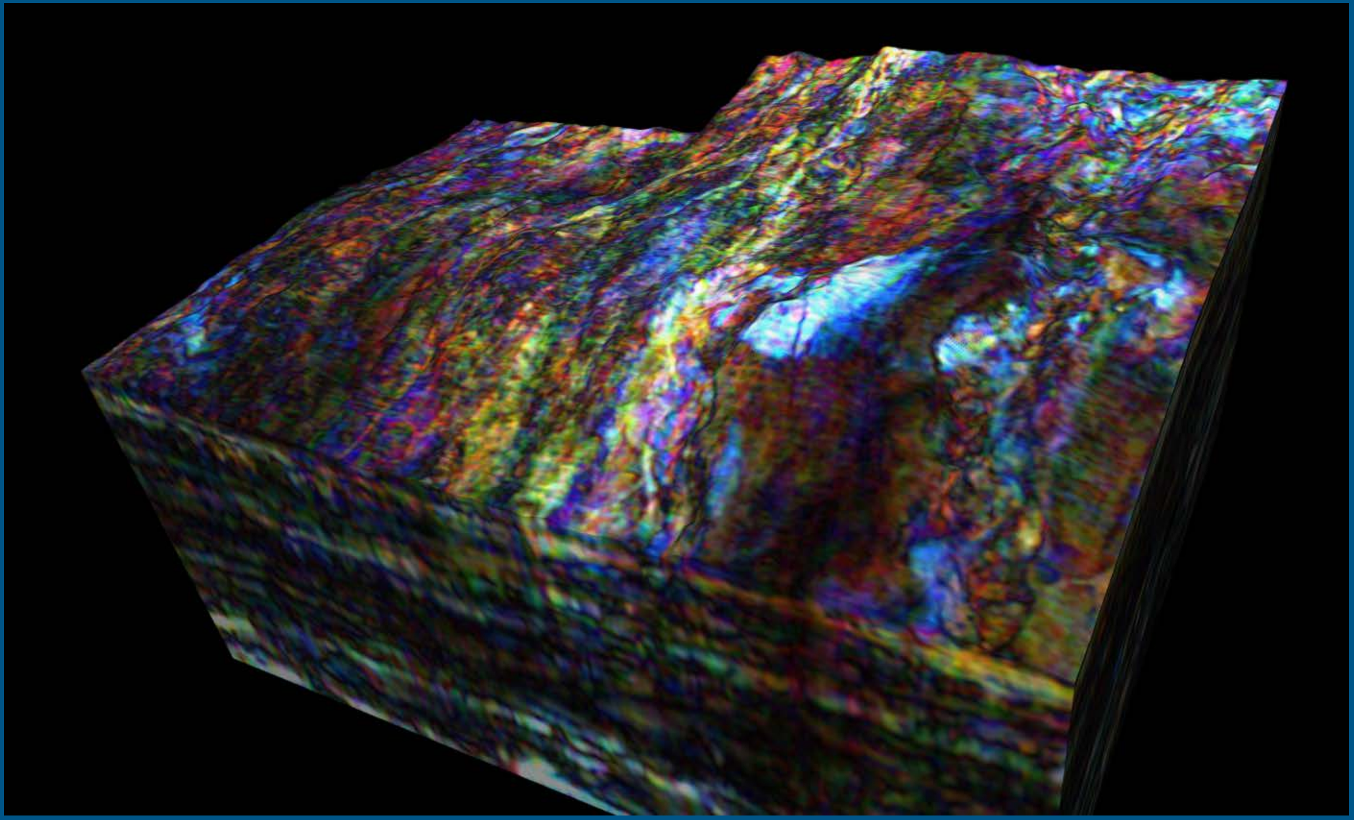
Reservoir characterisation by application of a novel AVO anomaly imaging technique: Examples from Block 7, Offshore Mauritania



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Korea National Oil Corporation

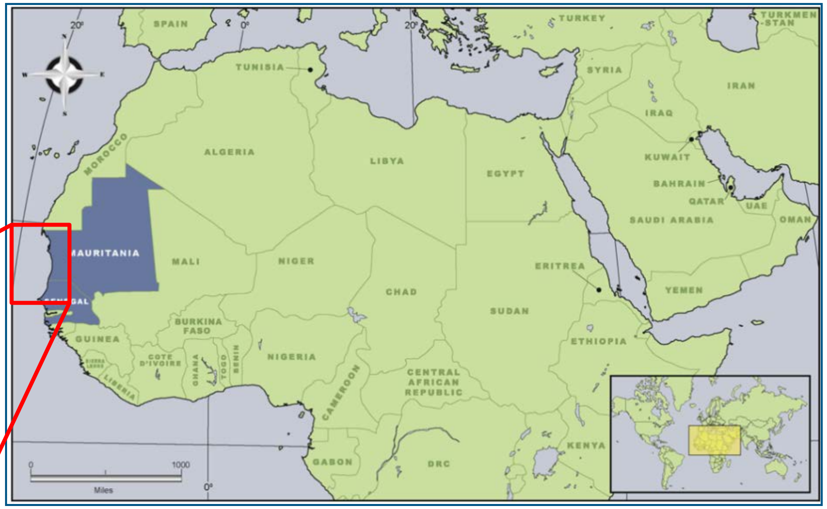
Tullow Oil plc

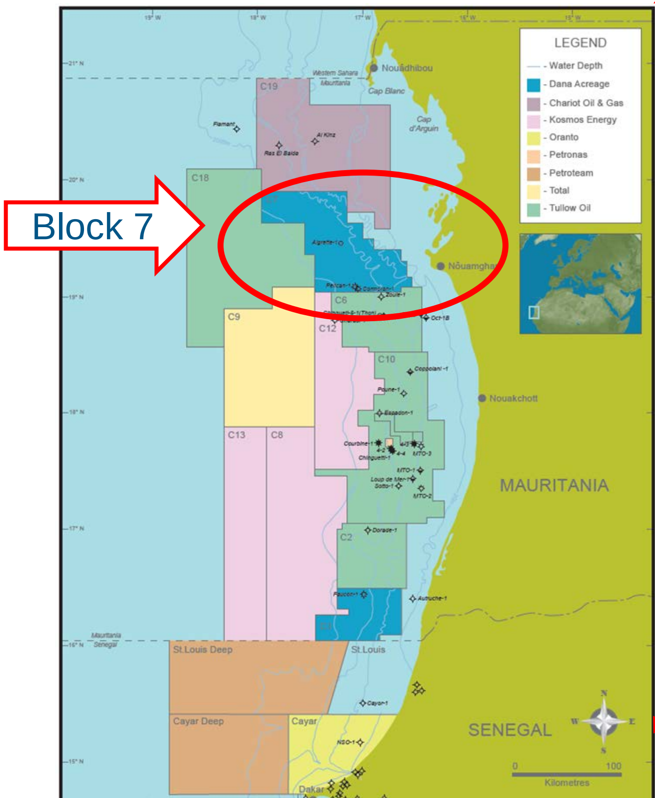
GDF SUEZ

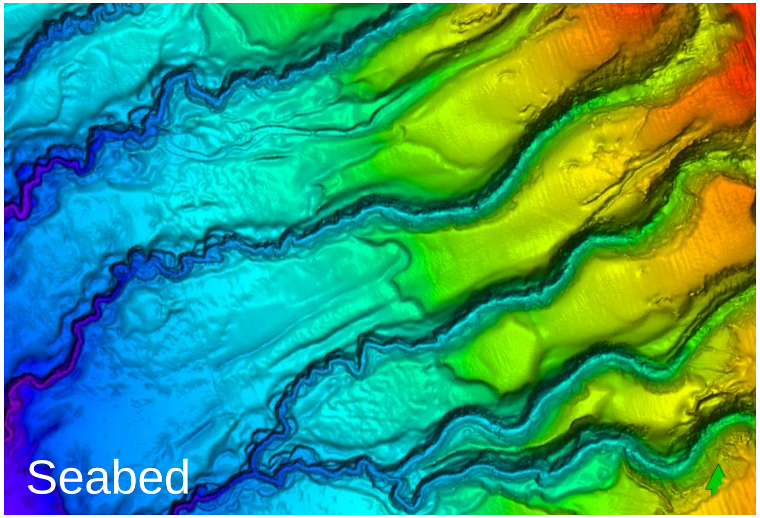
PETRONAS

Introduction

- Block 7 Offshore Mauritania,
  - operated by Dana Petroleum plc (a wholly owned subsidiary of KNOC)
  - water depths of 50 to 2500m.
  - 3D data shot in 2001 and 2005
  - 1600km^2 re-processed PSDM in 2008.
  - 3700km^2 re-processed PSDM in 2013







Introduction

- Four wells have been drilled by Dana and partners in Block 7;
  - Pelican-1 (2003)
  - Aigrette-1 (2007)
  - Cormoran-1 (2010)
  - Frégate-1 (2013)

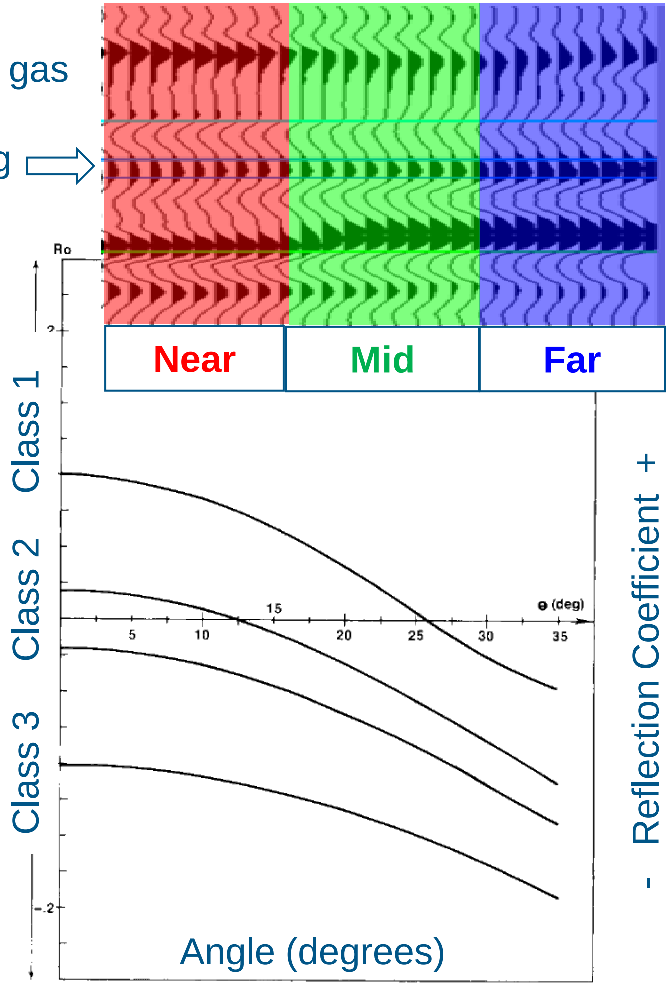
- All four wells discovered hydrocarbons in Cretaceous slope turbidite deposits.

- The reservoir sands typically exhibit a class 2 to class 3 AVO response.

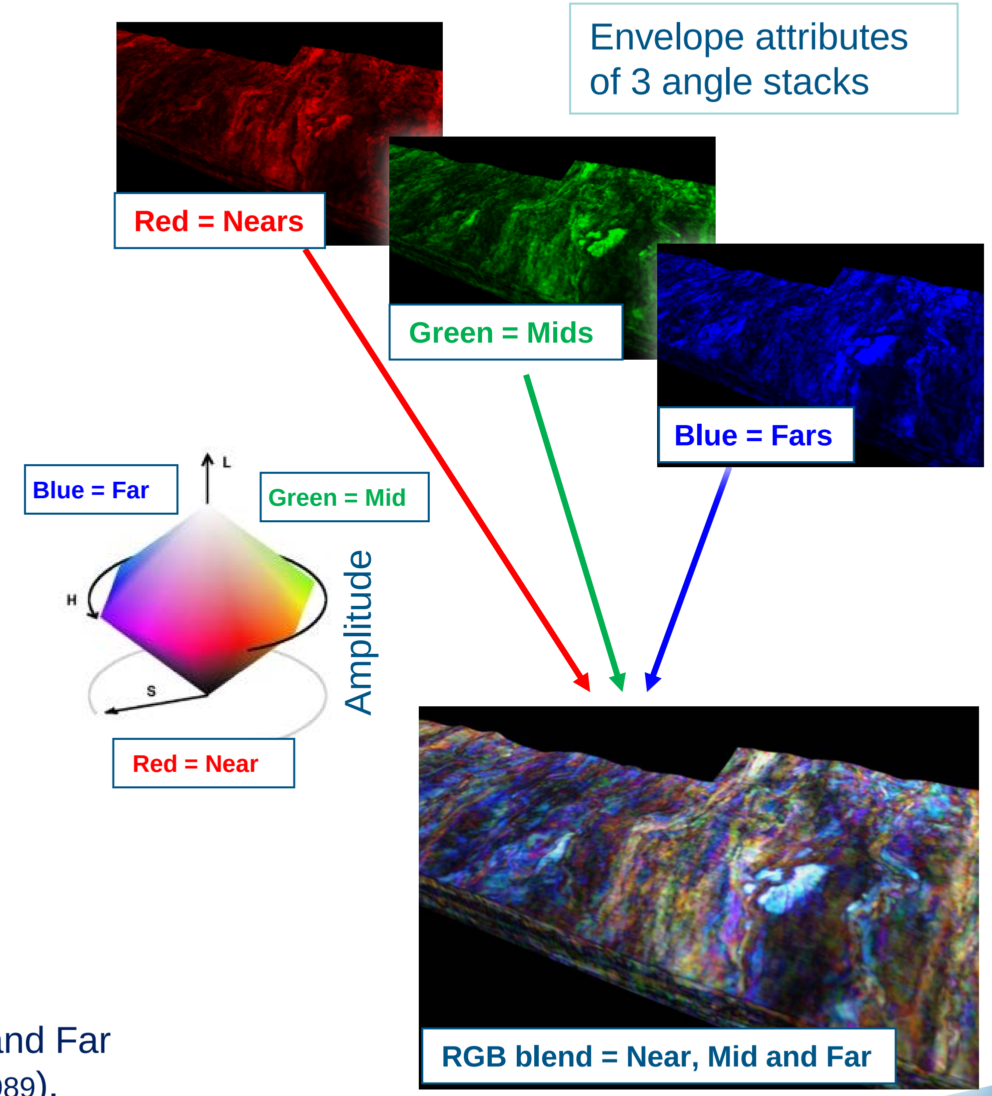
- Depositional model - thicker reservoir sands mainly deposited in
  - channel fairways
  - proximal levees
  - crevasse splays

AVO RGB Blending technique

Gather at gas sand illustrating AVO

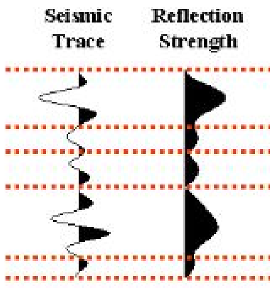


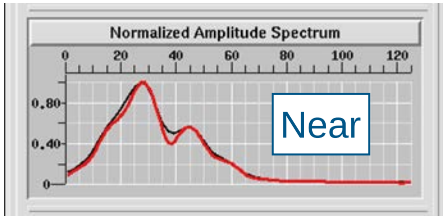
AVO class diagram illustrating Near, Mid and Far stacks in colour (after Rutherford and Williams 1989).

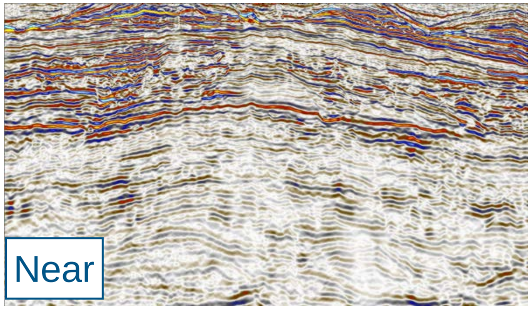


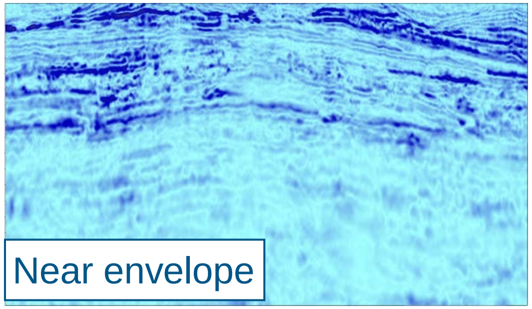
Step 1 – Compute Envelope attribute

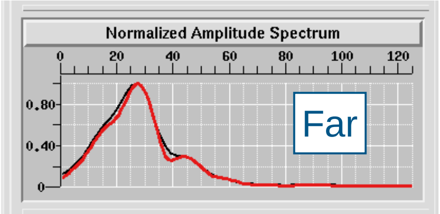
Compute the Envelope attribute to prevent artefacts occurring during the RGB co-rendering of the Near Mid and Far cubes.
Note that the sign of the amplitude is lost in this process.

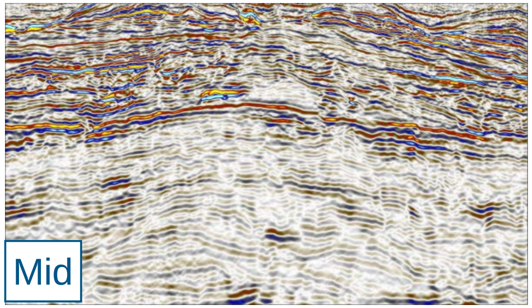


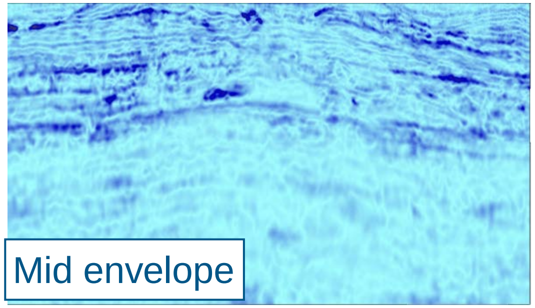




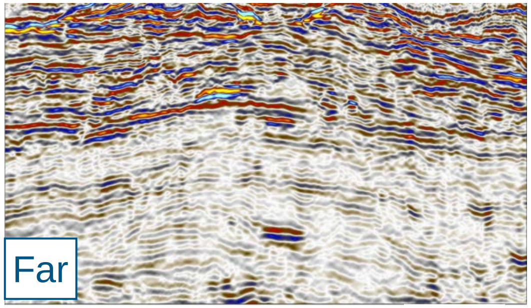


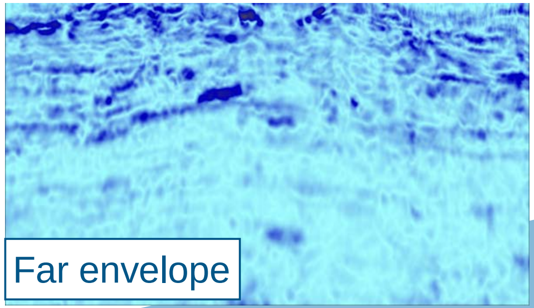




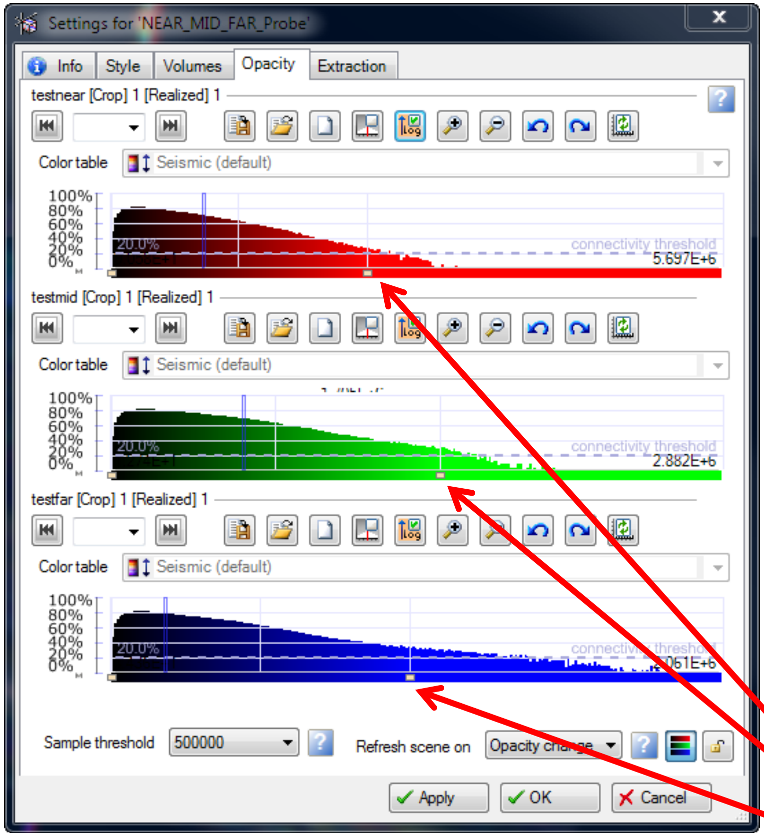


Attenuation of higher frequencies in Far stack has some similarity to Frequency Decomposition RGB blending

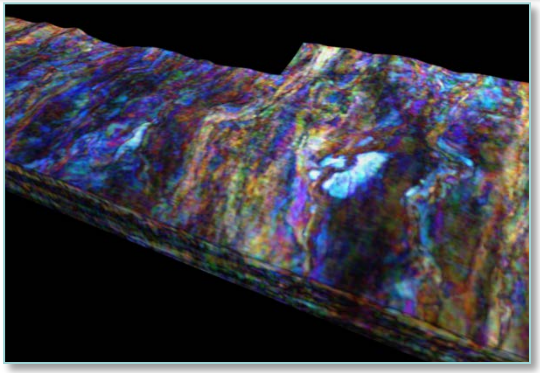




Step 2 – Create Horizon probe and select RGB display



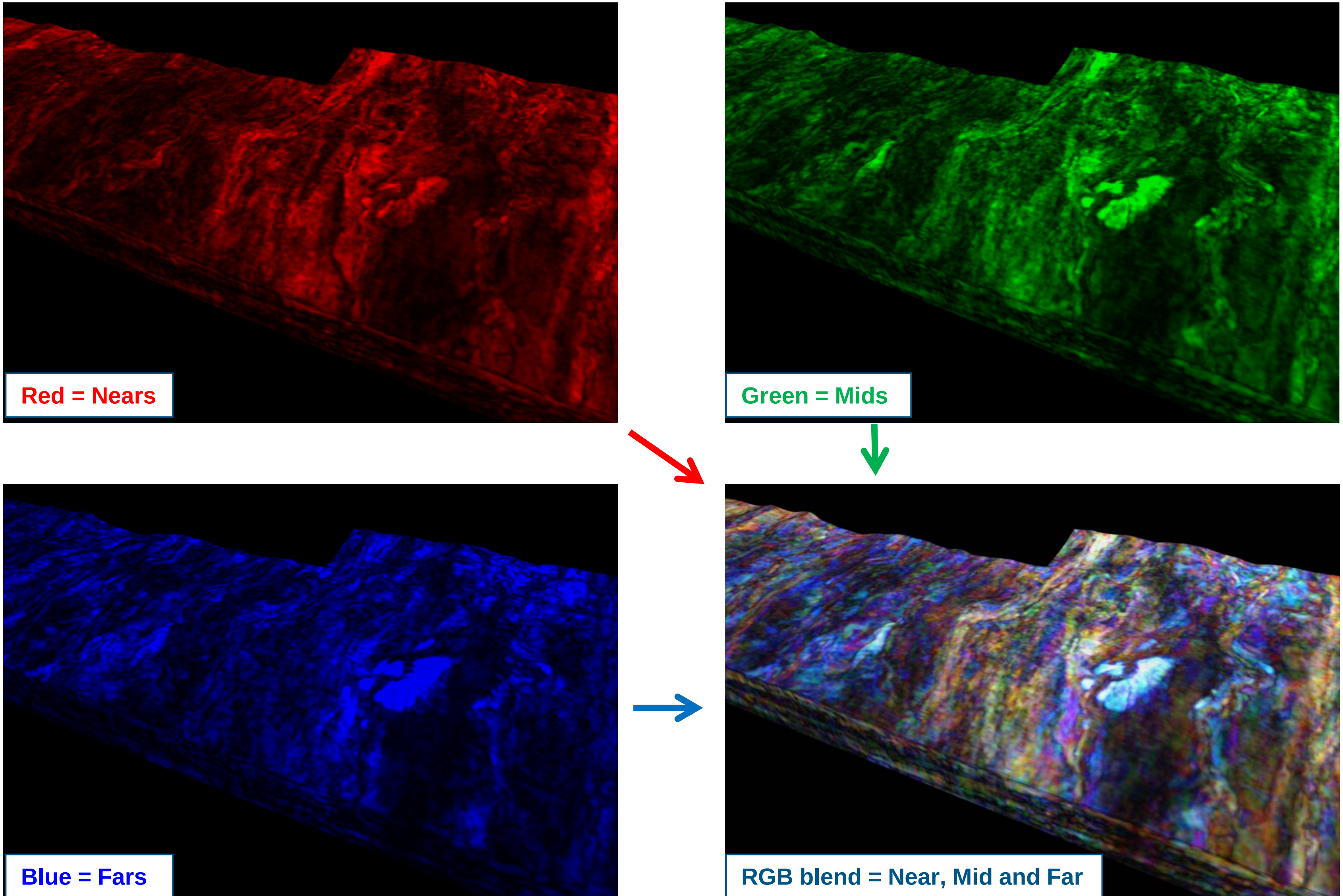
- RGB blending 3 volumes in colour:
  - **Red for Near**
  - **Green for Mid**
  - **Blue for Far**



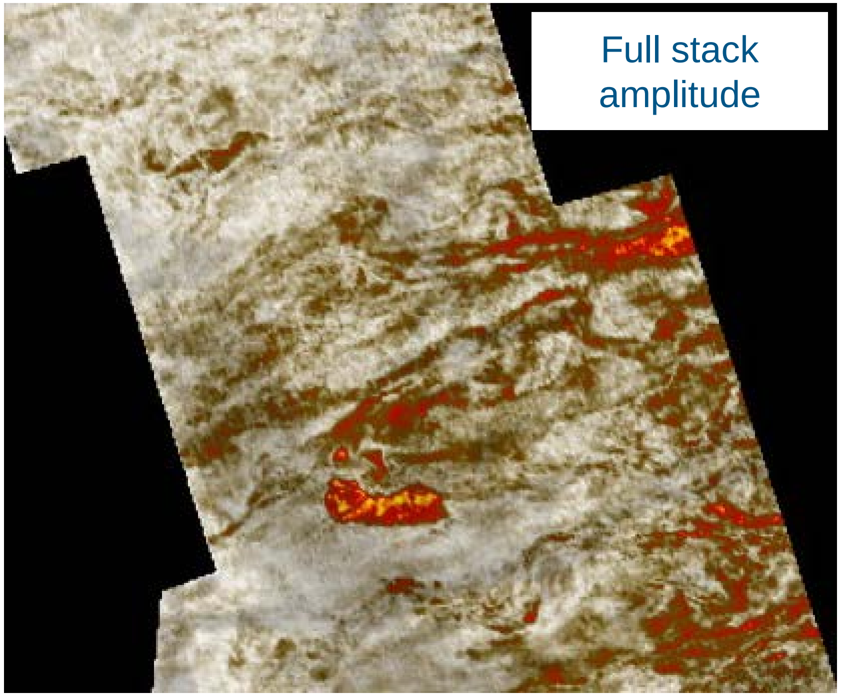
- Balance the background colours in the image.
- Background should be a fairly neutral colour so AVO anomalies stand out.
- Too much clipping (slider further to the left) makes highest amplitudes white.

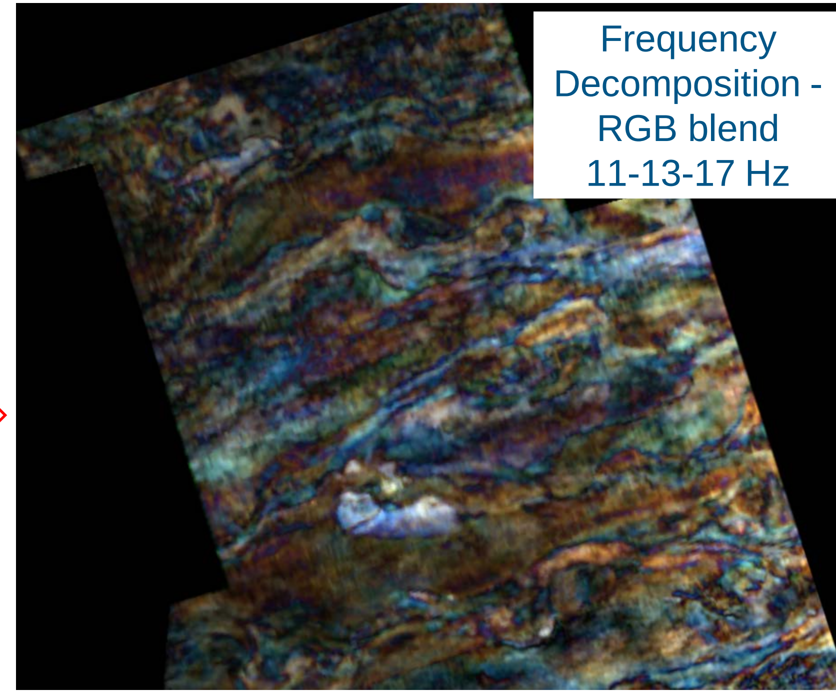
Purely a qualitative technique, ideal for screening purposes.

Step 3 – Co-render the 3 Angle Stacks – using RGB Blending



Comparison: Full stack amplitudes vs Frequency Decomposition

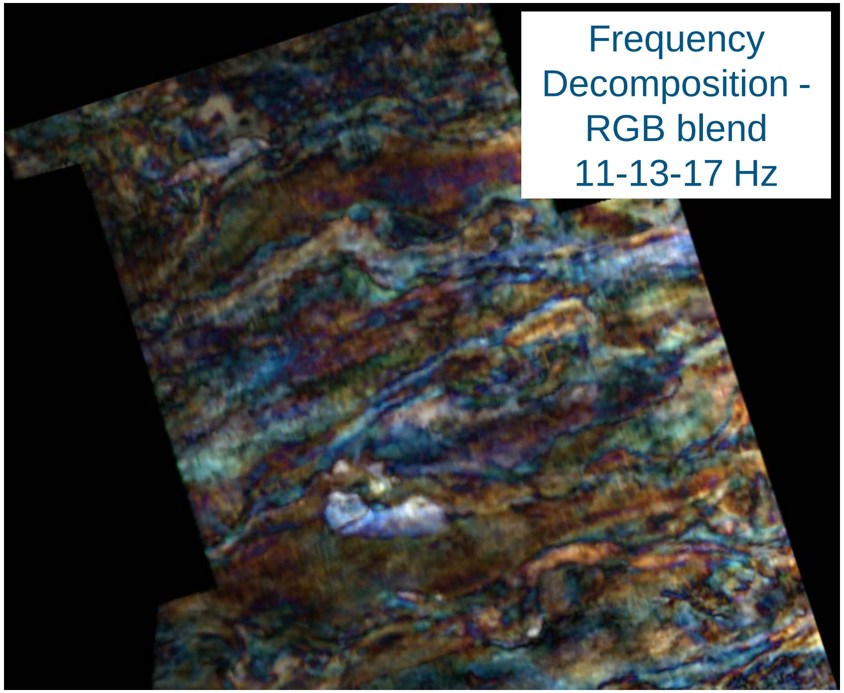




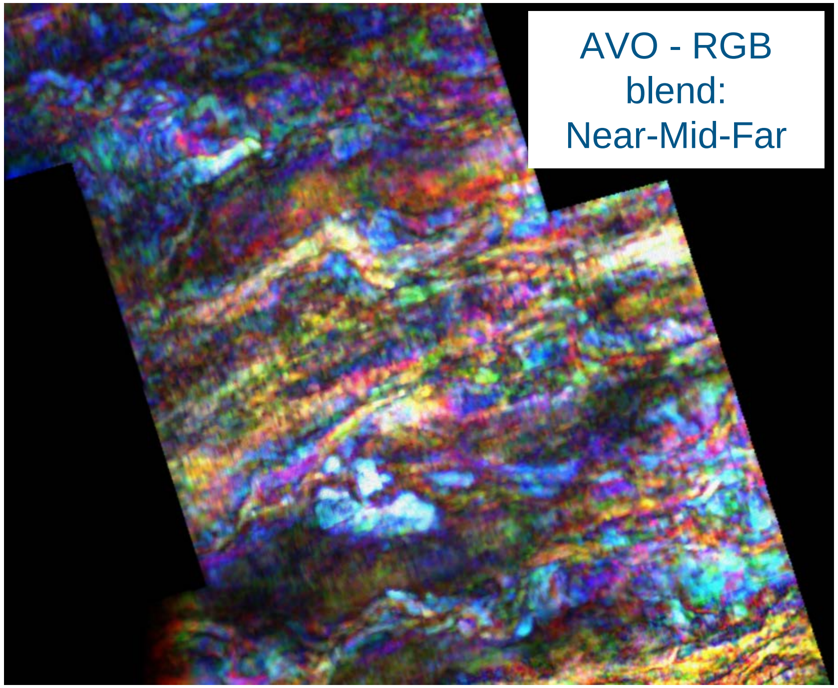
Derived from FULL Stack, hence no AVO information.

RGB blending of Frequency Decomposition data is an excellent tool for facies discrimination.

Comparison: Frequency Decomposition vs AVO RGB Blending



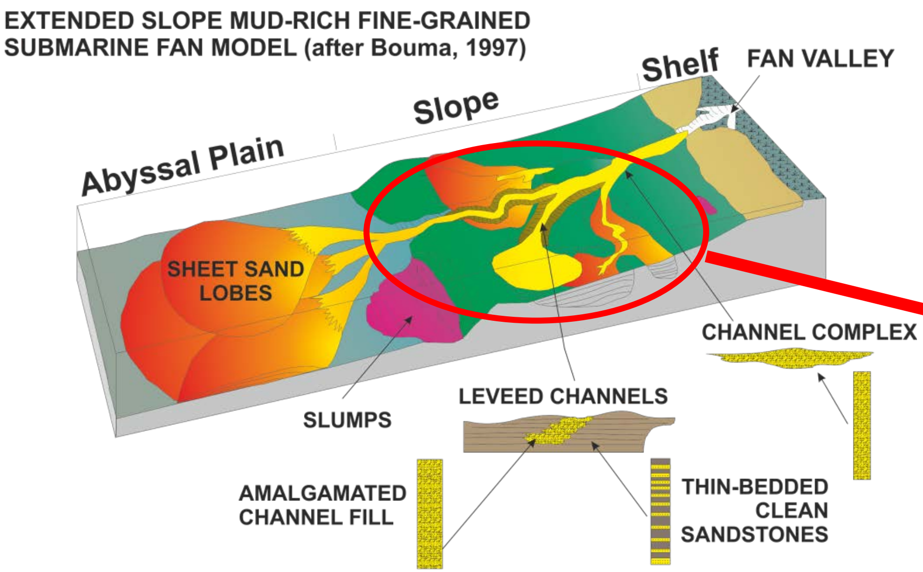
- RGB blending of Frequency Decomposition data is an excellent tool for facies discrimination.
- Derived from FULL Stack, hence no AVO information.



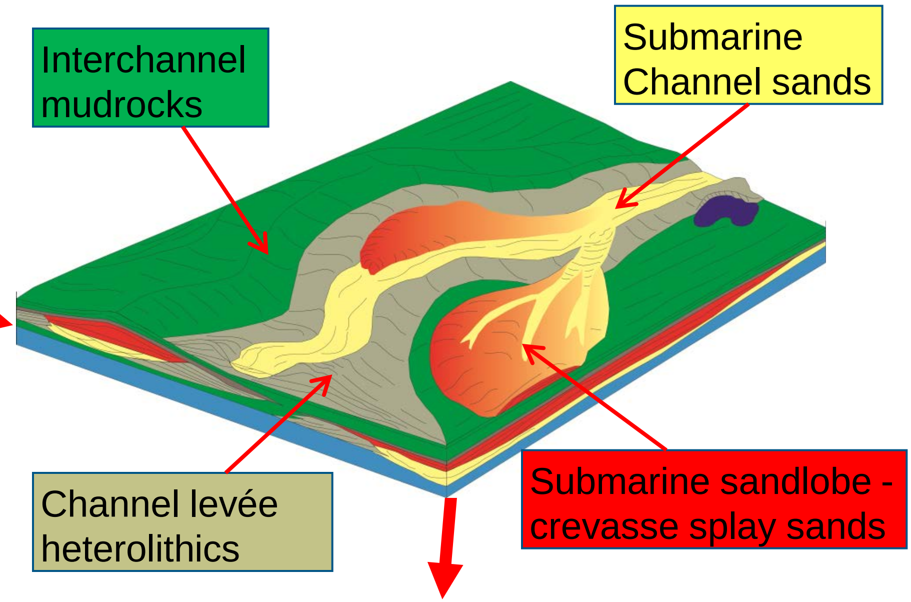
- Near-Mid-Far co-rendered in RGB also shows facies patterns.
- Adds discrimination of lithology and gas-filled sands in blue.

Calibration of seismic facies with core and log facies models

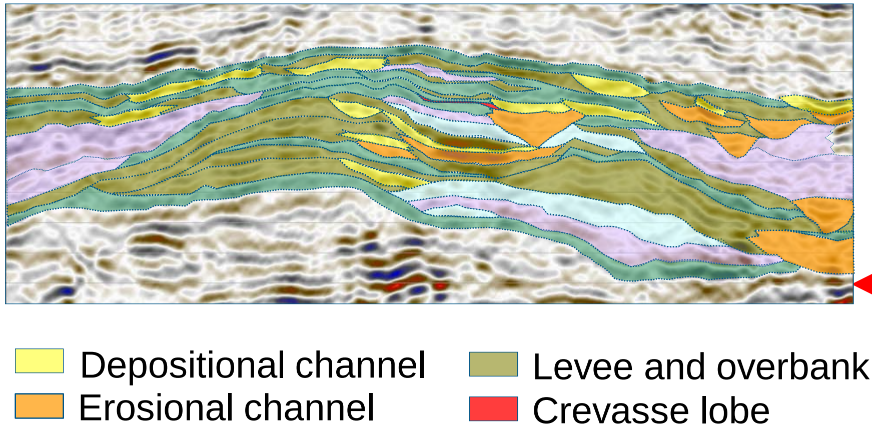
Conceptual extended slope model



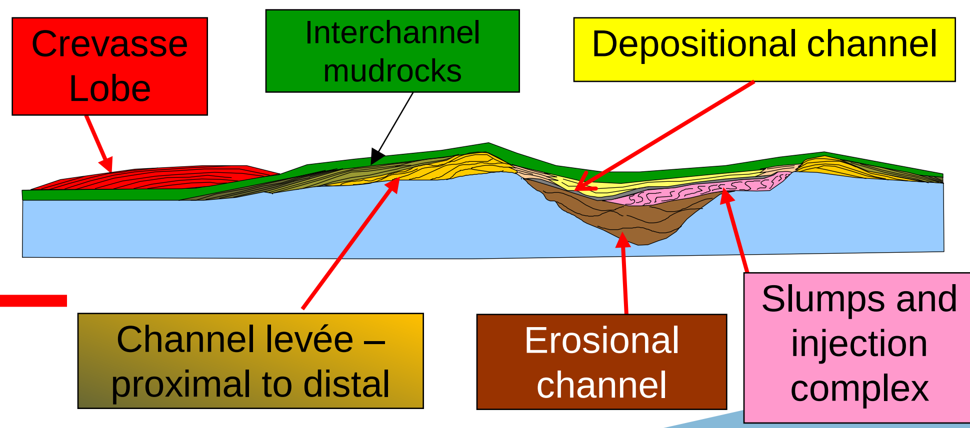
Levéed channel depositional model



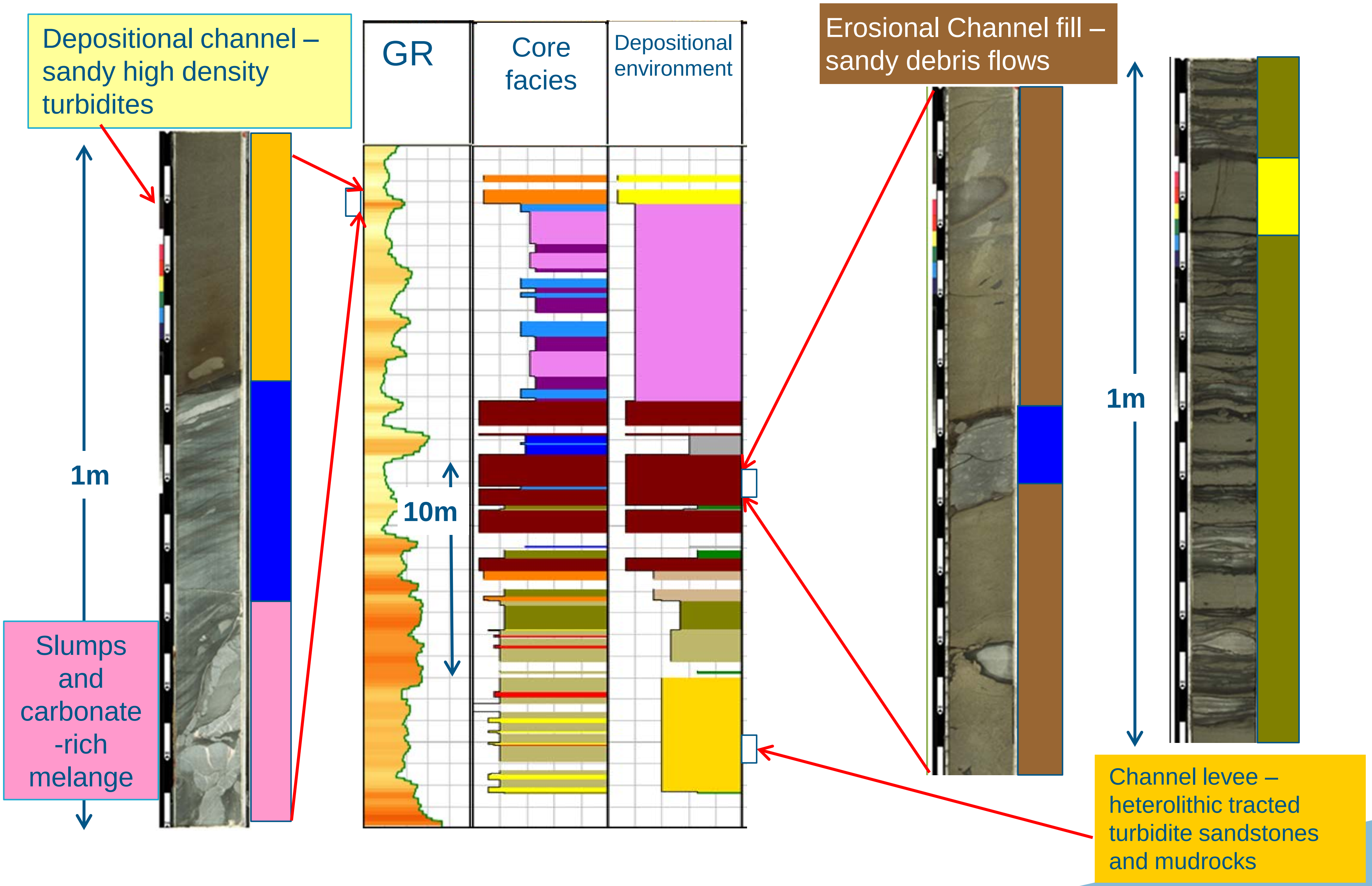
Seismic facies model



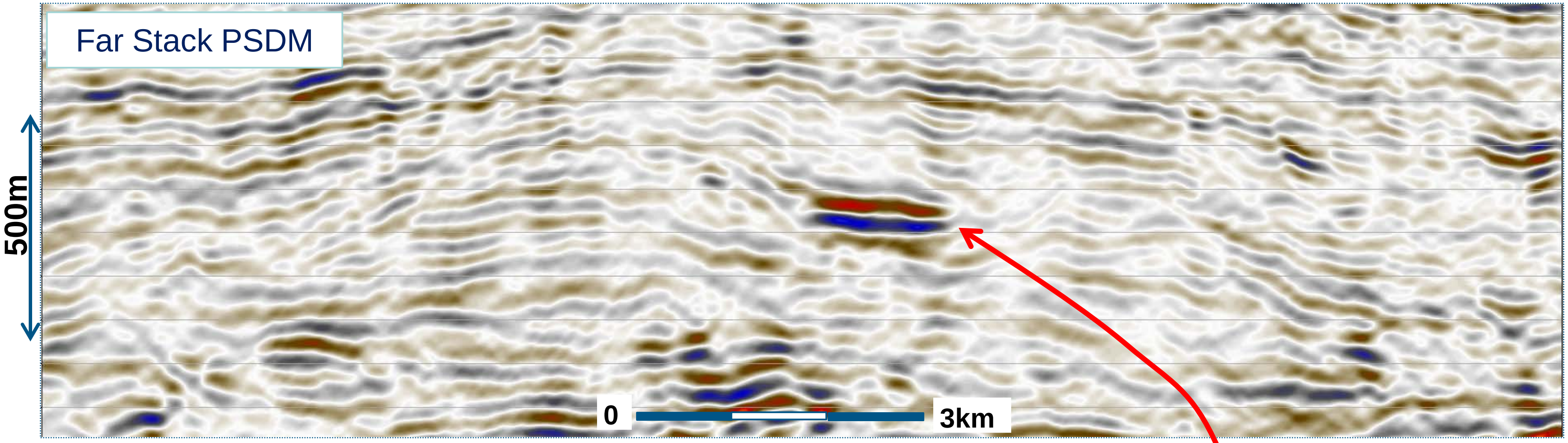
Core-based channel model



Core facies and depositional environments

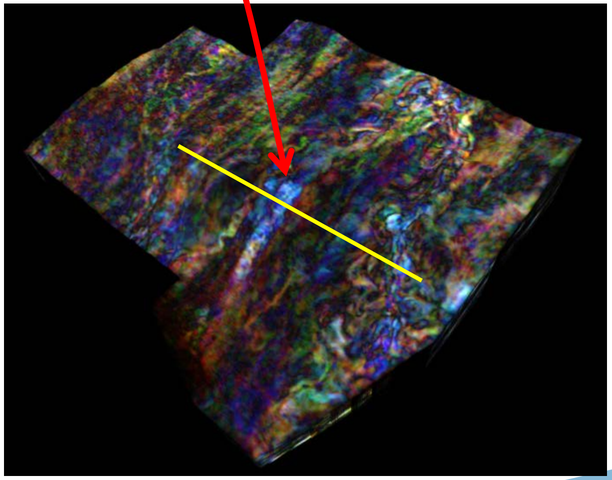


Calibration of core facies and depositional environments to seismic



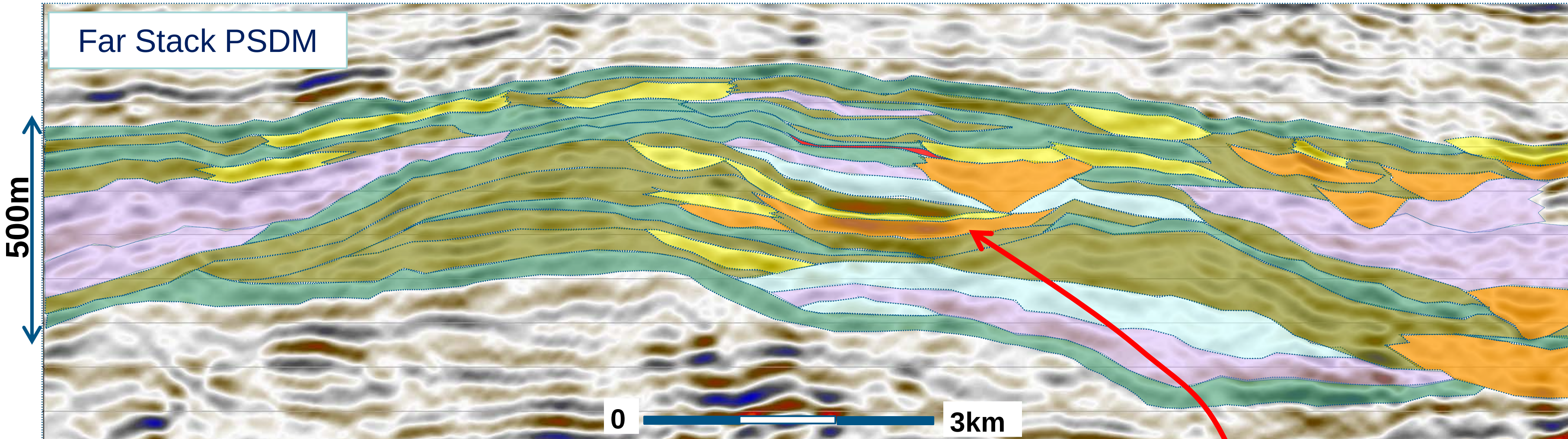
Depositional channel
Erosional channel
Levee and overbank
Crevasse lobe
Slumps
Mass wastage complex
Mudrocks

Fan 5 slope channel fill 45m thick 500m wide



AVO RGB display

Calibration of core facies and depositional environments to seismic



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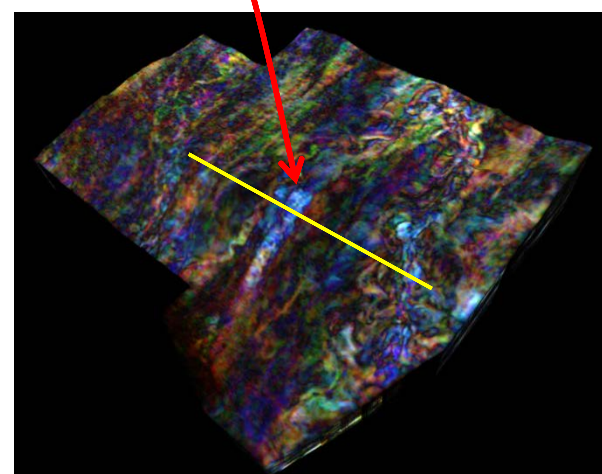


Field analogue comparisons – Lainsburg slope channels – Baviaans –Skielding Fan B

Thick bedded amalgamated sandstone unit – stacked massive T_a turbidites in channel axis - 35m+ thick in axis -1.2km lateral extent of channel complex

Medium bedded , non-amalgamated channel margin and overbank fines –dominated by T_c and T_a turbidites with thick-bedded climbing ripple laminated T_c

Slump folds in channel margin location – collapse and remobilisation of levee facies

Shale rip-up clasts concentrated in lag deposit – bypass phase at channel base.

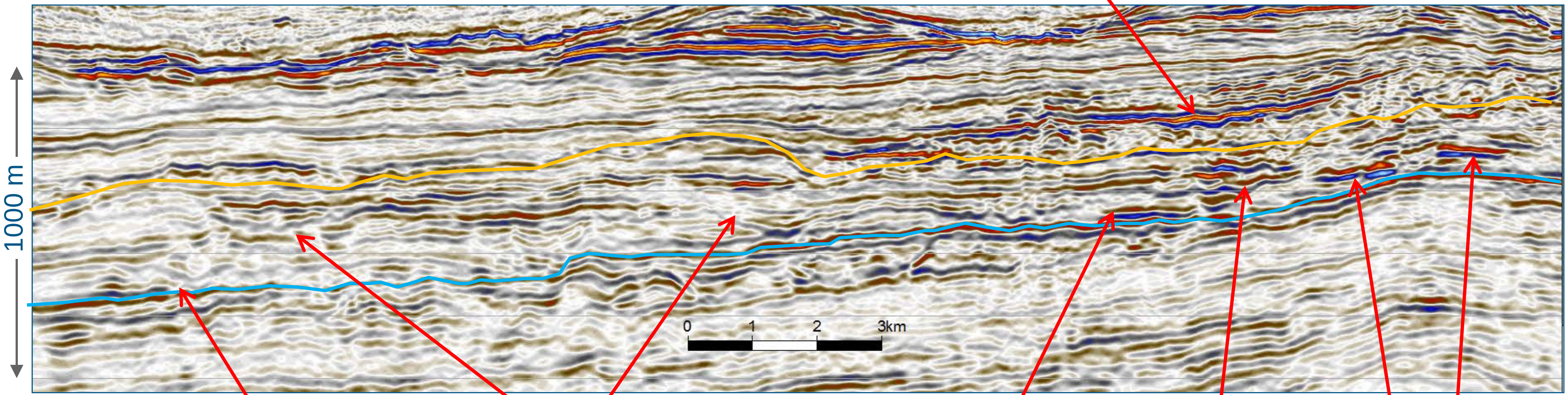
Injected sandstone dykes and sills beneath main channel cut

Overbank fines – homogeneous mudrocks deposited from suspension

Good analogue for the slope channel complexes.

Inline showing seismic facies

High amplitudes drape over MTC



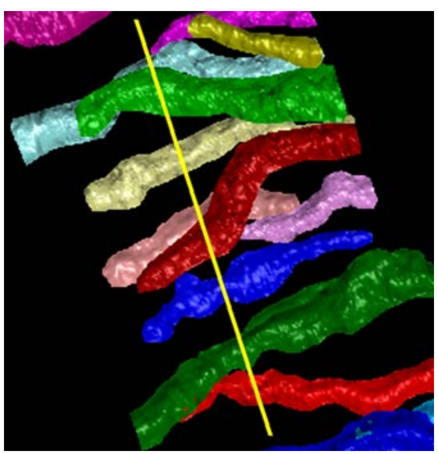
Low amplitudes within erosional channel cut, possible shale filled channel.

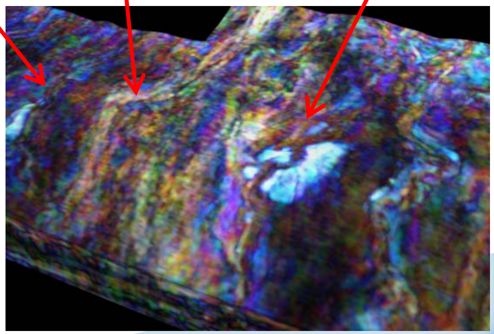
High amplitudes within broad channel cuts

High amplitudes in levee

High amplitudes within broad channel cut.

High amplitudes outwith channel cut = crevasse lobe with mud-filled channel





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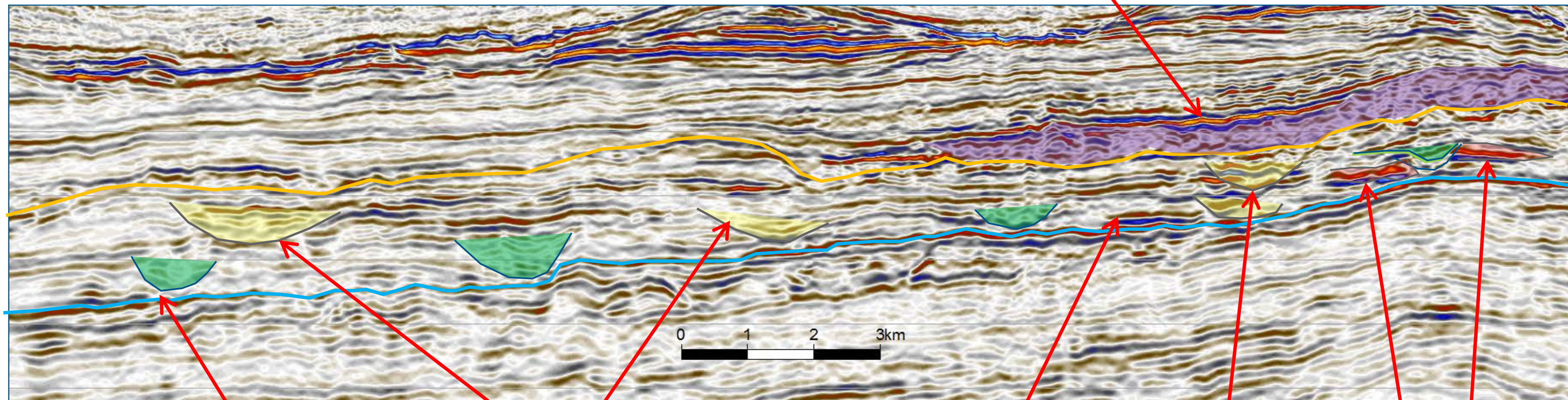
High amplitudes drape over MTC

1000 m



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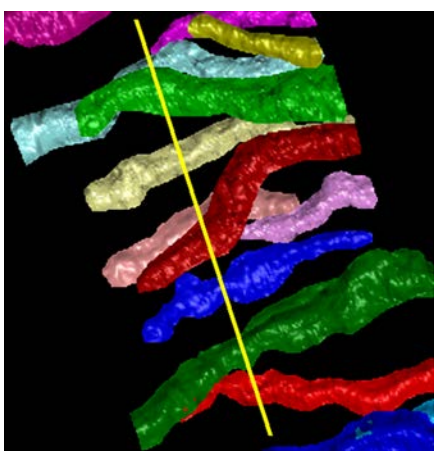
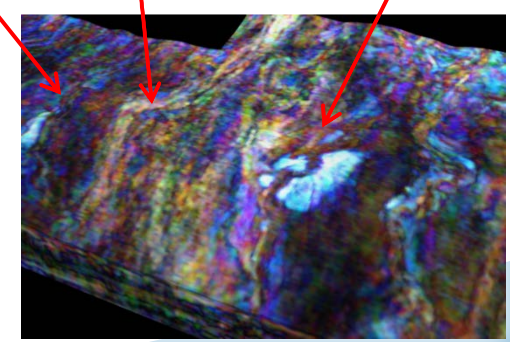
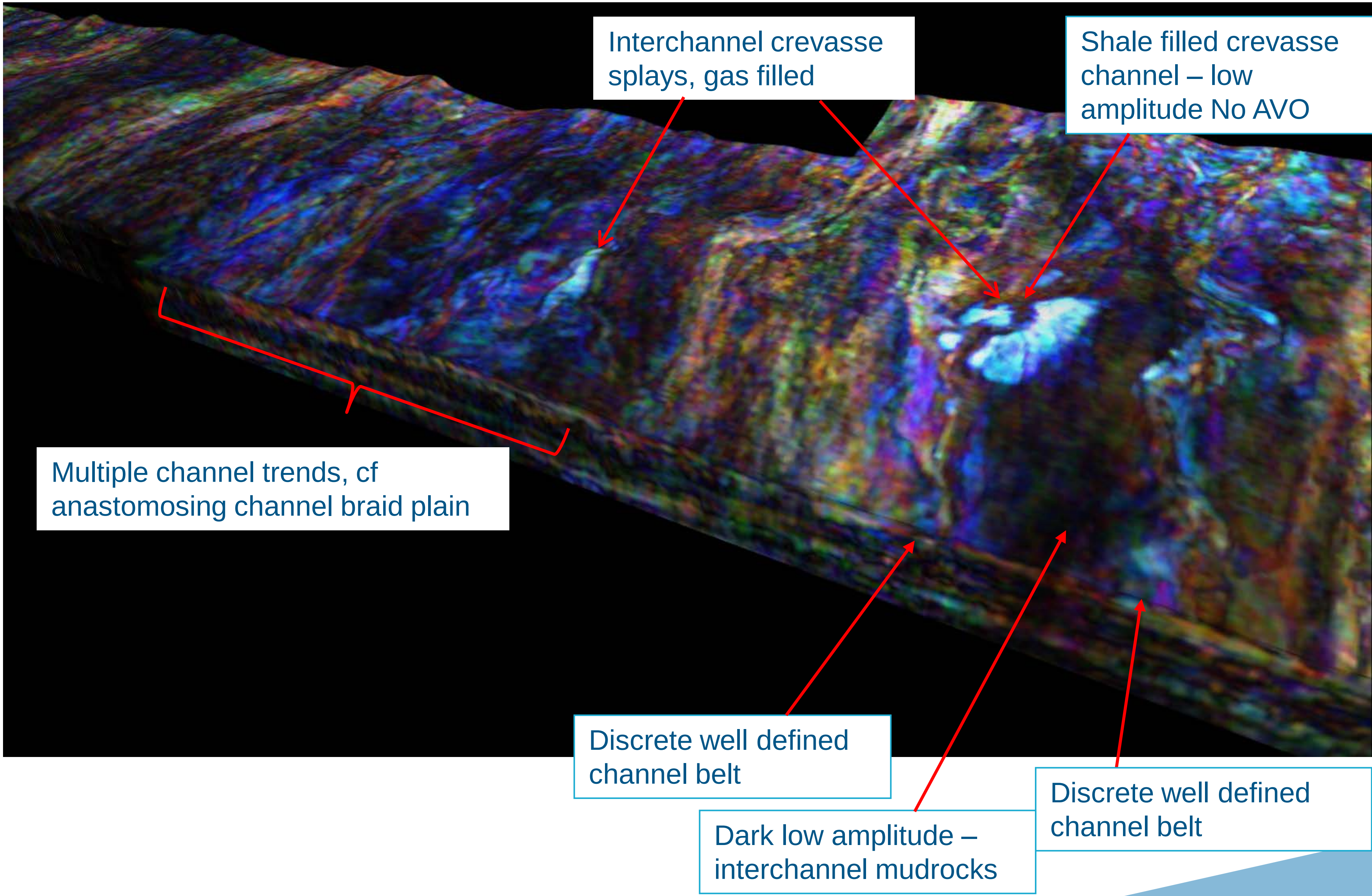


Simplified seismic facies

- Channel fill High amplitude seismic facies = sandy
- Channel fill Low amplitude seismic facies = heterolithic
- Lobe facies High amplitude seismic facies = sandy
- Mass Transport Complex = Chaotic seismic facies



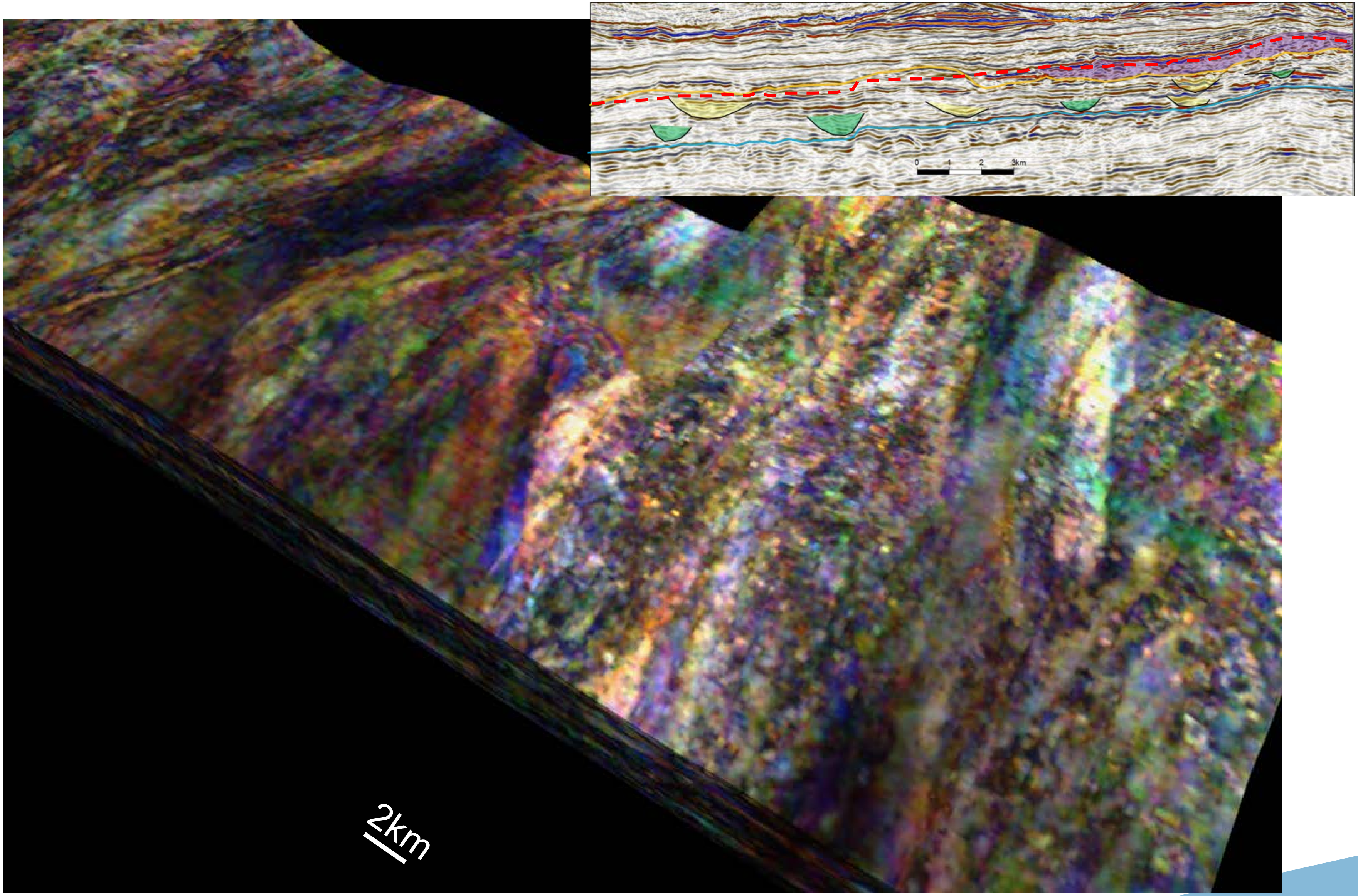
Horizon AVO blend



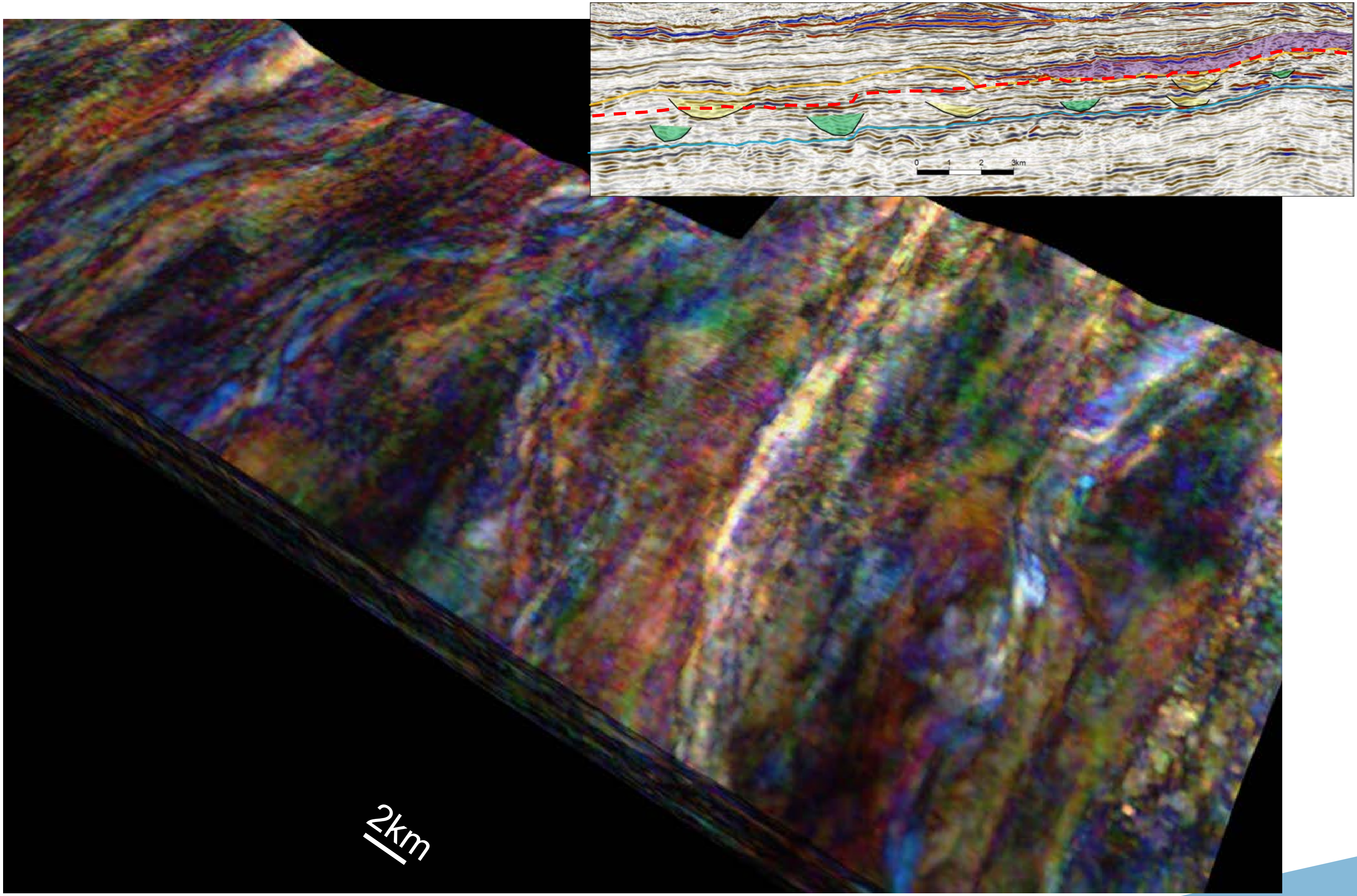
A series of horizon parallel slices to illustrate the technique

- First set is a regionally mapped Upper Cretaceous horizon, moved downwards in 10m increments.
- This ensures that the image is reasonably parallel to the stratigraphic grain
- Could use iso-proportional slices, but this slows the process down to a snail's pace

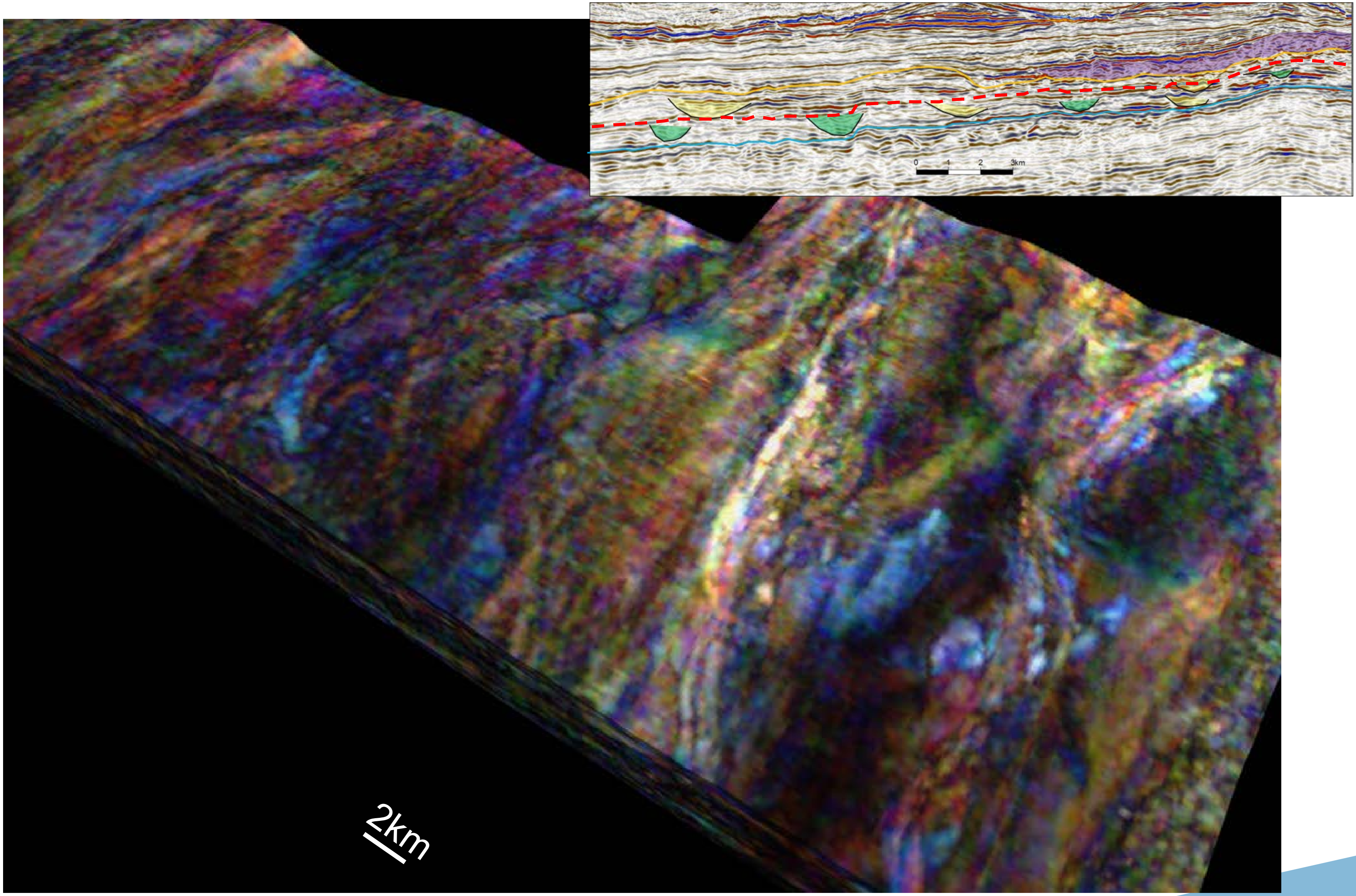
250 m above Horizon 5 circa 3.5km depth



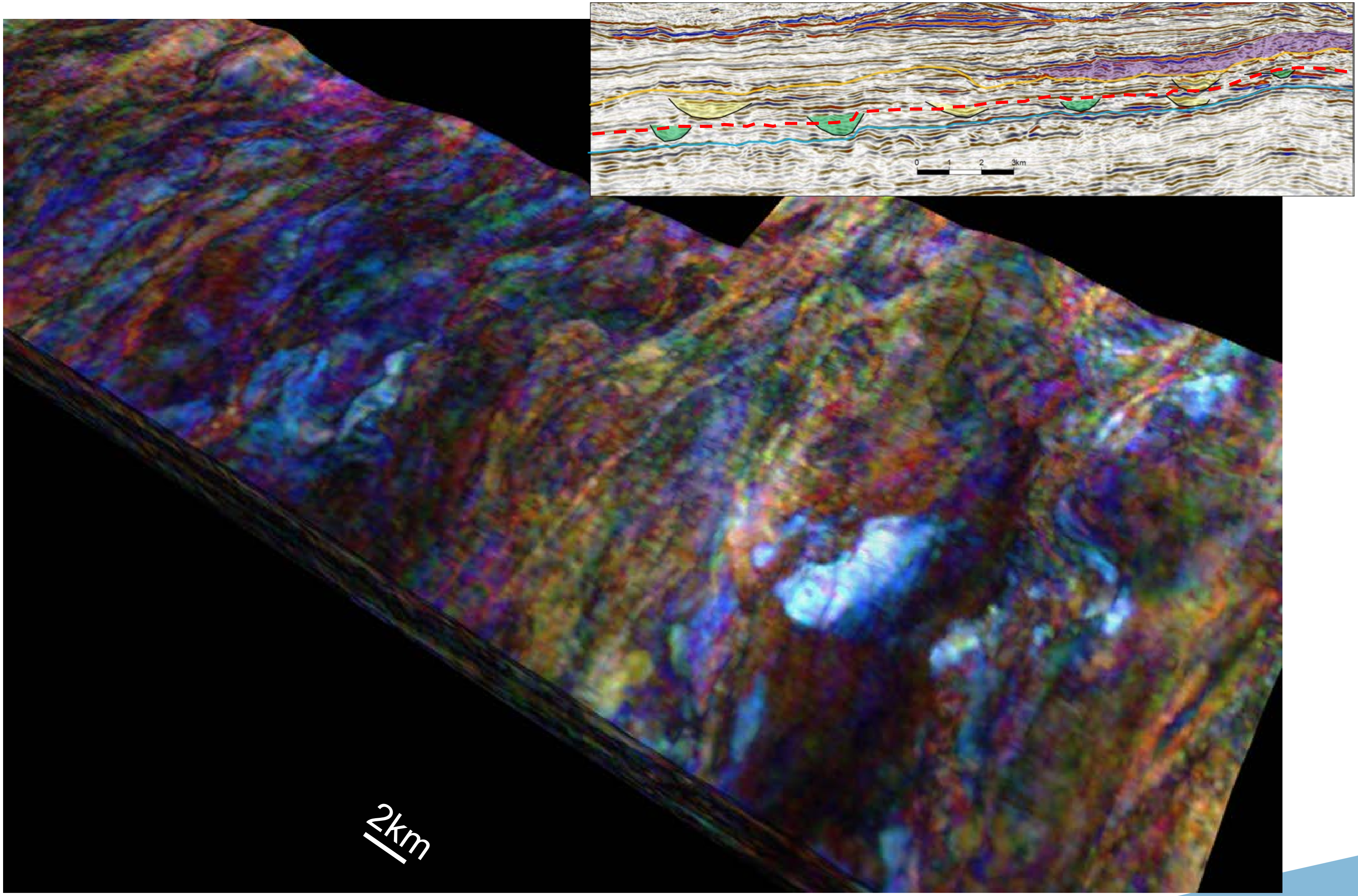
180 m above datum Horizon 5



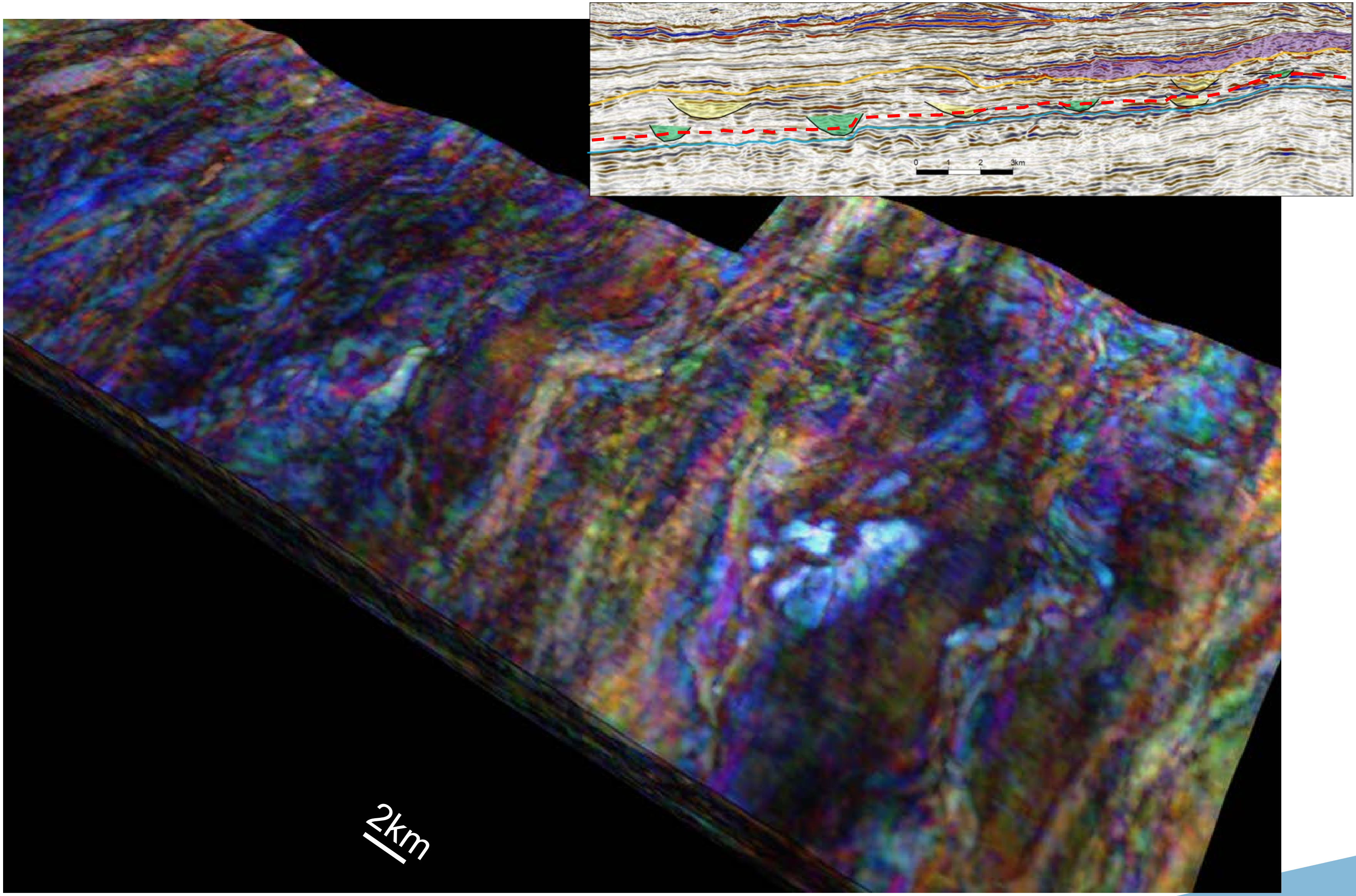
140 m above datum Horizon 5



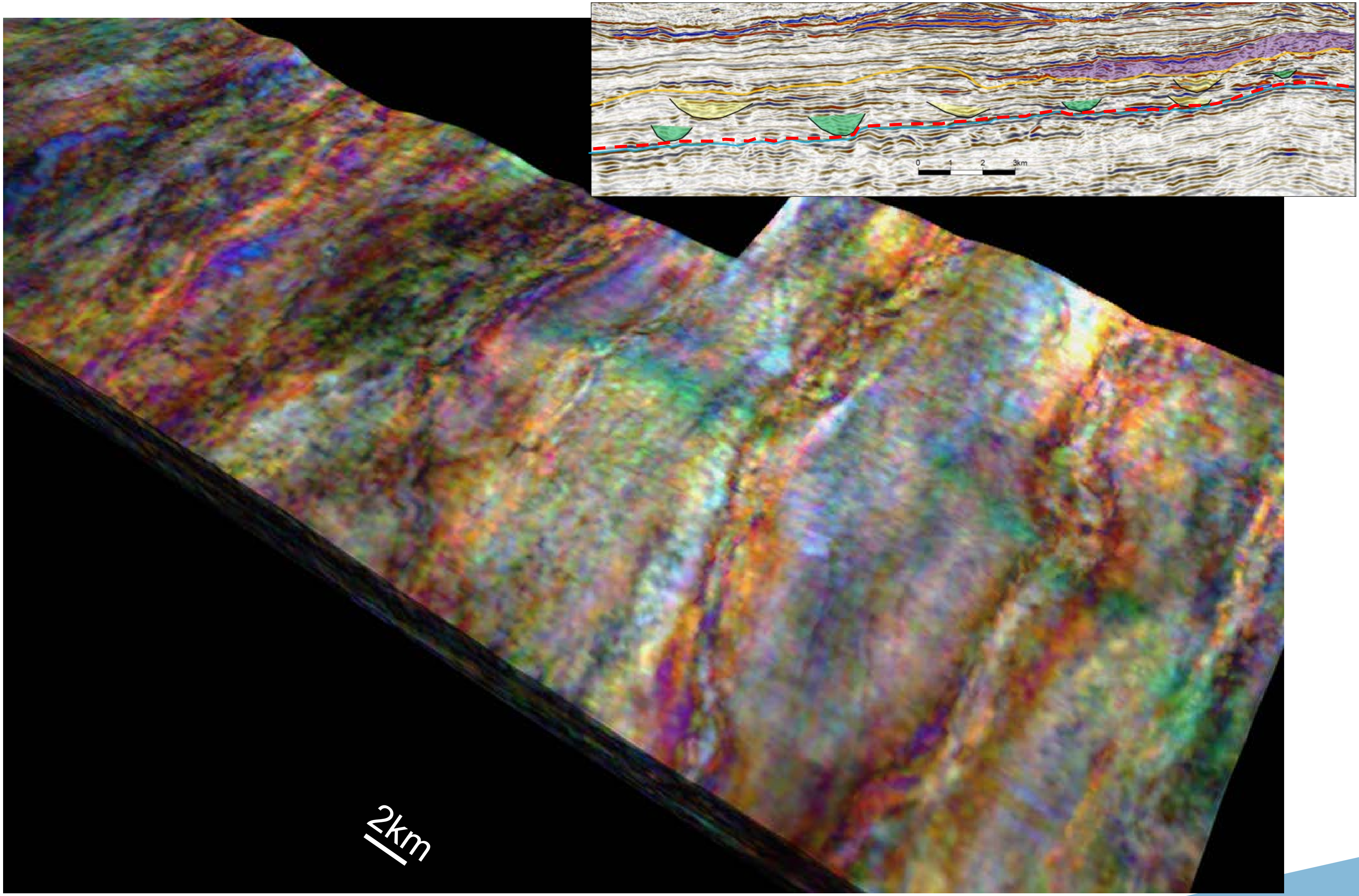
100 m above datum Horizon 5



60 m above datum Horizon 5 – Main reservoir



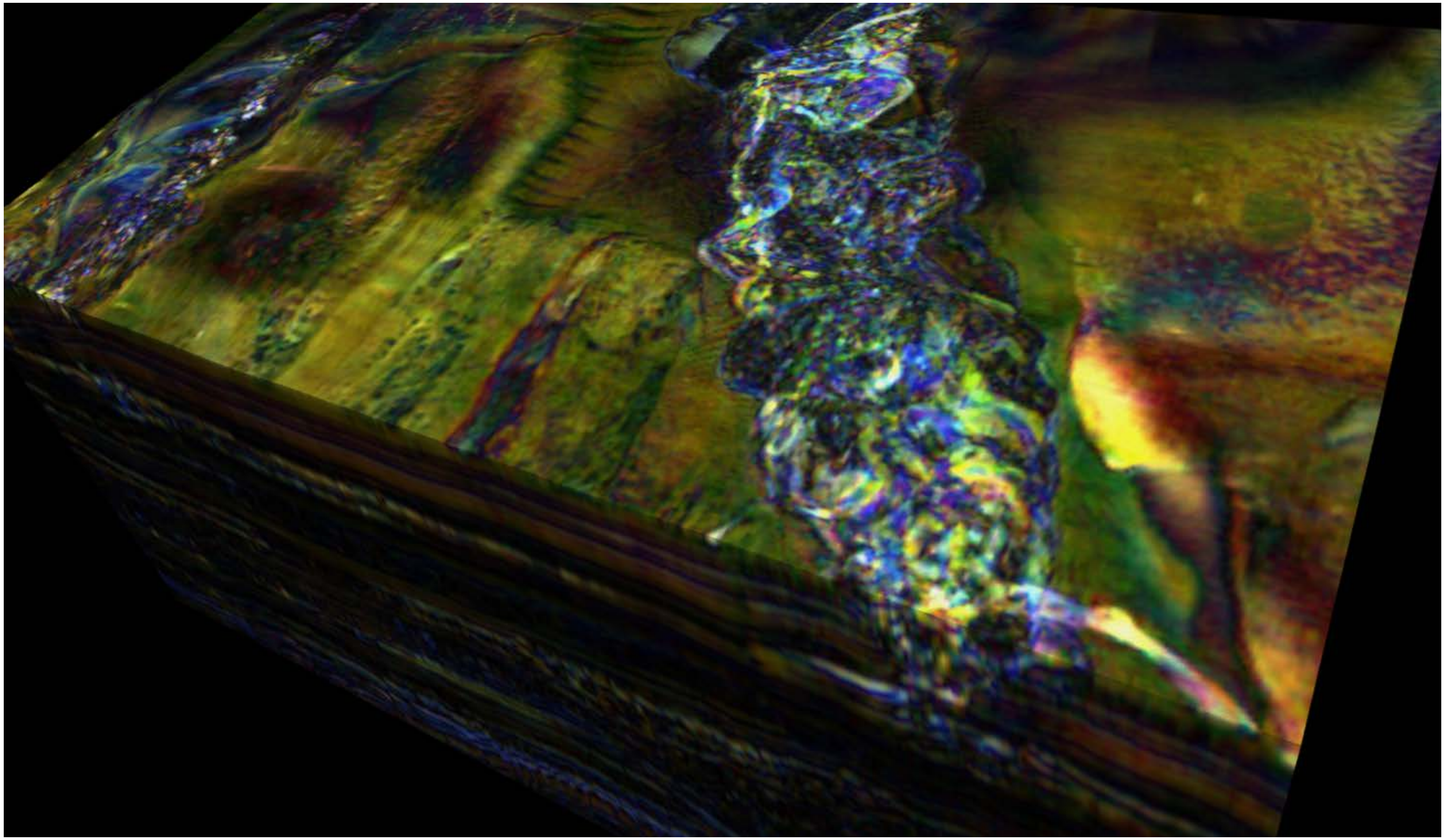
At datum Horizon 5 – Regional mapped shale prone interval



Use in shallow hazard analysis

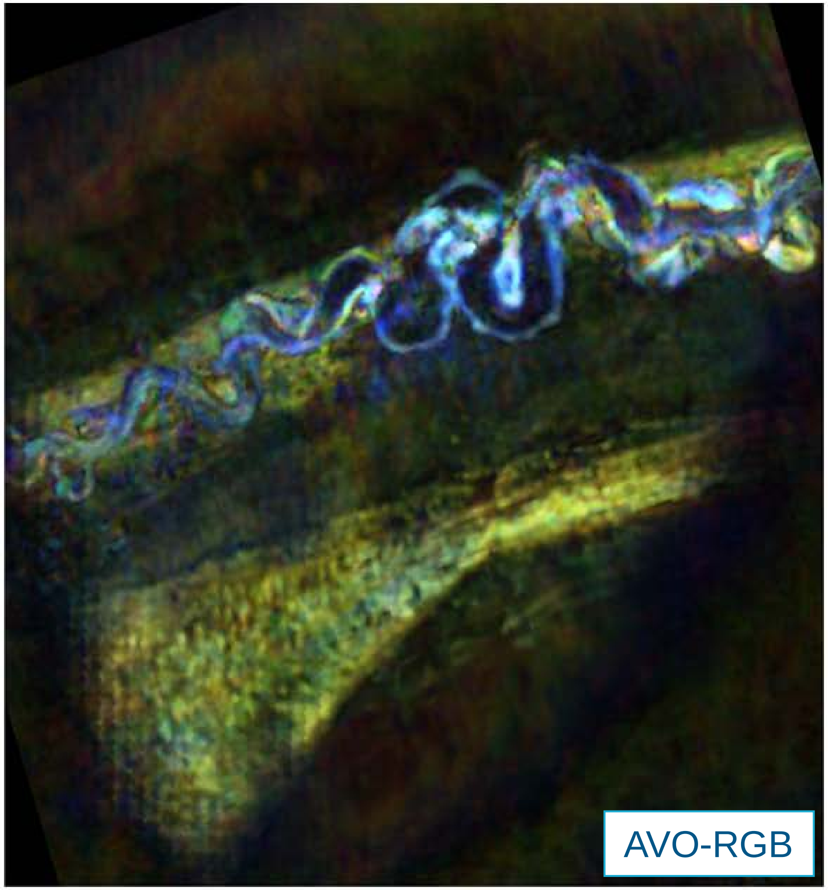
- The AVO RGB blend technique is also ideal for rapid screening for shallow gas hazards

Shallow Hazard Study Example 1: 280m below seabed



Shallow canyon fill with meandering channels showing blue colours indicating strong AVO response and likely shallow gas hazards.

Shallow Hazard Study Example 2: 550 mtr below seabed



AVO-RGB blend on the left, on the right an RMS amplitude extraction from a 40mtr window centered on the horizon from the full stack. Bright blue colours are caused by higher amplitudes on the far stack indicating a potential shallow gas hazard in the meandering channel, though not in the funnel shaped amplitude anomaly.

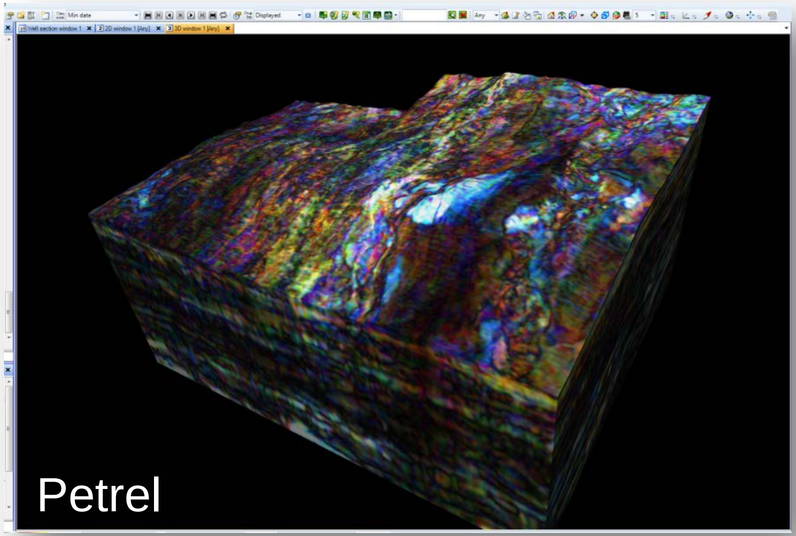
Conclusions

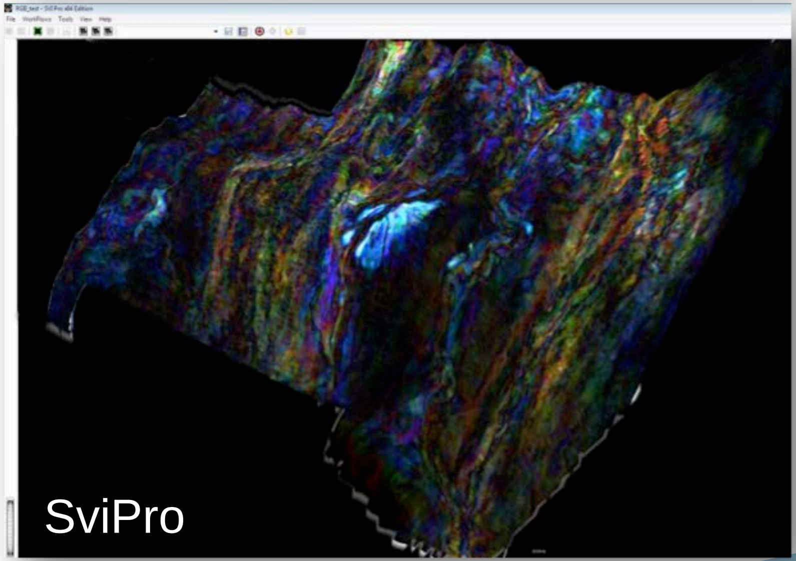
AVO RGB blending of the Near, Mid and Far angle stacks has a number of advantages:

- No specialist software required, we used Petrel, but SviPro or any package that allows RGB blending of 3 seismic cubes should work.
- required pre-processing is a simple envelope attribute computation.
- sedimentary bodies and AVO anomalies in one display.
- better description of seismic facies.
- aids in identifying potential hydrocarbon bearing reservoirs.

This makes AVO RGB blending an ideal tool for:

- rapid screening of large volumes for exploration .
- appraisal and development facies mapping and well planning.
- Shallow hazard identification





Acknowledgements

dana PETROLEUM

KNOC Korea National Oil Corporation

TULLOW plc Tullow Oil plc

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