Integrated Seismic Characterization and Reservoir Modeling of Neocomian Fluvial System for Water Injection: Tengiz Oil Field, Republic of Kazakhstan*

Elrad Iskakov[1], Steve Jenkins[1], Zhanat Kabdesheva[1], and Henry W. Posamentier[2]

Search and Discovery Article #20163 (2012)**
Posted August 13, 2012

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Long Beach, California, April 22-25, 2012

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Abstract

Newly processed, high resolution PSDM 3D seismic data have provided important insights into the architecture of a Neocomian fluvial complex located above the super-giant Tengiz Oil Field in the Republic of Kazakhstan. Produced water from the Tengiz oil processing plant is being injected into Neocomian sandstone intervals above the Tengiz carbonate platform. A thorough analysis of new PSDM images has significantly improved the characterization of this shallow, high-sinuosity channel system. This analysis has also enabled the construction of improved numerical models to understand water movements.

A detailed seismic interpretation and reservoir characterization project was completed using several new techniques. Discrete sand bodies were mapped using geobody detection methods on a series of stratal slices to reconstruct the original depositional geometry. Stratal slices were useful to map individual channels and reveal their internal morphology. Multi-attribute cubes and animation provided new insights into the architecture of the channel system.

The interpreted Neocomian fluvial system is characterized by moderate to high-sinuosity channels that range from 40-2000 m wide. The internal architecture within the channel belts contains lineaments within point bar deposits, which are interpreted as scroll bars. The high level of stratigraphic detail gained from seismic interpretation was captured in a numerical model of the field.

The interpretation of seismic facies enabled the definition of high Net to Gross (NTG) regions within the channel complex and reduced uncertainty associated with sand distribution. Based on the seismic stratigraphic and seismic geomorphologic analyses, a set of 3D water injection models have been constructed to characterize the range of Neocomian sand connectivity. In order to assess alternate model building strategies and the value of soft constraints such as NTG maps, seismic trends and vertical proportion trends of sand facies, a blind cross-

validation was carried out on alternative models. Blind cross-validation was also a useful tool to optimize parameters for property distribution in the model. As a result of this exercise, a suite of low/mid/high case models of sand connectivity were constructed for the Neocomian sand interval. These models have subsequently been used for flow simulation to understand the movement of water in the Neocomian channel system, and to assess the interval connectivity of the water injection sands.

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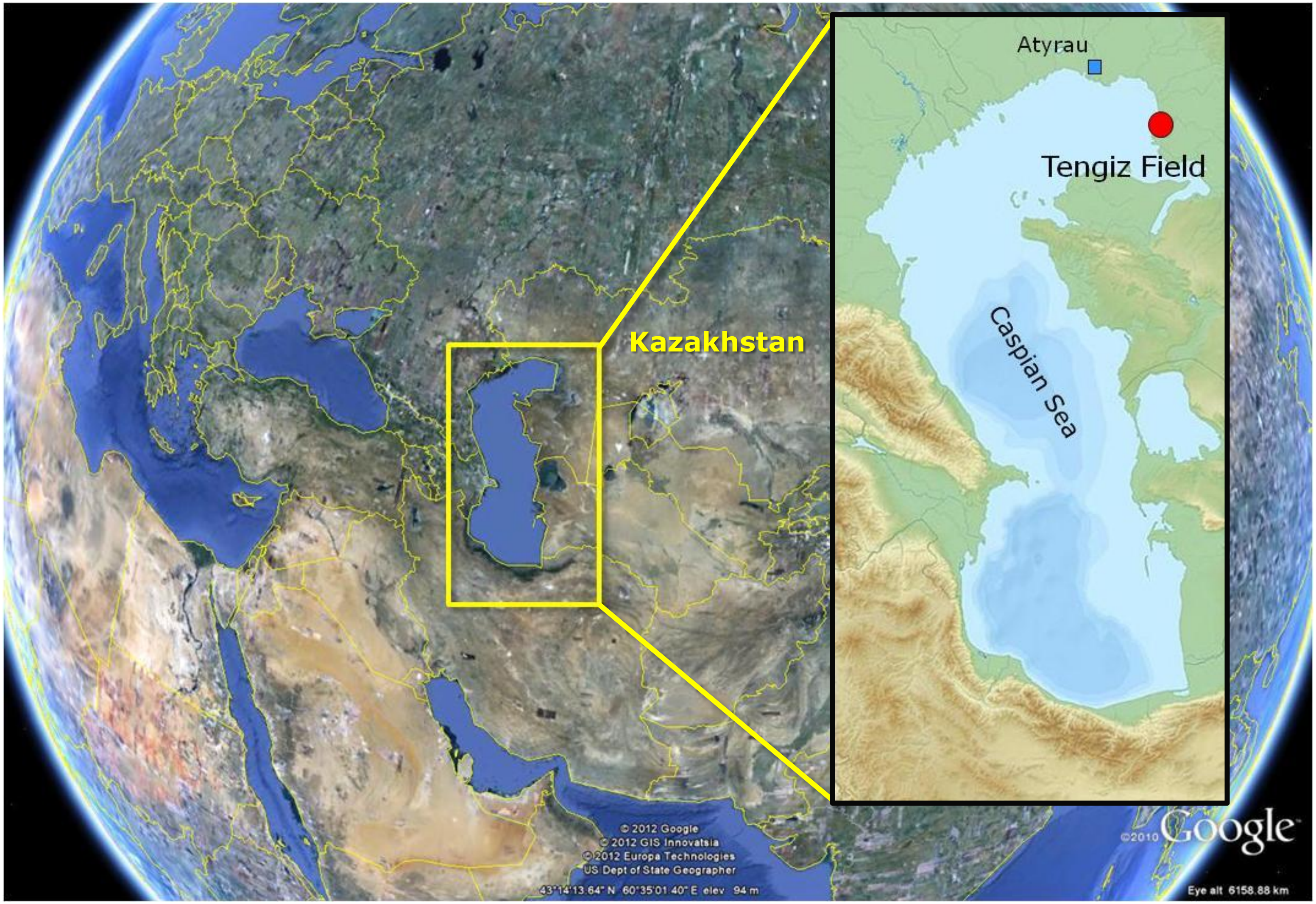
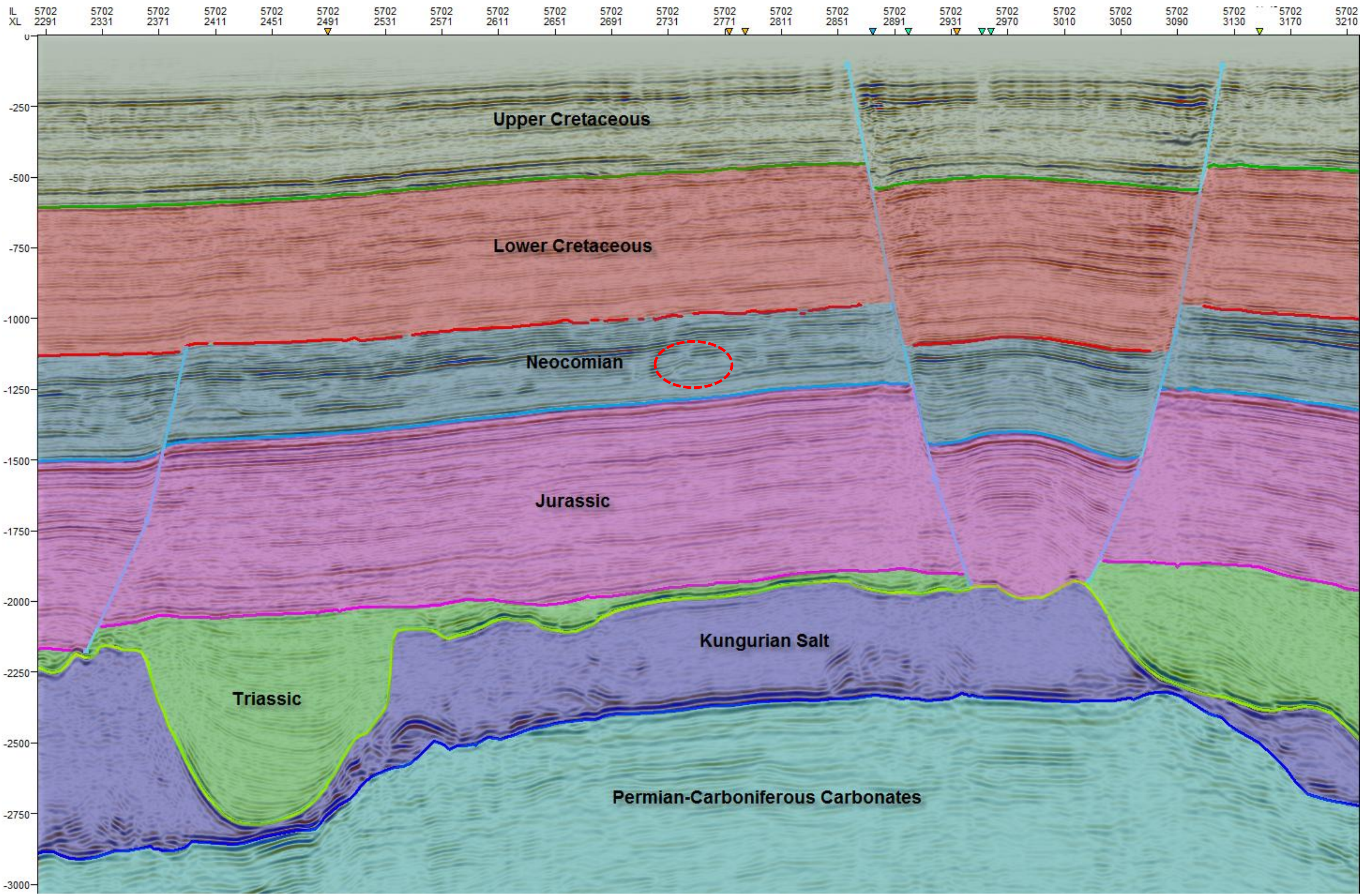
April 2012

Introduction - Field Location

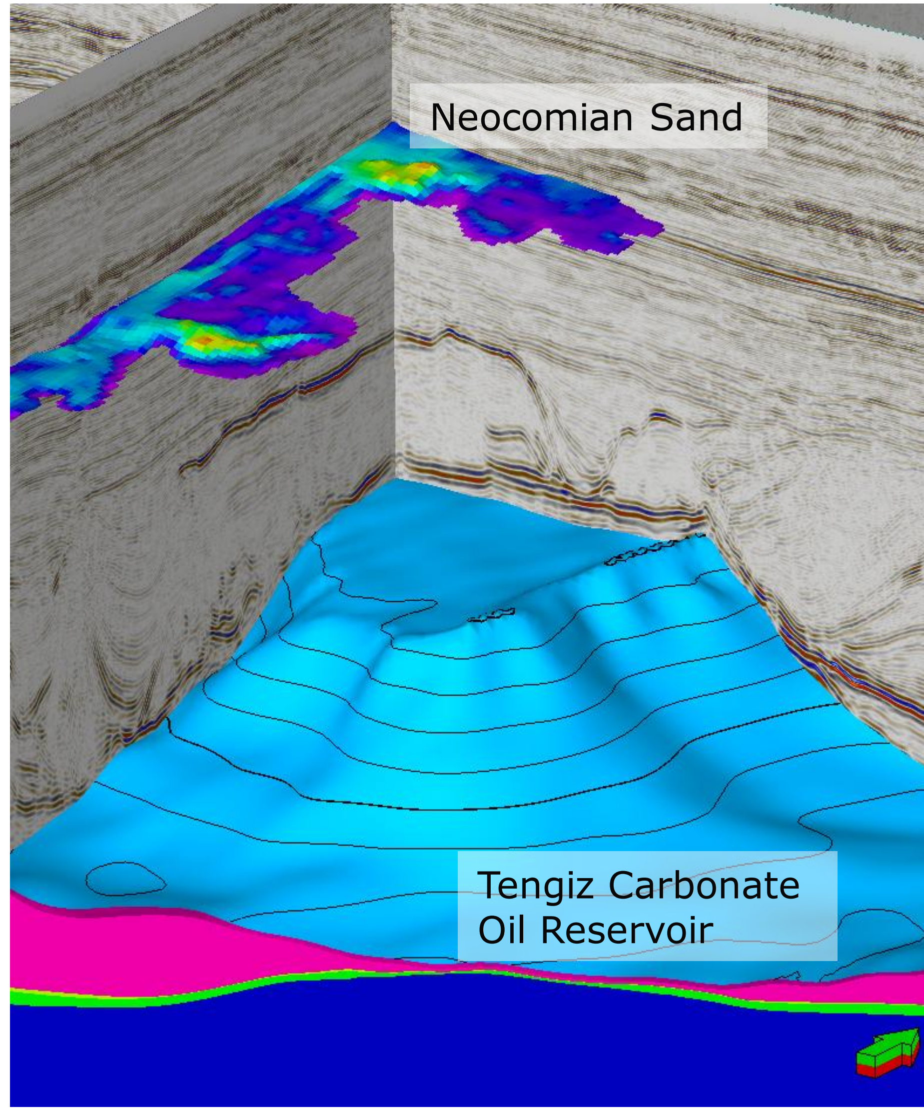


Neocomian WWD interval at Tengiz



Neocomian WWD interval at Tengiz

- Tengiz plants and operations produce waste water that cannot be recycled/utilized
- Disposal began in 1992
- Environmentally safe disposal into Neocomian sand:
  - Good properties for water storage
  - location & size of the reservoir
  - vertical isolation

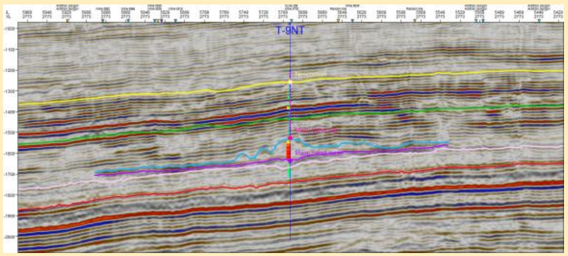


Neocomian Characterization and Modeling

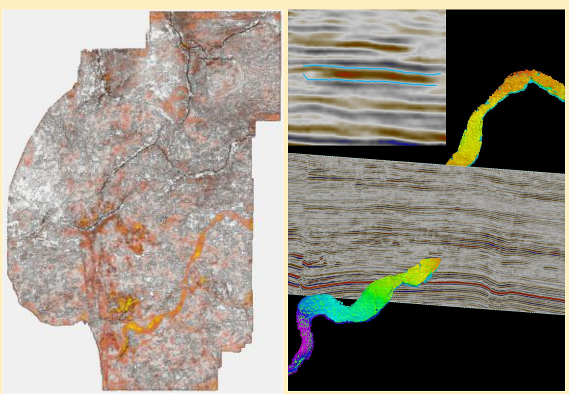
Data Preparation and Analysis

Structural Framework Building

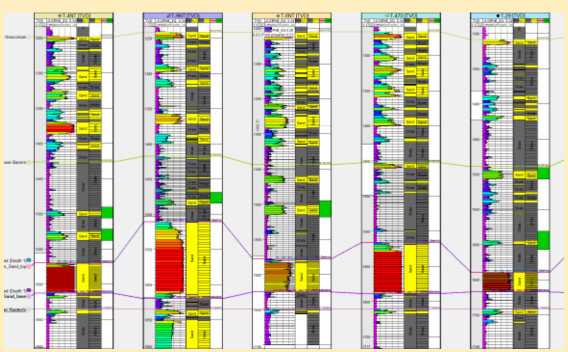
Property Distribution



Horizon and fault picking

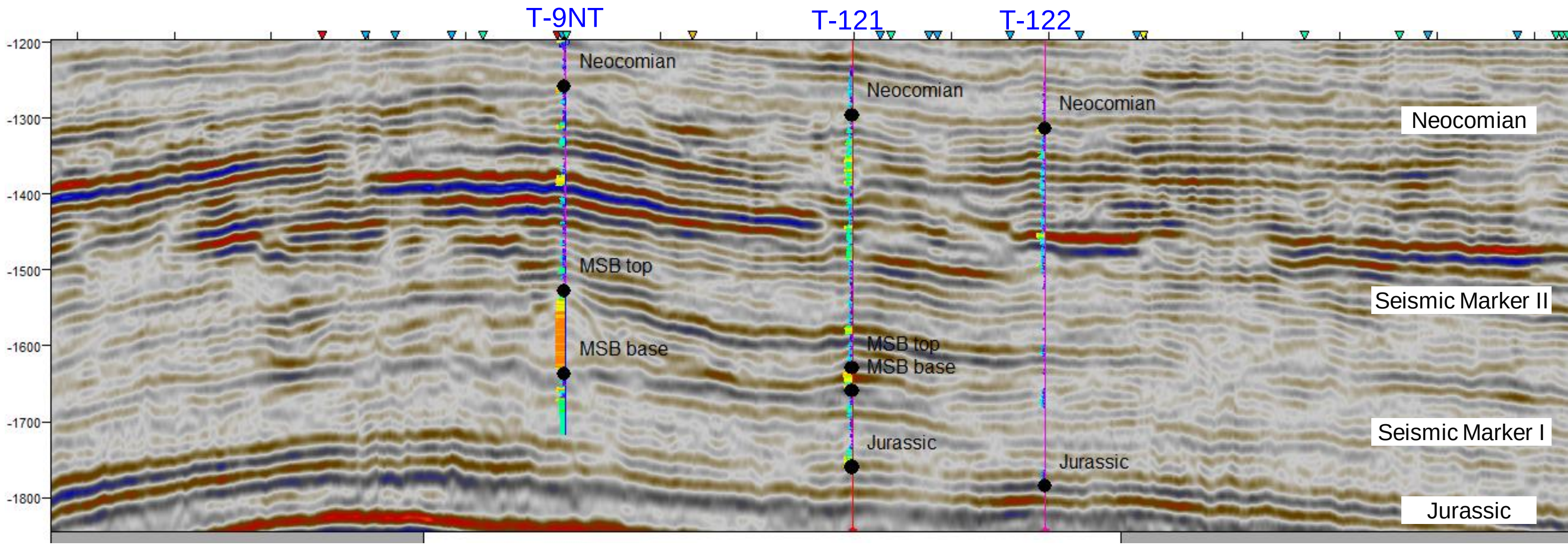


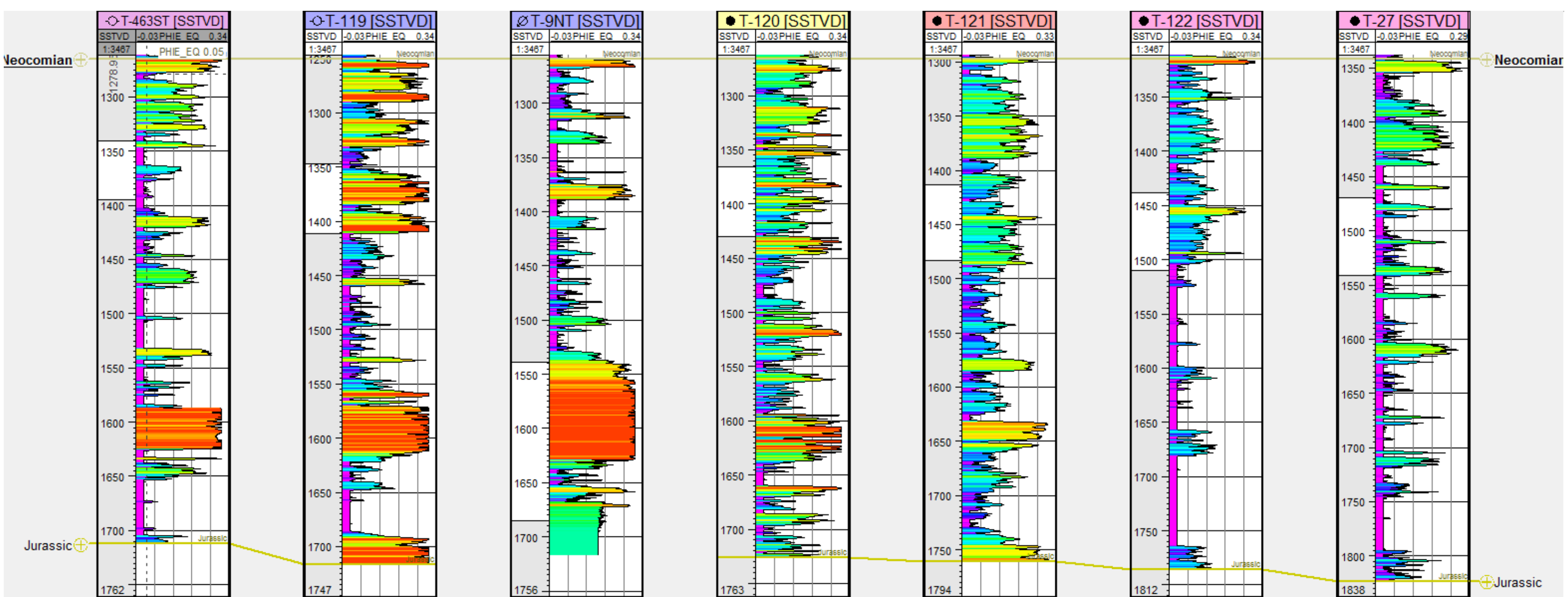
Geobody detection



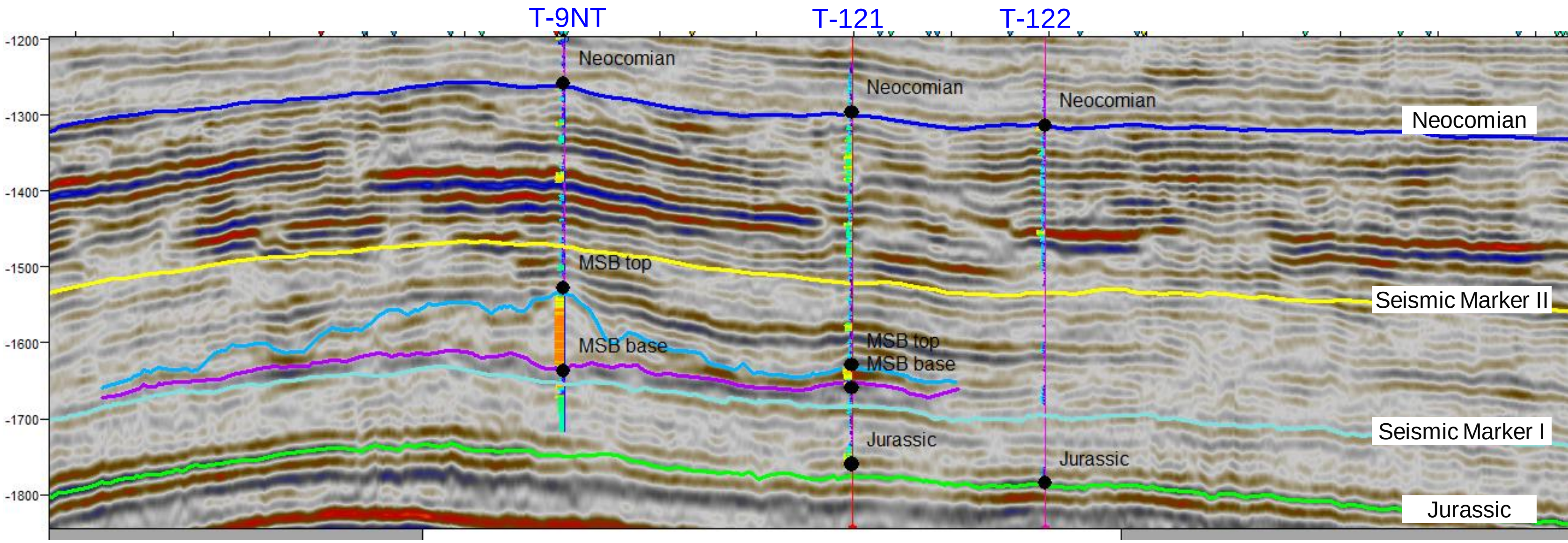
Well Data

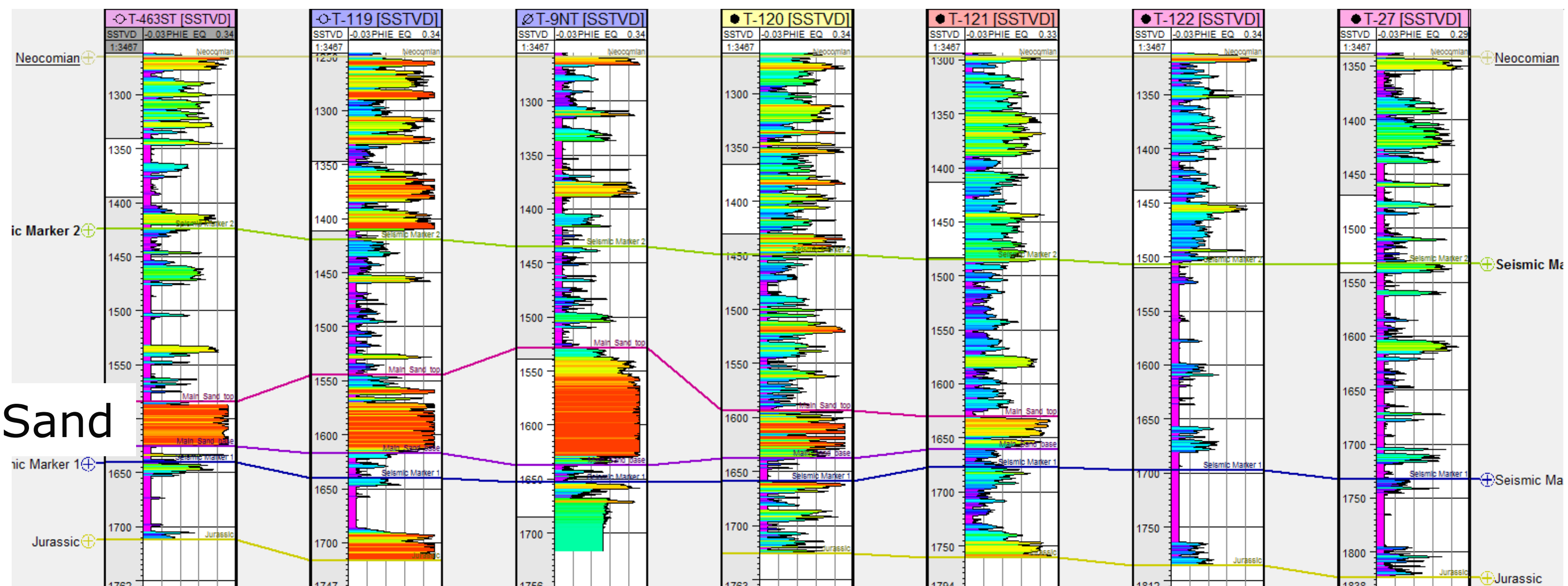
Horizon interpretation





Horizon interpretation

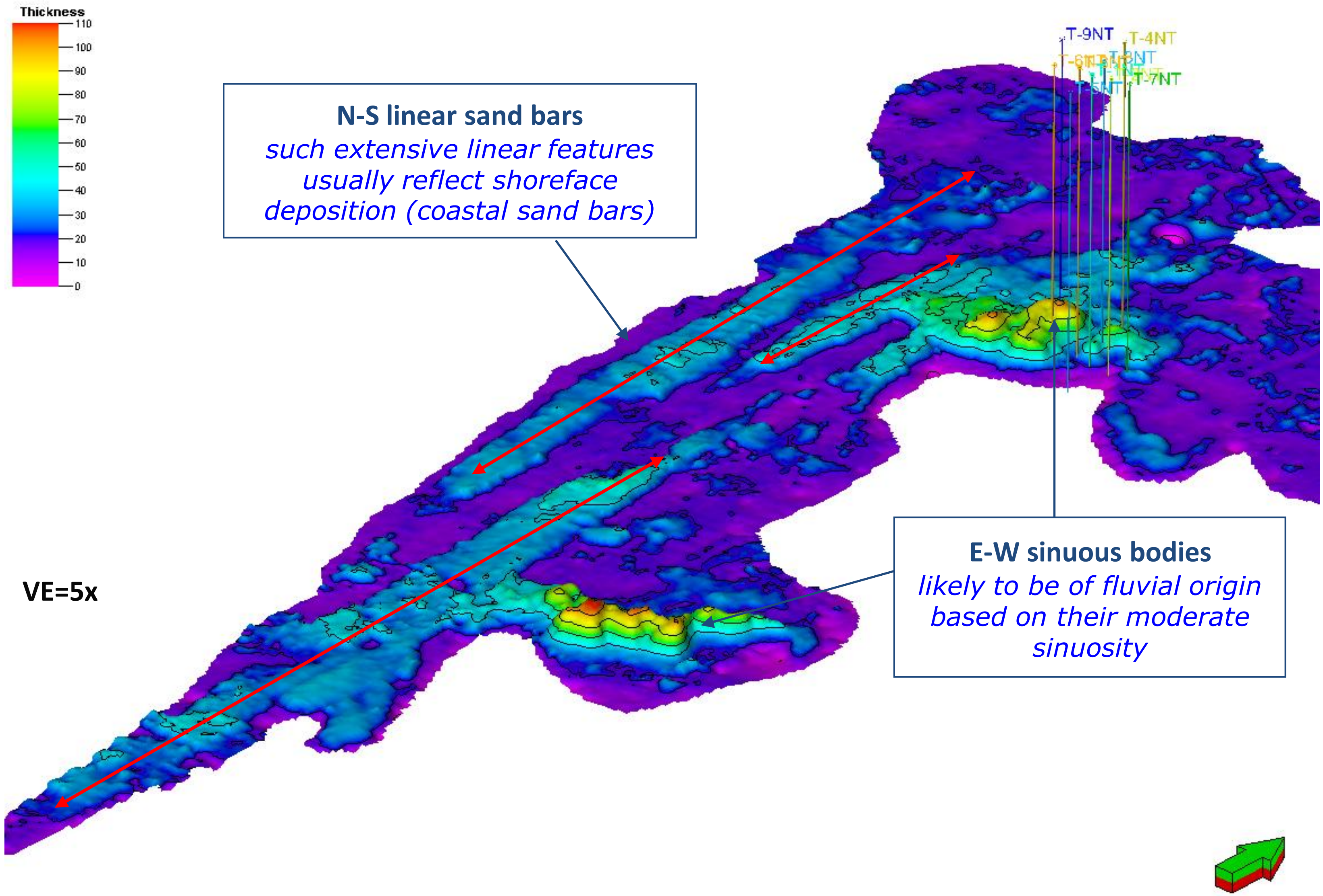




Main Sand

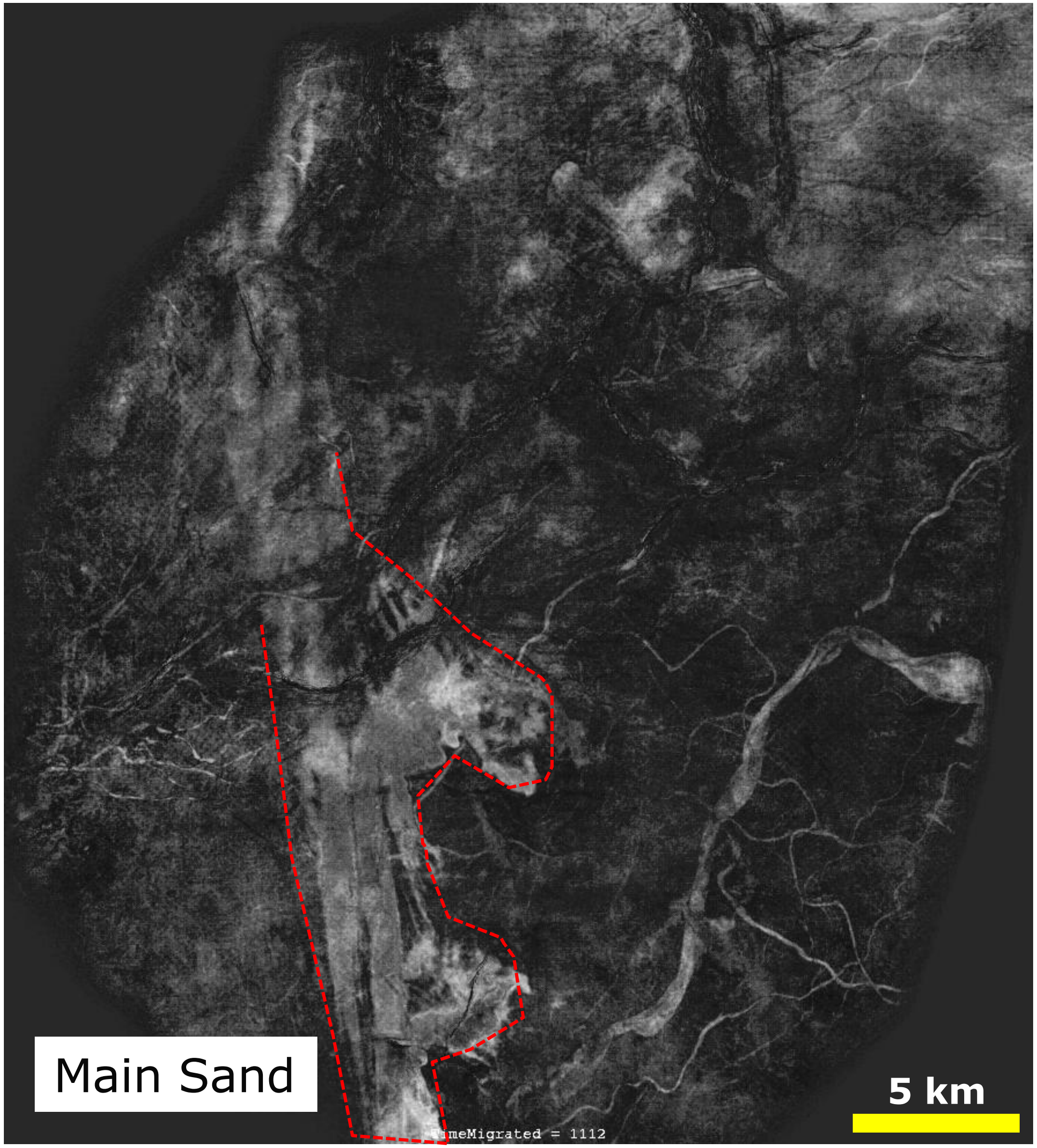
Sand Isopach - Main Injection interval

Result of detailed seismic mapping



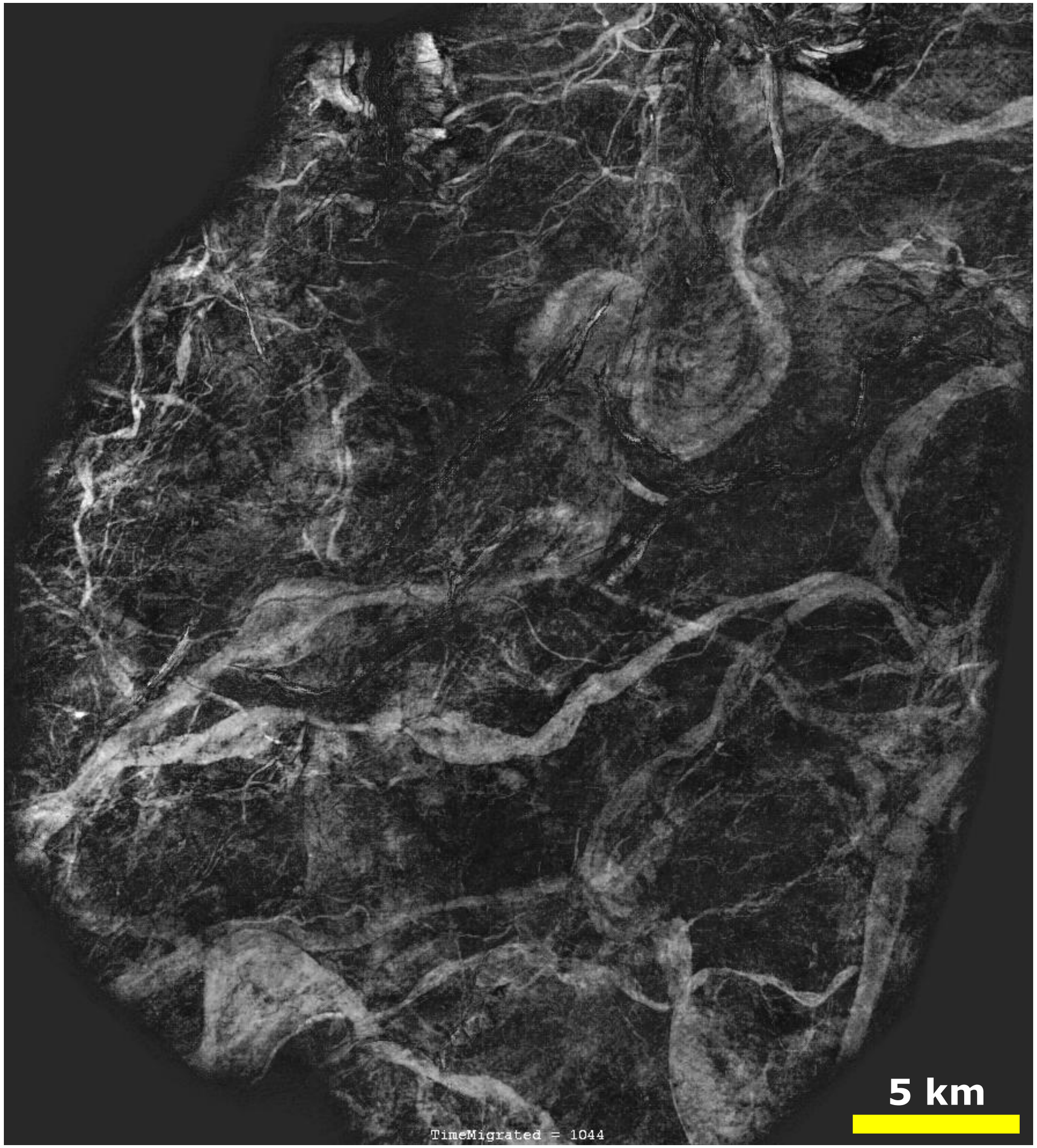
Seismic interpretation – Fluvial channels
Optical Stack at Main Sand level

- The observed channel network is interpreted as a **fluvial environment** based on shapes of individual seismic elements, their size, orientation and sinuosity
- **The flow direction** is from east to west
- Channels have **moderate sinuosity** and are characterized by side-attached bars (point bars)
- Size and amalgamation of channel elements above main sand **increases upwards**



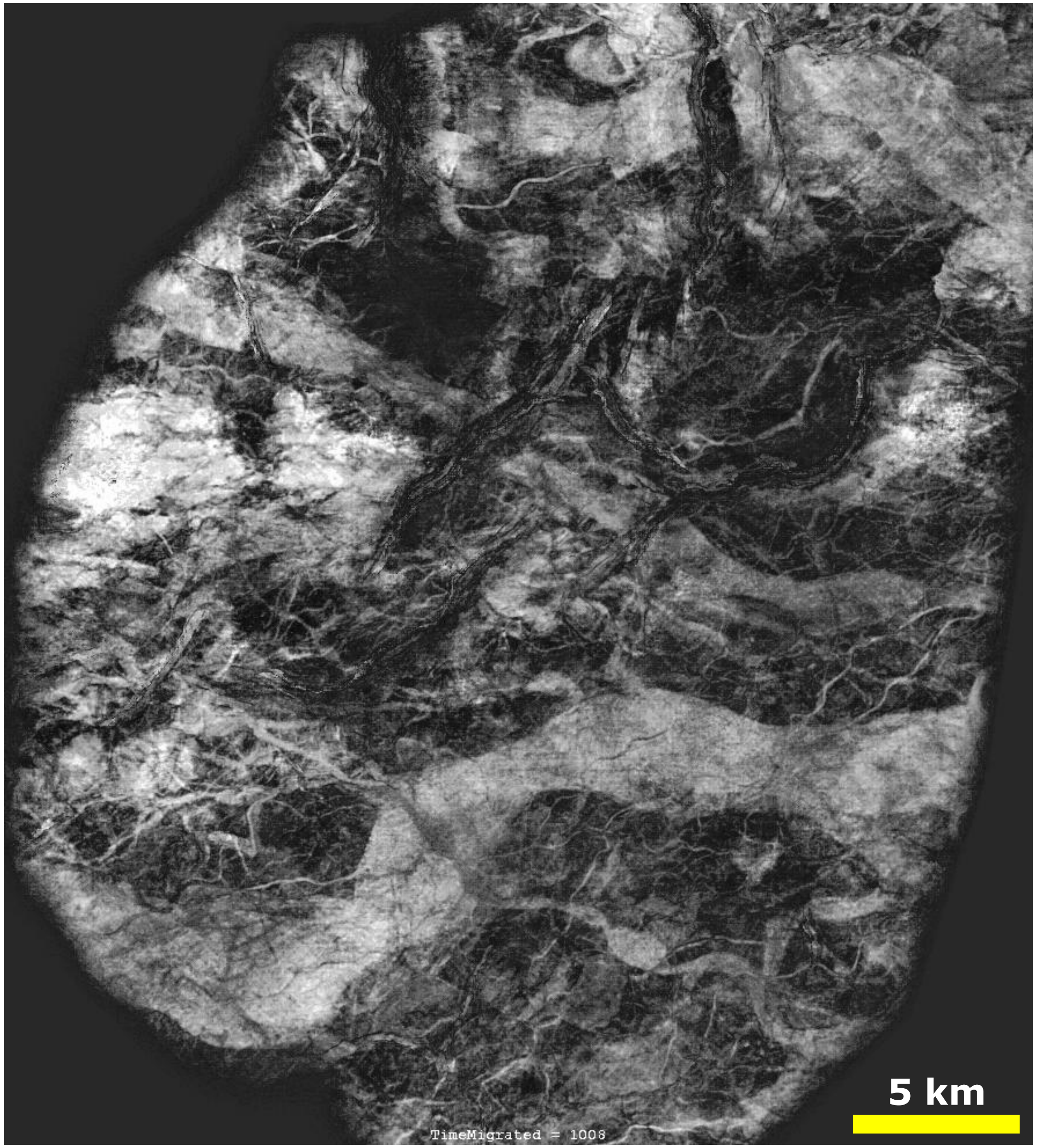
Seismic interpretation – Fluvial channels
Optical Stack 40ms (~60m) above Main Sand

- The observed channel network is interpreted as a **fluvial environment** based on shapes of individual seismic elements, their size, orientation and sinuosity
- **The flow direction** is from east to west
- Channels have **moderate sinuosity** and are characterized by side-attached bars (point bars)
- Size and amalgamation of channel elements above main sand **increases upwards**



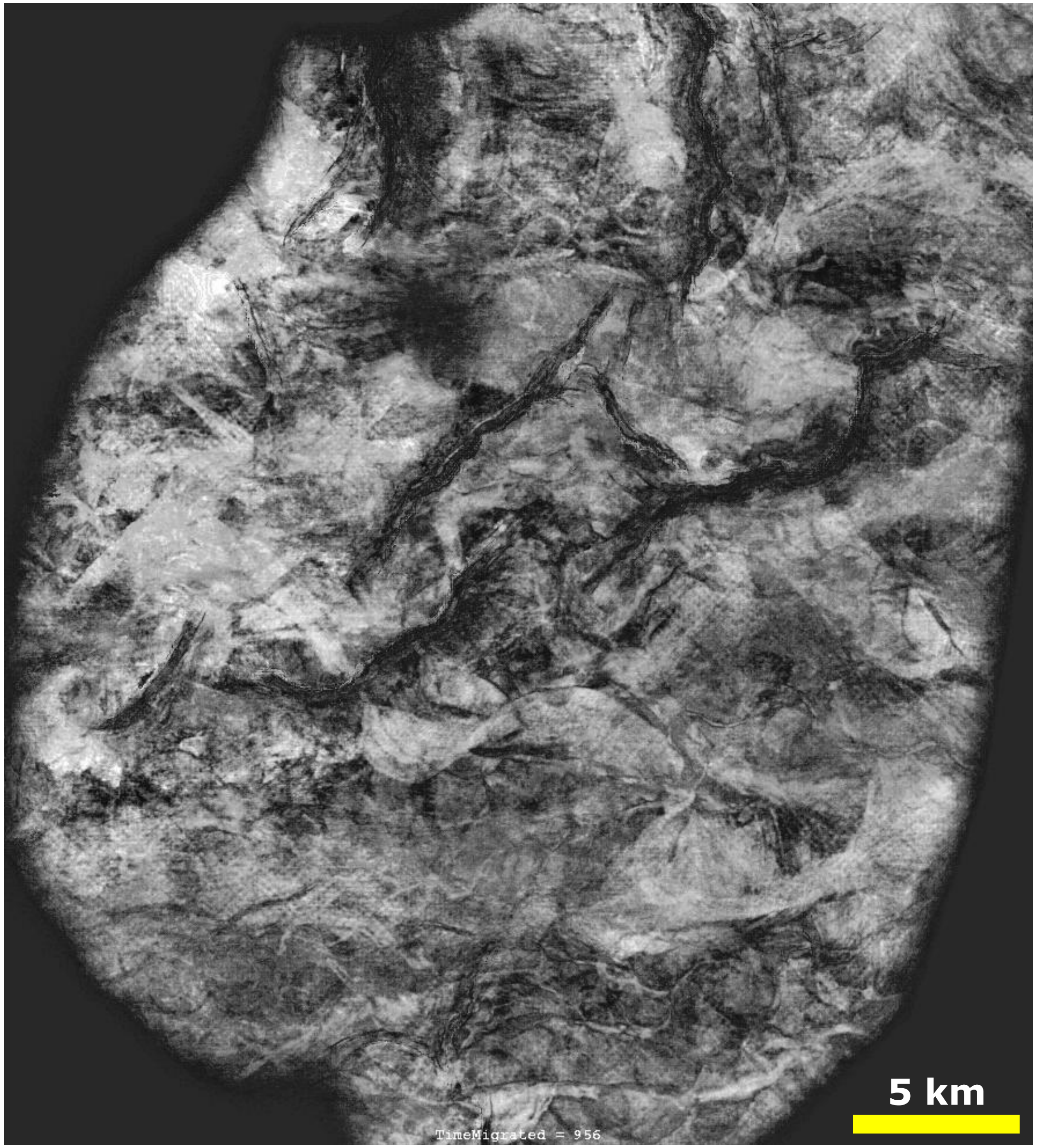
Seismic interpretation – Fluvial channels
Optical Stack 80ms (~120m) above Main Sand

- The observed channel network is interpreted as a **fluvial environment** based on shapes of individual seismic elements, their size, orientation and sinuosity
- **The flow direction** is from east to west
- Channels have **moderate sinuosity** and are characterized by side-attached bars (point bars)
- Size and amalgamation of channel elements above main sand **increases upwards**

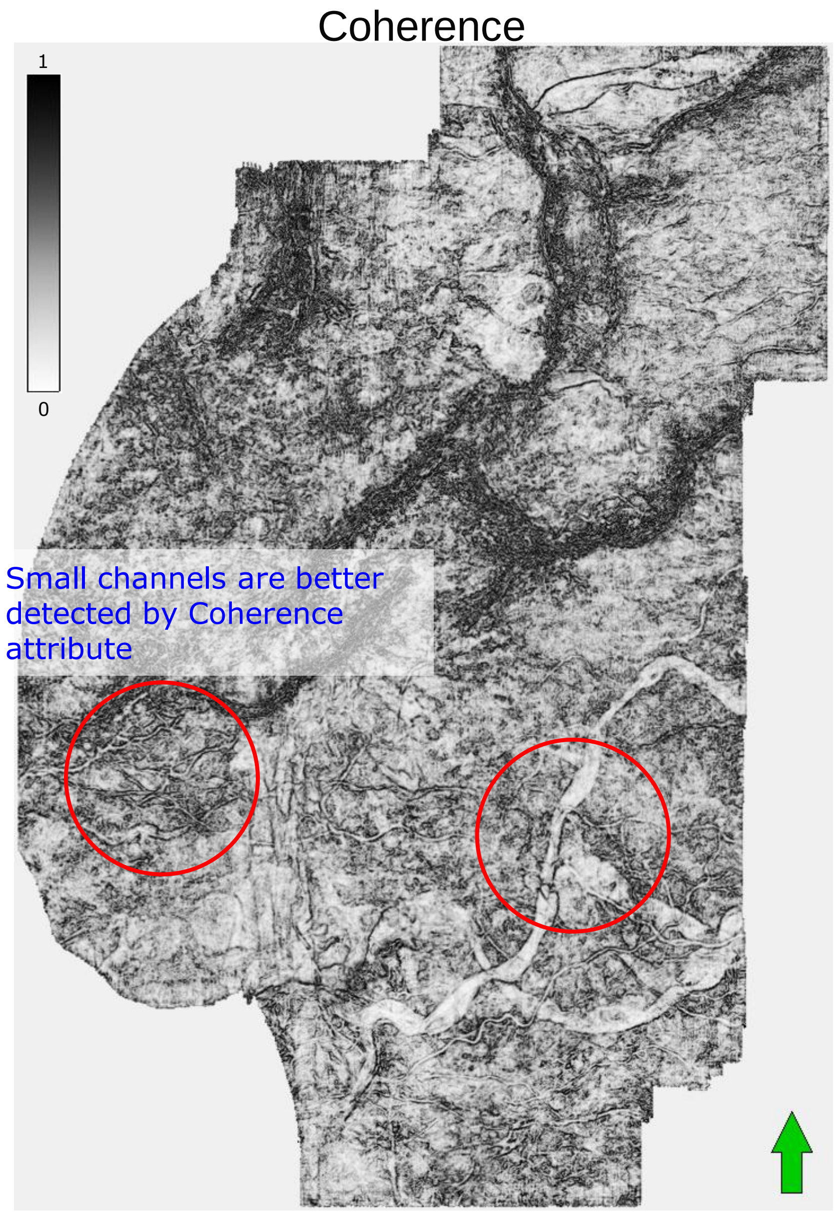


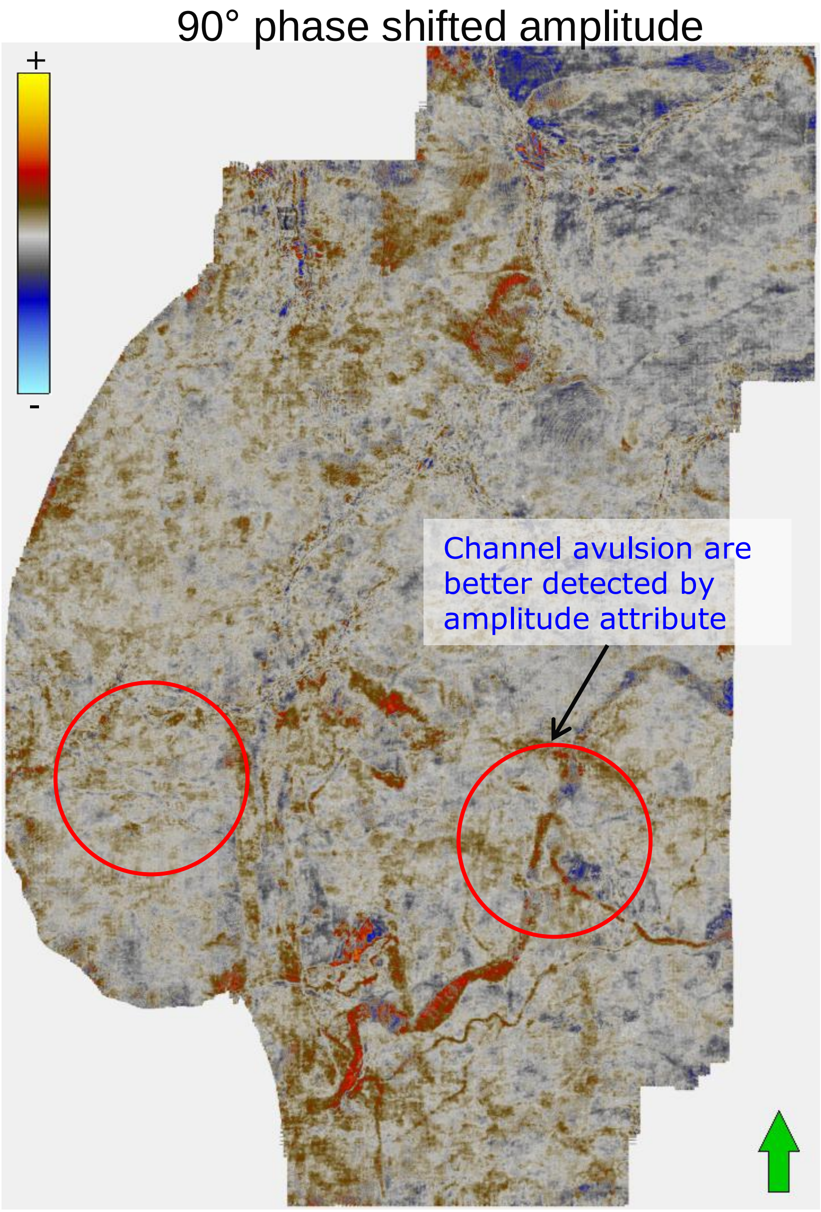
Seismic interpretation – Fluvial channels
Optical Stack 120ms (~180m) above Main Sand

- The observed channel network is interpreted as a **fluvial environment** based on shapes of individual seismic elements, their size, orientation and sinuosity
- **The flow direction** is from east to west
- Channels have **moderate sinuosity** and are characterized by side-attached bars (point bars)
- Size and amalgamation of channel elements above main sand **increases upwards**



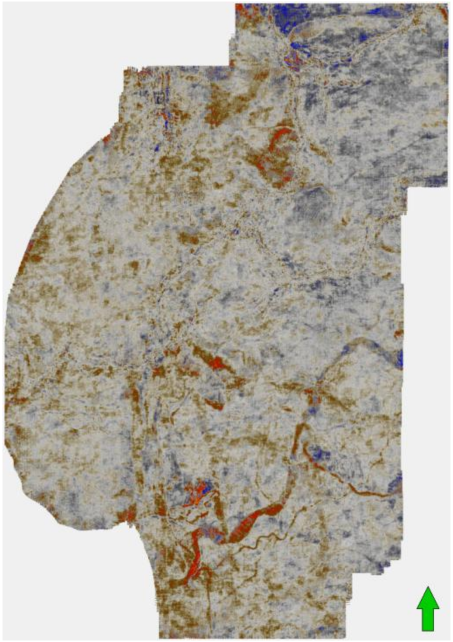
Corendering

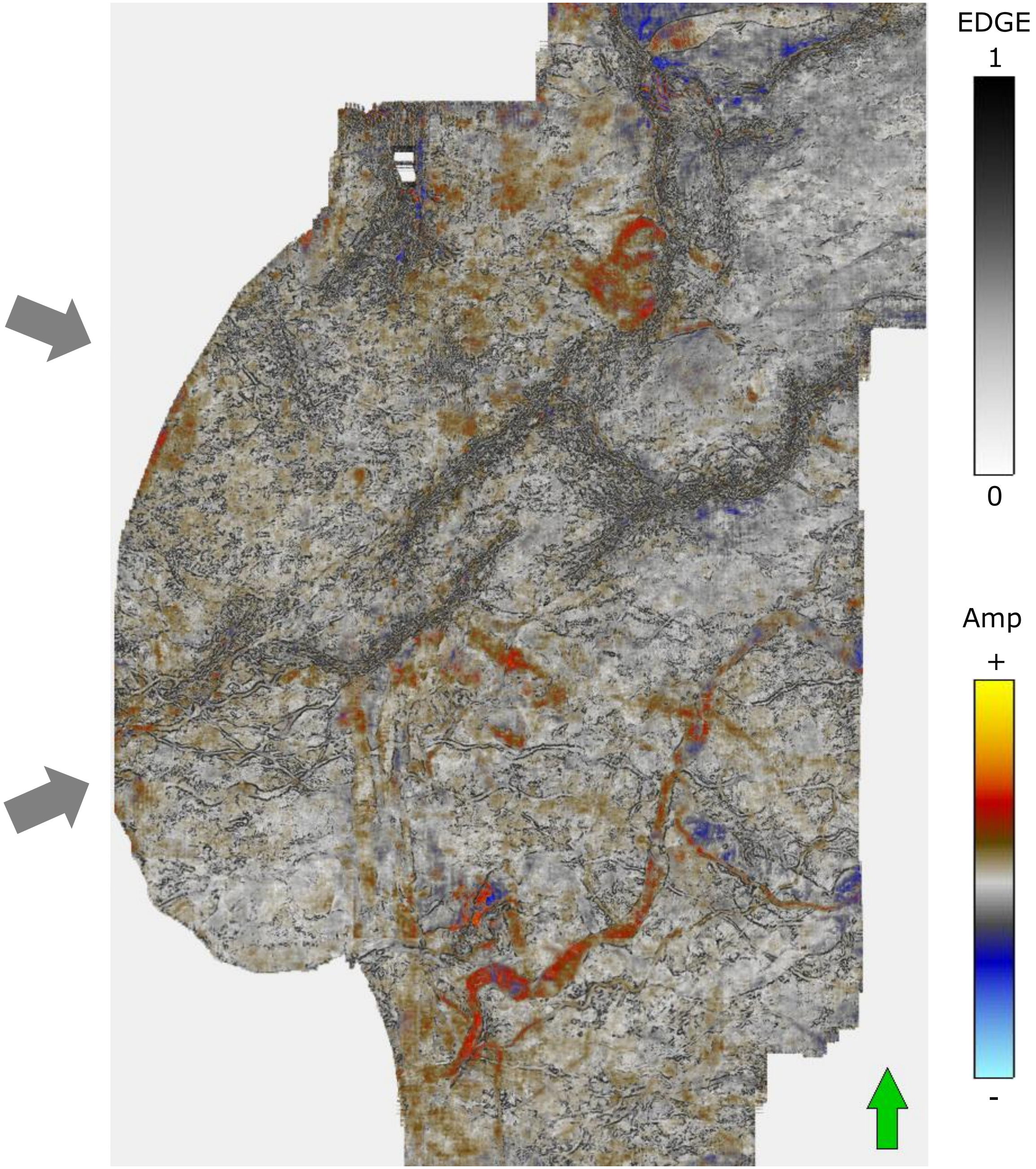




Single attribute tells only part of the story – need to combine them

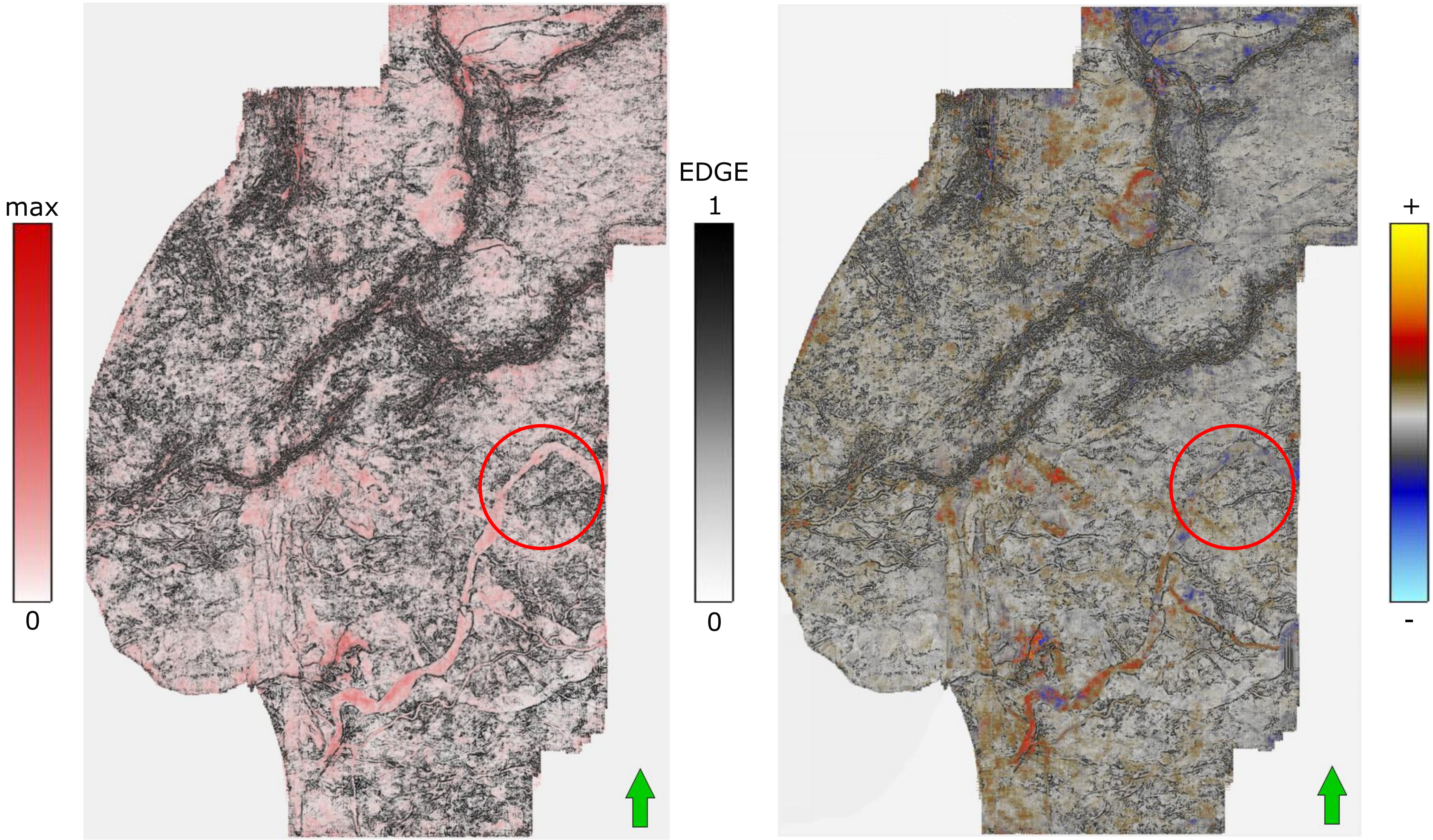
Corendering





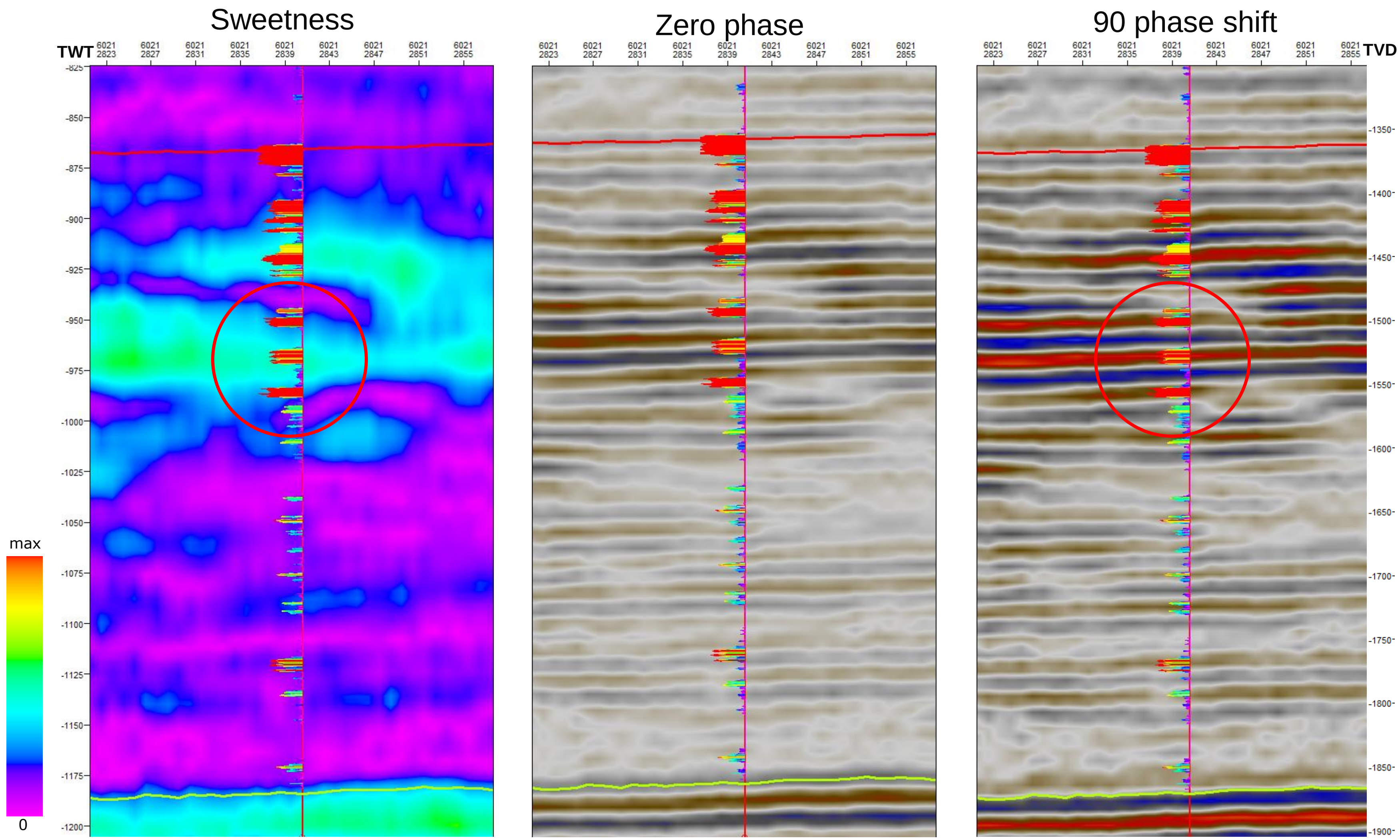
Stratal slice interpretation
Attribute Selection

(Coherence +Sweetness) (Coherence +90° amplitude)



Channel shapes are more clear on the stratal slice with sweetness display (lateral vs. vertical resolution trade-off)

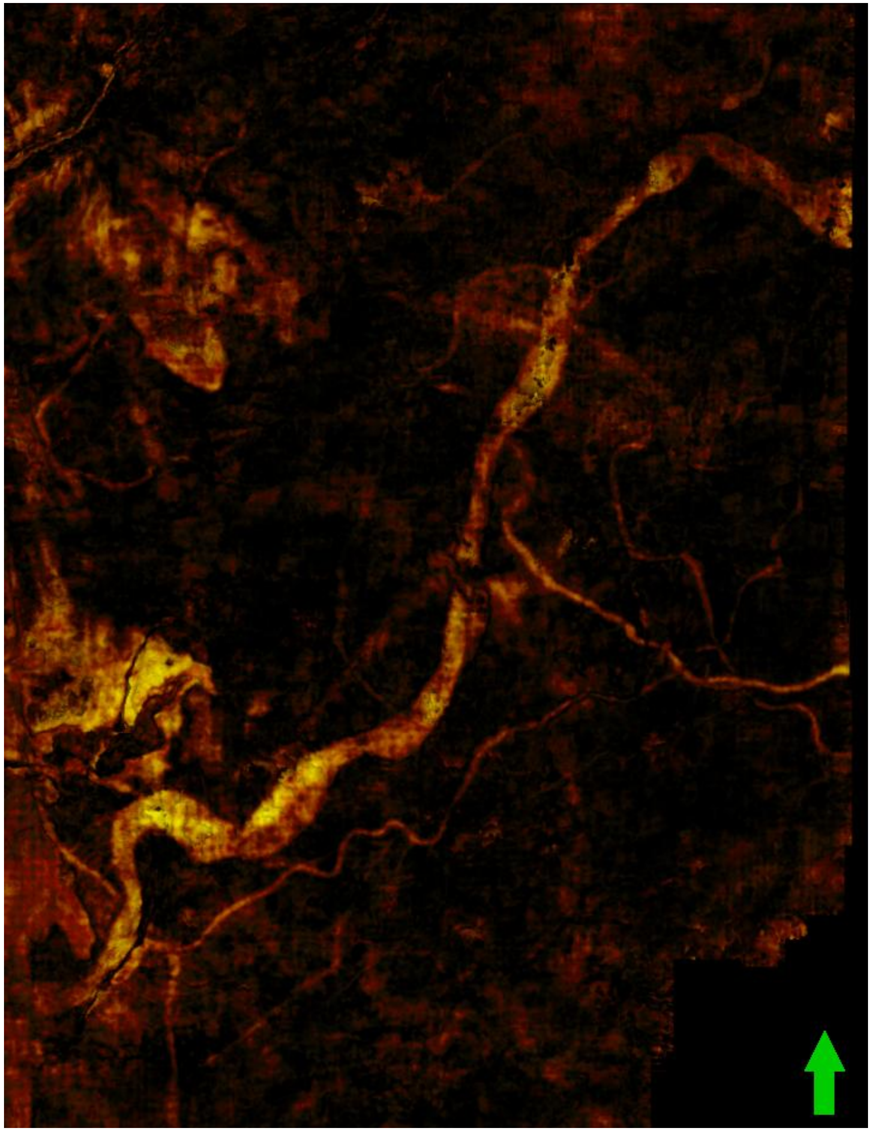
Stratal slice interpretation
Attribute Selection



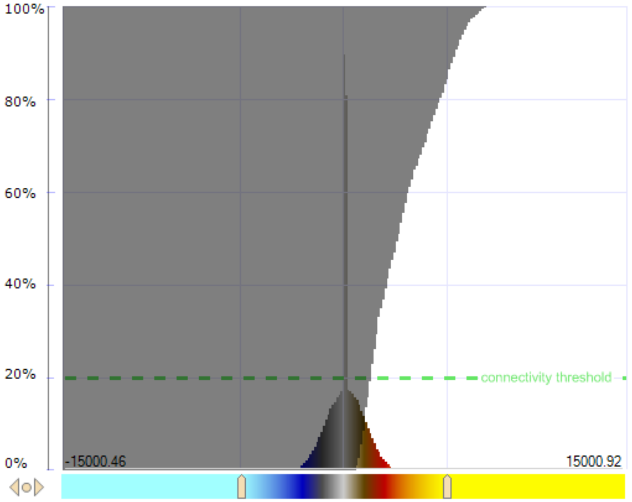
Sweetness can't distinguish separate closely spaced sand layers and overestimates sand thickness

Geobody Detection

Amplitude

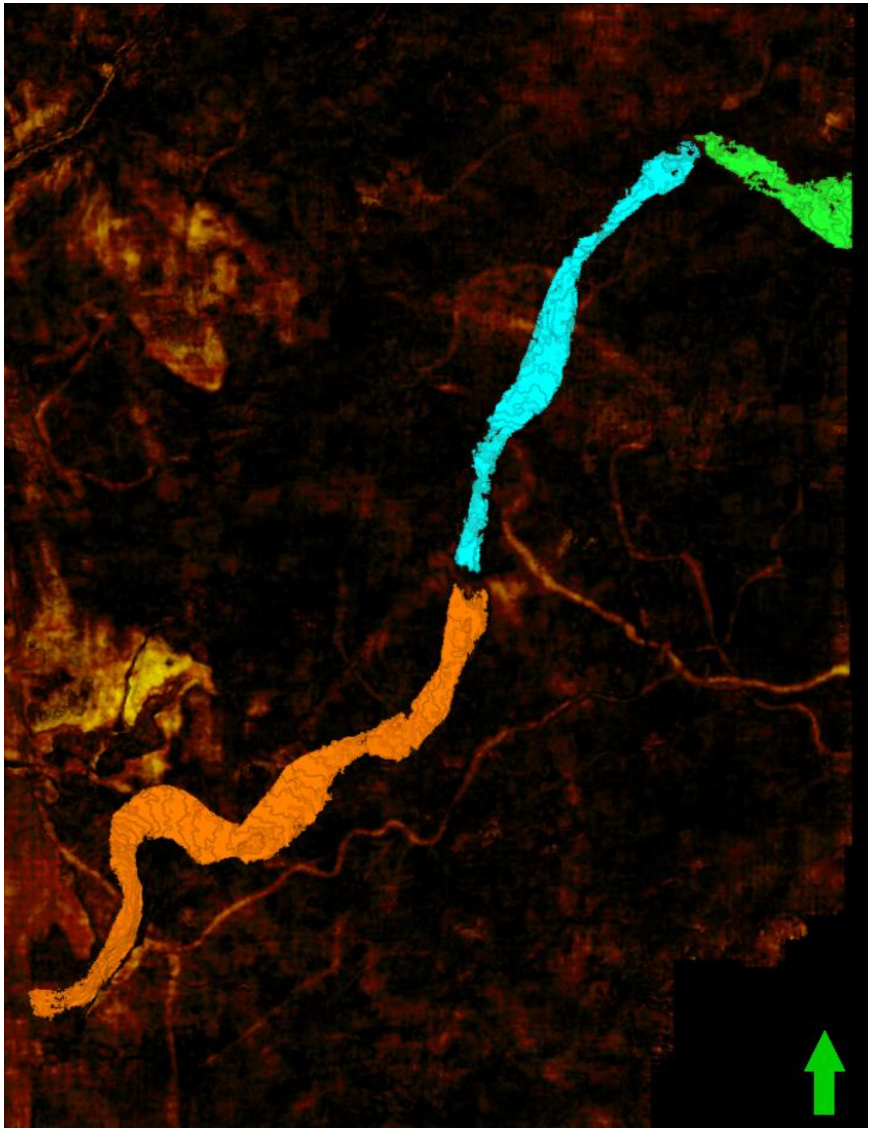


- Make a seismic probe from selected horizon
- Adjust opacity curve so that channels are clearly visible
- Seed pick the channels



Geobody Detection

Amplitude



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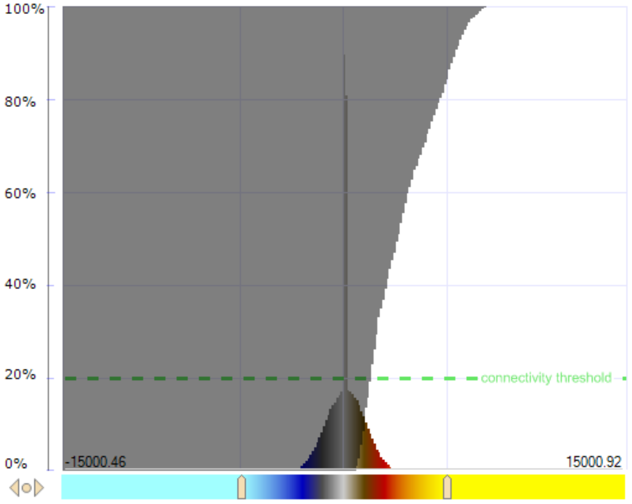
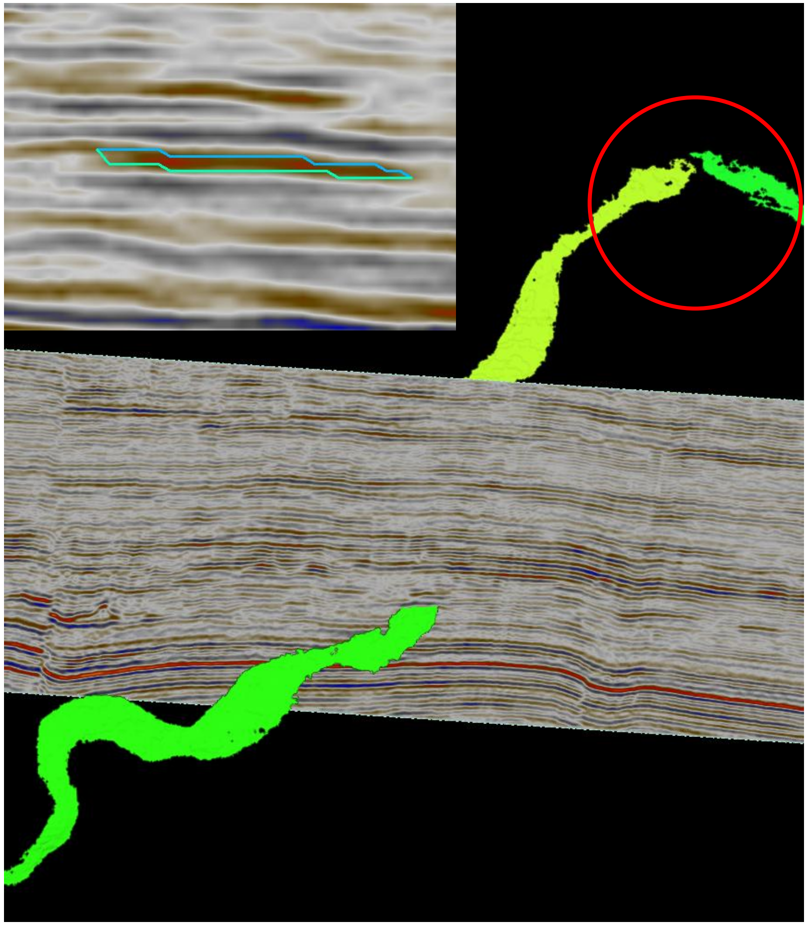
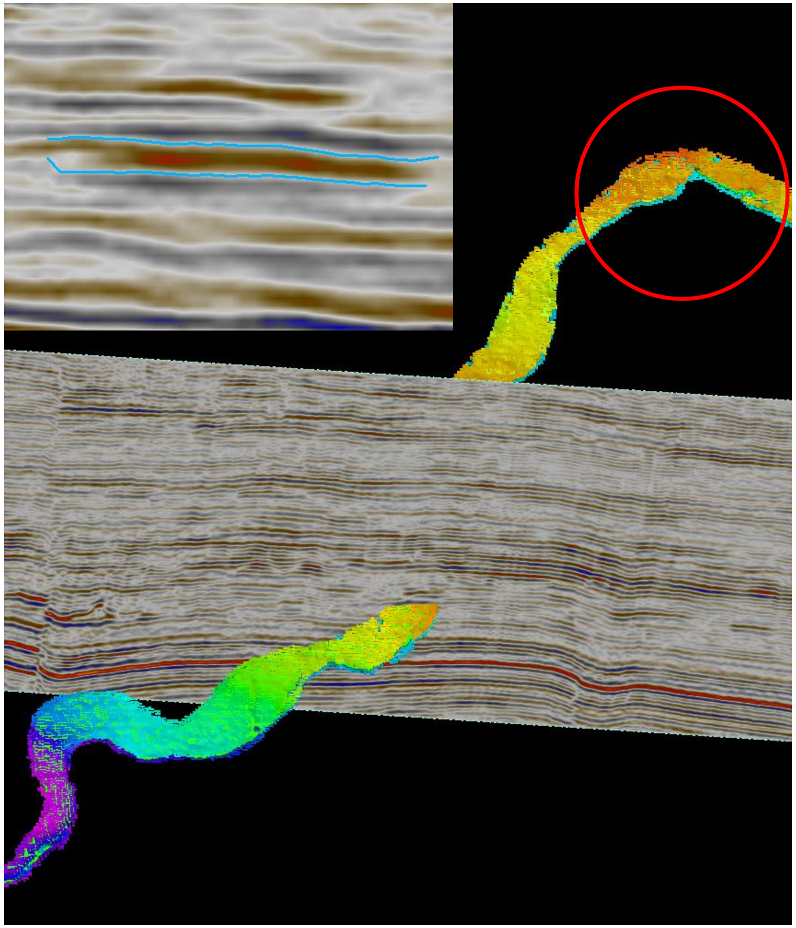


Channel interpretation using geobody detection

Detected channel body

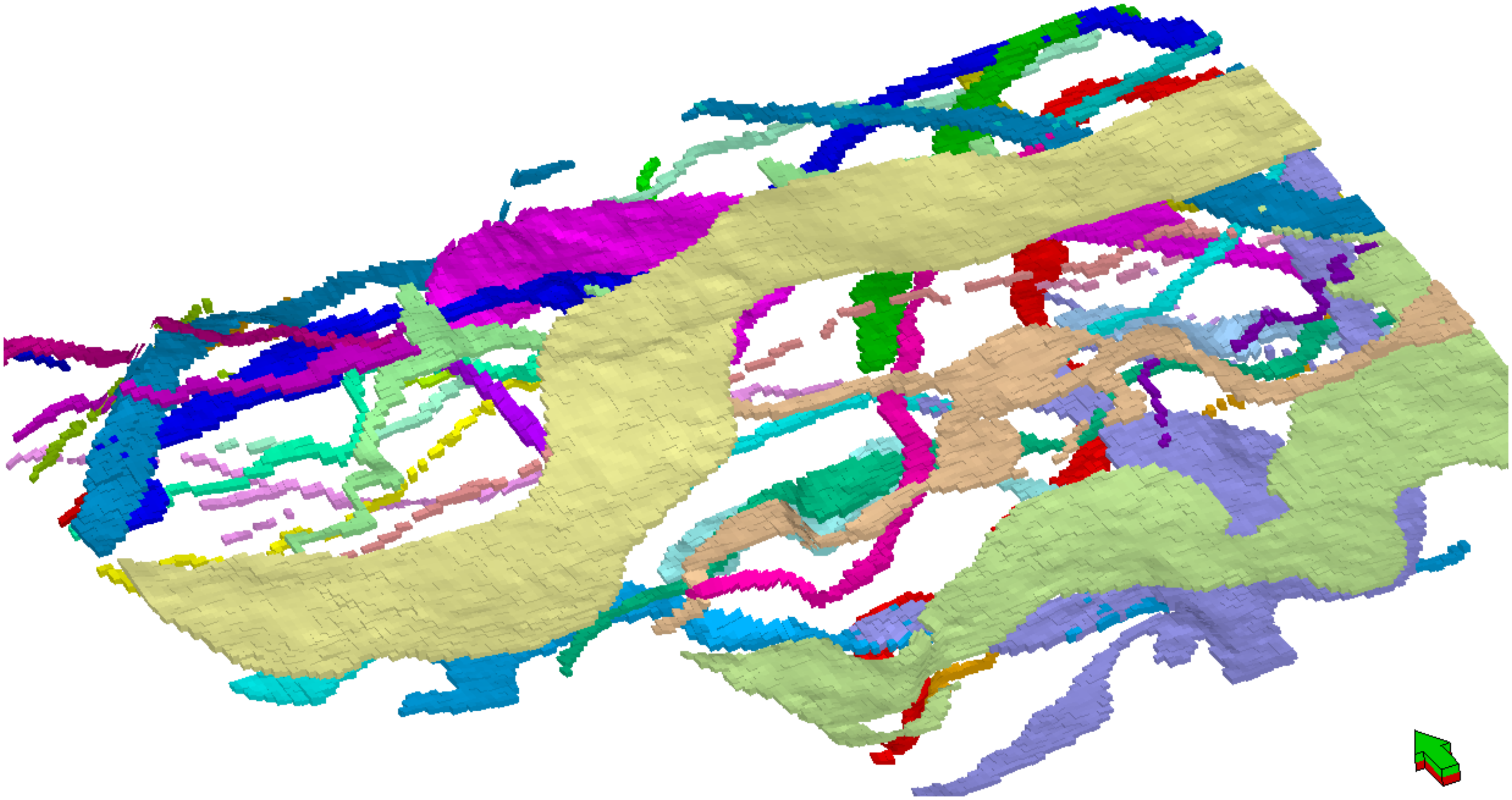


Autopicked channel top and bottom horizons



This method results in better continuity of channel bodies and more accurate thickness estimation

Channel interpretation using geobody detection



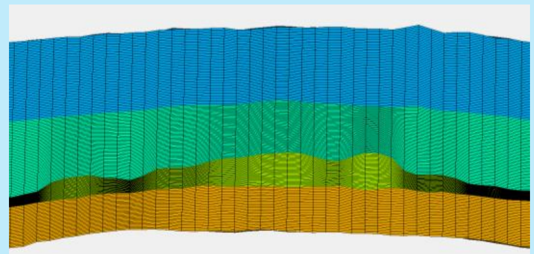
Interpreted channels were sampled into geocellular grid and used to deterministically define high NTG regions associated with channel deposits

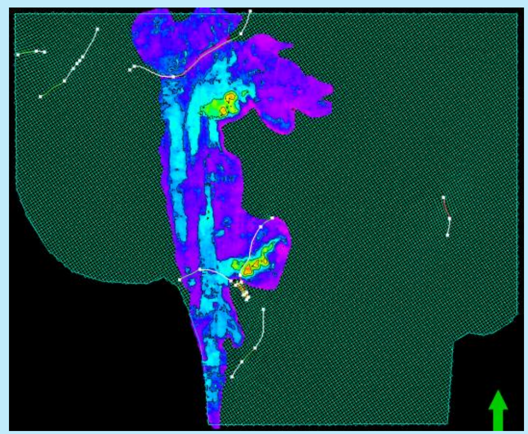
Neocomian Characterization and Modeling

Data Preparation and Analysis

Structural Framework Building

Property Distribution and Upscaling



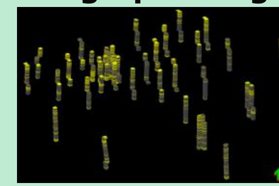


Input:

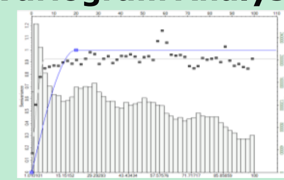
- *Key horizons and faults*
- *Grid boundary*
- *Layering option*
- *Cell size*

Optimal parameters selection (cross-validation runs)

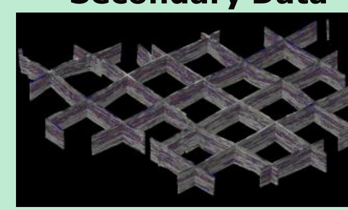
Log Upscaling



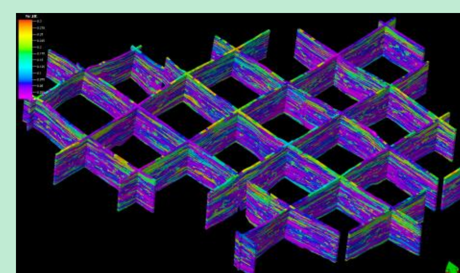
Variogram Analysis



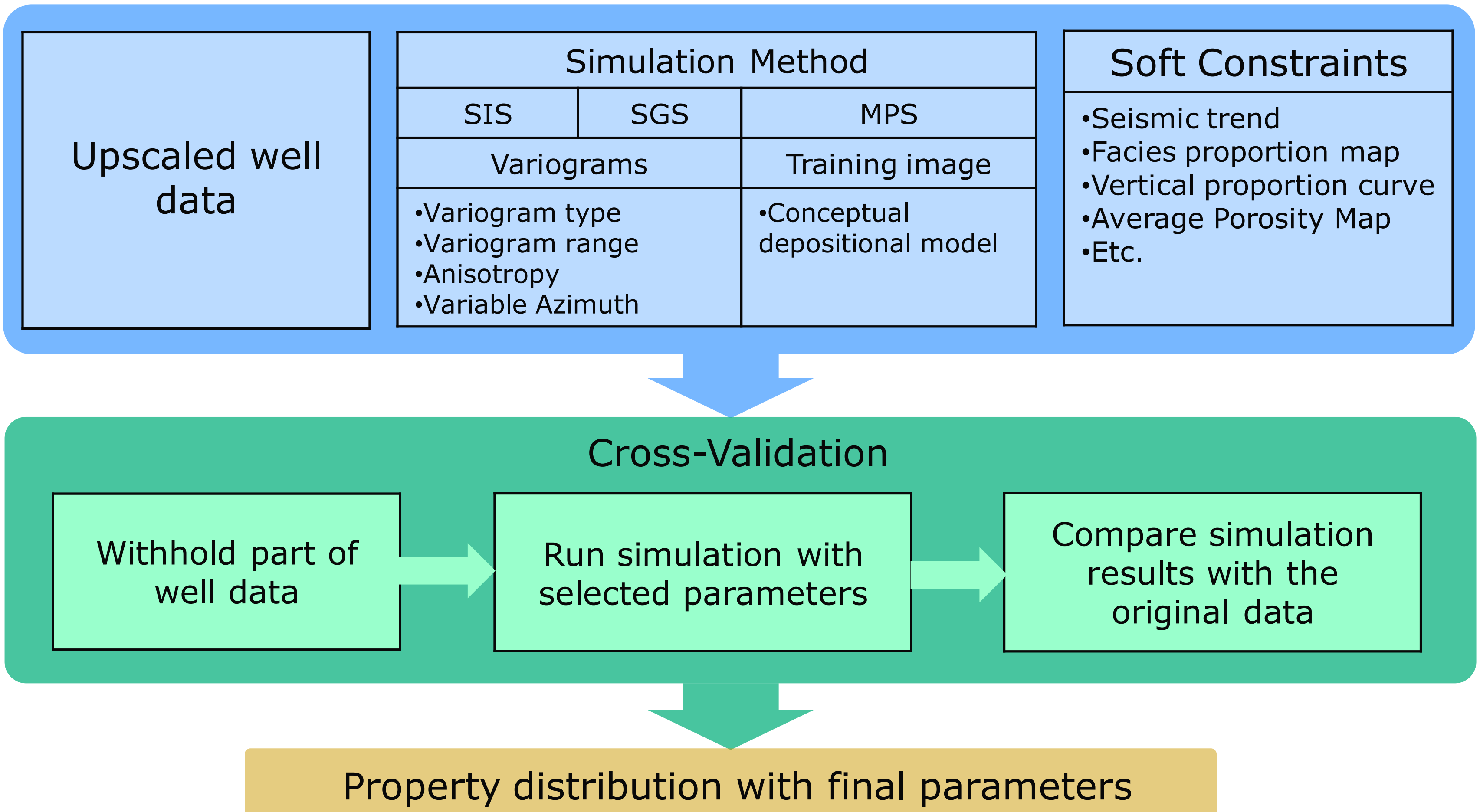
Secondary Data



Final model



Property distribution
Optimal parameters selection

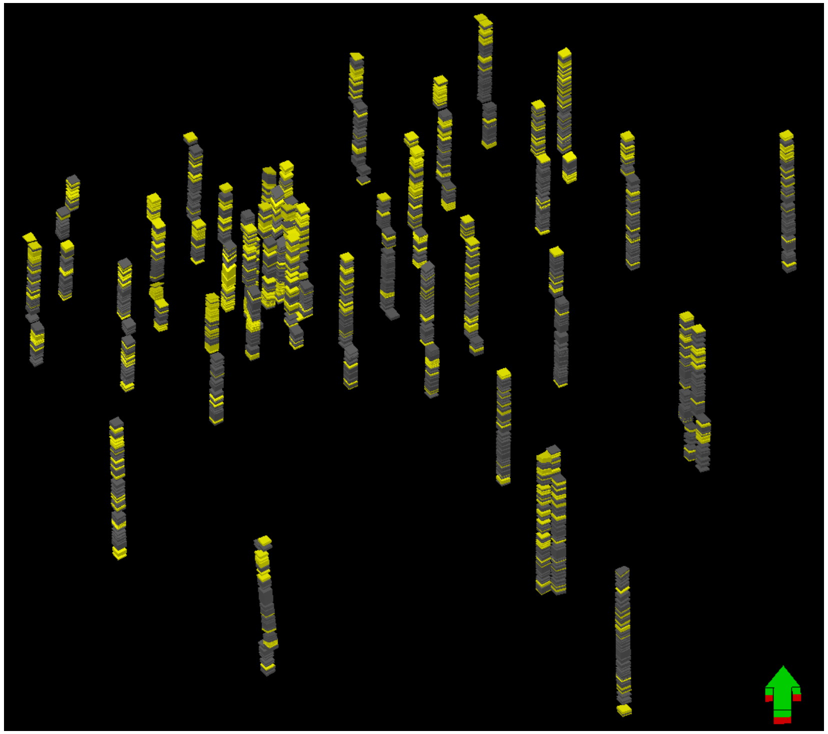


Cross-validation gives numerical estimation of the model predictability

Property distribution

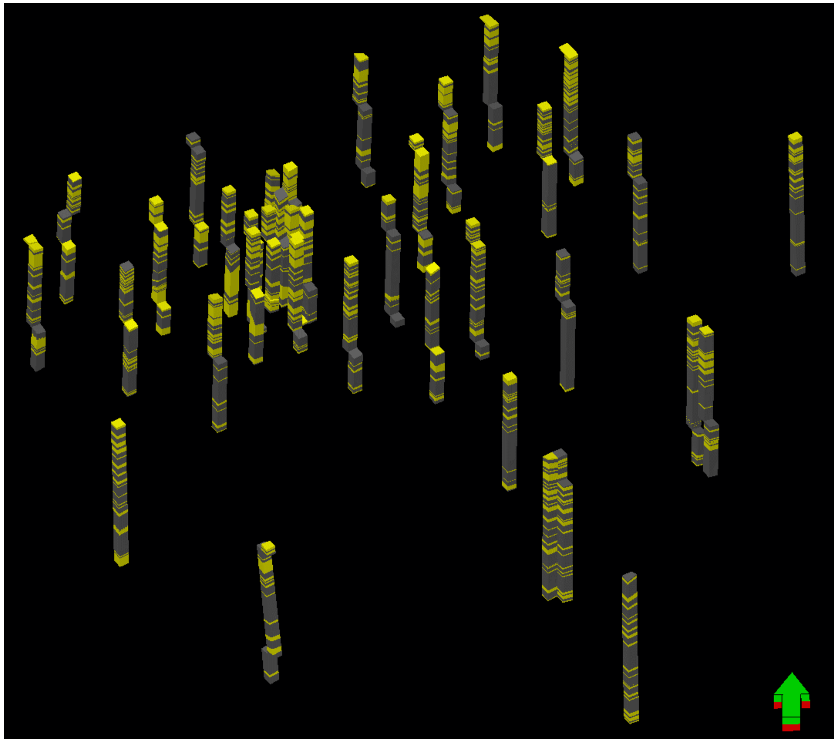
Two Cross-Validation Methods

1: Random Function



- Cells are randomly picked and made blank (40% of the original data)
- Cross-validation run = 1 simulation run
- Cross-validation is ran 50 times to get statistically meaningful results

2: Well-by-well



- Cells which belong to particular wells are removed from the simulation (3-4 wells at a time defined manually)
- Cross-validation run = 12 simulation runs
- Cross-validation is ran 20 times to get statistically meaningful results

Property distribution
Cross-Validation results (Sand Flag)

Run description

	Zone1	Zone2_channels	Zone2_rest	Zone3	Zone4
Run1	SGS/seis	SGS/seis	SGS	SGS/NTG	SGS/VPC
Run2	SGS/seis	SGS/seis	SGS	SGS/NTG_CCK	SGS/seis
Run3	SGS	SGS	SGS	SGS	SGS
Run4	SIS	SGS	SIS	SIS	SIS
Run5	SGS/VPC	SIS	SIS	SGS/VPC	SIS/VPC
Run6	SIS/VPC	SIS	SIS	SIS/VPC	SIS/VPC

Results

Random Function

	Zone1	Zone2_channels	Zone2_rest	Zone3	Zone4
SIS	0.2863	0.2714	0.2194	0.7027	0.2589
SGS	0.2991	0.2306	0.1854	0.7096	0.1875
SIS/VPC	0.2915	-	-	0.7256	0.2873
SGS/VPC	0.3462	-	-	0.7204	0.3201
SGS/seis	0.3753	0.2981	-	-	0.2345
SGS/NTG_trend	-	-	-	0.7272	-
SGS/NTG_CCK	-	-	-	0.7486	-

Well by Well

	Zone1	Zone2_channels	Zone2_rest	Zone3	Zone4
SIS	0.0823	0.0427	-0.0096	0.3408	0.0397
SGS	0.0793	0.0216	-0.0139	0.4144	0.0280
SIS/VPC	0.1027	-	-	0.3691	0.1611
SGS/VPC	0.1385	-	-	0.4271	0.1702
SGS/seis	0.2112	0.1496	-	-	0.1013
SGS/NTG_trend	-	-	-	0.3835	-
SGS/NTG_CCK	-	-	-	0.4466	-

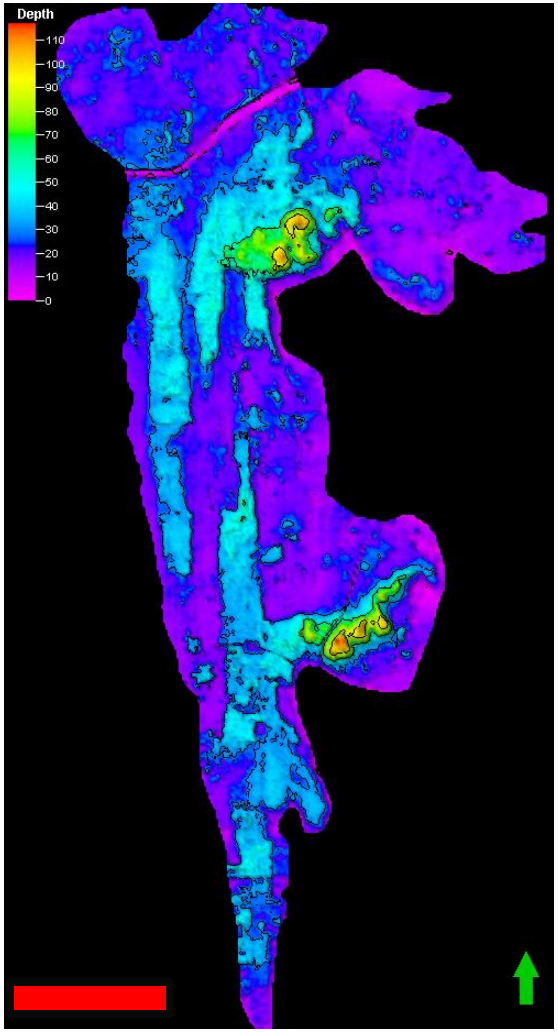
- highest correlation coefficient (yellow highlight)

The both methods show consistent results

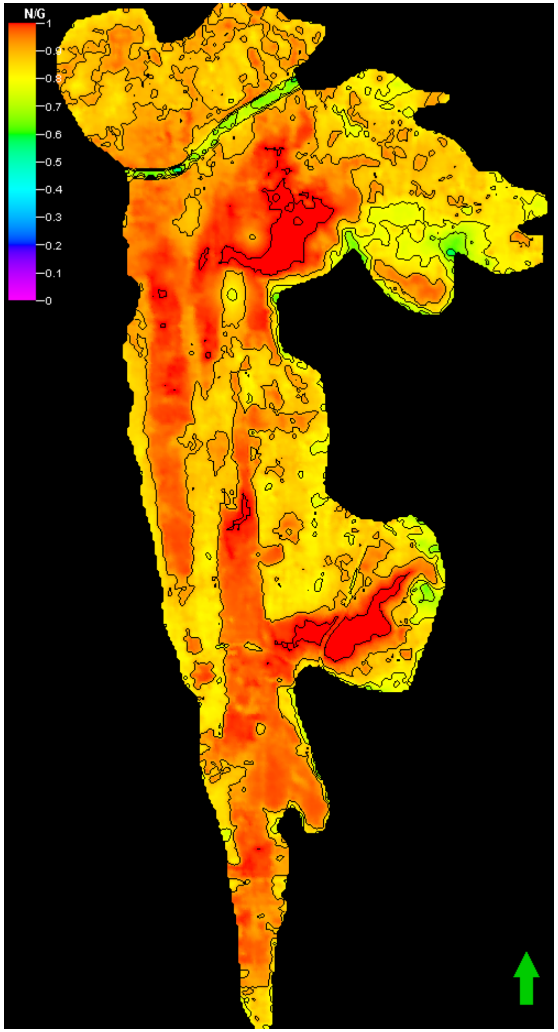
Property distribution

Main Sand: NTG and Porosity trends

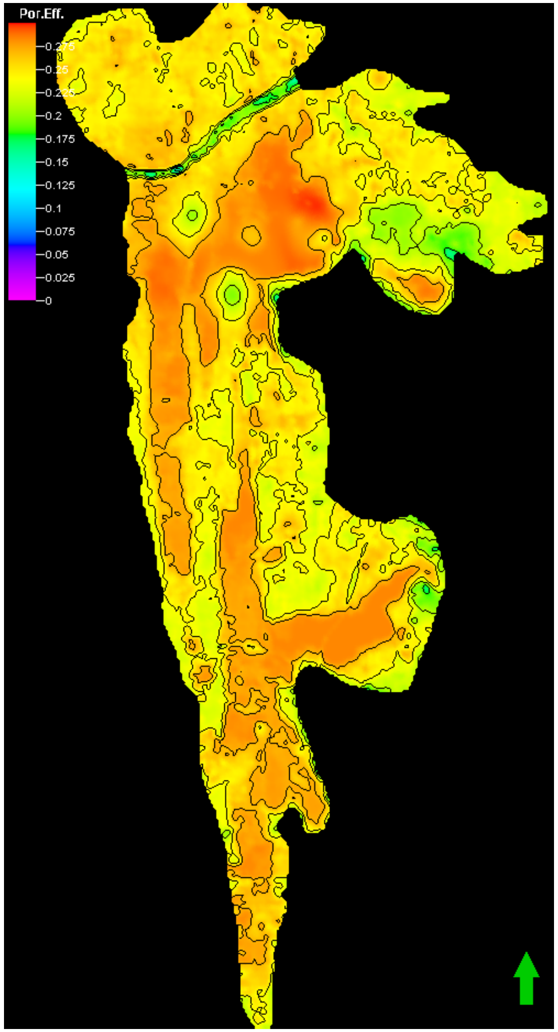
Seismic Ispoach



NTG trend (CCK)



PHIE trend (CCK)

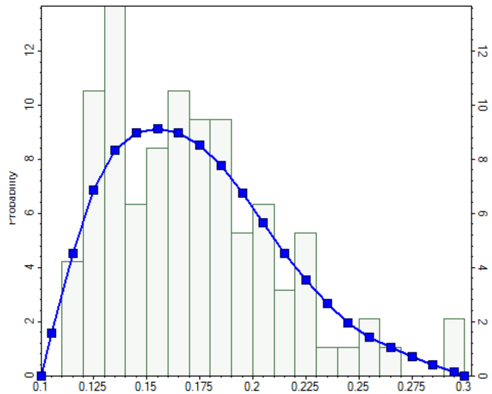


Improved Porosity Distribution in Model

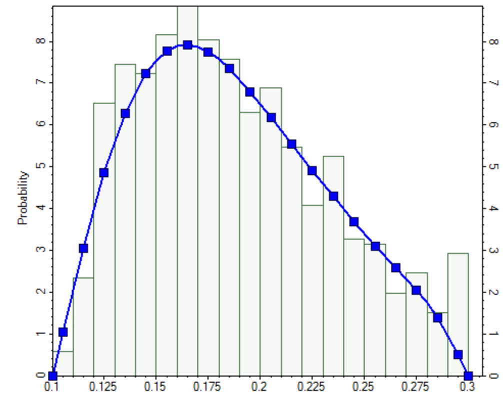
Detailed Seismic mapping guides porosity trends for sand simulation

No Channel Regions from Seismic

Lower Neocomian

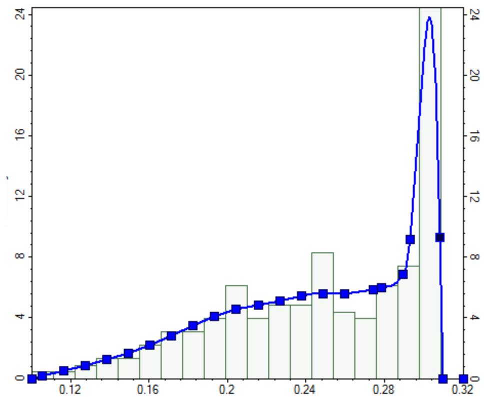


Upper Neocomian

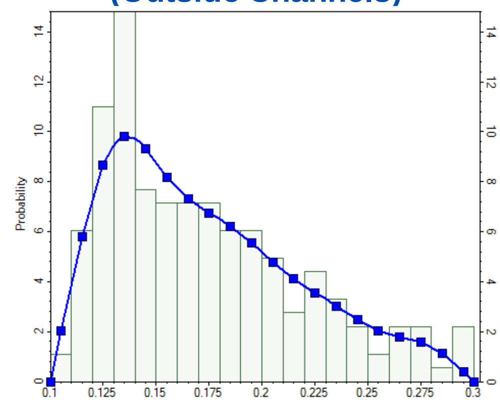


Deterministic Channel Regions from Seismic

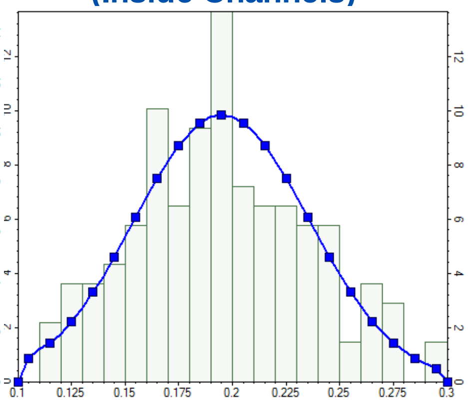
Main Injection Sand



Middle Neocomian (Outside Channels)

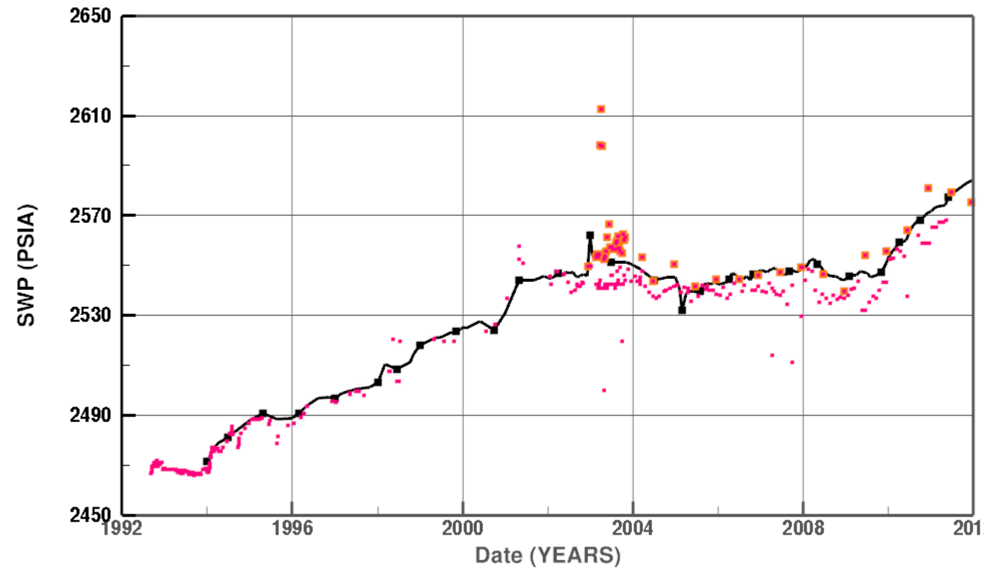


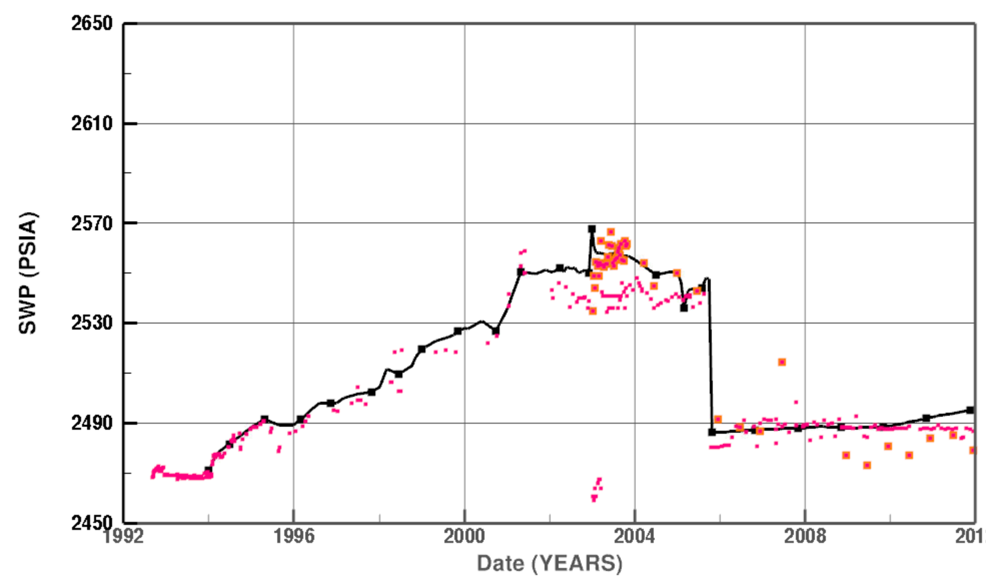
Middle Neocomian (Inside Channels)



Dynamic Model
History-Match Results

- Static model was validated by History Match
- Only minor changes to permeability field and adjustment for boundary conditions to get a good HM





Simulated Pressure
SGS Pressure
Water Level Pressure

Summary/ Conclusions

- **Stratal slices, optical stacks and corendering** techniques assisted interpretation of depositional features at very fine scale
- Main Injection interval and other channels were **deterministically mapped from seismic** allowing better definition of high reservoir quality regions in the static model
- **Cross validation techniques** improved parameter selection for the model. Validated variogram parameters, tested impact of soft constraints (NTG map and Vertical Proportion Curves)
- **Waste Water Model verified by History Match** for water disposal. Static model required only minor changes to permeability field and adjustment for boundary conditions