Practical application of real-time and post-drill integrated analysis using Techlog 3D-Petrophysics and Petrel Geosteering module on Sakhalin offshore ERD development wells

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Outline

- Horizontal Well Data Specific Challenges
- Horizontal Well LWD Data Integrated Processing
  - Multiscale Data Integration
  - LWD Data Processing Using Techlog 3D-Petrophysics
  - Well Examples
  - Impact of 3DP Processing on Interpretation Results
- Conclusions and Observations

Horizontal Wells' Data Challenges

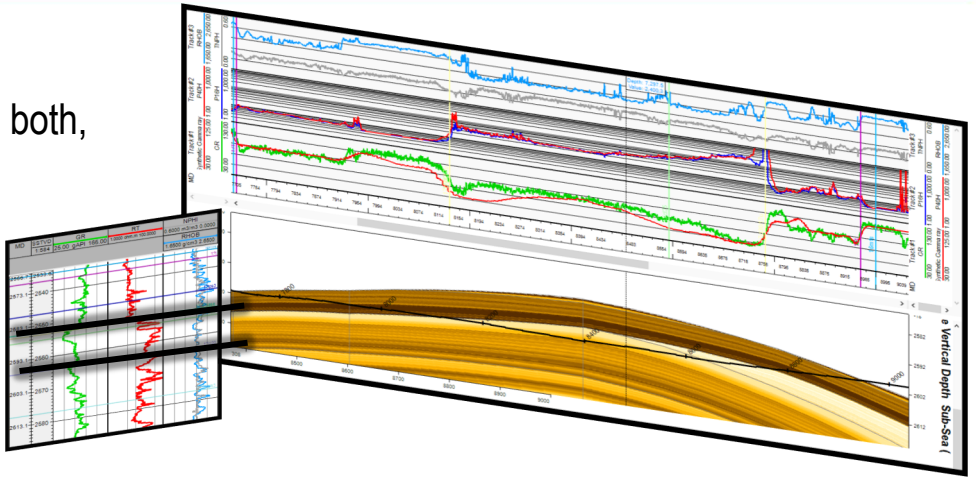
- 3D geological modelling challenge:

Generally based on spatial analysis algorithms utilizing both, horizontal and vertical variation of properties.

In Ha/Hz wells:

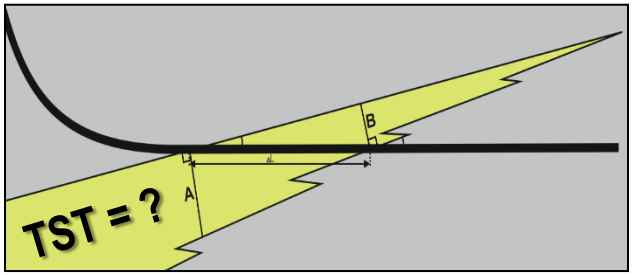
✗ No input data for vertical variogram

✓ Information on lateral distribution of layers and their properties



- Well-based Net and Net Pay thicknesses concept limitations:

Traditionally True Stratigraphic Thickness (TST) method is applied:
pay thickness (**TST**) determined using the MD distance (**ΔL**) and dip angle.



In HaHz wells:

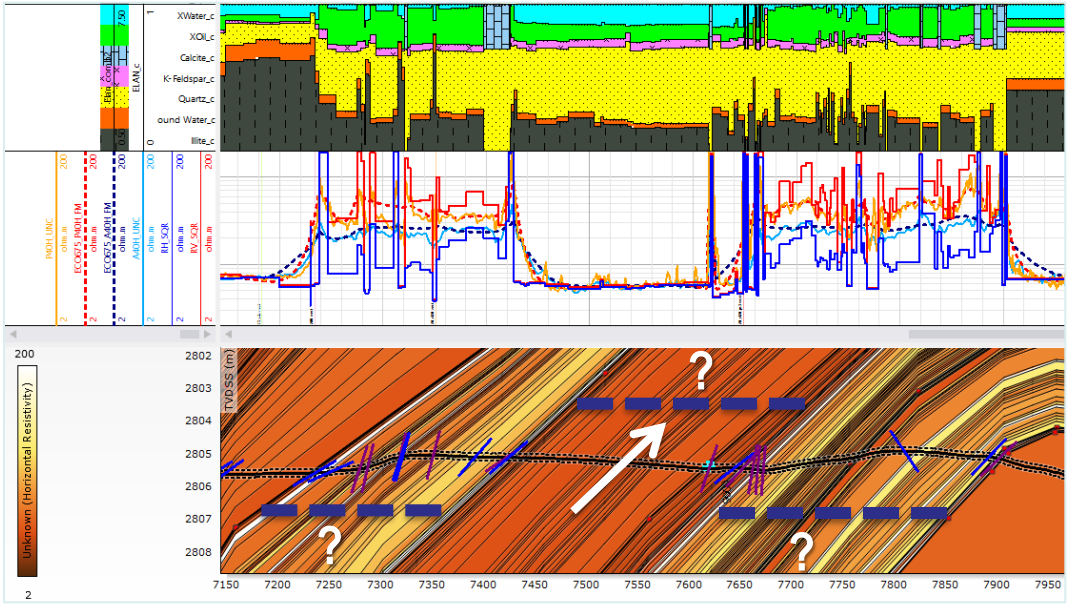
✗ Uncertainty of dip estimation using LWD image logs increases with offset

✗ Net pay thicknesses mapping using data from horizontal wells is uncertain

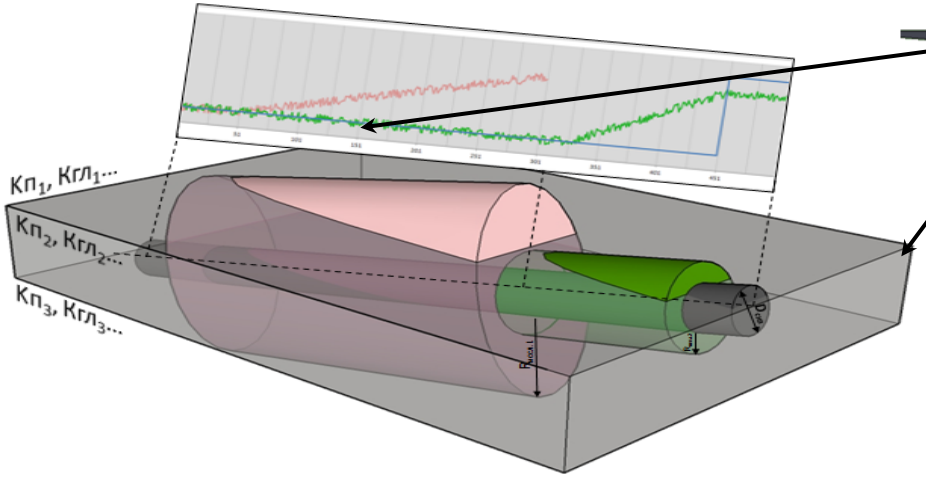
Horizontal Wells' Data Challenges

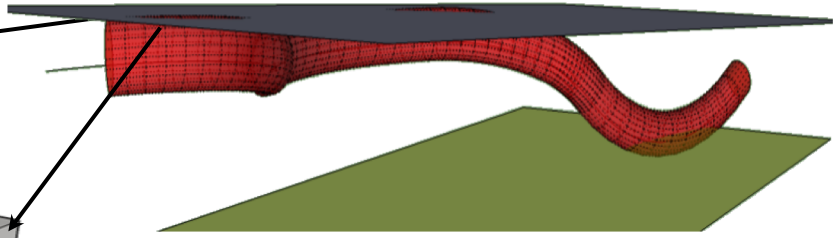
Saturation in Ha/Hz wells:

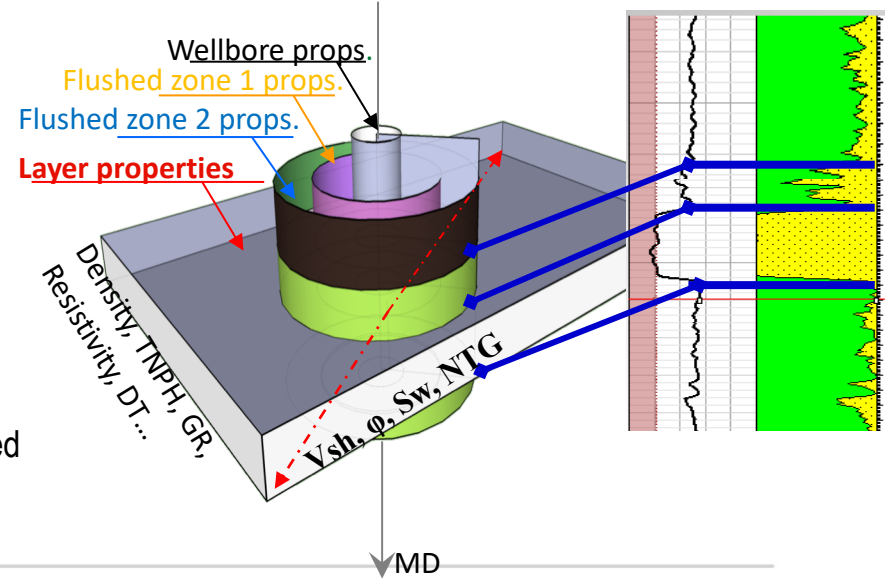
- ✘ Fluid contacts position indeterminable in most cases
- ✓ Valuable information for initial saturation distribution based on capillary pressure models and/or field development driven current saturation evaluation



Horizontal Wells' Data Challenges





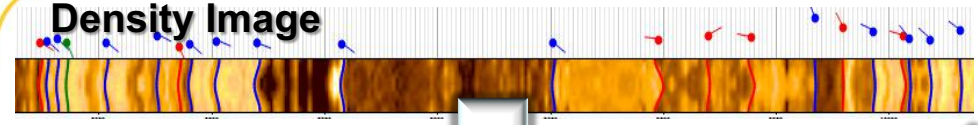


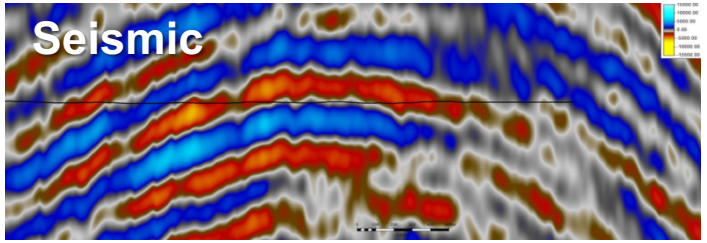
Specific environmental effects having significant impact on Ha/Hz LWD data:

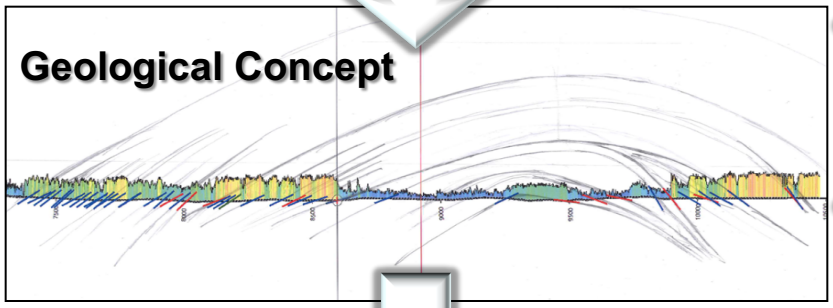
- Wellbore- bedding system geometry
- Complex formation properties (anisotropy, adjacent beds etc.)
- Wellbore geometry (keyholes, asymmetrical washouts, partial bed penetration)
- Depth of investigation matching for different logs

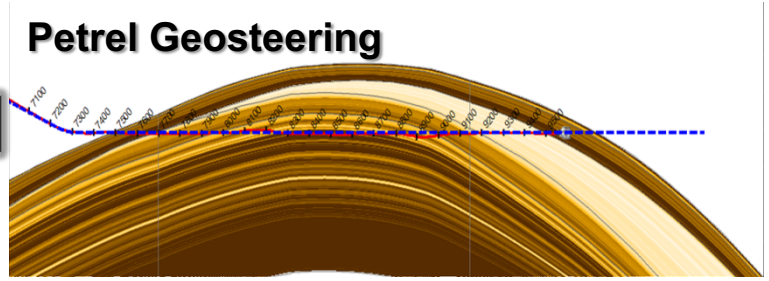
✘ **Raw LWD curves are inapplicable for reliable quantitative interpretation.**

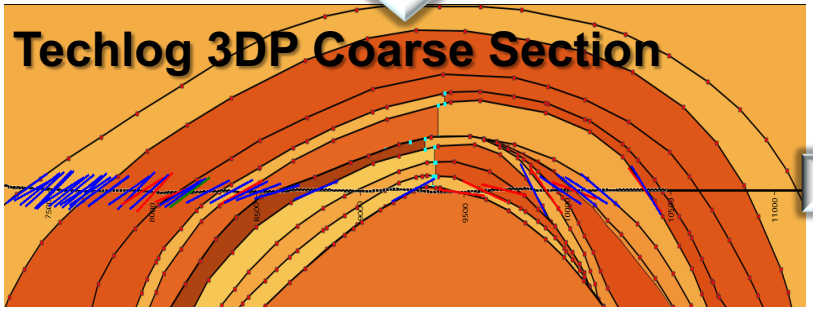
Multiscale Data Integration

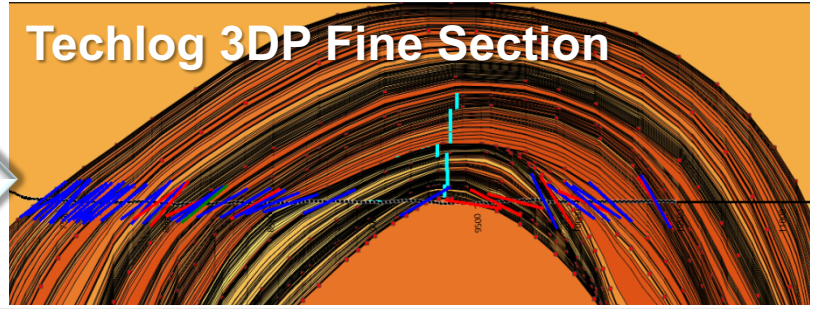






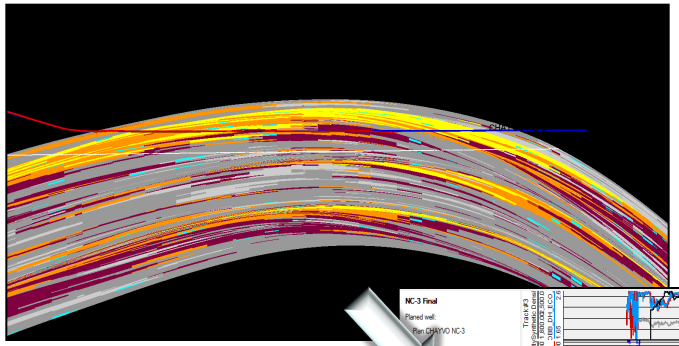




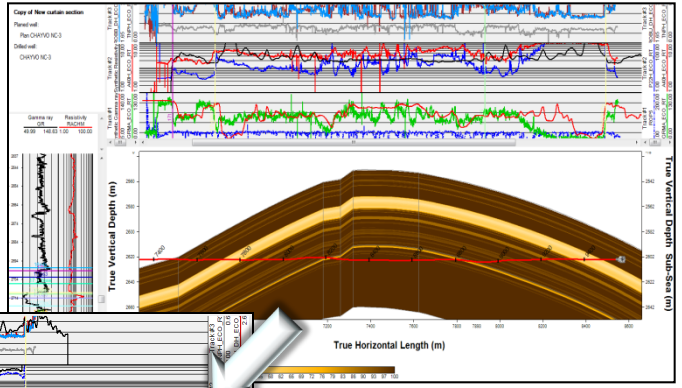


Multiscale Data Integration

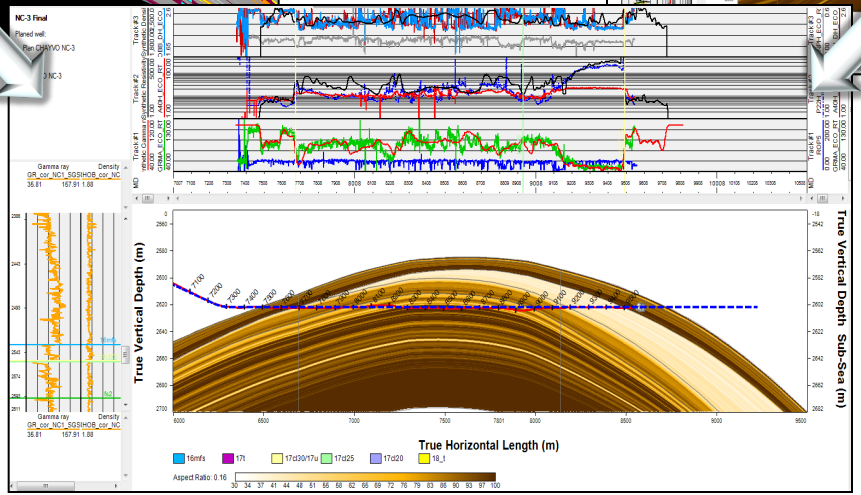
Geomodel



Standard Approach



Petrel Geosteering based detailed coarse well section



Advantages:

- Direct integration with geomodel using single platform
- Lateral layer thickness variation driven by the geomodel
- Target formation penetration depths reliable forecast while drilling

Combined Approach

Integrated LWD Data Processing Workflow

Techlog 3D Petrophysics Workflow:

Curtain section creation along the wellbore trajectory

- Image Logs
- Seismic
- Geosteering results

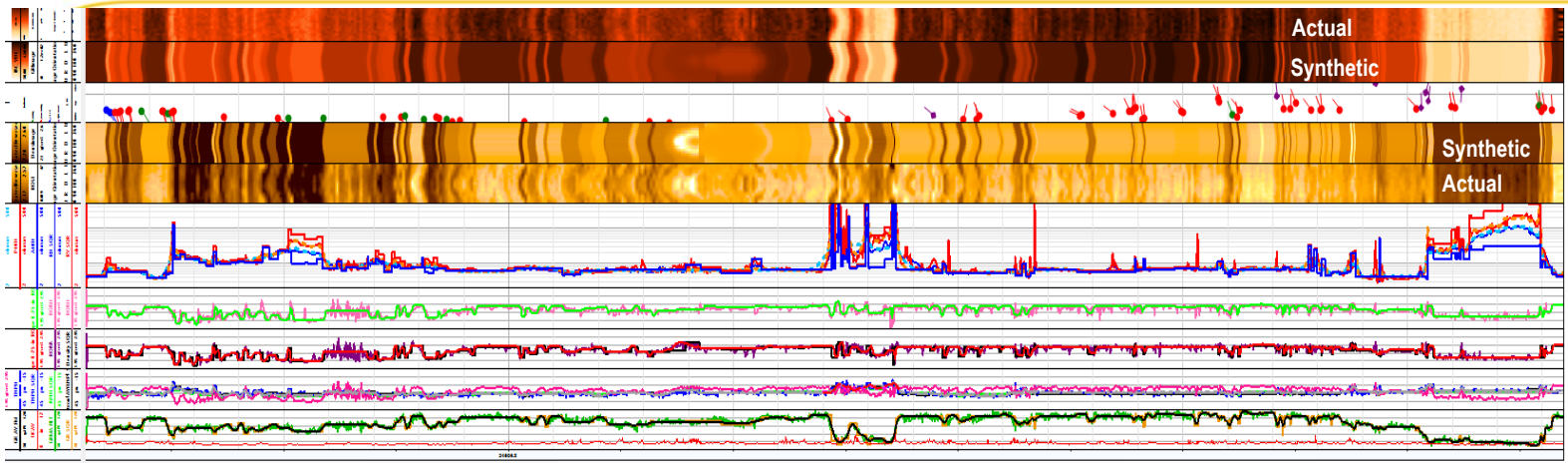
Modelling log responses and section refinement

- Density and PEF
- Natural Radioactivity (GR)
- Neutron Porosity
- Vertical and Horizontal Resistivity

Model based properties square logs

- Applicable for interpretation

Well Example. 3DP Forward Modelling Results



GR Image

Dips from Dens Image

Density Image

Resistivity

A40 / A40_model

P40 / P40_model

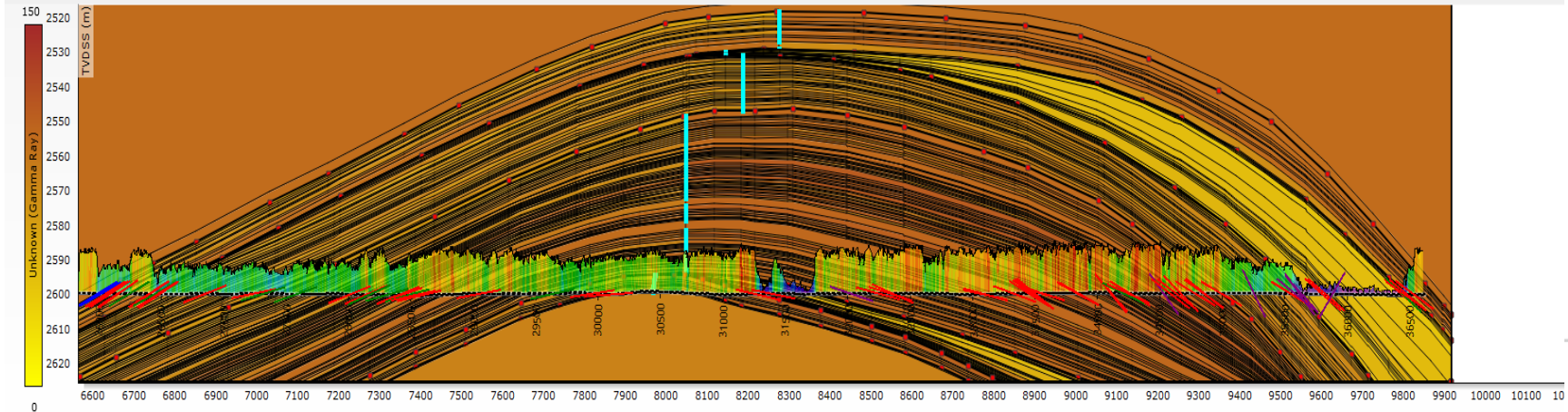
Density

Up / Up_model

Bottom / Bottom_model

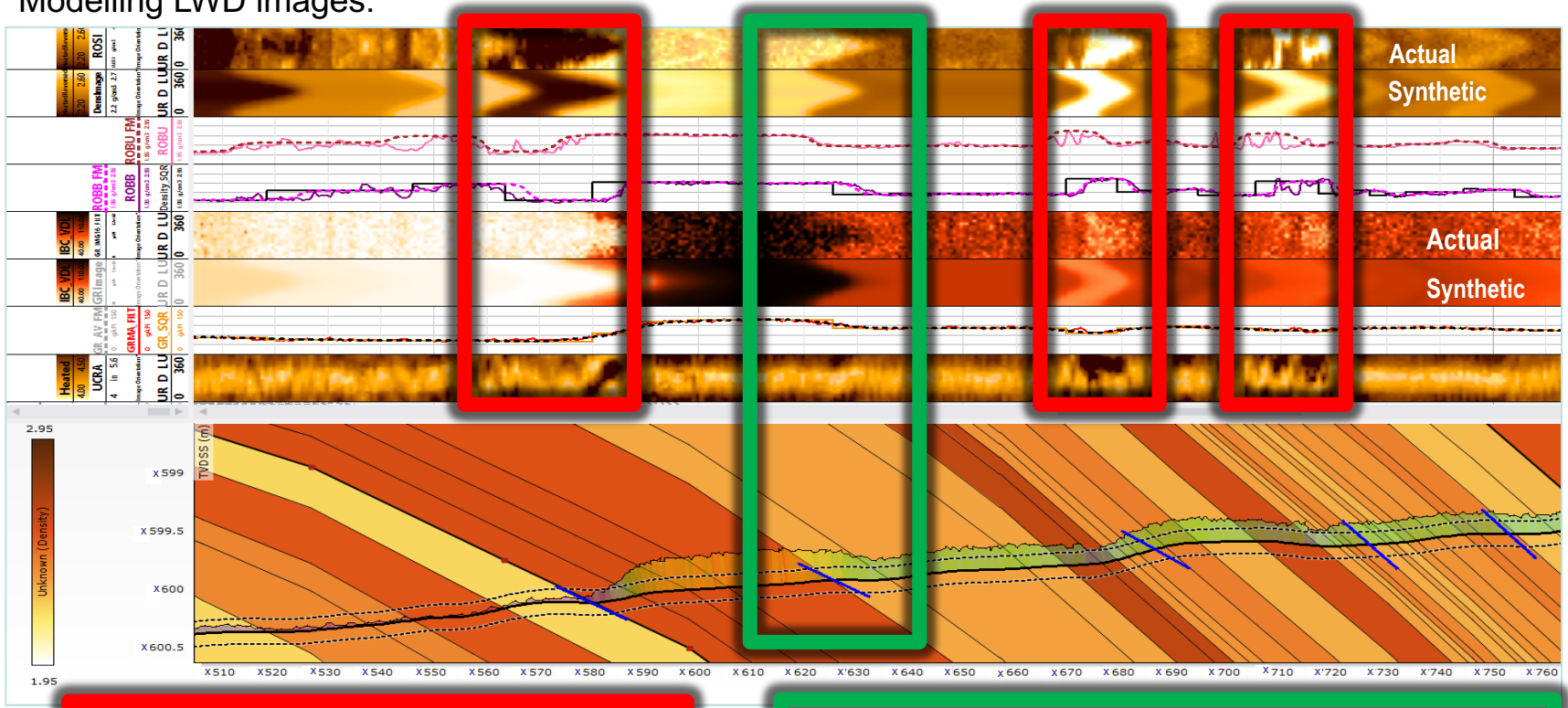
Density_ave / Neutron / Neutron_model

GR_ave / GR_model



3DP. Using Image Logs Data

Modelling LWD images:

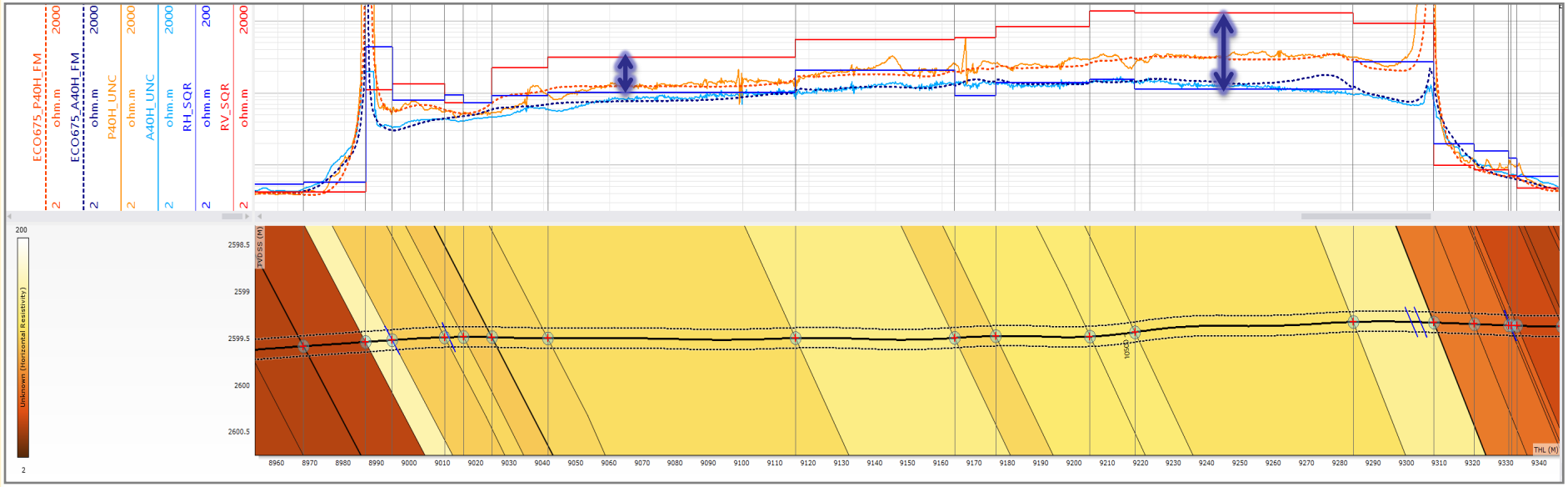


Low image data quality due to well shape imperfection

Dip picking uncertainty reduction using forward modelling techniques

3DP. Anisotropy

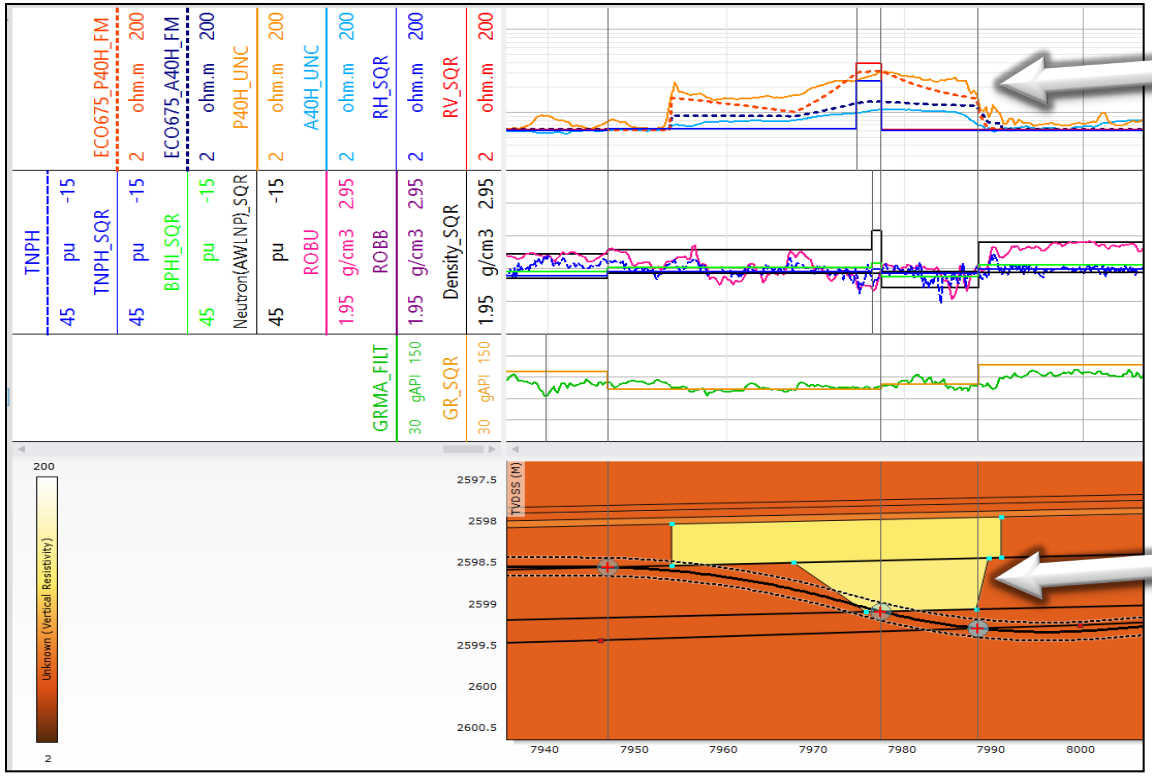
Anisotropy impact on resistivity log responses:



Significant anisotropy identified by the resistivity forward modelling application.
Investigating the possible link with flow anisotropy, currently work in progress.

3DP. Visualisation

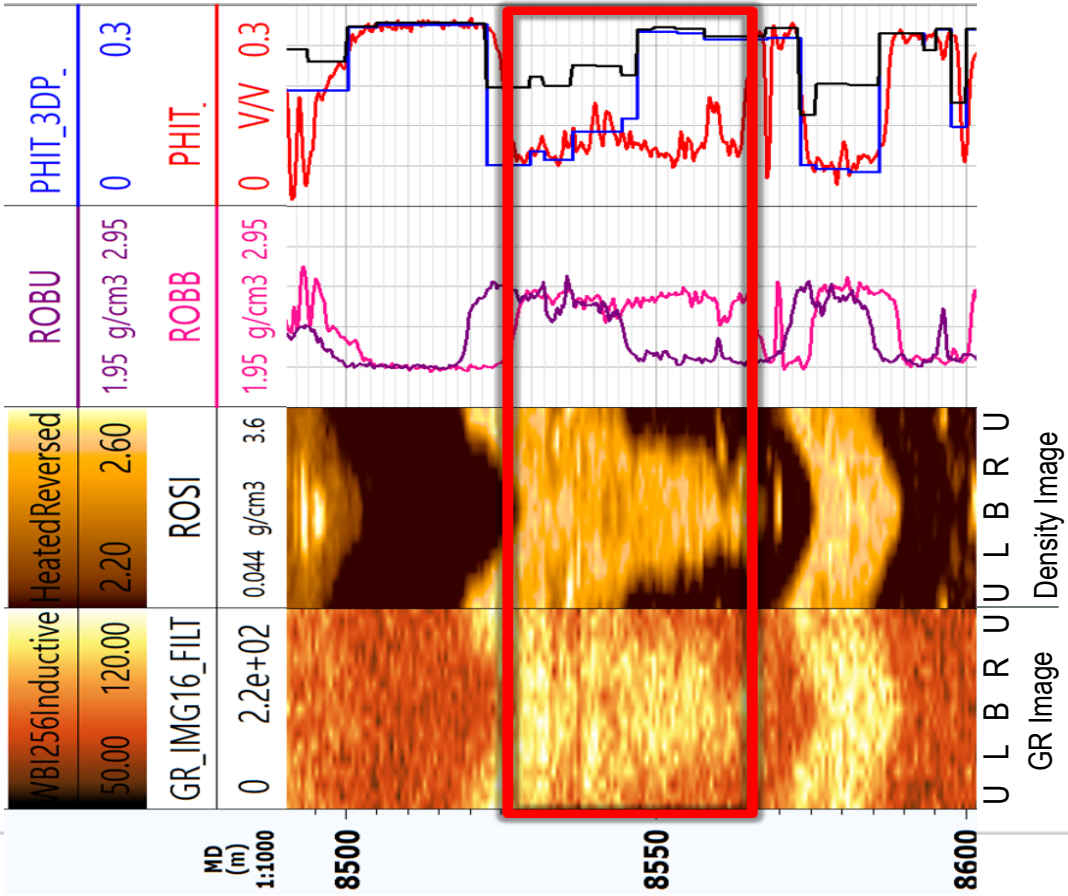
Reducing the interpretation uncertainty in HA/HZ environment:



Standard raw LWD data driven interpretation suggests HC reservoir presence

3DP visualization and modelling results attribute the resistivity increase to the adjacent tight carbonate cemented streak

3DP. Results of Porosity Estimation

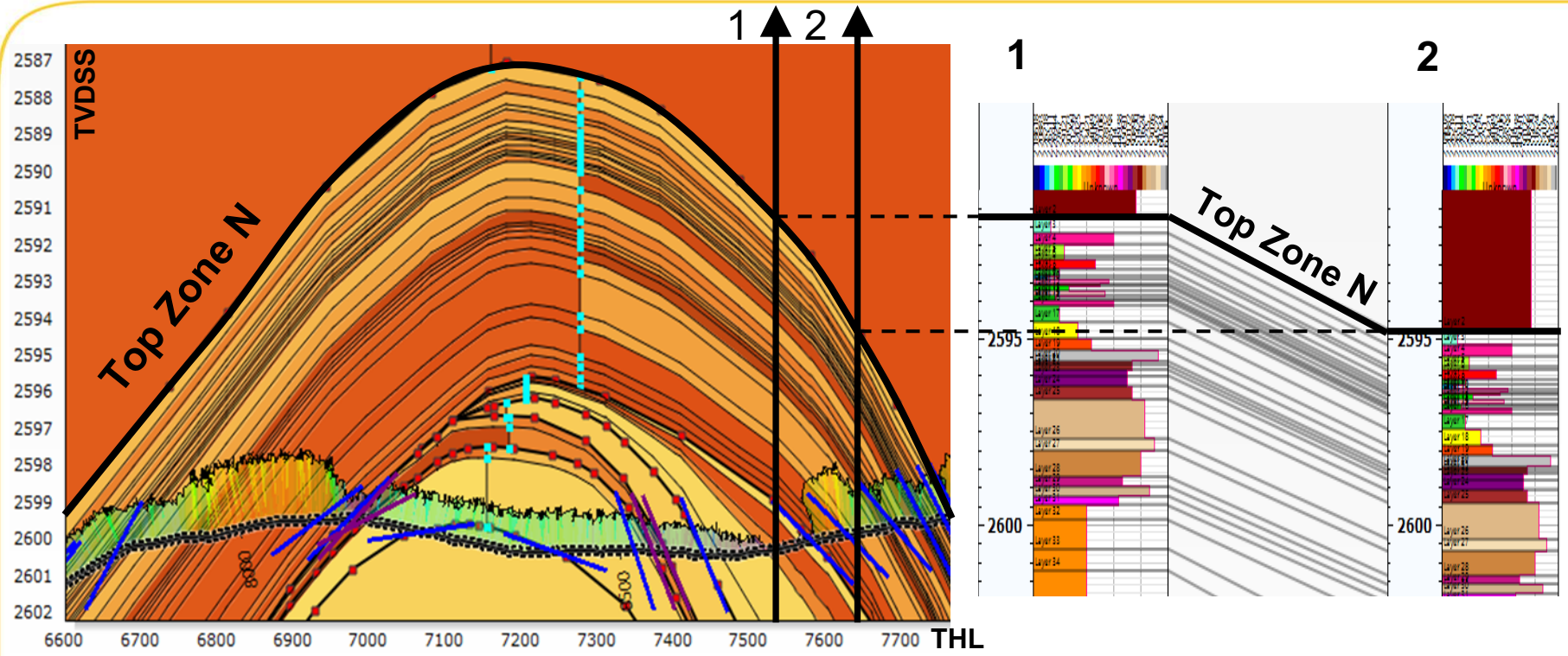


Using 1 density quadrant curve leads to uncertainties in porosity estimations.

Traditionally porosity is calculated using bottom density quadrant (PHIT), here being underestimated due to borehole imperfection

3DP approach (PHIT_3DP) allows more adequate porosity estimation leading to **17 m** Net length increase

Forward-modelling based processing results application

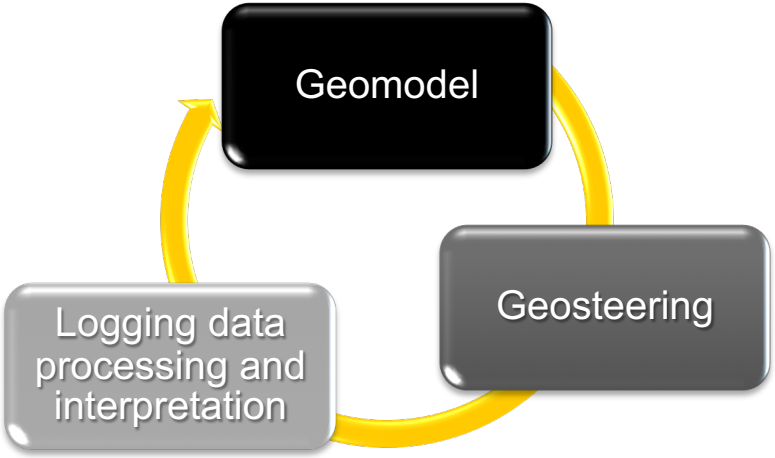


Synthetic wells 1 and 2 “penetrate” the modelled section at chosen THL values. Selected sections of those wells can aid the geological model verification and even vertical adjustment.

Conclusions and Observations

Conclusions

- 3DP forward model based square properties logs along the well trajectory provide more reliable input for quantitative formation evaluation
- Fine scale bed geometry modelling using the image data and forward model based multi-log verification process provide additional basis for HA/HZ log data integration with the field scale geologic model



Observations

- Cross-application data link enhancement would improve the quality of obtained results and increase the integration process speed
- Automation of accounting for LWD radii image would improve the understanding of wellbore – layer system geometry.
- Deep sensing LWD data integration (e.g. GeoSphere) would drastically improve the value of Ha/Hz wells data for the spatial interpretation and refinement of geologic model.