Re-using old Formation MicroScanner logs to help understand reservoir and fracture development at the Dover East Field, SW Ontario, Canada

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Summary

Schlumberger ran three FMS (Formation MicroScanner) logs in 1988 over the Black River oil bearing reservoir section in the Dover East 7-5-VE field. Microresistivity variations recorded by the FMS tool were converted into digital color images using standard processing parameters. At the instruction of Liberty Oil & Gas the main objective was to provide a continuous log of interpreted dip results and near-wellbore images and to answer the following:

- Do we see systematic trend(s) to the fracture orientation?
- Can we determine fracture distribution and orientation (single and multi-wells)?
- Is there a relationship between fractures orientation/density and production?

Several dip categories were identified on the images: bed boundaries, natural fractures (open, partially open and healed) and drilling induced fracture and faults.

A cumulative rose diagram of bed boundaries reveals bimodal distribution of dip azimuths. The subhorizontal bed boundaries dip toward “NNE” and “S” either indicating a gentle undulating surface or faulted block surfaces. The bedding data confirms the location of Dover on the crest of the Algonquin Arch.

The analysis of fractures in three Dover East wells shows that the Black River oil bearing reservoir is heavily fractured. A total population of 92 structures (open/healed fractures and fault) was identified showing two dominant populations indicating a complex tectonic history of the area. The most dominant set is “E-W”, with two minor subsets, and the secondary maximum is along a “N-S” trend. Both of these trends fall into Sanford’s conceptual fracture framework of SW Ontario.

The FMS study shows a direct correlation between fracture orientation and well productivity and helps predict which fractures are likely to be open (enhancing reservoir and production) or closed (creating a barrier to flow).

This fracture/fault and reservoir information in the Black River hydrothermal dolomite reservoir at Dover will also be directly applicable to the overlying Trenton reservoir. As such, it will be very valuable for the recently approved Jacob Gas storage pool development by Union Gas. This study is of distinct operational value and could be applied to other Ordovician pools in SW Ontario.

Introduction

Although it has been widely acknowledged that understanding fractures are of critical importance for oil and gas production, no particular regional fracture study has been done on fracture orientation and distribution in SW Ontario apart from conceptual model of Sanford (Sanford et al. 1985).
The goal of this study is to evaluate fracture population in the Dover East area and to distinguish if there is a direct correlation between reservoir production and the fracture distribution.
Stratigraphically the analysed Dover East wells cover middle Ordovician carbonates of Black River and Trenton groups. These sediments regionally dip to the SW and unconformably overly Cambrian sediments and Precambrian basement. Two major basement features control the structural framework of the Ordovician sediments in SW Ontario – the NE plunging Findlay Arch and the SW plunging Alqonquin Arch.

There is a general consensus that the majority of fractures in the Paleozoic cover rocks are strongly controlled by the basement influence, but their mechanism of formation is unclear. The spatial association of aeromagnetic lineaments and field data were interpreted as basement reactivation and upward propagation of faults and fractures (e.g. Sanford et al. 1985, Boyce et al. 2002). However, based on the field evidence Andjelkovic & Cruden (1999, 2000) propose passive inheritance over basement highs as the prevailing mechanism for “NE-SW” fracture set origin.

Wolfsberg et al. (1988) originally extracted structural and stratigraphical information from the three FMS wells analysed in this paper. However, no statistical analysis and correlation between fractures and production were offered.

Based on the geological, geophysical and production data Colquhoun & Johnston (2004) concluded that Ordovician structures define compartmentalised reservoirs. The major features include “E-W” striking terraced fault blocks, a cross-structure fault and inactive fault splays along the margins of the pull-apart zone. The Dover East field is, therefore, characterized as a negative flower expression created by sinistral shearing.

Similarly, Davies and Smith, (2006) are interpreting most sags to record transtensional negative flower structures on wrench faults and are the preferred drilling targets for Ordovician “sags’ in SW Ontario. They emphasise that productive flow rates commonly are dependent upon open fractures that are postdolomite (younger tectonic) in origin.

Methodology

The FMS Formation MicroScanner provides microresistivity formation images in water-base muds and generates an electrical image of the borehole from 64 microresistivity measurements. Special focusing circuitry ensures that the measuring currents are forced into the formation, where they are modulated in amplitude with the formation conductivities to produce both low-frequency signals with petrophysical and lithological information and a high-resolution component that provides the microresistivity data used for imaging and dip interpretation. The depth of investigation is about 10 cm (3 inches), similar to that of shallow lateral resistivity devices. The three wells interpreted are run as FMS-2 (2 pads as FMI and two as dip meter) and with two runs thus effectively making a four pad FMS.

Several dip categories were identified on the images: bed boundaries, natural fractures (open, partially open and healed) and drilling induced fracture and faults. Examples of the fractures identified are given on Figures 1-3.

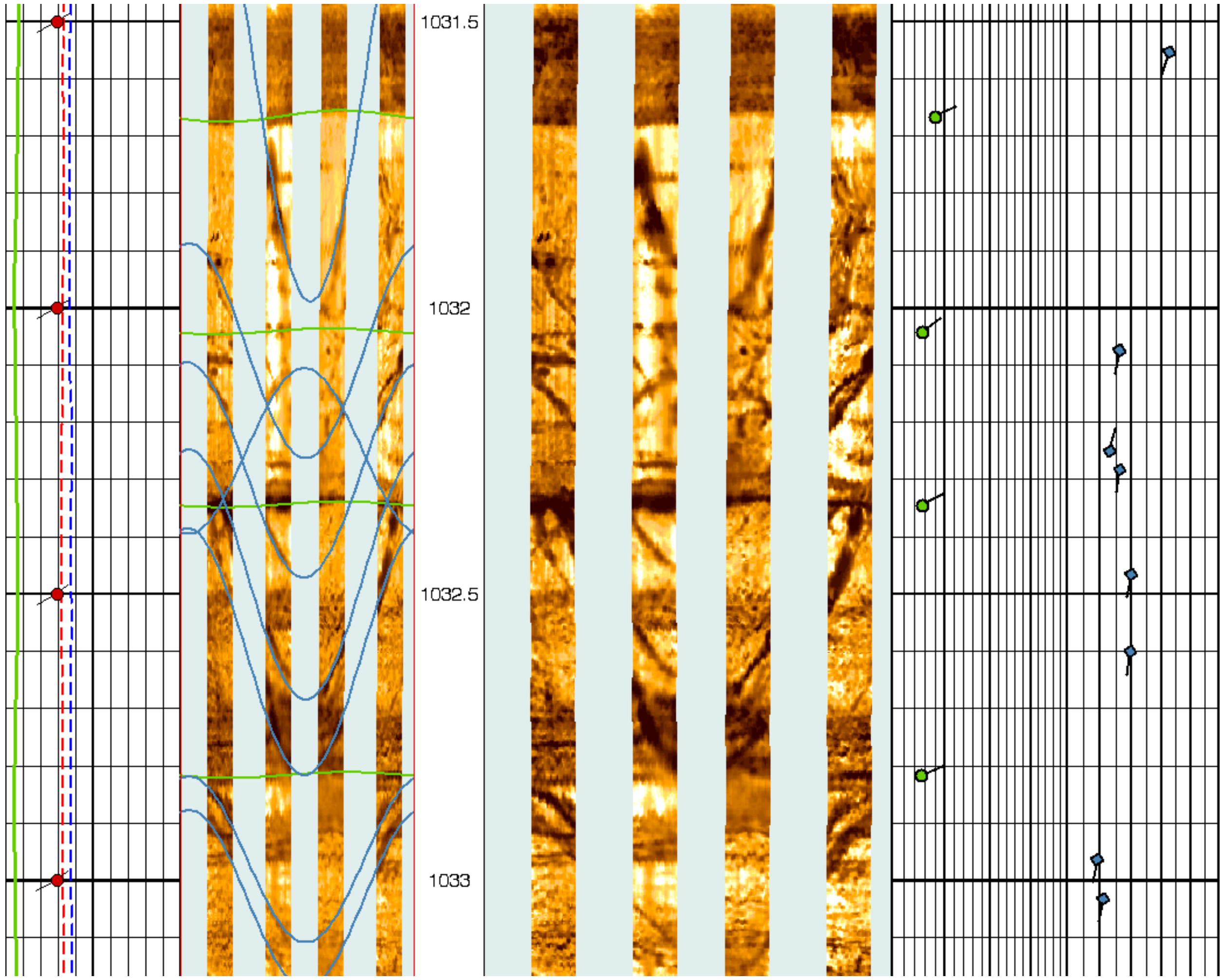

Figure 1. A swarm of ~ “E-W” striking partially open fractures that is most commonly observed on the image. Partially open fracture is seen as a conductive dark band that has more than 50% of sinusoidal trace and is frequently bed bounded. The example was taken from PPC-RAM “15” in the Gull River Formation. Bed boundaries are uniformly dipping towards “NE”.

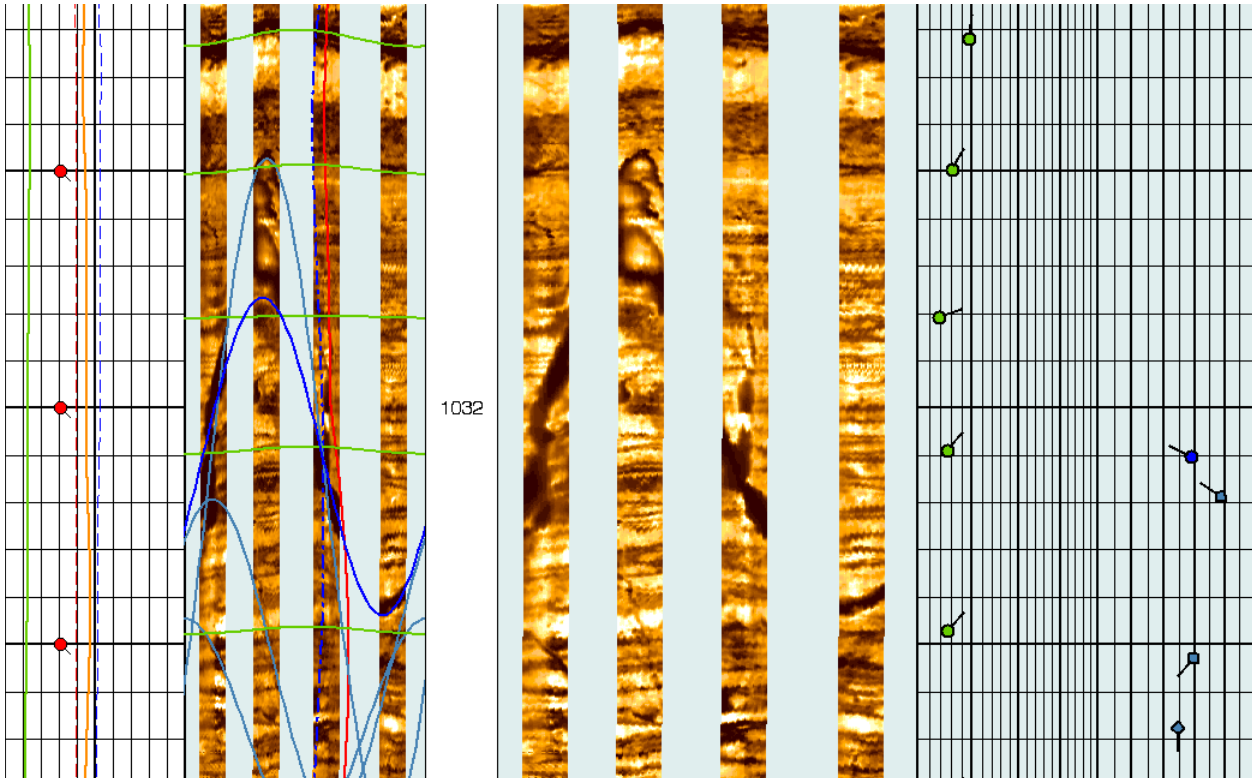

Figure 2. An open fracture is a conductive fracture that is visible on the image as a dark band on at least 80% of the sinusoidal trace. The dark blue sinusoids is an example of a “NE-SW” striking open fracture in the Gull River Formation of the PPC ”13” well.

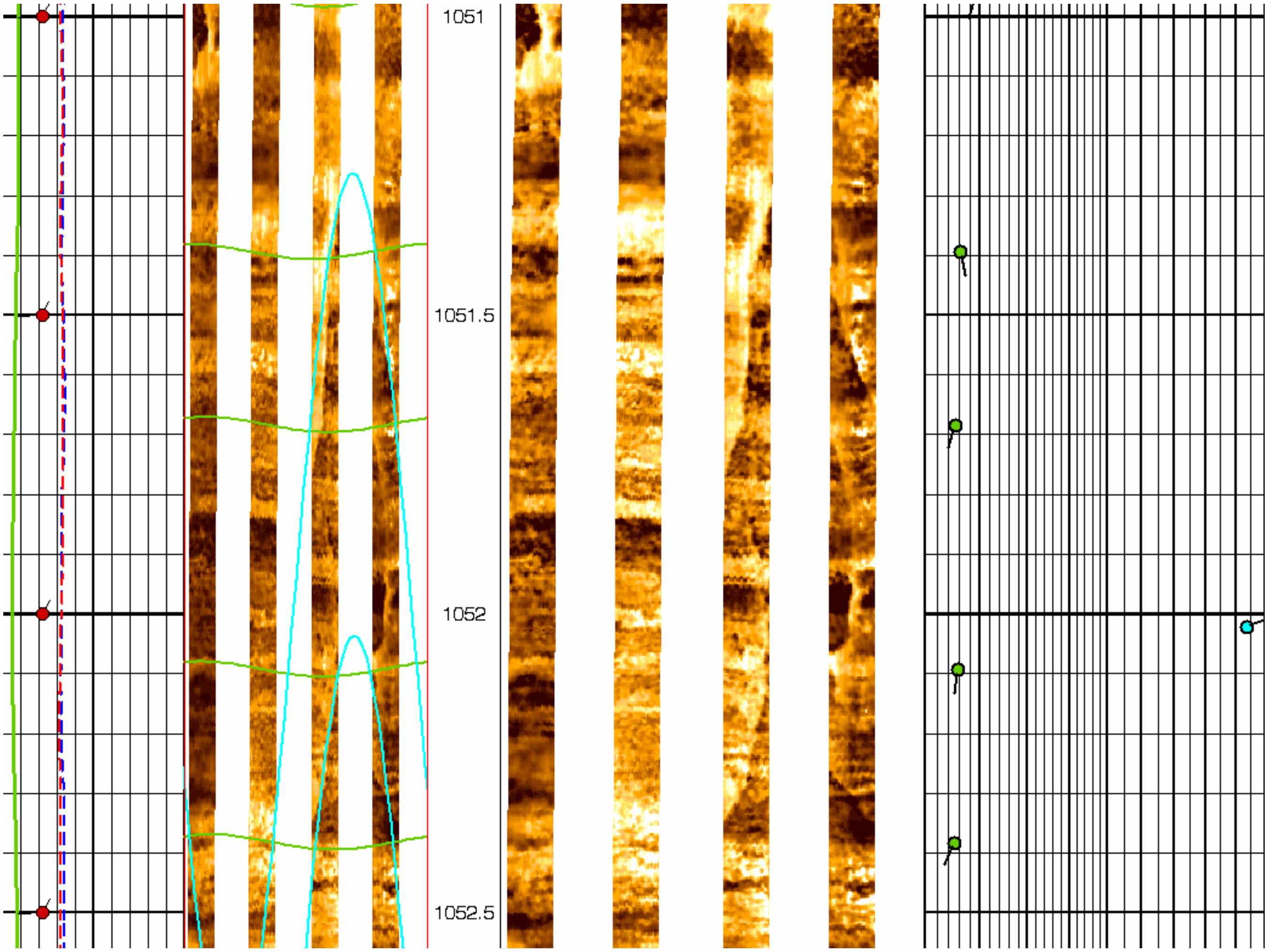

Figure 3. Two examples of “NNW-SSE” subvertical resistive fractures. A resistive fracture is a healed (cemented – most commonly calcite filled) fracture and show as white band trace on at least on 50% of sinusoidal trace. This example is taken from PPC “15” in the Gull River Formation.

Data analysis

The aim of the study is to identify possible regional or local sets of fractures from FMS data and to correlate their distribution to well production. Fractures from all three wells were grouped to produce cumulative fan plot diagrams in order to identify fracture sets in the area (Fig. 4).

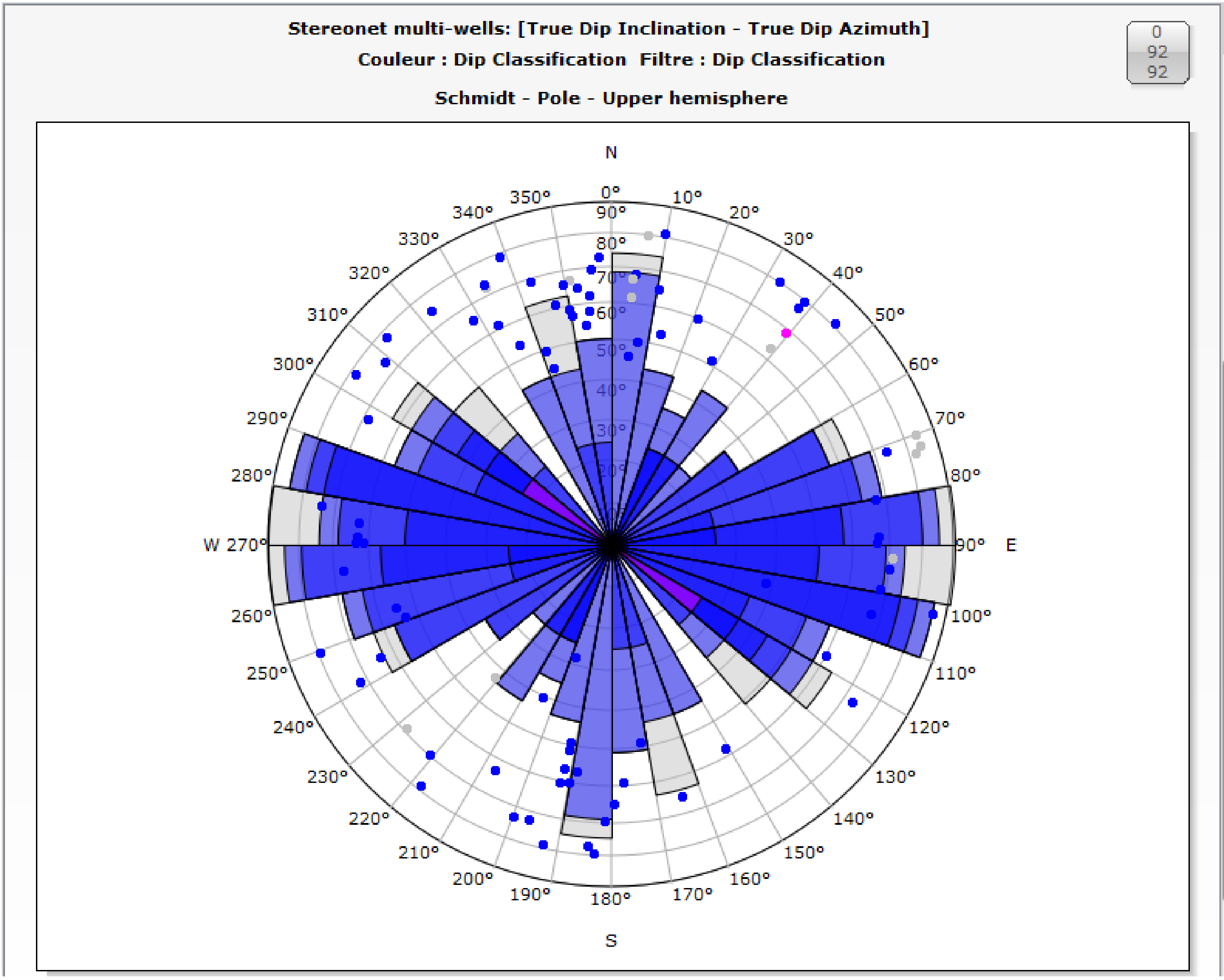

Figure 4. Cumulative fan plot of fractures in Dover East wells showing two distinctive sets. The most dominant set is "E-W" striking set and the secondary maximum is striking "N-S".

The Dover East wells analysis show that the Black River oil bearing reservoir is heavily fractured, despite considering the fact that the tool geometry was not designed to intersect vertical fractures.

A total population of 92 structures (open/healed fractures and fault) was identified showing two dominant populations (Fig. 4). The most dominant set is and "E-W" set with two minor subsets showing maximum at $85^{o}/265^{o}$ and $115^{o}/295^{o}$. Secondary maximum is rather anomalous "N-S", and is only observed in the PPC "13" well.

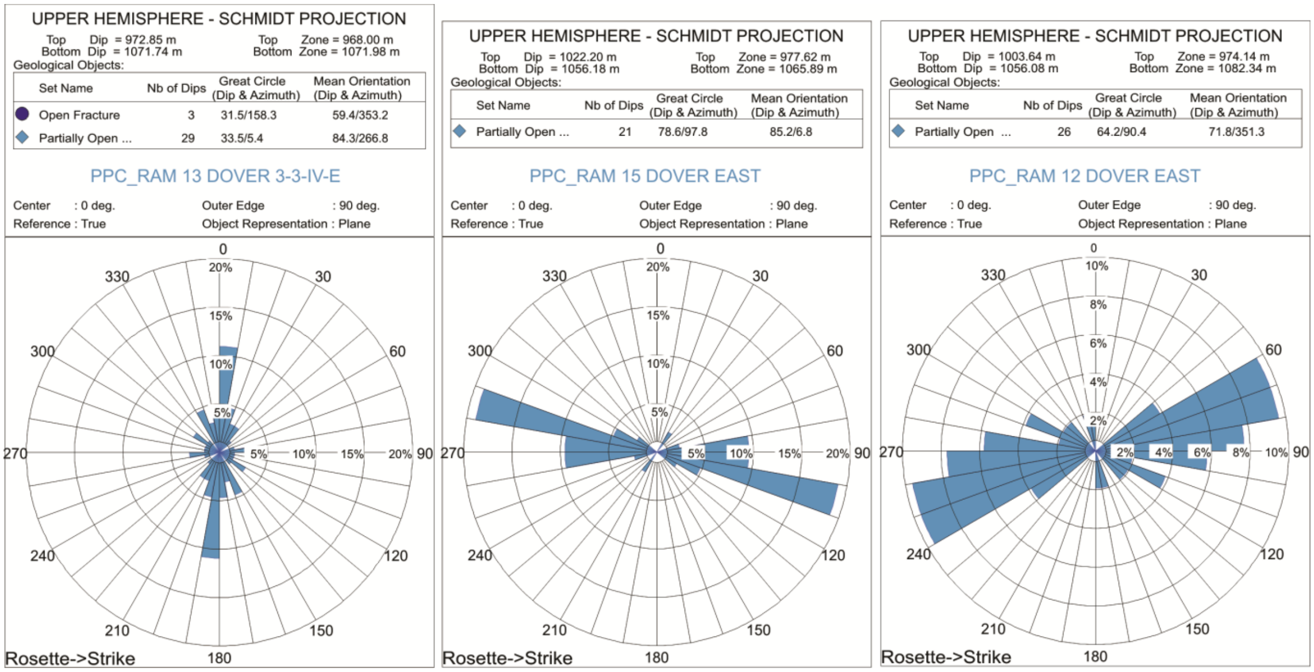

Figure 5. A summary of fracture identification on Schmidt fan plots identifying fracture sets for each Dover East well.

The orientation of fractures in the most western well PPC “13” differs from the other two. However, once multi-well fracture orientations was dispayed and correlated to stratigraphy of the area (stratigraphical fracture zonation) on Fig. 6, it can be seen that a strong population of “NNE-SSW” striking fractures exist below a possible fault. Above the identified fault, strike of fractures are in agreement with the “ENE-WSW” and “ESE-WNW” trend as displayed at wells PPC “15” and PPC “12”.

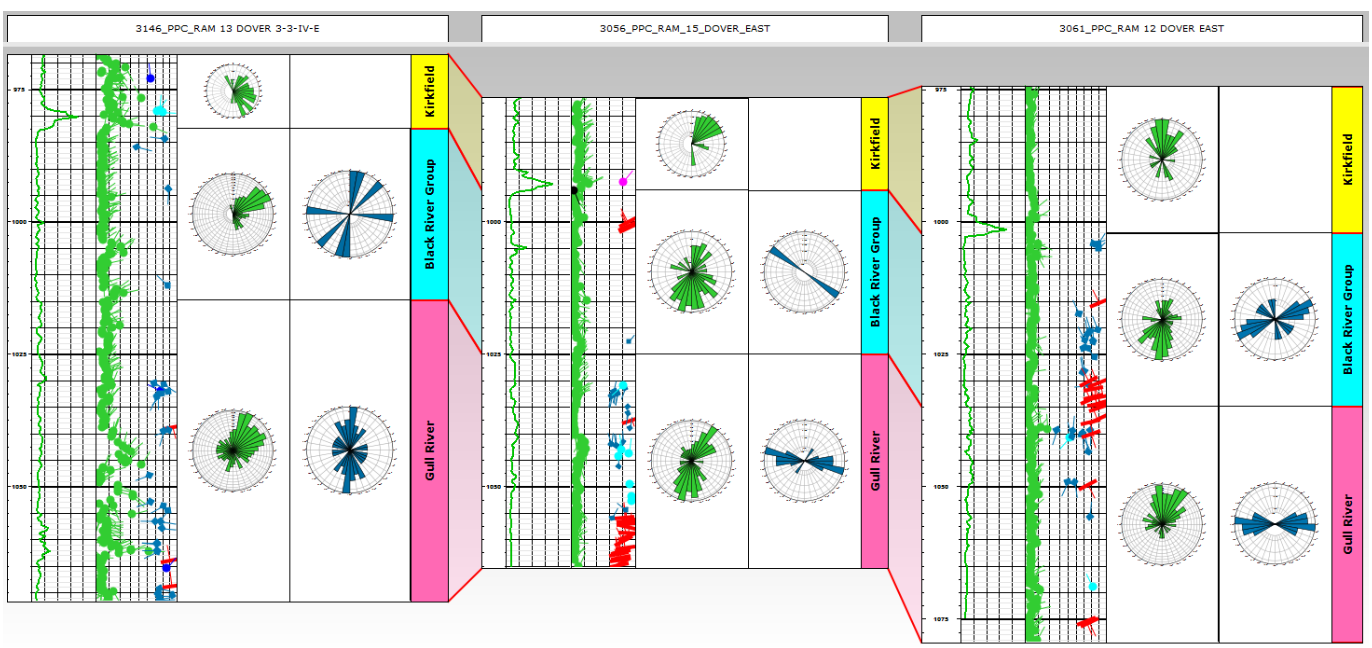

Figure 6. Fracture zonation based on the stratigraphy of the area. Majority of fractures are distributed in Gull River Formation. Wells PPC “12” and PPC “15” have identical orientation with ~ “E-W” striking fractures within Gull River. Well PPC “13” has possible faulting with different fracture sets above and below the structure -a “N-S” trending fractures below and “NE-SW” and “NW-SE” trending fractures above the fault.

Fracture Orientation and well production

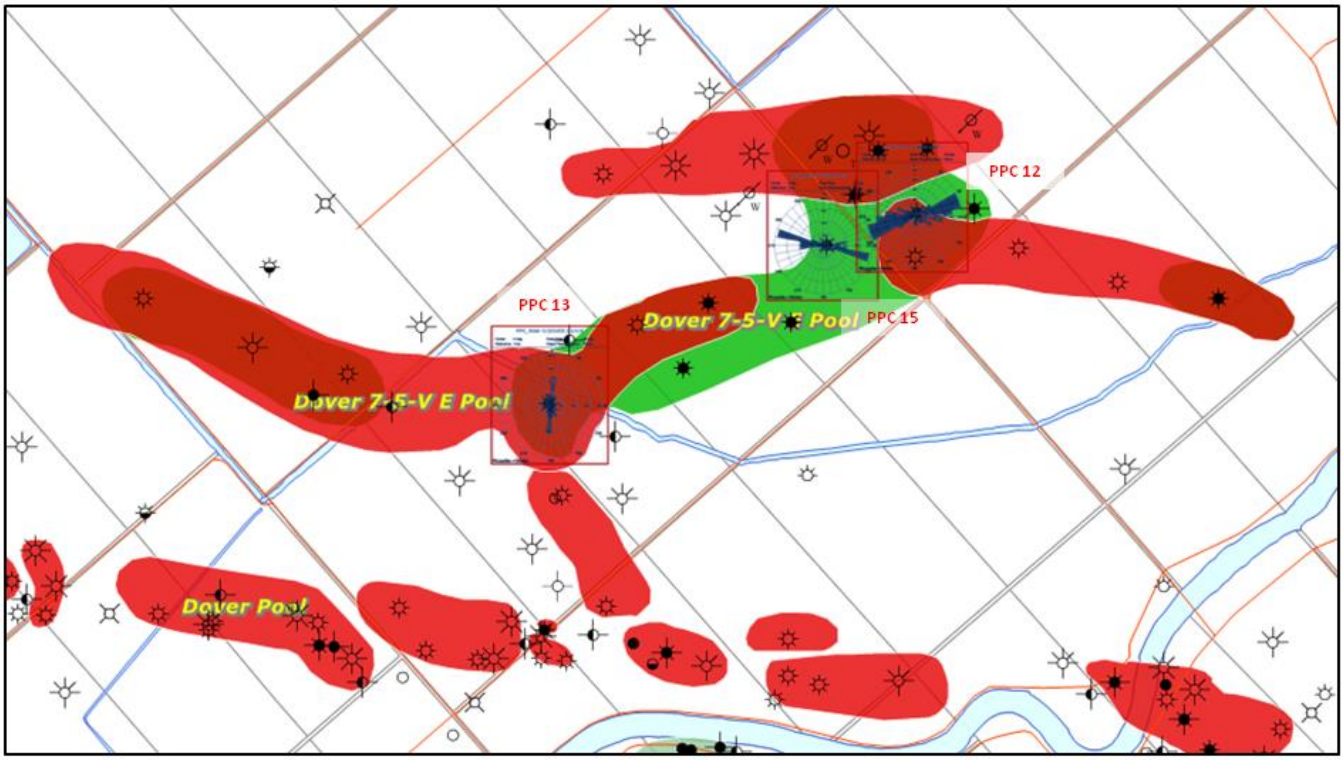

Figure 7. Spatial Orientation of Fractures (fan plots in blue) identified on FMS Images, placed upon the Dover East pool map. The Trenton gas pools are in red and the Black River oil pools are in green. (Modified after Welychka, 2005).

The Dover East field was discovered in 1983 and since then has produced about 1.3 million bbls of oil and 9.7 bcf of gas. Figure 7 shows a map of the Dover East pool with dry gas production (shown in red) from the Ordovician Trenton (Sherman Falls and Kirkfield Formations) and oil with solution gas (in green) from the Black River (Coboconk and Gull River Formations).
The PPCR "12" and "15" wells are both prolific Black River producers with recoverable reserves to date of 143,000 and 287,000 bbls respectively. Both wells have very low water production and have an "E-W" fracture orientation.
The PPC "13" wells has only produced about 46,000 bbls of oil from the Gull River and has high water cuts which is unusual for producing wells in the pool. The low recoverable reserves and high water production is assumed to be associated with the uniquely anomalous N-S fracture orientations and possible faulting associated with it.

Conclusions

Schlumberger was able to retrieve old FMS data (1988) and convert these into digital color interpretations with a high quality and very usable dip and fracture analysis study of the Dover pool helping better interpretation the seismic data (both 2D and 3D).
There is a bimodal set of fractures with a dominant "E-W" set and a secondary "N-S" trend. The numerous fractures indicate a complex tectonic history. This FMS study shows a direct correlation between fracture orientation and well productivity and helps predict which fractures are likely to be open

(enhancing reservoir and production) or closed (creating a barrier to the flow). The relationship between fracture orientation and productivity (and ultimately reserves) will help to improve field optimization (e.g. locating bypassed zones, why are some wells under-performing, shutting off water, prediction of the water flood response, better understanding of the reservoir communication, and developing new drill locations). This type of study will also be applicable to the overlying Trenton gas reservoir and useful for development of the recently approved Jacob Gas storage pool by Union Gas Limited.
A review of FMS MicroScanner images at Dover East reveals a distinct operational value and could be applied to other Ordovician pools in SW Ontario.

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