



Fault Driven Production from an Unconventional Reservoir- Case study and evaluation by Integration of Hi-tech Log data and Reservoir Pressure profile.

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Keywords

FMI, CMR, Conventional logs, Pressure, Fault

Summary

Integration with hi-tech logs and the reservoir pressure profile for effective evaluation of fault driven production from the unconventional reservoir where conventional log data evaluation appeared to be ambiguous and challenging.

Introduction

The pay sands in Cauvery Basin are known to have distinct characteristics like log features, salinity, pressure etc. These characteristics may vary from field to field and well to well even within the field. Cases exist wherein early cretaceous Andimadam formation sand has salinity ranging from 18 gpl to 128 gpl. And poor reservoir facie in conventional log sands proved to be having good hydrocarbon potential on testing. Interpretation through conventional logs in such reservoirs becomes challenging. Hi-tech logs like CMR, FMI & DSI provide value addition in evaluating the unconventional reservoirs. The reservoir pressure profile are in agreement with the log driven results.

Structure

Exploration activity started in Kovilkalappal structure in the year 1984 after drilling holiday in Cauvery Basin. Hydrocarbon strike in Kamalapuram formation changed the hydrocarbon prospect of entire Cauvery basin. The prospect of the area further enhanced by the discovery of gas and oil in the cretaceous age formation.

An exploratory well was drilled to explore the hydrocarbon prospects in the independent four way closure between Kovilkalappal and Adichapuram field. The discovery of oil in the well made to remap the field as North Kovilkalappal. The prospect of this field was enhanced by the discovery of oil and gas in Andimadam sand in the early cretaceous age. Three wells were drilled in this field A, B & C out of which; Well B was dry and other two were completed as oil producers. Two development wells were released to exploit oil sand in this field. Well-D was one of the development locations and was drilled as inclined well. It was completed in Andimadam sand as an oil producer.

Log analysis

The study Well-E was the second development well, drilled vertically with an objective to exploit oil in the objective sand and terminated within Andimadam Formation Hydrocarbon shows in the form of GYF/PYF and Faint cut was observed during drilling.

Conventional logs i.e, HDIL-DAL-ZDEN-CN-GR-SP-CAL were acquired and analysed. The objective sand appeared to be deteriorated when compared to other wells in this field. Log motif is shown in Figure-1.

The other two wells in the four way closure were completed in the same sand & producing oil @ 30-50 m³/d. A comparison of log characteristics of the three wells is given in Figure-2. The objective sand in Well-E is entirely different when compared to other wells and which made to reconsider the decision for lowering the casing for conventional testing.

The Andimadam sand developed in the interval XX03-XX10 m with a calcitic streak in between is having low resistivity around 1.2 Ω .m and porosity about 17-18%. An object tested with similar characteristics flowed formation water in Well-D, which was completed just prior to the present study well. But as hydrocarbon shows were observed during drilling in this well, the interpretation of this sand was ambiguous and challenging. It was recommended to record FMI and CMR logs for further evaluation of the objective sand. Based on FMI and CMR logs, the SWC depth points were decided.

FMI log was processed for Static and Dynamic images and analyzed. A change in resistivity contrast is observed from XX03.5 m indicating sandy features. Calcitic streak is developed in the interval XX05.3- XX06.8 m. A thin conductive shale layer is observed at depth XX07 m. The interval XX07.2-XX08.5 m is sandy in nature with a conductive patch on two pads which might be the reason for averaged out low resistivity measured on conventional log. In FMI log shows reversal in azimuth of the dipping beds in intervals (Figure-3), indicating that the well is in faulted region.

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In addition to FMI log, CMR log aided the interpretation by indicating free fluid porosity in the interval XX04-XX10 m and late T₂ arrivals. The calculated permeability from CMR log is in the range of 100-1000 mD.

Log motif of FMI and CMR log are given in Figure-4 & 5.

Based on FMI and CMR log analysis, SWCs were attempted in 24 depth points and 12 cores were recovered. The side wall core recovered at depth XX08 m showed GYF and strong +ve cut with gross lithology as sandstone. Prominent hydrocarbon show of the side wall core recovered in low resistivity sand, built confidence for lowering casing and testing the well.

On integration with all available data, the interval XX03-XX10 m was recommended and approved for conventional testing.

Testing Results and Analysis

During testing, well flowed oil @ 75 m³/d and gas @ 8000 m³/d through 6 mm bean. Multi bean reservoir studies were carried out and maximum flow rate of 105 m³/d and gas @ 28000 m³/d was attained through 8 mm bean.

The high potential flow rate turned out to be surprising with such a deteriorated sand features. It was believed that the hydrocarbon flow may not be from the sand alone, so the data was re-analysed to find out the factors aiding for the high flow rate in this well.

From FMI log, it is evident that two reversal azimuth trend of the beds in the intervals XX08-XX13 m and XX15-XX30 m which depicts intersecting faults in the near vicinity of the well (Figure-6 & 7). The structure contour maps of the field also indicate a major fault near to the well location. Analyzing the geological aspects of this area, the production of the well seems to be of fault driven hydrocarbon flow. Well locations are shown in Figure-8.

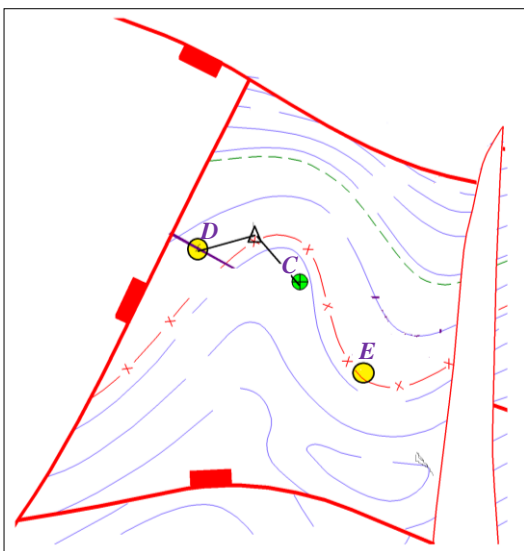


Figure-8

Though the Wells-D & E are structurally almost at the same level, on top of objective sand, the bottom hole pressure recorded in Well-E: 2930 psi is much higher than that of Well-D (SBHP-2571 psi) which indicates that the wells are flowing from different pressure compartments.

Pressure buildup plot

The down hole pressure build up during the initial well testing was analyzed. Boundary effect of Well-E shows that the well is located in between an intersecting faults located at a distance of 180 ft and 330 ft.

Pressure build up plot is given in Figure-9.

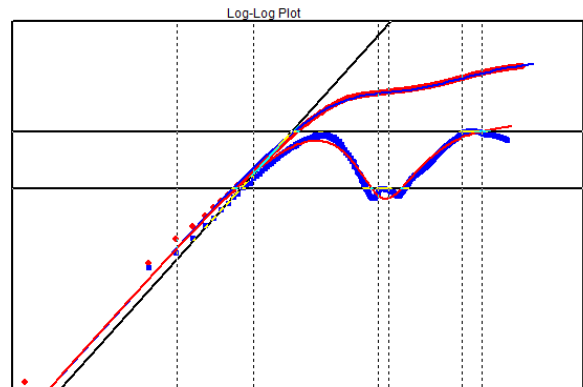


Figure-9

Conclusions

Though on conventional logs, the objective sand appeared to be of marginal interest, Hi-tech logs proved to be very effective in evaluating the unconventional reservoirs. FMI data providing vital information for further evaluation of the sand. On CMR log, the free fluid porosity with late T₂ arrivals indicated that the sand is interesting from hydrocarbon point of view. Based on CMR & FMI logs, the SWC recovered in the low resistivity sand confirmed the presence of hydrocarbon. The high potential flow of the well could be explained as fault driven hydrocarbon flow by FMI and pressure analysis. So Hi-tech log data analysis and an integrated approach is a success key for evaluation of unconventional reservoirs.

References

SPE/ISRM 47234.

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Figure 1: Conventional logs showing pay sand in Well-A

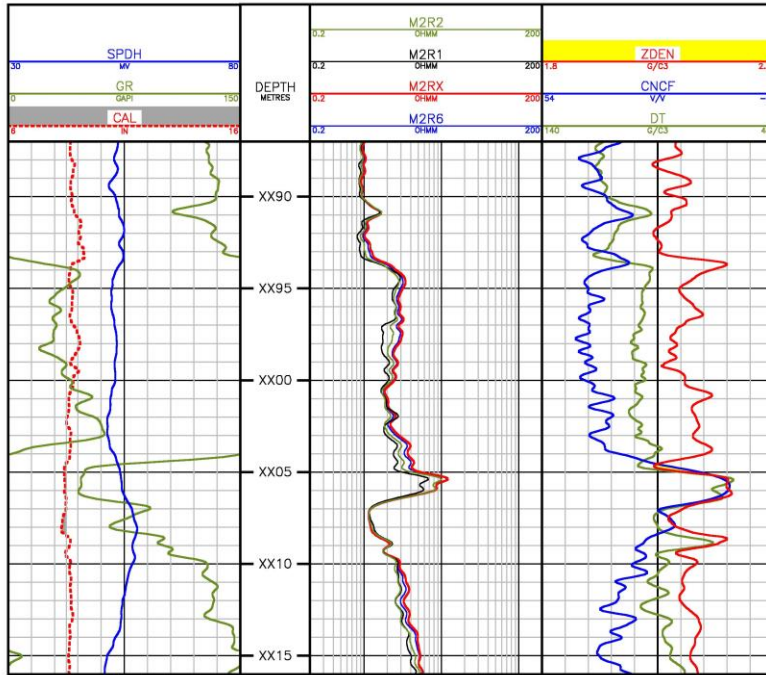
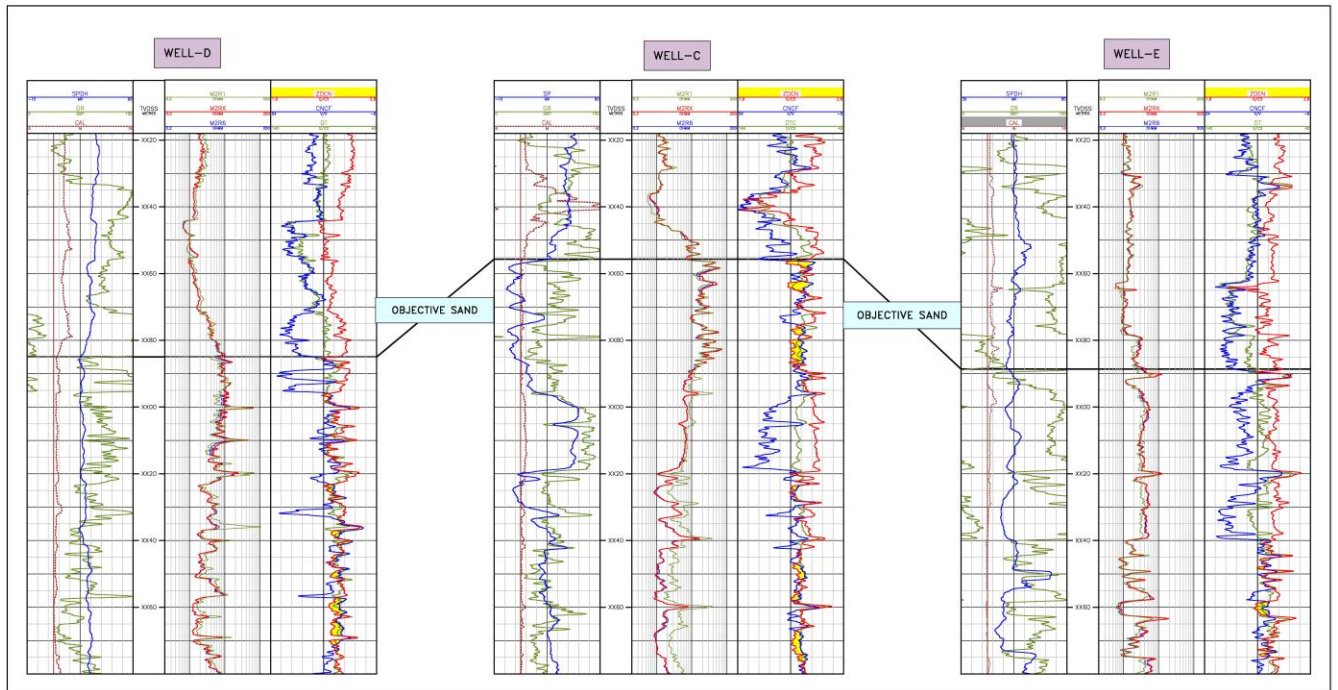


Figure 2: Well Log correlation of the wells in the four way closure



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Figure 3: Faults on FMI log

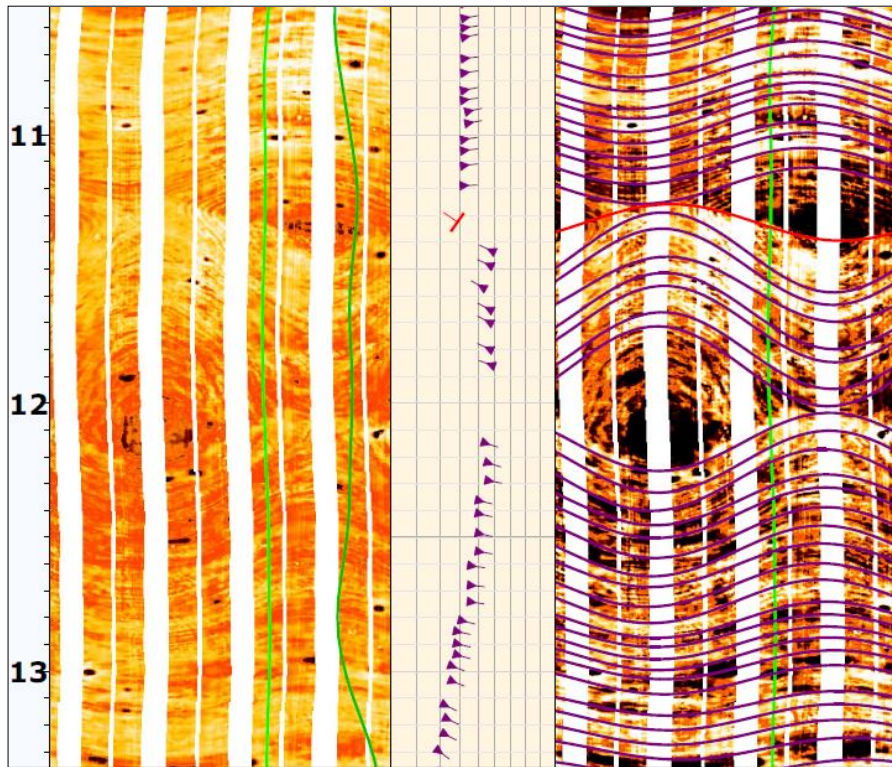
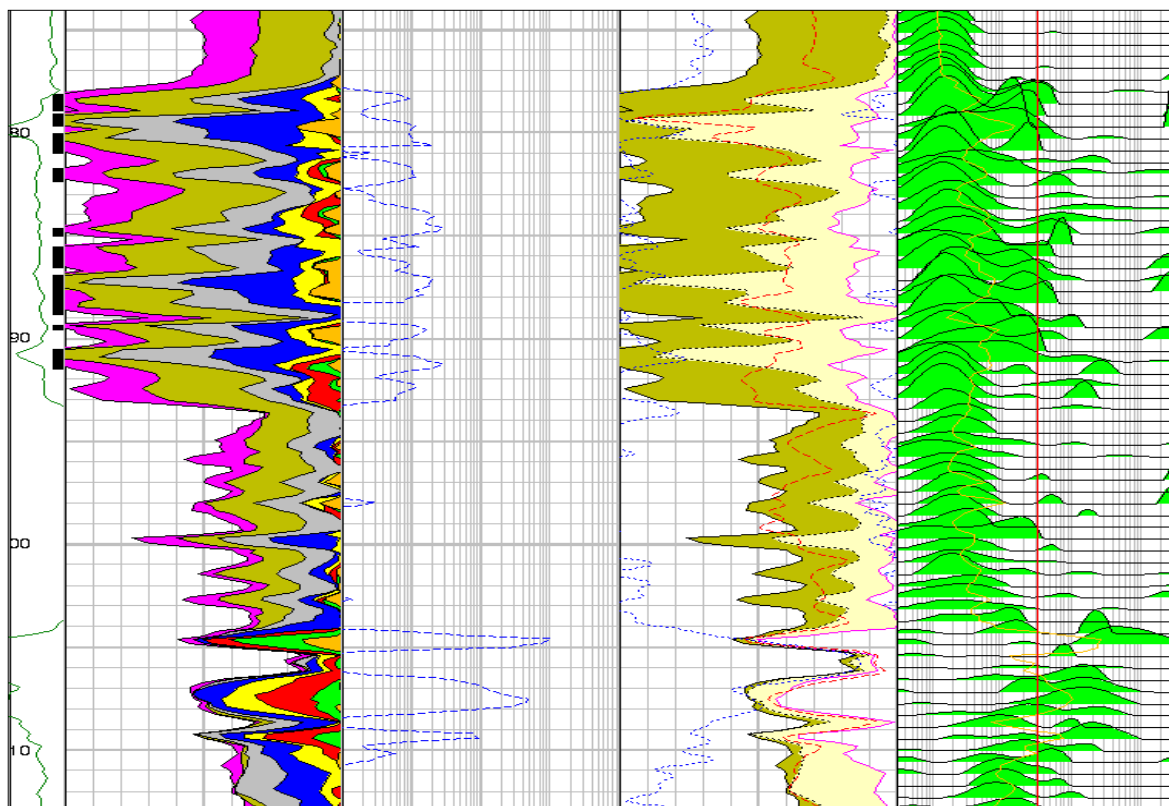
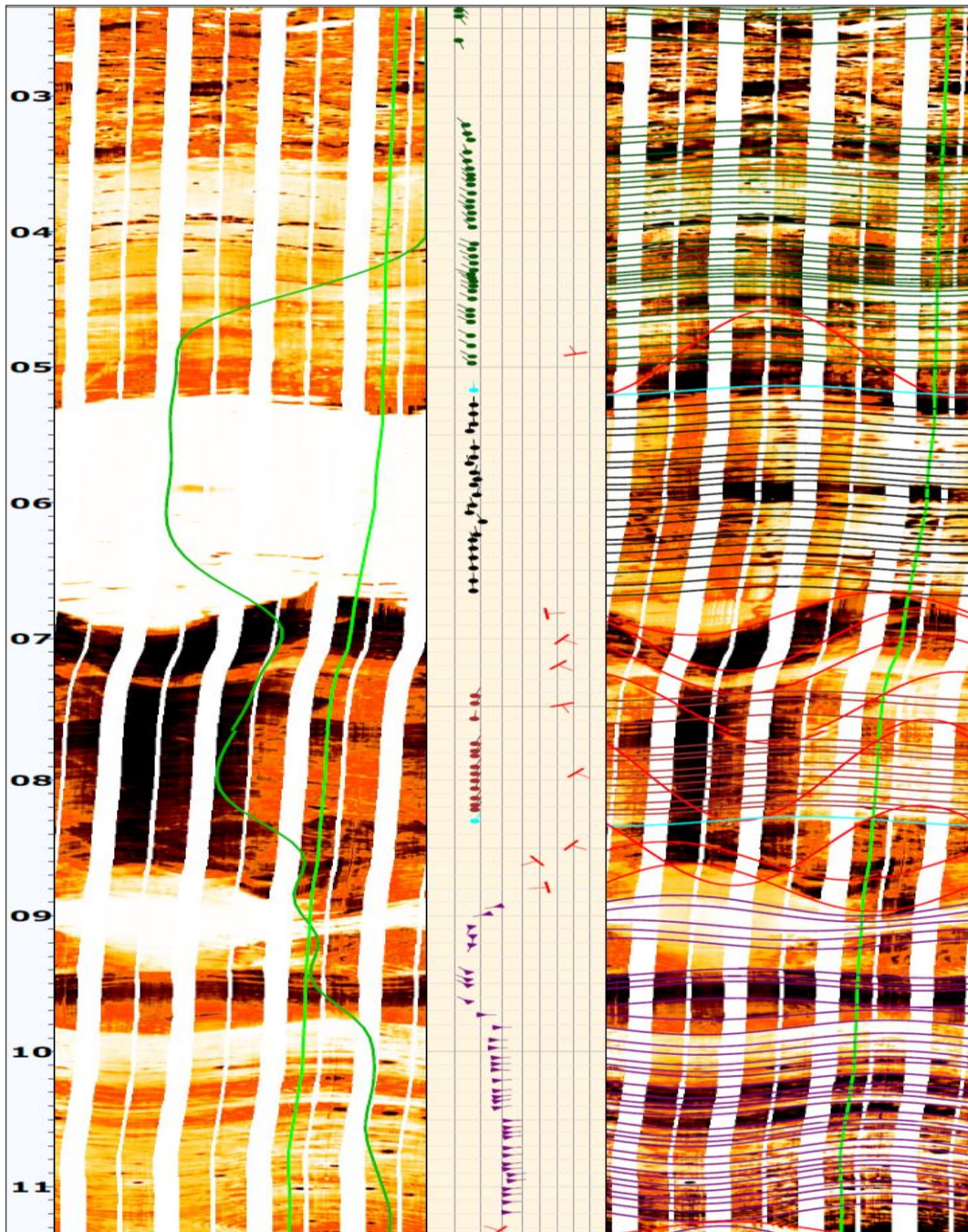


Figure 4: CMR log in pay sand



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Figure 5: FMI log in pay sand



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Figure 6: Processed log with FMI image showing a Fault

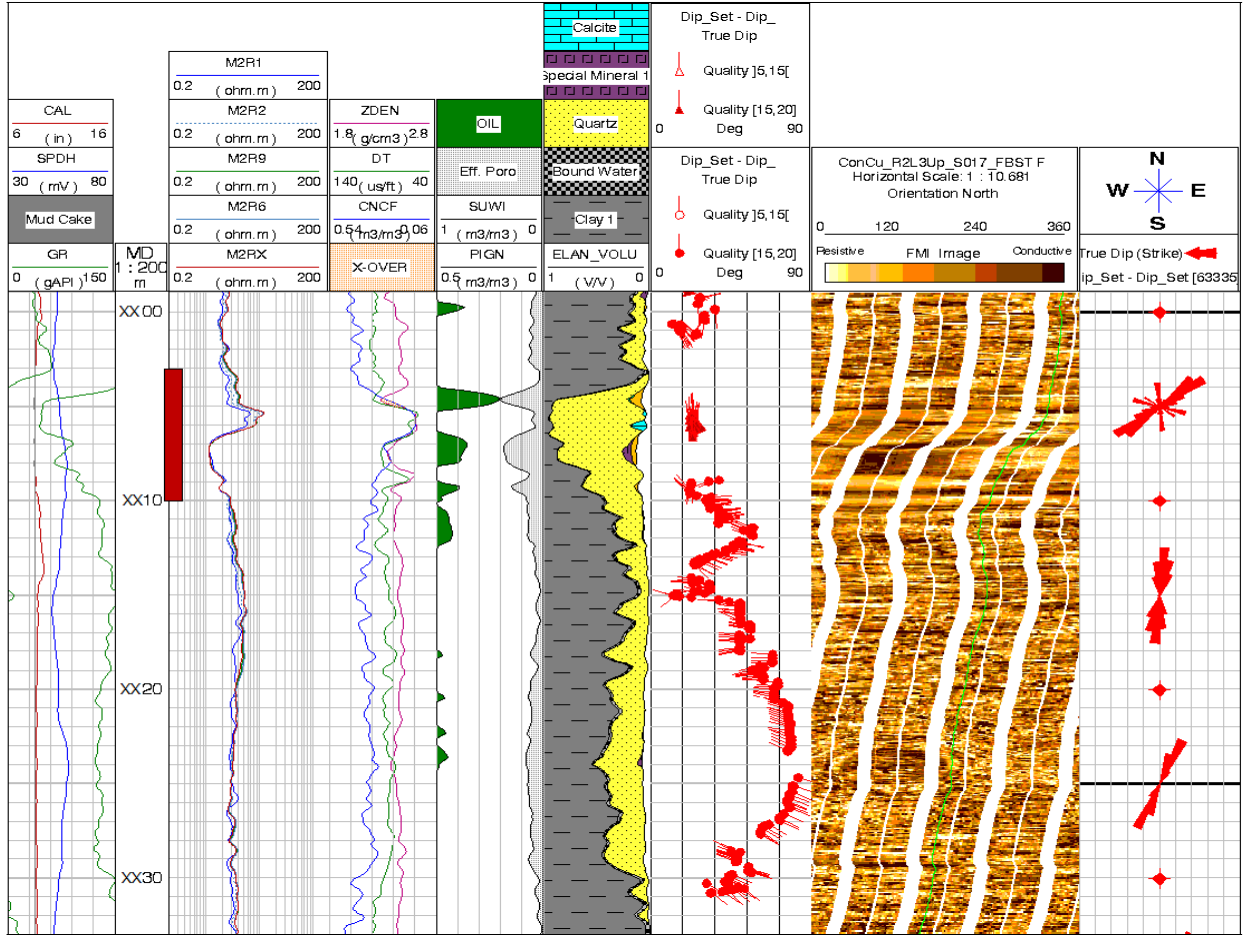


Figure 7: FMI image showing reversal in azimuth

