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IMPROVING RESERVOIR SIMULATION MODELING WITH SEISMIC ATTRIBUTES

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Schlumberger

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AGENDA

- Seismic attributes description
- Horizon and fault interpretation
- Geological modeling
- Facies modeling
- Property modeling
- Conclusions

OUTLINE

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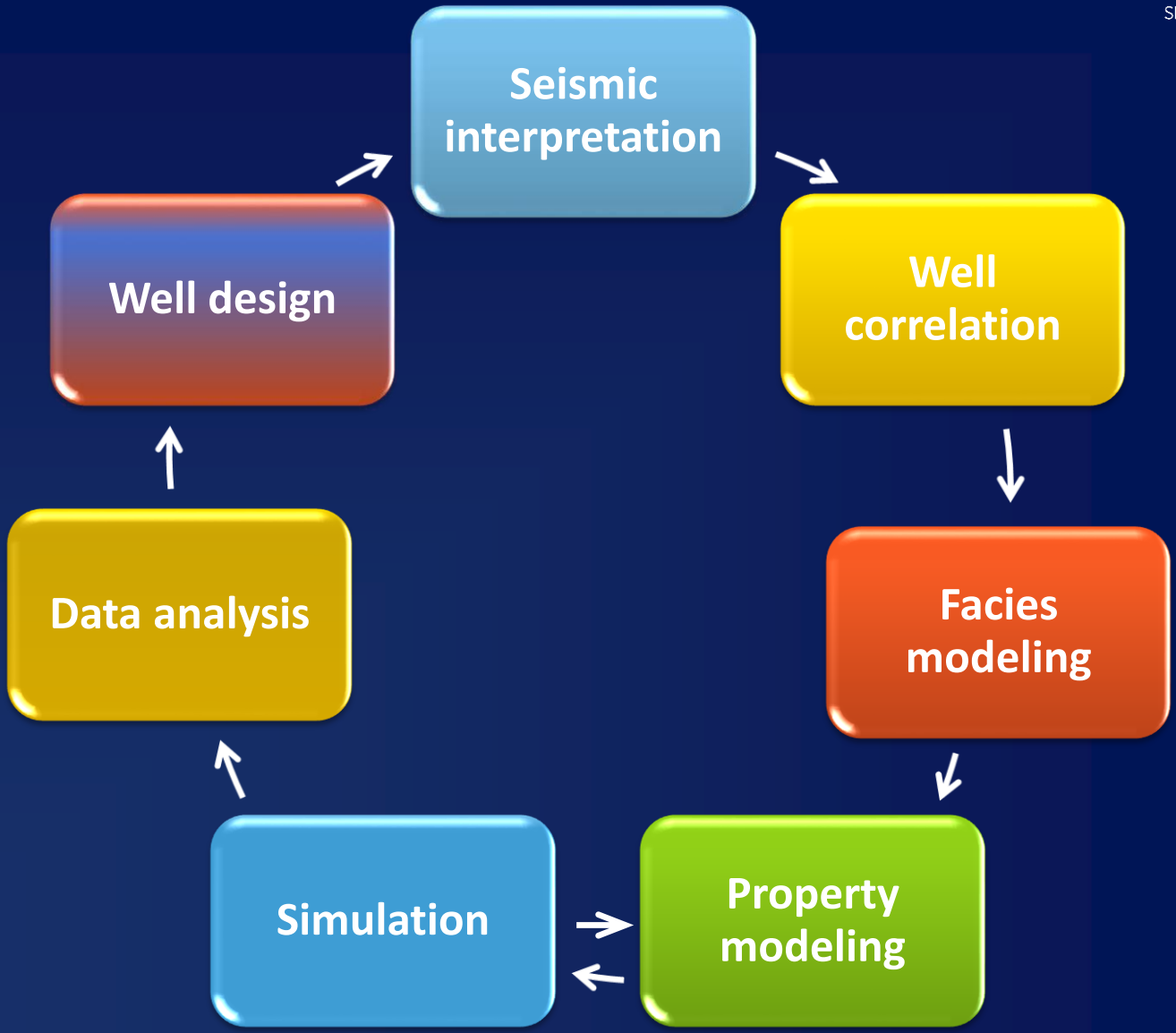
- Seismic interpretation is an integrated part of the reservoir modeling process.
- Besides standard structural interpretation of horizons and faults, seismic attributes make a major contribution to geological modeling.
- Seismic attributes provide very useful information regarding stratigraphy, facies distribution, and reservoir properties.

INTEGRATED RESERVOIR MODELING



HOW CAN SEISMIC HELP?

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- The sound waves are reflected and refracted by different rock layers and they are captured on the surface by sensors.
- The analysis of the time the waves take to return to surface and the changes in their properties, provides important information about the rock types, their properties and possible fluid content.
- Different types of seismic processing, computation and interpretation can generate several surface and volume attributes that can be used to better understand and characterize the hydrocarbon reservoirs.

SEISMIC ACQUISITION AND INTERPRETATION

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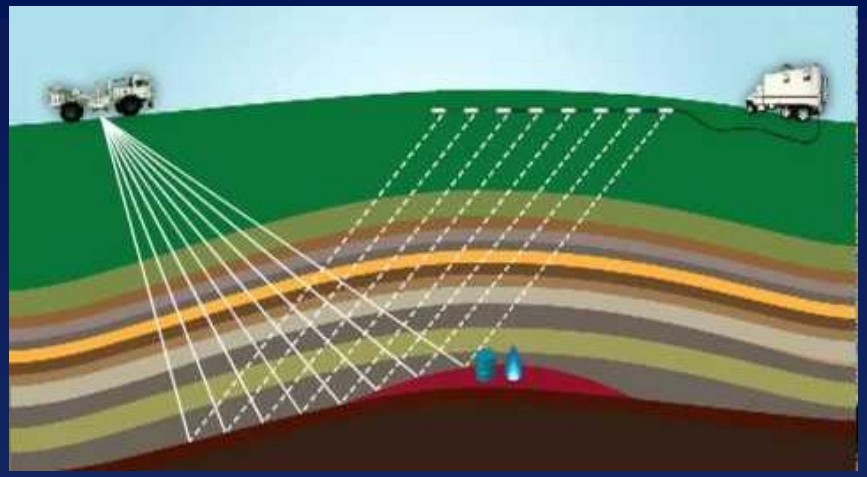
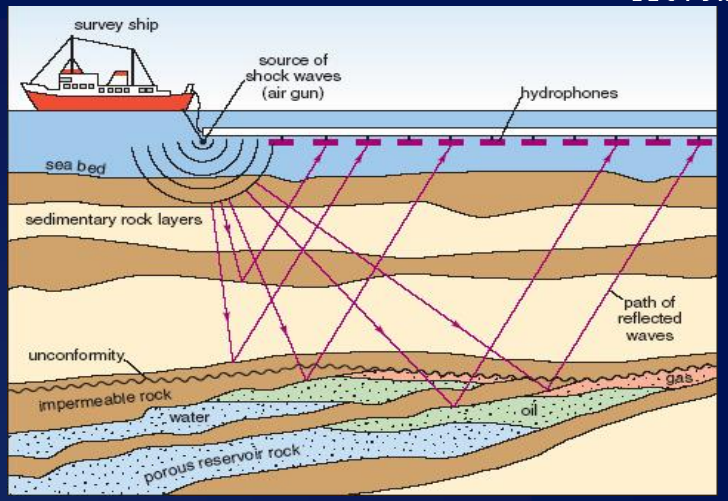
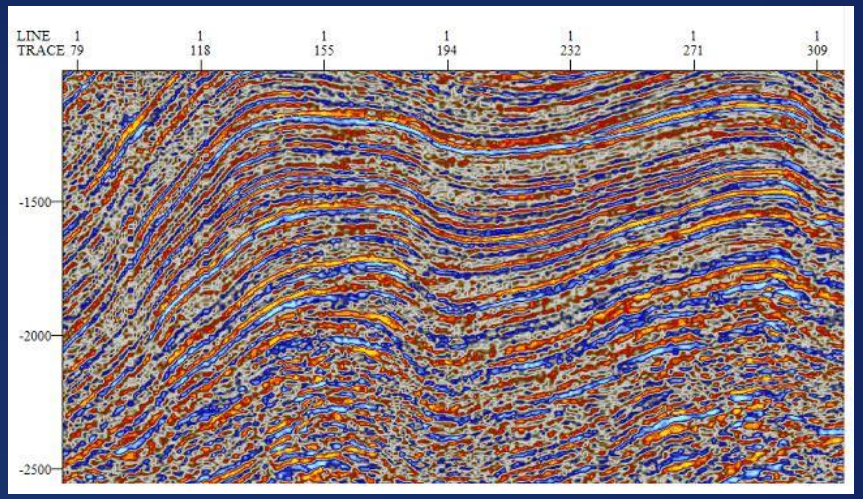


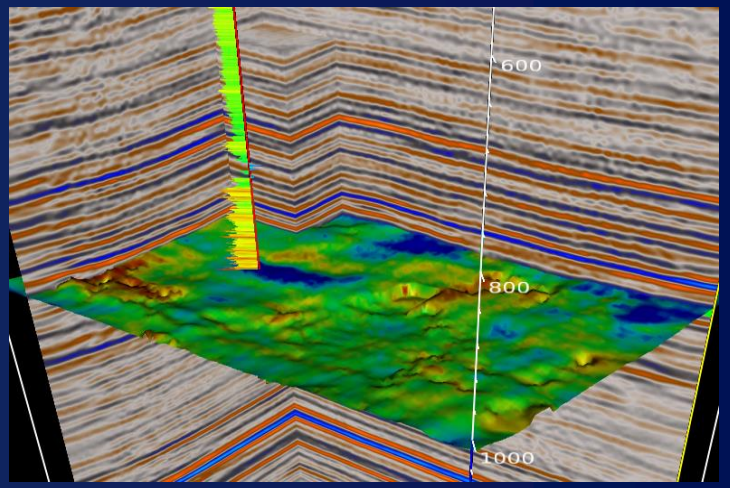
Land seismic acquisition



Offshore acquisition



Processed seismic trace



Seismic attributes extraction

SEISMIC ATTRIBUTES APPLICABILITY

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- The seismic attributes are most often used in siliciclastic reservoirs (sandstones).
- Compared with sandstones, the carbonates present many challenges, such as: stronger lateral variations in rock properties, facies changes, velocity dispersion due to permeability heterogeneity, etc.
- All of these characteristics make quantitative analysis in carbonate reservoirs more difficult.

J. Wang, D. Dopkin – Visualization, Analysis, and Interpretation of Seismic Attributes for Characterizing a Carbonate Reservoir. 7th International Conference & Exposition on Petroleum Geophysics, Hyderabad, India, 2008. P-375

WORKFLOW

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- Seismic interpretation: horizons and faults
- Volume and surface attributes extraction
- Correlation with petrophysical properties from wells
- Use of seismic attributes for facies and property modeling

VOLUME ATTRIBUTES

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- Volume attributes are extracted inside a 3D seismic cube, based on various properties of the analytical signal.
  - Structural attributes – for horizons and faults interpretation
  - Stratigraphic attributes – for lithology and facies interpretation
  - AVO attributes – for fluid and lithology interpretation

HORIZON INTERPRETATION

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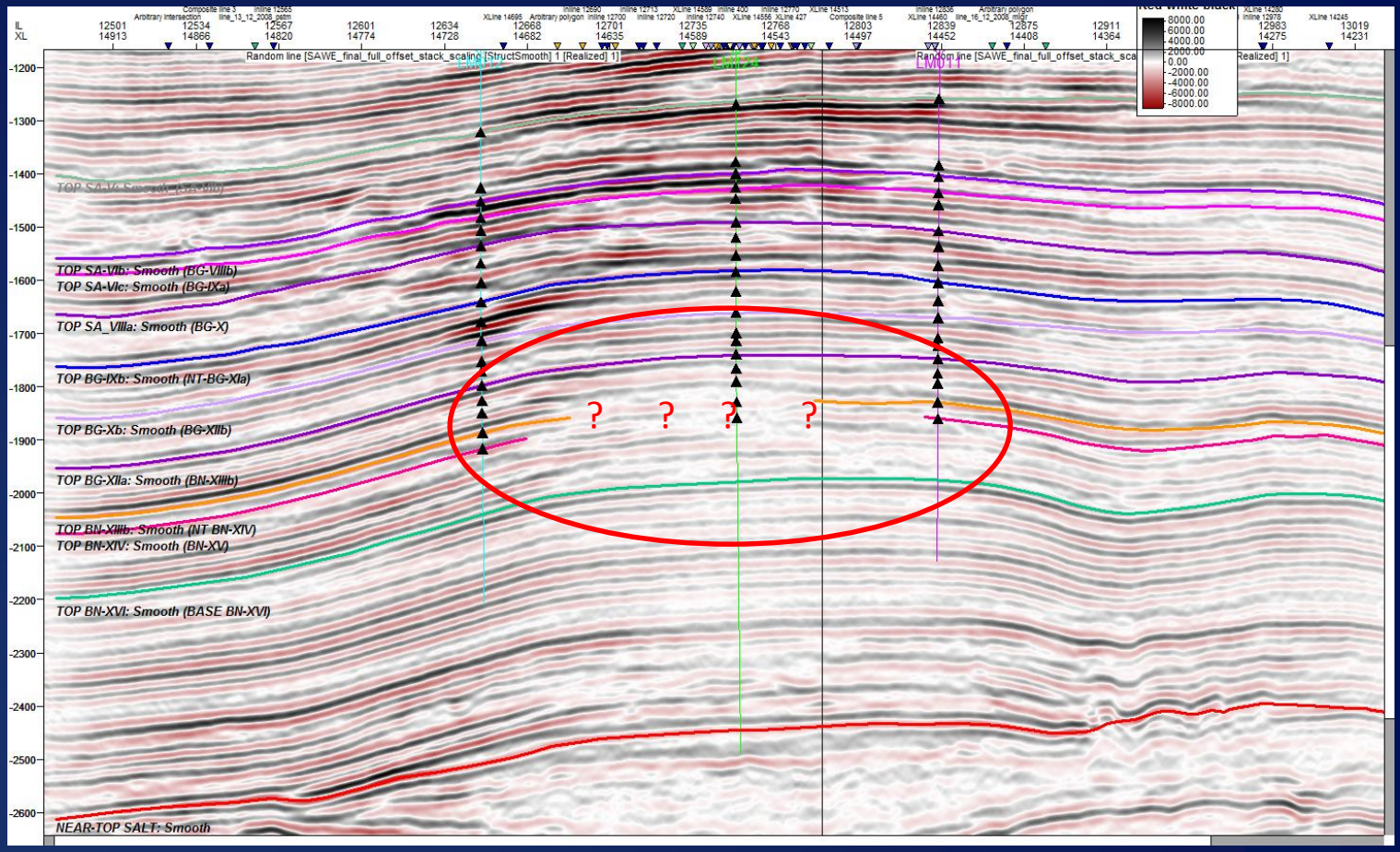
- Sometimes the seismic signal is poor and horizon interpretation can be difficult.



SEISMIC ATTRIBUTES FOR STRUCTURAL INTERPRETATION

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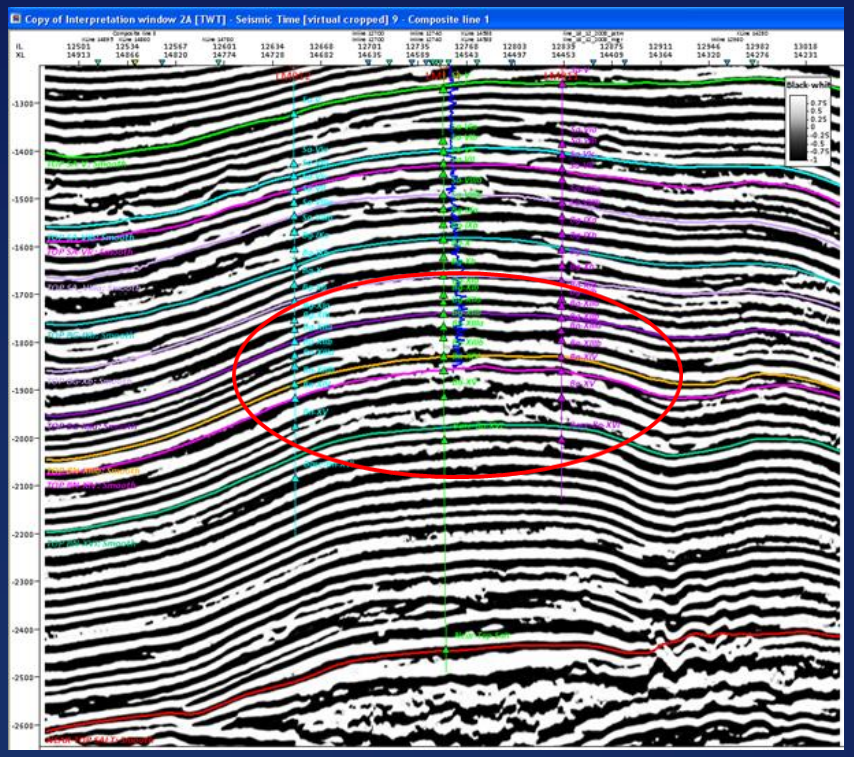
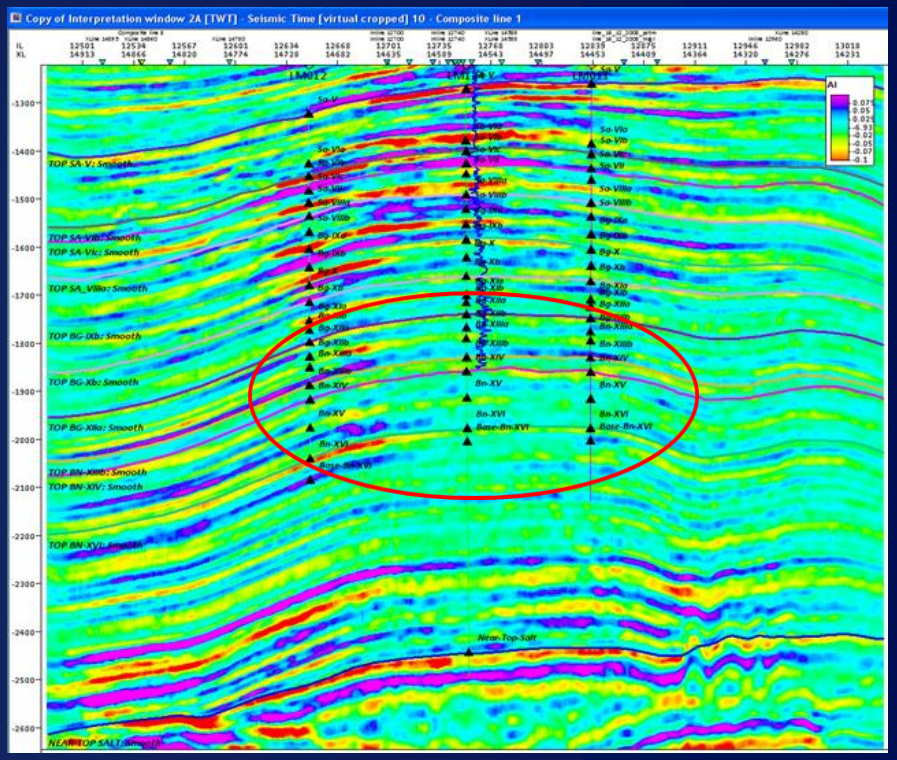
- Volume attributes can be used to help with the horizon interpretation when the seismic signal is poor.



Cosine of phase



Relative Acoustic Impedance

HORIZON INTERPRETATION

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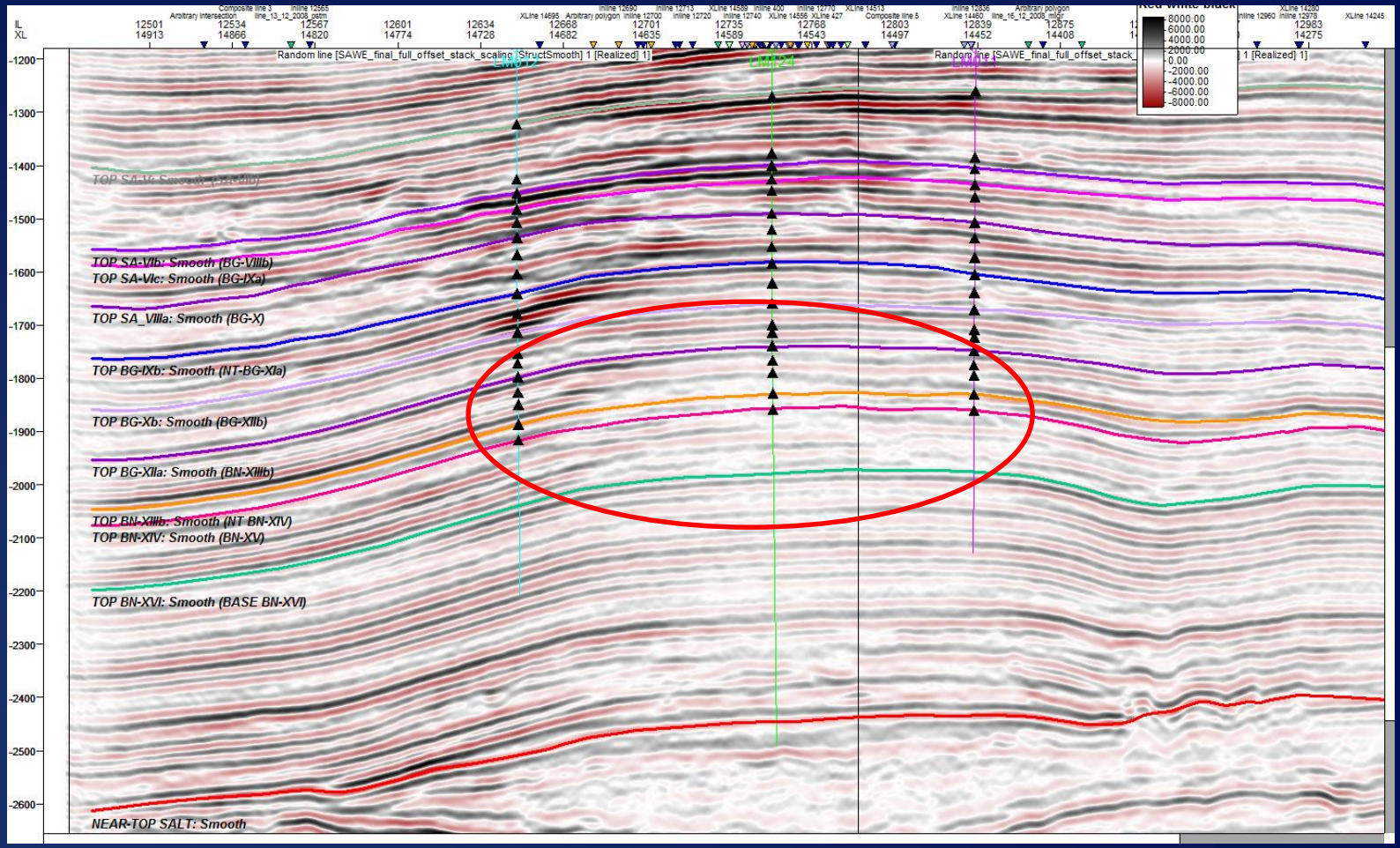
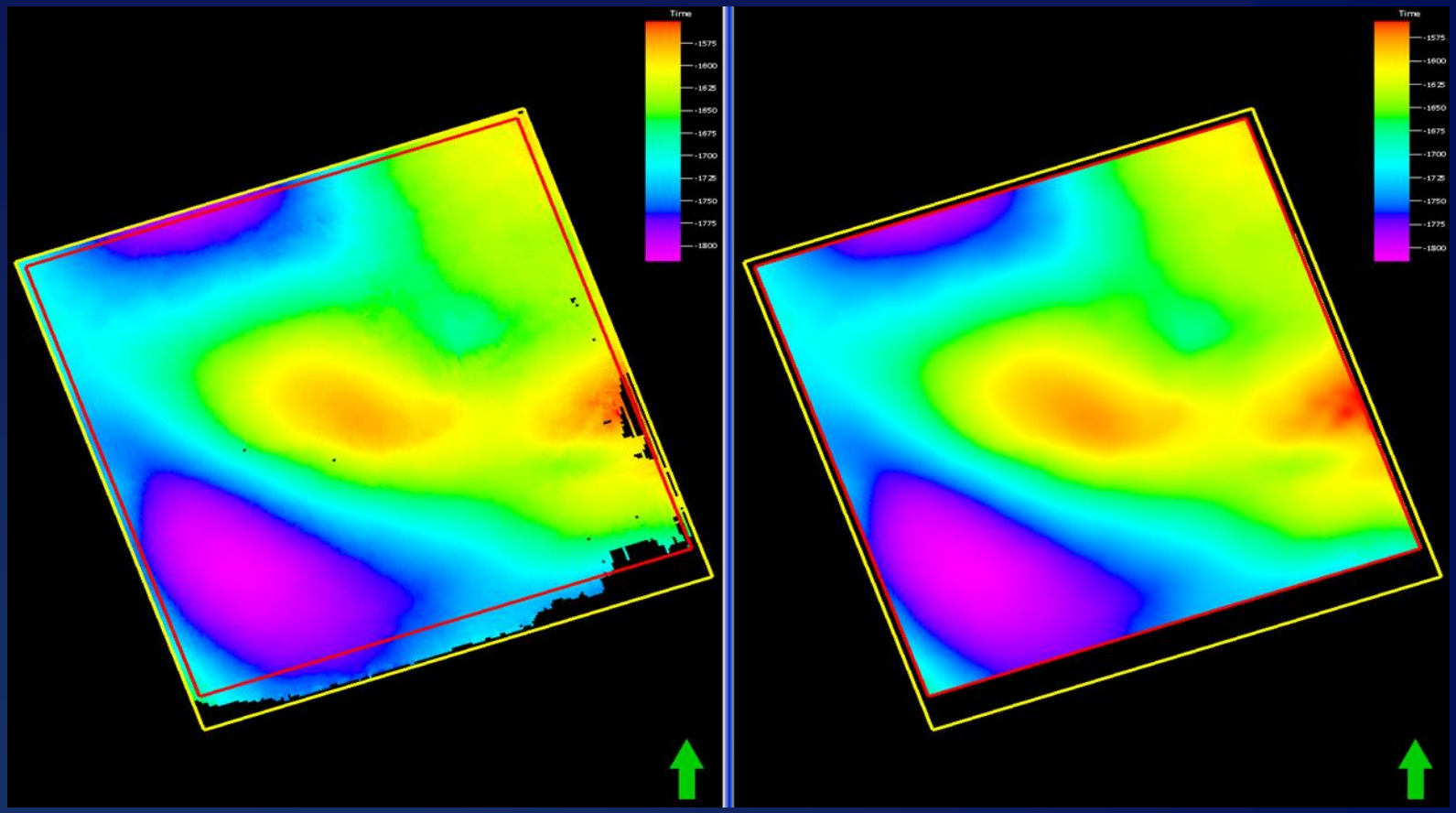
- Improved seismic interpretation based on 3D attributes

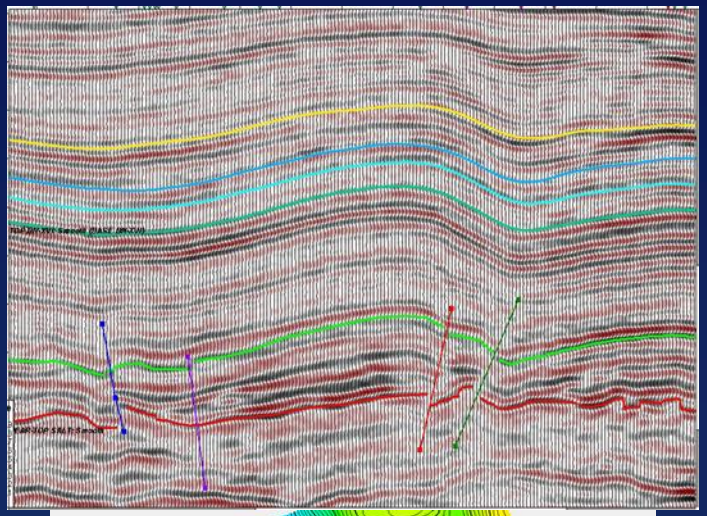


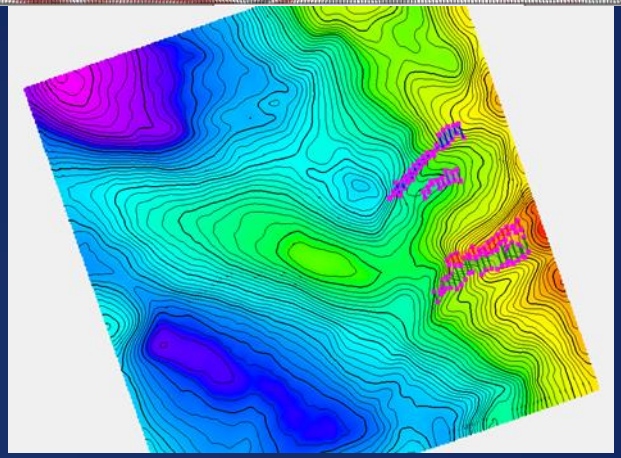
AUTO-TRACKING & MANUAL EDITING



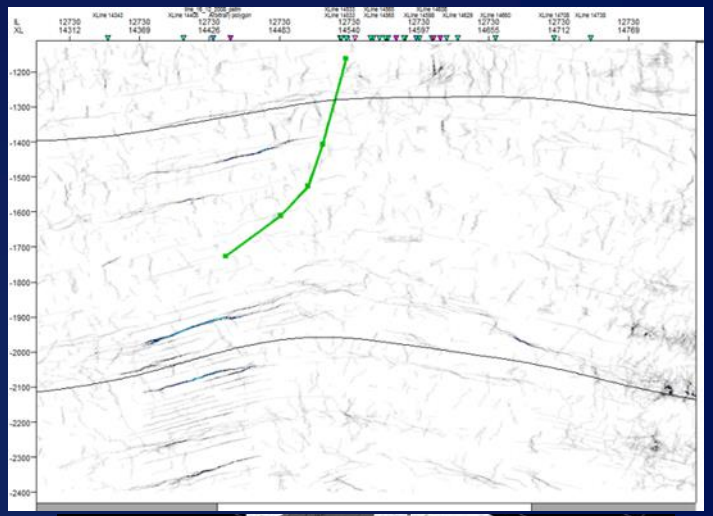
When the seismic signal shows good lateral continuity, the interpretation can be done by auto-tracking

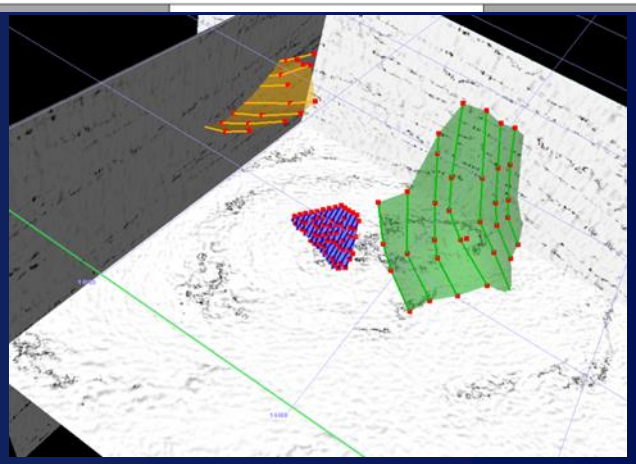
FAULT INTERPRETATION: MANUAL INTERPRETATION AND AUTO-TRACKING





Manual interpretation

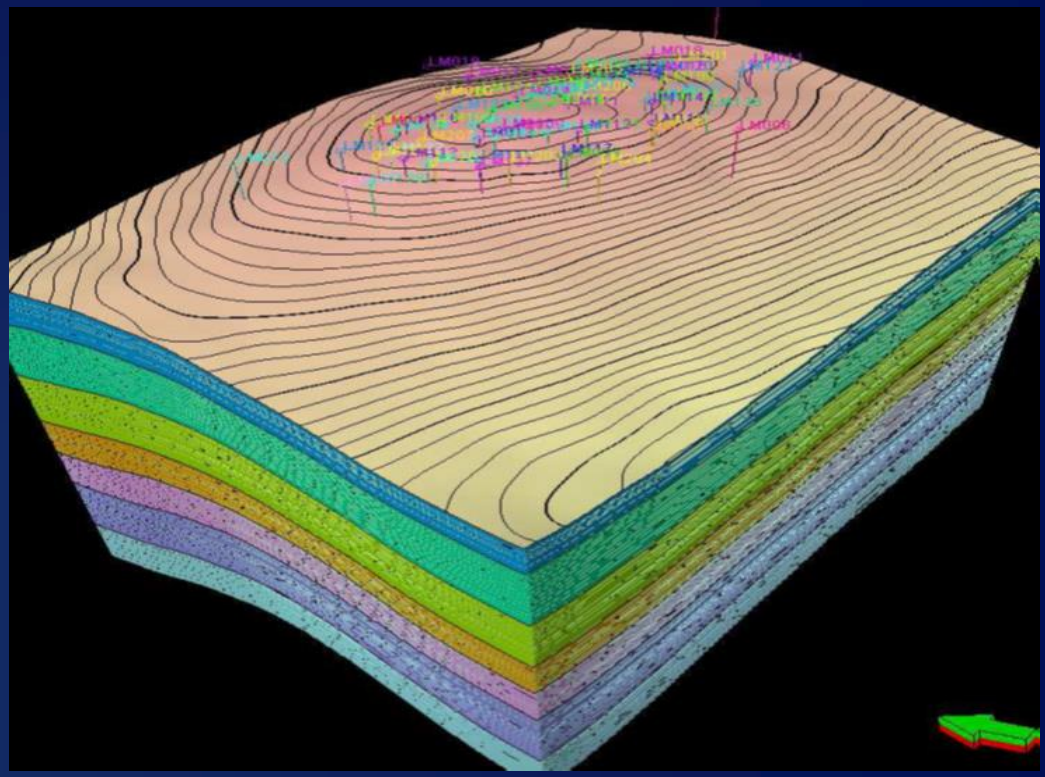




Auto-tracking

GEOLOGICAL MODELING

- Time surfaces are converted to depth using a velocity model.
- These surfaces are used to create the geological grid.
- The geological model is vertically divided into zones/layers.



WELL CORRELATION

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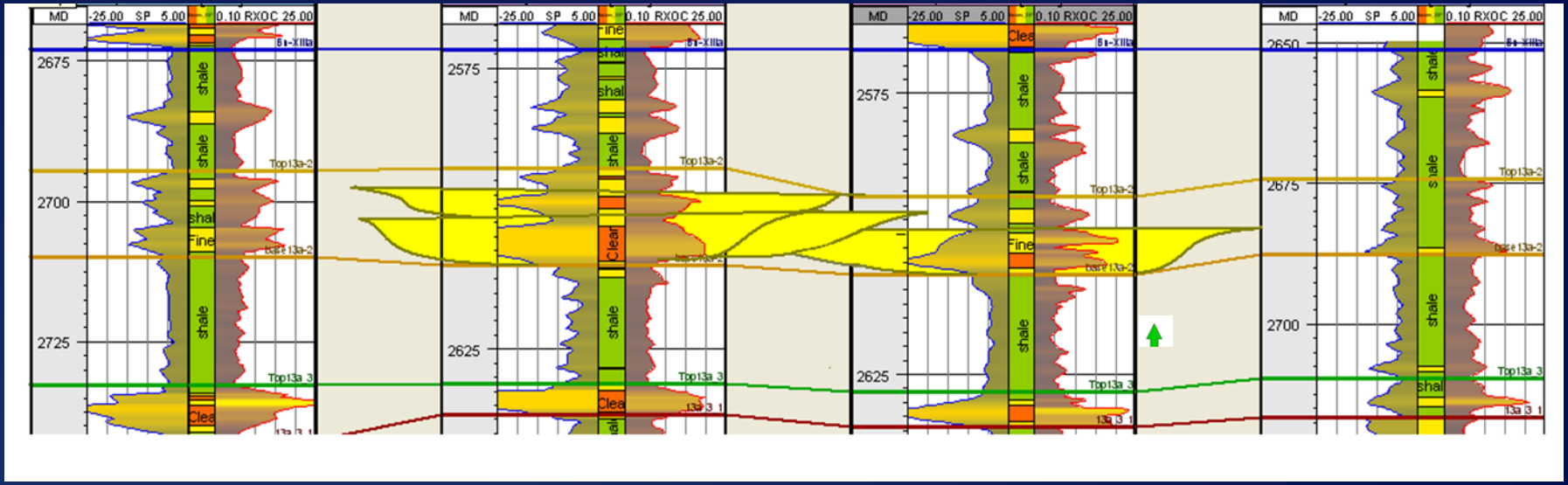
- Well correlation is the first step in the geological modeling.
- Complex stratigraphy (channels, sand lenses, etc.), can make the correlation challenging.
- Seismic makes a major contribution in understanding the large scale facies distribution.

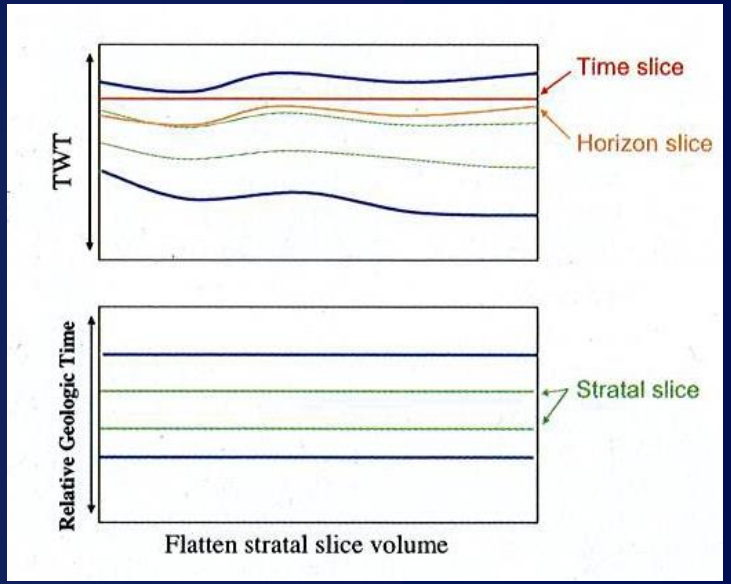
WELL CORRELATION SHOWING LITHOLOGY VARIATIONS



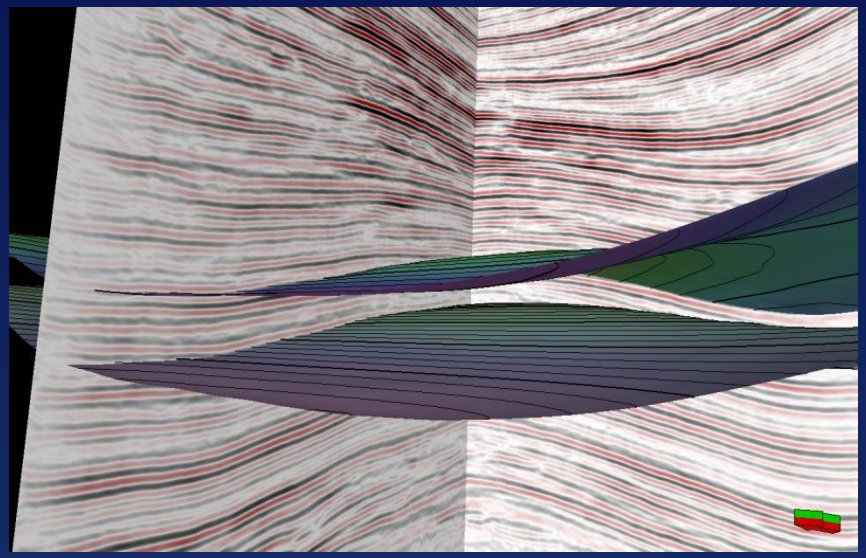
Channels observed in some of the wells are difficult to correlate laterally with other wells. Seismic attributes can show the direction of channels and their connectivity.

SEISMIC ATTRIBUTES BY LAYERS

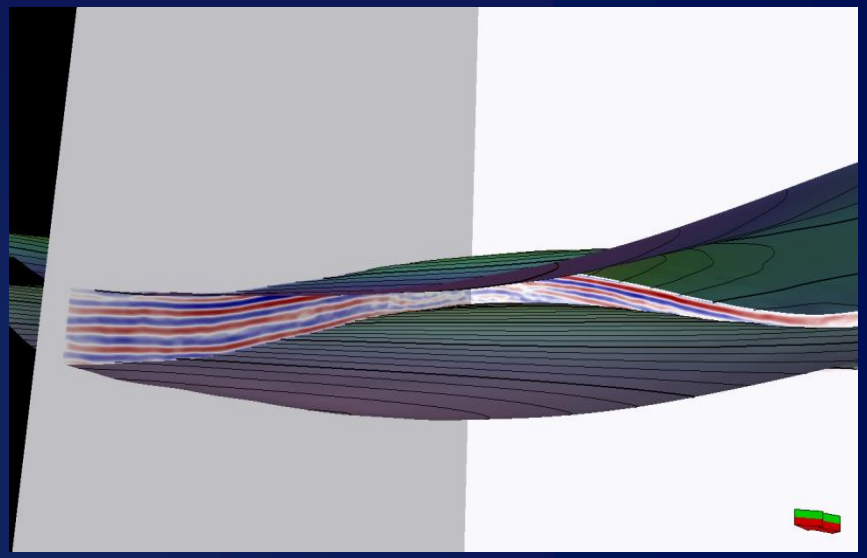
- Volume attributes can be extracted between two horizons and flattened.
- This way we can create stratigraphic slices parallel with sedimentation layers.
- This is very useful for understanding the depositional processes.



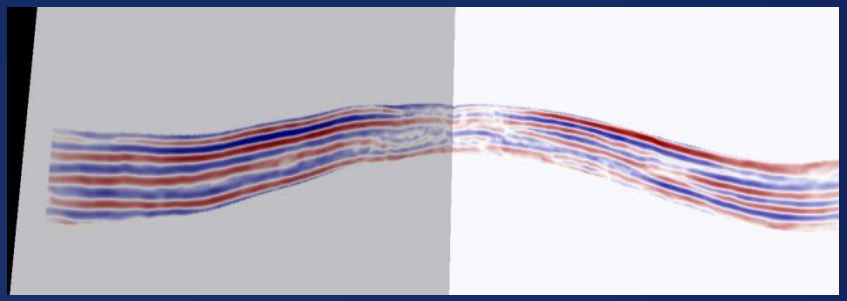
SEISMIC EXTRACTION AND FLATTENING BETWEEN TWO HORIZONS



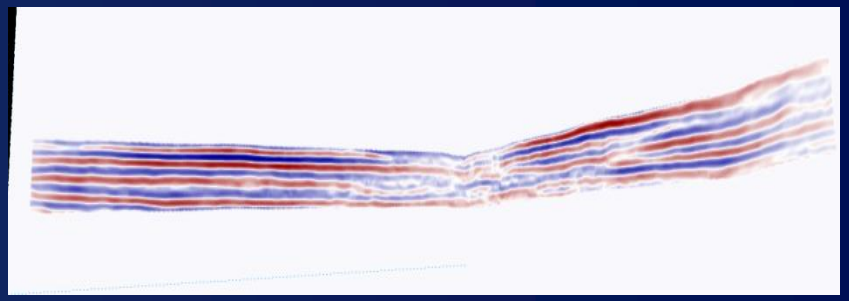
3D seismic with two interpreted horizons



Seismic slice extracted between horizons



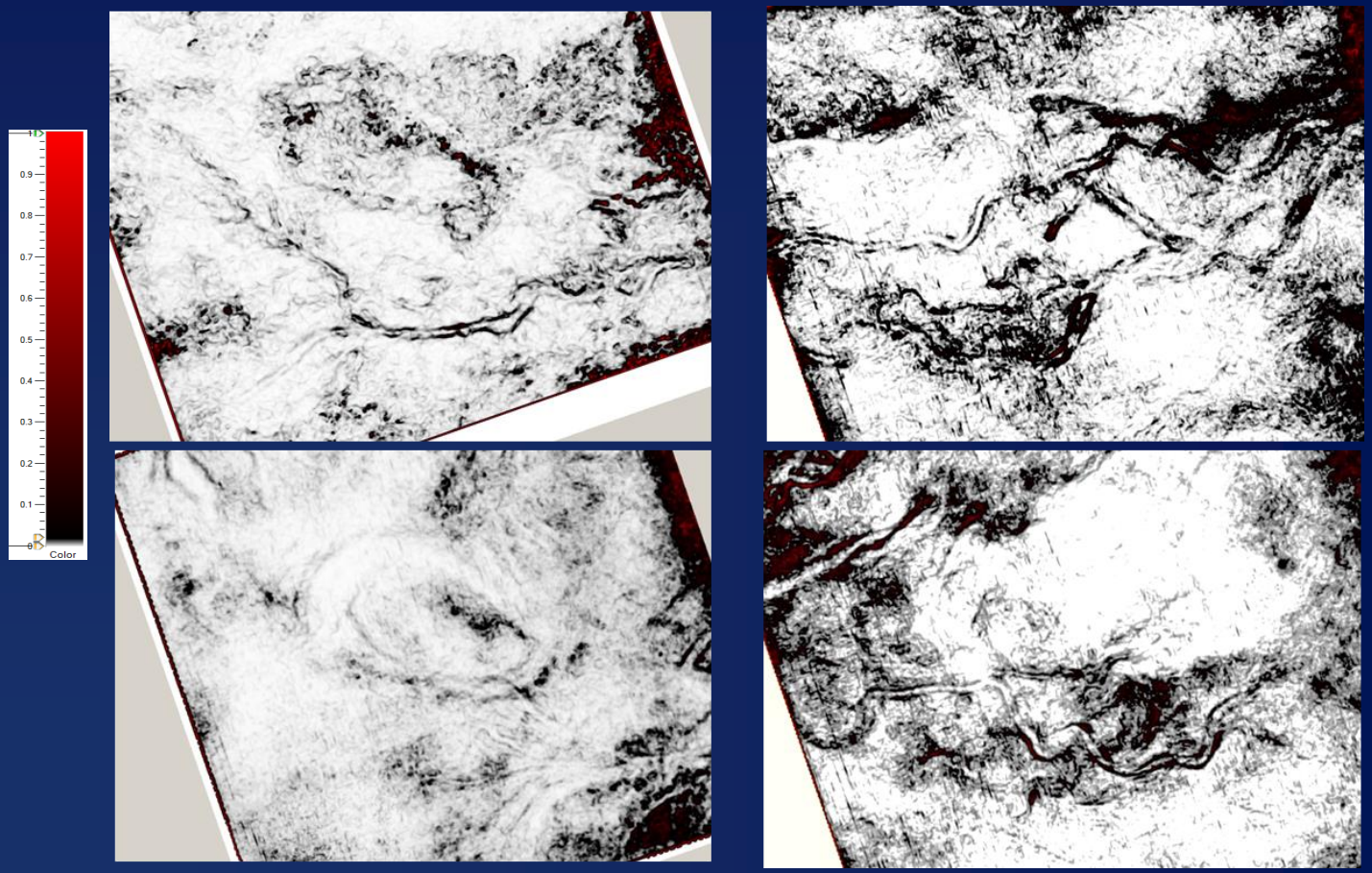
3D seismic slice extracted



3D seismic slice flattened

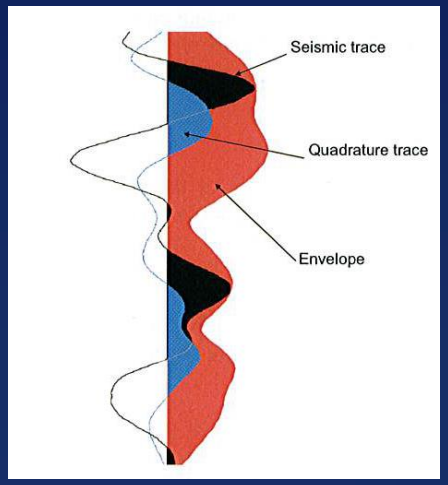
VARIANCE ATTRIBUTE

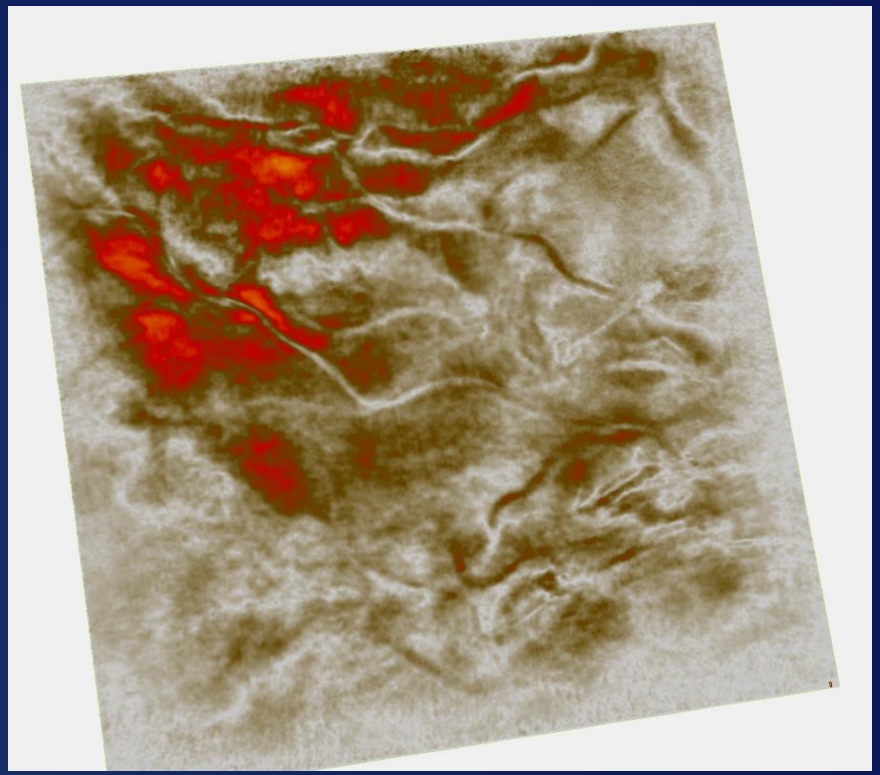
- Variance attribute is calculated from 3D seismic and it represents trace-to-trace variability of seismic signal (discontinuities)
- Helps identifying channels and faults

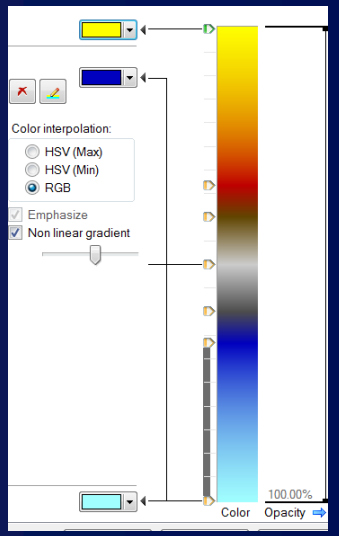


ENVELOPE ATTRIBUTE

- Is defined as total energy of the seismic trace
- Shows lithological changes that might not be apparent on the seismic data, caused by strong energy reflections and sequence boundaries

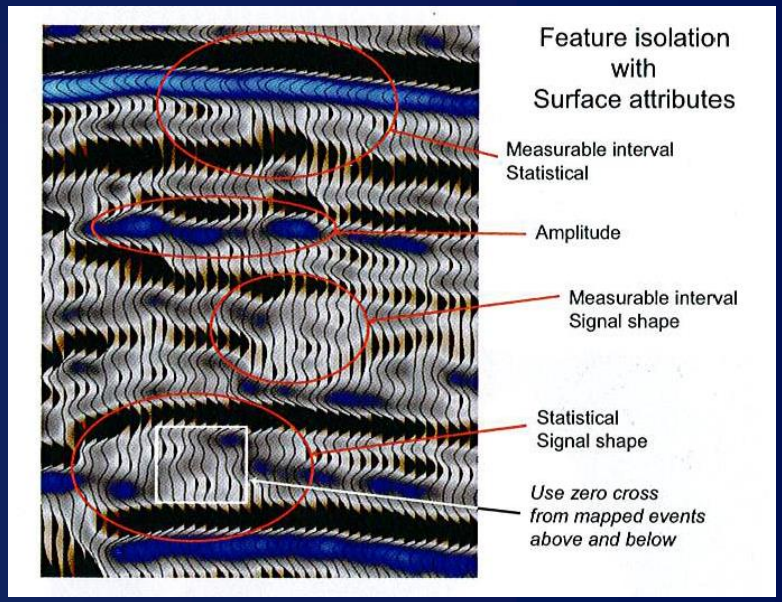






SURFACE ATTRIBUTES

- Surface attributes are extracted from a seismic volume across a surface, within an interval near the surface.
  - Amplitude attributes
  - Statistical attributes
  - Signal shape attributes
  - Measurable interval



- These attributes can be used for facies and property distribution inside reservoir layers

EXAMPLES OF SURFACE ATTRIBUTES

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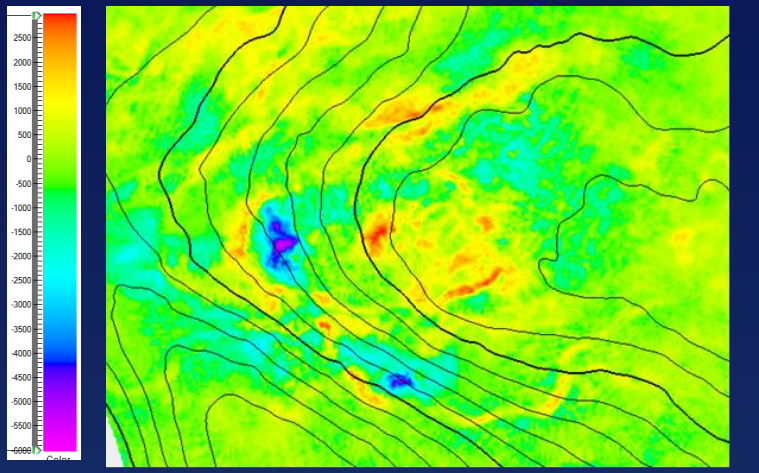
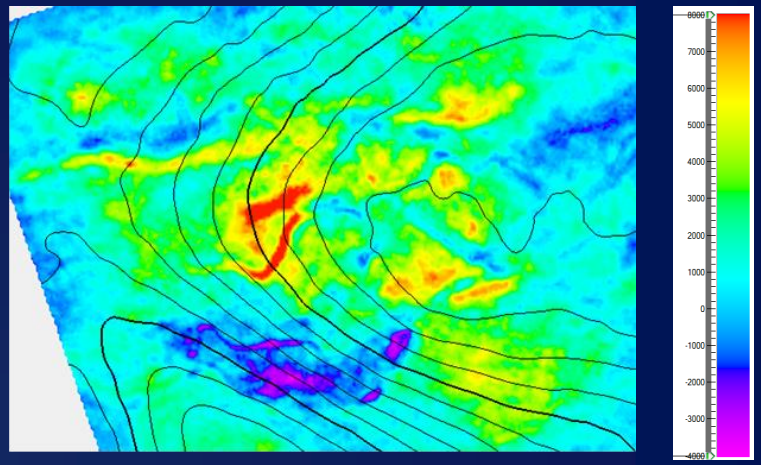
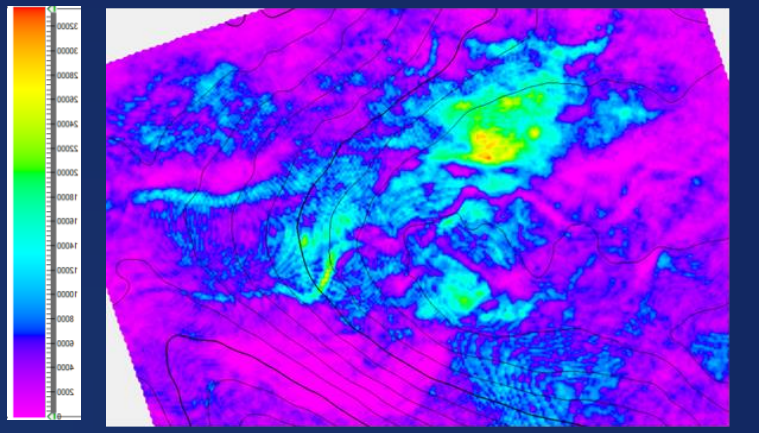
- The attributes were extracted from the same reservoir, but different depths.



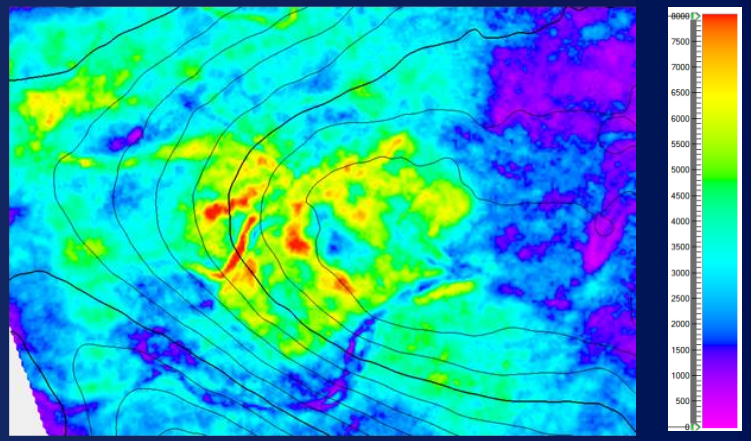
MEDIAN



MAXIMUM AMPLITUDE



SUM OF POSITIVE AMPLITUDES



MAXIMUM MAGNITUDE

NEURAL NETWORK MODEL USING SEISMIC ATTRIBUTES

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- Neural Network can be used to predict and estimate reservoir properties by correlating log or core properties with surface or volume attributes
- One or more seismic attributes can be used as input, and different log types can be used for supervising the data training process
- Based on the input data, the output can be a 2D or 3D probability distribution
- The resulted probability can be then used in the facies or property modeling process, as a 2D or 3D distribution trend

NEURAL NETWORK WORKFLOW

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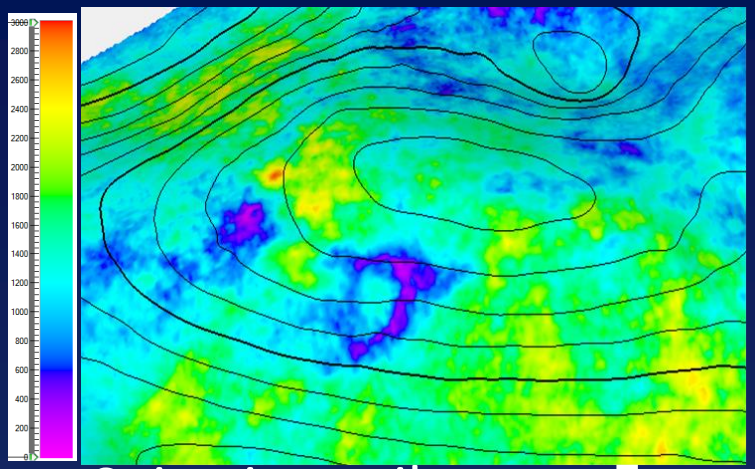
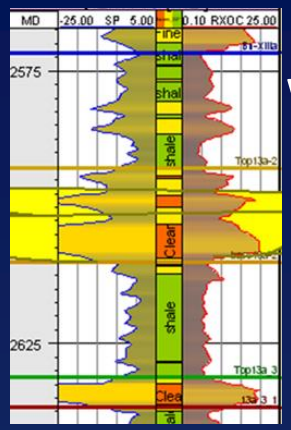
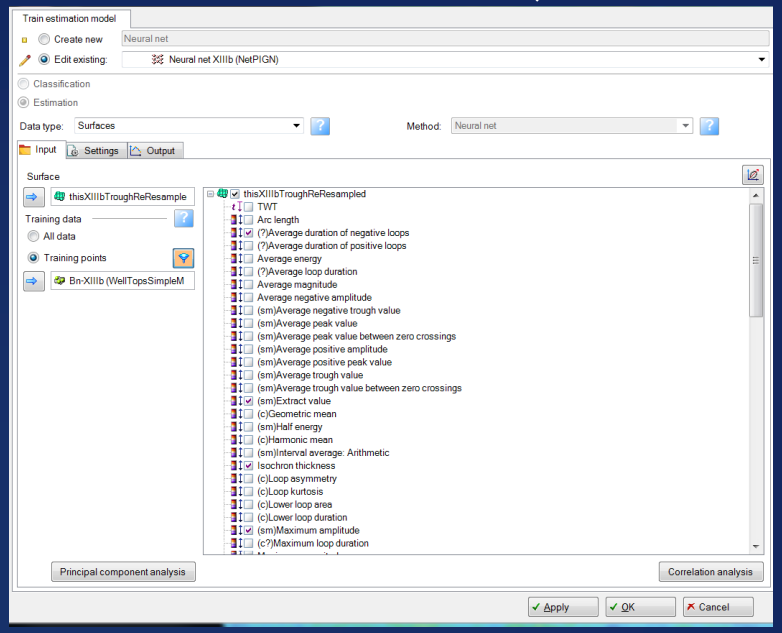


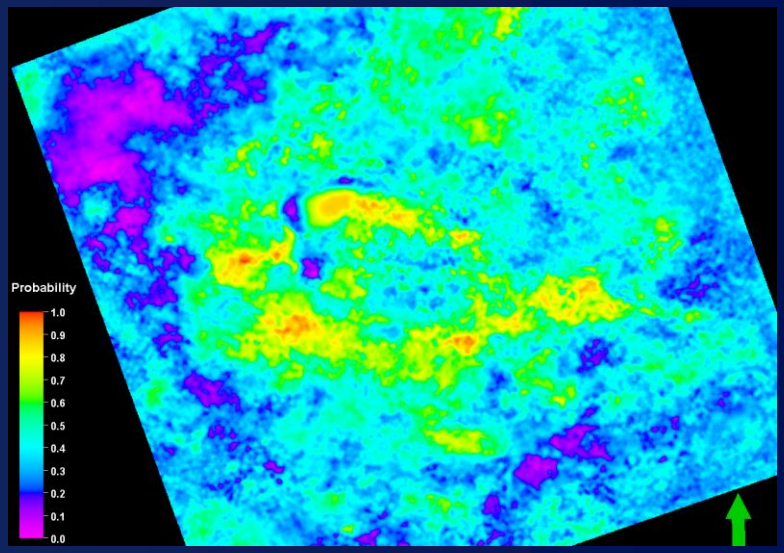
Seismic attributes



Well log property



Probability of sand distribution



STRATIGRAPHIC FEATURES FROM SEISMIC ATTRIBUTES

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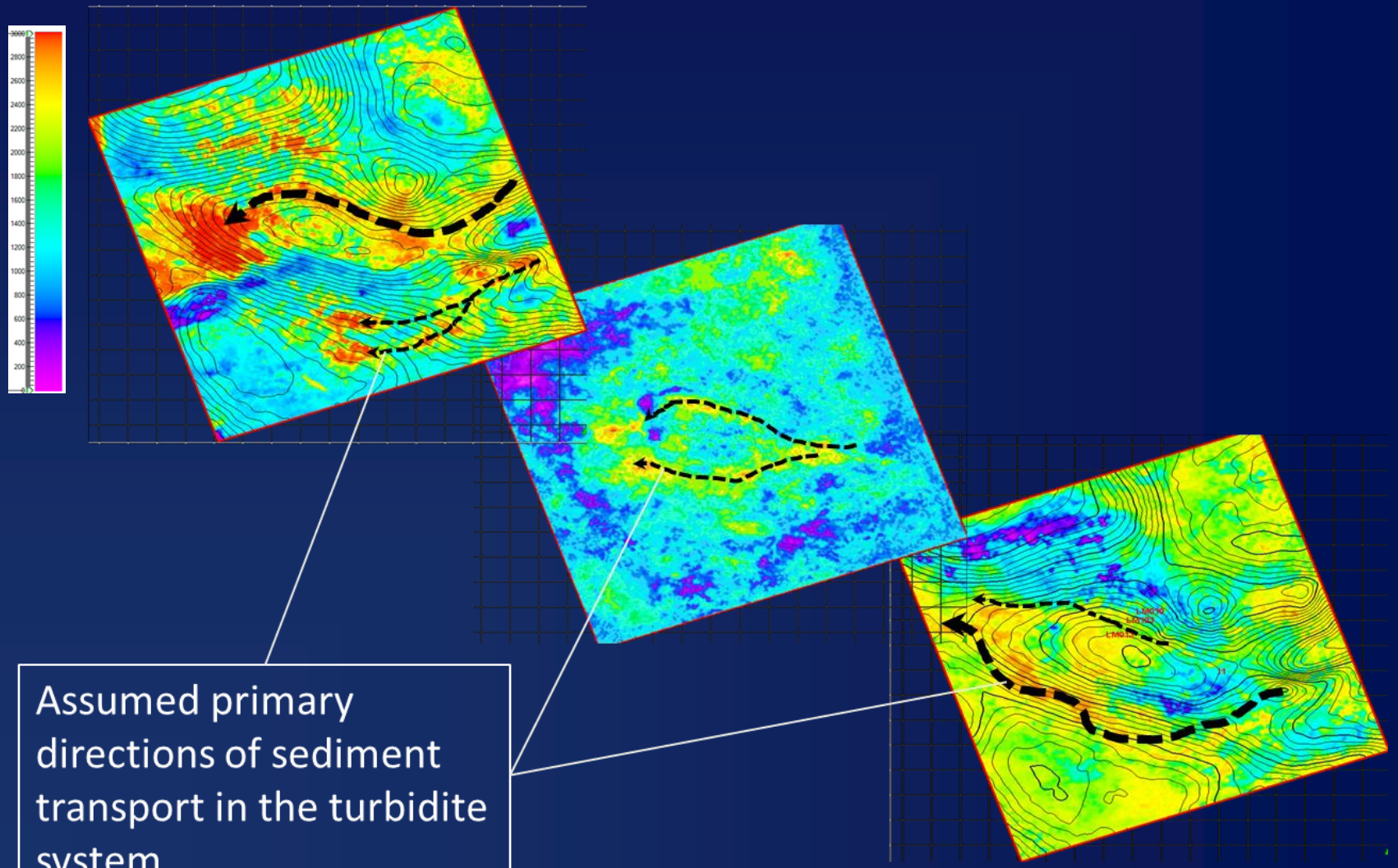


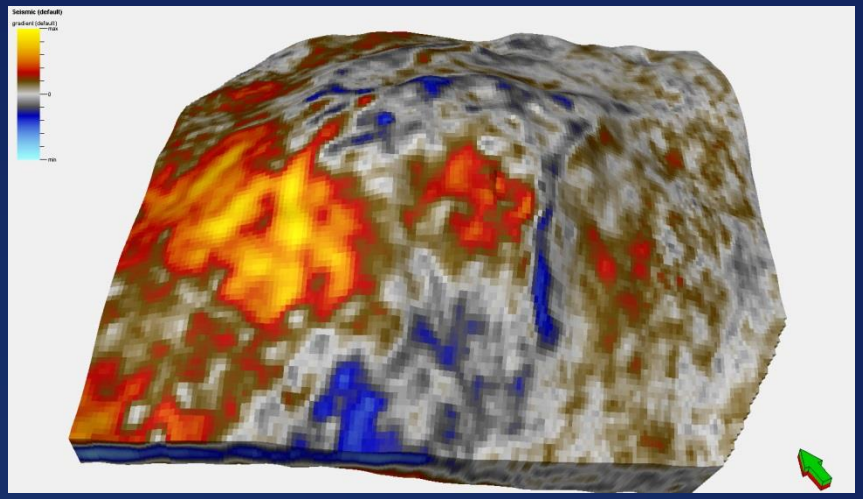
Assumed primary directions of sediment transport in the turbidite system

FACIES MODELING BASED ON SEISMIC ATTRIBUTES

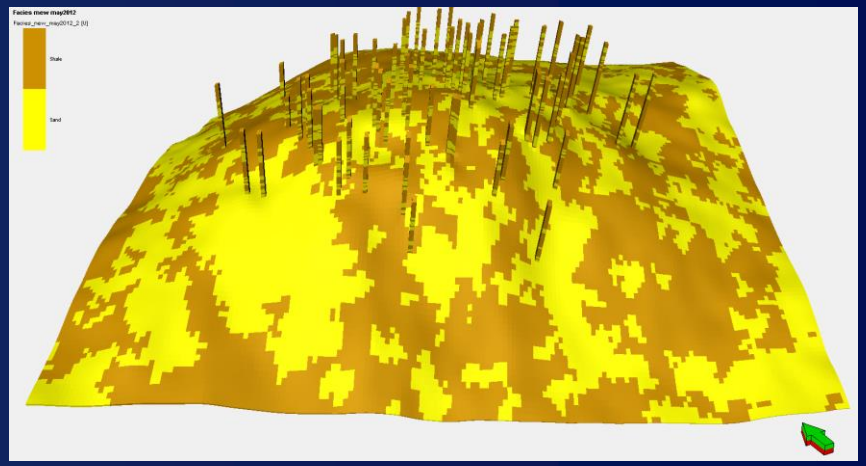
- Facies modeling is based on facies logs defined from petrophysical interpretation (VCL, GR, etc.).
- Surface or volume seismic attributes can be used in the modeling process as probability trends.
- 2D trends help with lateral distribution only.
- 3D trends help also with vertical distribution of lithology, which is very useful in case of channels.

FACIES MODEL BASED ON SEISMIC ATRIBUTES

- A 3D AVO gradient attribute was used as probability trend to distribute lithology between wells and in areas without wells.

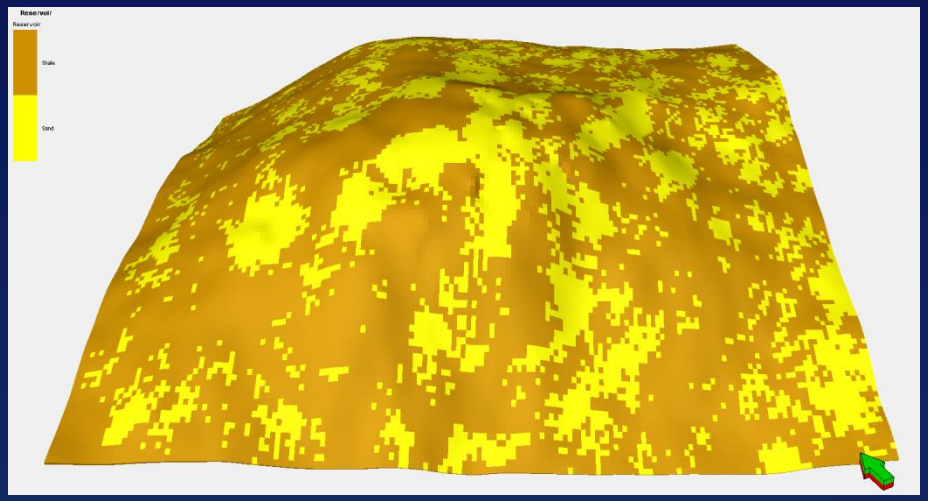


AVO gradient rescaled

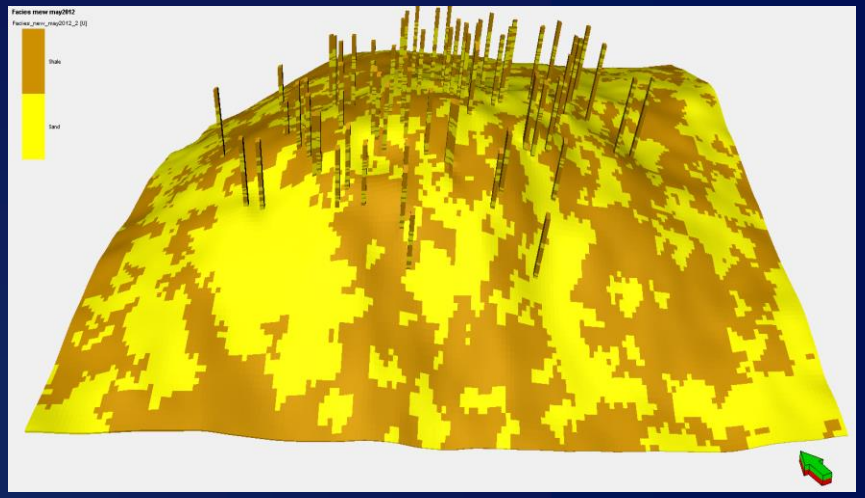


Facies model

FACIES MODEL COMPARISON



From wells only

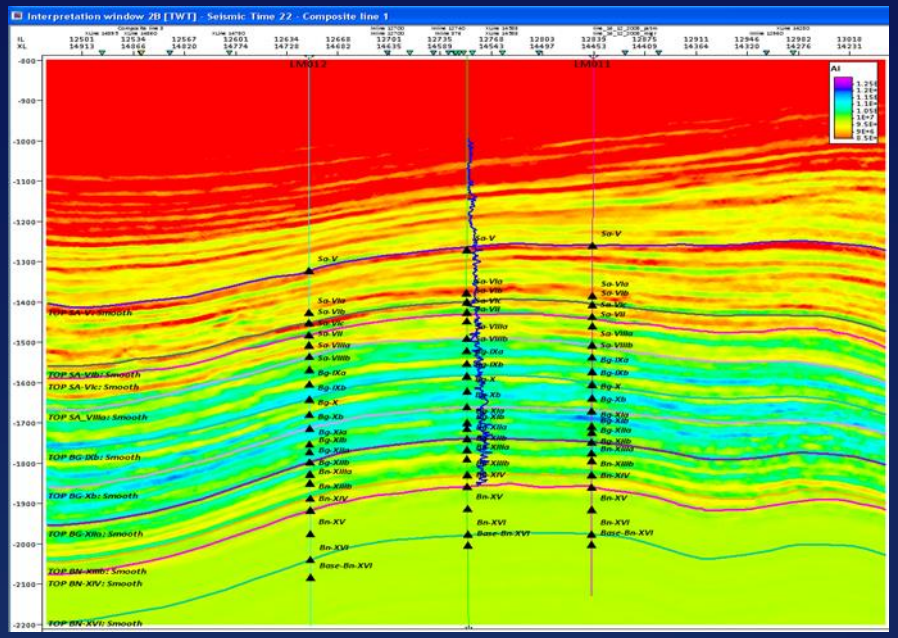


Using seismic attribute as a 3D probability trend

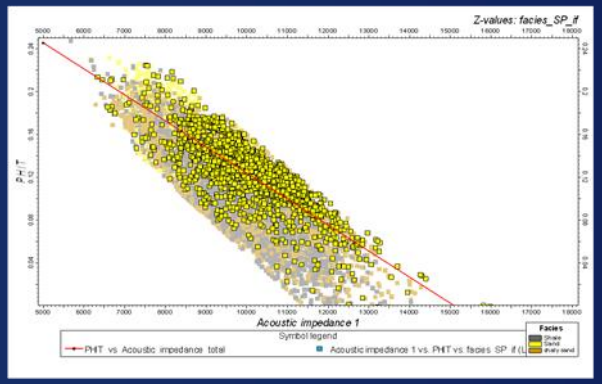
PROPERTY MODELS

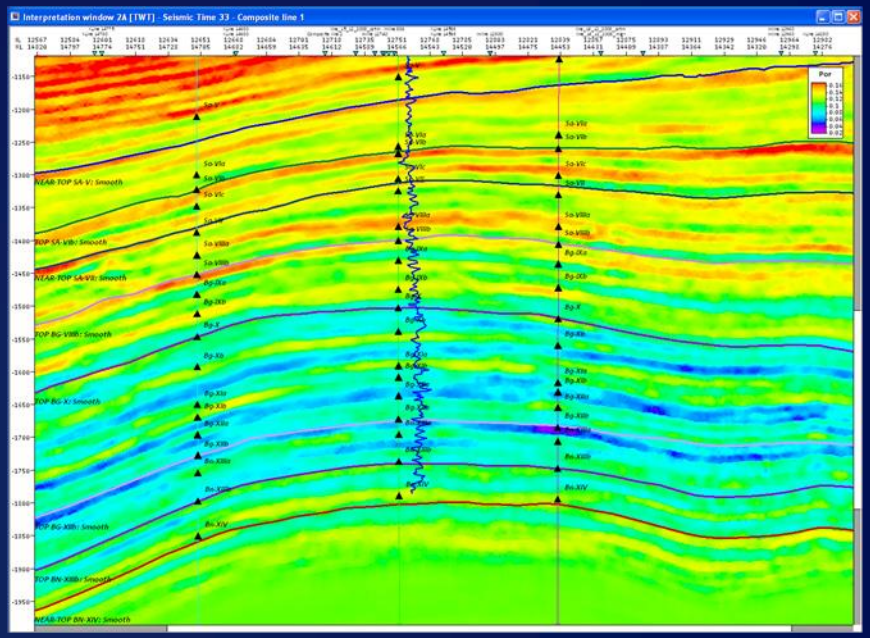
- Porosity distribution can be conditioned to the facies models.
- Acoustic Impedance (AI) shows a good correlation with porosity in sandstone reservoirs and can be used as a 3D probability trend for porosity modeling.
- Surface attributes can also be used as horizontal trends, if AI not available.

SEISMIC INVERSION RESULTS CONVERTED TO POROSITY MODEL



Acoustic Impedance inversion results





Porosity from Acoustic Impedance

Acoustic Impedance vs. Total Porosity function from log data

POROSITY MODELING WITH 2D TRENDS

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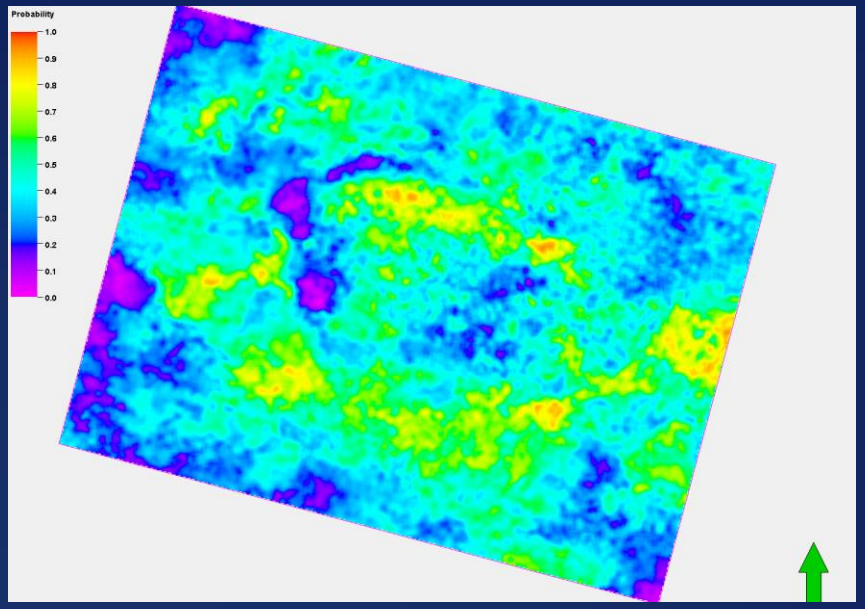
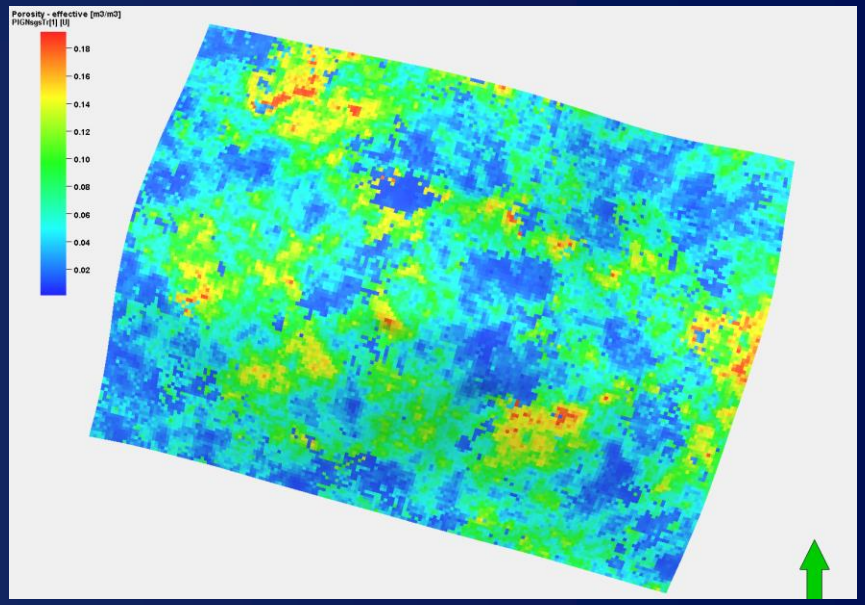
- The 2D probability trend was created from a seismic attribute and used as a secondary variable for porosity distribution.



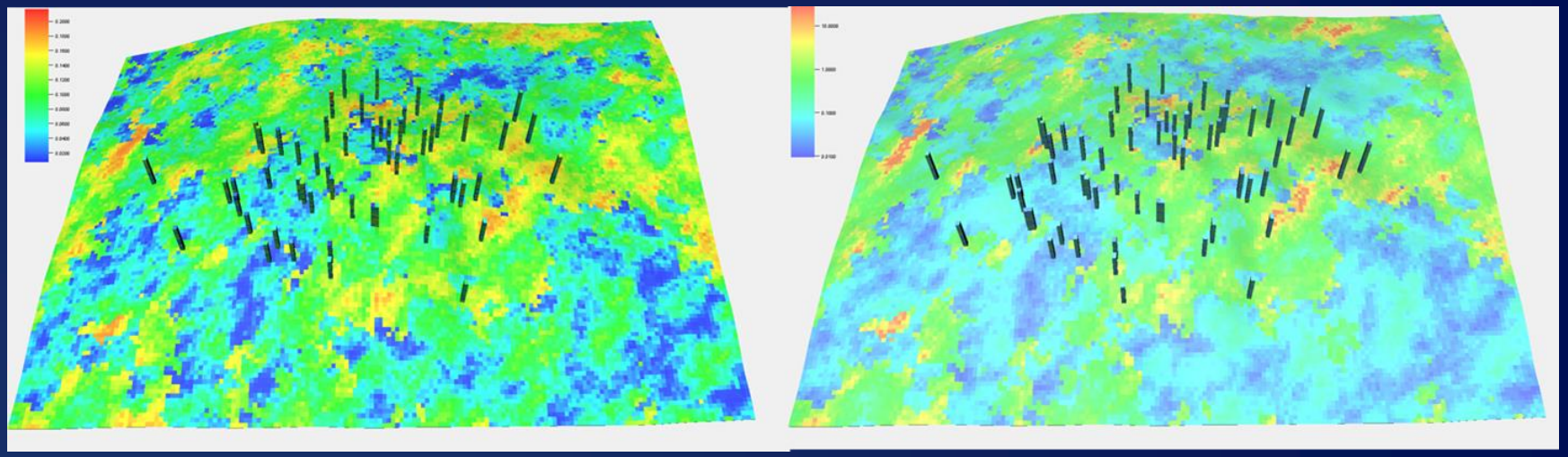
2D seismic trend



Porosity model

PERMEABILITY MODELING

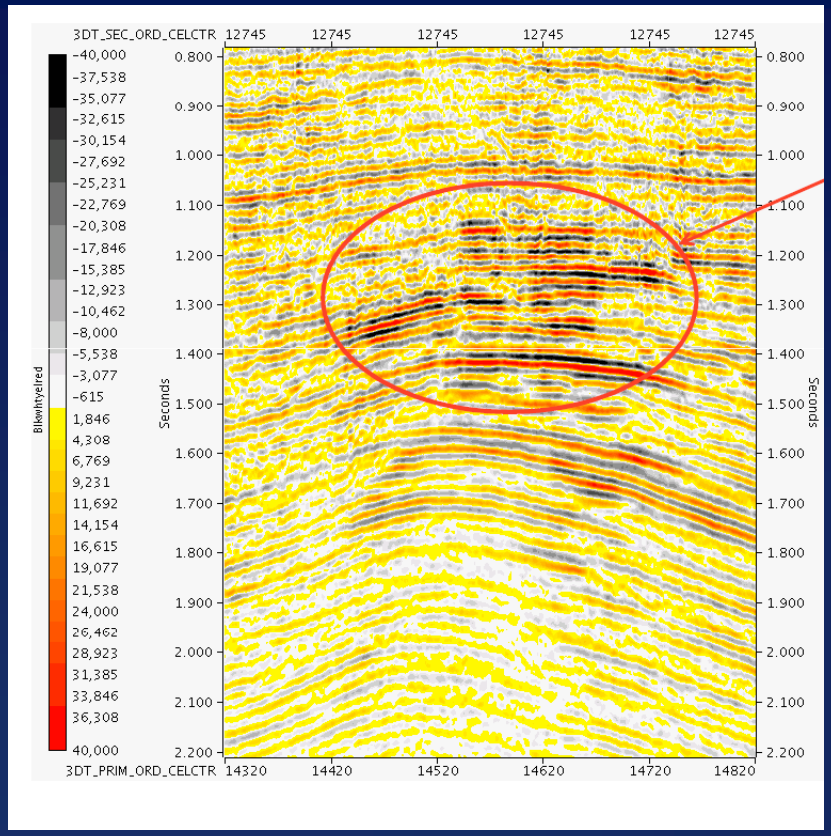
- The permeability model is created after the porosity model, using cokriging with porosity.

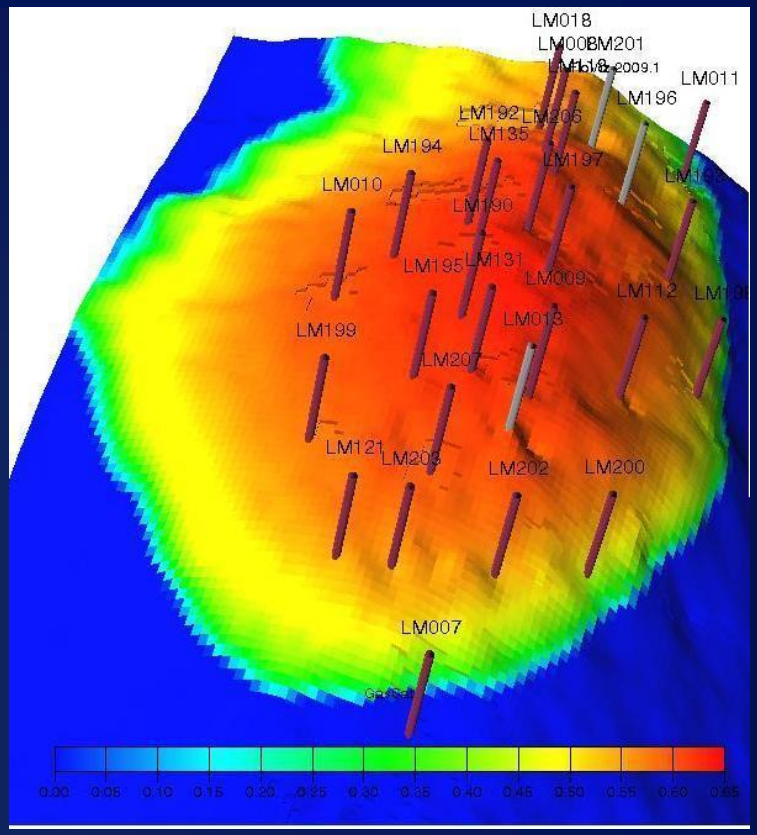


Porosity model

Permeability model

SATURATION MODELING





- Fluids distribution can be interpreted from AVO attributes.

CONCLUSIONS

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- Seismic attributes can significantly improve the facies and property modeling.
- They are very useful for the lateral distribution of the reservoir properties between the wells and in areas without wells.
- As a result, dynamic reservoir models, simulation processes and production forecasts are improved.
- More reliable hydrocarbon volume estimations and well planning are achieved.

Thank You For Attending!
Question & Answer Session

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