‘Integrating Core Data and Image Logs: The Critical Steps in Modelling a Fractured Carbonate Reservoir’

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ABSTRACT

In many of the oil fields in the Middle East the presence of fractures can be the characteristic that defines the flow of fluids within the system. Consequently the identification, description and classification of fractures in such fields are essential to effective formation evaluation and production planning.

This paper will present five case histories that describe the mapping of the fracture network using both core and borehole image data. We show how the data from the two methods can differ and how reconciliation can lead to a better understanding of the formation being studied.

INTRODUCTION

Corpro have cut and analysed approx 20,000 feet of core in the Gulf area that has been used specifically for fracture description and structural analyses. During the course of this work there have been instances where the data from the core appeared to differ significantly from that determined from borehole images.

In order to assess the reasons for these differences a systematic study was made that allowed the comparisons of data from both direct core measurements and borehole images captured using recent tools operating with different principles.

The basis for this study comprises data from five wells that had been selected from the original data base of 20,000 feet. The selection of studies was based on having quality core data. Typically, this meant core that had been cut using the Corpro Triple Tube corebarrel and the ‘Half-Moon’ inner barrel system. The significance of this system being that the rapid access to the core meant that all of the structural geology was undertaken at the wellsite without the potential disturbances to the core resulting from core transportation and core handling. All of the cores were analysed by Corias using the AS-3D computer-aided goniometry.

The borehole image logs (BHI) data covered recent tools, including sonic and resistivity, and combination tools that had been selected in order to capture the fracture features expected in the formations under study. All of the tools were used under optimum conditions.

CASE STUDY 1

The data overleaf (Figure 1) are the results obtained independently from BHI analysis and analysis of the core over the same interval. The most obvious difference between the data sets is that the core data is a much richer data set as the BHI could not be used to identify fracture type.

In addition, all of the fractures observed from the BHI are listed as open fractures and all are in the same orientation. One of the perennial difficulties of interpretation from BHI images is being able to differentiate between open and partially open fractures. In this instance, the BHI interpretation logged 174 instances of open fractures, while the core data showed 93 open fractures and 355 partially open fractures. The BHI images were unable to capture data from stylolites. The photograph in Figure 2 shows conjugated partially open fractures and thin tectonic stylolites that were not observed in the BHI images. One of the reasons impacting the BHI images in this well was the well orientation. Because of the tool configuration image tools are notoriously poor at collecting data that is not in line with the well orientation.

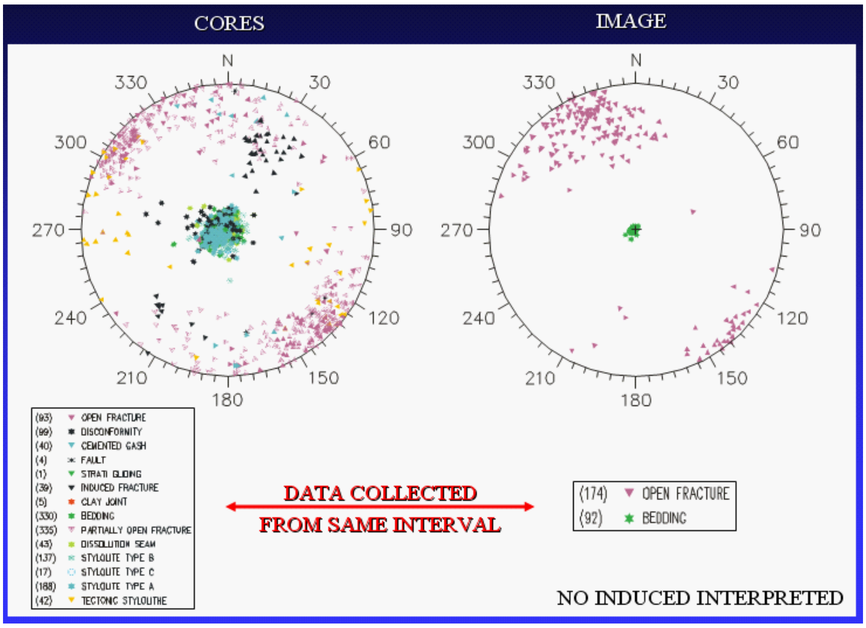

Figure 1 Stereonet - Case History #1

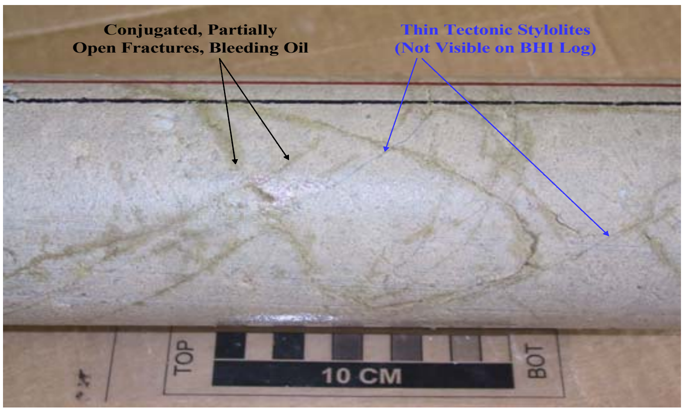

Figure 2 Conjugated Fractures, Bleeding Oil

CASE STUDY 2

The deficiencies of BHI log data in deviated holes are apparent in the data from this well. The Stereonet plots differ in that the data from the cores show two distinct families of fracture data (open & partially open) whilst the BHI data show only open and hairline fractures.

On the BHI log the features appear only on one side of the well. There appears to be some confusion related to the nature of partially open fractures, especially when cores showed partially open fractures that exhibited a series of open/closed nature along the same fracture plane. Those were interpreted on the BHI log as Hairline series of many small fractures (Figure 4).

The BHI data are all consistent with the orientation of the well (N210, 37º). In addition it appears as though the BHI data and core data differ regarding the interpretation of partially filled fractures and hairline fractures.

In this well the BHI data recognise some induced fractures but as above they are those that are in line with the plane of the well. The core data are characterised by a second family of induced fractures that are 180º opposed to the data seen in the BHI. We believe that the greater density of data provide more confidence in the selection of the direction of maximum stress.

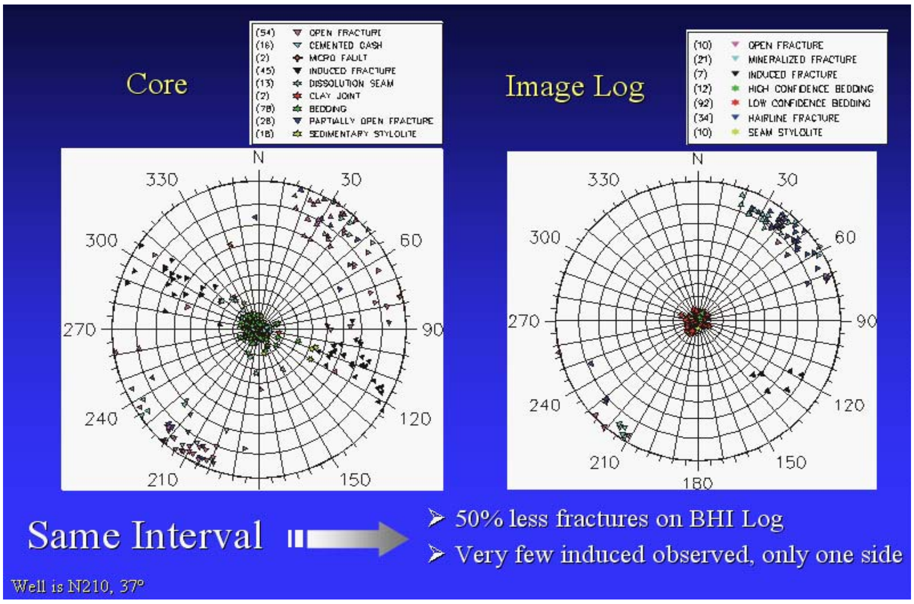

Figure 3 Stereonet Plot – Case #2

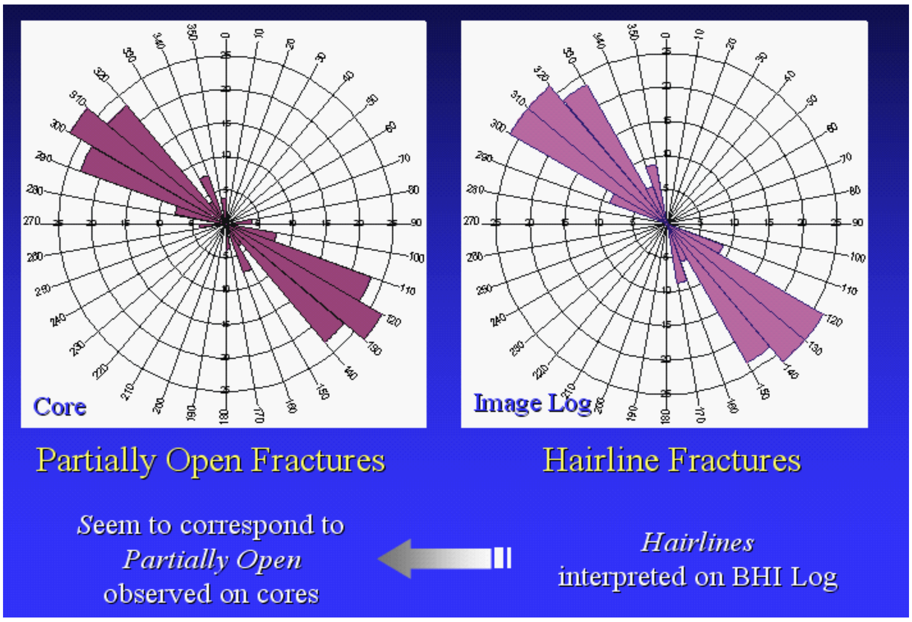

Figure 4 Partially Open Fractures Interpreted as Hairline Fractures on BHI log

Case Study 3

In case study 3 the BHI and core data also show some differences due to the clustering of data in the BHI image. In this instance we believe the inability to account for the nature of fracture filling materials is the root cause of this problem.

The data in Figure 5 show the full stereonet results and Figure 6 shows the fracture filling mineralization as obtained from the core data. On BHI image no distinction of the infilling material is possible. In general, infilling material is sometimes confused with host rock response due to low resistivity contrasts.

In several intervals on the BHI log there was also some confusion that caused misinterpretation of natural fracture features that appeared as oil-bleeding fractures on the studied cores (Figure 7), and which were reported as stress-related induced fractures.

Up to two third of those *'En Echelon'* natural fractures (Figure 8) were missing altogether on the BHI log in some intervals, leading to unrepresentative fracture density. The confusion was to some extent attributed to the *'En Echelon'* position of the short extended partially open fractures that could not be recognised as natural fractures on the BHI images.

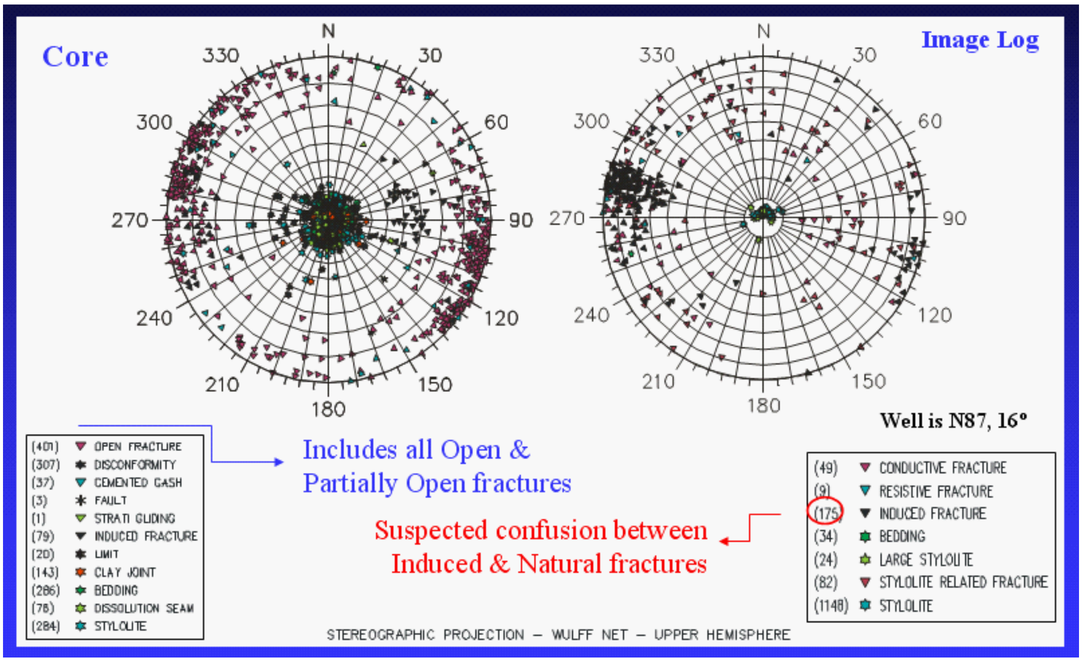

Figure 5 Core Stereonet Plot shows all open & partially open fractures. On BHI, 1148 Stylolites were not plotted to make the diagram clearer because those Stylolites features were confused with all other sedimentary and fracture features.

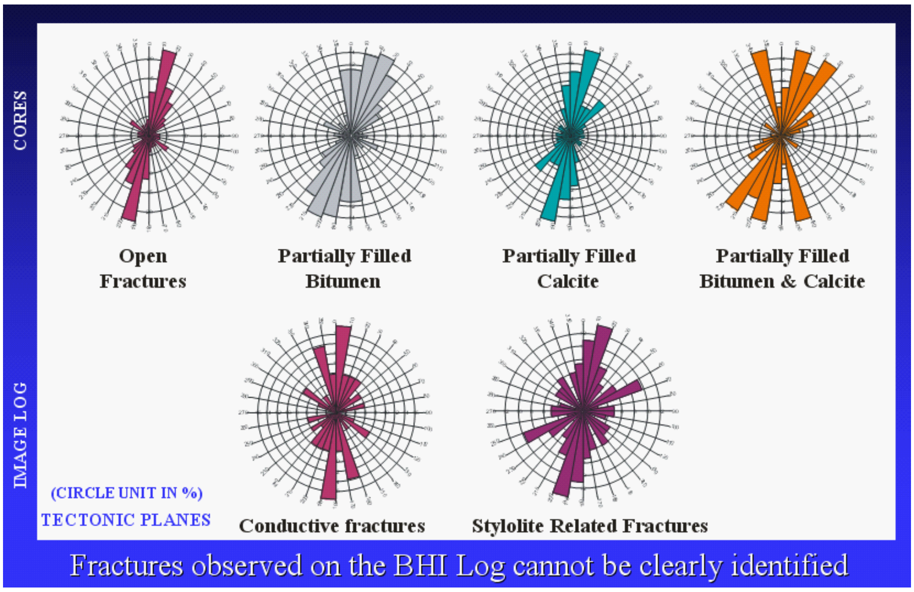

Figure 6 Core strike rose diagrams showing open fractures, partially open fractures and filling material. BHI strike rose diagrams showing only conductive and stylolite related fractures.

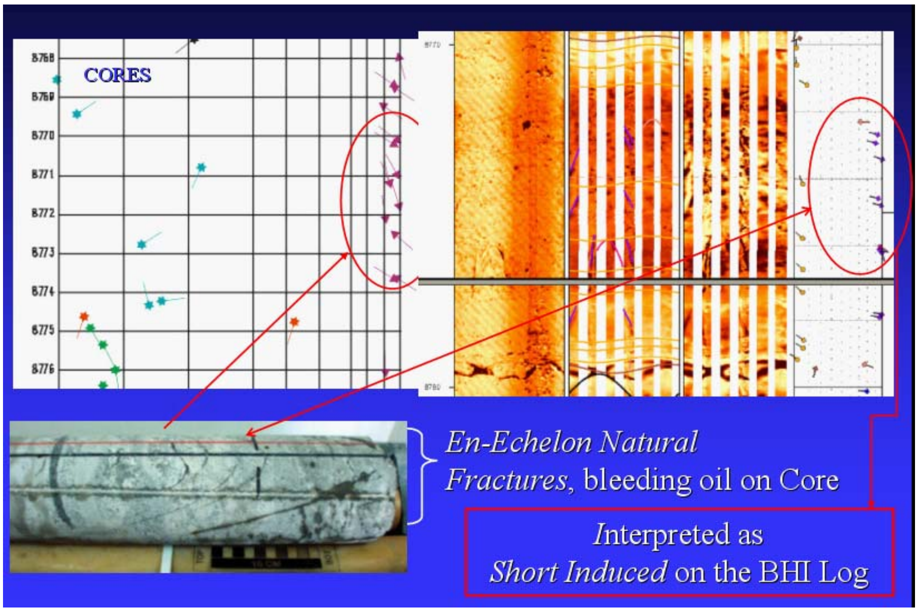

Figure 7 Many Natural 'En Echelon' fractures on cores reported as short induced fractures on BHI log.

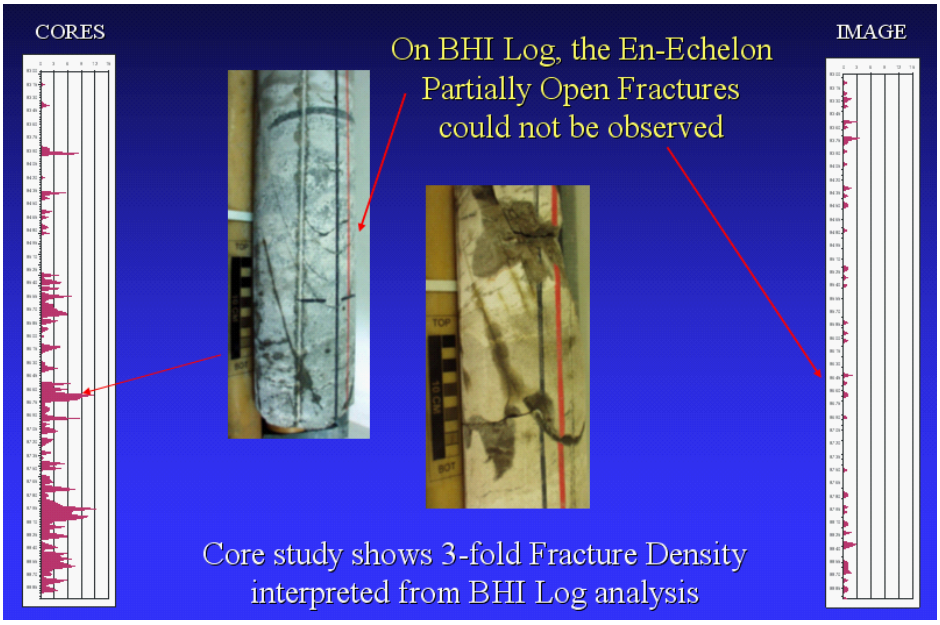

Figure 8 Many 'En Echelon' natural fractures did not appear on BHI log, leading to unrepresentative fracture density.

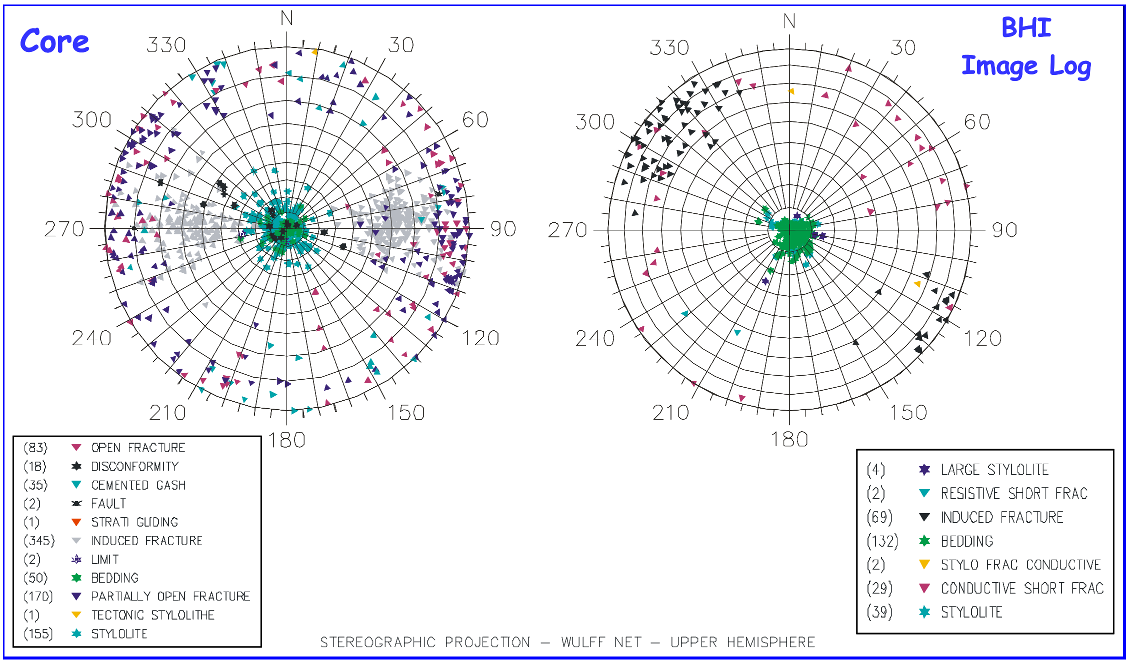

Figure 9 Stereonet plots – Core & BHI Log.

Case History -4

In this case the core data show significantly higher density features (See Stereonet plots Figure 9), with over 50% more tectonic features on cores. The high range of dip of induced fractures on core is due to presence of Petal to Centreline fractures (Figure 10). The difficulty in interpretation of the BHI Log is clear, especially where many induced fractures were misleadingly interpreted as natural fractures, thus producing unrealistic fracture density log.

It was evident that core observations were much more satisfactory with respect to typology characterisation than BHI logs.

As shown on Figure 10 the family of *'En Echelon'* partially open fractures between stylolites did not appear on the BHI Log.

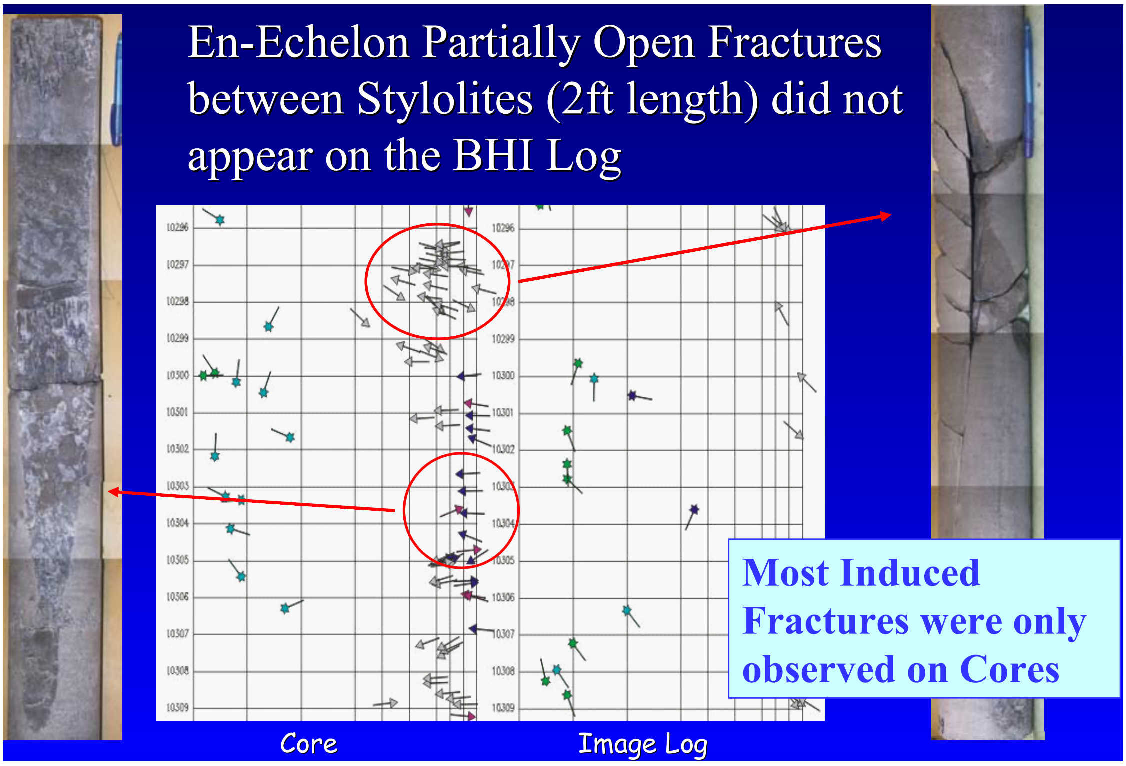

Figure 10 Photo on left side shows partially open fracture with Calcite (white) filling.

CASE HISTORY -5

In this case the original BHI interpretation included an exaggerated number of discontinuous open fractures due to wrong interpretation of very short *'Hairline'* features in very small thicknesses. As in the previous case histories, the BHI logs recorded a higher instance of fractures perpendicular to the well direction. In this instance, the fractures seen by the BHI were short hairline fractures that were in tight clusters. Counting these data as open fractures had the effect of skewing the data. In the core, the open fractures were considered to be a secondary feature (Figure 12) and the closed fractures the primary aspect. The BHI interpretation could have lead to a wrongful view of fracture density and fractures direction. Figure 11 show a comparison of the original BHI and core interpretation and the revised BHI log after reviewing the BHI in the light of data from core.

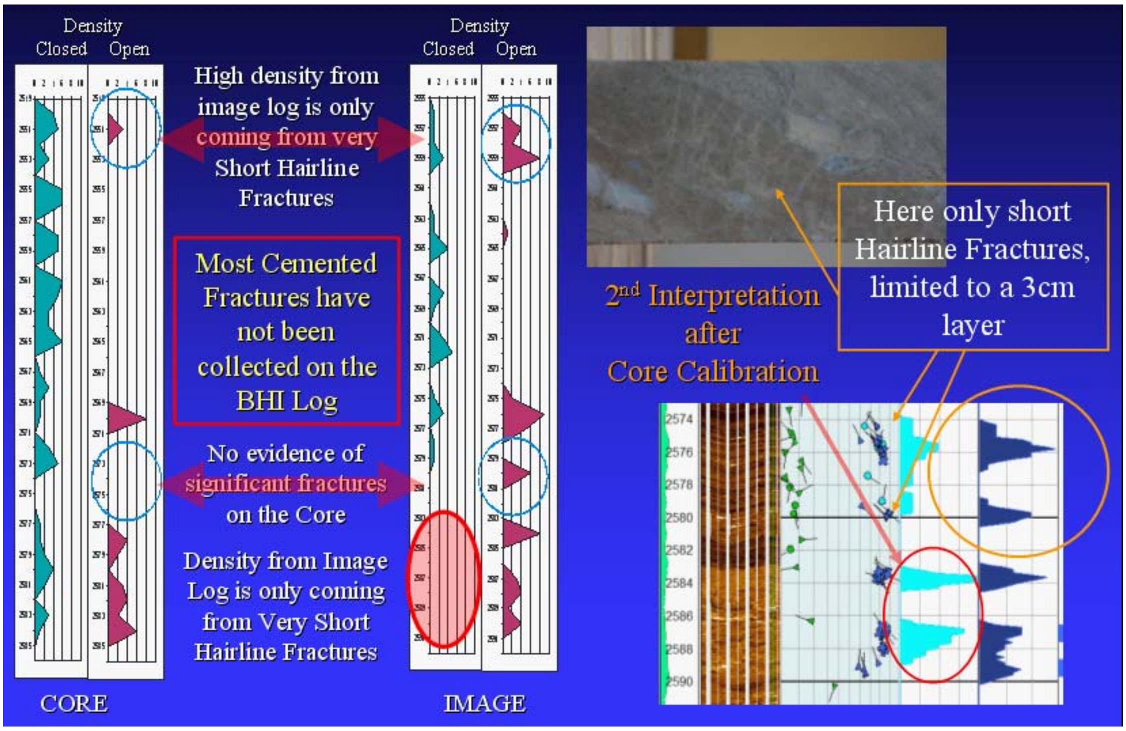

Figure 11 Comparison of original BHI and core interpretation, and revised BHI log after reviewing the BHI in the light of data from core.

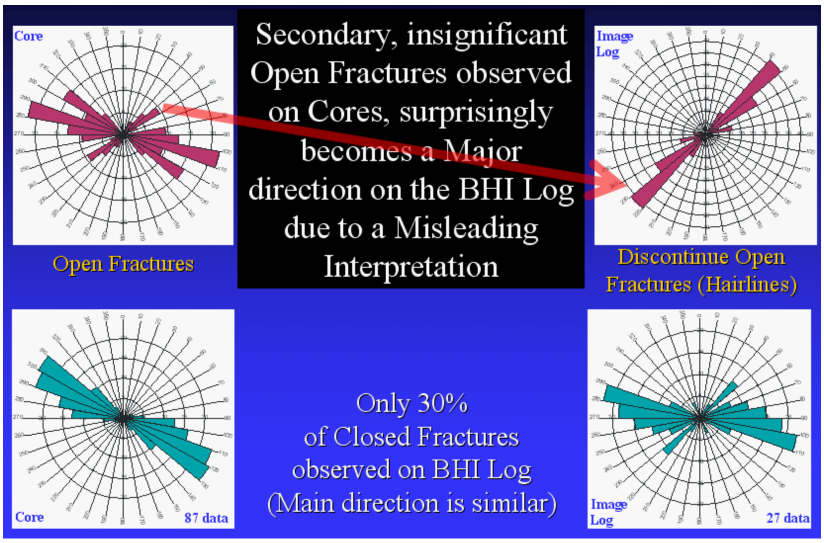

Figure 12 BHI interpretation could have lead to a wrongful view of fracture density and fractures direction of the different fracture families.

CONCLUSIONS

The case histories above are shown in order to support the need for the integration of core and log data during the interpretation of downhole BHI logs. It is clear that the interpretation of BHI images is difficult with instances where mismatches between the two data sets are testament to this. We have shown cases where interpretation of the logs without using the core for guidance has lead to the inclusion of fractures that are unlikely to be in the formation, instances where the fracture density is determined incorrectly and how being able to differentially distinguish between open and partially filled fractures can alter the understanding of the data.

Whilst this paper uses core data as the calibration tool for the logs we recognise that core data is not infallible. In the case histories shown all of the core data is considered valid as it was determined soon after the core was taken and without core damage from handling and transportation. Such an approach is only possible if the collection of such data is integrated into the data acquisition plan at the outset.