3-D Near-Wellbore Structural Modeling Based On High Resolution, Logging While Drilling Borehole Image Analysis: An Example from Sichuan Basin, China*

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Abstract

This paper presents how a new generation, 3-D near wellbore structural modeling software can dramatically reduce uncertainty related to structural geology, well placement and hydraulic fracture stimulation planning. The subject horizontal well is the first commercial oil well drilled into a tight carbonate reservoir in Sichuan Basin, China. The target reservoir is situated within an anticline structure and near a series of major complex faults having associated minor faults and natural fractures. Due to the relatively low resolution of seismic data and limited well control, detection and interpretation of these structural features is difficult. This presents a challenge during drilling, specifically with regards to well placement. Additional challenges arise during well completion and stimulation planning as the objective is to have induced, hydraulic fractures remain in the zone of interest. These issues were addressed by acquiring high-resolution borehole micro-resistivity images while drilling and creating an advanced near-wellbore structural model.

The applications of borehole images within complex structural environments are well demonstrated. The structural interpretation includes the identification and mapping the orientation of bedding planes, natural fractures and fault planes. The specific approach was to analyze the dip sequences along the lateral wellbore and perform a structural analysis using the local curvature axis technique on a Schmidt plot. This structural zoning method enables geometric characterization of the multiple structures encountered during drilling. Furthermore, defining the drilling polarity and computing true stratigraphic thickness enables accurate correlations between various drilling sections and allows for an estimation of the magnitude of fault displacement. The result is a detailed, three-dimensional near-wellbore structural model that, when integrated with logged rock properties, provides critical information for use when designing the well completion and stimulation. This technique is being used to guide current drilling and completion practices in the area and provides input to reservoir scale modeling.

Selected Reference

Meng, Q.-R, E. Wang, and J.-M. Hu, Mesozoic sedimentary evolution of the northwest Sichuan basin: Implication for continued clockwise rotation of the South China block: Bulletin of the Geological Society of America, v. 117/3-4, p. 396-410

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Yu Yang, Camron Miller, Philippe Marza, and Jack Zhao
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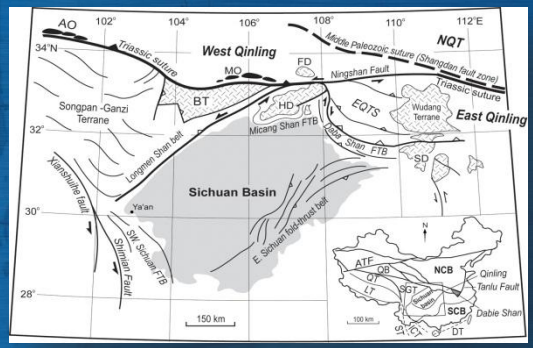
An-Fu Zhou and Yang Yang
PetroChina



Schlumberger

Outline

Introduction

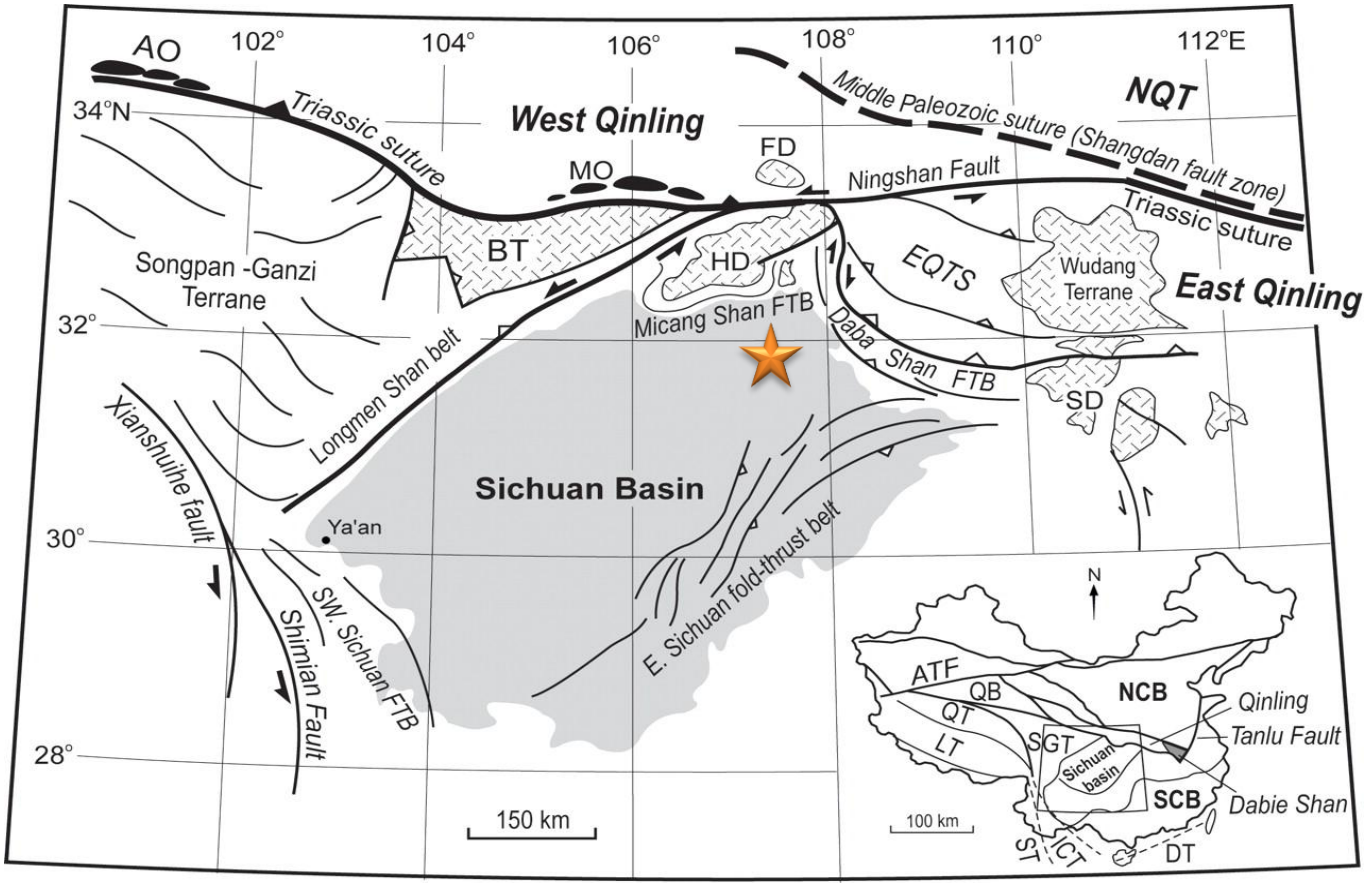
Structure dip interpretation & analysis

Fault analysis & fracture characterization

3D near-wellbore geological modeling

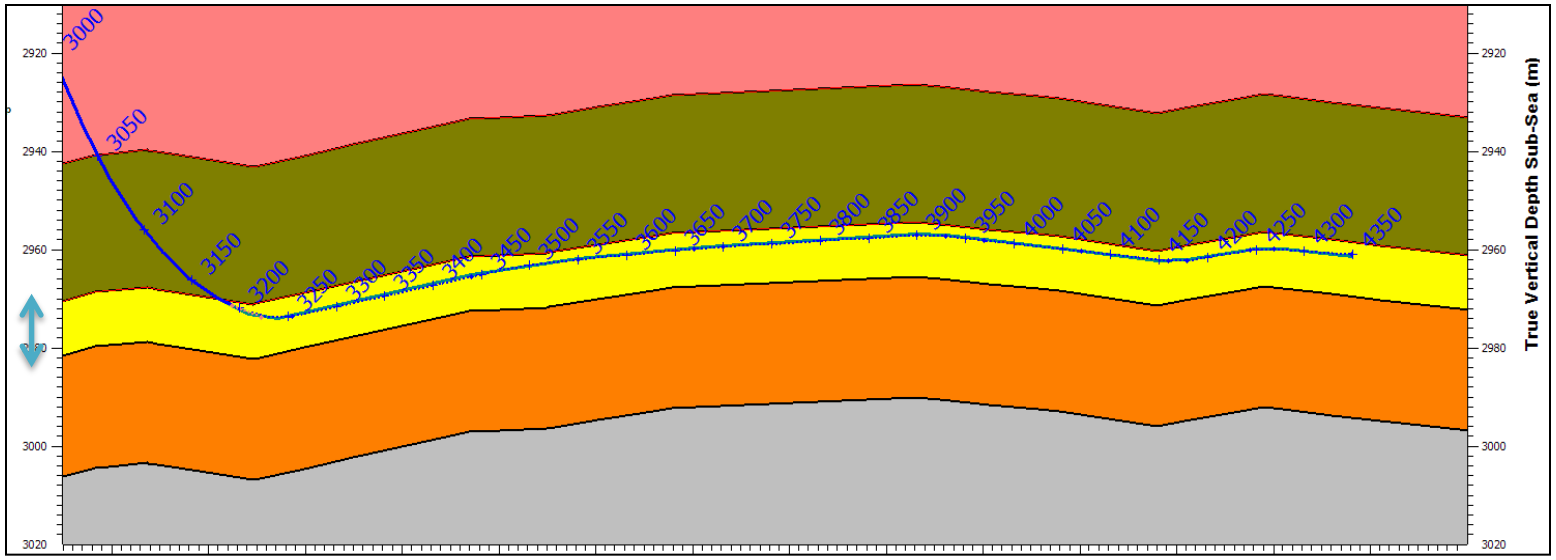
Conclusion

Background

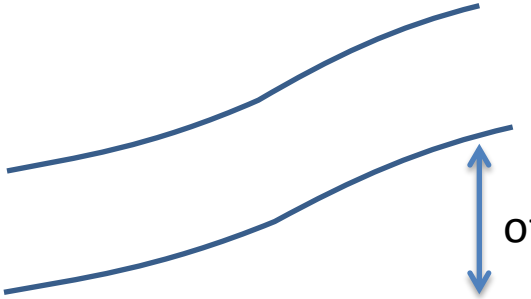


Tectonic map of Sichuan basin area (Meng, Q.-R, Wang, E, Hu, J.-M, 2005)

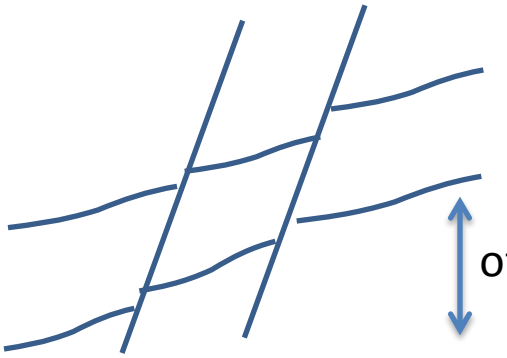
Pre-drilling model



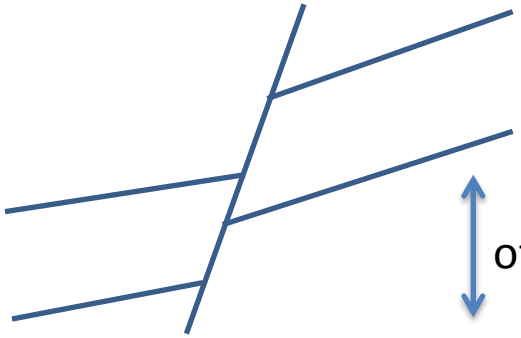
~10m
(~32ft)



ductile deformation
(Seismic scale)



ductile & brittle deformation
(Near borehole scale)



brittle deformation
(Seismic scale)

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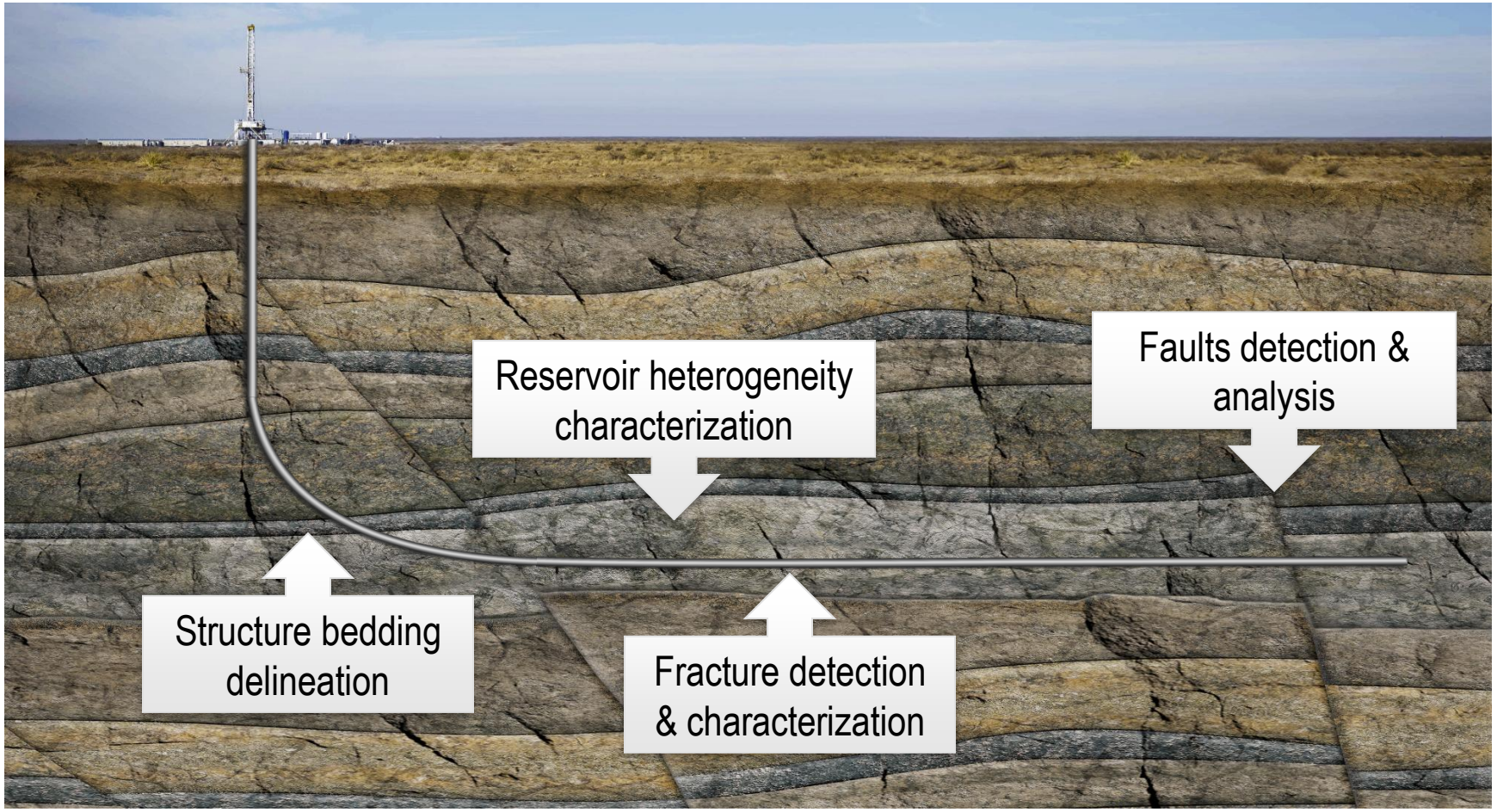
Well Completion & Stimulation Consideration



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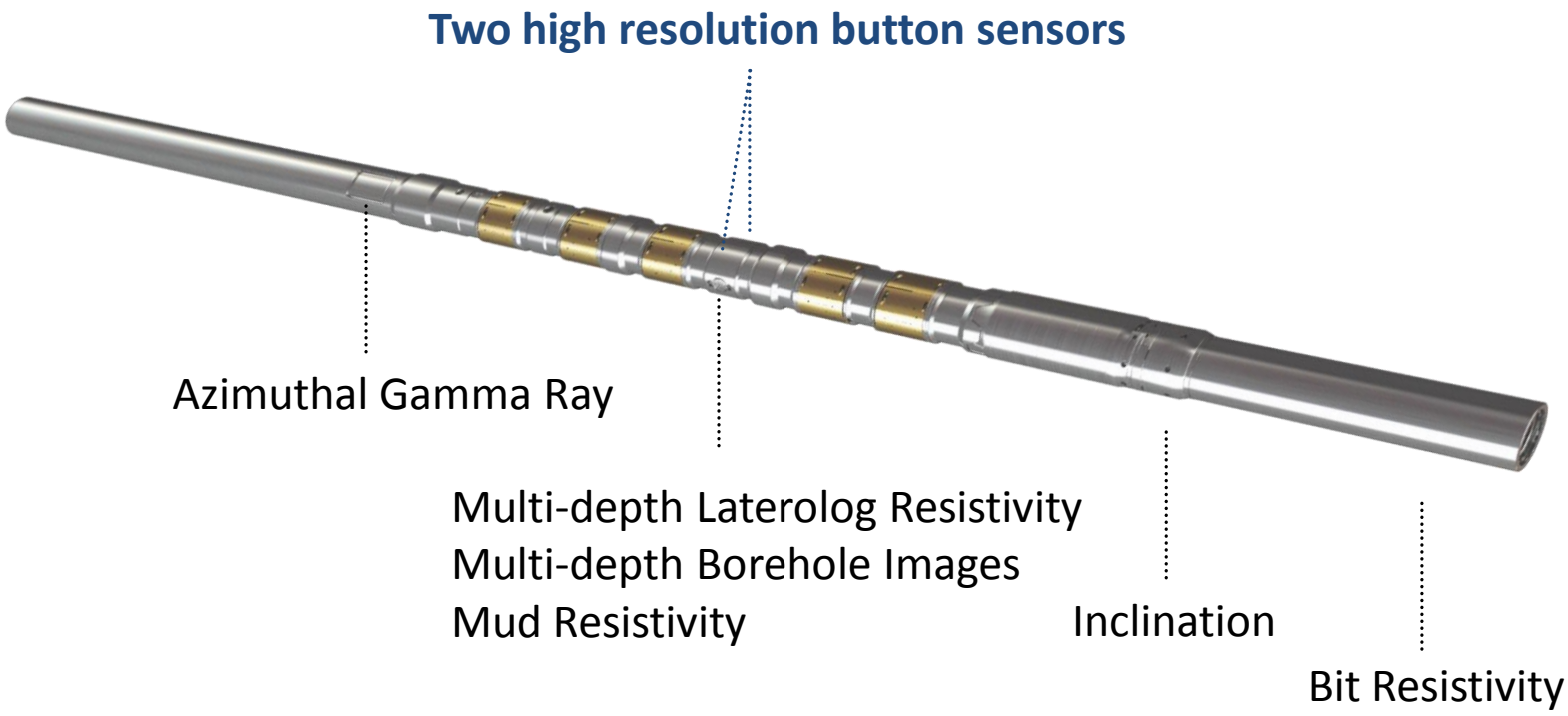
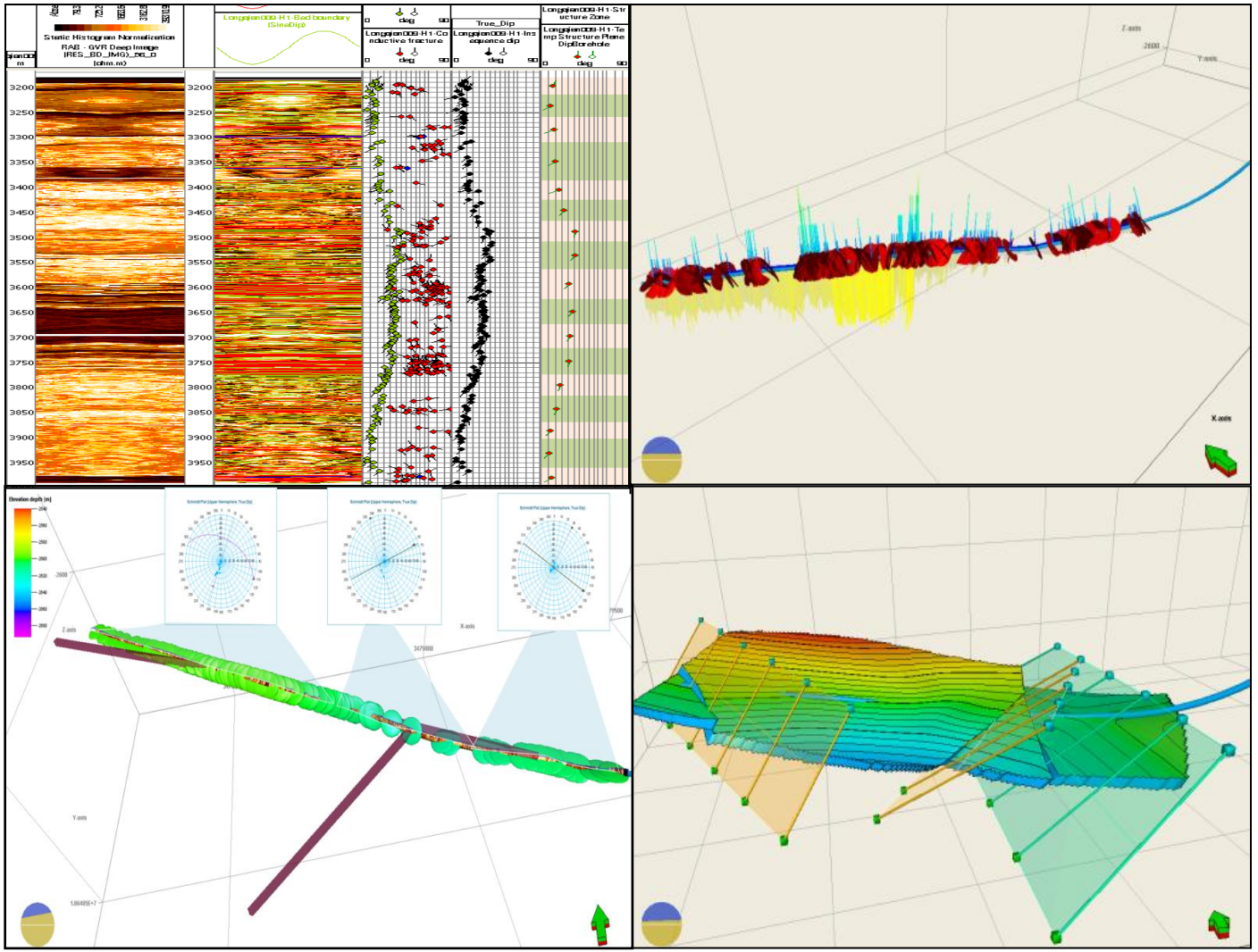
Resistivity- and Imaging-While-Drilling Service



High-resolution resistivity and imaging-while-drilling service

Near-wellbore Scale Structure Modeling



Integrated borehole geological analysis

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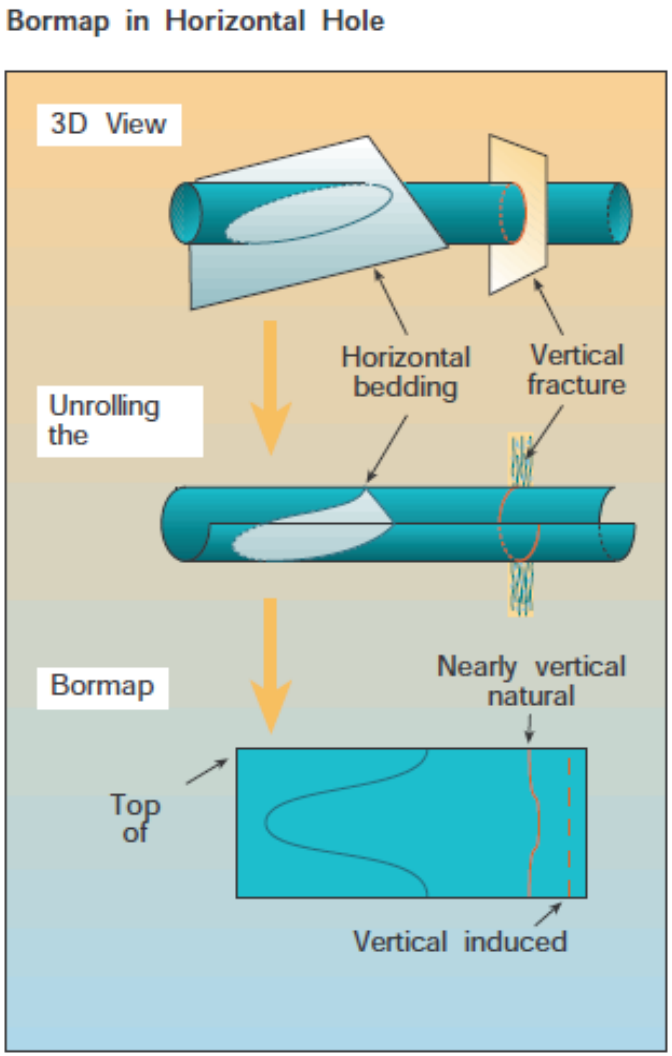
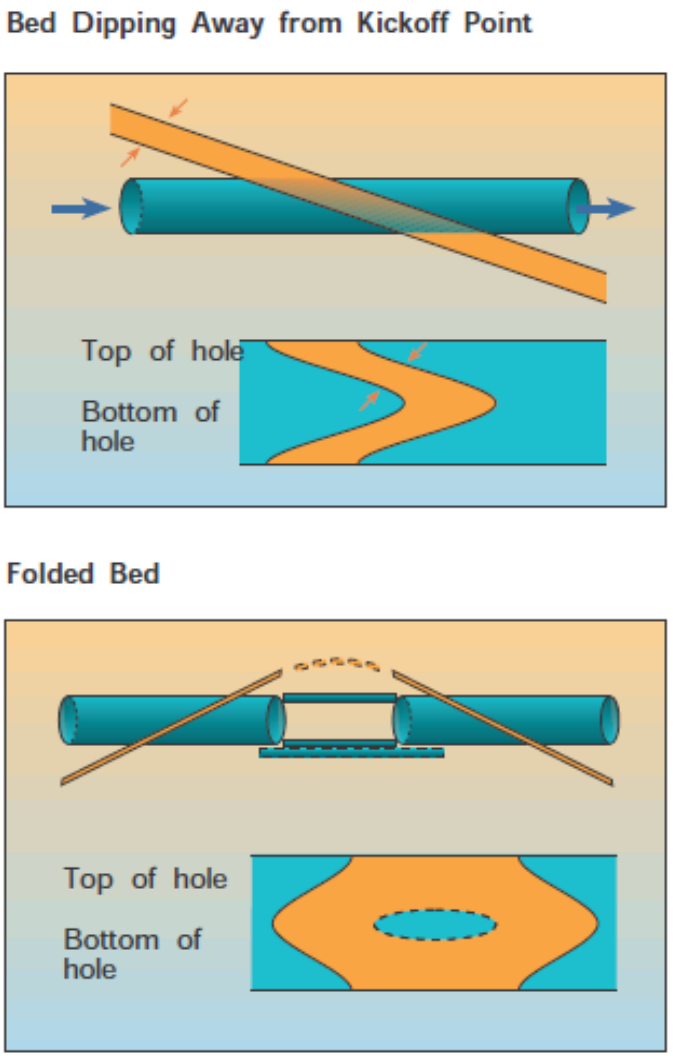
Structure Dip Interpretation & Analysis





Jeff Prilliman, Tom Bratton, 1997

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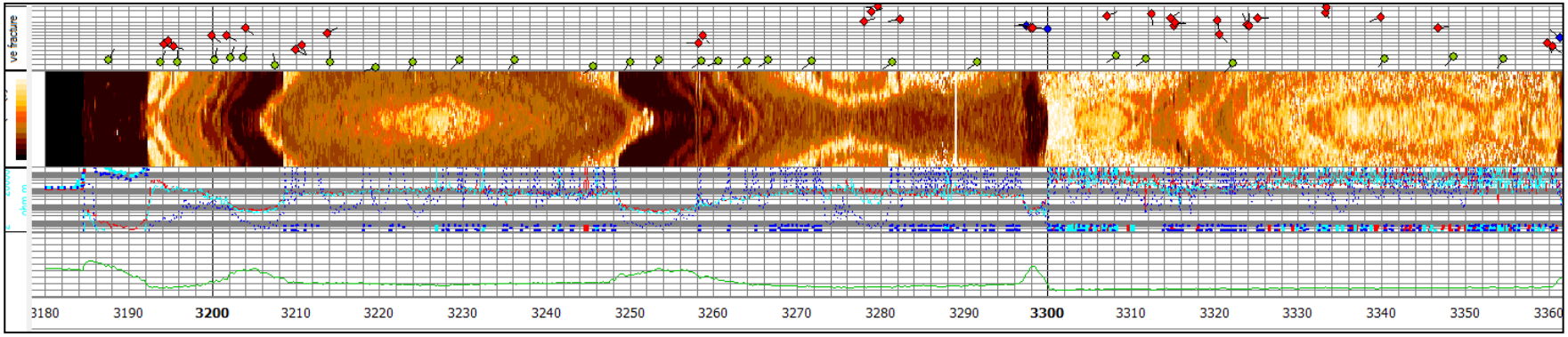
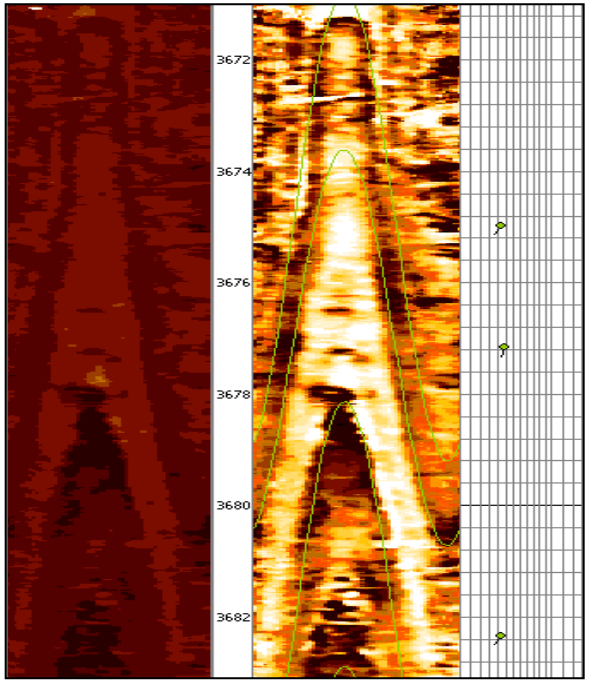
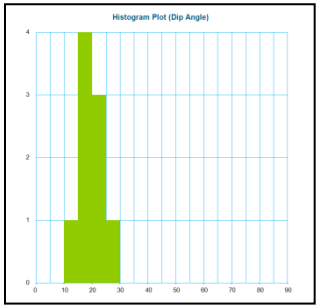
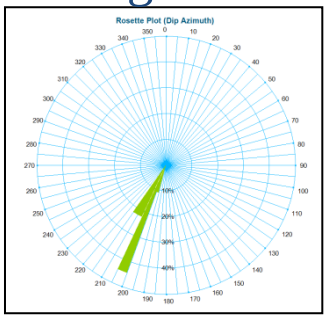
Structure Dip Interpretation & Analysis



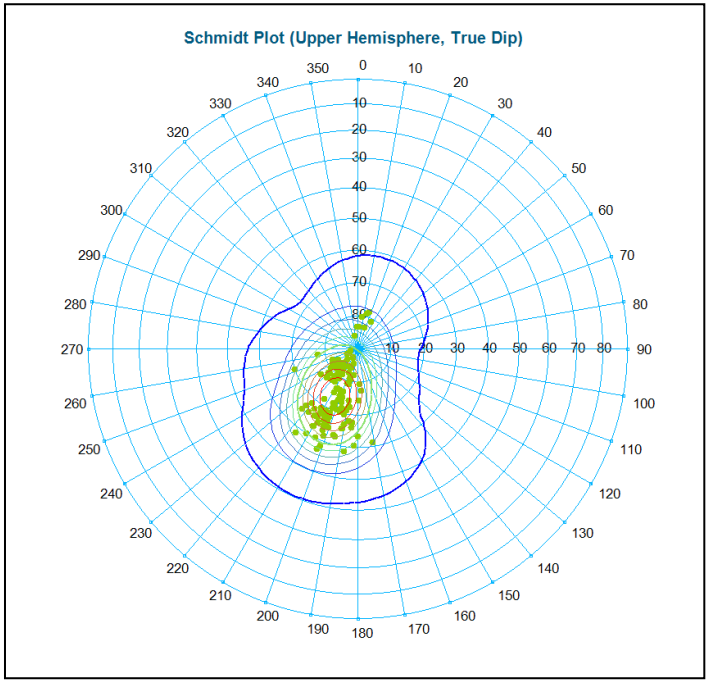




Histogram Plot



Azimuth Plot



Schmidt Plot

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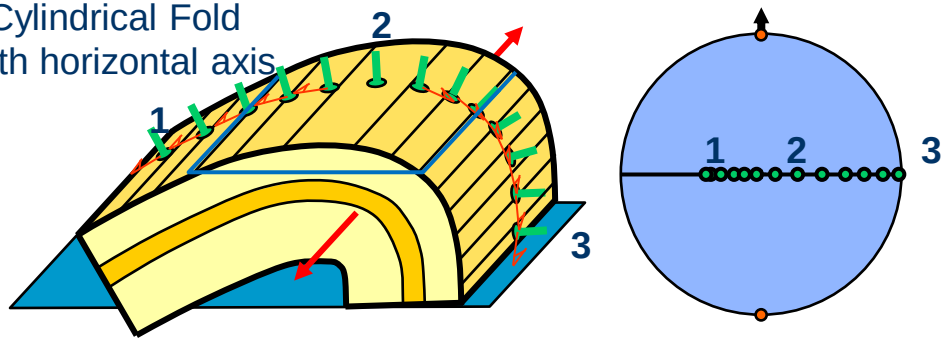
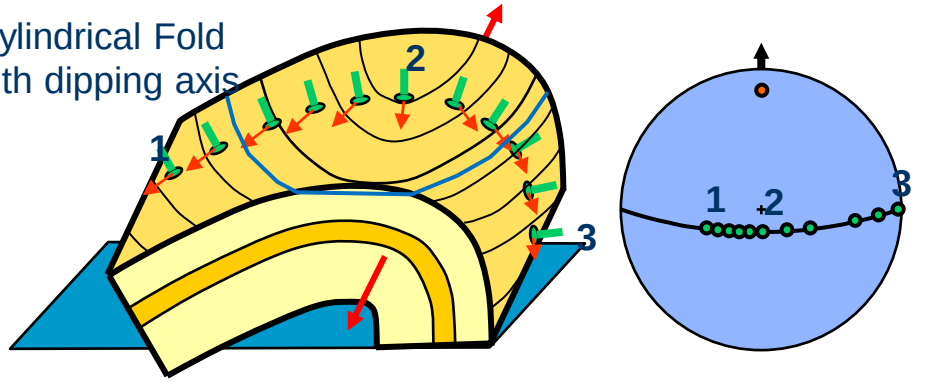
Fold Signature on Schmidt Plot

Cylindrical Fold
with horizontal axis



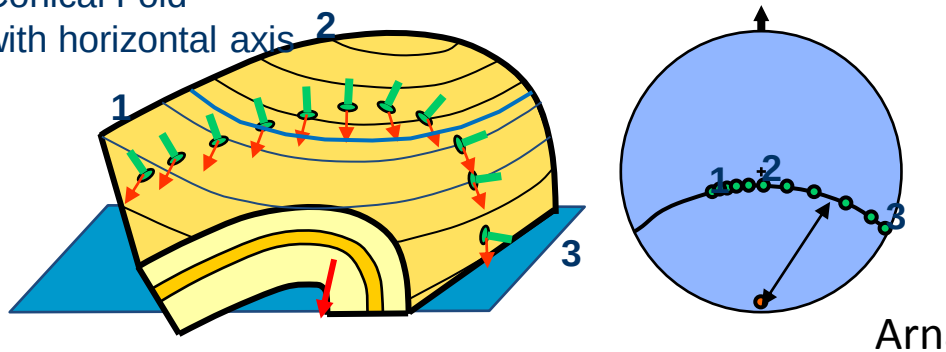
Dips fit a vertical GC, i.e. a diameter of the net. Two azimuths (180 deg apart of each other) are possible

Cylindrical Fold
with dipping axis



Dips fit a GC. Azimuths may vary a lot, especially in the hinge zone

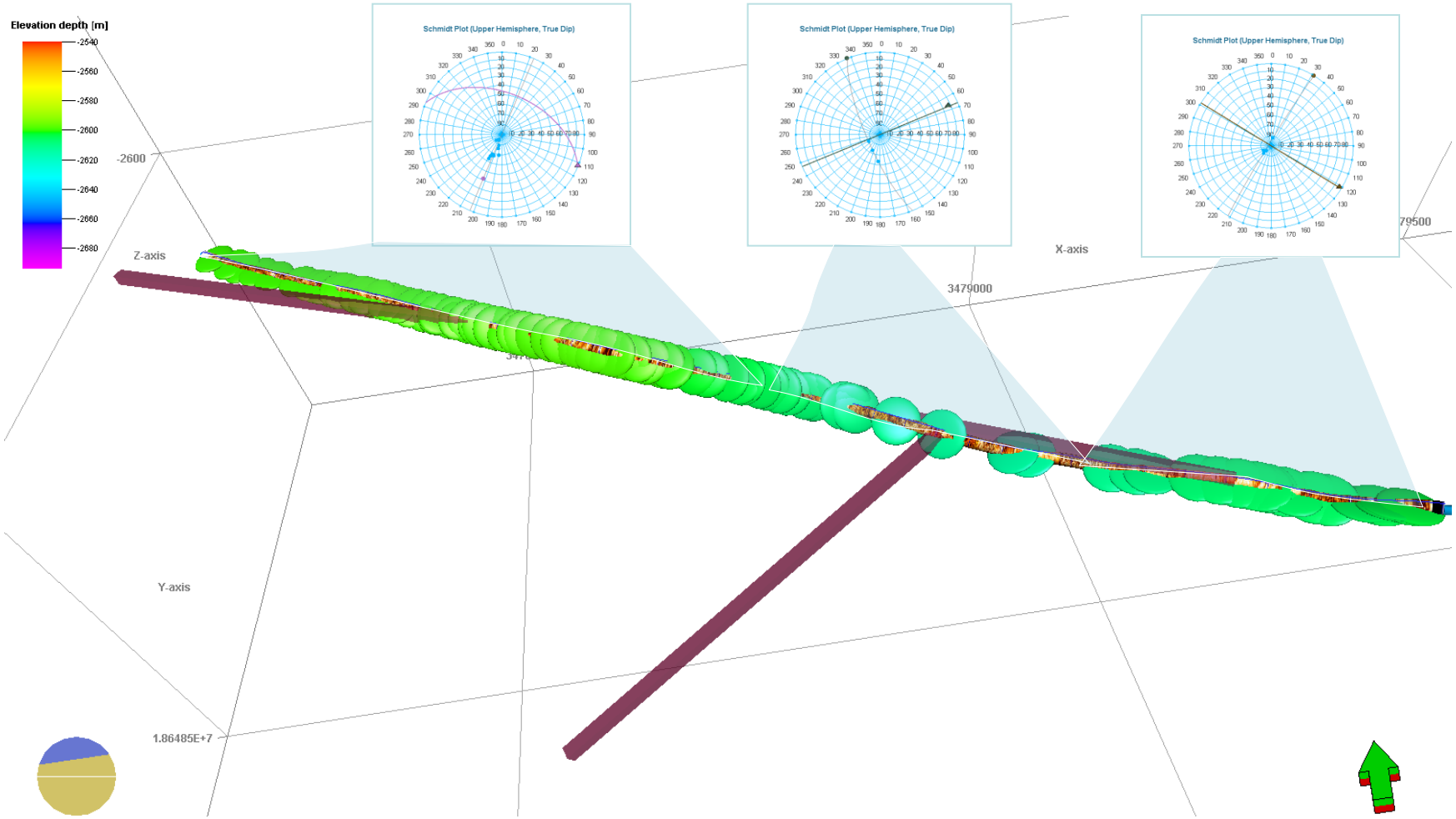
Conical Fold
with horizontal axis



Dips fit a Small Circle whose angular distance to the axis corresponds to the conicity. Azimuths may vary a lot, especially in the hinge zone

Arnaud Etchecopar, Philippe Marza, 2009

Structure Type and Axis Delineation



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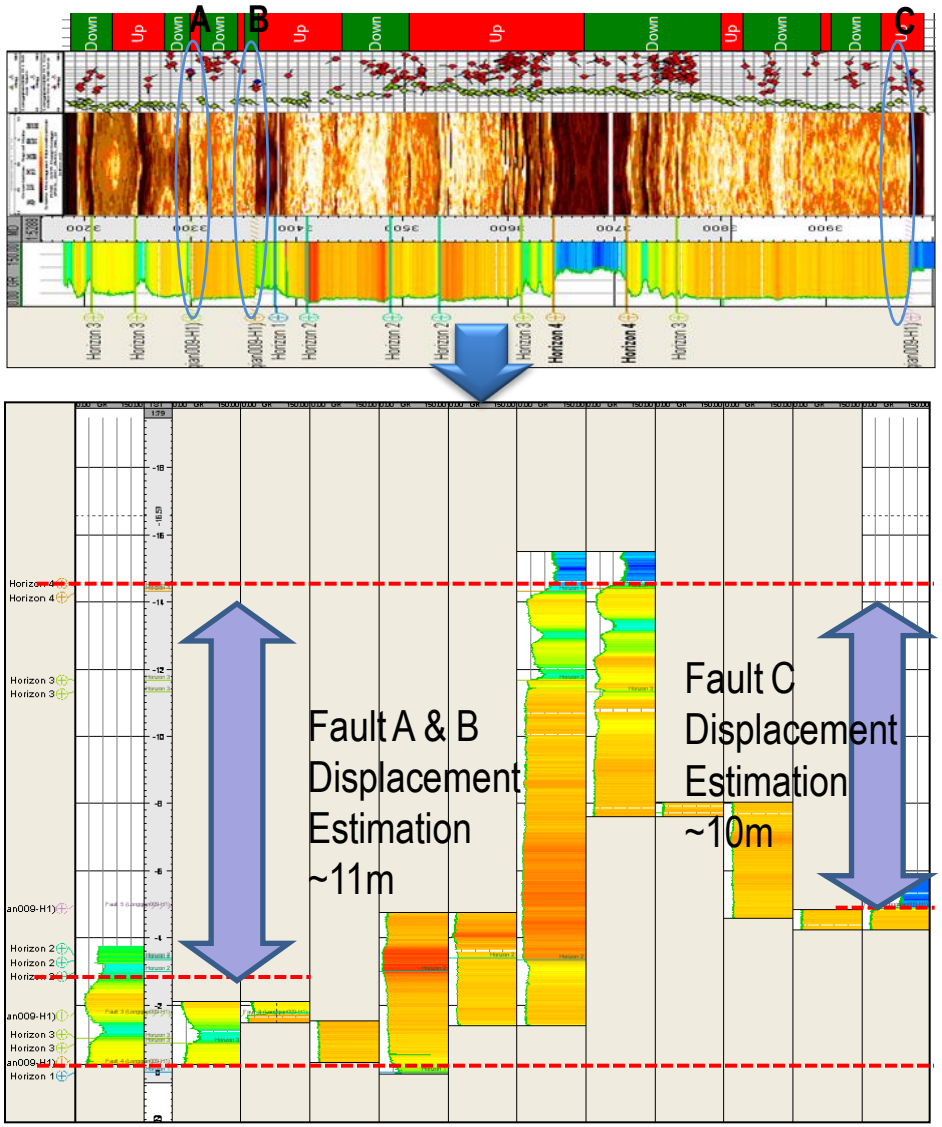
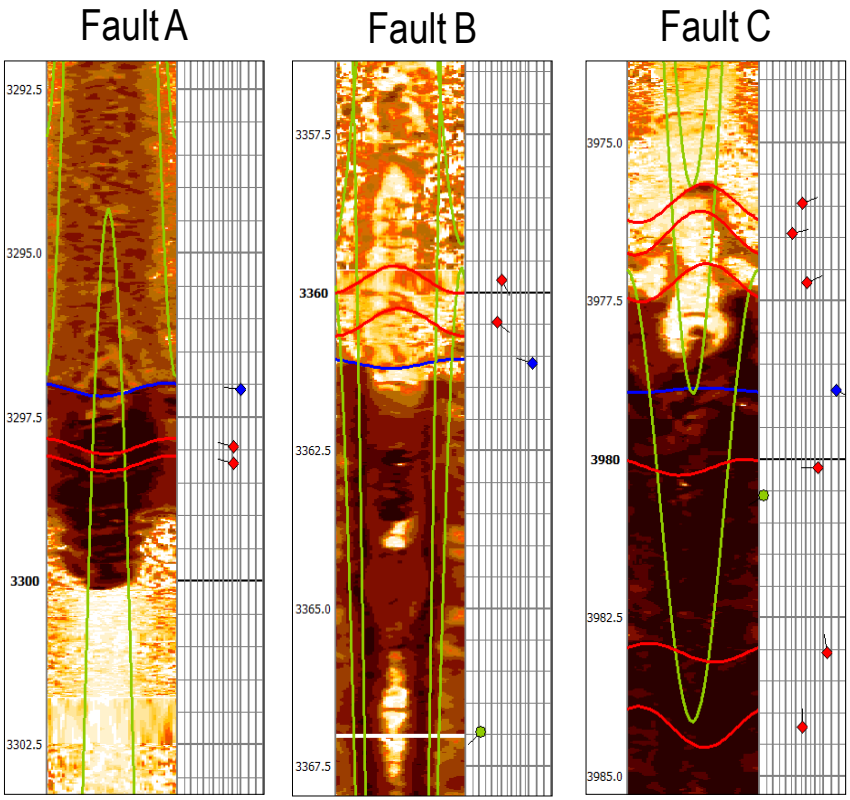
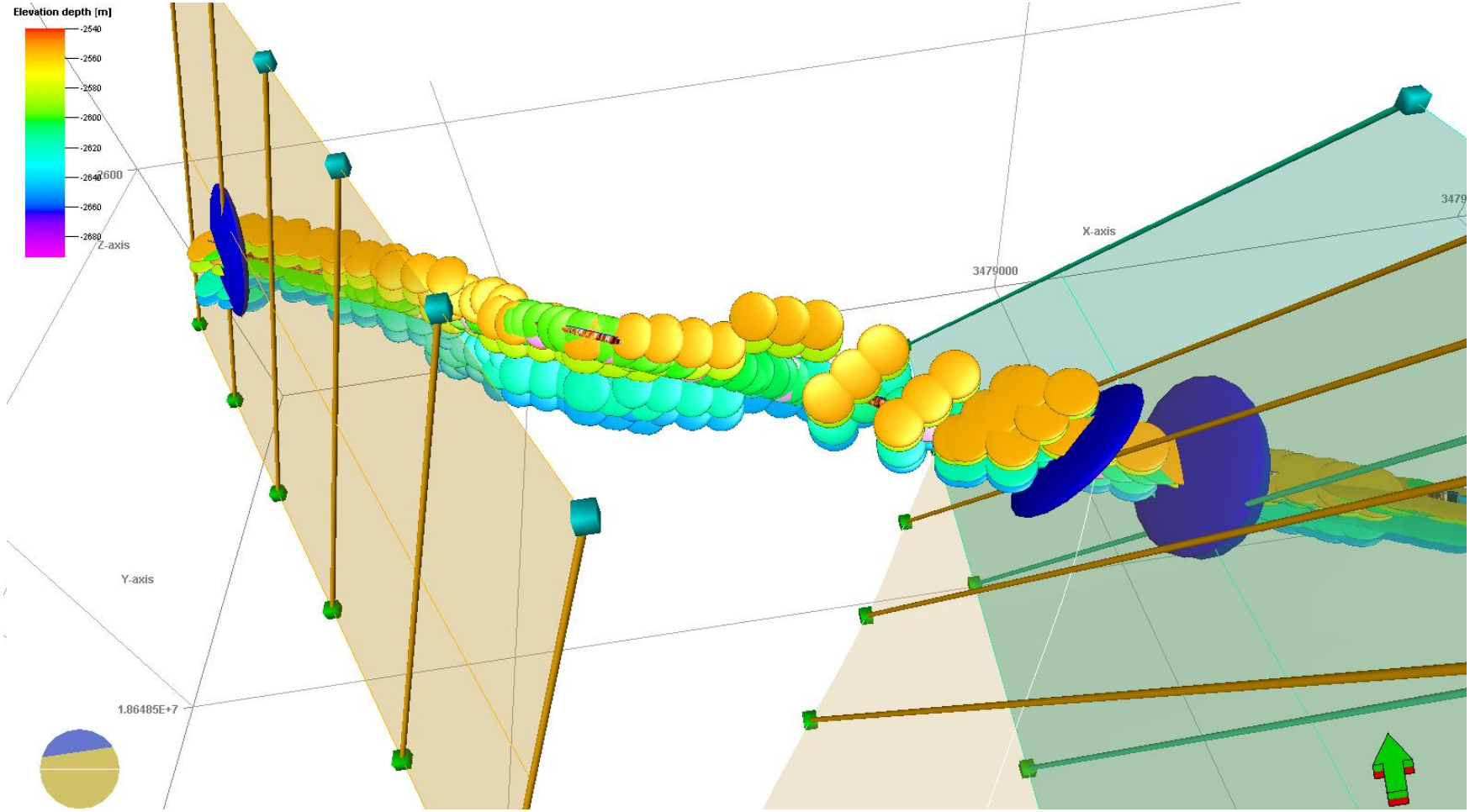
Fault Analysis





Using computed TST scale to show reservoir thickness change & analyze fault displacement

Fault Plane Characterization



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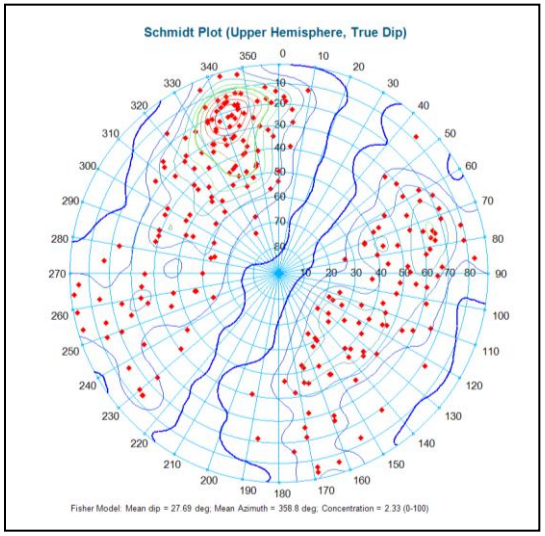
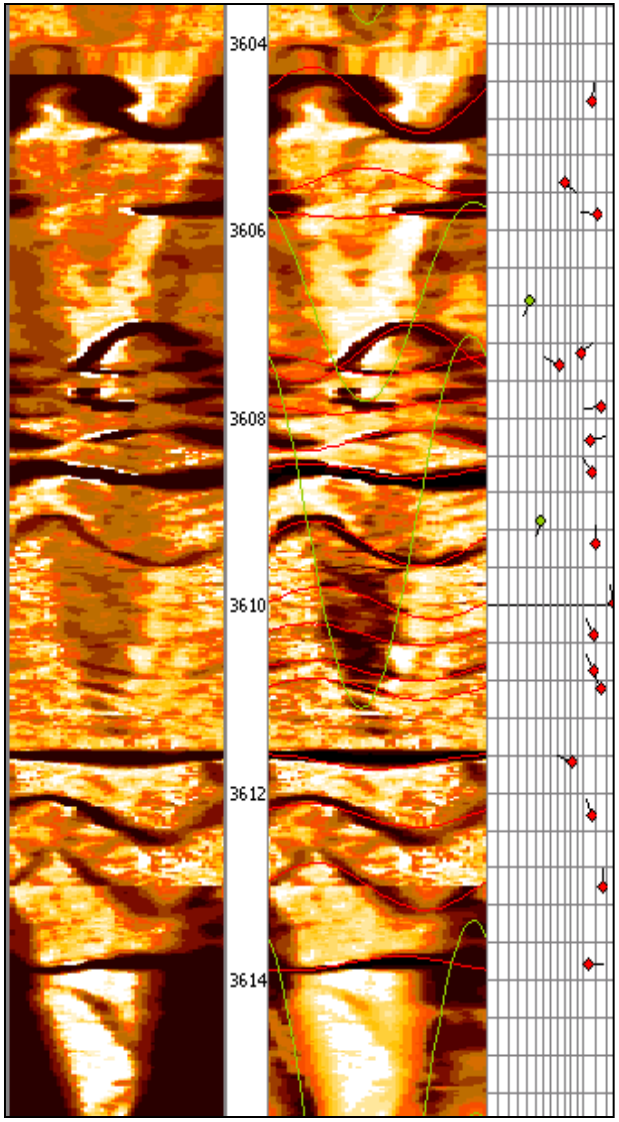
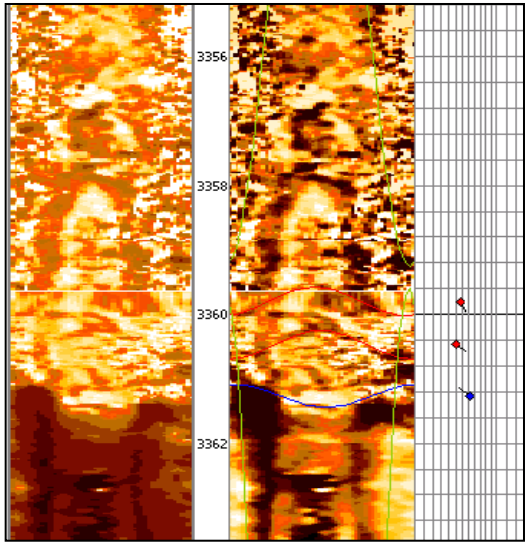
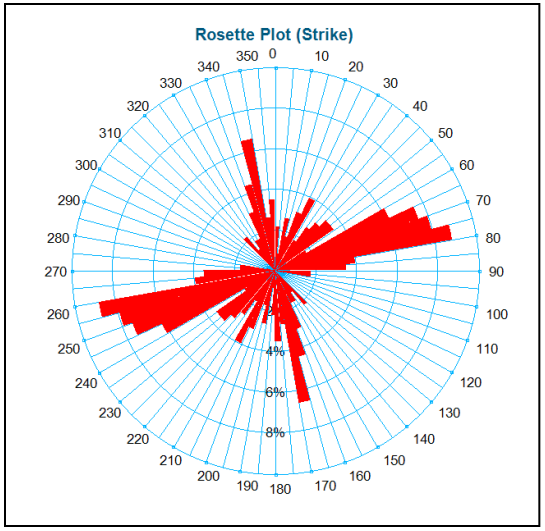
Fracture Orientation Analysis





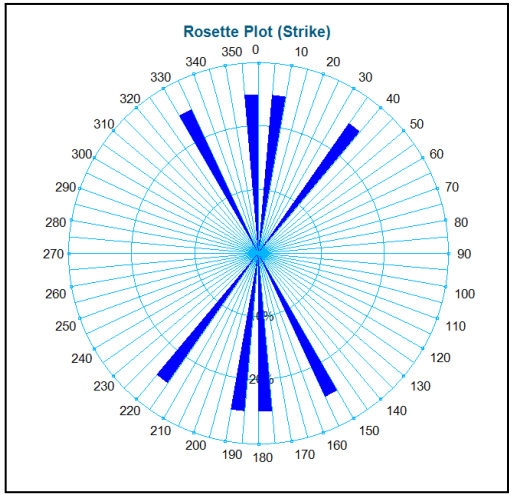


Fault plane



Fracture Strike

Fracture plane



Fault Strike

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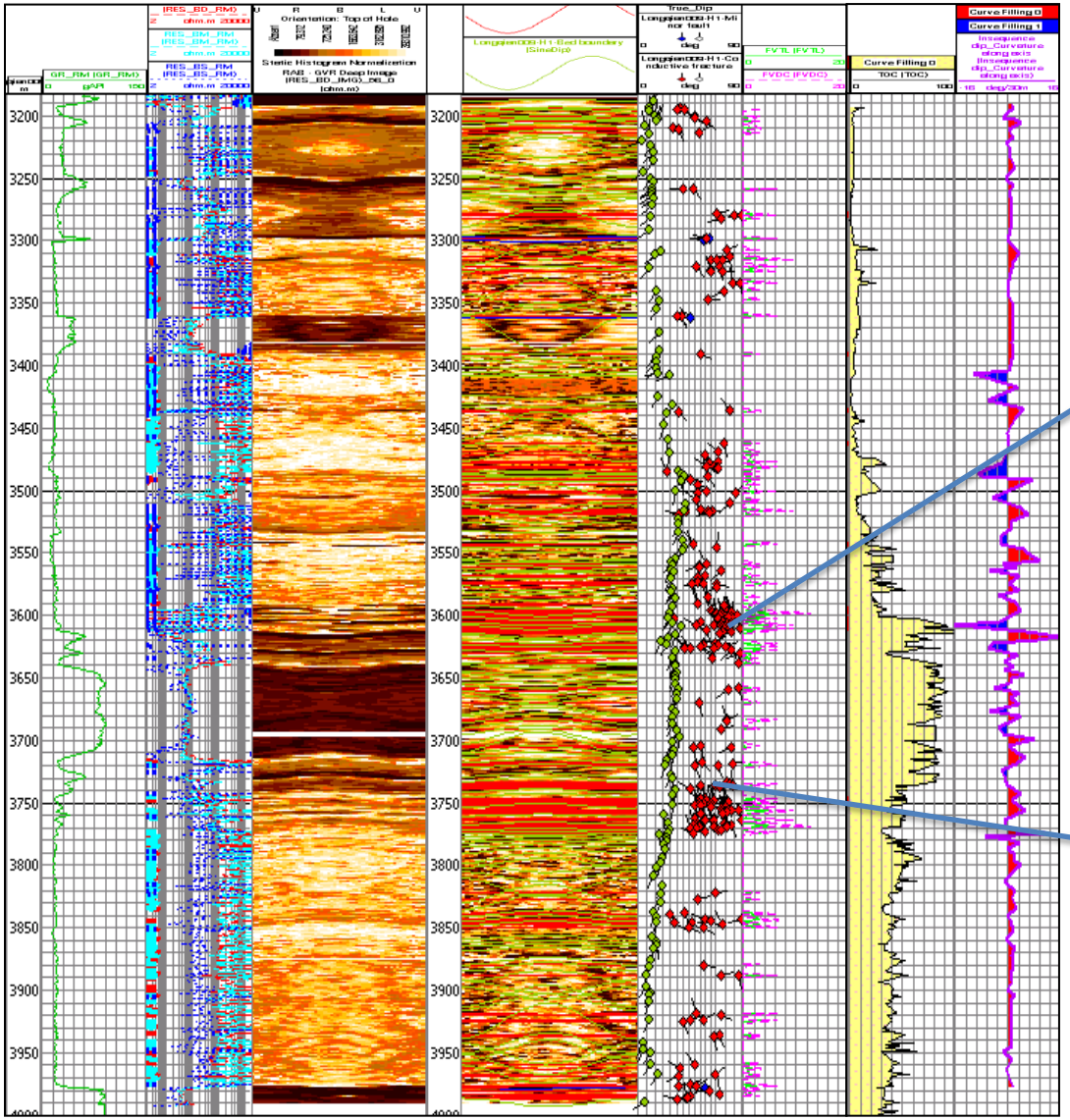
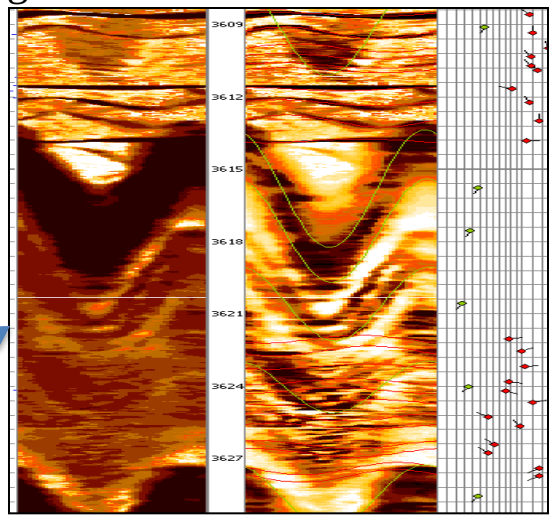
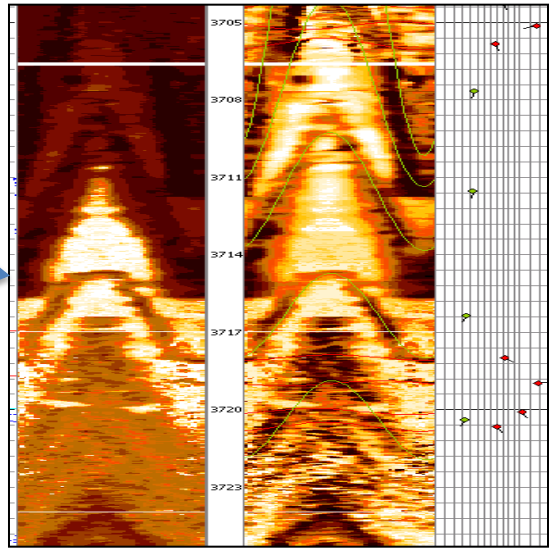
Fracture Distribution Analysis

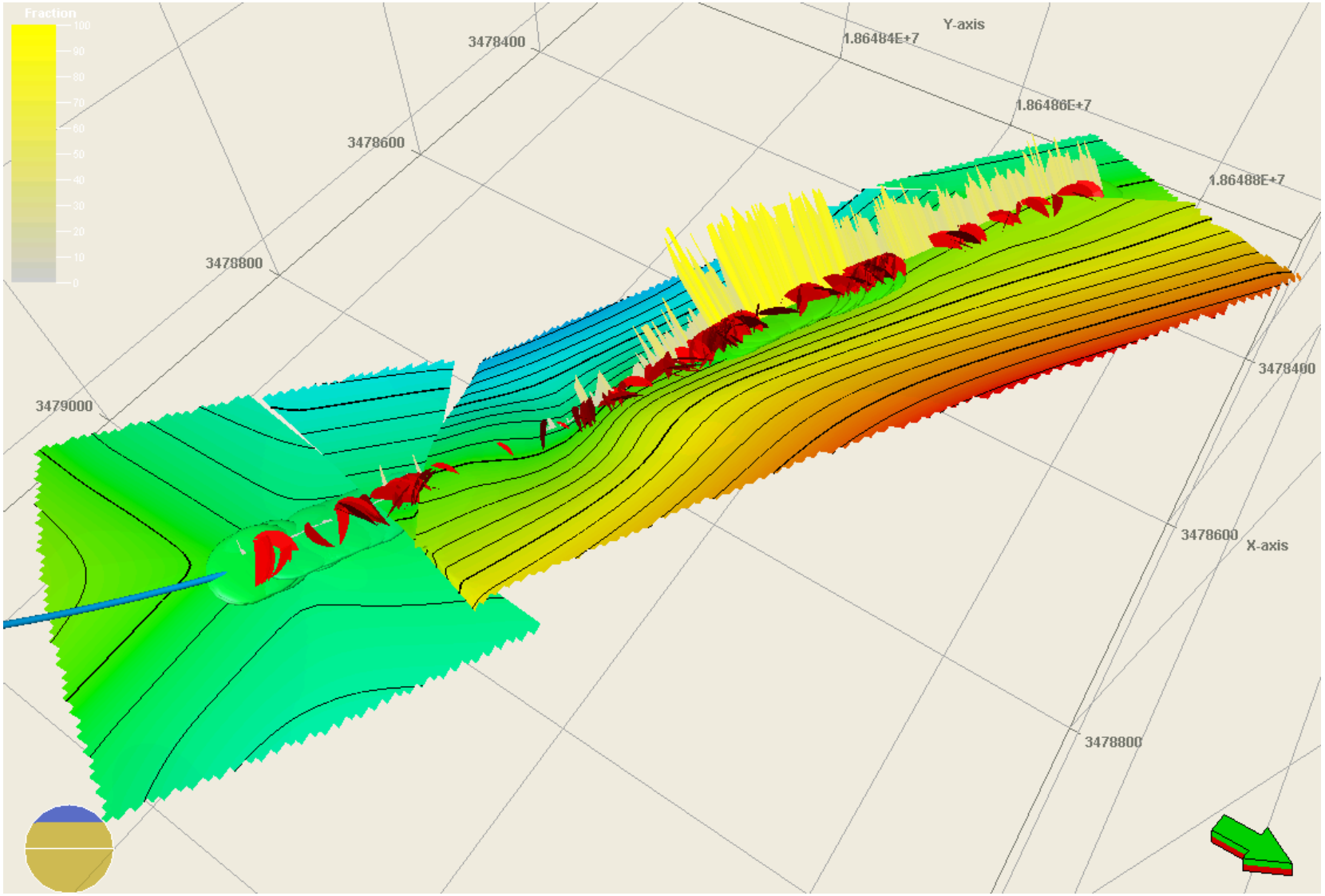


Curvature along Axis





Fracture Characterization



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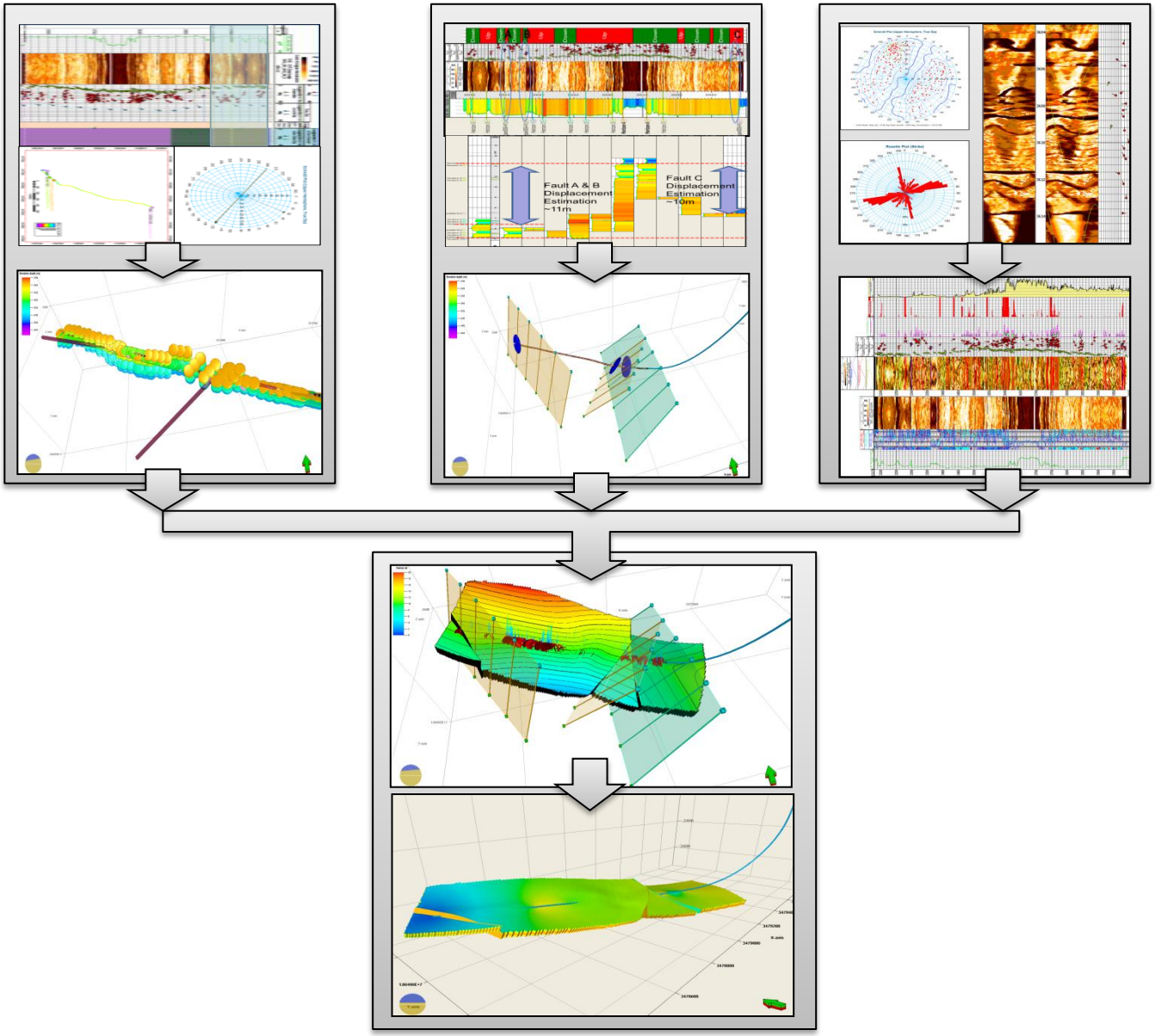
3D Near-Well Geological Modeling Workflow



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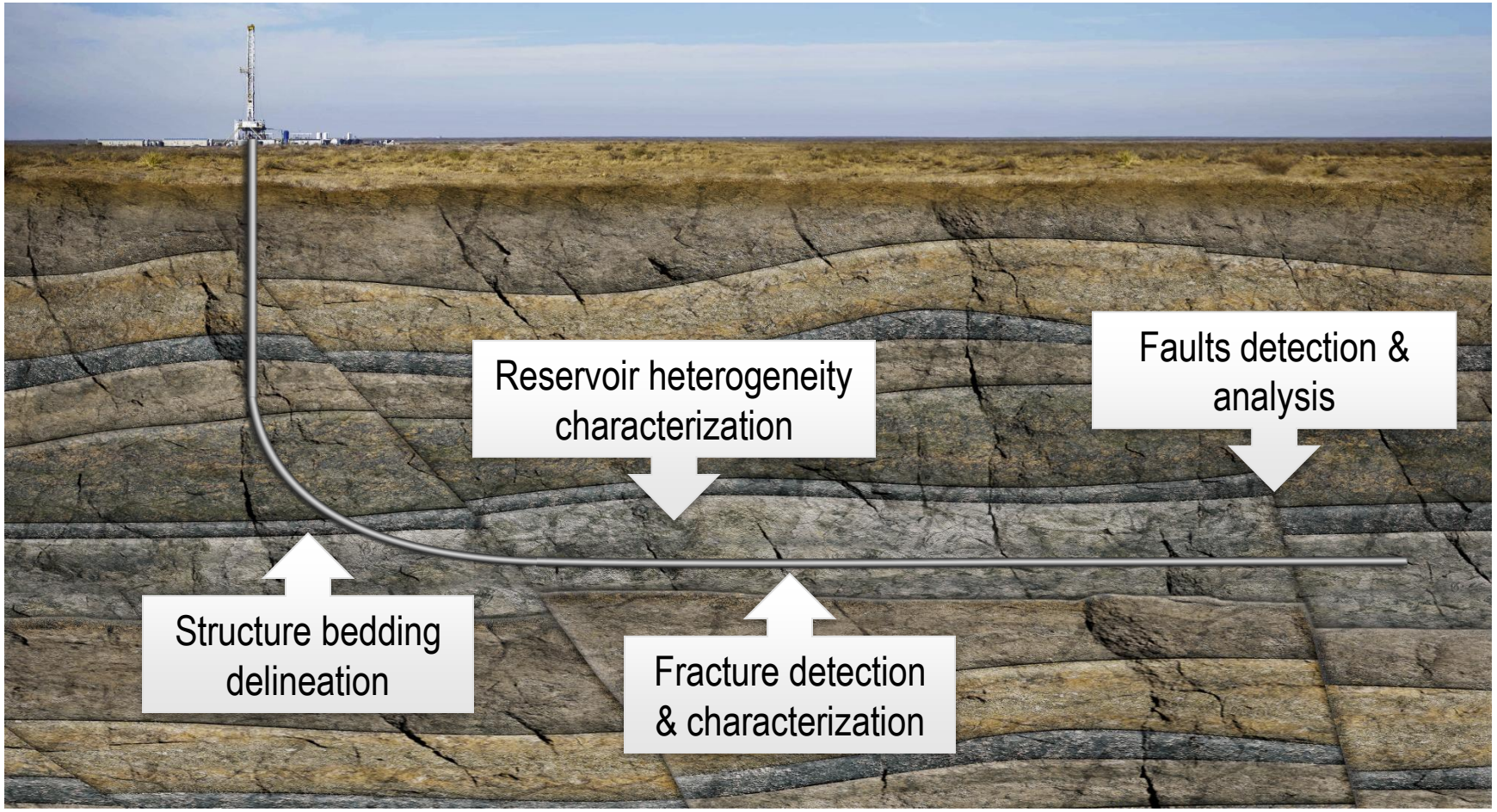
Well Completion & Stimulation Consideration



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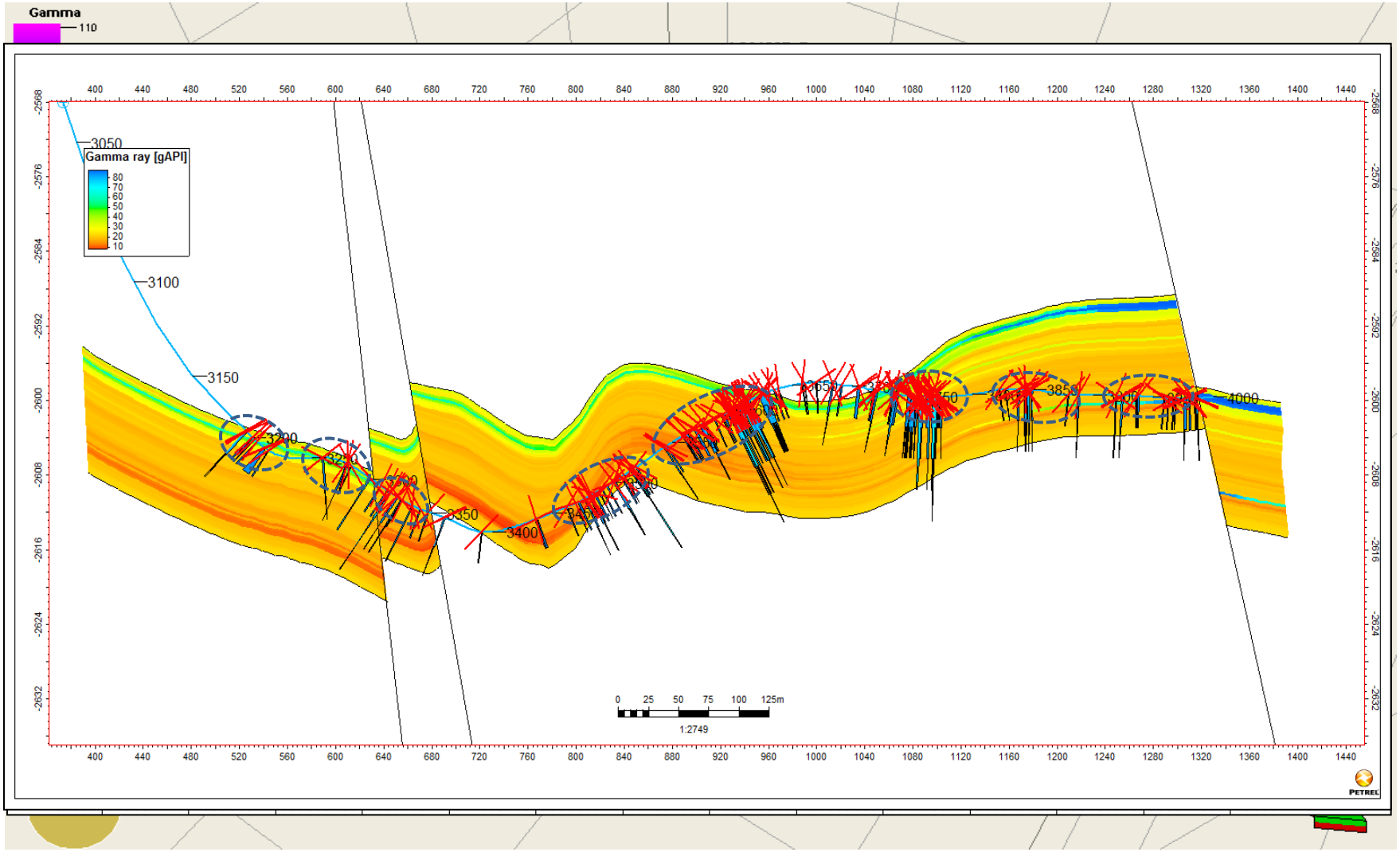
3D Near-Well Geological Modeling



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Conclusion

The unique borehole geological tool made best use of high-resolution LWD resistivity images and revealed the detail near-borehole scale faulted reservoir with open natural fractures related to both faults and structure beddings

A integrated 3D near-wellbore geological model reconstructed the geometries near-borehole and contributed to post-drilling analysis and well completion design

Acknowledgement

PetroChina for permitting us to present the results of their well information and data

Schlumberger for giving this opportunity to present the result