Synthetic seismograms, Synthetic sonic logs, Synthetic Core

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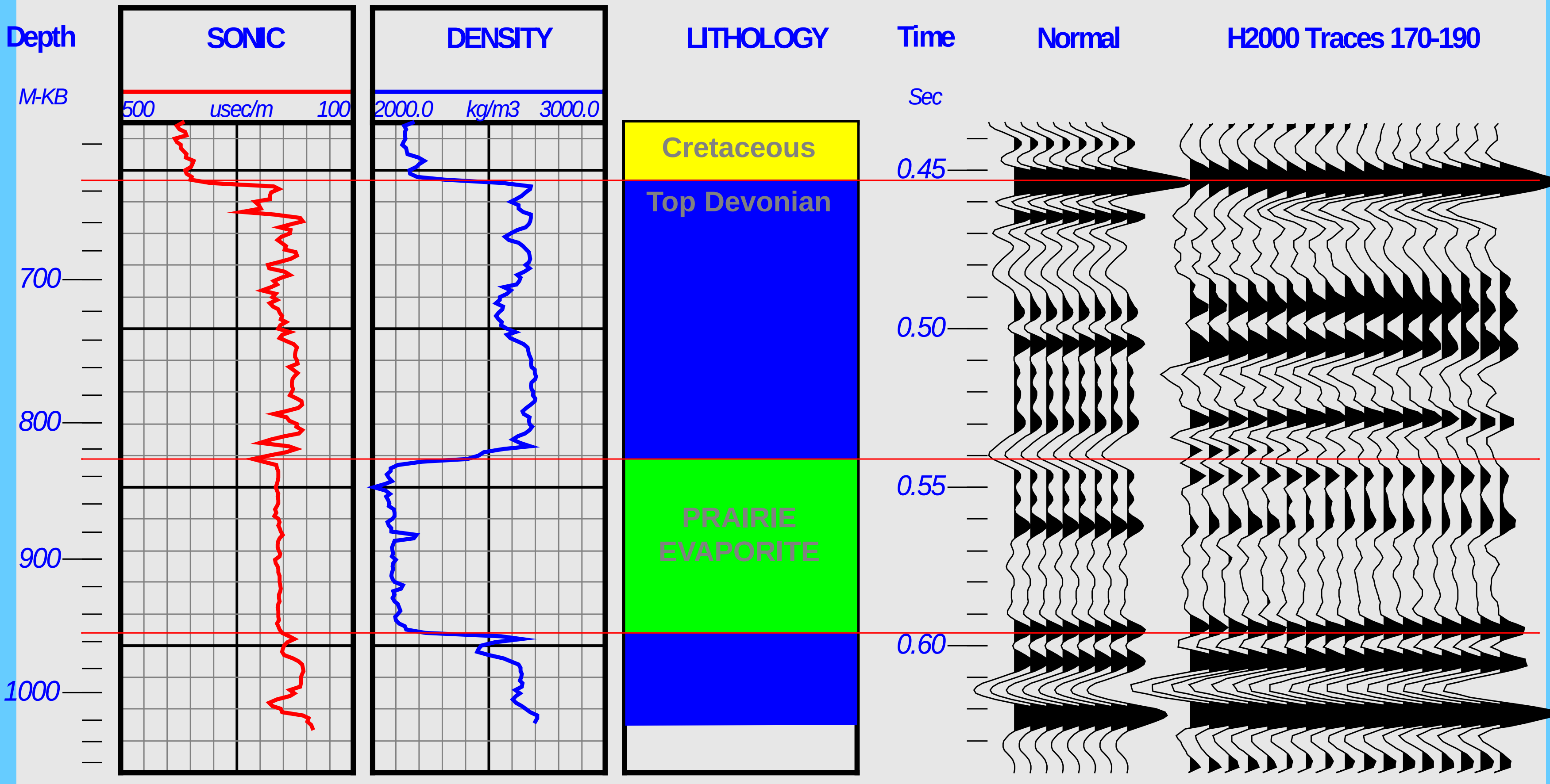
Synthetic Seismograms

- Synthetic seismograms range from 1-D model seismograms that are least general but most economical to the most general and expensive methods such as viscoelastic 3-D finite difference modeling.
- The 1-D synthetic seismogram derived from sonic and density logs initiates seismic interpretation and is still the workhorse of the industry.

1D- Synthetic Seismograms

- 1-D Synthetic seismograms utilize sonic and density logs to simulate seismic reflection responses from a layered medium. See example below from Watson (2004).



Synthetic Sonic Logs (Lindseth, 1979)

- While 1-D synthetic seismograms, use sonic and density logs to simulate seismic data through:

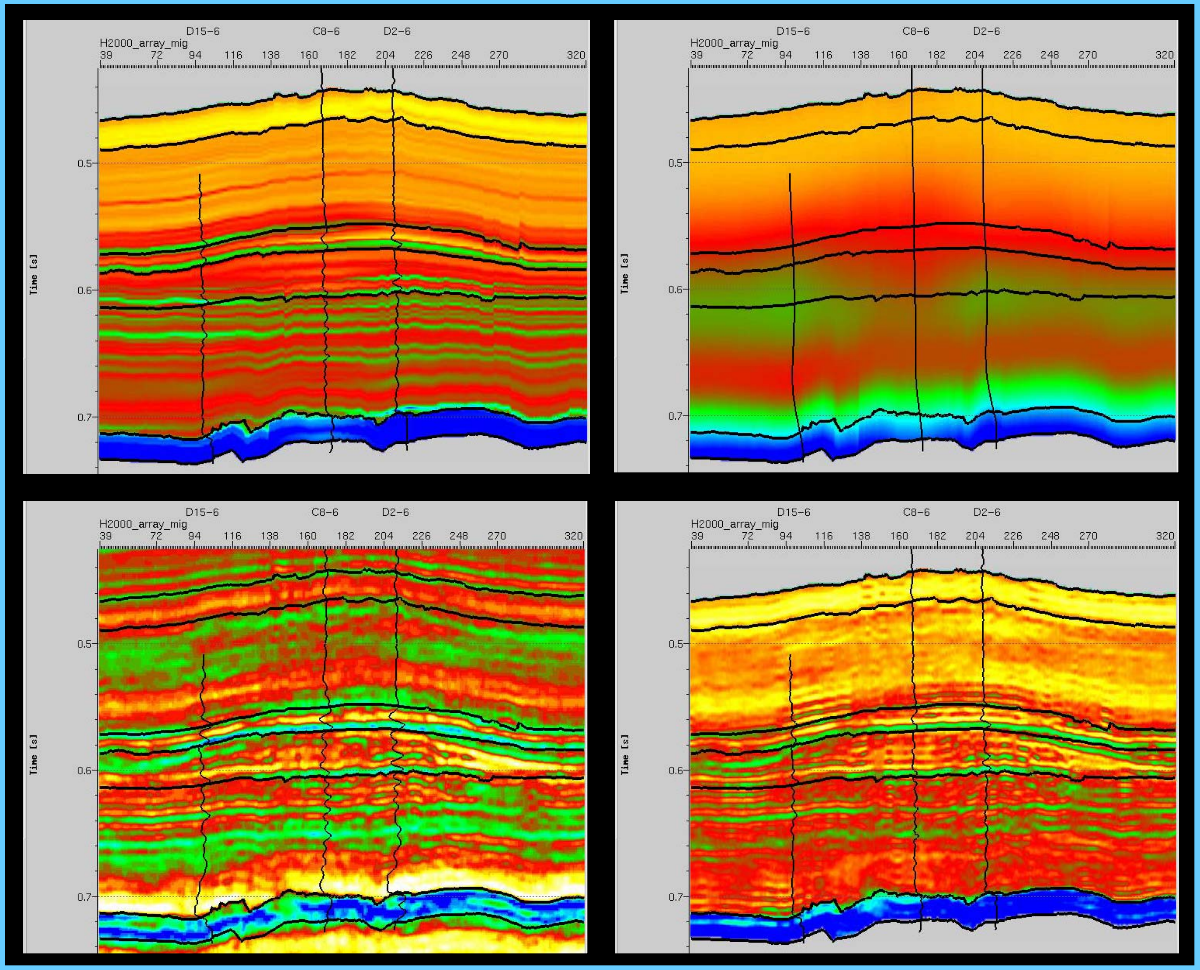
$$c_k = \frac{\rho_{k+1} V_{K+1} - \rho_K V_K}{\rho_{k+1} V_{K+1} + \rho_K V_K}$$

- Computing synthetic sonic logs (Lindseth, 1979) used seismic data, with log information for missing frequency bands, to simulate acoustical impedance logs.

$$\rho_{K+1} V_{K+1} = \frac{\rho_K V_K (1 + c_K)}{(1 - c_K)}$$

Synthetic sonic logs

- These impedance plots from Watson (2002) show:
- Upper left: impedance model built from interpolation of well logs
- Upper right: Low pass filter (0-10Hz) of upper left model
- Lower left: Bandlimited inversion of seismic data only
- Lower right: Full inversion from combining upper right and lower left.



Synthetic Core

- The concept of “synthetic core” was discussed by Alam (2012 MSc thesis, U of Calgary) who interpreting data from a heavy oil field in Saskatchewan (designated here as P-field).
- Logs and cores were available in a neighbouring field.
- Logs were available, but no cores were available in P-field.
- The depositional environment of the region was known from logs, cores and seismic data in the area.
- Alam synthesized core for wells that had logs but no core.

Synthetic Core Methodology

- The first step involved the computation of shale volumes from gamma ray, density and neutron density logs using shale volume formulae in *“The Geological Interpretation of Well Logs” by* Rider and Kennedy (2011).

Methods: Shale Volume Calculations from Well Logs (Alam, 2012).

Empirical relationships that use gamma ray, neutron and density logs

$$I_{sh} = \frac{\gamma_{\log} - \gamma_{Min}}{\gamma_{Max} - \gamma_{Min}}$$

$$V_{sh1} = 0.083\left(2^{3.7(I_{sh})} - 1\right)$$

(For Tertiary and younger)

$$V_{SH2} = \frac{\phi_D - \phi_N}{(\phi_D)_{SH} - (\phi_N)_{SH}}$$

$$V_{SH} = (V_{sh1} + V_{SH2}) / 2$$

Here, I_{sh} = Initial Shale Volume Factor

V_{sh1} = Shale volume Factor from Gamma log

V_{SH2} = Shale volume Factor from Porosity logs

V_{SH} = Average Shale volume Factor

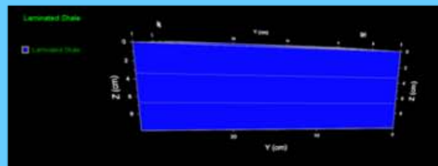
(After Thomas and Steiber , 1975)

Facies Templates for Depositional Settings

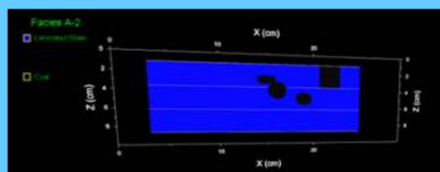
- Templates were established that corresponded to different depositional environments in the area.
- Each of the templates has different shale and sand volumes ranging from “A” grade (pure sand) to “G” (pure shale)
- There were core samples in the neighboring fields corresponding to these seven different templates.
- Using well logs to establish templates will allow these core samples to serve as “surrogate core” for wells without real core.

Methods: Core Analysis and Facies Distribution

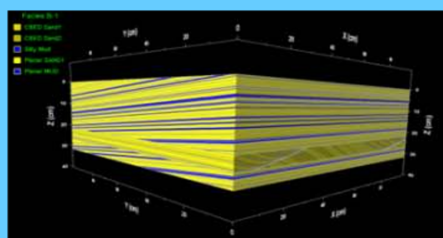
SBED Facies Templates



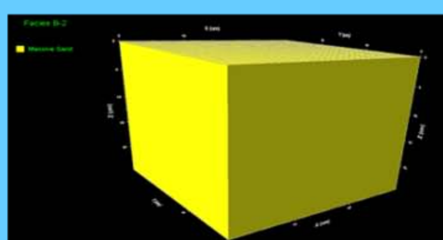
Facies A1: Laminated Shale



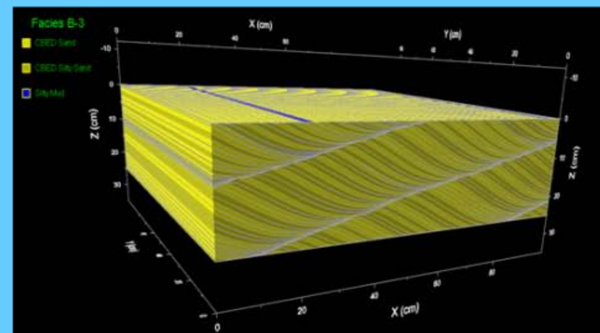
Facies A2: Bioturbated Shale



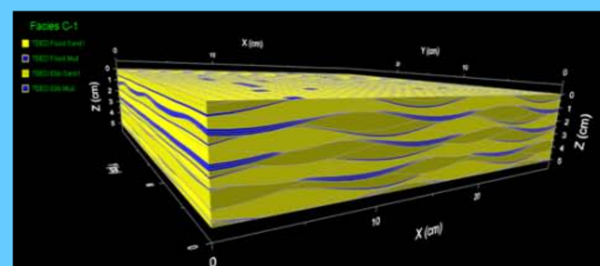
Facies B1: Planner bedded Sand



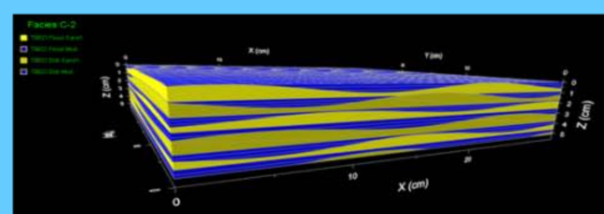
Facies B2: Tabular / Massive Sand



Facies B3: Trough Cross-bedded Sand



Facies C1: High Angle ripple Sand (less shaley Silt)



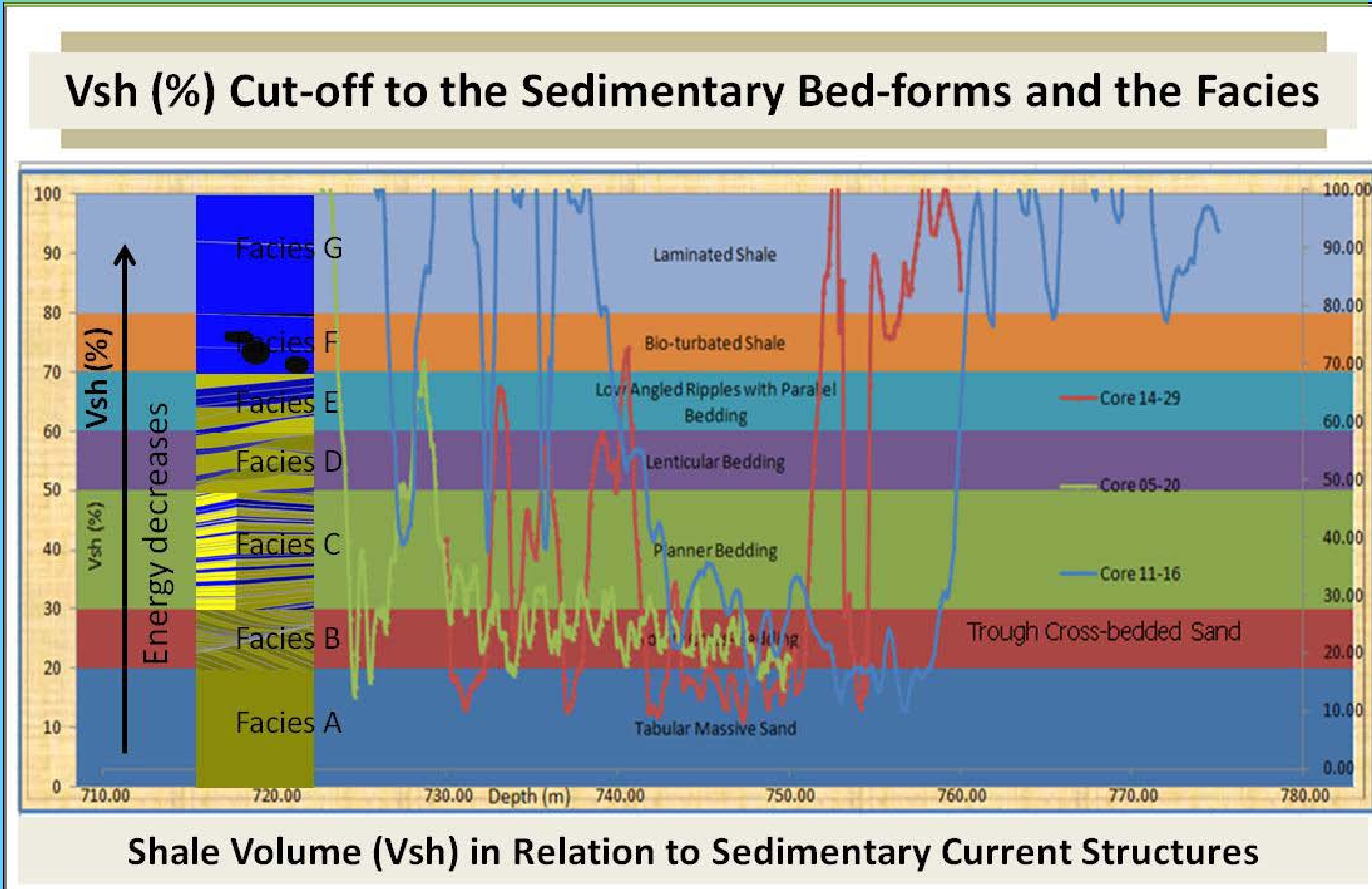
Facies C2: Low Angle ripple (more shaley Silt) with parallel bedding Shale

Facies

A1	=	G
A2	=	F
B1	=	C
B2	=	A
B3	=	B
C1	=	D
C2	=	E

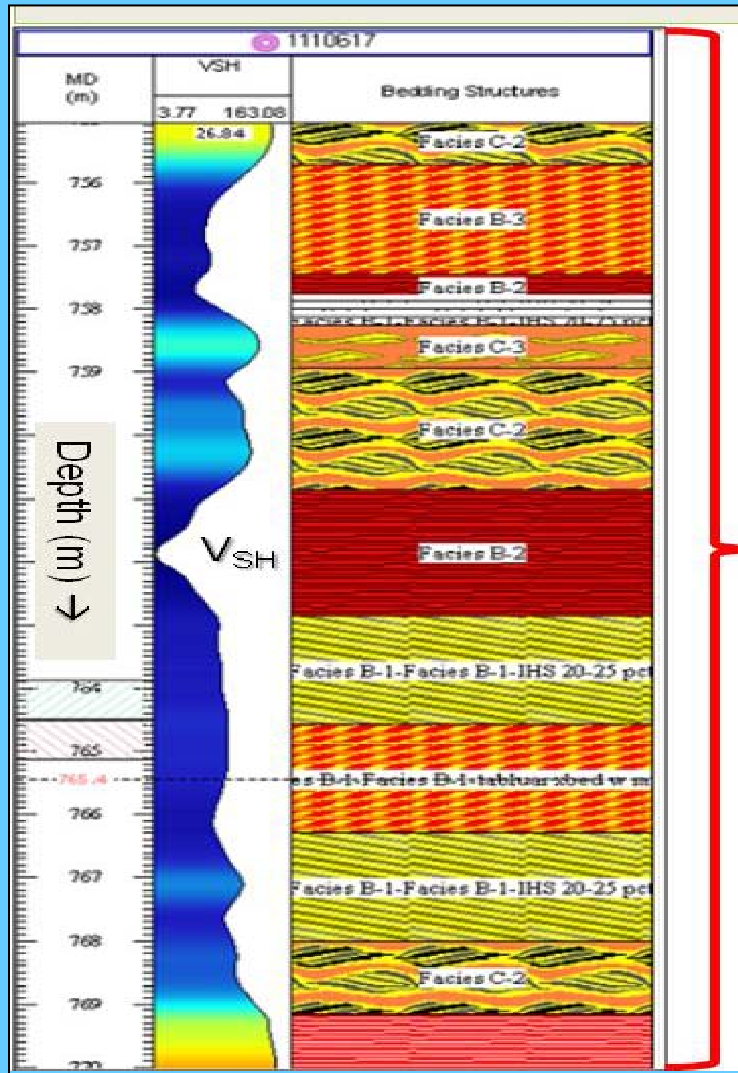
Sedimentary structures have been put in SBED templates for the reservoir modeling.

Methods: Core Analysis and Facies Distribution



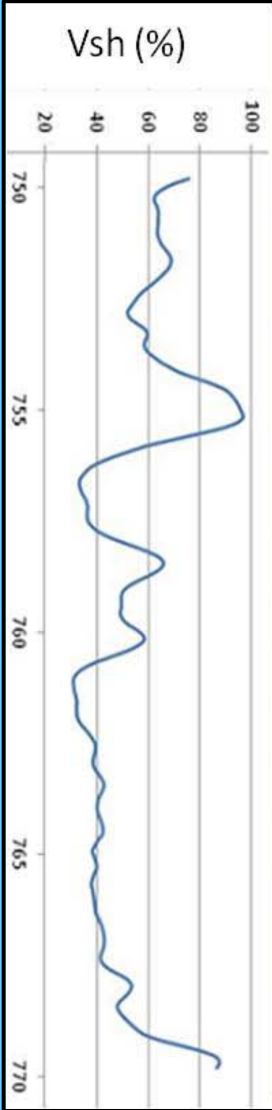
The relationship of the Sedimentary facies to the Shale Volume factors .

Methods: Shale Volume and Facies Distribution



Shale Volume Factor (V_{SH}) and the sedimentary facies for an individual well (1110617) is at the left side and an example of SBED controls is shown at the right side.

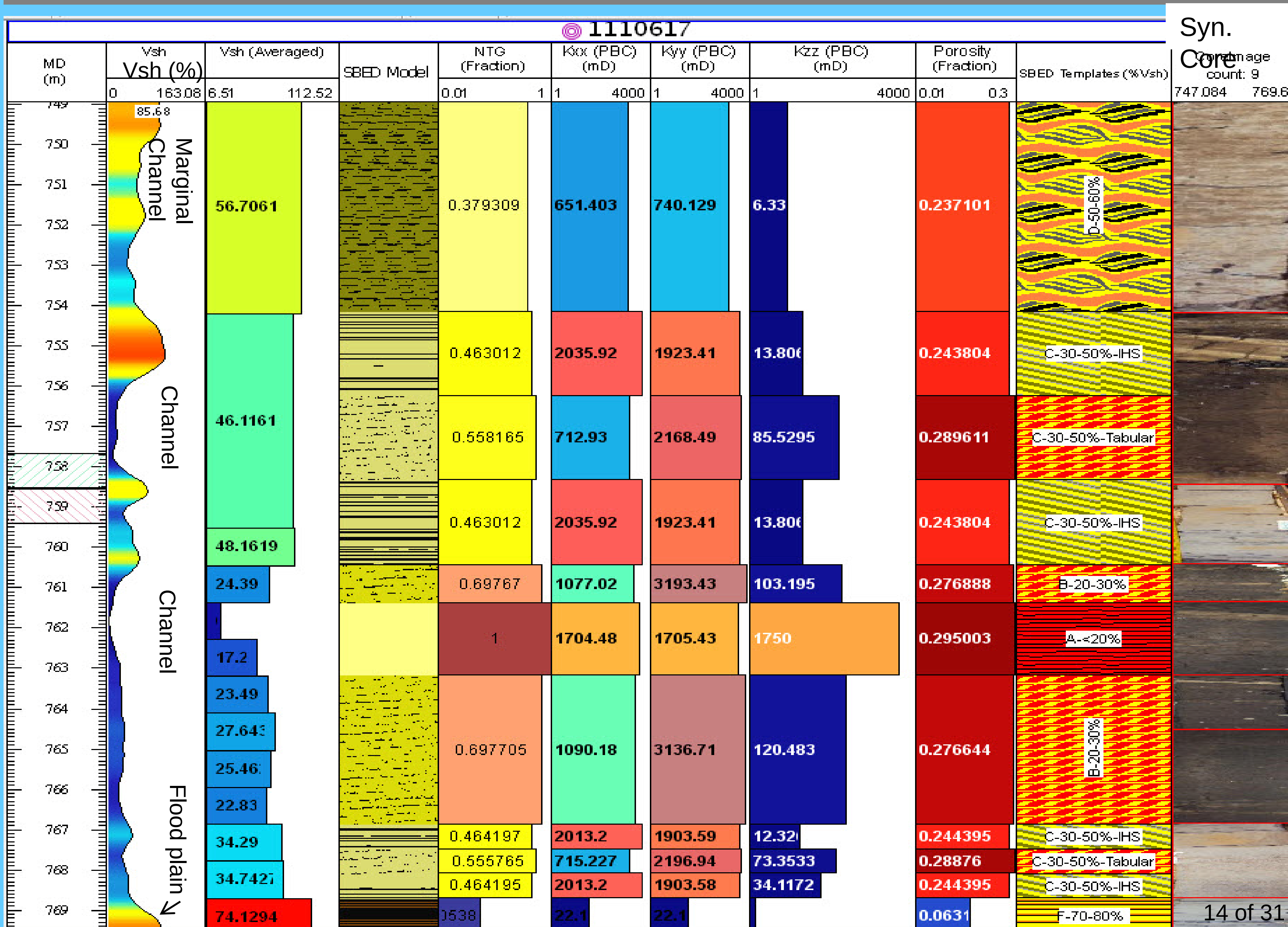
Methods: Core Analysis and Facies Distribution



Facies Stacking (The well 1110617)		
Depth Interval	Facies Type	Lithology
749.0 – 750.0	Facies A2	Bioturbated / organic Shale
750.0 – 751.5	Facies C2	Silty sand (more sandy)
751.5 – 752.0	Facies C1	Silty sand (more silty)
752.0 – 754.0	Facies C2	Silty sand (more sandy)
754.0 – 756.0	Facies A1	Massive shale
756.0 – 758.0	Facies B2	Massive sand
758.0 – 759.0	Facies C1	Silty sand (more silty)
759.0 – 760.0	Facies C2	Silty sand (more sandy)
760.0 – 760.7	Facies C1	Silty sand (more silty)
760.7 – 763.0	Facies B2	Massive sand
763.0 – 765.0	Facies B3	Sand (low angled lamina- more shaley)
765.0 – 767.0	Facies B1	Sand (high angled lamina – less shaley)
765.0 – 767.0	Facies B1	Sand (high angled lamina – less shaley)
765.0 – 767.0	Facies B1	Sand (high angled lamina – less shaley)
767.0 – 768.0	Facies B3	Sand (low angled lamina- more shaley)
768.0 – 769.0	Facies C2	Silty sand (more sandy)
769.0 – 770.0	Facies A1	Massive shale

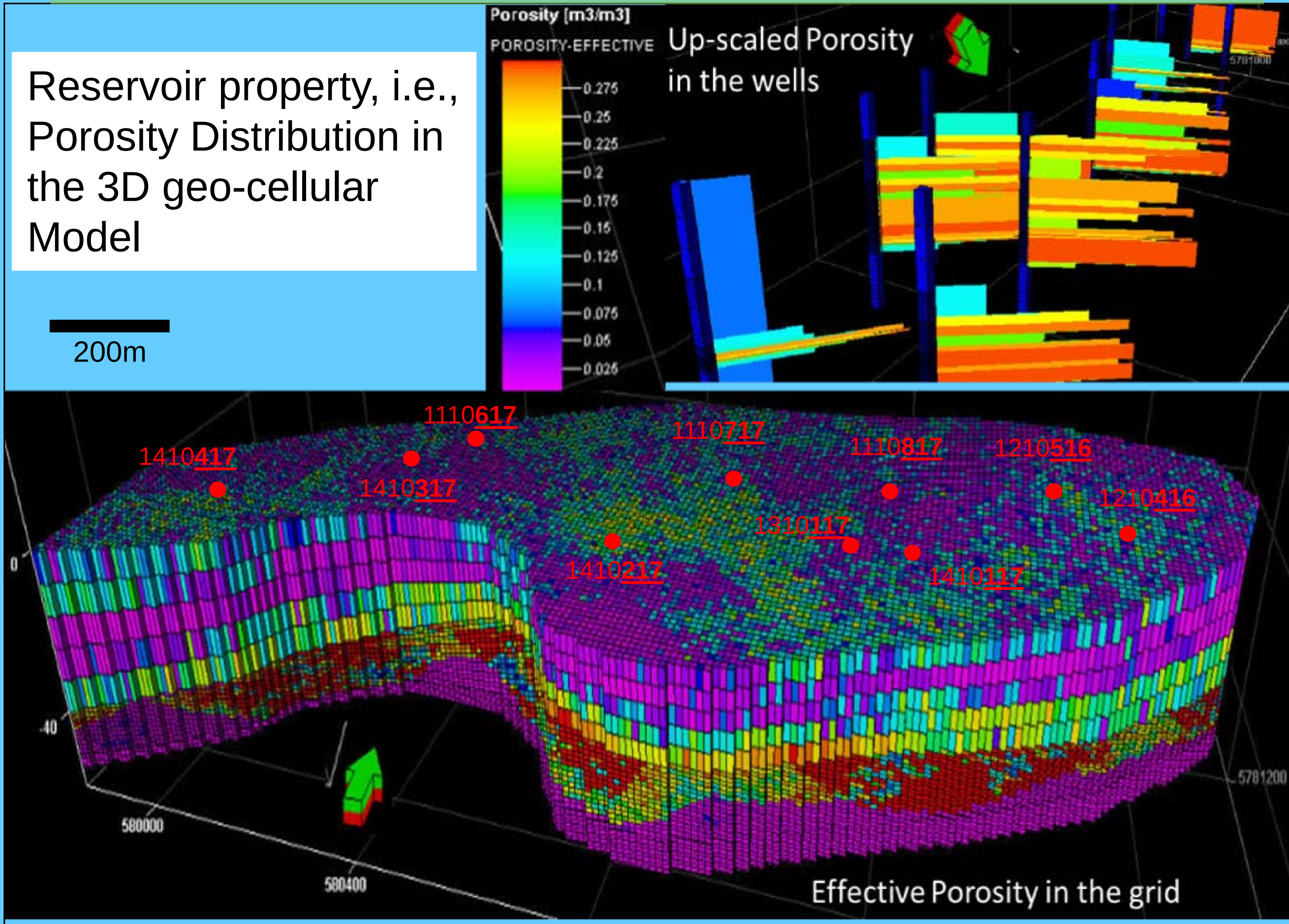
Sedimentary facies have been translated from the Vsh curve to the well that has no core data, i.e., well 1110617.

Lamina-Scale Modeling- Well 1110677



3D Geo-cellular Modeling

Reservoir property, i.e., Porosity Distribution in the 3D geo-cellular Model

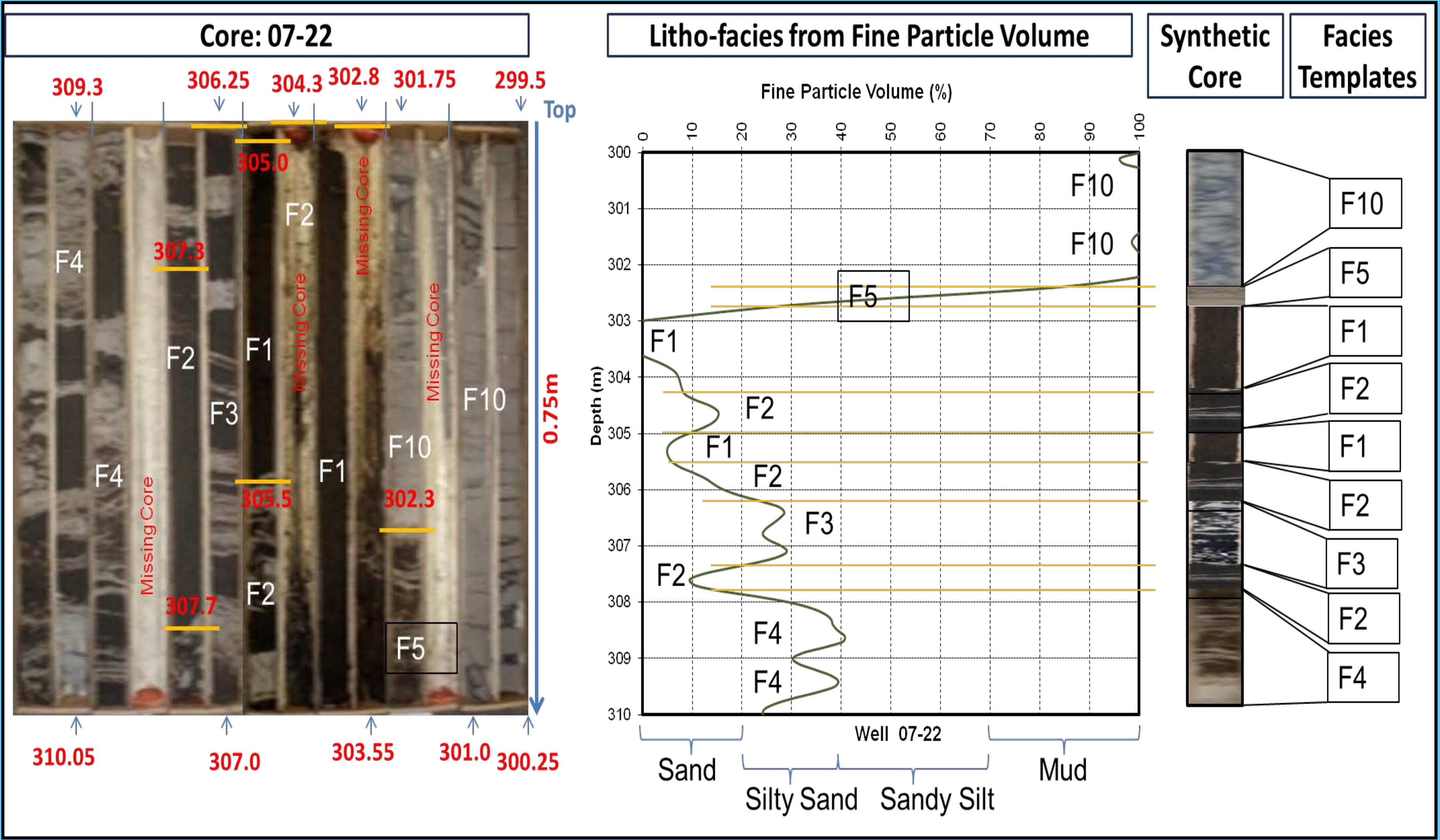


Reservoir properties in the 3D Model: Porosity Distribution .

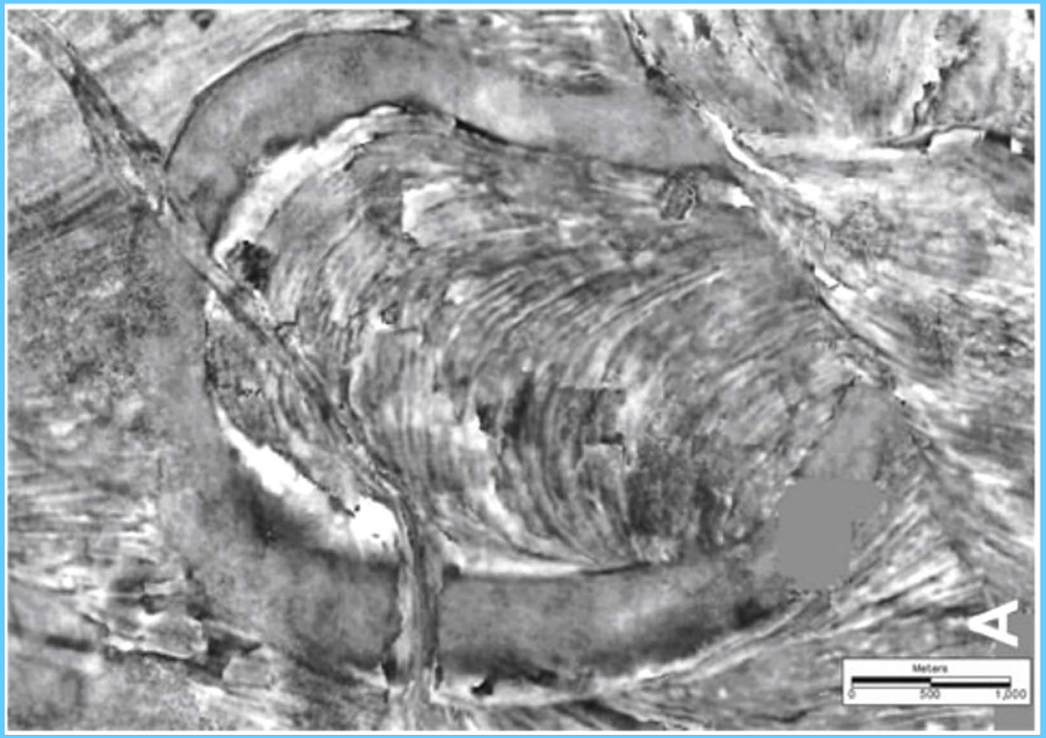
Self-Validation Tests

- Self-validation tests have been conducted.
- That is, we chose a well where core exists, and pretend we don’t know the core.
- Use this method to synthesize core.
- Compare synthetic core to the actual core.

Self-validation test:
Comparison of Synthetic Core to Real Core



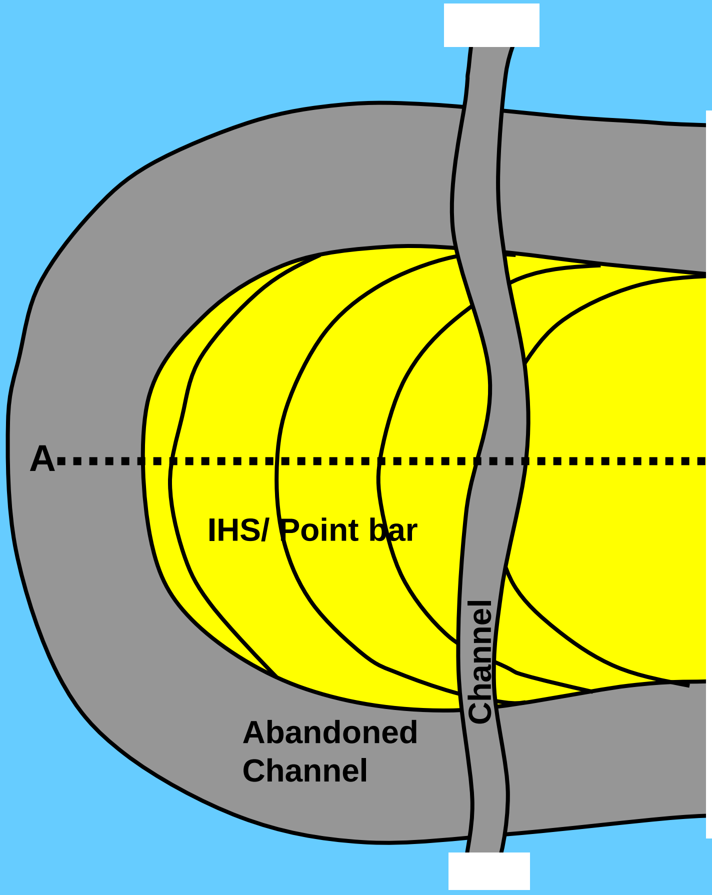
Channels and shale volumes can be imaged effectively with 3-D seismic

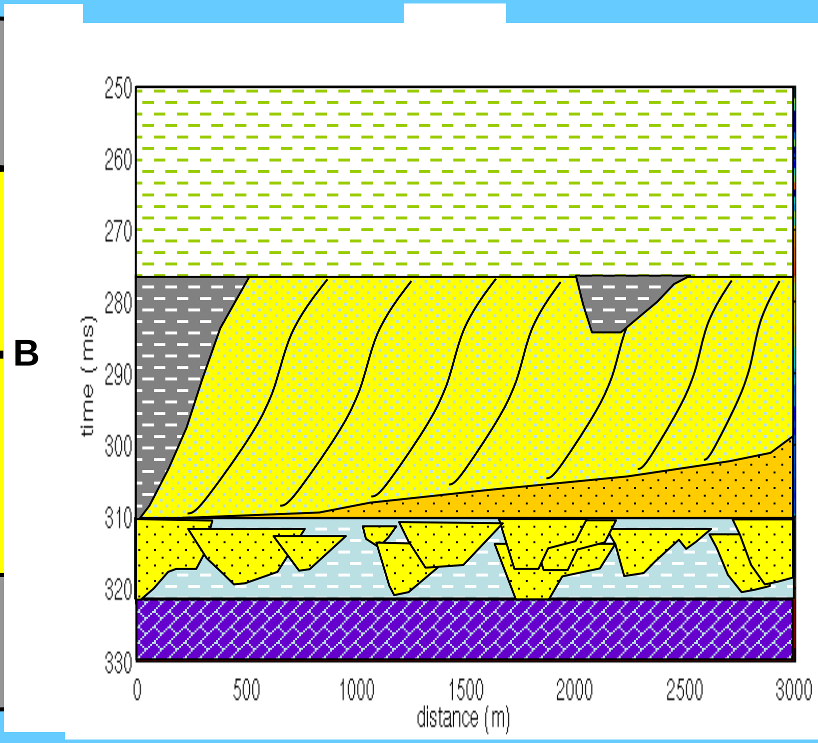


- Time slice of 3D seismic amplitude, showing point bars in the McMurray Formation (Source: Fustic et al, 2007) shown in PhD thesis of Xu (2012)

Developing geological templates corresponding to the seismic images

The point bar system (shown in map view and cross-section (Xu, 2012 PhD thesis) would have a distinct set of depositional templates.





Future Directions

- Self-validation tests have been encouraging. Do more testing.
- Use 3-D seismic data to aid in shale volumes. This should improve our description of Vshale.

Acknowledgements

- CREWES and CHORUS sponsors
- Colleagues who listen to our wild theories.

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