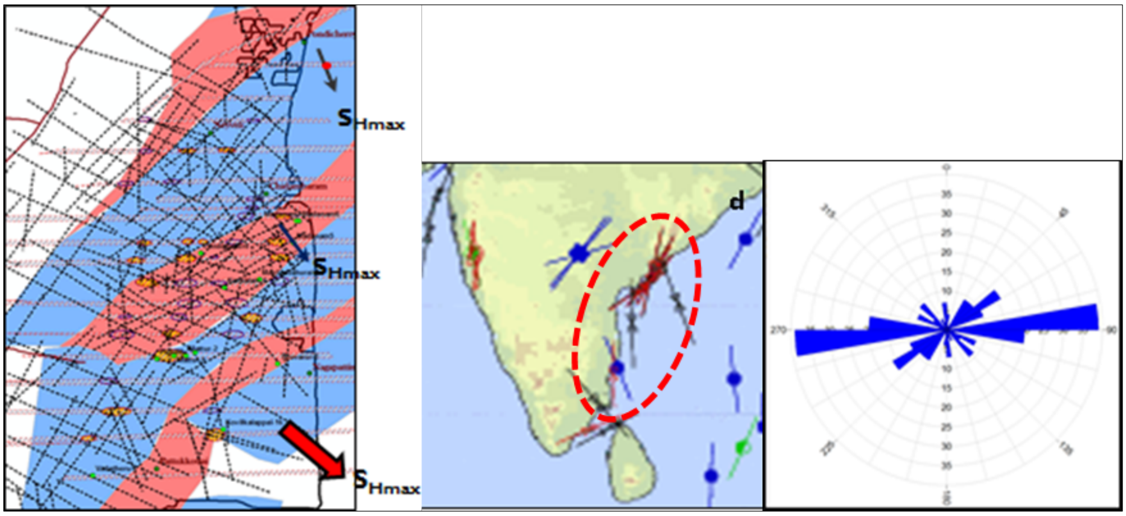
Hydrocarbon potential of basement has been established in a number of drilled wells in Pundi and Mattur fields in Cauvery basin. Fractures in basement prospects located in Cauvery basin are principally fault tip propagation fractures, fault damage zone fractures and fractures related to flexures as in Pundi-Mattur areas. Characterizing basement anisotropy and identifying critically stressed fracture orientations is the key to understanding anomalous hydrocarbon accumulation patterns in Pundi and Mattur basement reservoirs irrespective of their structural disposition. In comparison, wells drilled in Mattur high met with no success and the only accumulation could be established at the flank of the Mattur horst. Recent discovery of hydrocarbon in Mattur west field necessitated characterisation of fractures vis-a-vis migratory pathways. A study integrating seismic attributes and trends from discontinuity volumes has been able to map basement anisotropy in general and has been able to successfully explain the anomalous accumulation patterns in basement in this area.

Introduction

The Cauvery Basin is an extensional Basin in the form of a number of sub-parallel horsts and grabens, trending in a general NE-SW direction. The initial rifting caused the formation of these NE-SW horst-graben features. Subsequent drifting and rotation caused the development of NW-SE cross faults (Fig 1).



These dominant trends have been affected by strike slip movements which are likely to have occurred due to counter clockwise rotation of the Indian plate during its rapid northward movement. E-W trending faults are the most reactivated under the present day stress regime (Fig 2). Analysis of hydrocarbon distribution in basement in Pundi and Mattur fields demonstrate concentration of basement hydrocarbon occurrences in the crests as well as on the flanks of prominent horsts, where juxtaposition of source rock against basement highs, as well as high angle faults offset by frequent cross faults have created reservoir conditions for basement.



Stress direction for Cauvery Basin found to be oriented NW-SE

(Courtesy: World stress map)

E-W trending faults most reactivated under the present stress regime

Fig 2: Present day stress pattern of Cauvery Basin

Study area (Fig 3) is located in the northern part of Tanjore sub basin on the rising flank of Kumbakonam Madanam horst. Mattur structure is an ENE-WSW pre rift and neotectonic reactivations trending basement high dissected by a number of faults. Hydrocarbons have migrated from surrounding kitchen areas along unconformity surfaces and through fault to fractured basement reservoirs.

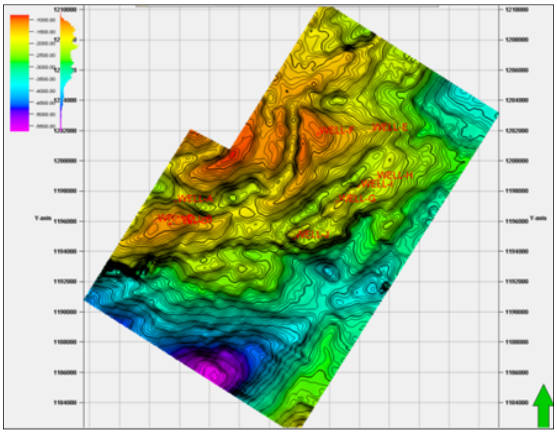


Fig 3: Study Area

Analysis of FMI logs of basement section drilled in six wells in the area have helped to visualize the principal stress direction as ENE-WSW which is validated by pattern observed in AntTrack attributes. Mapping of fracture distribution in the basement has been done using Seismic data with different edge detection attributes e.g. Variance, Chaos, 3D Curvature and finally AntTrack and with image log data. These attributes are very powerful tool to visualise the edges which are connected and form fracture networks.

In the present study an attempt has been made to characterise fracture attributes using petrophysical data and seismic edge detection tools integrating a static fracture model, to satisfactorily explain the anomalous behaviour and hydrocarbon accumulation in basement in this area.

Methodology

Faults and natural fractures can have significant effect on the permeability of reservoirs and it can have impact on productivity and efficiency (Neves et al., 2006; Chopra and Marfurt, 2007). Fractures occur at many scales but most of them are below the seismic resolution and thus are not easily visible in a standard seismic display (Singhal et al. 2010). Seismic attributes based on discontinuity principle provide useful tools to characterize faults and fractures (Hakami et al., 2004; Chopra and Marfurt, 2007; Basir et al., 2013). AntTrack is an important volume attribute, which can be used to extract information about faults and fractures from seismic data. The accuracy and quality of these seismic attributes are directly proportional to the Signal to Noise ratio of the seismic data.
The input data for this study is Pundi-Mattur 3D pre stack time migrated data (PSTM) volume. AntTrack itself is a multistep process. Data was conditioned with Gaussian smoothening filter using Structural Smoothening method guided by the local dip and azimuth to increase the continuity of the seismic reflectors. It reduces the structurally oriented random and coherent noise and increases thecontinuity and visibility of faults and fractures by preserving and at the same time sharpening the edge and relative acoustic impedance to boost low frequencies. The conditioned data was used as input for generating discontinuity volume e.g. Variance and Chaos for edge detection. These two discontinuity volumes were combined and analysed based on regional trends matching and the continuity and visibility of faults and fractures. Based on the result variance volume shows better discontinuity and was used to generate the final AntTrack volume after a number of iterations. Directional filtered AntTrack volume has been generated for highlighting the fractures connectivity to source. Regional fault NE-SW trends and NW-SE cross faults have been highlighted by AntTrack attribute (Fig 4). These directional filtered AntTrack were generated by stereo net filtering of data.

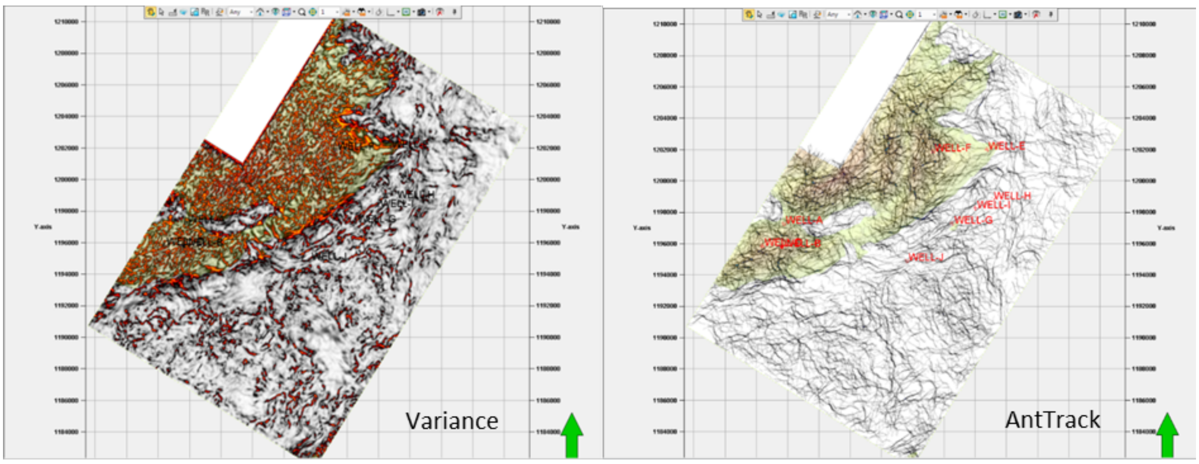


Fig 4: Variance and AntTrack attribute

Mapped fault framework has been used as an input for preparation of Geological model. Broadly three step process was executed after AntTrack volume generated to evolve the total fracture intensity model.In the first step, analysis FMI data of 6 wells (Fig 5), brings out presence of dominant EW along with a few NE-SW cross trends.

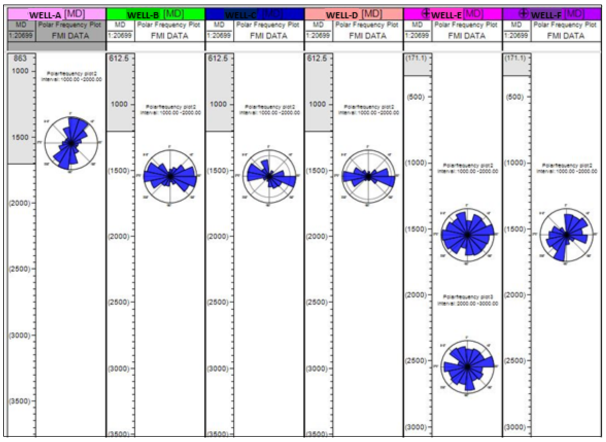


Fig 5: Strike Rosette plot of Pundi-Mattur area wells

The second step involved was property modelling- upscaled intensity log. The final part was integration of well data analysis and seismic attribute analysis to build fracture intensity model. 3D structural model (Basement top to 400m below) with cell size of 50mx50mx10m has been created for analysing the data which was used to statistically model the 3D fracture patterns (Fig 6).

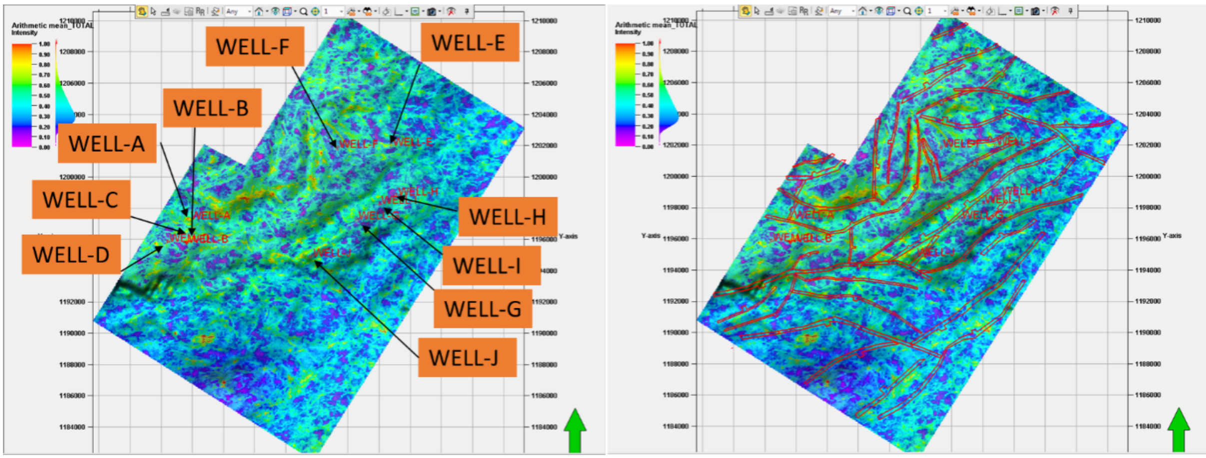


Fig 6: Fracture intensity with and without fault overlaid near basement top

Results and Case Study

Resistivity image logs of 6 wells falling in the area were analysed (Fig 5). It is observed that three of the wells B, C and D which fall on the Pundi ridge exhibit a dominant EW trend. The well A falling in Pundi area shows the regional NE SW trend. Well E and F which are located on Mattur high exhibit a scattered trend, suggesting presence of stress field with multiple orientations (Fig 7). All these well have moderate to good fracture intensities. Well A was not tested in basement. However all the remaining wells during testing flowed. Well E, located in the structurally lower part produced water on testing, while the rest of the wells,viz B, C and D produced oil (Fig 8). Critically stressed fracture Analysis of Pundi area (CEWELL, 2017), the NE-SW direction corresponds to the minimum horizontal stress orientation, since the Critically stressed fracture (CSF) were found to be striking NE-SW with dip angles ranging between 50-70°, an highly inclined well in the direction of NE-SW is more likely to intercept the critically stressed fractures resulting in higher productivity. The large number of CSF are seen in Well B ,C , & D and Almost no CSF is seen in Well A which is well in agreement with the testing results (Fig 8). These wells demonstrate the fractures providing the storativity in basement.

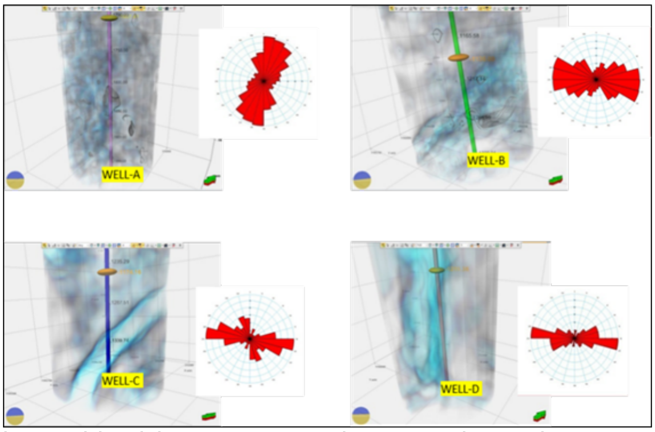


Fig 8: Ant Track section through well A, B, C, D

Well G, H, I and J have been drilled in Mattur area between the main Mattur high and the Pundi structure. The well I &J were tested and dry in basement, while well G flowed oil & H indicated presence of hydrocarbon. The AntTrack & intensity section (Fig 9) demonstrate that wells G and H cut through fractured sections, while well I and J did not encounter fracture sections in basement, though they were located on distinct structural high adjacent to the source facies.

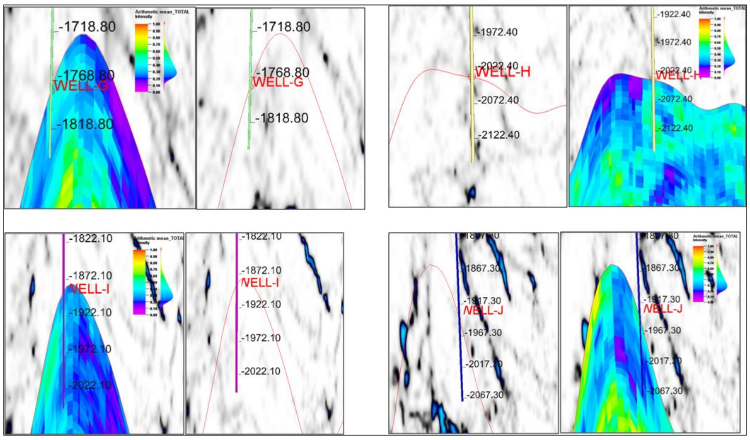
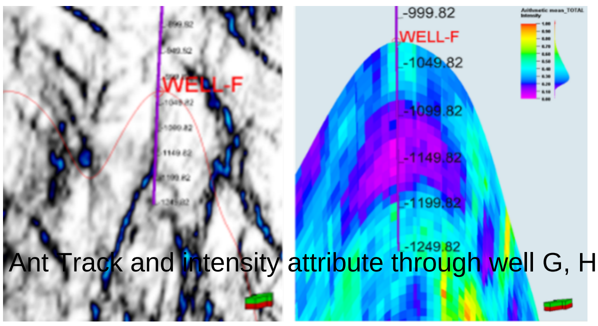


Fig 9: Ant Track and intensity attribute through well G, H, I, J

Well F (Fig 10) was identified for drilling by integrating all the available information pertaining to wells A, B, C, D & E. On drilling the well was produced hydrocarbon from basement, though the reservoir appeared to be devoid of reservoir pressure.



Fracture intensity at well bore simulated from total intensity model indicated fairly good fracture intensity at depths over 200m+ within basement which was validated by FMI, sonic scanner and real time drilling observations.

The result of well F in Mattur west field suggests that the well falls in hydrocarbon migration pathway and it is connected to the source through fractures (Fig 11). The variance attribute extracted at basement surface (Fig 7) validated with FMI data, also corroborates this observation.

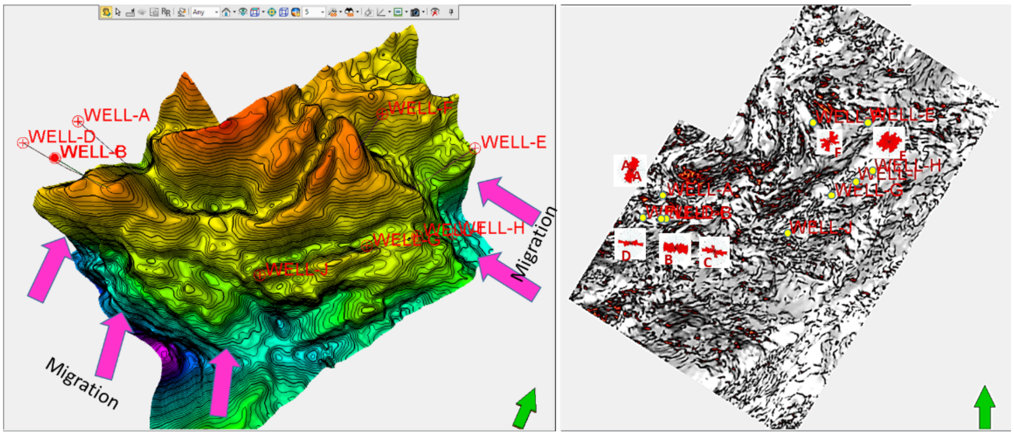


Fig 11: depth relief showing migration pathway

Conclusions

AntTrack and fracture intensity model provides a better visualization the trends of faults and fractures, which were not possible to be visualised in seismic data. It can be used to optimize well locations, as in the case of well F. In this case study, AntTrack and fracture intensity was effectively used to anticipate fracture intensity at wells which, to fair degree of accuracy, matched with well data. It also highlighted the migration path way. Basement hydrocarbon accumulation is a complex function of basement lithological heterogeneity, localised stress-strain patterns with relation to major tectonic episodes and local weathering effects, all of which have a bearing on the final static model of statistically populated fractures. NE-SW direction corresponds to the minimum horizontal stress orientation, since the Critically Stressed Fracture were found to be striking NE-SW with dip angles ranging between 50-70° a horizontal well in the direction of NE-SW is more likely to intercept the critically stressed fractures resulting in higher productivity. The large number of Critically Stressed Fracture are seen in Well B ,C , & D and Almost no Critically Stressed Fracture is seen in Well A which is in agreement with the testing results. Seismic attributes and trends from discontinuity volumes has mapped basement anisotropy and has successfully explained the anomalous accumulation patterns in basement in this area.

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