Fracture characterization and present day stress orientation analysis of Basement - An integrated approach for optimal hydrocarbon exploitation

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Keywords

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Summary

Naturally fractured zones are important, and sought after, in reservoir rocks because of the extra drainage and considerable increase in permeability they promise. Although fractures can have a very significant effect on the total permeability of a rock, they usually have very little effect on the porosity, saturations, or other petro-physical characteristics of the rock.

Natural fractures usually occur in compact, competent rocks where the hole would normally be cylindrical and in gauge in the absence of fractures. Only fractures that are at least partially open are useful from the point of view of production.

This study pertains to fracture identification, characterization and present day stress orientation of Mattur-Pundi Basement using resistivity images, stoneley reflection coefficient and chevron pattern using Dipole Shear Sonic log. The Mattur-Pundi area is located in the northern part of Tanjore sub basin, on the rising flank of Kumbakonam-Madanam horst in Cauvery Basin of India. The Basement has been established as a hydrocarbon play with HC strike from Basement in many wells of Mattur-Pundi Area.

Natural fractures have been identified and characterized within Basement in terms of fracture aperture, fracture density, fracture porosity and fracture trace length and integrated with production testing data & core data. The study also inferred best bore hole trajectory for future wells to get optimal hydrocarbon production from the fractured Basement.

Introduction

Mattur-Pundi area is located in the northern part of Tanjore sub basin, on the rising flank of Kumbakonam-Madanam horst (Figure-1) of Cauvery Basin of India.

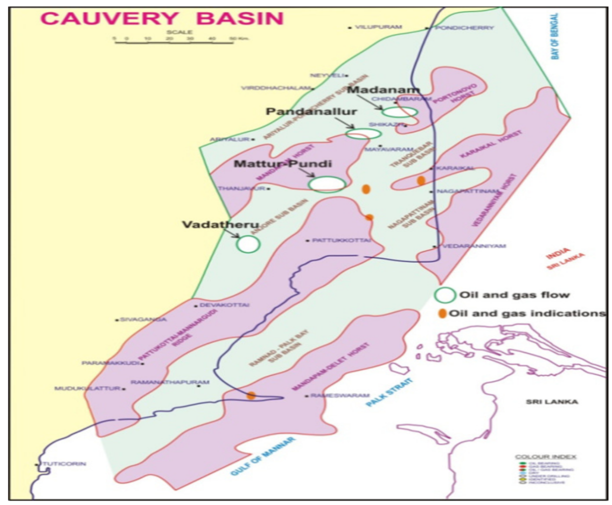

Figure 1: Map Showing Tectonic Elements of Cauvery.

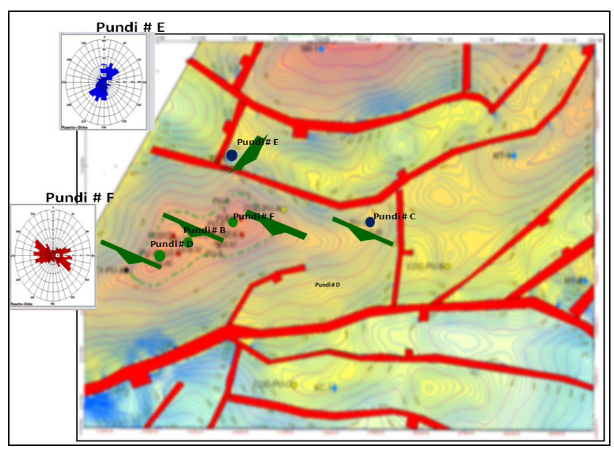

Figure 2: Fracture orientation superimposed on structure contour map of Basement.

The Basement has been established as a hydrocarbon play with HC strike in many wells of Mattur-Pundi area. Mattur structure is an ENE-WSW trending Basement high, dissected by a number of faults. In Pundi field, six wells have been drilled in this field so far (Figure-2). The wells Pundi # A, C & E are dry and abandoned. The well Pundi # B was completed as an oil well in Basement, on Conventional testing it produced 3.3 m3/d oil and minor gas and after producing over 12,000 Tons; the well was transferred to upper horizon. Subsequently, Pundi # D, a vertical development well and Pundi # F, development deviated well produced oil @ 3.3m3/d along with water 2.4m3/day and oil@ 36 m3/d respectively from the Basement. In Pundi field, well Pundi # F, is the best hydrocarbon producer so far.

Tectonic set up and stratigraphy

The Cauvery Basin is an intra-cratonic rift basin (Figure-1), which came in to existence since Late Jurassic/Early Cretaceous as a result of fragmentation of Gondwanaland. It is an extensional Basin which exhibits signatures of India-Srilanka/Antarctica, as well as that of India-Australia separation in the form of a number of sub-parallel horsts and grabens, trending in a general NE-SW direction.

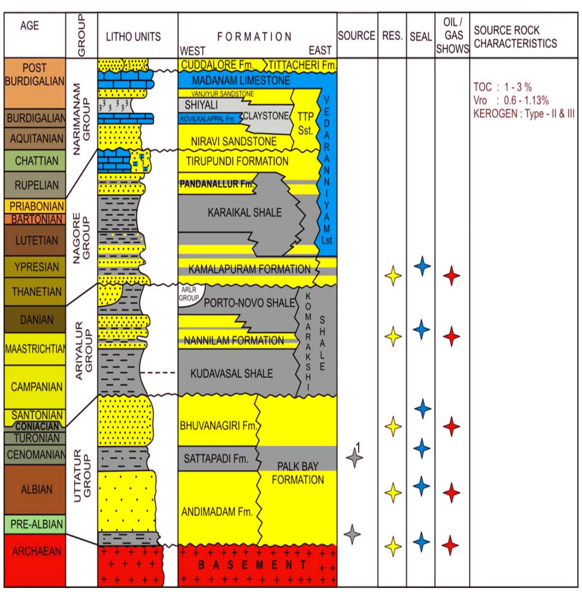

Figure 3: Generalized Stratigraphy- Cauvery Basin

Lithological units ranging in age from Late Jurassic to recent make the stratigraphic succession in the area (Figure-3). In this area Basement and Late Cretaceous are known hydrocarbon plays. The Basement is Granite-Granite Gneiss in the area.

Methodology and Discussions

Fracture identification and characterization

Natural fractures have been identified within Basement in all the three studied wells, using FMI static and dynamic images and fracture characterization has been done interactively. These identified conductive fractures have been characterized in terms of fracture attributes like true dip azimuth, magnitude, aperture, density, porosity and trace length. The attributes are further integrated with production testing and megascopic study done on SWC and cutting samples.

A typical identified conductive fracture zone with its attributes like fracture true dip azimuth, magnitude, porosity and aperture for well Pundi # F is presented in Figure-4. The presence of open fractures with flow potential have also been corroborated by stoneley reflection coefficient and chevron pattern evident by fracture analysis of Dipole Shear Sonic data of well Pundi # F (Figure-5).

On initial testing, wells Pundi # F and Mattur # A (well from nearby field) produced oil@ 36 m3/d and water 148 m3 respectively, from barefoot testing of Basement. Pundi # E was not tested in Basement as not found promising from hydrocarbon point of view. However megascopic study on SWC and cutting samples concludes that Basement is highly fractured.

Therefore stoneley reflection coefficient and chevron pattern coupled with production testing and megascopic study done on SWC and cutting samples corroborates the presence of identified open fractures.

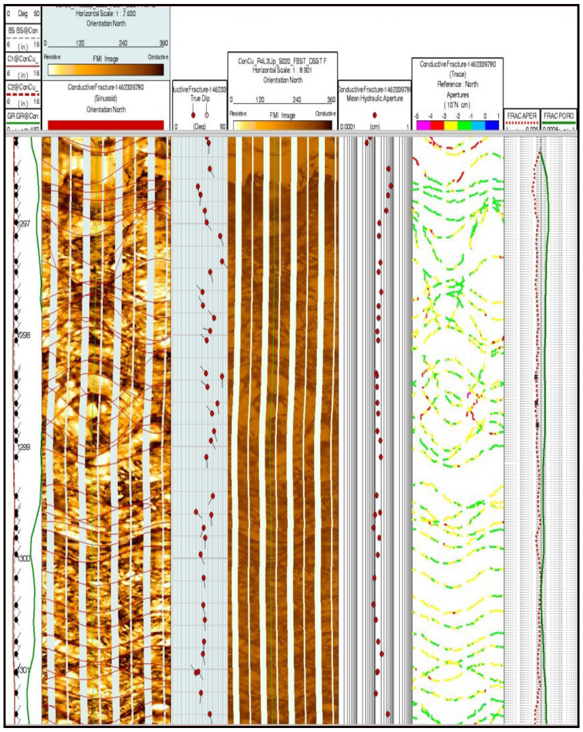

Figure 4: Fracture analysis in well Pundi#F

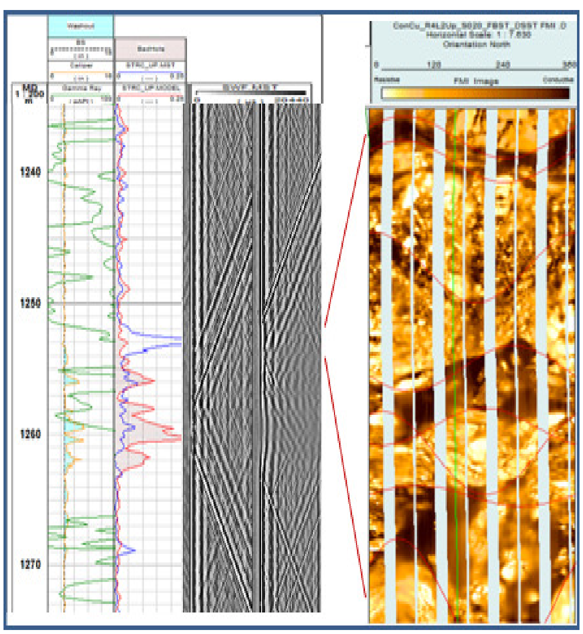

Figure 5: FMI log showing conductive open fractures, interval 1252-1254 m are corroborated by stoneley reflection coefficient and chevron pattern (Pundi#F)

Fracture Analysis

The Rosette-strike & dip magnitude plot for identified conductive fractures shows dominant conductive fractures orientation in NW-SE and NE-SW direction for Pundi # F and Pundi # E respectively (Figure-6 & 7).However for well Mattur # A, no dominant fracture orientation is observed.

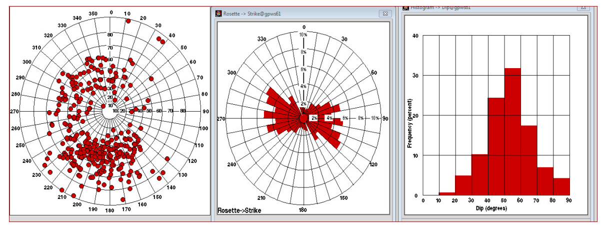

Figure 6: Pundi# F Conductive Fractures Orientation

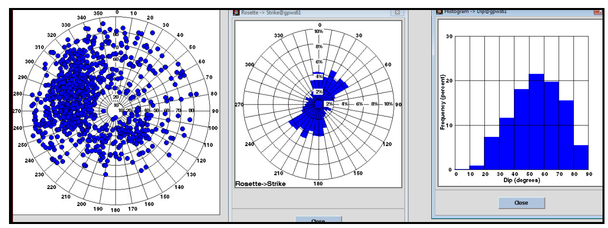

Figure 7: Pundi# E Conductive Fractures Orientation

Former studies carried out on wells Pundi #B, Pundi # C and Pundi # D also inferred dominant fracture orientation to be inNW-SE direction which is in line with fracture orientation observed in present studied well Pundi # F.

Observations on Pundi field

Wells Pundi #B, D, Fand C falling in the same fault block, are characterized by conductive fractures dominantly striking due NW –SE direction. All these wells are oil & gas bearing except structurally deeper well Pundi #C. The strike of the fractures is conforming to the prominent fault situated at northern side of this block (Figure-2).

Well Pundi #E is falling in a separate fault block and is characterized by conductive fractures dominantly striking due NNE-SSW direction. The strike of the fractures is conforming to the fault situated at western side of this block (Figure-2).

Fracture porosity, aperture, density and fracture length were computed on borehole image logs. The maximum Fracture Porosity is found to be 0.36%.Assuming fractures to be open, increase in fracture aperture leads to corresponding increase in fracture porosity (Figure-4, last track).

Stress Analysis

In wells Pundi #E and Mattur # A, Drilling Induced Tensile Fractures have been observed on FMI images and some of them are presented in Fig. 8. Based on these features, the deduced maximum horizontal stress direction (SHmax) is inferred as NW to NNW. This inference is also corroborated by bore hole break out observed in nearby well.

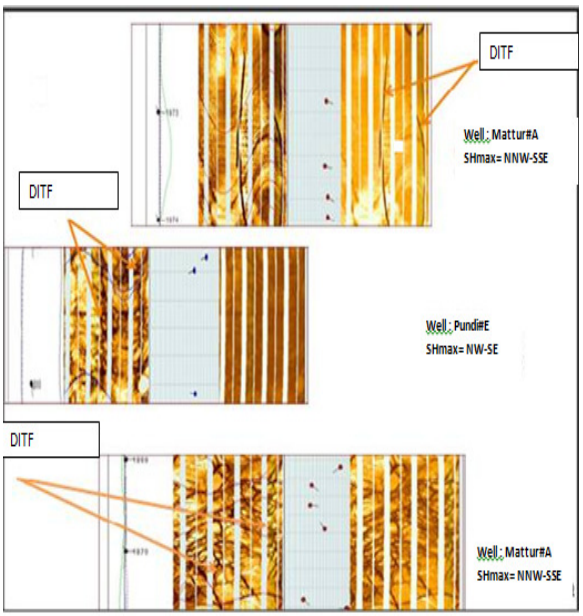

Figure 8: Determination of SHmax using Drilling Induced Tensile Fractures

The present study infers maximum horizontal stress (SHmax) direction falling on the same trend as dominant fracture orientation, for the oil bearing fault block of Pundi Field.

Conclusions

For oil bearing fault block of Pundi Field comprising of wells Pundi #B, D, F and C, the following major points emerges:

1. The conductive fractures are dominantly striking due NW –SE directions and the strike of the fractures is conforming to the prominent fault situated at northern side of this block. The flow potential of these conductive fractures has also been validated with stoneley reflection coefficient.

2. Drilling an inclined well close to NE direction may lead to better hydrocarbon productivity because more number of open fractures is expected to intersect the borehole.

3. The above fact is very well corroborated by drilling of well Pundi #F which has borehole trajectory in NE (N 42 deg) direction and is the best hydrocarbon producer so far (flowed oil@ 36 m3/d & water 2 m3/d) whereas both vertically drilled wells, Pundi #B & D have flowed oil @ 3.3 m3/d along with minor gas and water only from the Basement.

4. The maximum horizontal stress (SHmax) direction is inferred to be NW to NNW which is closely matching with dominant fracture orientation.

5. Acquired knowledge of present day stress direction, fracture density, fracture aperture and fracture porosity can be further used in seismic characterization and will be of immense help in planning for optimal hydrocarbon exploitation from the fractured Basement of this field.

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