Successful Characterization Using Images in Real-Time Interpretation: A Challenging Lateral Well from Ultra High Resolution Microscope Measurement*

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Abstract

PDO has utilized successfully the Ultra high resolution LWD resistivity images in well "X" (a heavily fractured and complex heterogeneous carbonate formations) for fracture identification in real time to identify the fractures zones that contributed to the drilling mud losses and design completion to isolate those fractures zones and selecting a proper perforation zones away from the fractures. On the other hand, having different depths of investigation can help to analyses invasion, to provide inputs for petrophysical formation evaluation, and to differentiate between features that appears near wellbore deep in the formation.

After drilling, geological interpretation was performed utilizing memory data which has better sampling and data density. The interpretation included full structural borehole features identification such as (structural dip computation by picking bed boundaries intersected while drilling), detailed fractures characterization to identify type of fractures (conductive, resistive), morphology and geometry of each fractures (continuous, discontinuous), fractures density, and distribution along the logged interval. Minor faults were also identified from the images.

The geological interpretation of the high resolution resistivity images revealed the presence of a few major conductive fractures that were possibly enhanced by drilling and a large number of partial discontinuous conductive and resistive fractures were also seen.

Using latest software technology in the office while on the job in real-time helped both petrotechnical and well placement engineers to better image log interpretation and to visualize the data in 3D.

Successful introduction of the Ultra high resolution LWD resistivity images in the right fit applications opened another door on solving reservoir issues and needs bearing in mind for drilling environments that become more challenging.

Theory

After drilling, geological interpretation was performed utilizing memory data which has better sampling and data density. The processing of the raw Ultra high resolution LWD resistivity images (UHRI*) in well "X" was done in the Schlumberger Petro Technical Services Centre, Muscat. Following processing chain is used to process and interpret UHRI* dataset into Techlog software were UHRI* static and dynamic normalized images produced. All dips and fracture identification is performed using static images with Techlog software.

Well "X" is a horizontal well with a maximum deviation of approximately 91.3º. From the processed and normalized UHRI* images different types of fracture and faults were identified. According to fracture morphology fractures may be conductive and non-conductive. Conductive fractures appear to have continuous/discontinuous conductivity and full/partial circumferential geometry. Non-Conductive fractures appear to have continuous/discontinuous resistive/white, appearance and full/partial circumferential geometry, see Table 1.

Fracture Analysis

Conductive Fractures

Three different types of conductive fractures were identified with a total of 12 fractures. Those fractures are Conductive-Continuous conductive nature-Full circumference trace (CCF), Conductive-Continuous conductive nature- Partial circumference trace (CCP), and Conductive- Partial conductive nature- Partial circumference trace (CPP).

Three (3) CCF were identified showing two dominant strike orientations of NNE-SSW and NNW-SSE. Six (6) (CCP) were identified shows a dominant strike orientation of NW-SE. Three (3) CPP fractures were identified striking NW-SE, NNW-SSE, and NNE-SSW (see Figure 1).

Resistive Fractures

Two different types of resistive fractures were identified with a total of 32 fractures. Those fractures are Non-Conductive-Continuous non-conductive nature- Full circumference trace (NCF), and Non-Conductive Partial Non-Conductivity -Partial Circumference trace fracture (NPP).

Thirteen (13) NCF and Nineteen (19) NPP fractures were identified in this well showing a dominant strike orientation of NW-SE (see Figure 2).

Faults

A total of four (4) faults have been identified in this well. These faults were classified into two types of faults; Non-conductive Faults (NF) and Conductive Fault (CF).

Three (3) NF and one (1) CF identified show a dominant strike orientation of NW-SE (see Figure 3).

Fractures Density

Among fracture properties required for reservoir studies are fracture density curve and cumulative number of fractures in the uphole direction. Techlog can provide this information by computing the number of fractures per meter perpendicular to the fracture plane. Eight types of fractures were interpreted (CCF, CCP, CPP, NCF, and NPP).

Figure 4, Figure 5, Figure 6, and Figure 7 shows some examples of the interpreted fractures and faults in this well.

Conclusion

The use of real-time image data is of great value for fast identification of faults and fractures. This enable a proactive completion plan and design for optimum well production.

On the other hand, such images in conjunction with other LWD logs enable real-time updates of the reservoir geological model and well placement decision. Sub-seismic faulting, conductive vs. resistive faults / fractures, formation resistivity and density, formation dips as well as invasion profiles characterization are reasons to use these tools namely in horizontal wells and in reservoirs where it is anticipated structural heterogeneities not revealed by the resolution of normal seismic.

However, it should be addressed that the tools to use real-time or recorded-mode depends on the objective of the well and the degree of structural uncertainty. Quality of the hole as well as mud system is vital to acquire a good image. The resolution of the latest LWD resistivity tool is high and can give similar images to the WL. This can save rig time and put the well faster on the production line.

Acknowledgments

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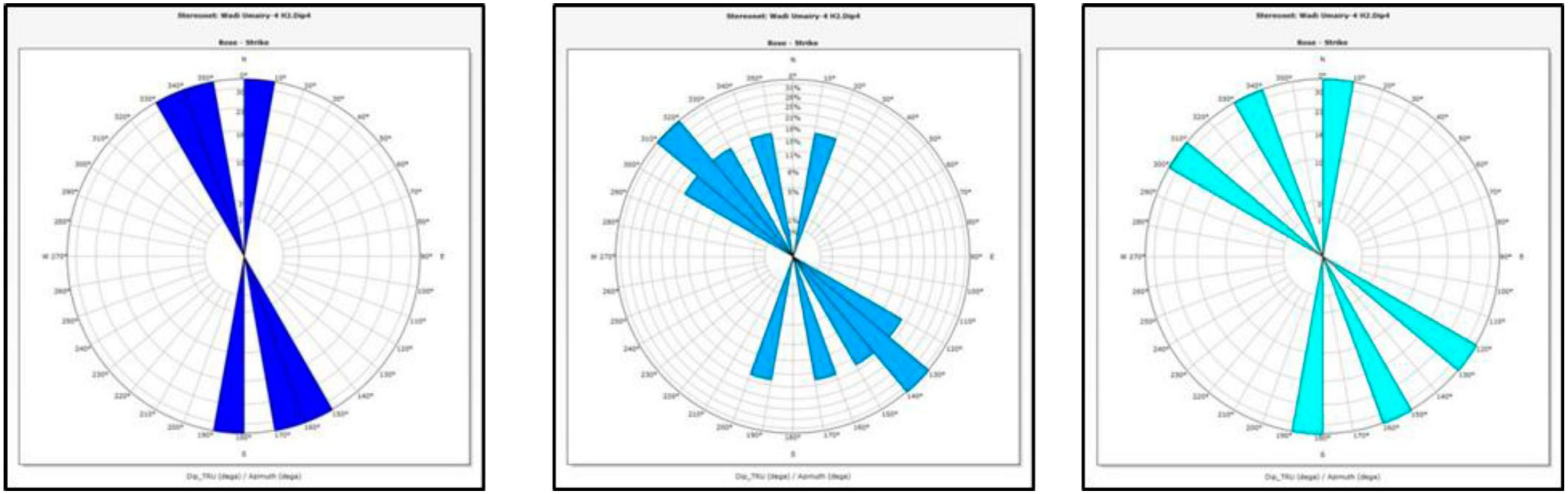

Figure 1. Strike orientation of different types of conductive fractures (CCF, CCP, and CPP).

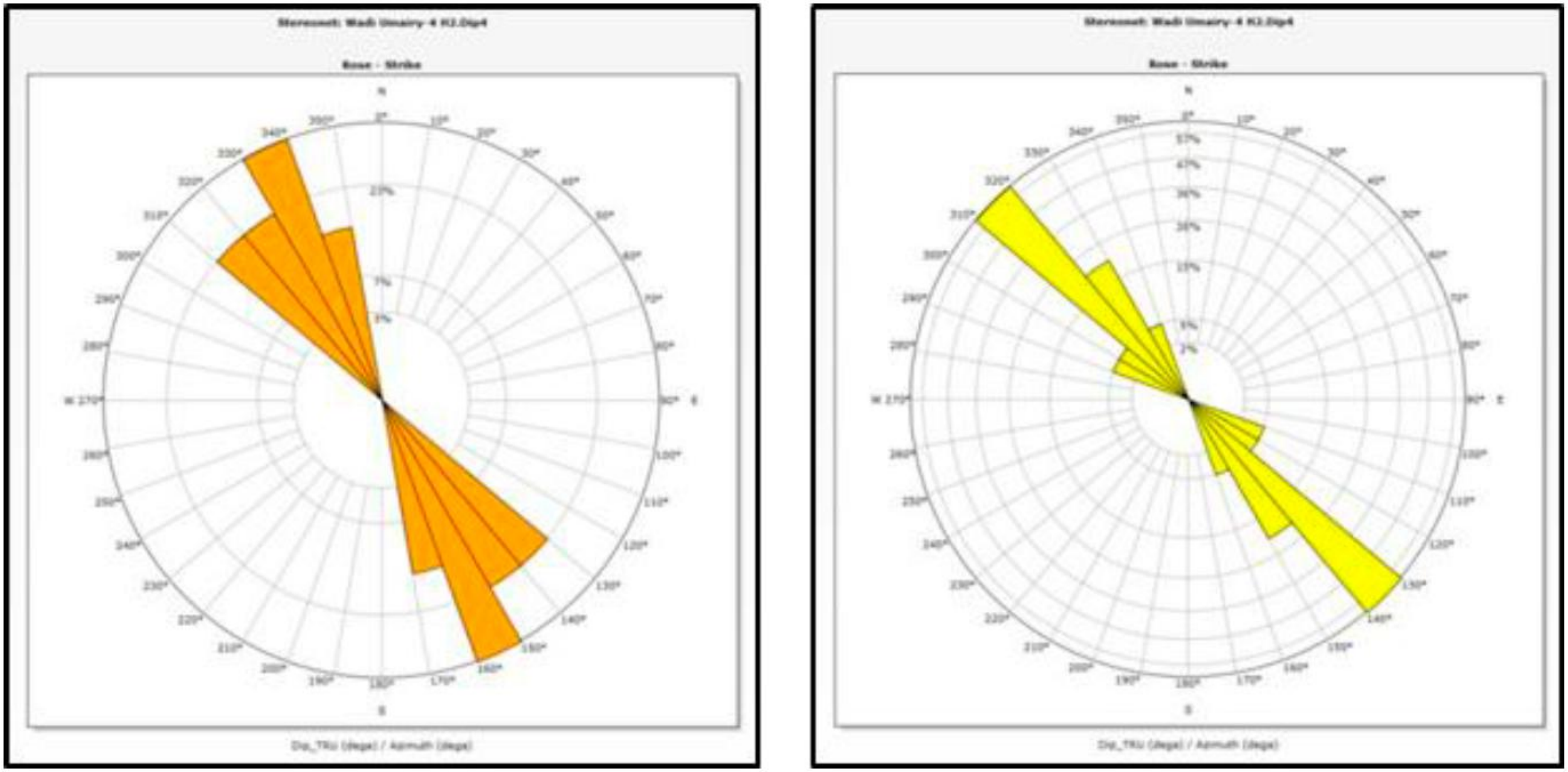

Figure 2. Strike orientation of different types of resistive fractures (NCF and NPP).

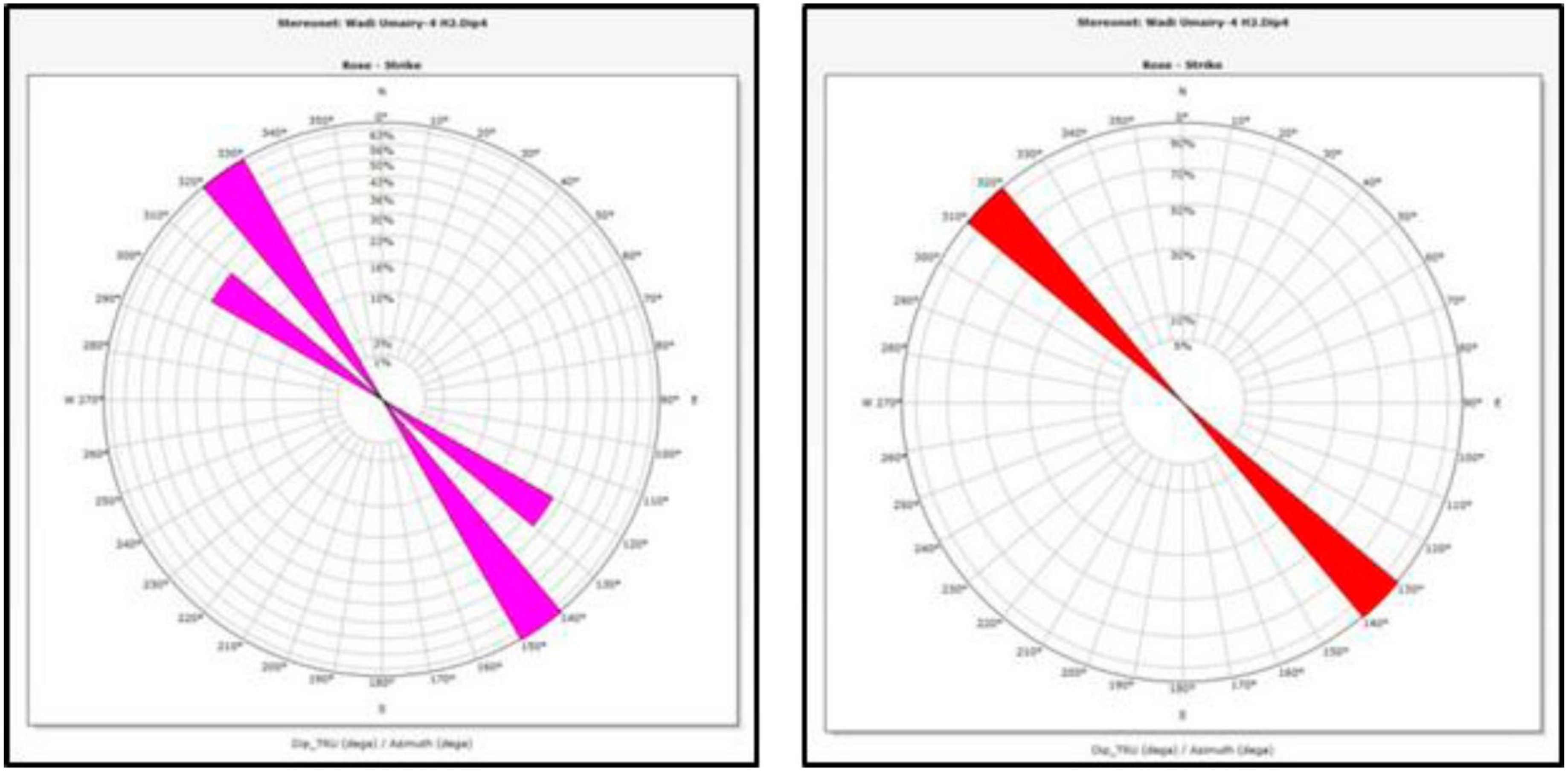

Figure 3. Strike orientation of different types of faults (NF and CF).

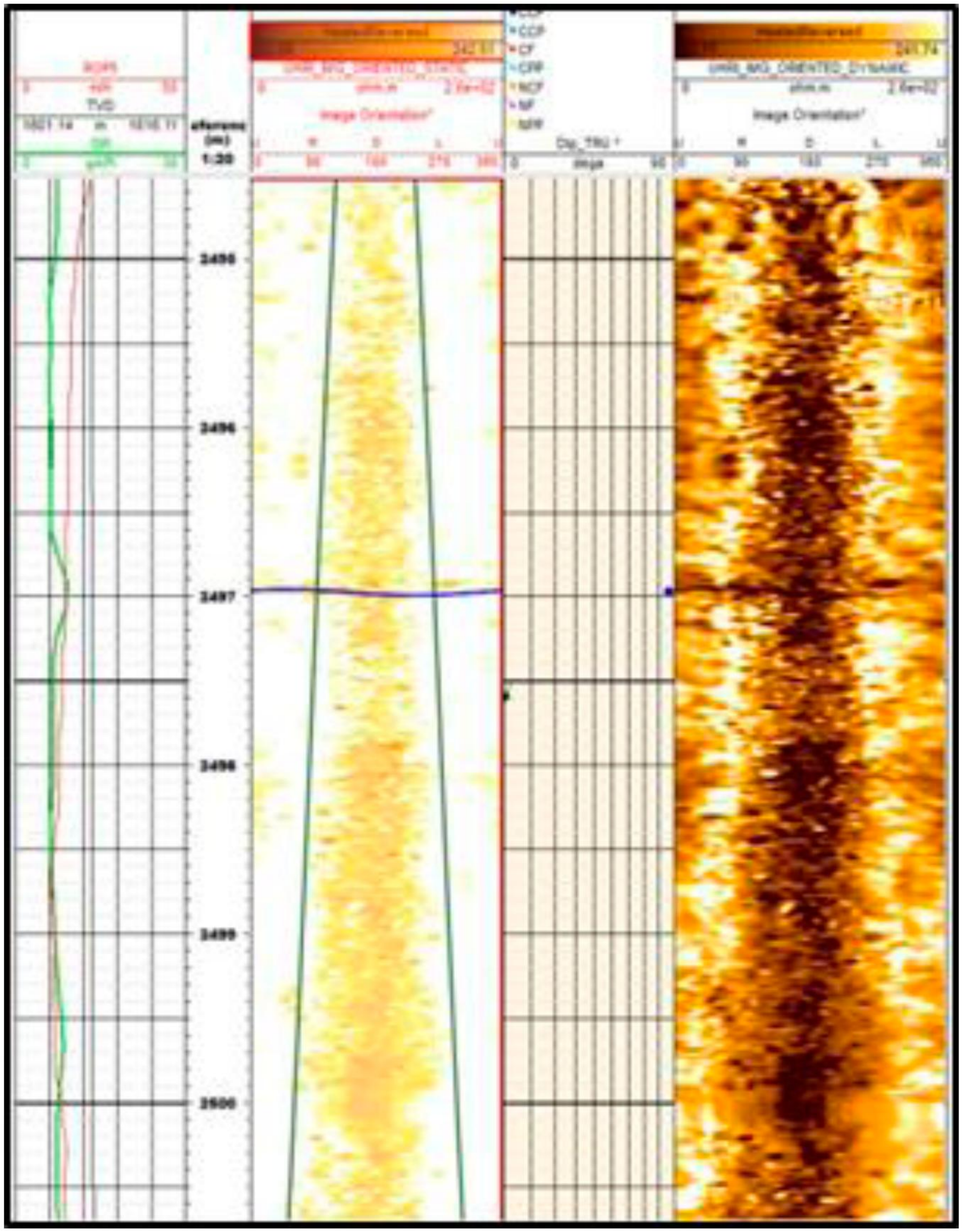

Figure 4. Example of CCF (blue circle tadpole).

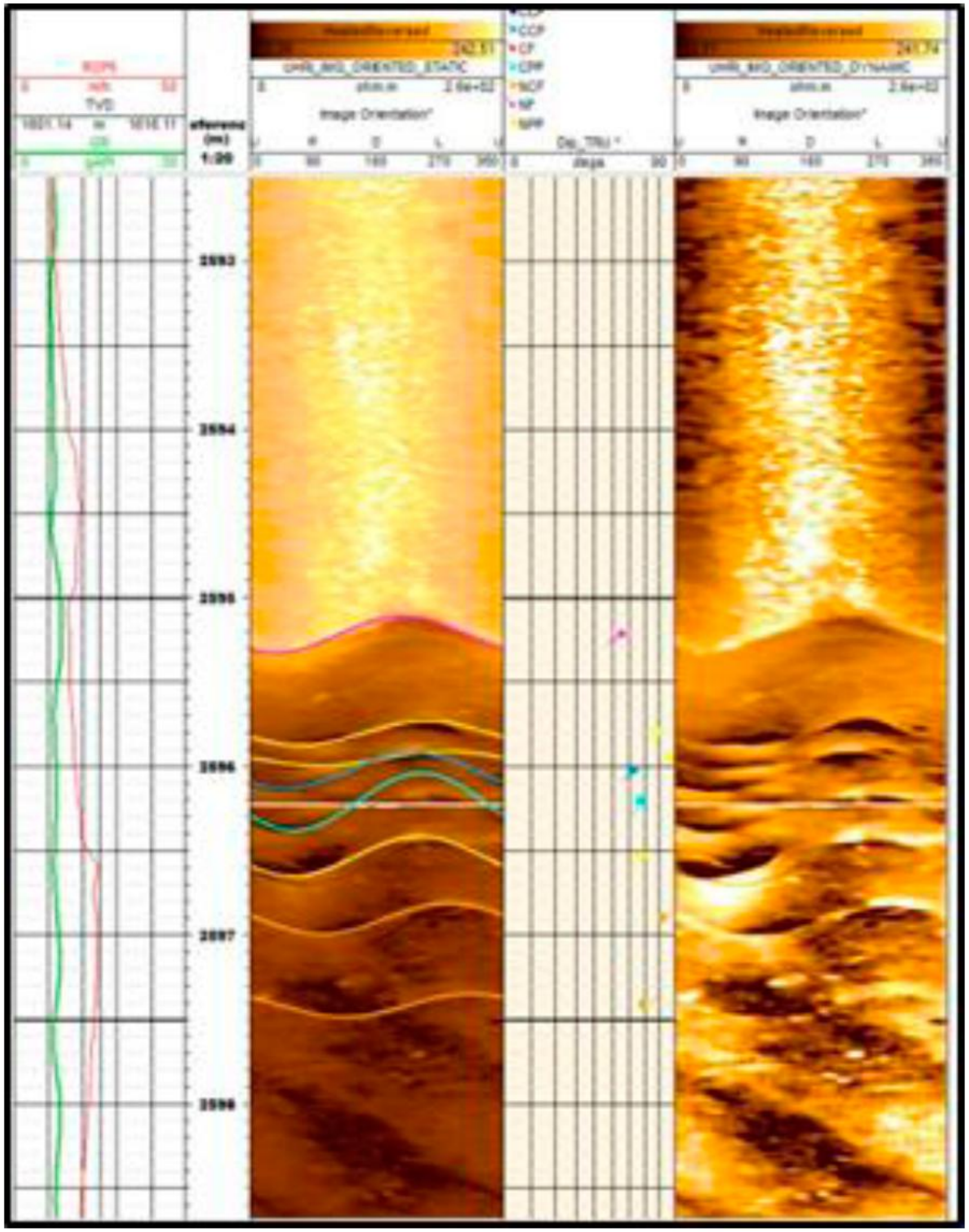

Figure 5. Example of NCF (orange circle tadpole).

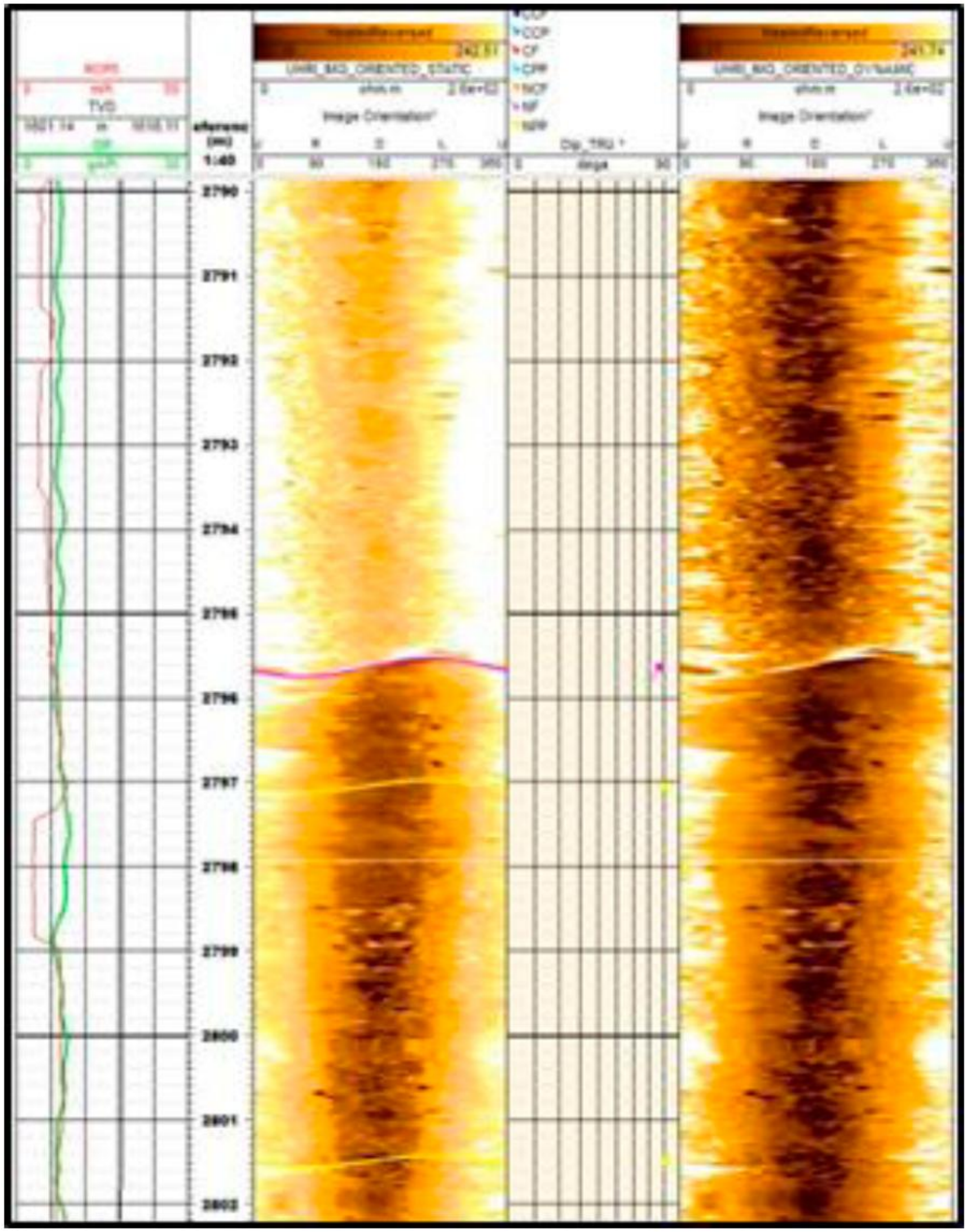

Figure 6. Example of NF (magenta triangle tadpole).

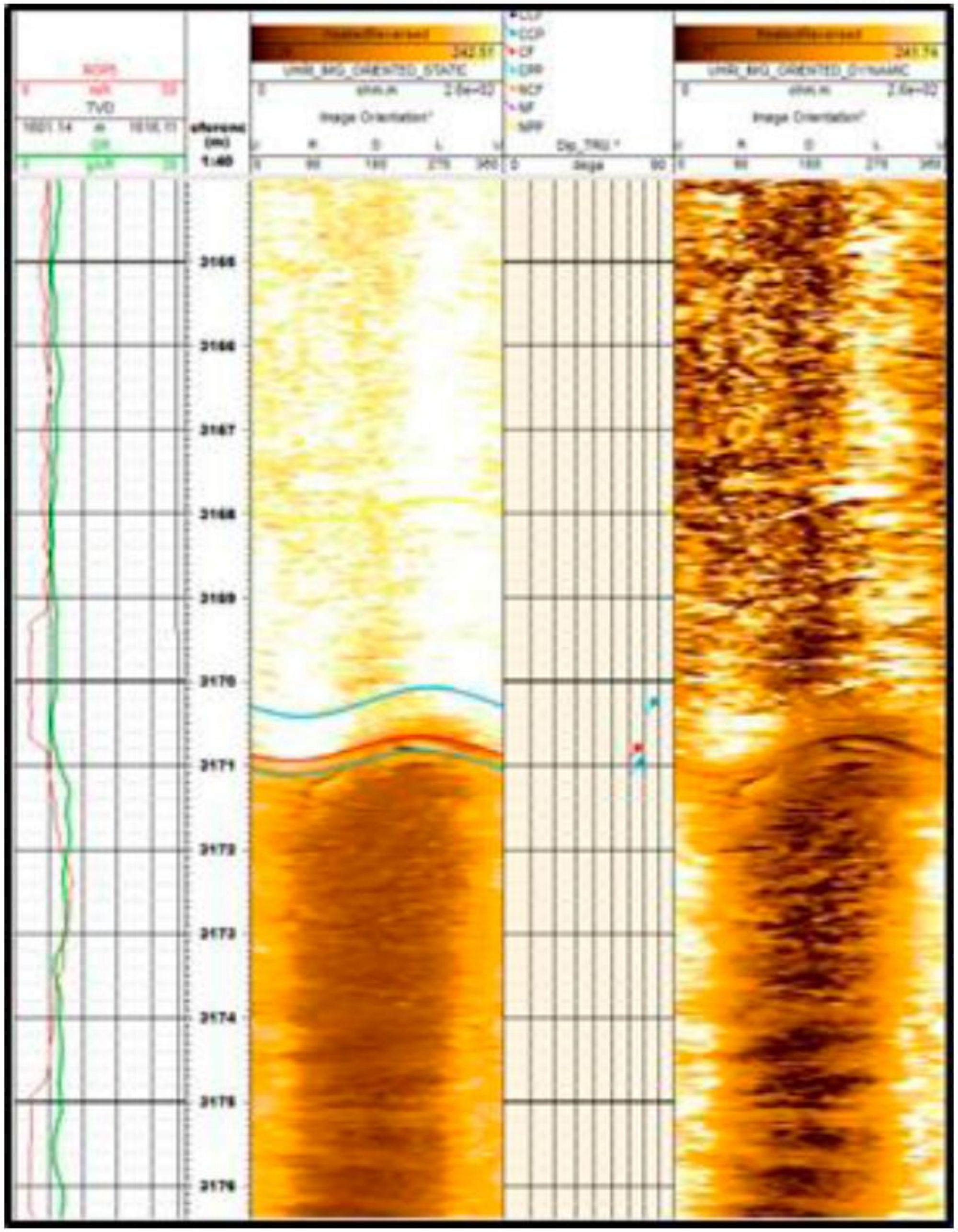

Figure 7. Example of CF (red strike tadpole).

Dip Set	COLOUR CODE
Bedding (B)	Green (circle tadpole)
Conductive-Continuous conductive nature-Full circumference trace (CCF)	Dark Blue (circle tadpole)
Conductive-Continuous conductive nature- Partial circumference trace (CCP)	Blue (circle tadpole)
Conductive- Partial conductive nature- Partial circumference trace (CPP)	Cyan (circle tadpole)
Non-Conductive-Continuous non-conductive nature- Full circumference trace (NCF)	Orange (circle tadpole)
Non-Conductive Partial Non-Conductivity -Partial Circumference trace fracture (NPP)	Yellow (circle tadpole)
Non-conductive Fault (NF)	Magenta (circle tadpole)
Conductive Fault (CF)	Red (circle tadpole)

Table 1. Dip sets nomenclature.