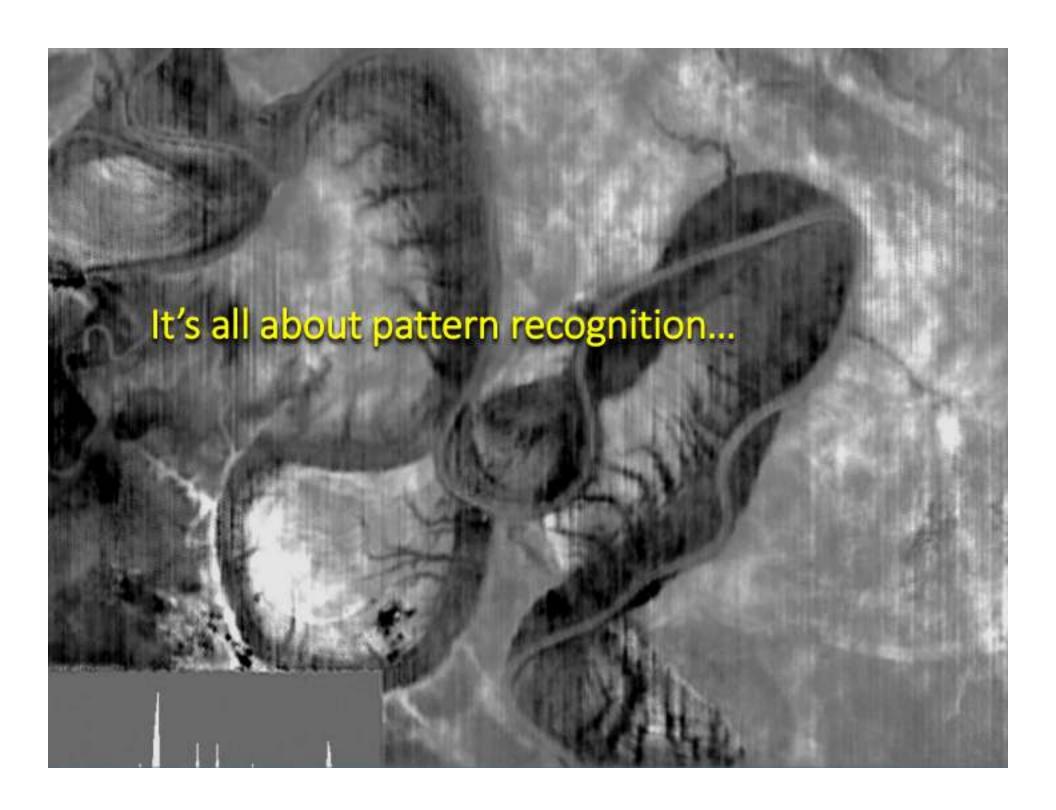
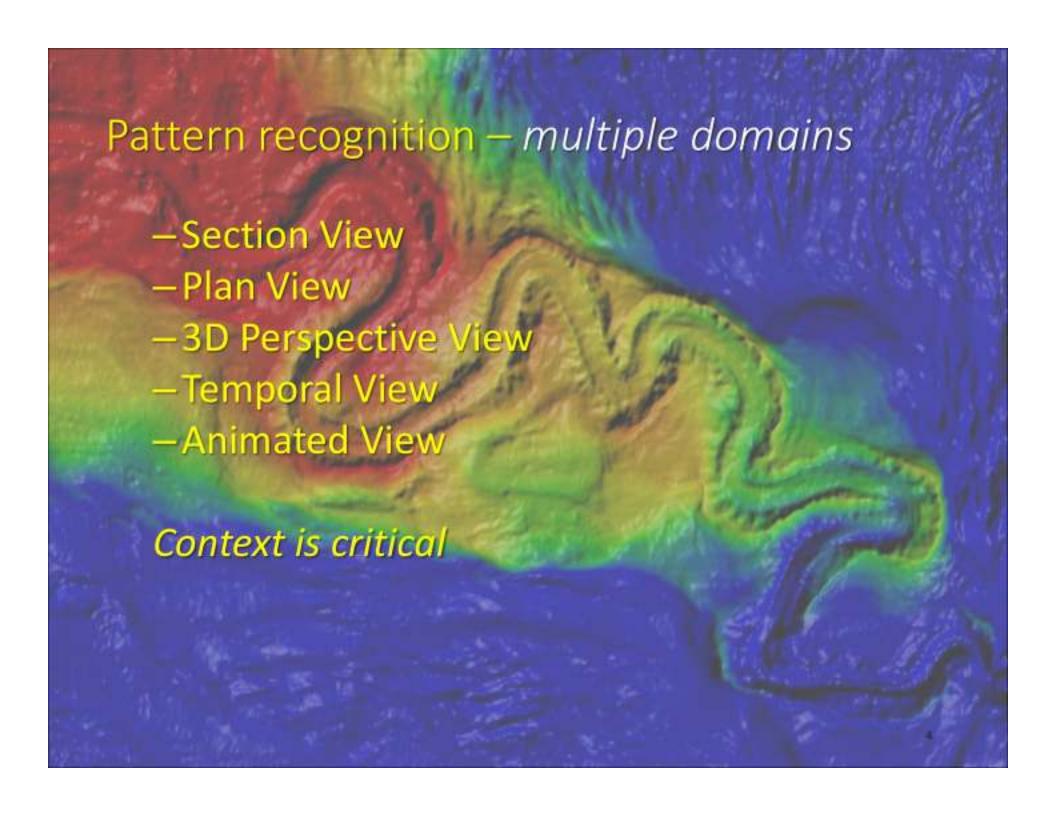


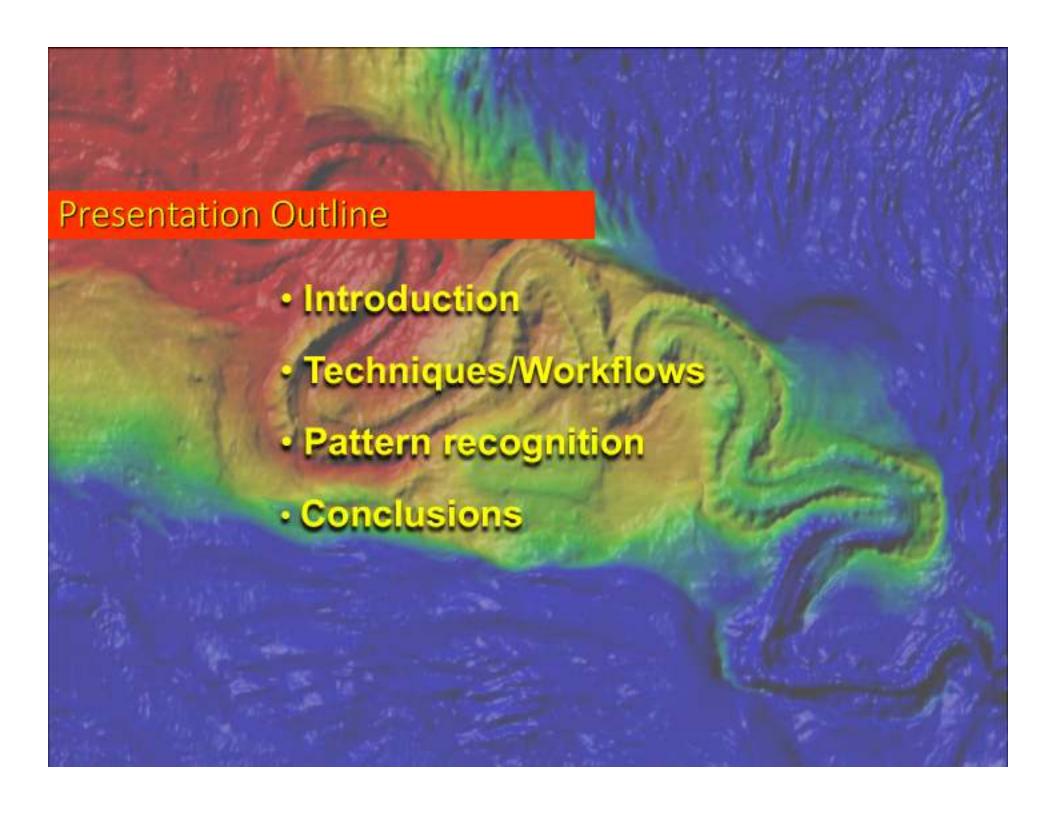
Seismic Stratigraphy and Seismic Geomorphology Analyses

Business justification:

- Reducing uncertainty with respect to lithologic prediction before drilling
- Assist seismic processing by identifying unequivocal geologic/geomorphic patterns and then using those features as a guide for comparison
- Leveraging and maximizing investment in seismic data much money is spent acquiring seismic data (it's an asset that should not be wasted!)



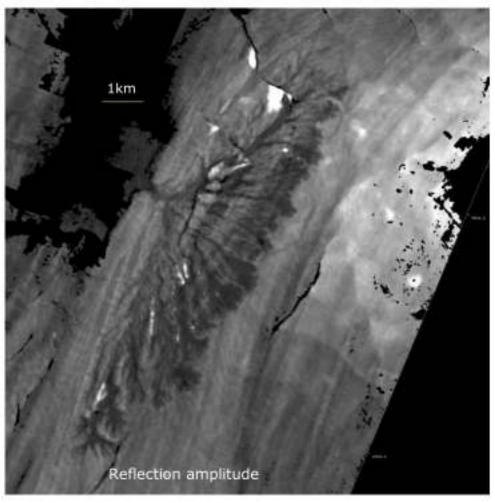




Course Objective

- It is my objective to expose you to subtleties of the seismic expression of geologic features and workflows that will get you there...
- I hope to change your thinking with respect to how you utilize seismic data to better understand geology
- I do not expect you to become expert practitioners overnight, but I do expect you to become aware of the potential of this approach!

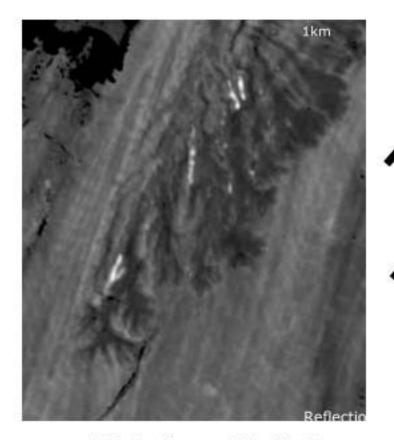
When things are not necessarily as they appear



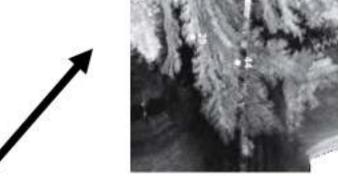
Distributive or Tributive?

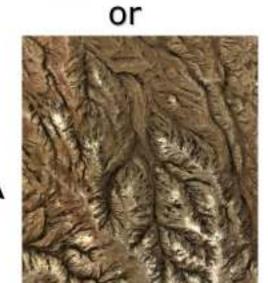
When things are not necessar:

appear



Distributive or Tributive?



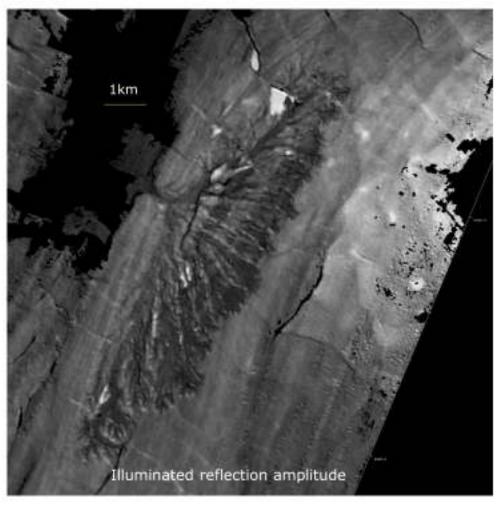


Tributive (Wyoming)

Distributive

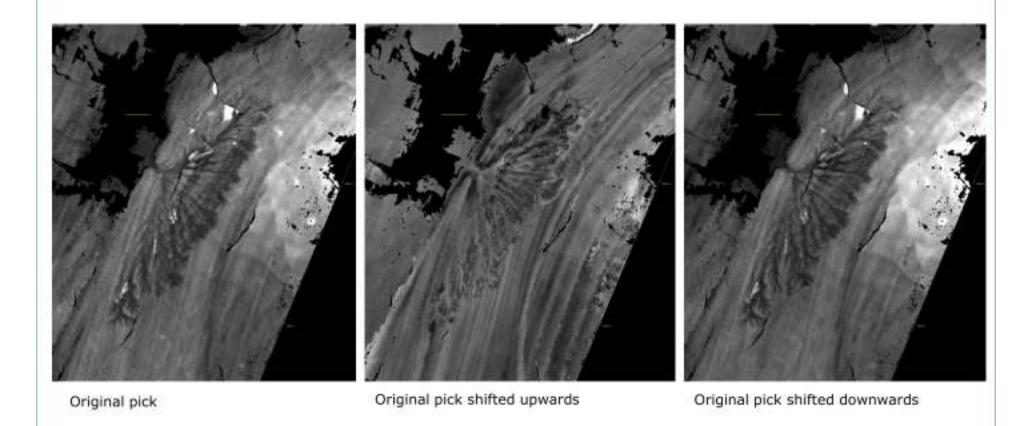
(GOM)

When things are not necessarily as they appear

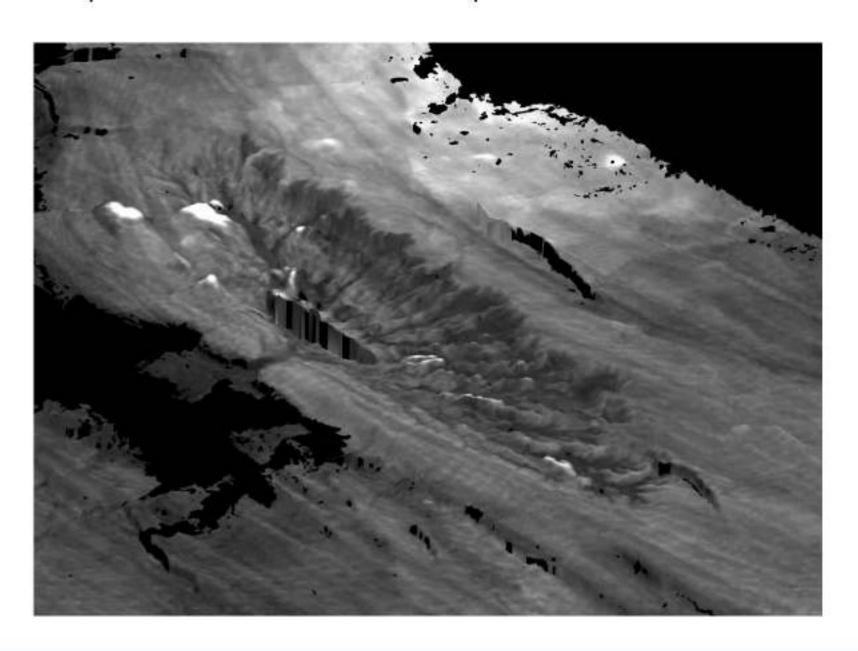


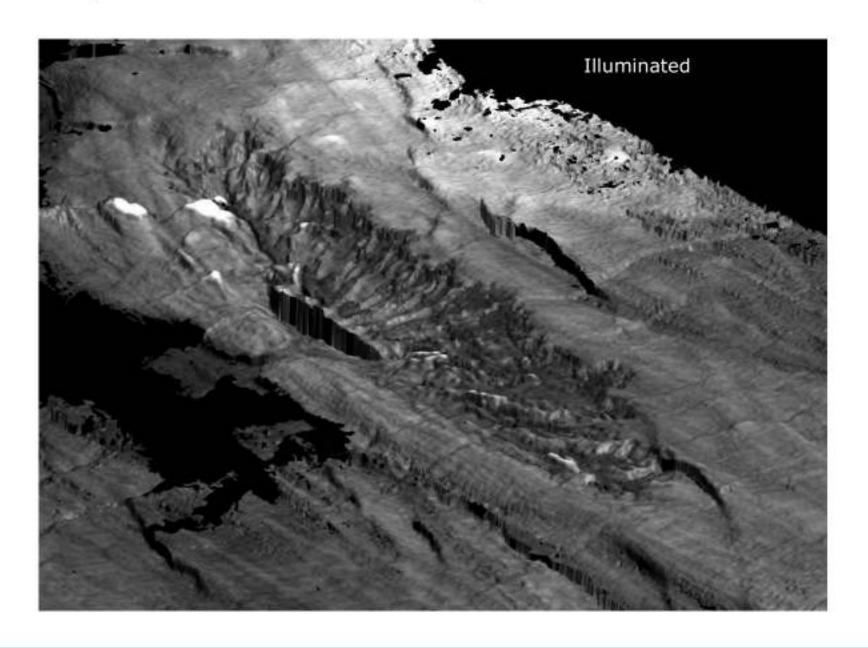
Distributive or Tributive?

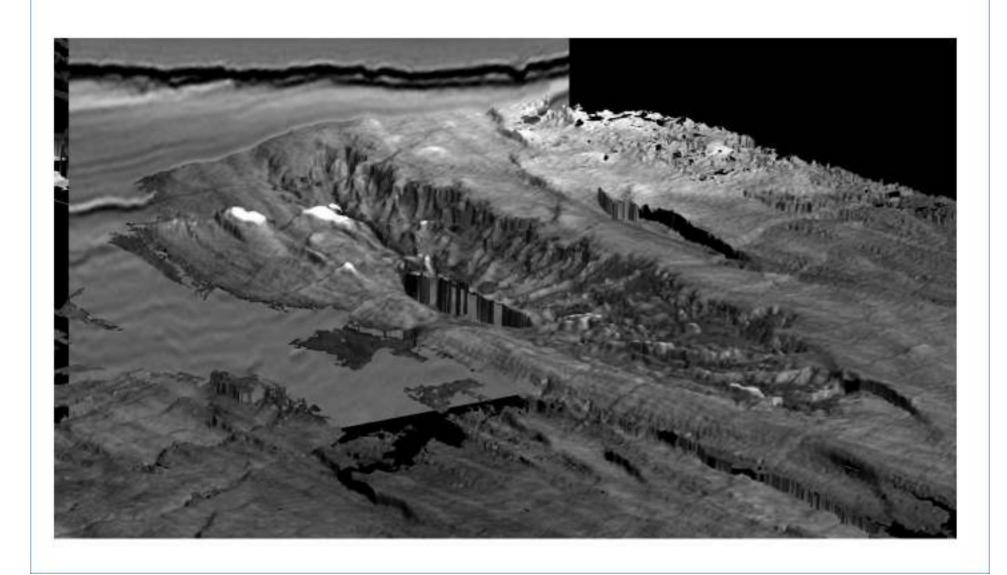
Amplitude Extractions

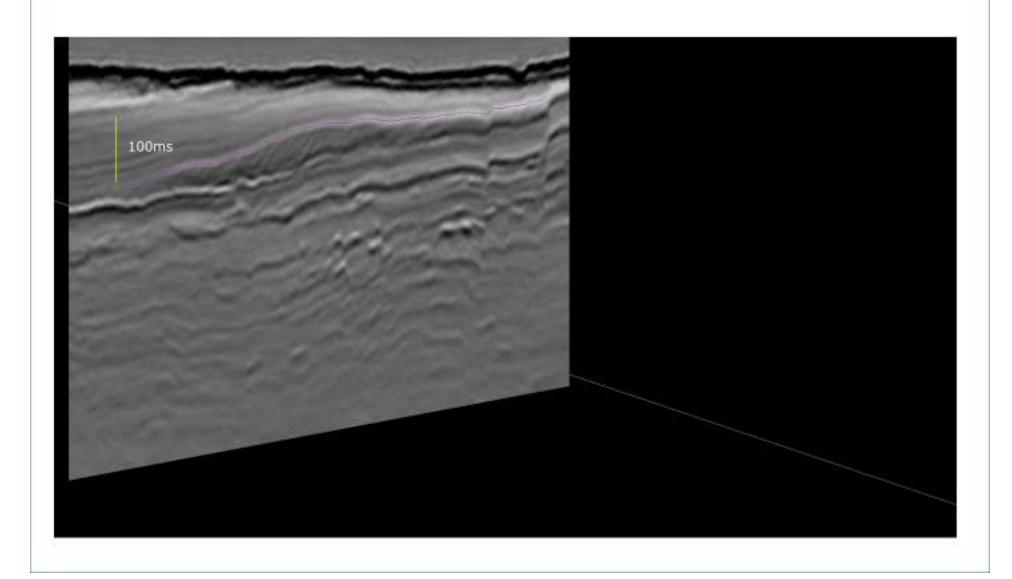


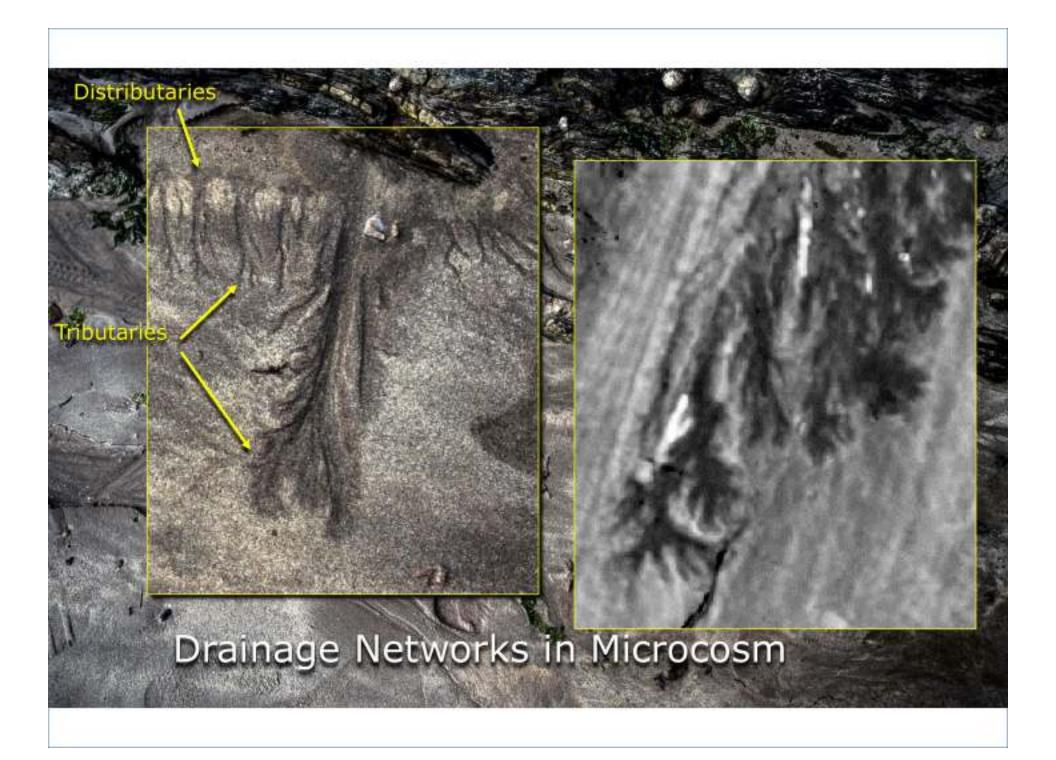
Distributive or Tributive?

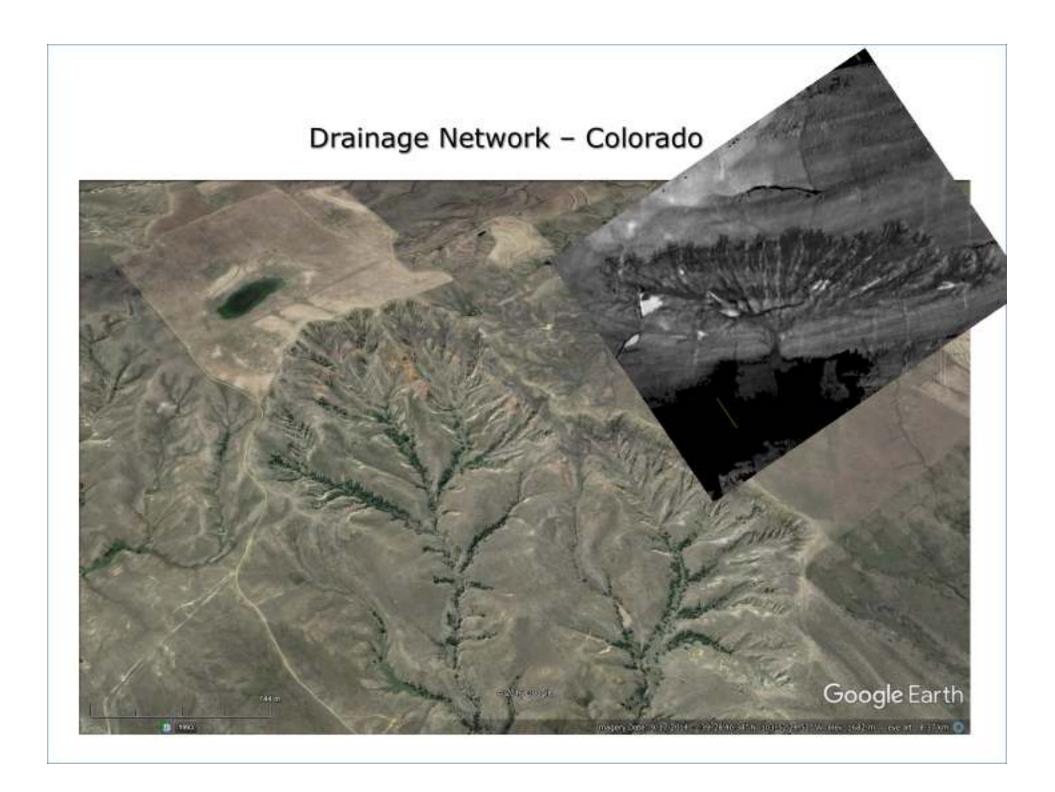


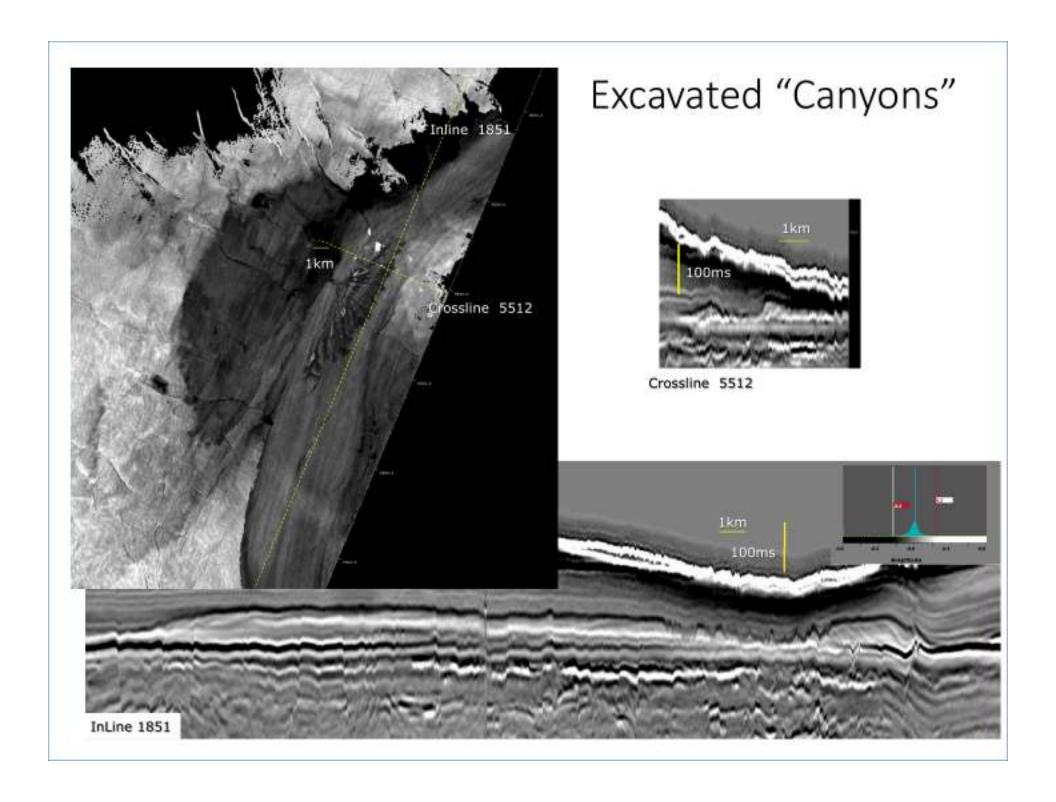


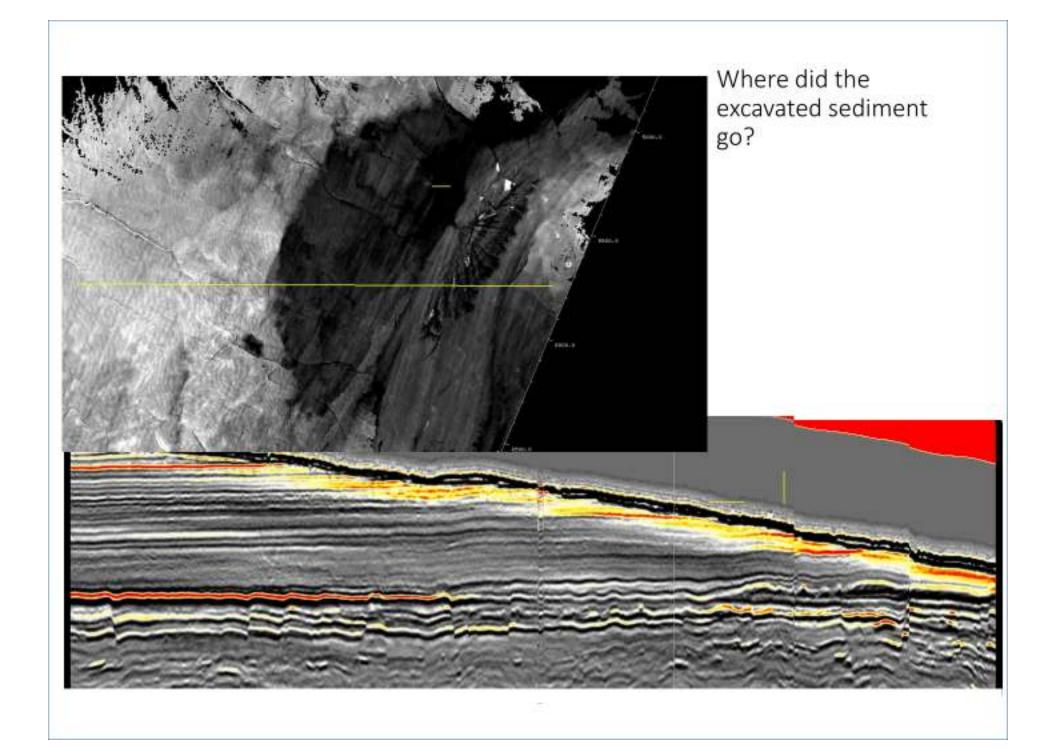




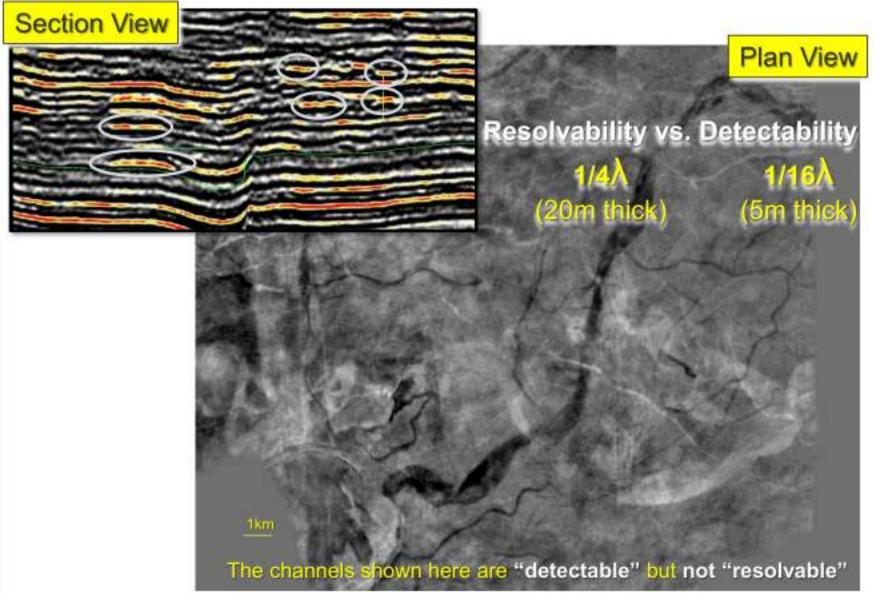


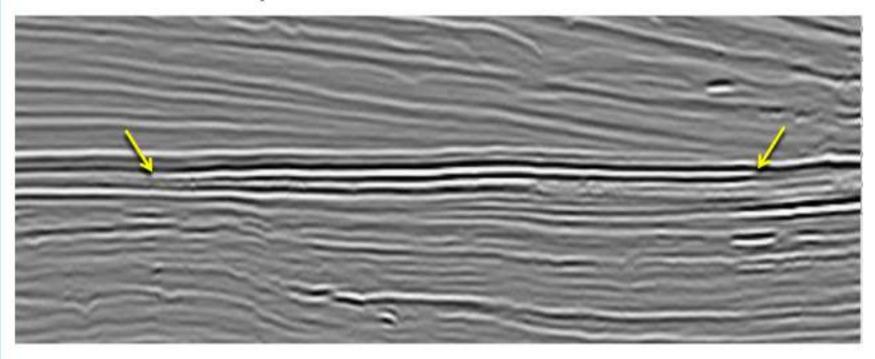




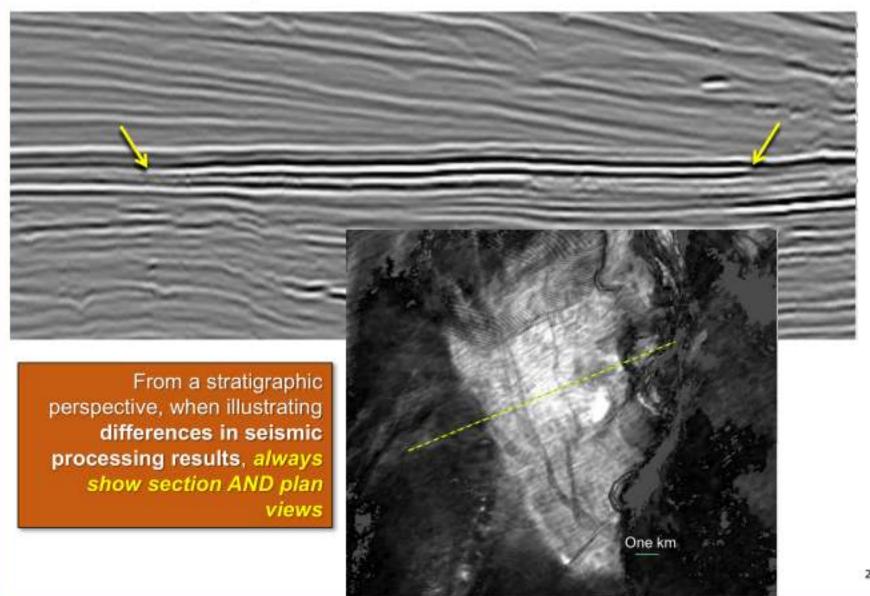


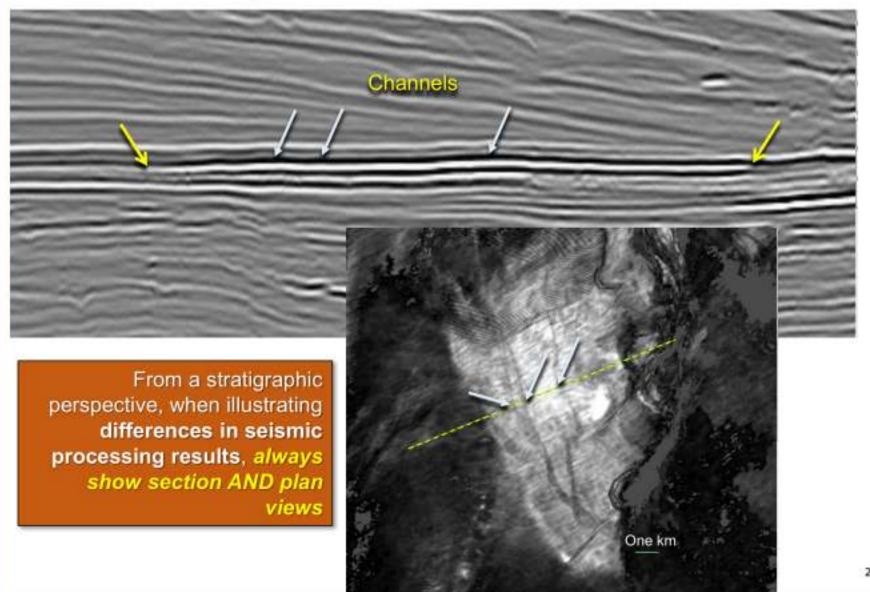
Pattern recognition: What can we see with seismic data?

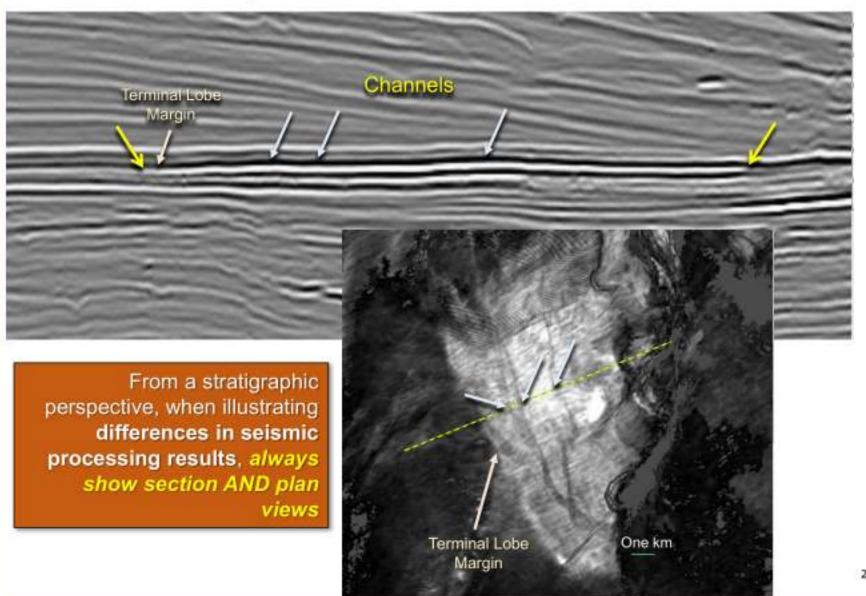




Can you see the channels and depositional lobe?







Workflows

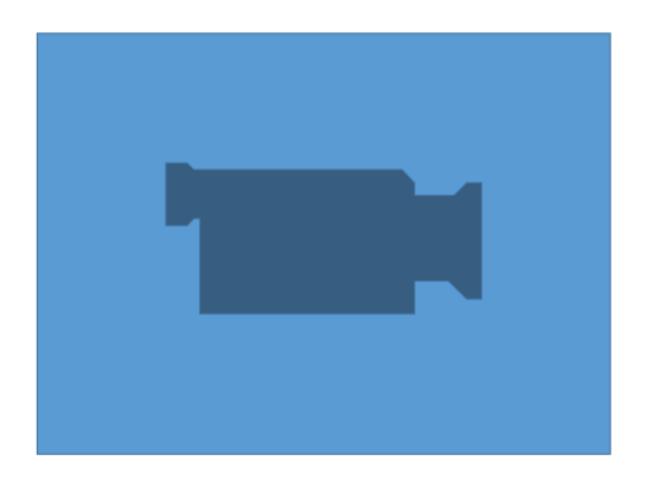
- Reconnaisance
 - Evaluate inlines, crosslines, and time/depth
 - Animation recommended
- Opacity rendering optical stacks
 - Animation recommended
- Flatten on key horizons near intervals of interest and reevaluate
 - Examine in multiple domains e.g., amplitude, coherence, spectral decomposition
- Focus on specific reflections where stratigraphic features have been detected
 - Evaluate horizon and interval attributes
- Evaluate the effects of lighting direction onto picked horizons

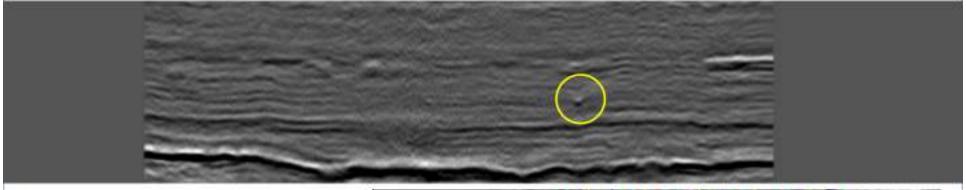
Throughout this process, always iterate between section and plan views

Leverage geologic context whenever possible!

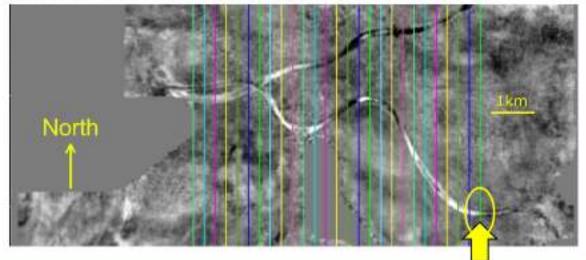


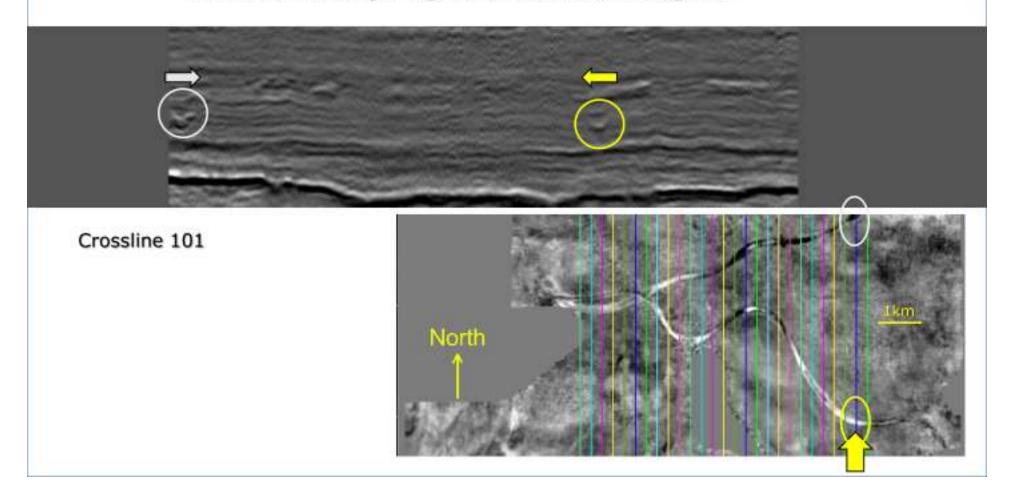
Animated View

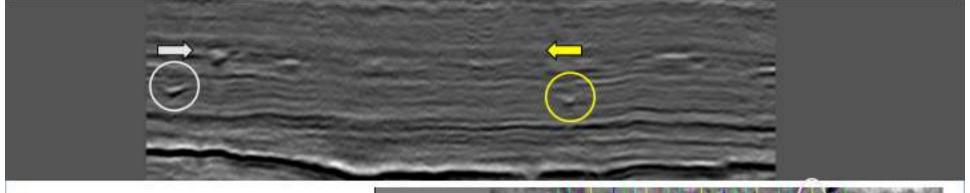




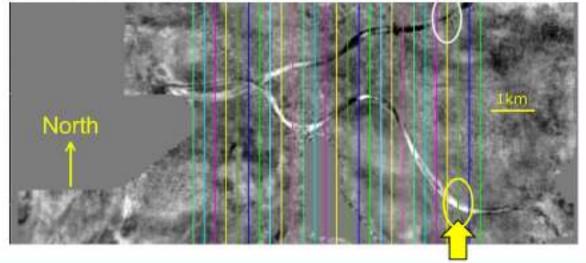
Crossline 91



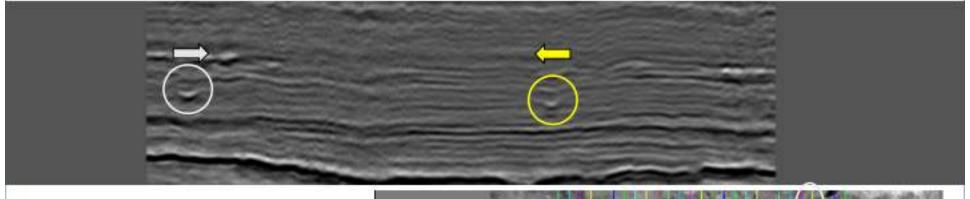




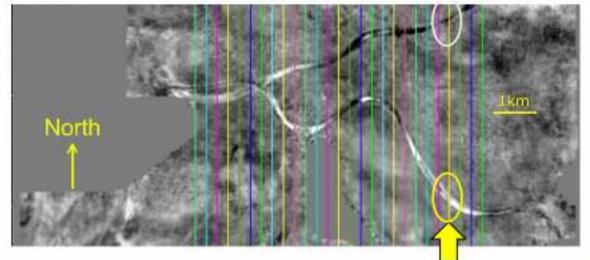
Crossline 111



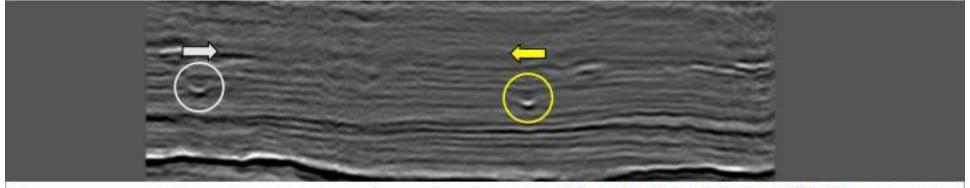
Note lateral shifting of high-amplitude reflection segment



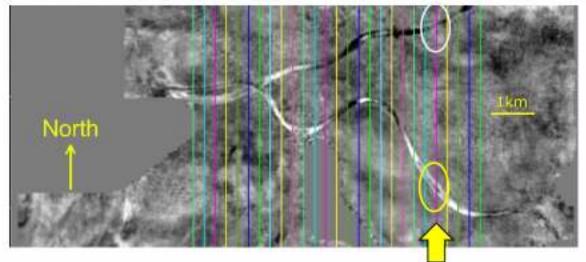
Crossline 121

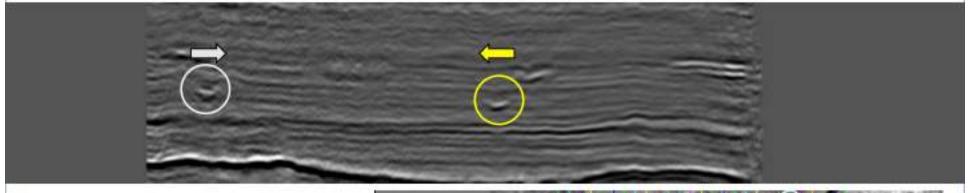


Note lateral shifting of high-amplitude reflection segment

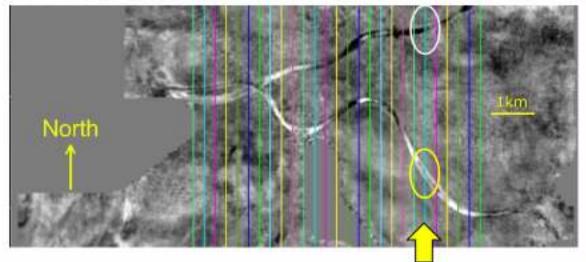


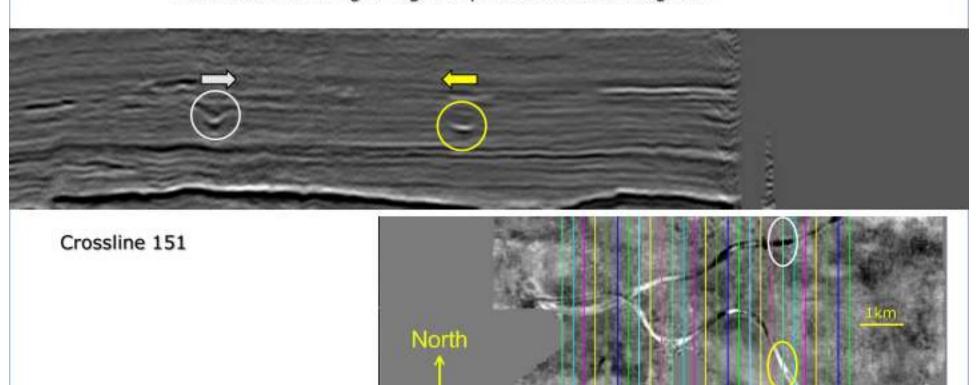
Crossline 131

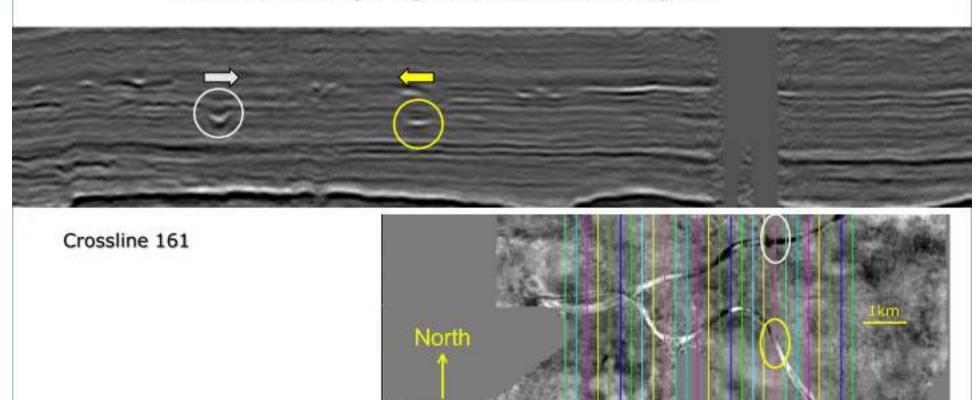


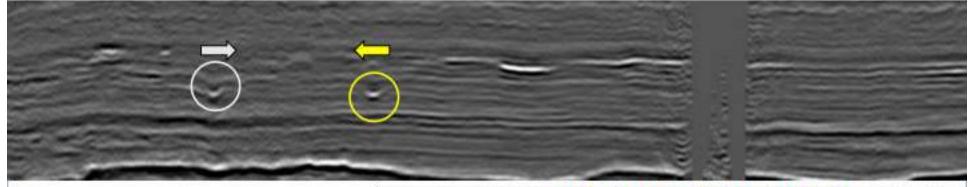


Crossline 141

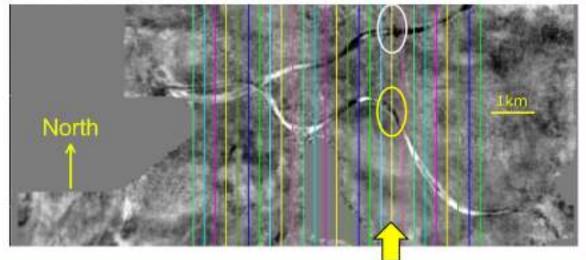




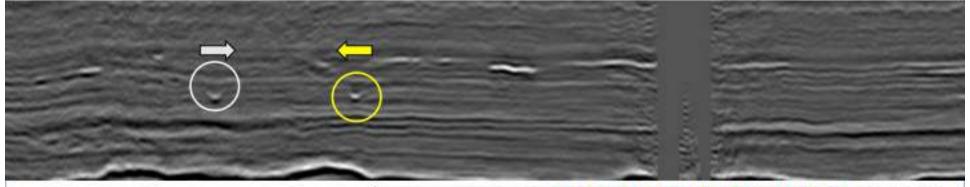




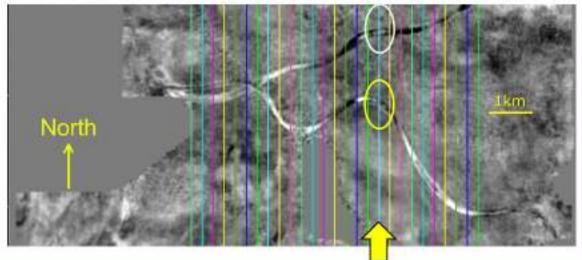
Crossline 171



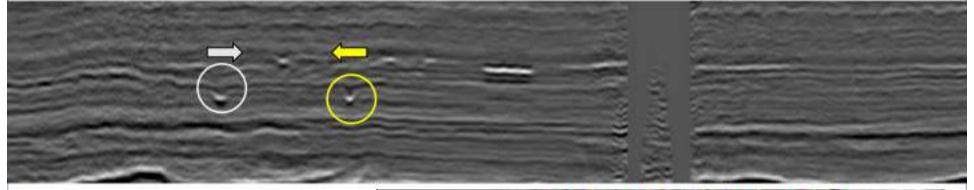
Note lateral shifting of high-amplitude reflection segment

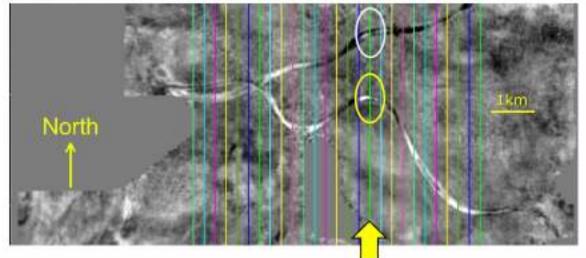


Crossline 181

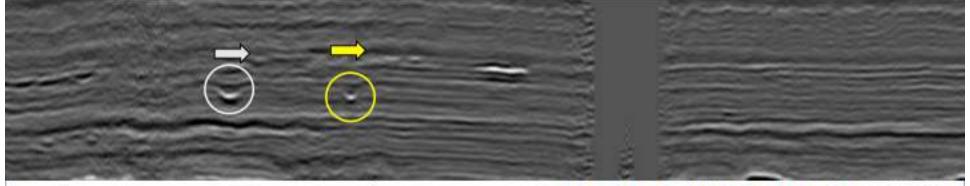


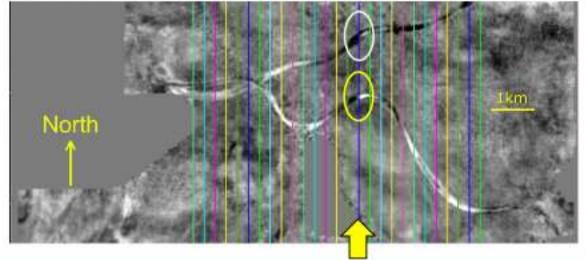
Note lateral shifting of high-amplitude reflection segment



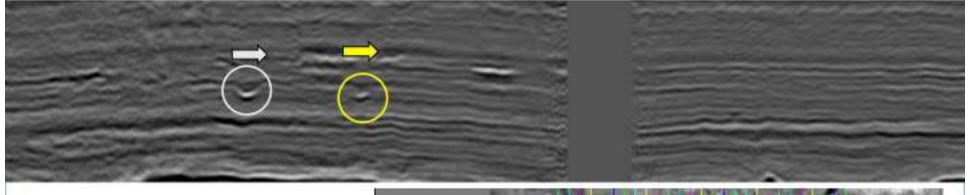


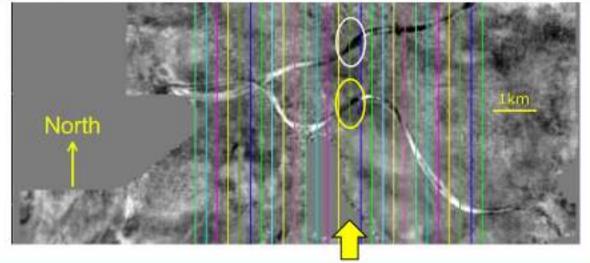
Note lateral shifting of high-amplitude reflection segment



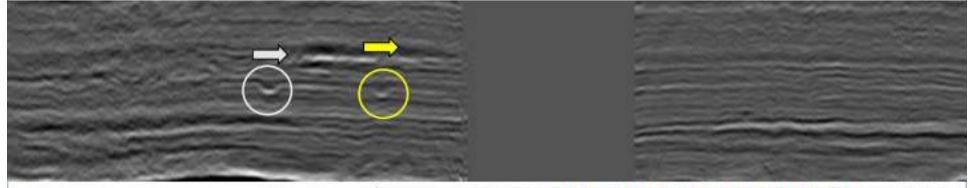


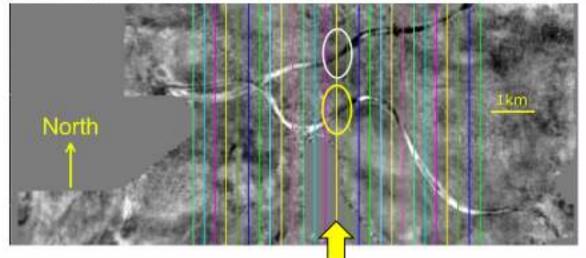
Note lateral shifting of high-amplitude reflection segment



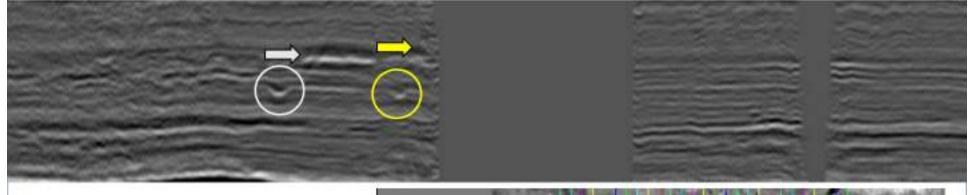


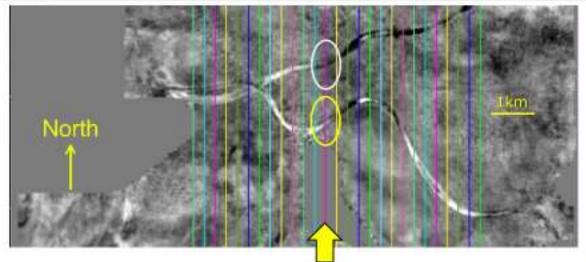
Note lateral shifting of high-amplitude reflection segment



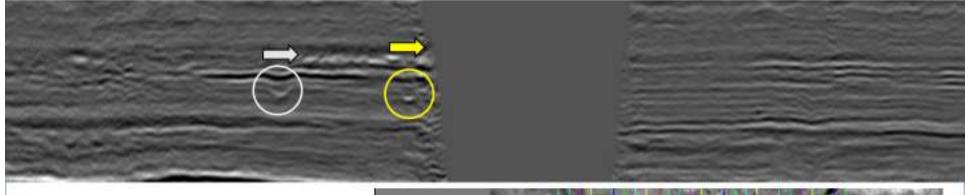


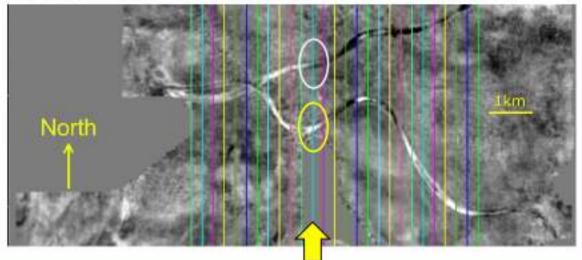
Note lateral shifting of high-amplitude reflection segment



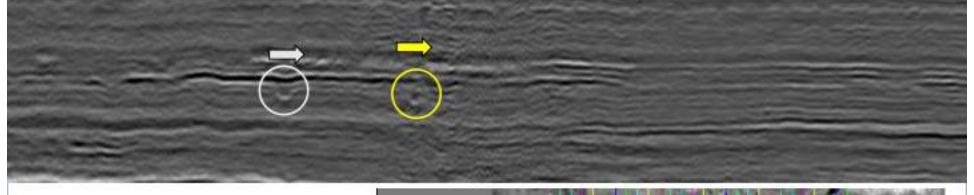


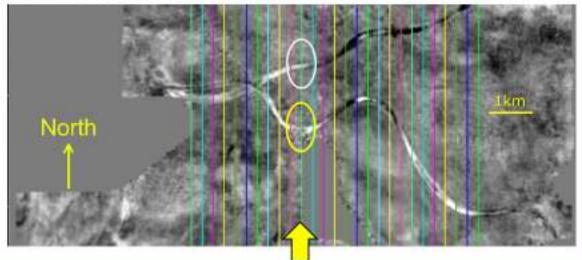
Note lateral shifting of high-amplitude reflection segment



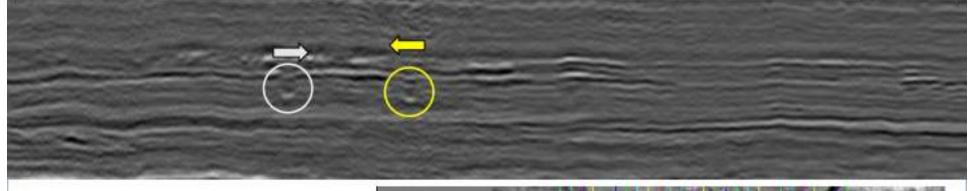


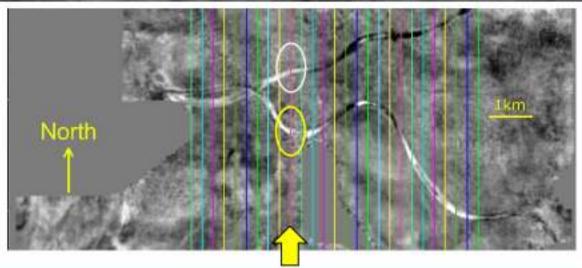
Note lateral shifting of high-amplitude reflection segment



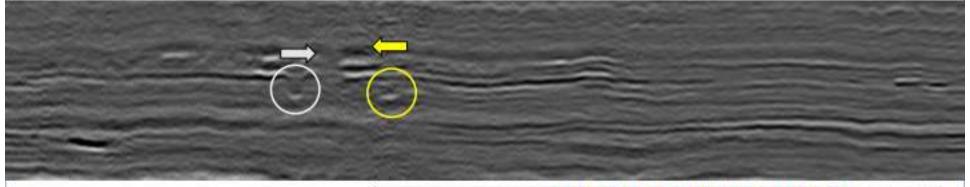


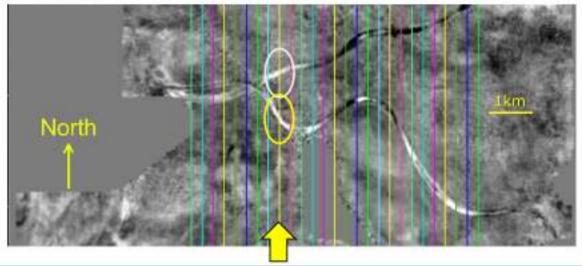
Note lateral shifting of high-amplitude reflection segment



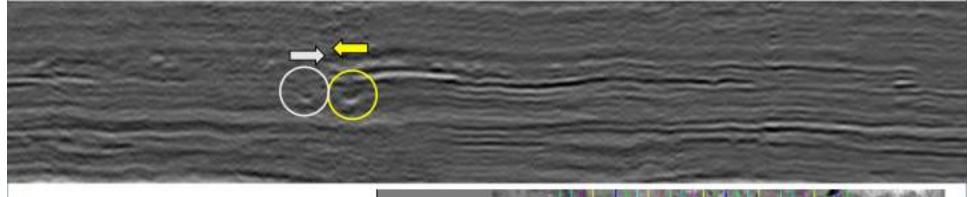


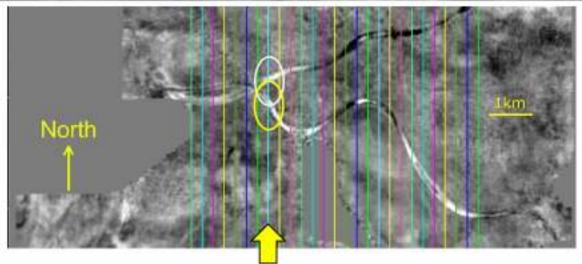
Note lateral shifting of high-amplitude reflection segment



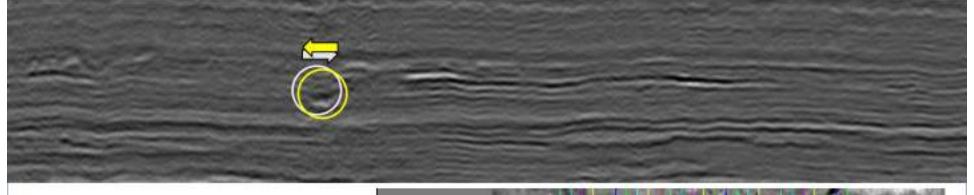


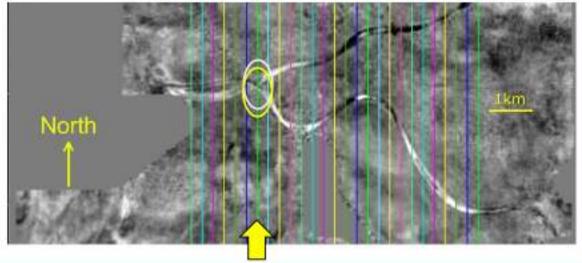
Note lateral shifting of high-amplitude reflection segment



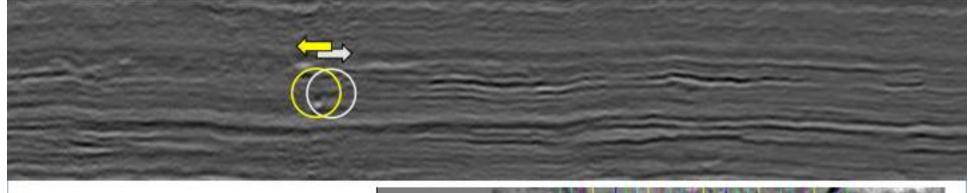


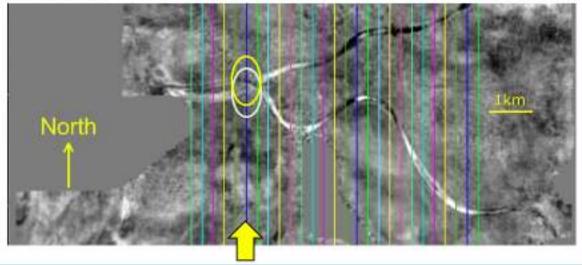
Note lateral shifting of high-amplitude reflection segment



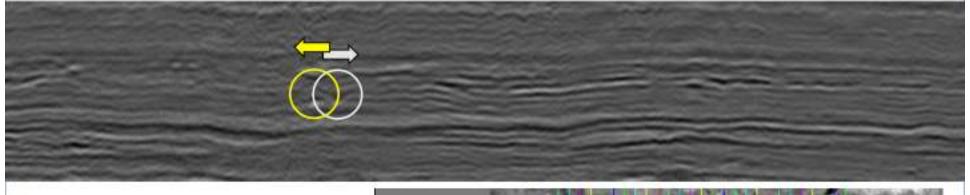


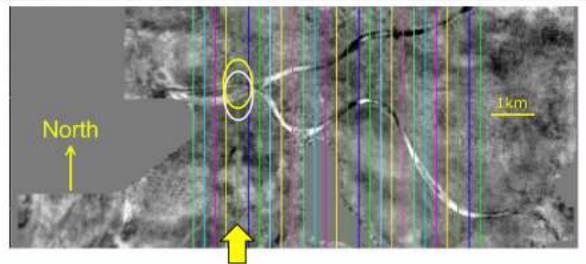
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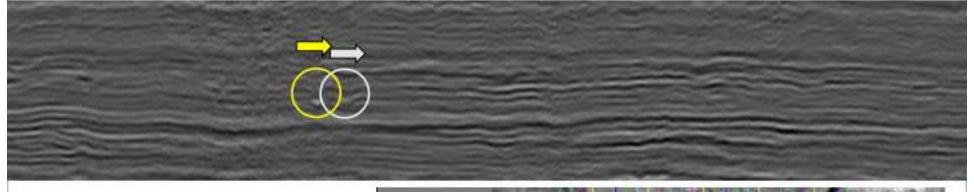


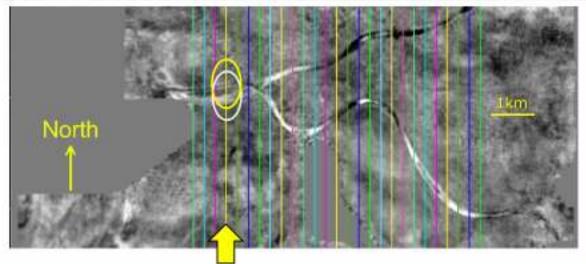
Note lateral shifting of high-amplitude reflection segment



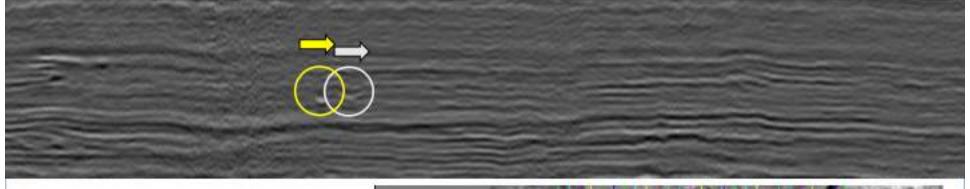


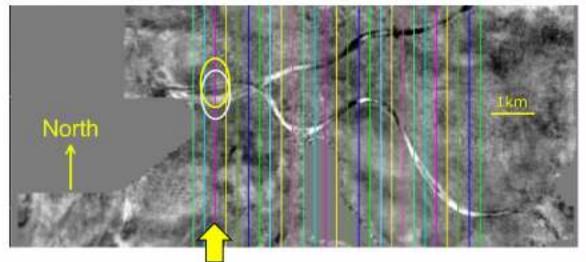
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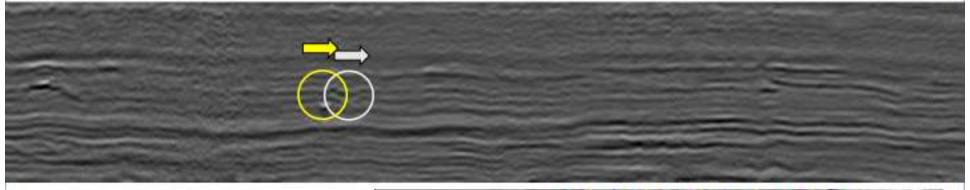


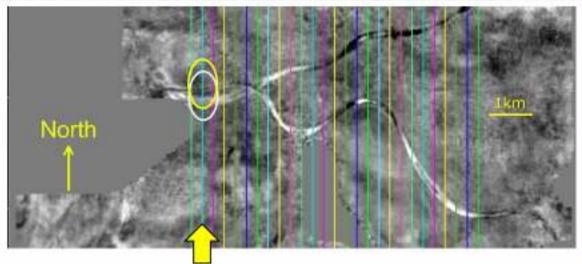
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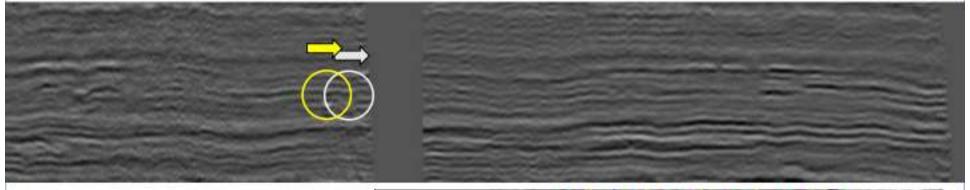


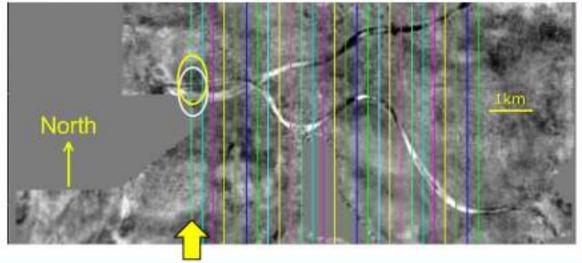
Note lateral shifting of high-amplitude reflection segment

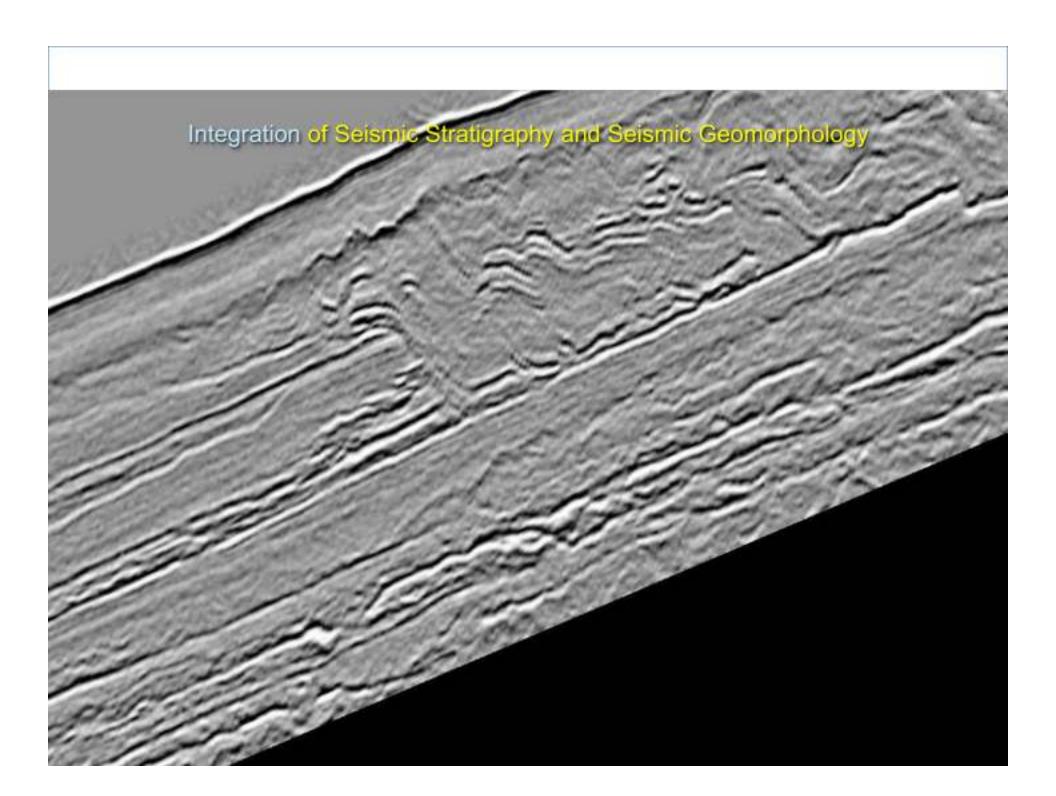


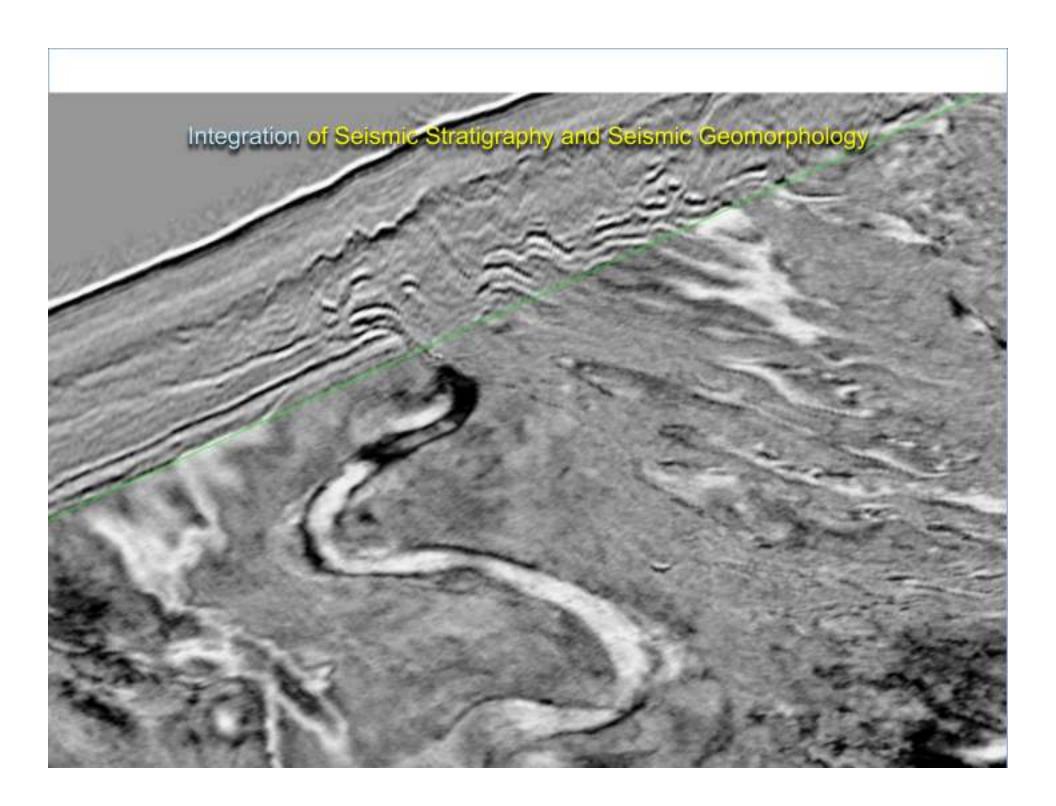


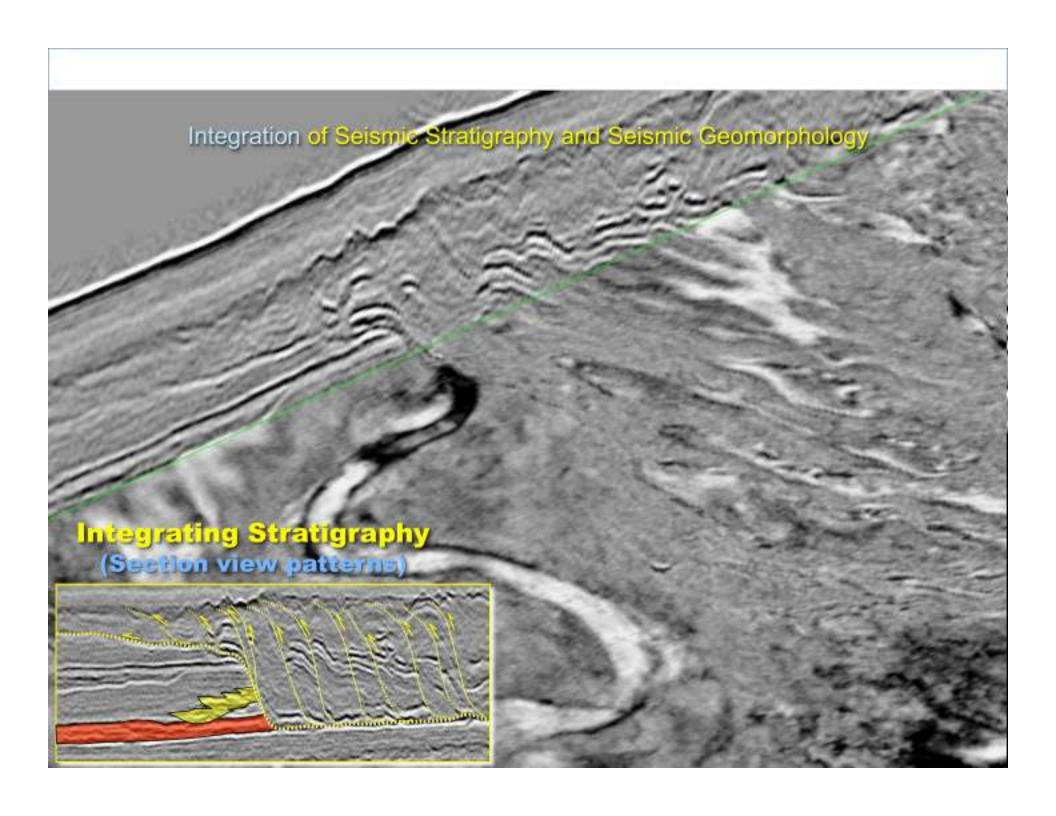
Note lateral shifting of high-amplitude reflection segment

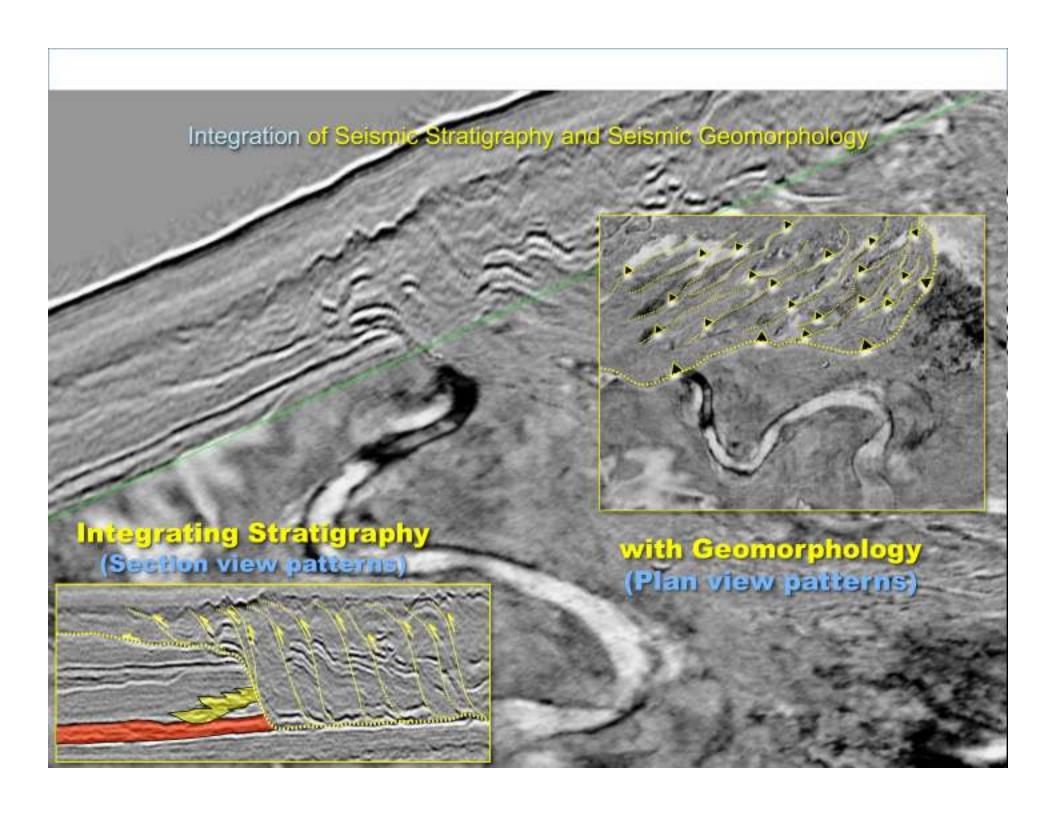


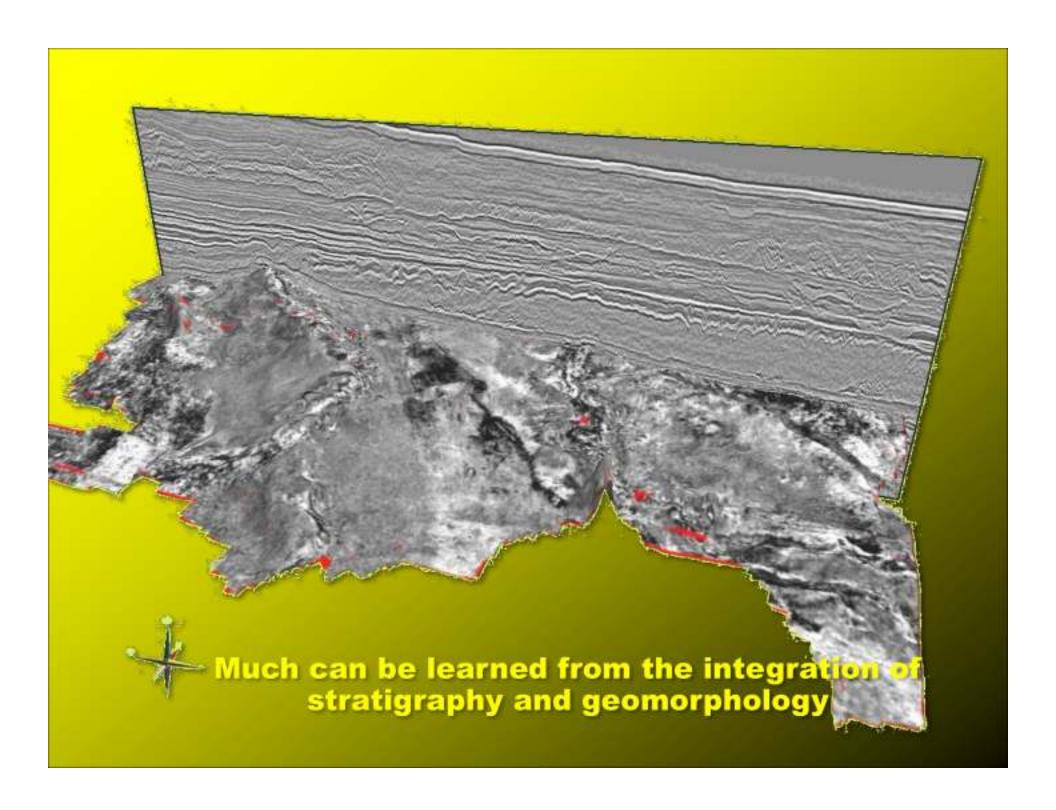












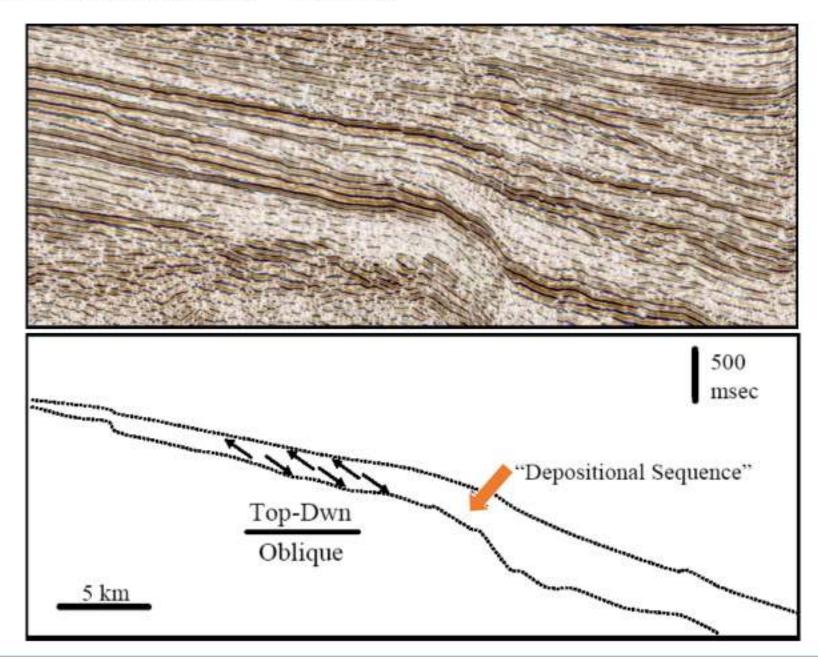


Identify depositional elements (on seismic data)

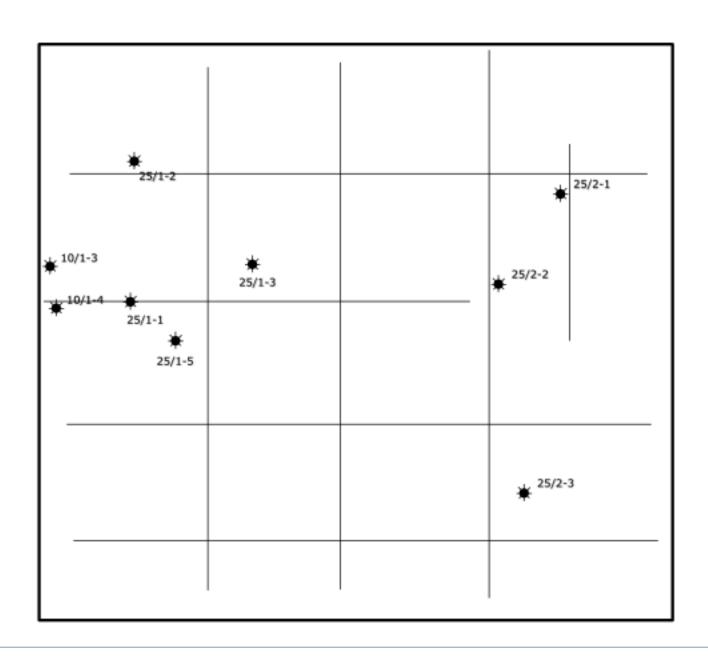


Populate depositional elements with appropriate lithology

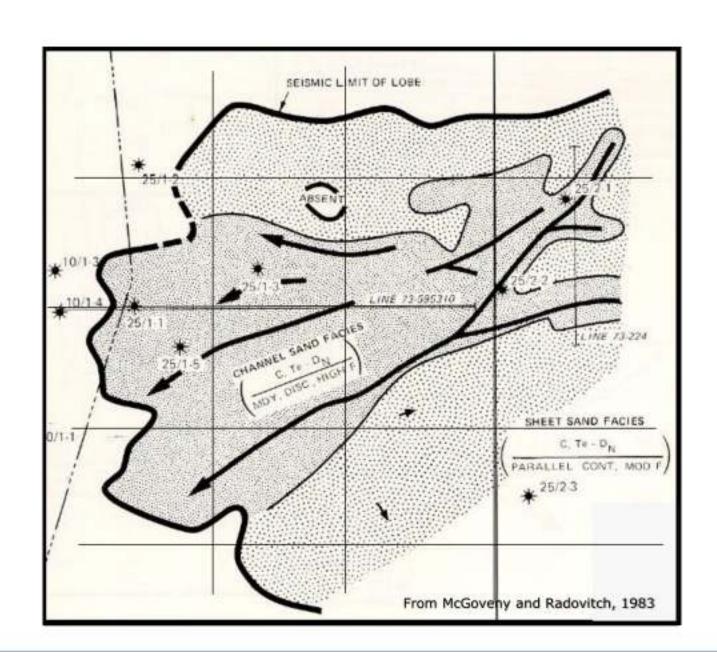
Seismic Stratigraphy - 1980's...

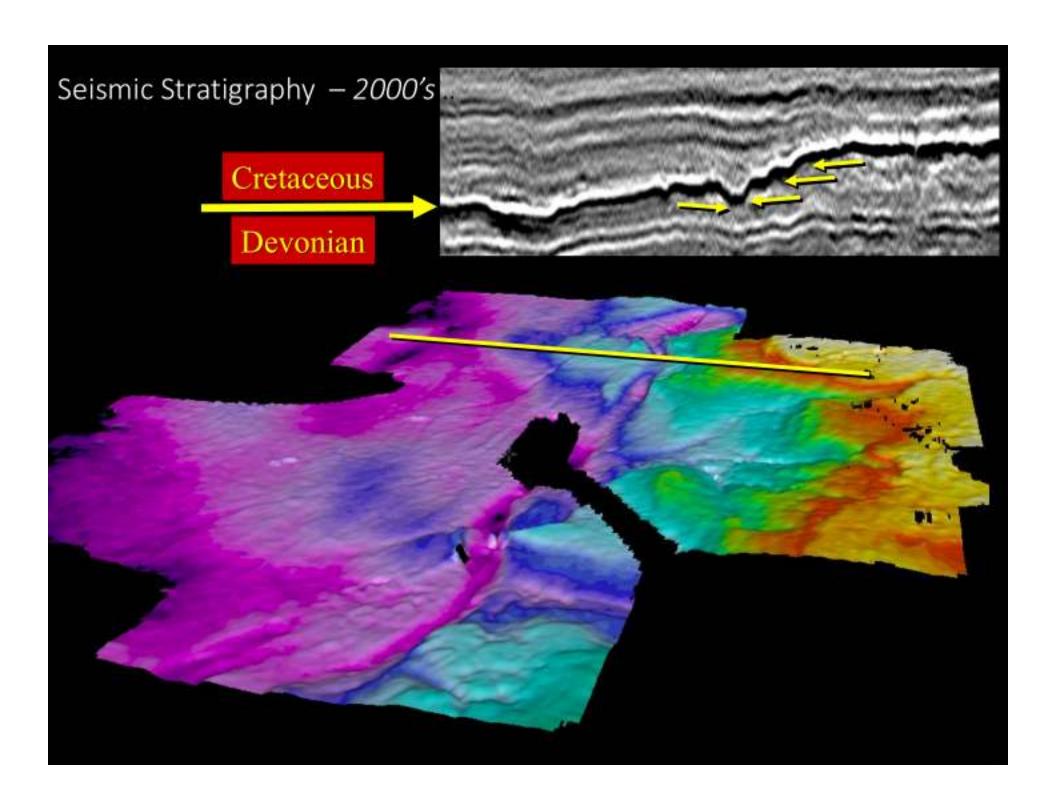


Mapping based on 2D seismic grid...



Mapping based on 2D seismic grid...





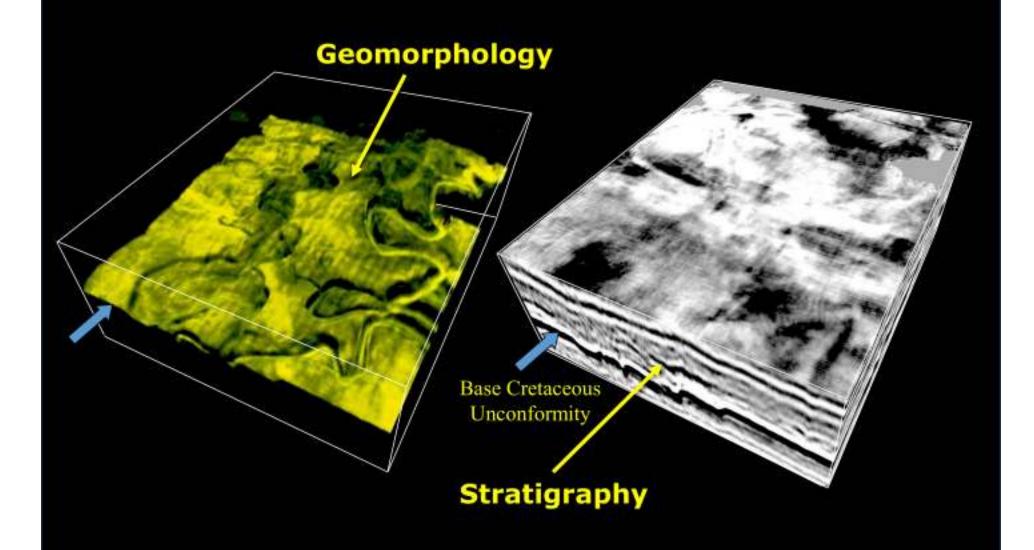
- Key Takeaways -

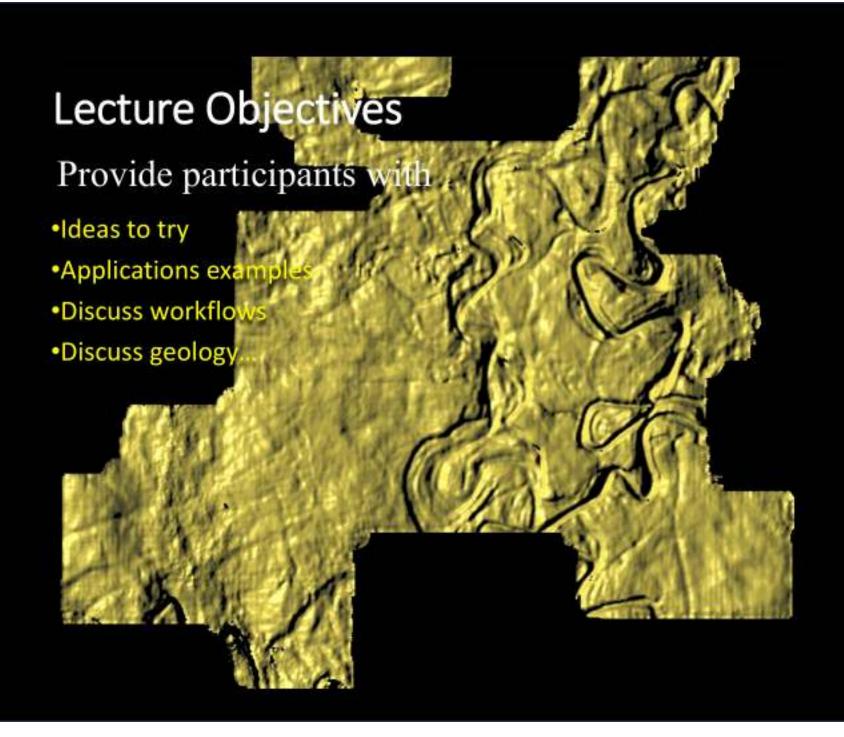
- Integration of seismic stratigraphy and seismic geomorphology
- Pattern recognition recognition of what "look" like geologically significant patterns
- Efficient and creative workflows
- Understand Context Know where you are (shallow vs. deep; CO3 vs. clastic)

Caveats - Uncertainty

- Reservoir quality is significantly more difficult to predict than reservoir presence
- Data quality diminishes with depth decreased resolution and detectability
- Data quality is impacted by presence above target section, of highimpedance deposits such as volcanics and carbonates
- Some stratigraphic patterns provide non-unique solutions.
- Seismic multiples, fluid contacts, low signal-to-noise can increase interpretation uncertainty

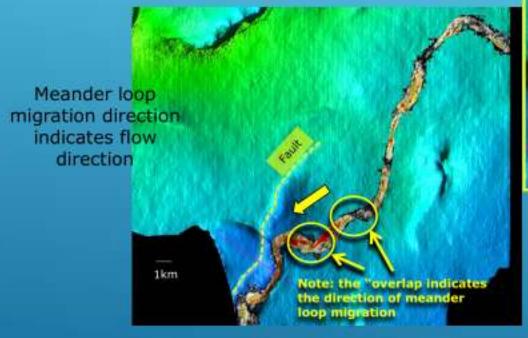
Mapping based on 3D seismic grid...



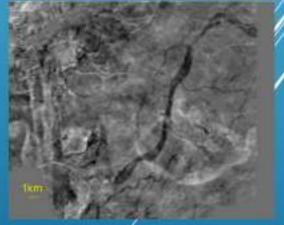


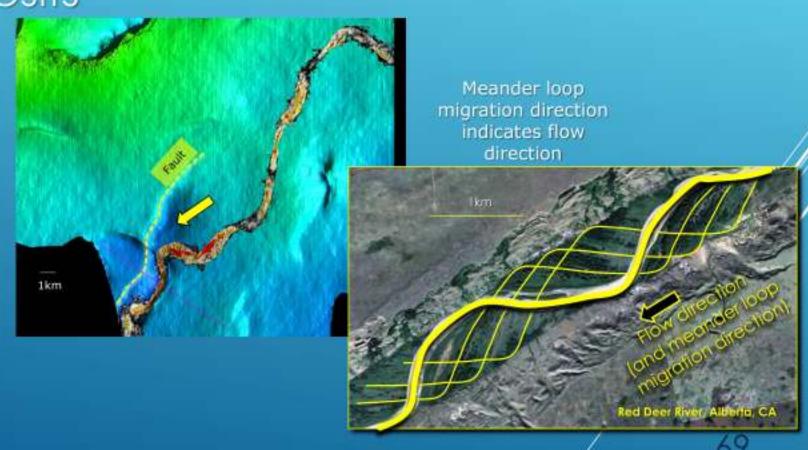
PATTERN RECOGNITION - FLUVIAL

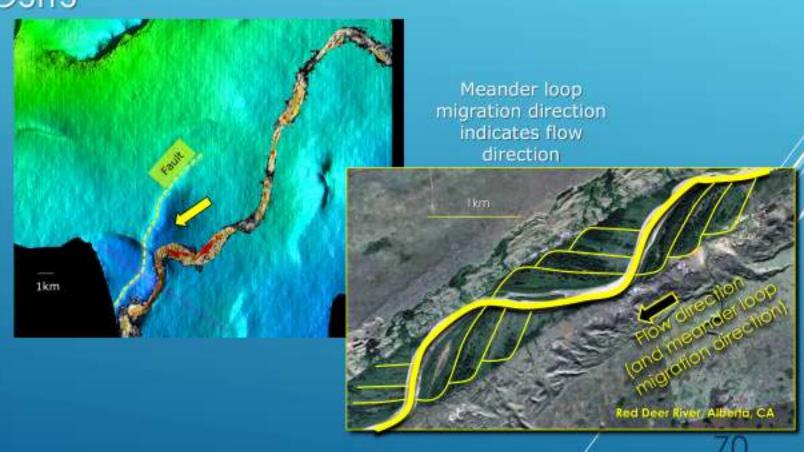
DEPOSITS

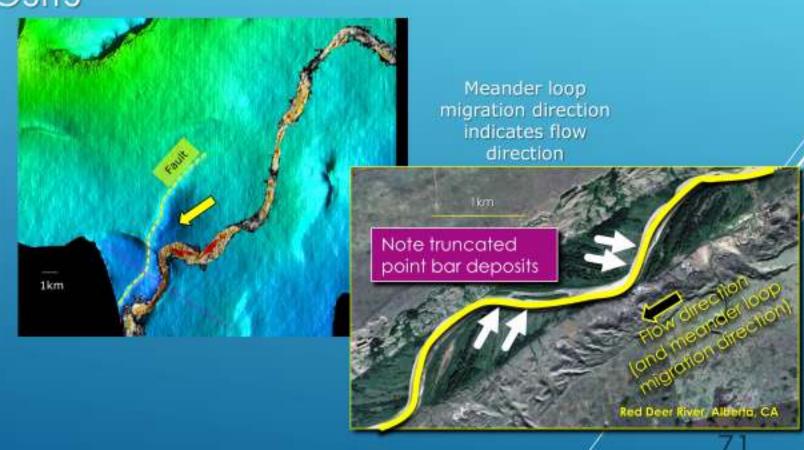


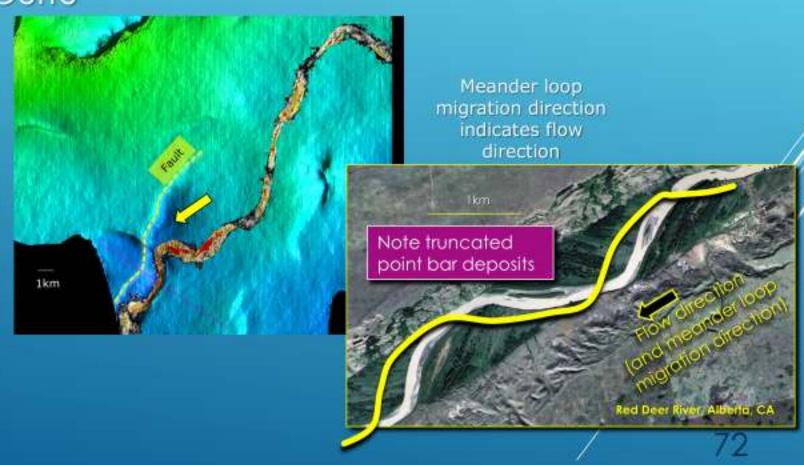




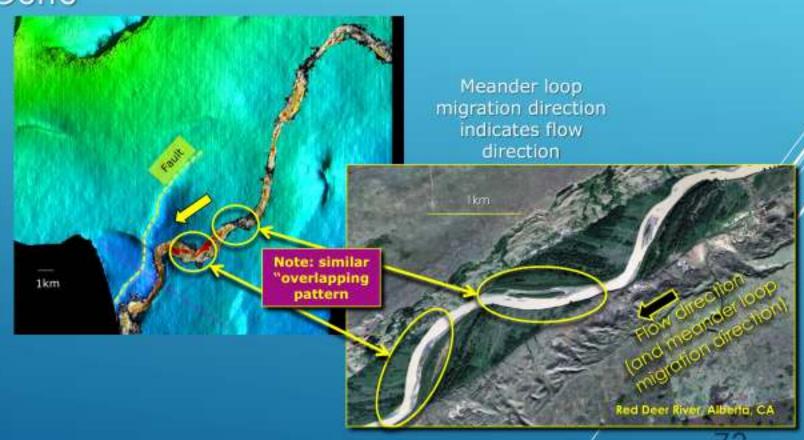




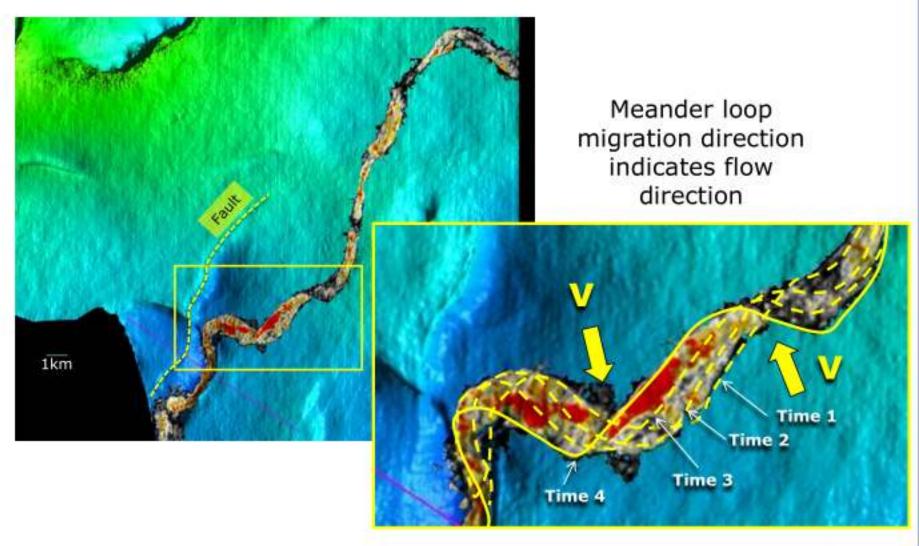




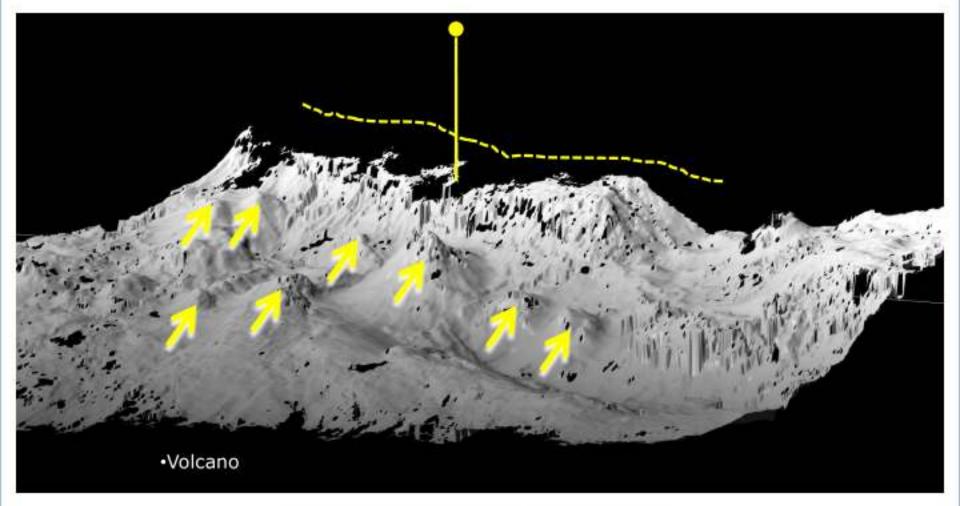
PATTERN RECOGNITION – FLUVIAL DEPOSITS



Pattern Recognition – Fluvial Deposits

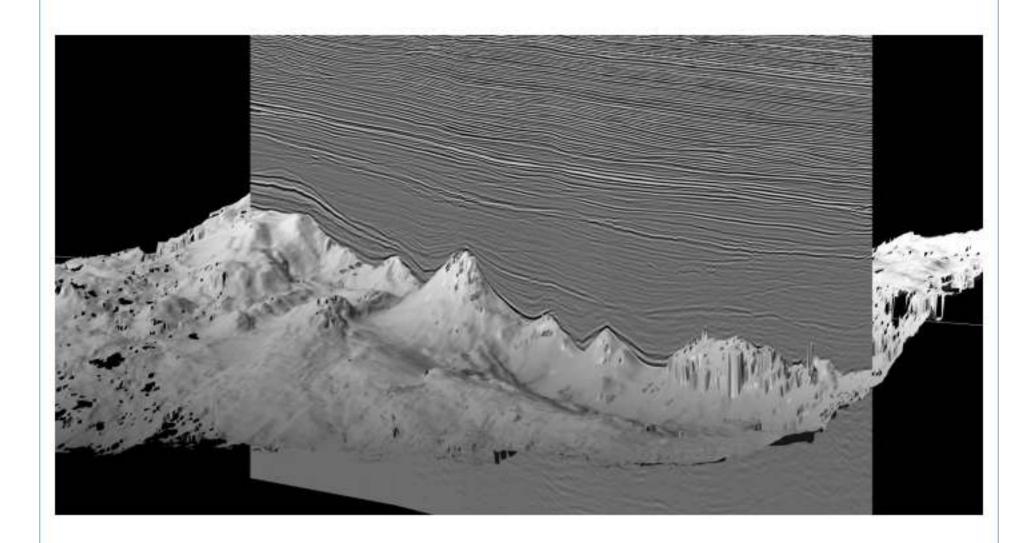


Volcanoes

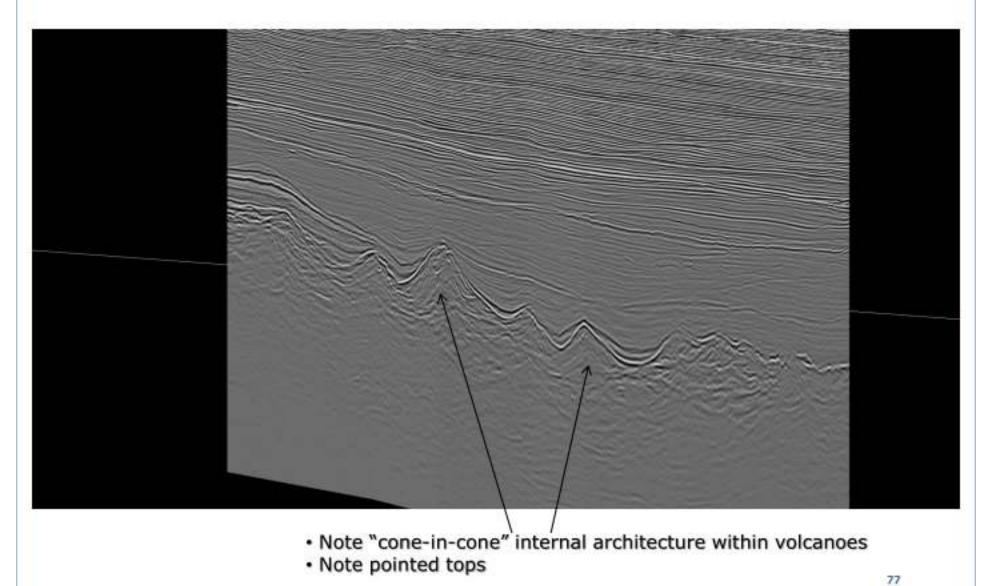


Multiple volcanoes on flanks of structure
 Note pointed tops

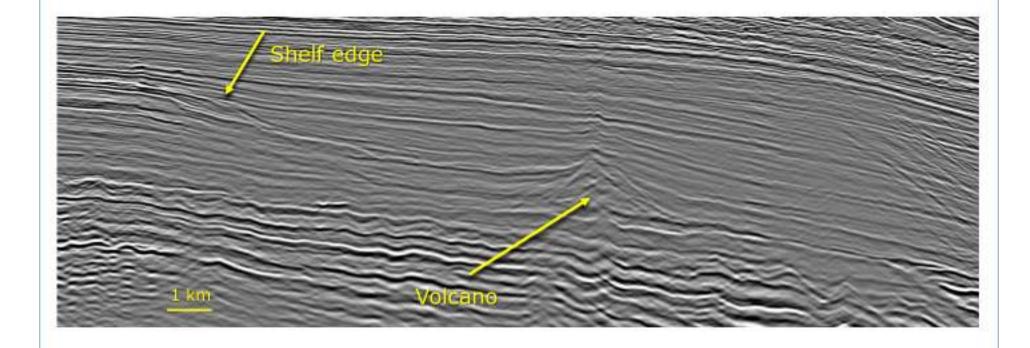
Volcanoes

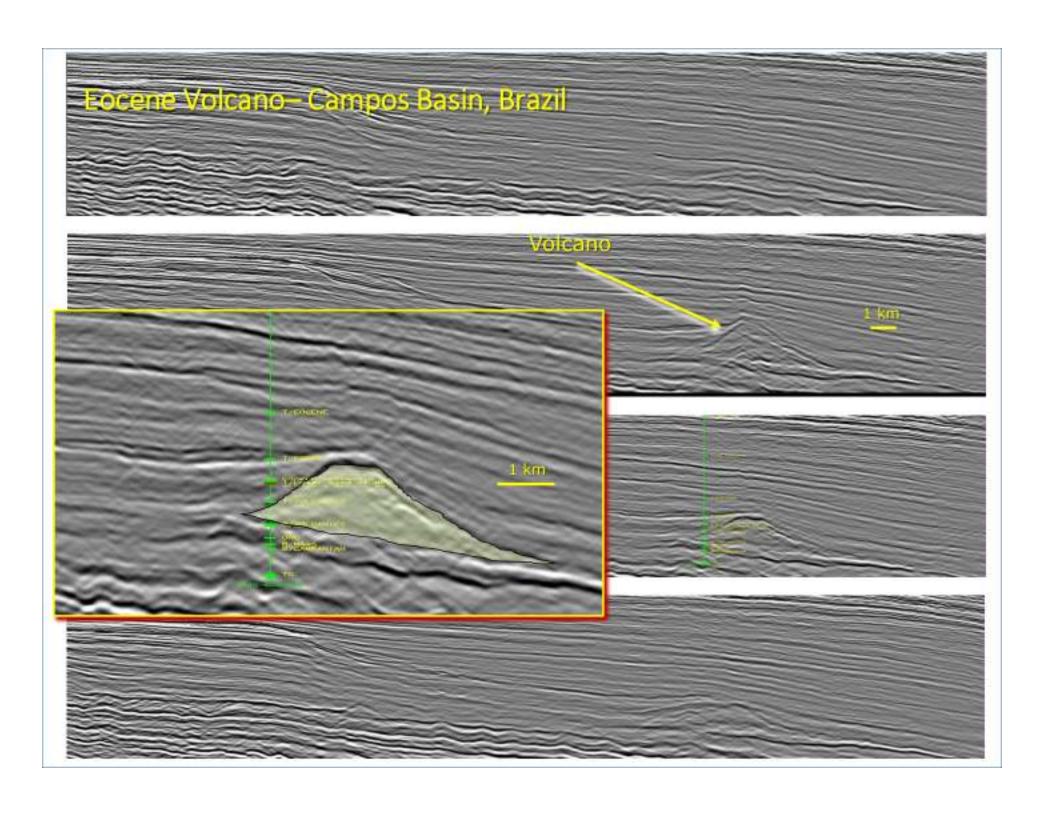


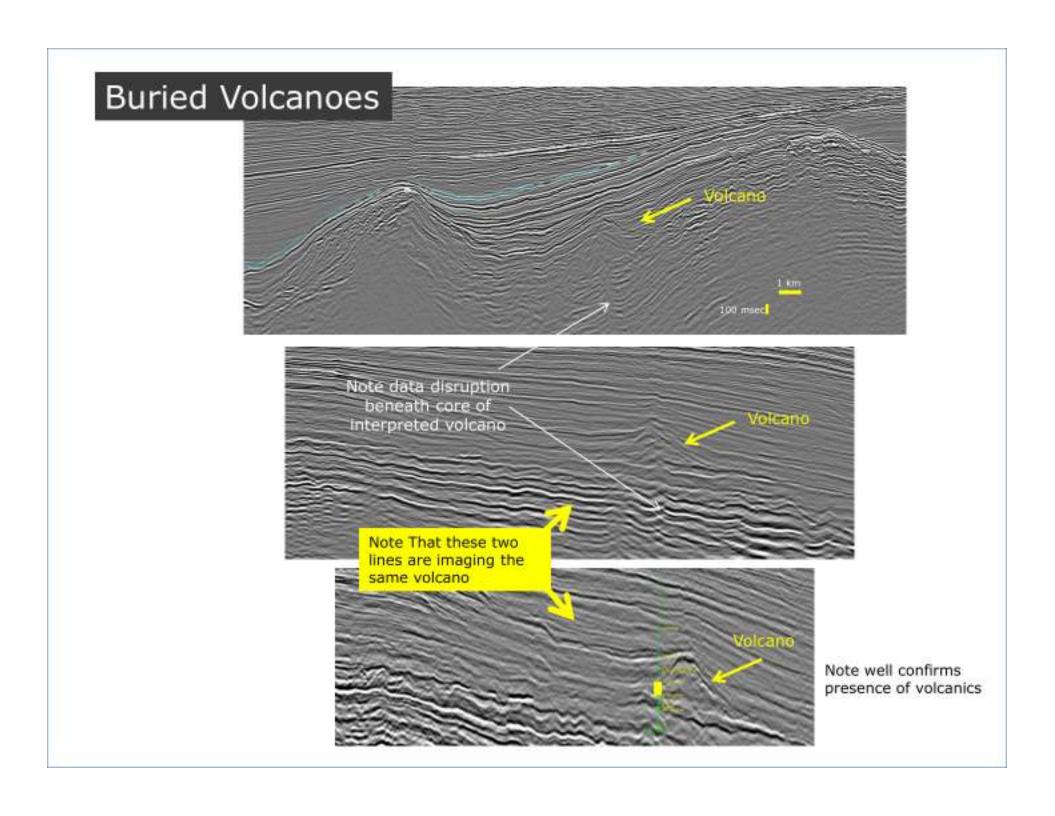
Volcanoes

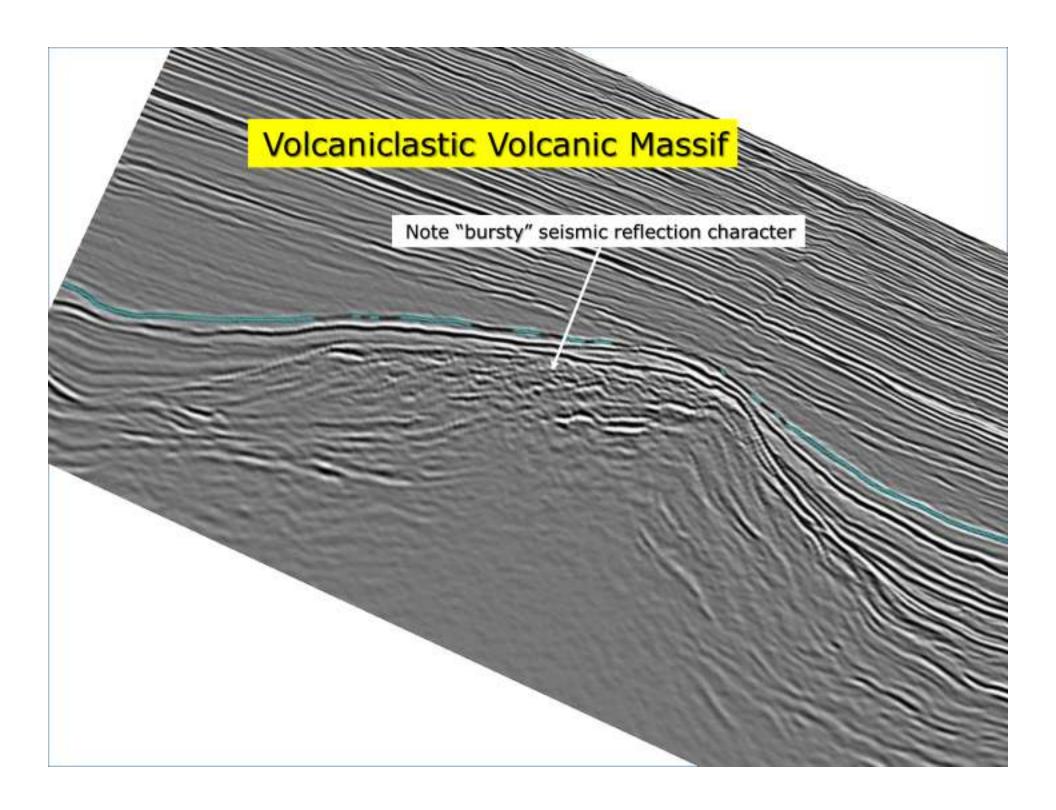


Paleo subaqueous volcano

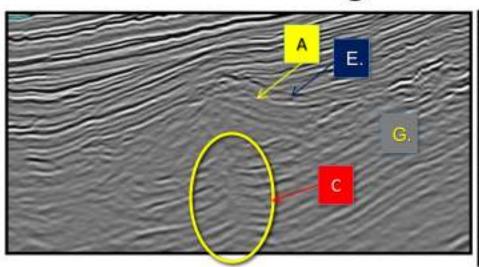


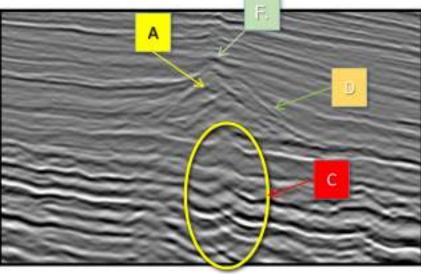




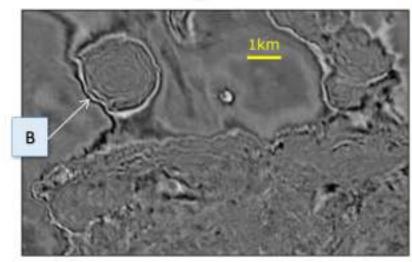


Volcanoes – Recognition Criteria

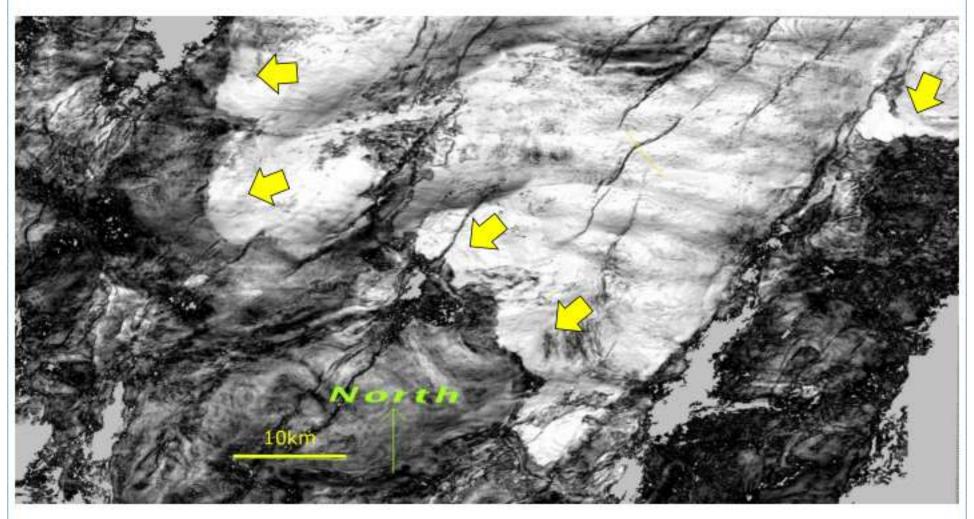




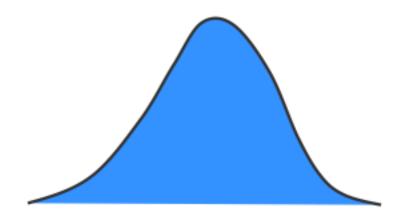
- A. Cone-in-cone architecture (section view)
- B. Concentric circles with minor rugosity (plan view)
- C. Data disruption beneath volcano core
- Onlapping reflections on both sides of cone
- E. Concave-up profile on flanks
- R Pointed top
- Angular discordance at volcano base



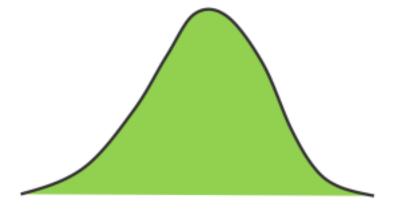
Extrusive Volcanics



Note arcuate margins Note influence of syndepositional faults



Carbonate pinnacle reef



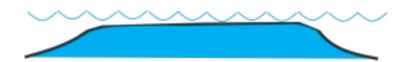
Volcanic cone

Carbonates vs. Volcanics

Distinguishing Architectural Attributes

Time 1







Time 2





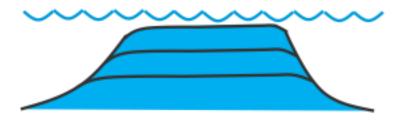
Rising sea level Shrinking carbonate "factory"

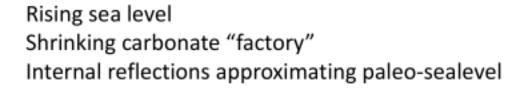


"Cone-in-cone" architecture Volcano growing below wave base

Time 3





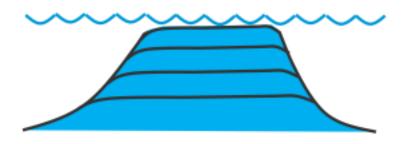


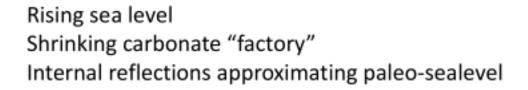


"Cone-in-cone" architecture Volcano growing below wave base

Time 4





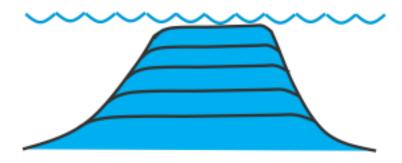


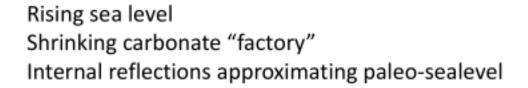


"Cone-in-cone" architecture Volcano growing below wave base

Time 5



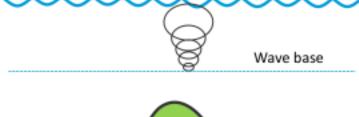


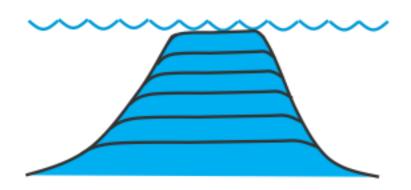




"Cone-in-cone" architecture Volcano growing below wave base

Time 6



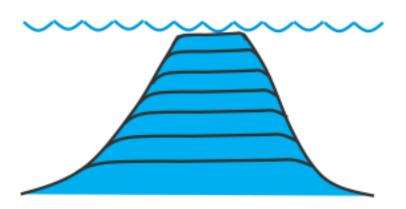




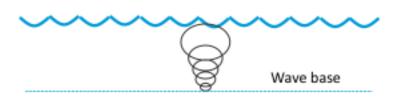
Rising sea level Shrinking carbonate "factory" Internal reflections approximating paleo-sealevel

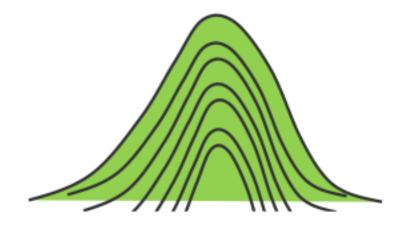
"Cone-in-cone" architecture Volcano growing below wave base

Time 7



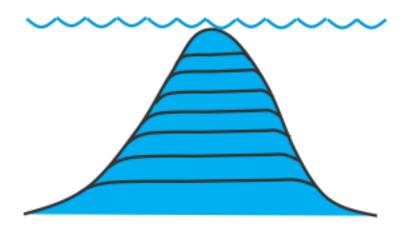
Rising sea level Shrinking carbonate "factory" Internal reflections approximating paleo-sealevel

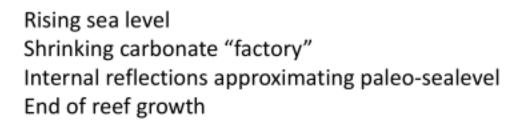


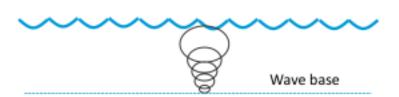


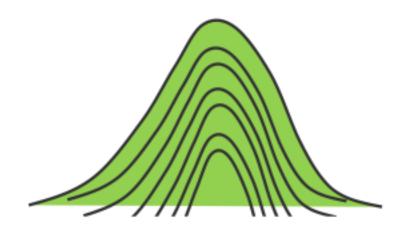
"Cone-in-cone" architecture Volcano growing below wave base

Time 8





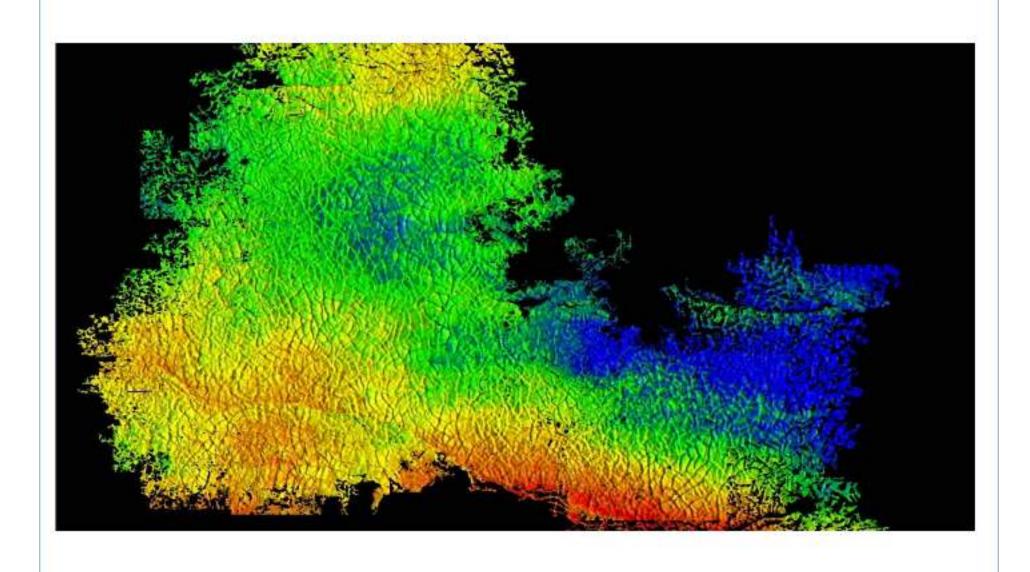


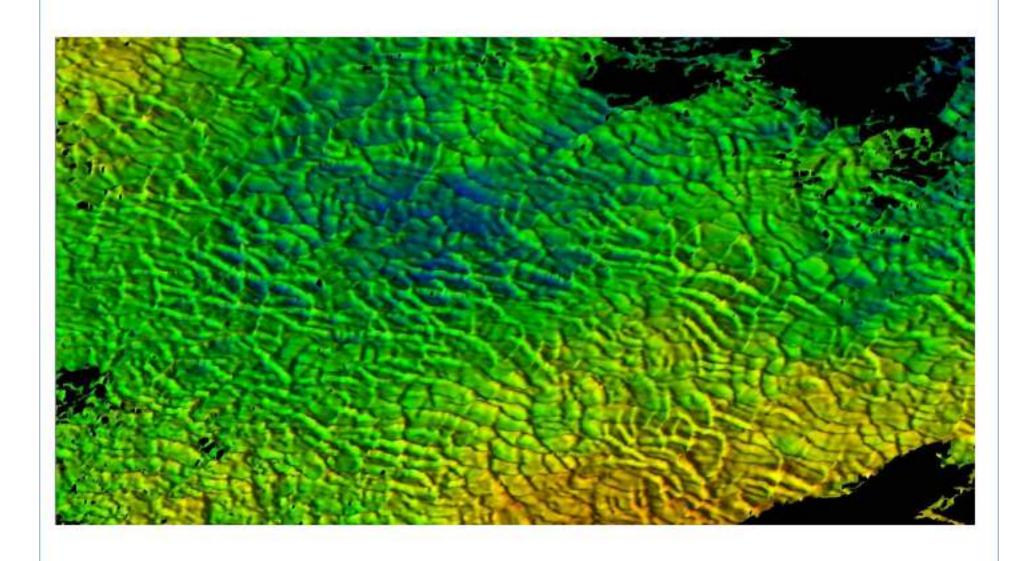


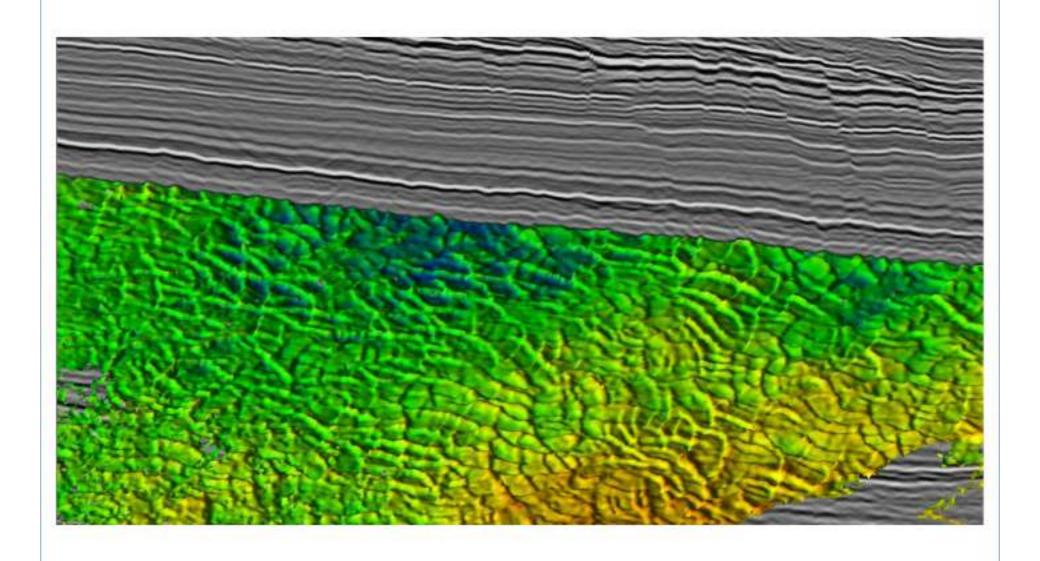
"Cone-in-cone" architecture Volcano growing below wave base

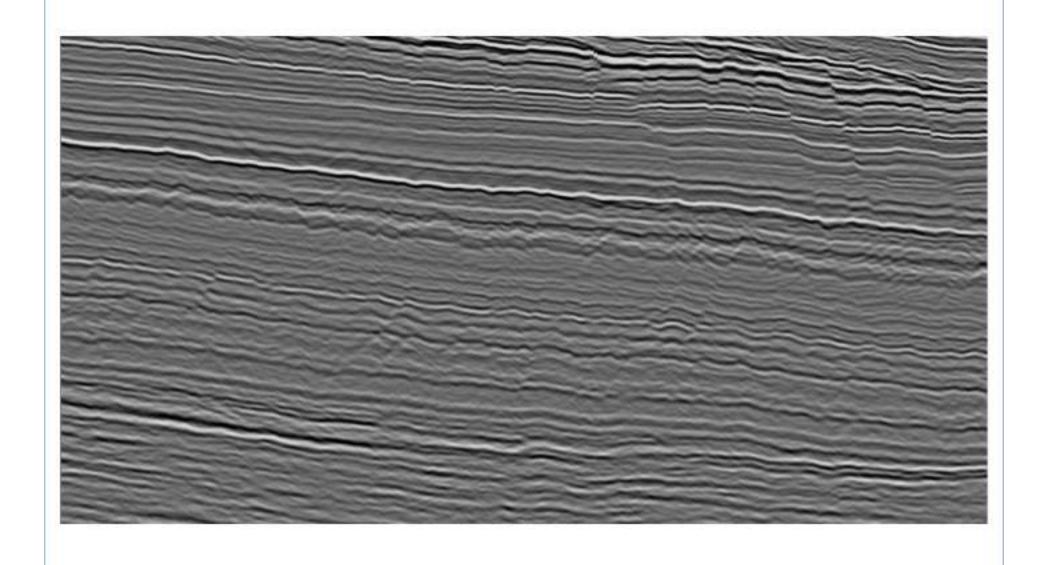
Time 8 Parallel horizontal internal reflections

Wave base

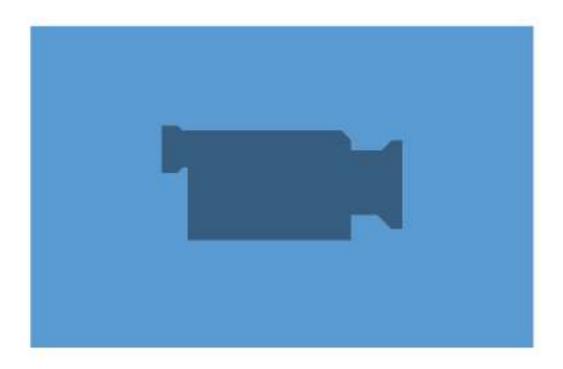


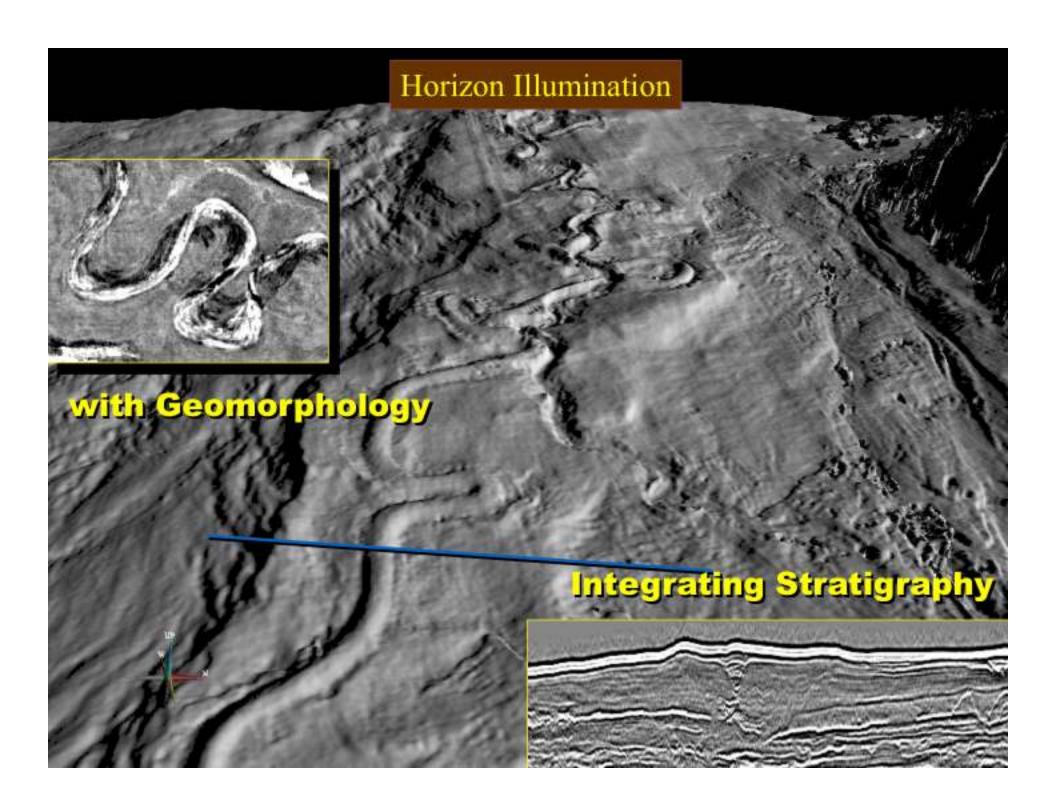




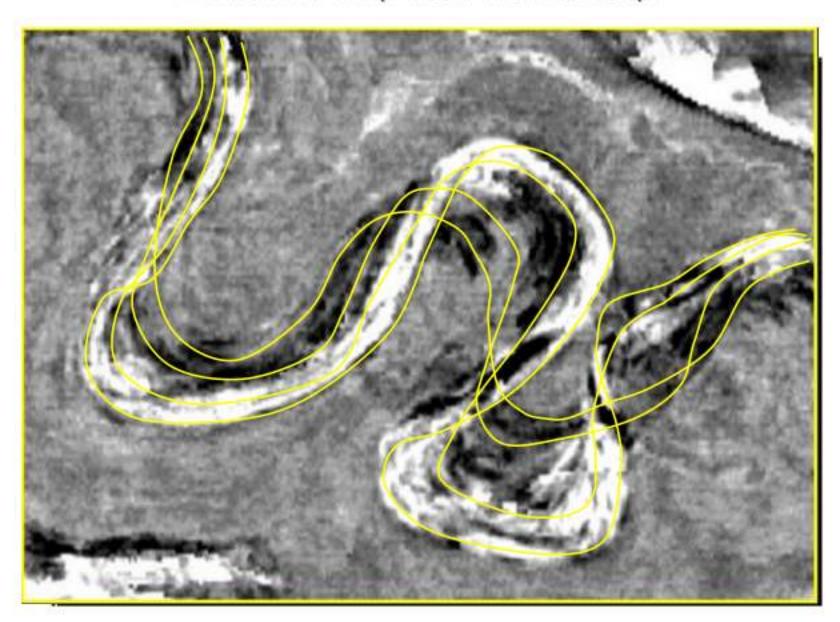


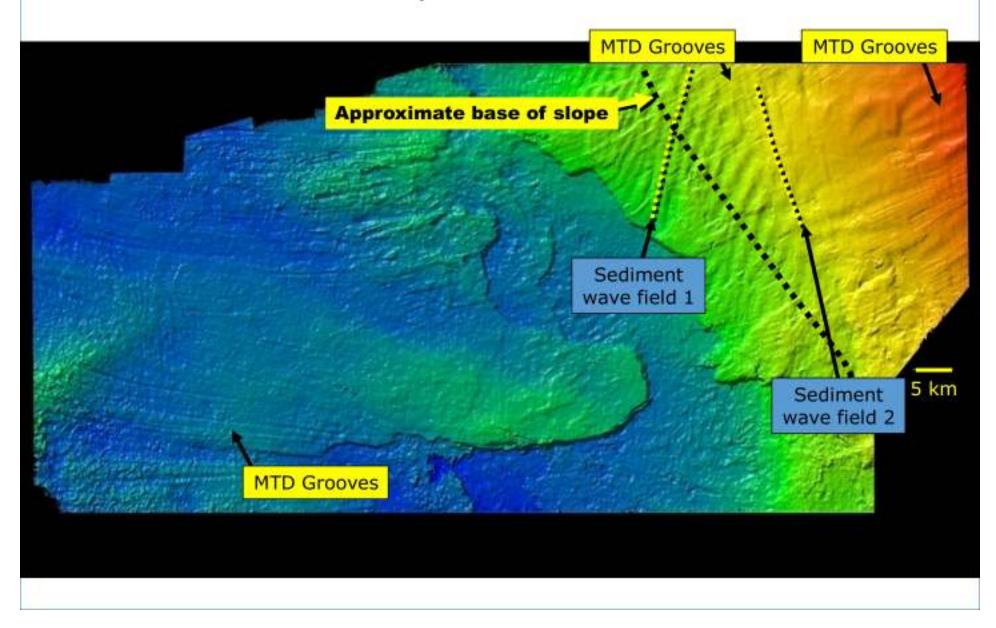
Mixing seismic stratigraphy and seismic geomorphology

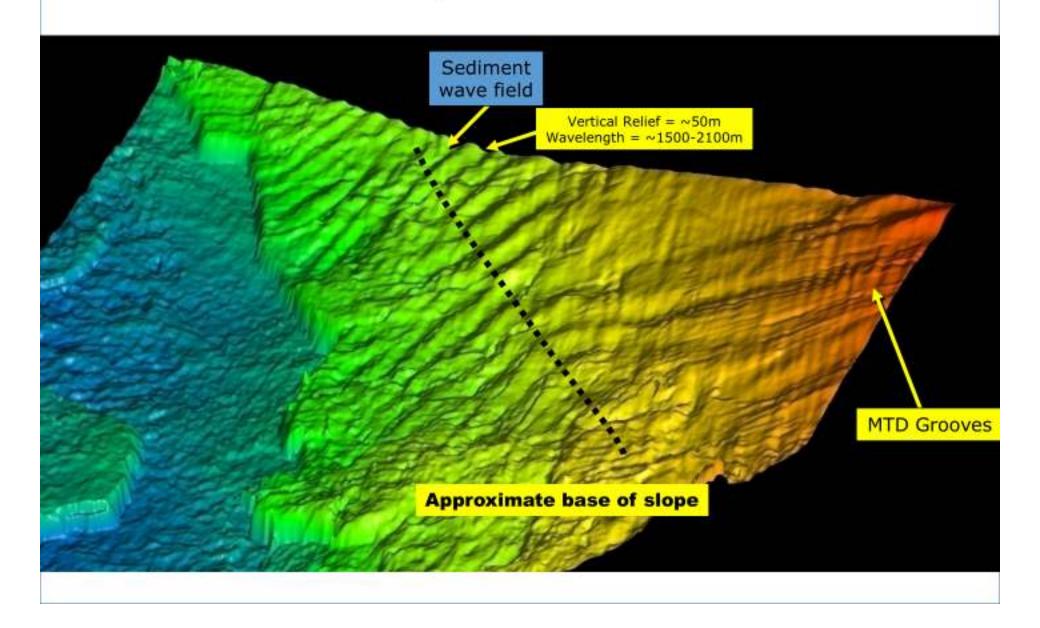


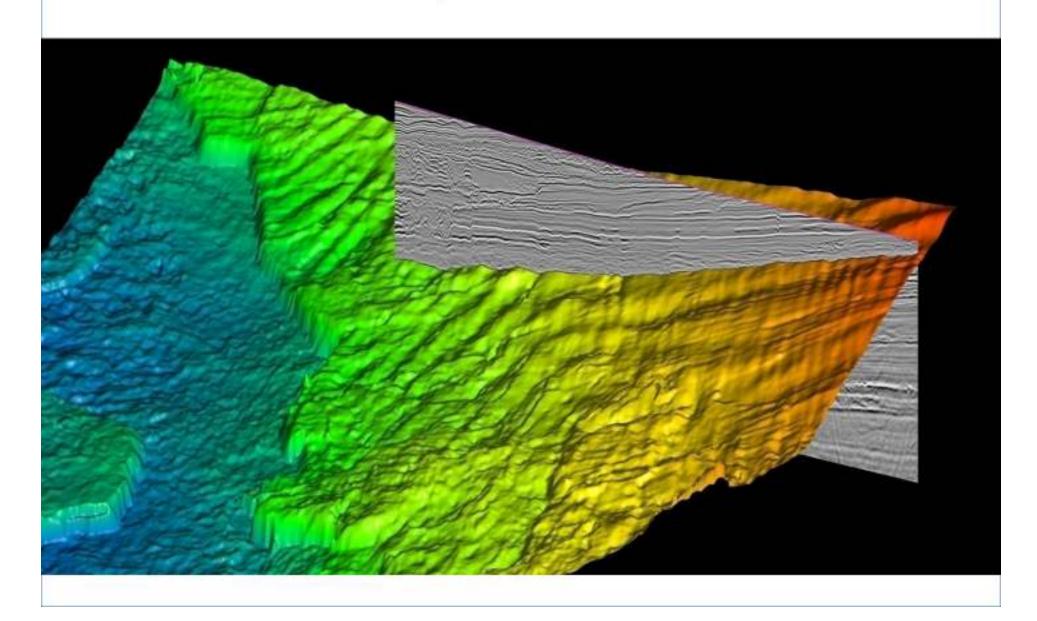


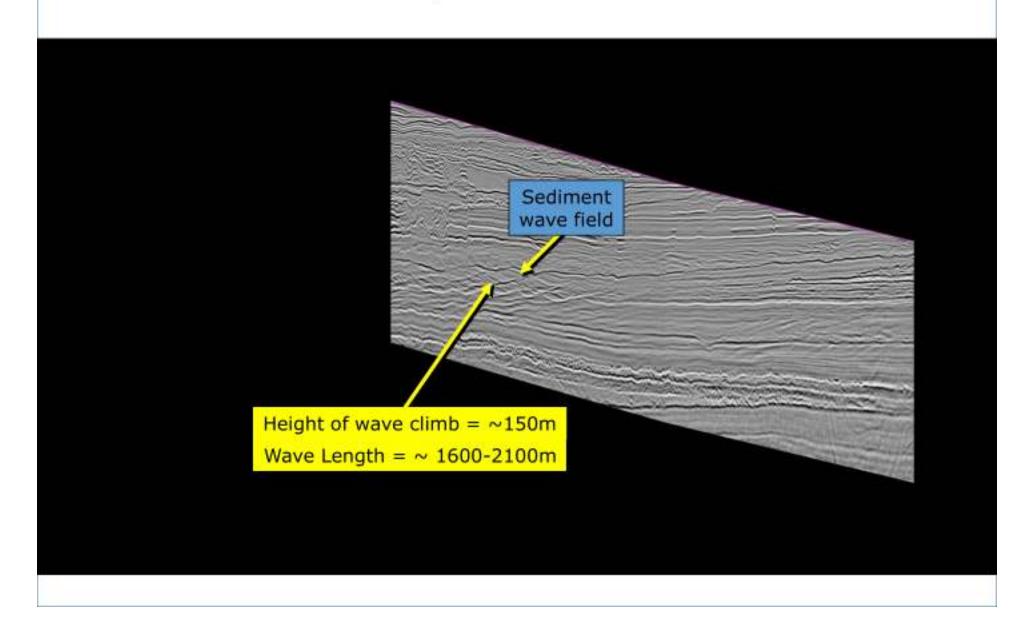
Evolution of Deep-water Meander Loops

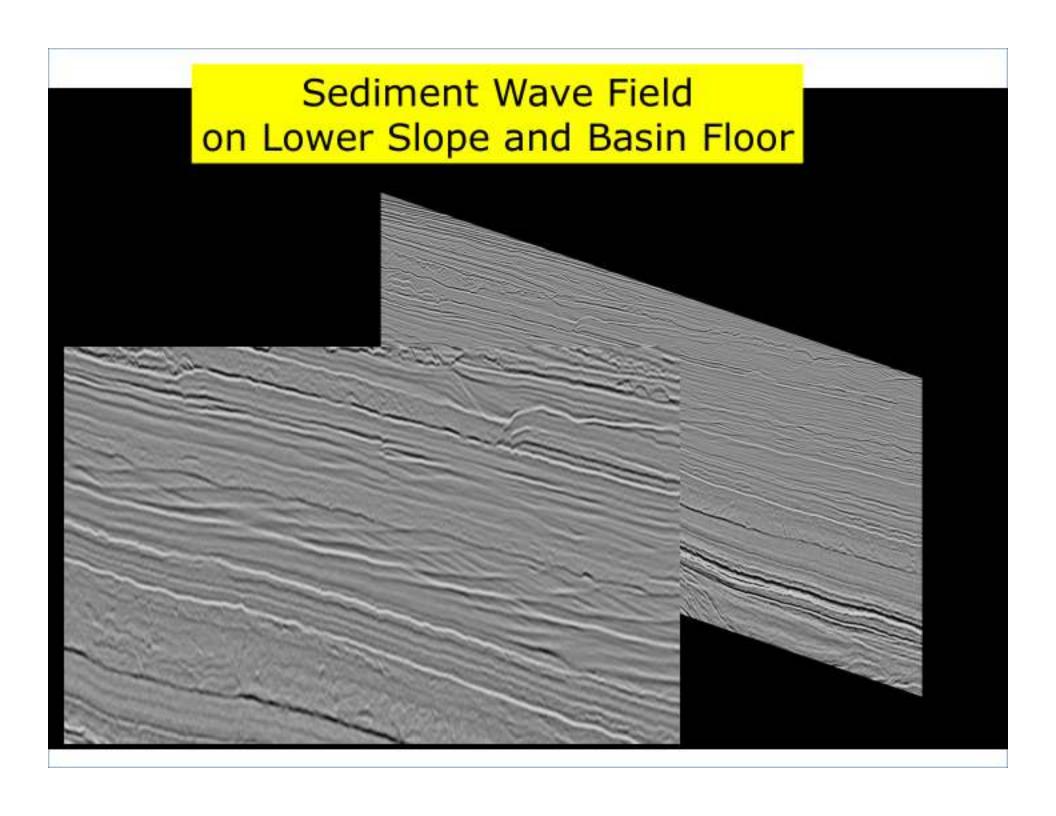




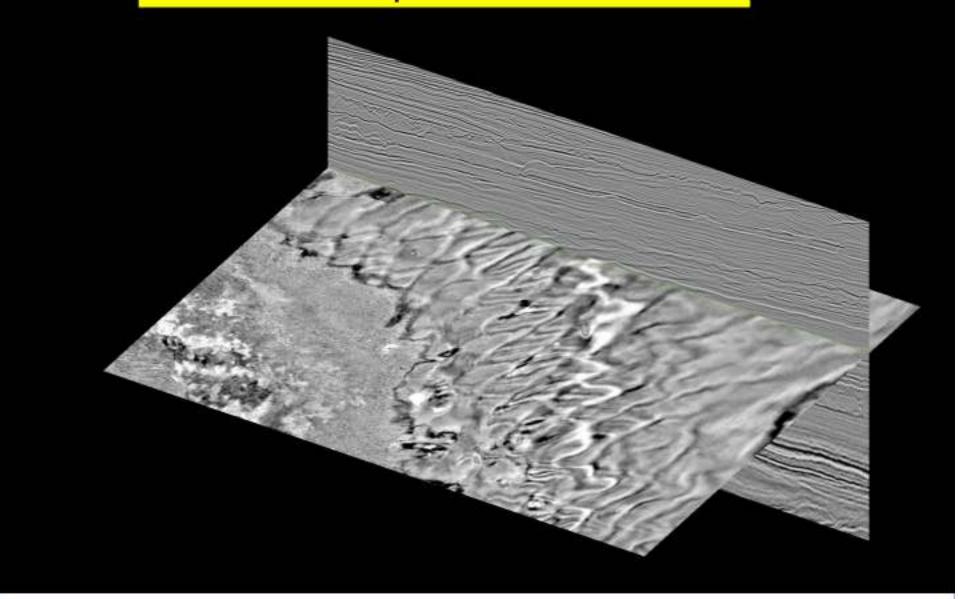






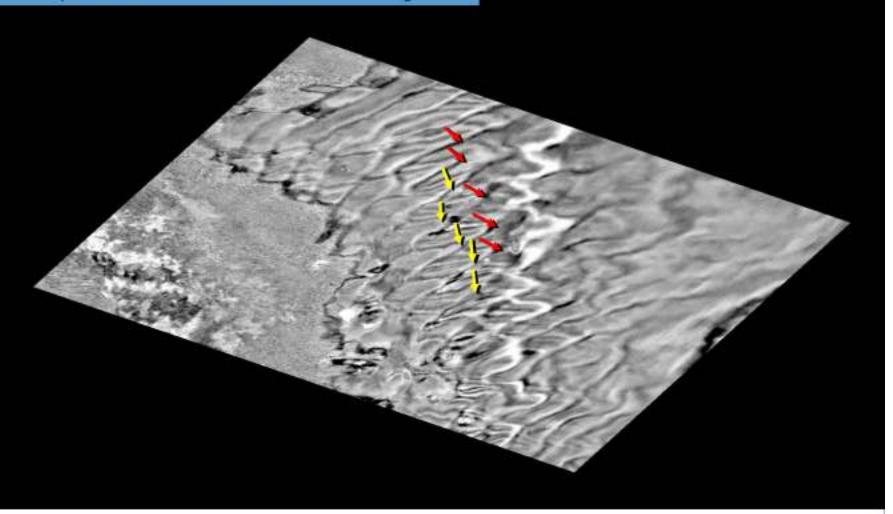


Sediment Wave Field on Lower Slope and Basin Floor

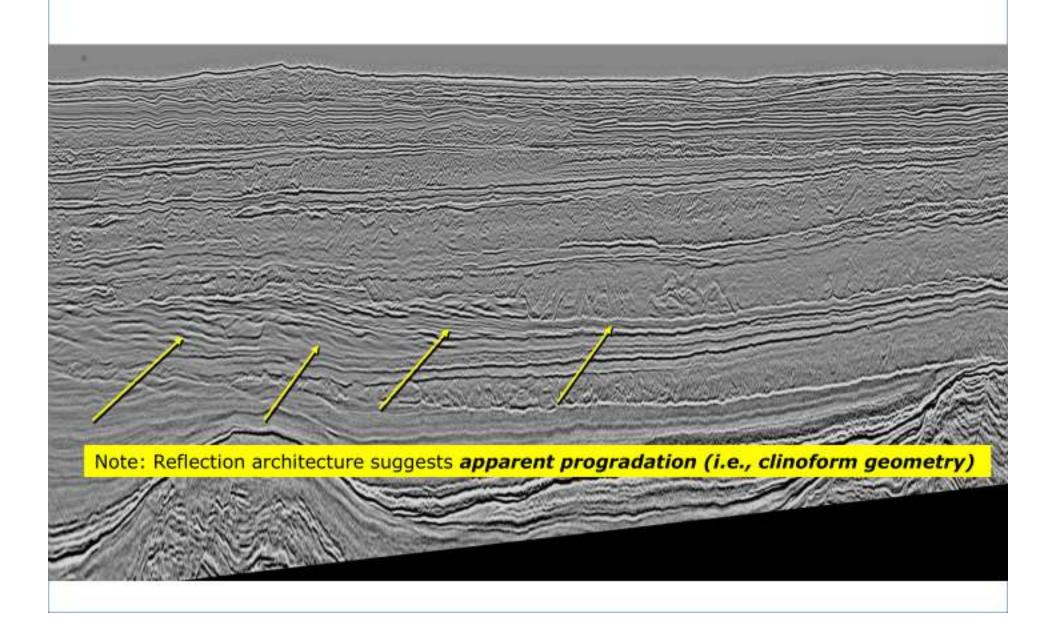


Sediment Wave Field on Lower Slope and Basin Floor

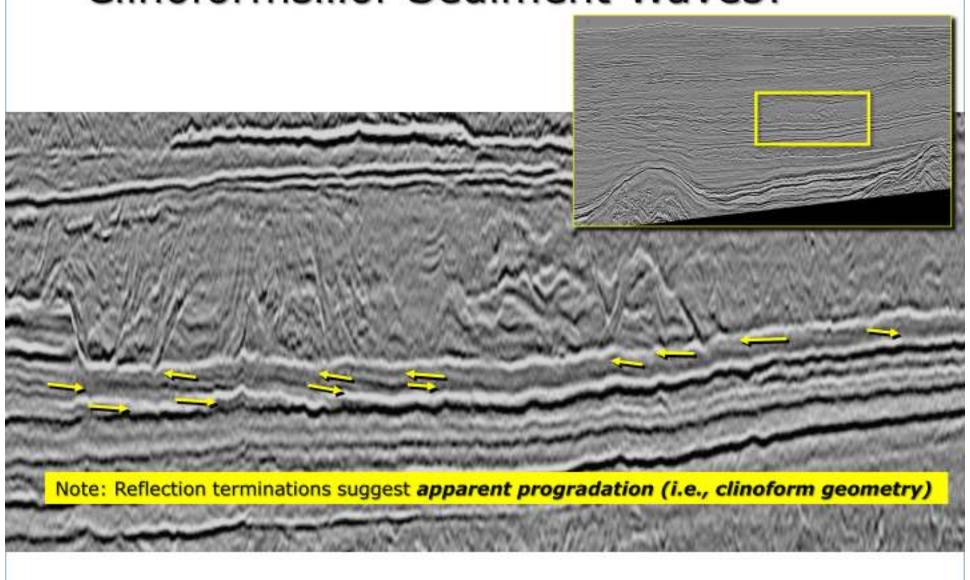
Note: Direction of sediment wave accretion is oblique to direction of sediment wave migration



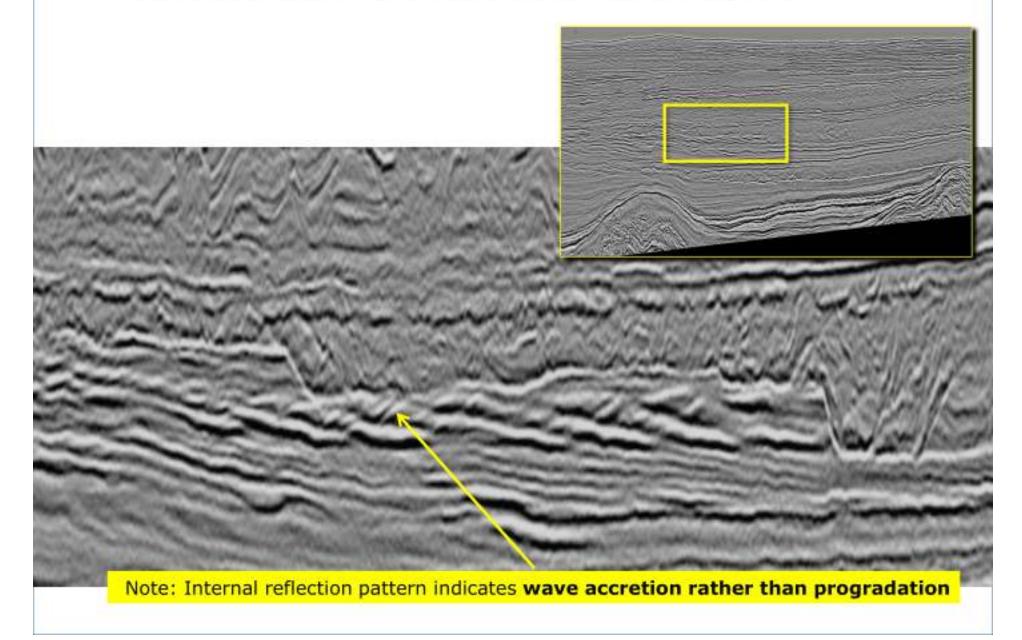
Clinoforms...or Sediment Waves?



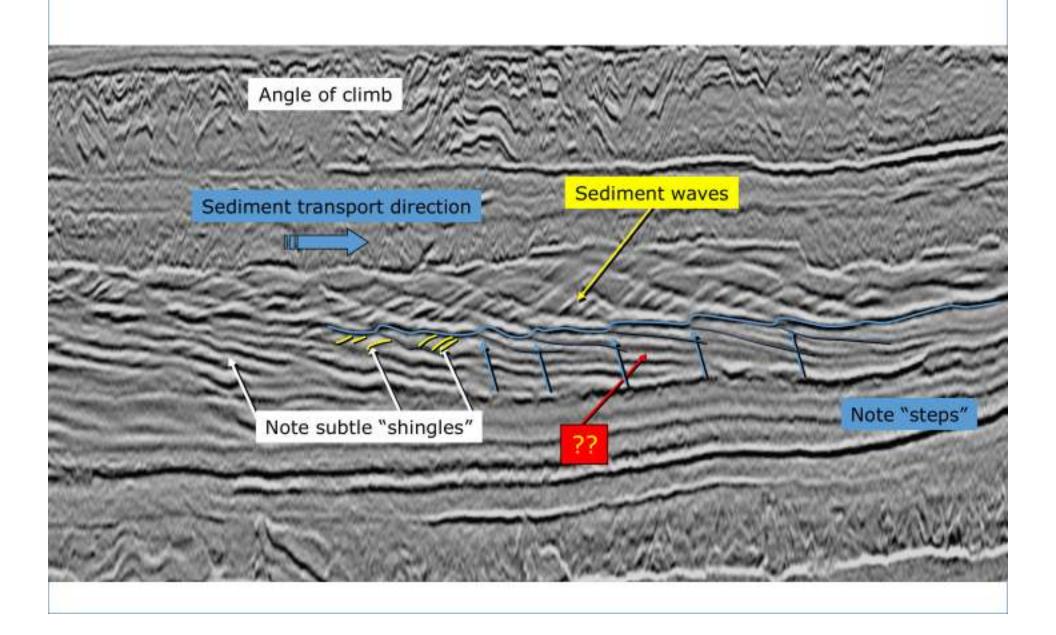




Clinoforms...or Sediment Waves?

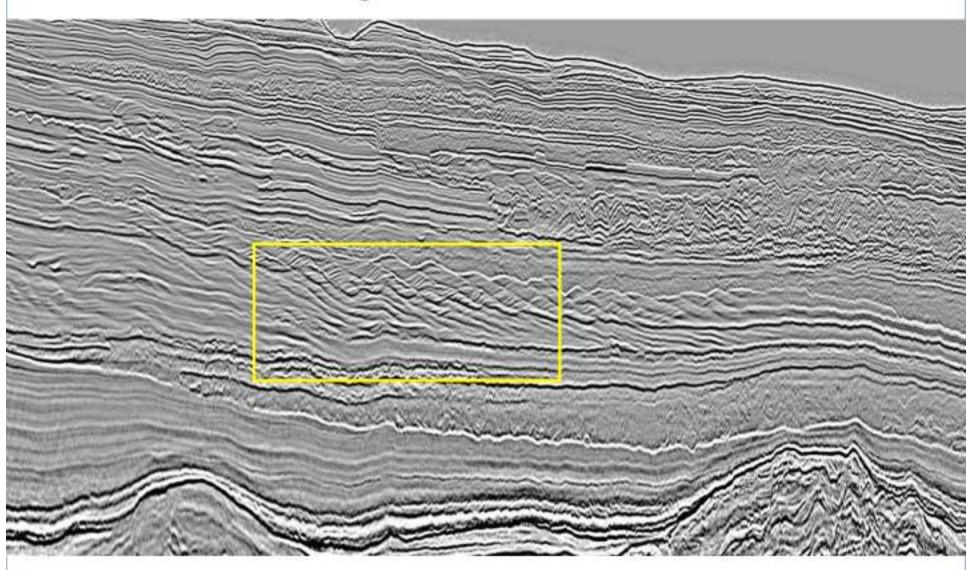


Clinoforms...or Sediment Waves



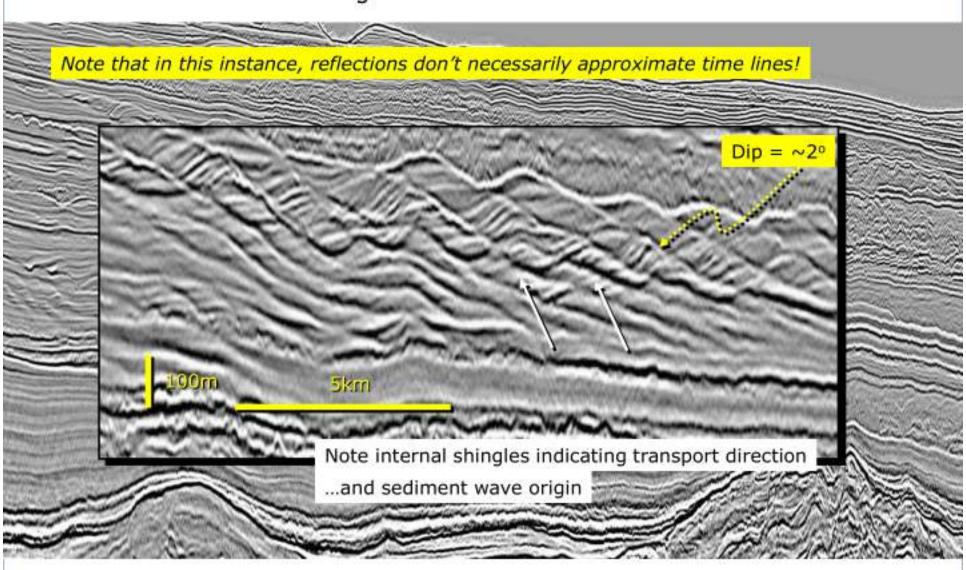
Clinoforms...or Sediment Waves

Sediment wave origin more clear in this section

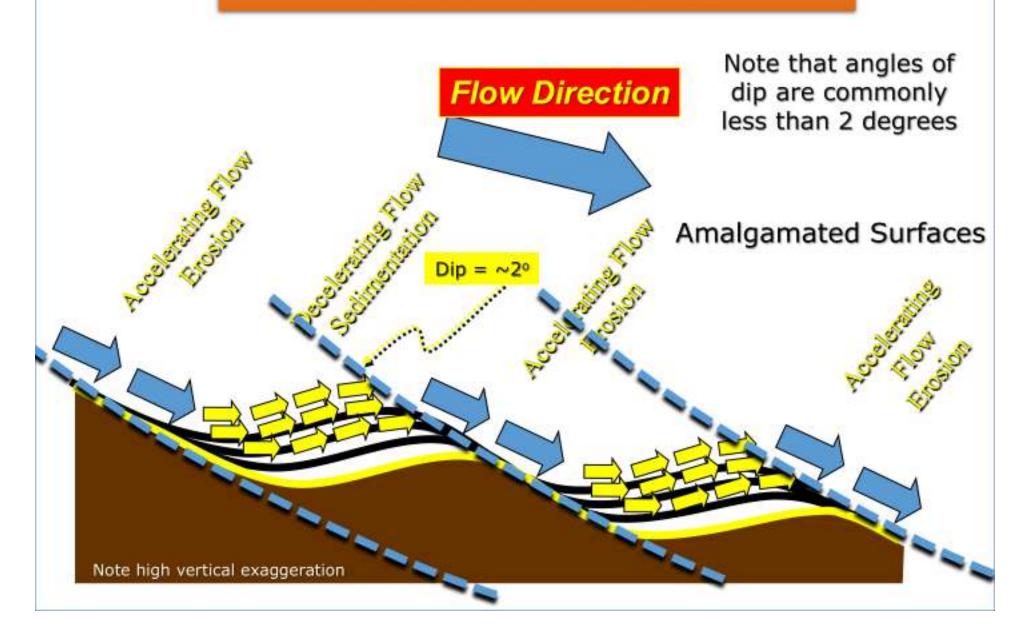


Clinoforms...or Sediment Waves

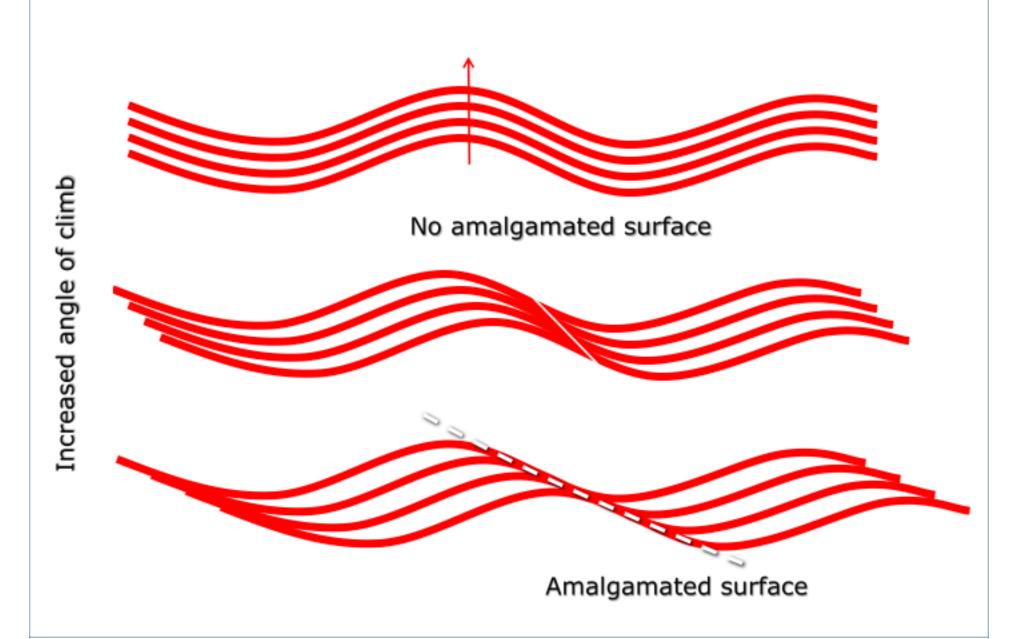
Sediment wave origin more clear in this section

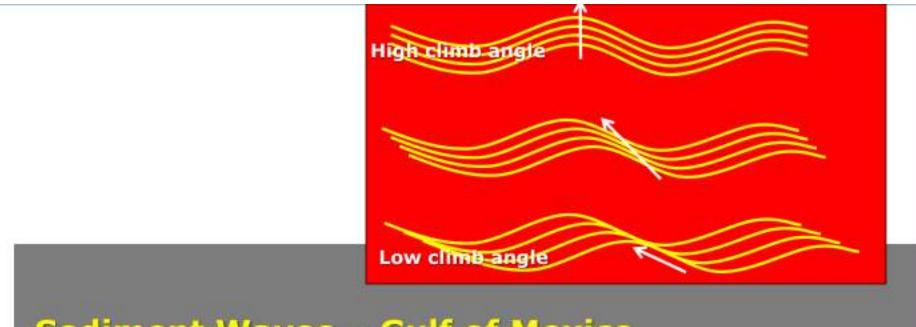


Process of Upstream Migration of Sediment Waves

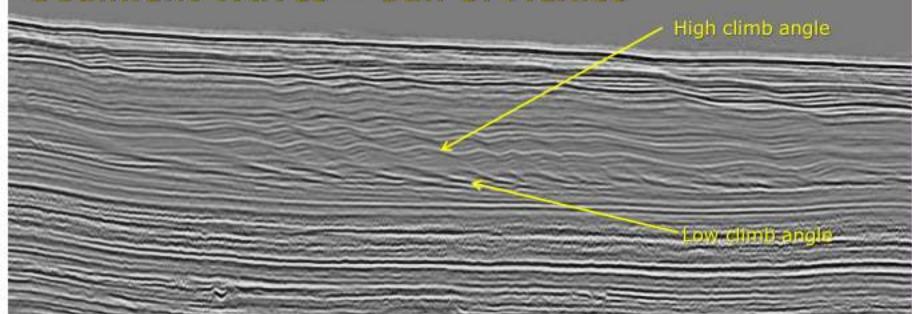


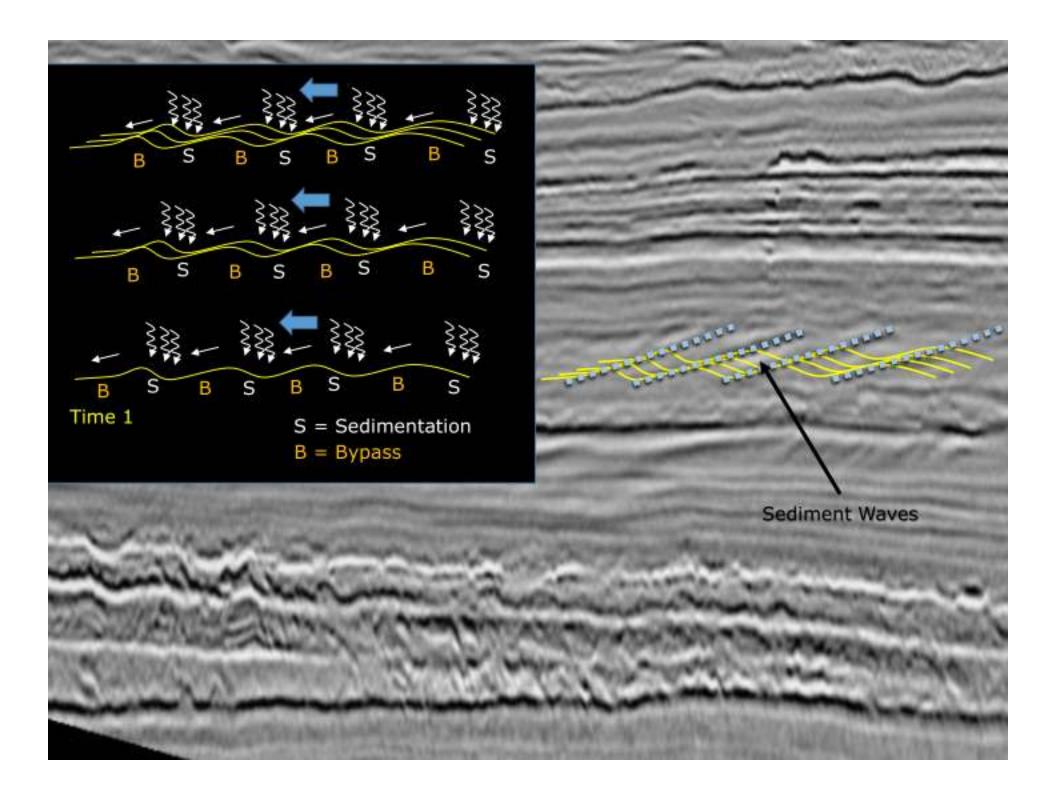
Sediment Wave Architecture

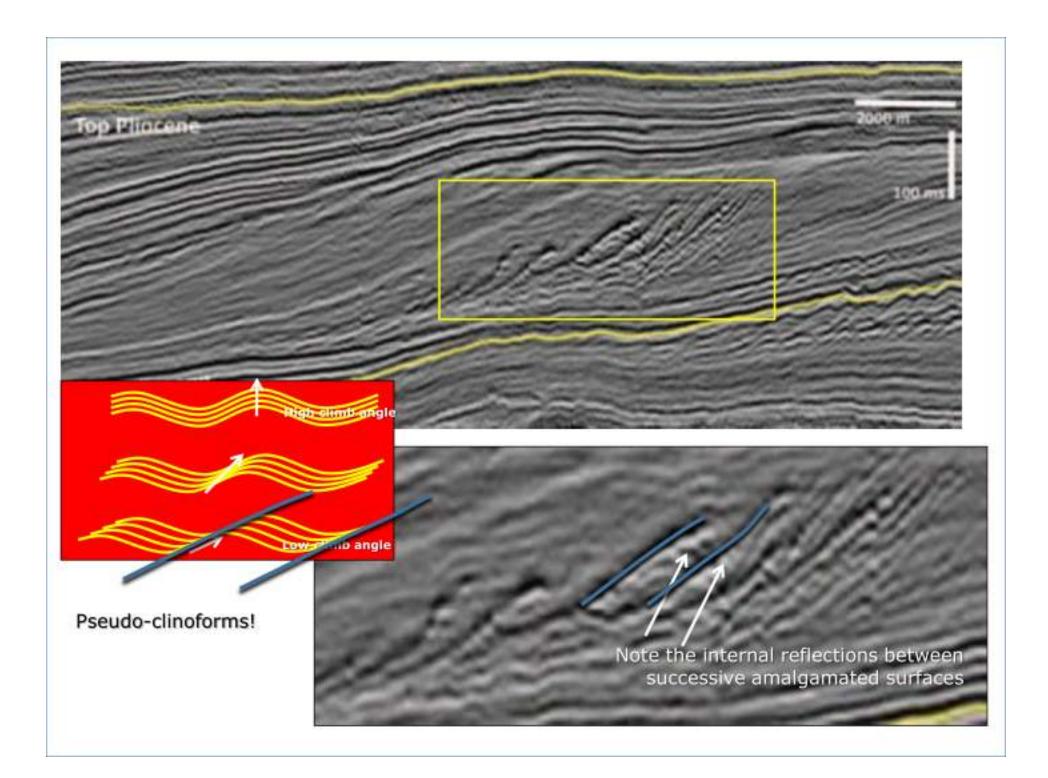




Sediment Waves - Gulf of Mexico

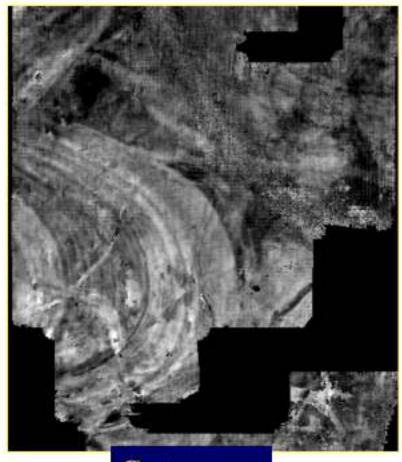


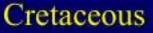




What constitutes an FLT?

A feature that "looks" geological.



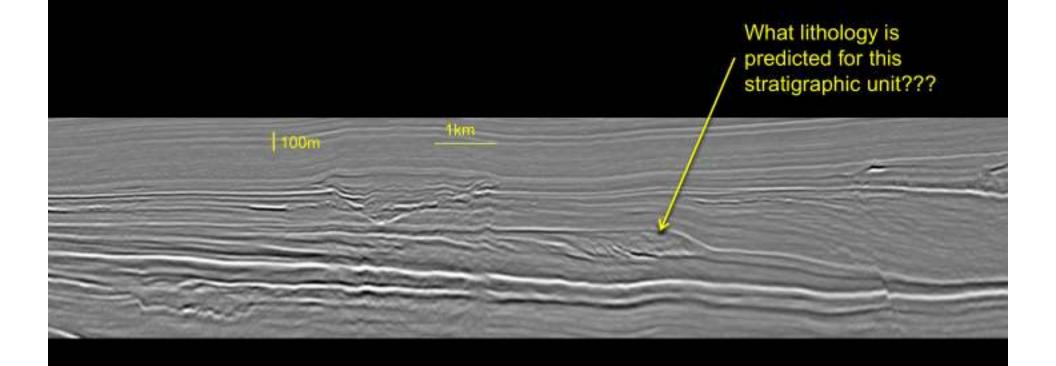


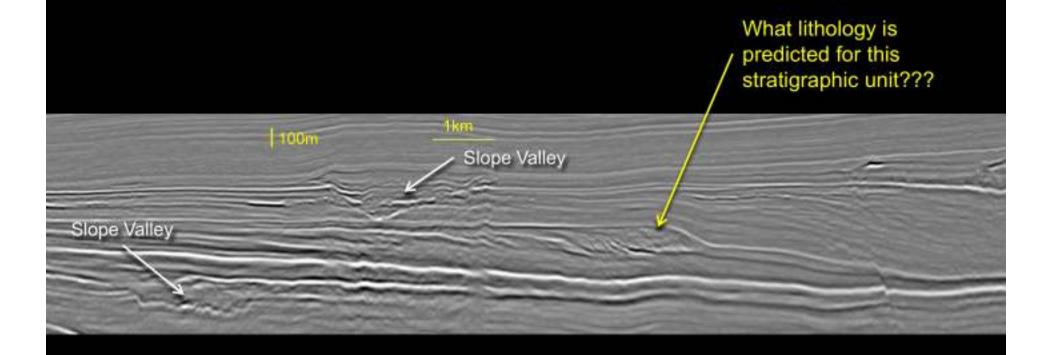


Modern

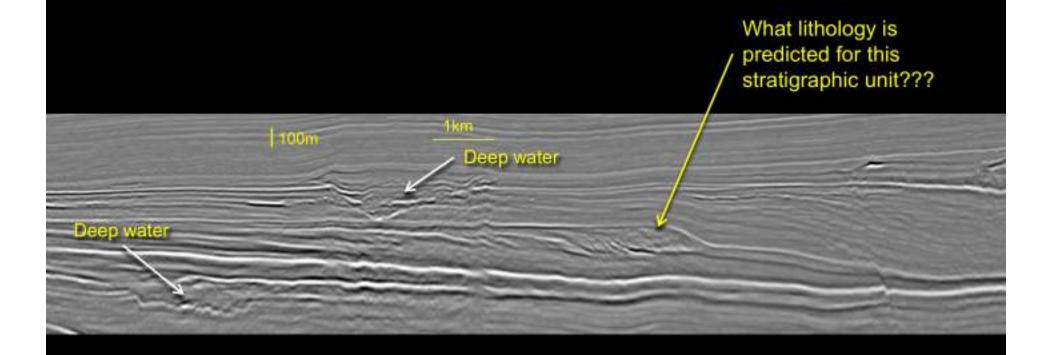
What constitutes an FLT?





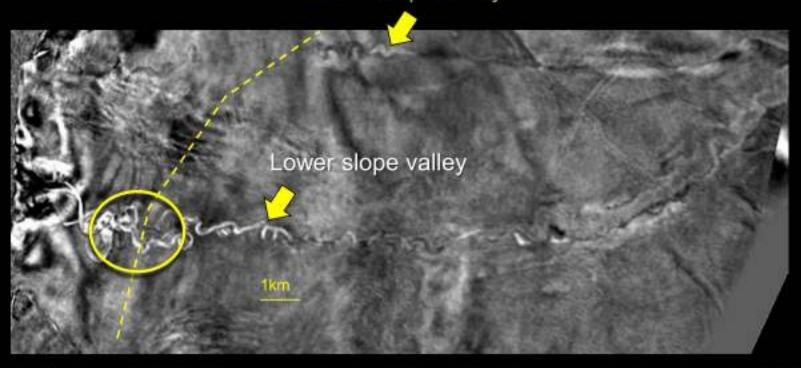


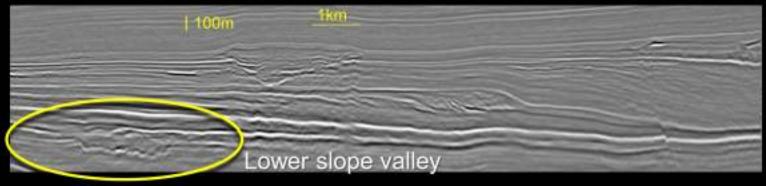
The bracketing slope valleys set the context

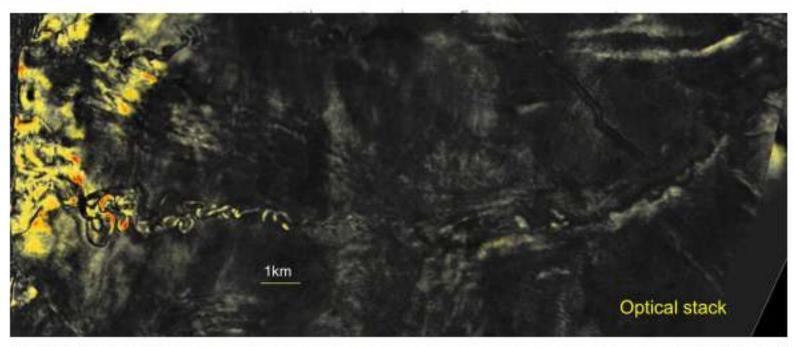


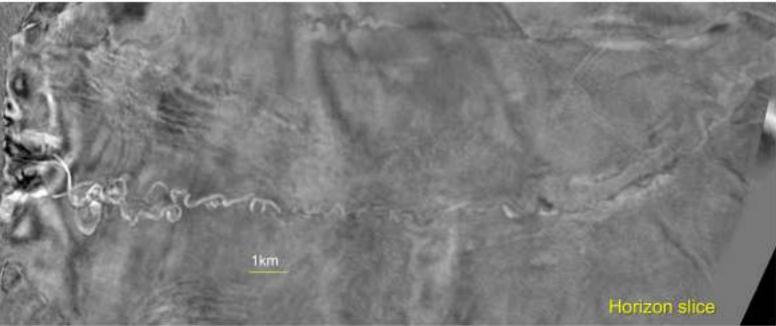
The bracketing slope valleys set the context: Deep water

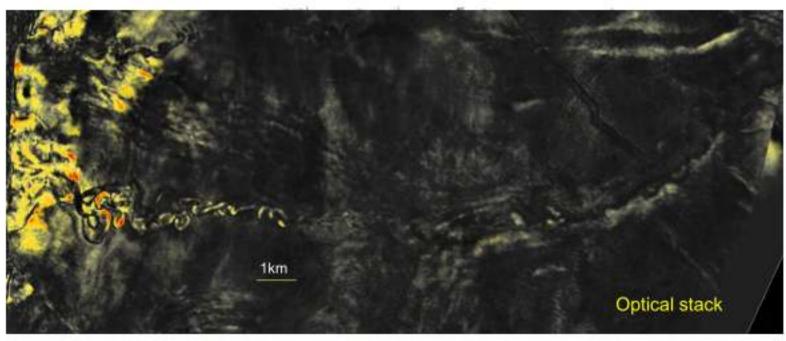
The Role of Context – the Lower Slope Valley

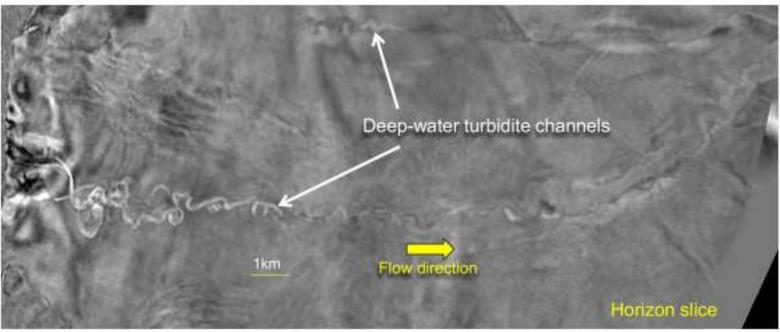


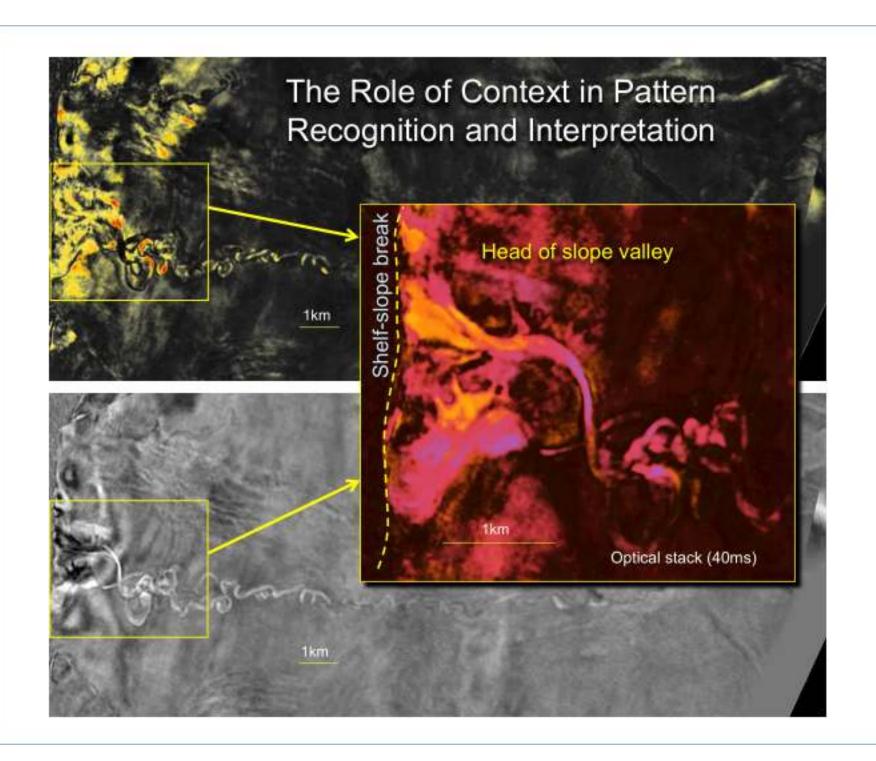


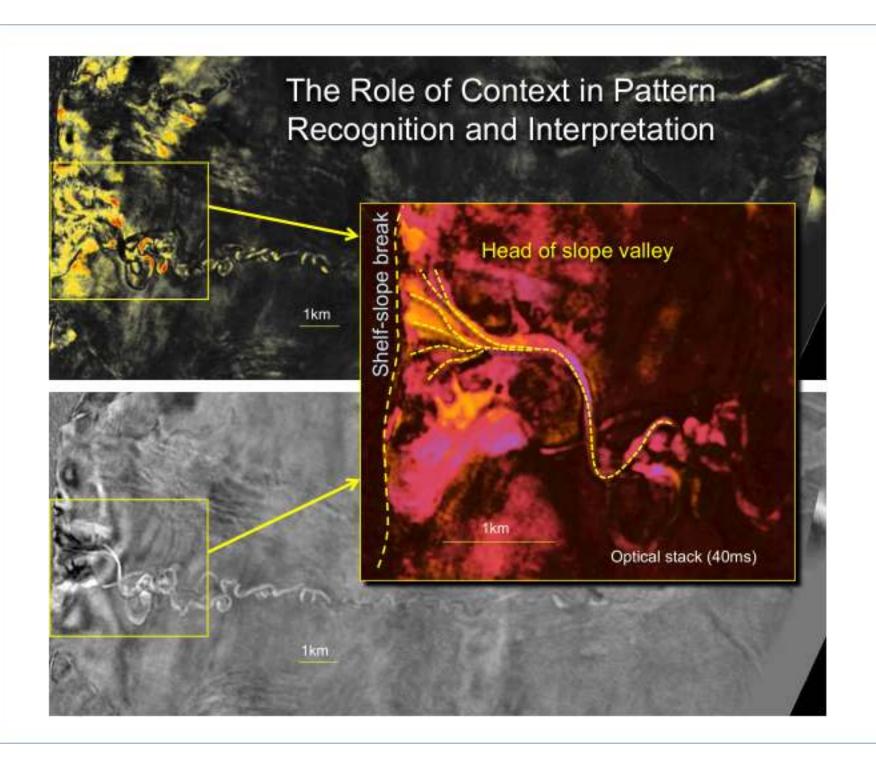


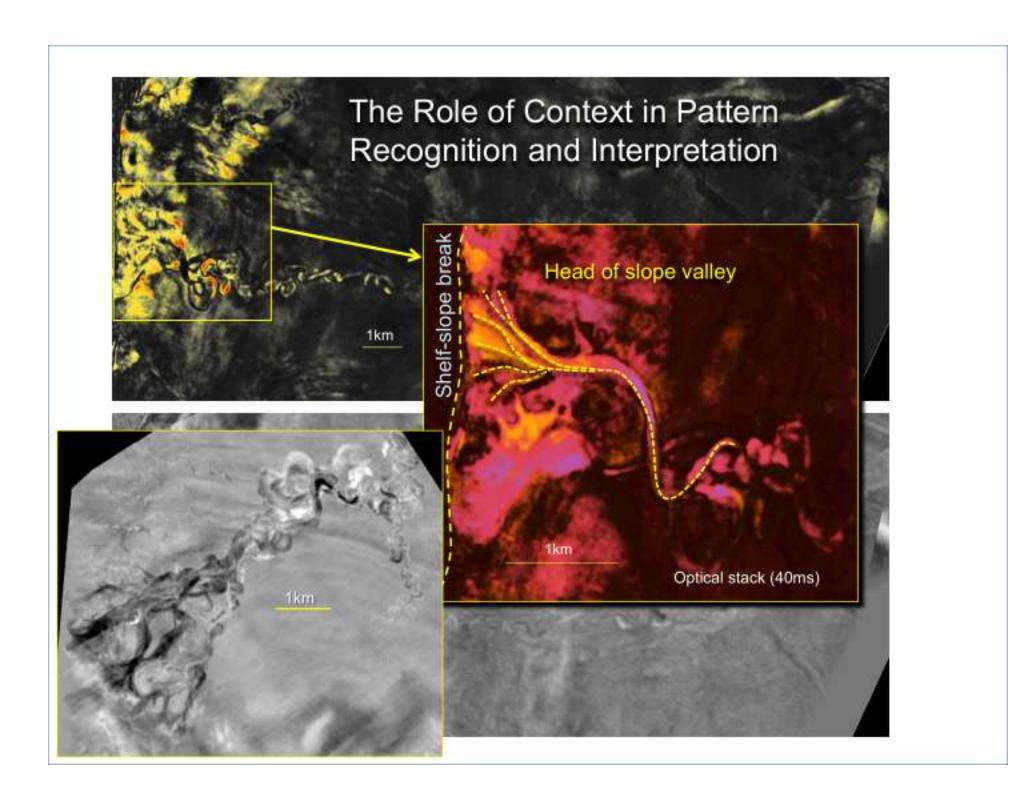


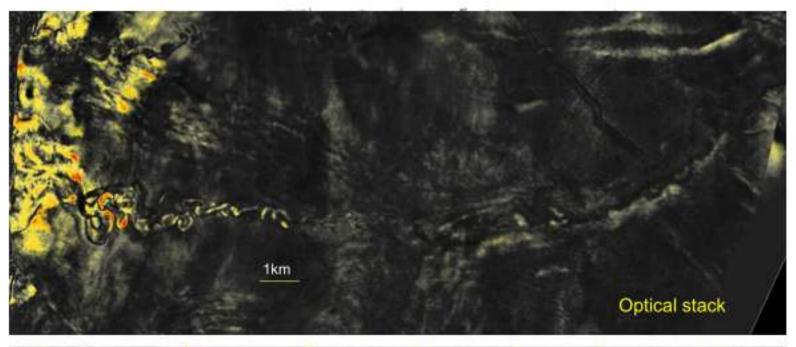


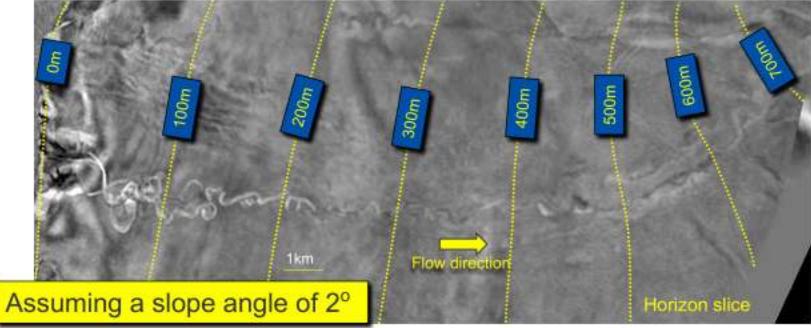






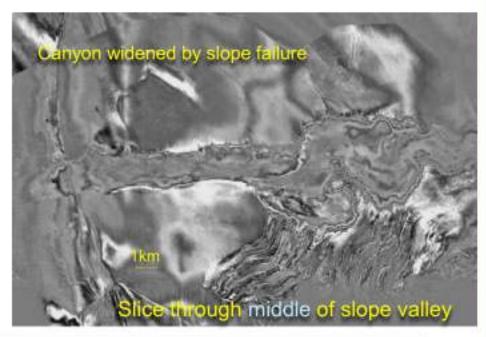


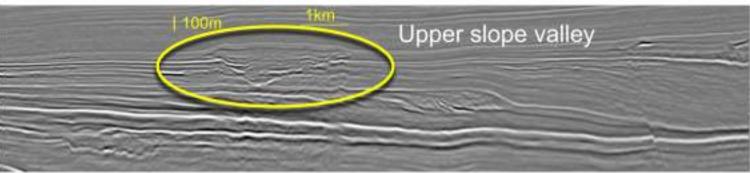




The Role of Context – the Upper Slope Valley

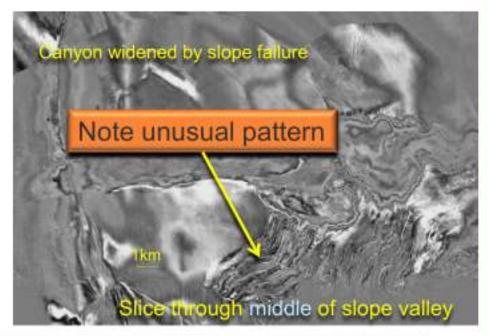


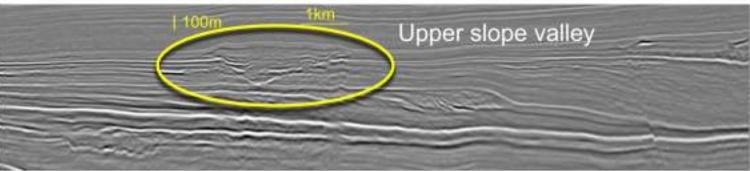


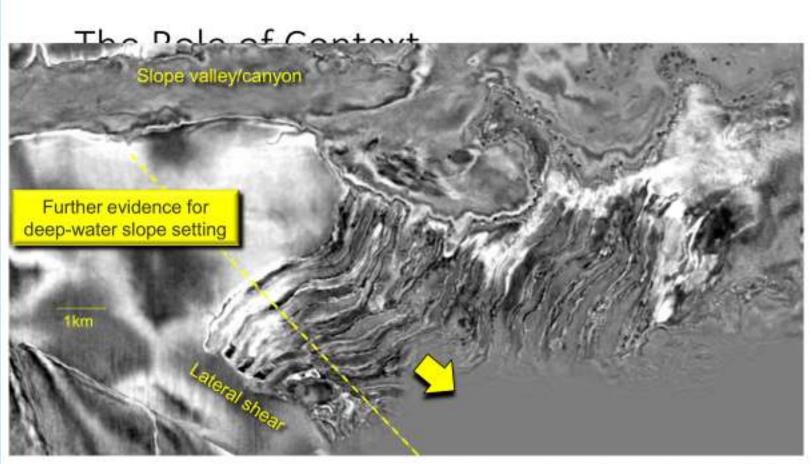


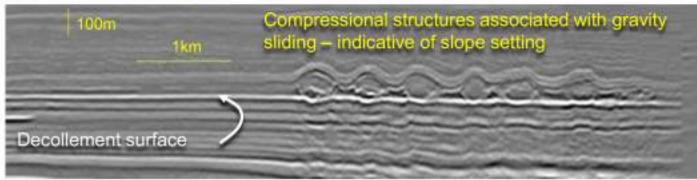
The Role of Context – the Upper Slope Valley

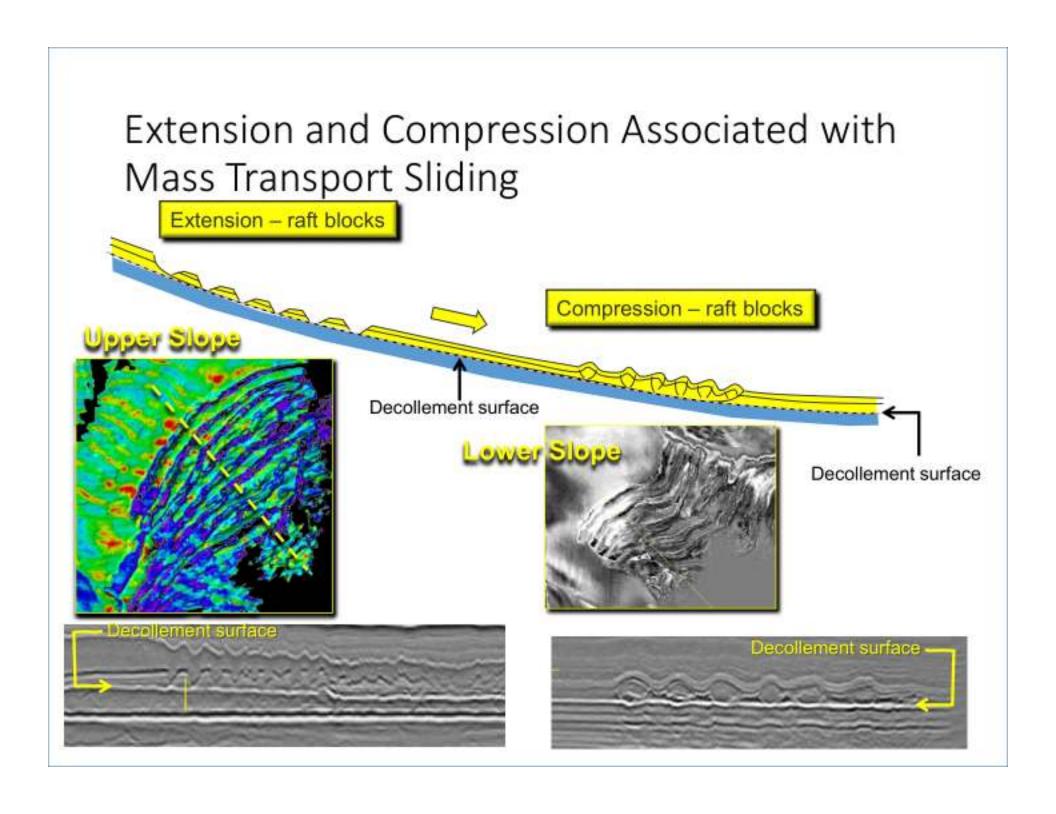


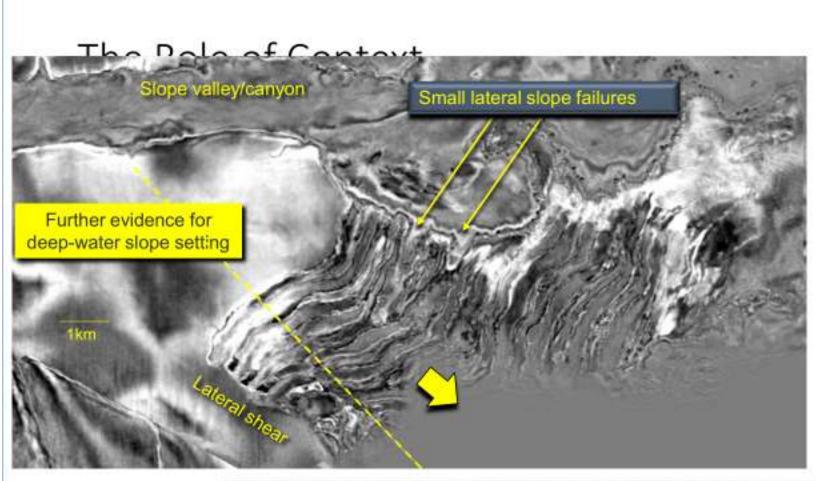


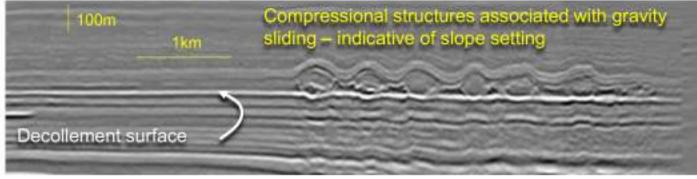


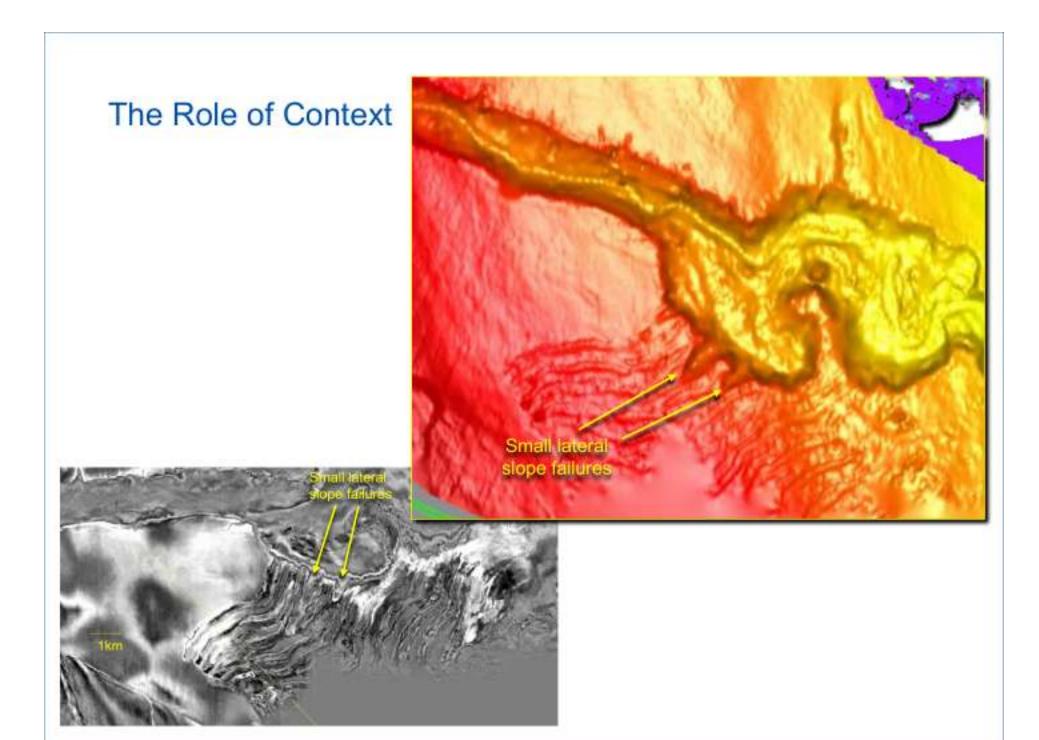


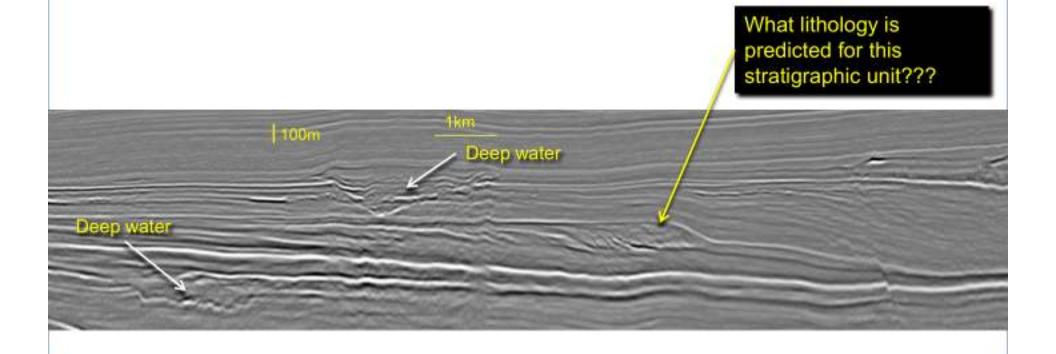






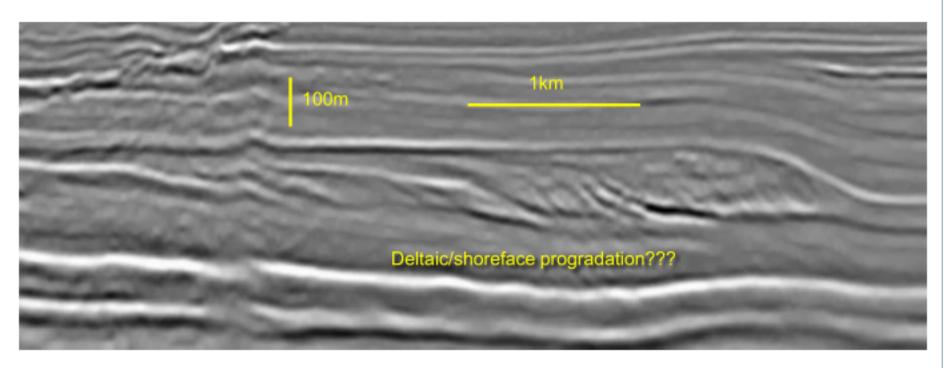






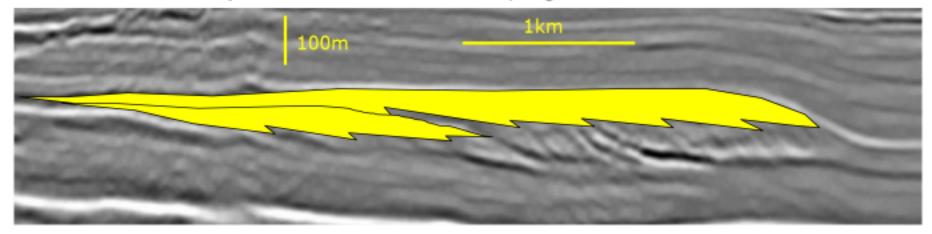
The bracketing slope valleys set the context: Deep water

however

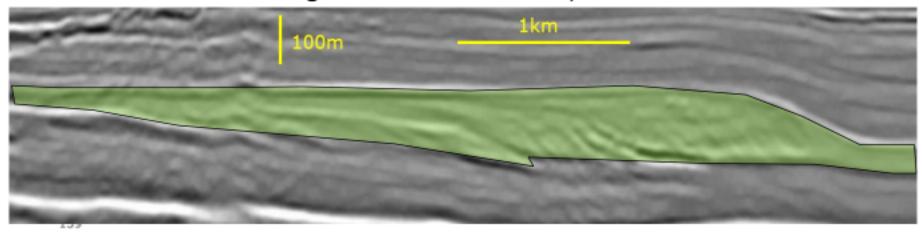


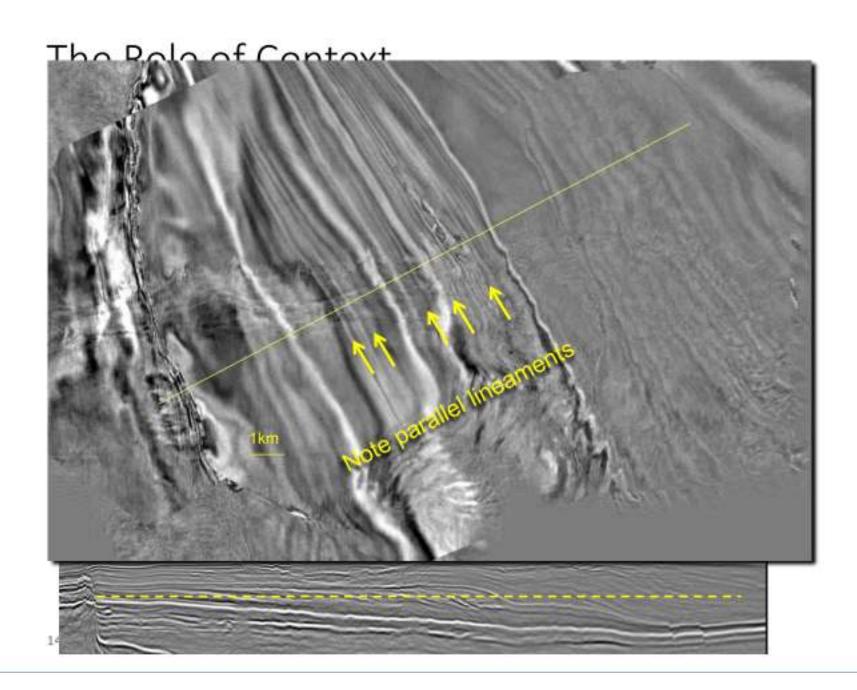
Significance of alternative interpretations

Reservoir prone - deltaic/shoreface progradation

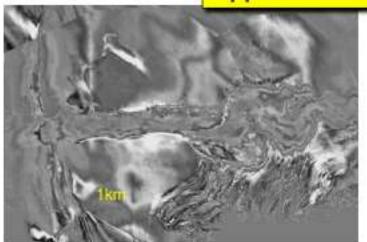


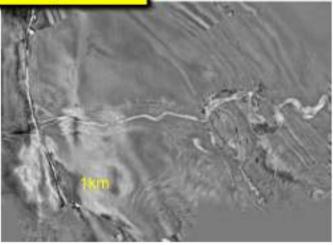
Reservoir Challenged – contour current deposited sediment drift

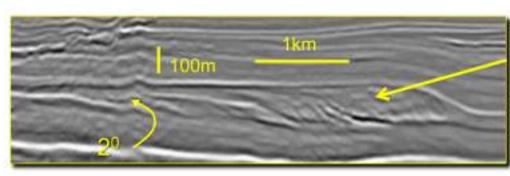




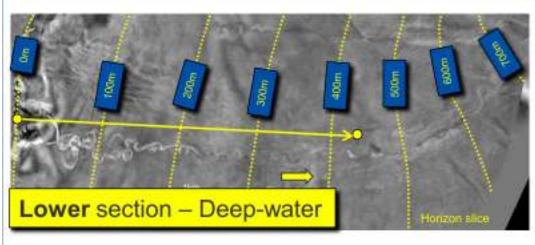
Upper section - Deep-water

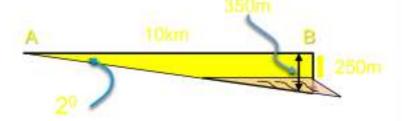




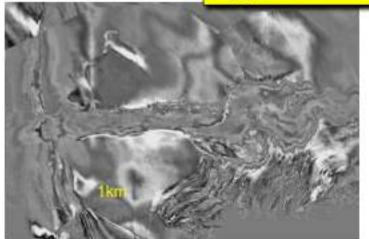


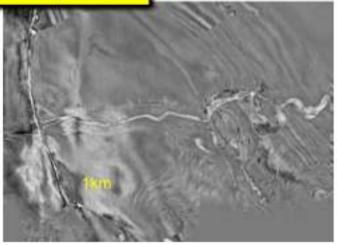
For this section to be deltaic or shoreface, relative sea level would need to have fallen 250-300m and then risen a similar amount (assuming a slope gradient of 2°)

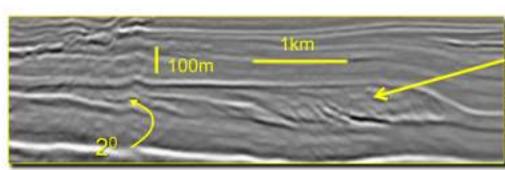




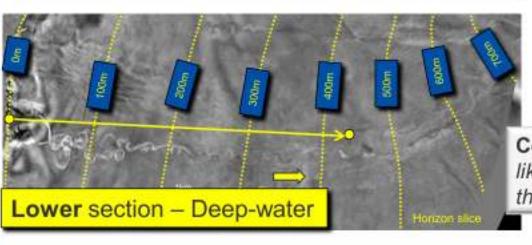
Upper section - Deep-water

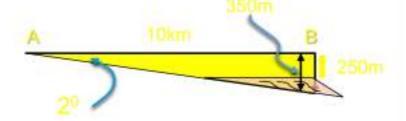






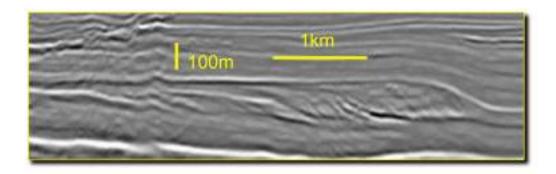
For this section to be deltaic or shoreface, relative sea level would need to have fallen 250-300m and then risen a similar amount (assuming a slope gradient of 2°)

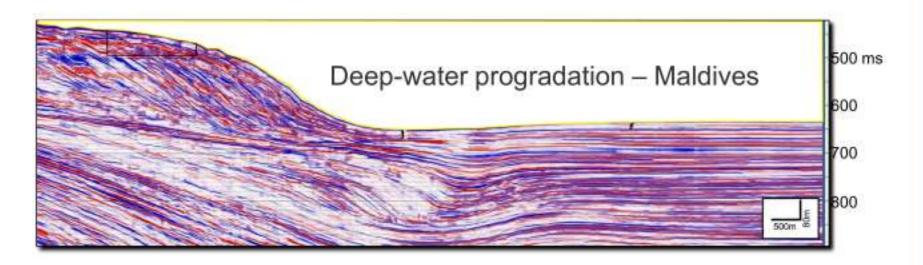




Conclusion: sand-challenged feature likely related to contour current rather than deltaic processes

Contour Current Progradation – Analog

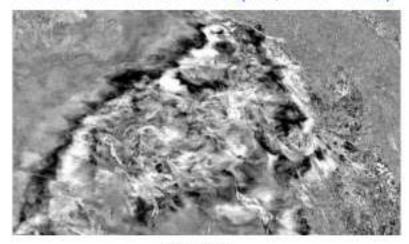




Workflows: Slicing Styles

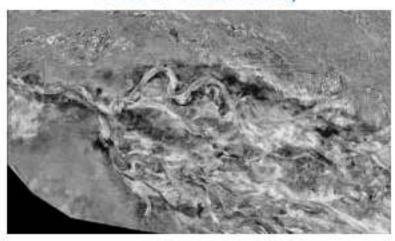
Stratigraphic Interpretation

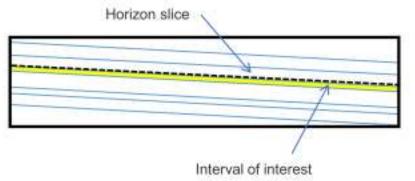
Horizontal Planar Slice (i.e., Time Slice)



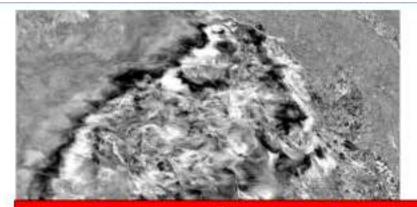
Time slice

Horizon Parallel Slice (i.e., Horizon Slice or Stratal Slice)

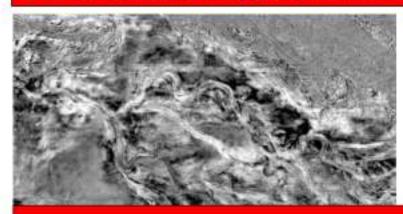




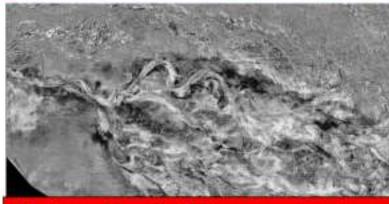
Slicing Styles



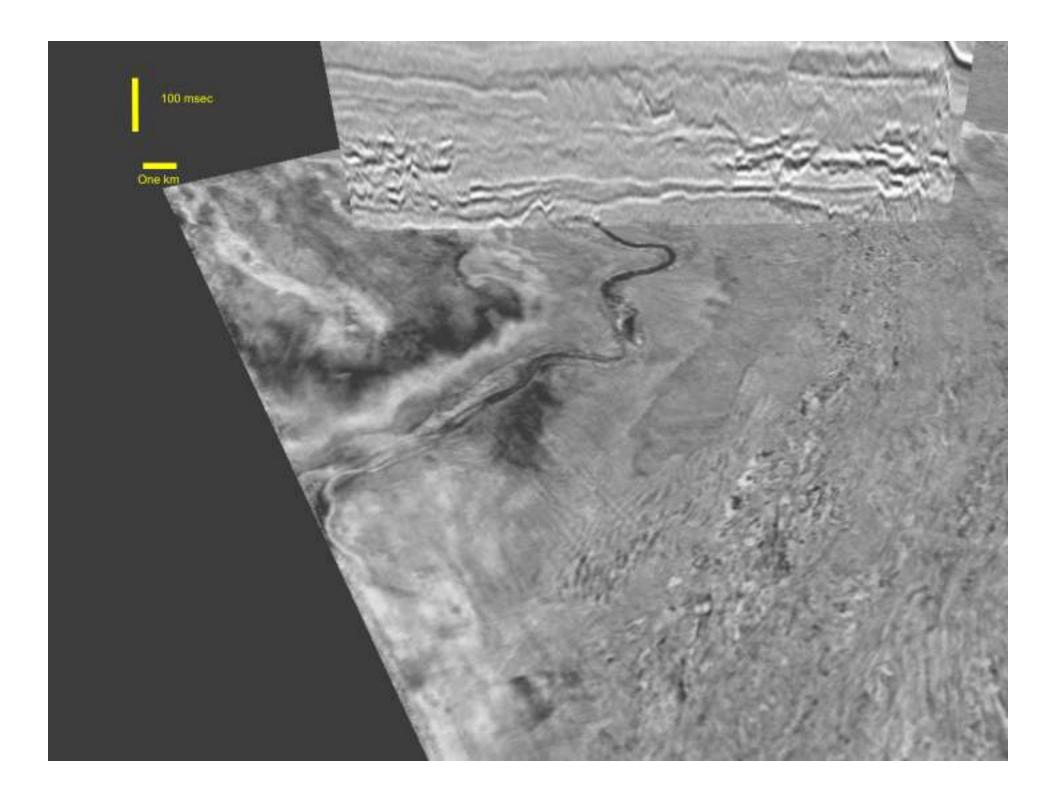
Horizontal Planar Slice (i.e., Time Slice)

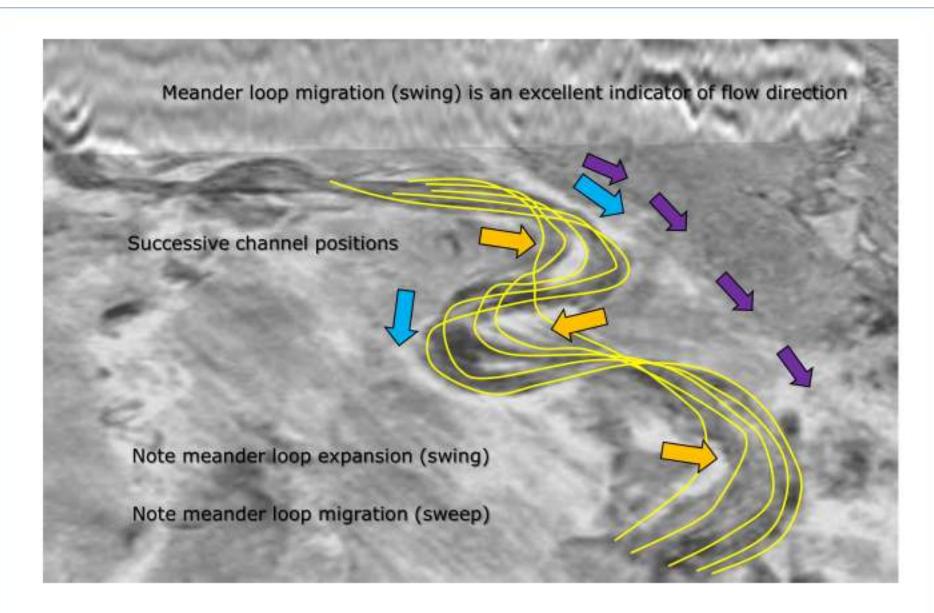


Inclined Planar Slice (i.e., Dipping Time Slice)



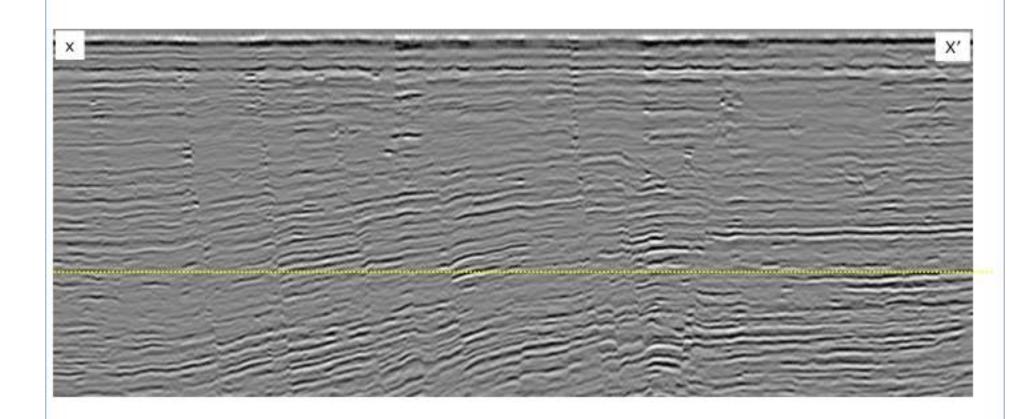
Horizon Parallel Slice (i.e., Horizon Slice)



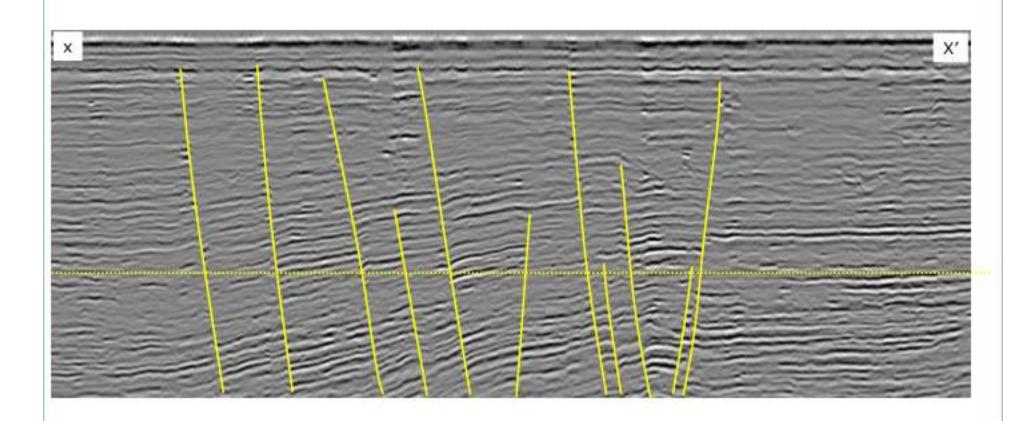


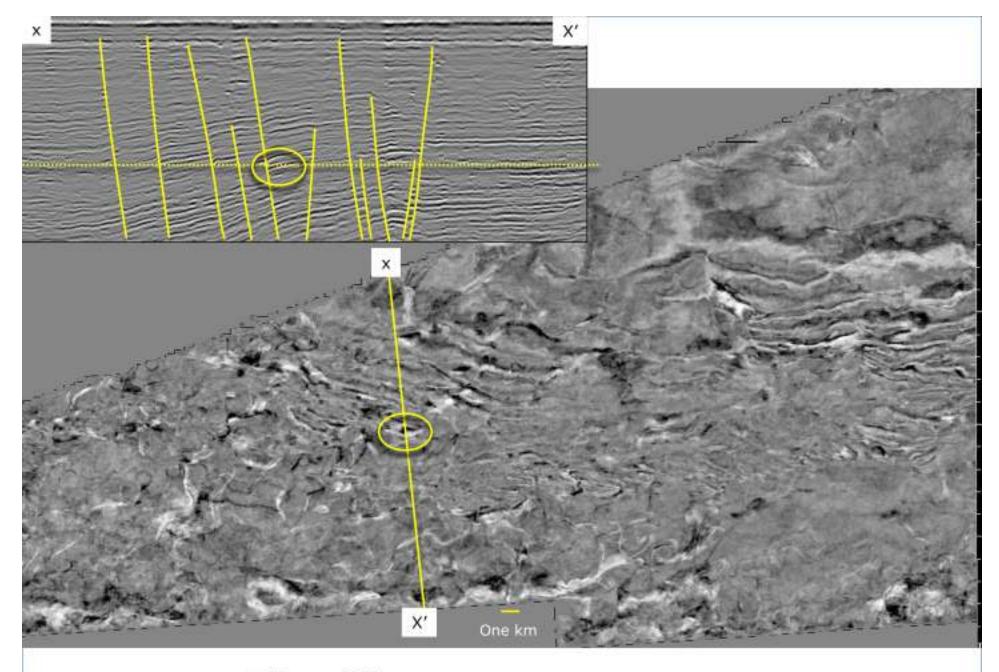
Meandering deep-water channel detail

Application of Optical Stacking - Thailand Seismic Transect



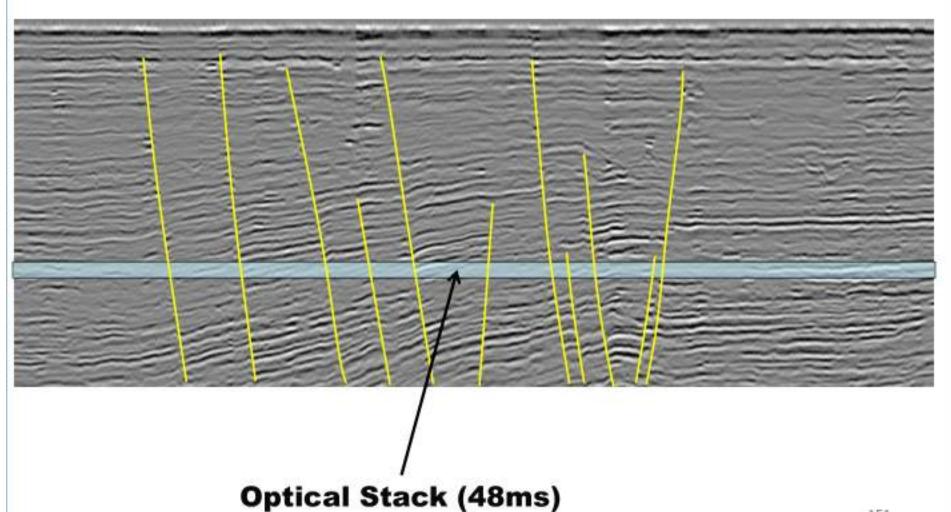
Application of Optical Stacking - Thailand Seismic Transect



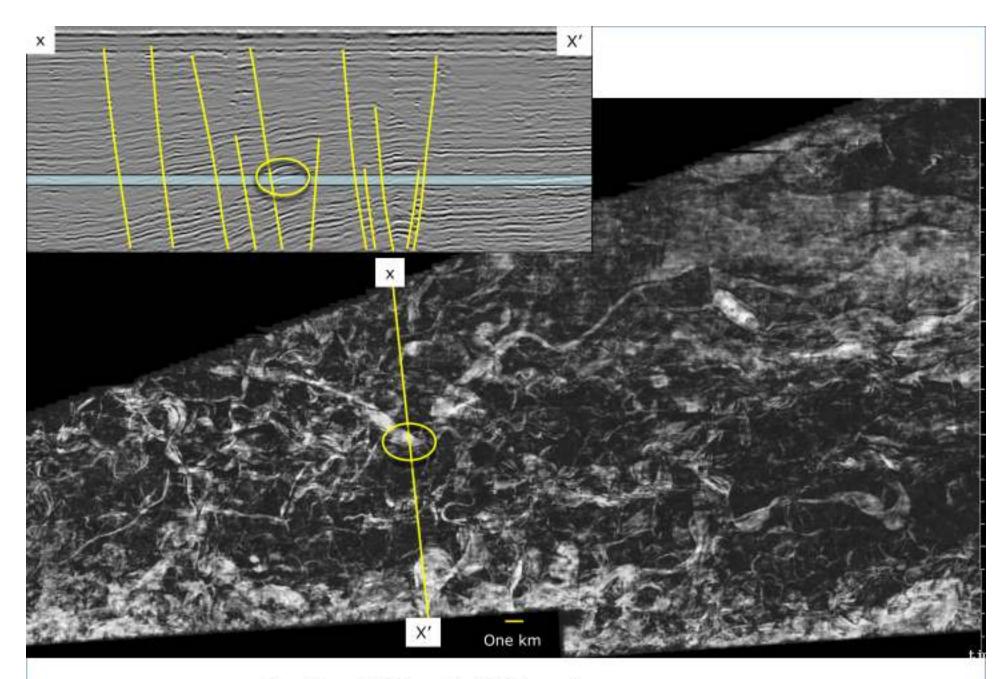


Time Slice

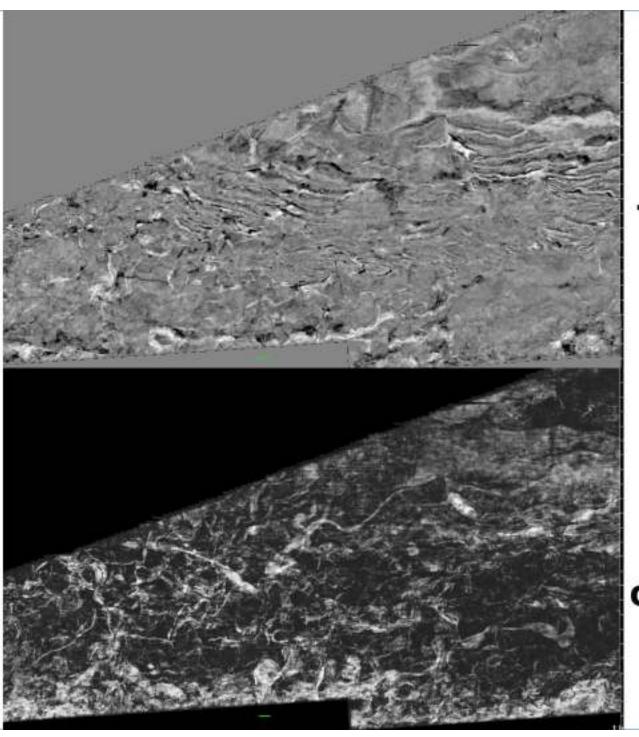
Application of Optical Stacking – Thailand Seismic Transect



151



Optical Stack (48ms)



Time Slice

Optical Stack (48ms)

Animations



Inline Animation (west Africa)



Optical Stack Animation (west Africa)

Animations

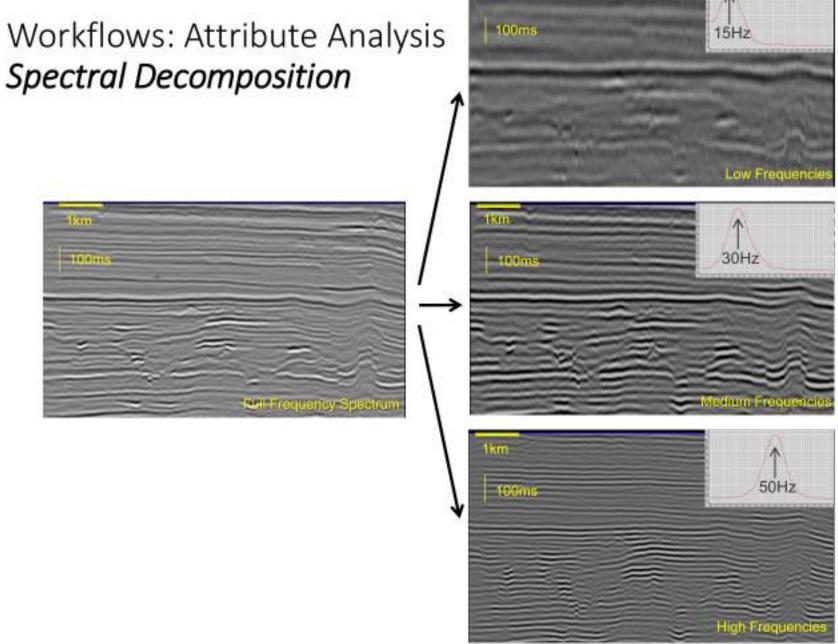
Thailand time slices

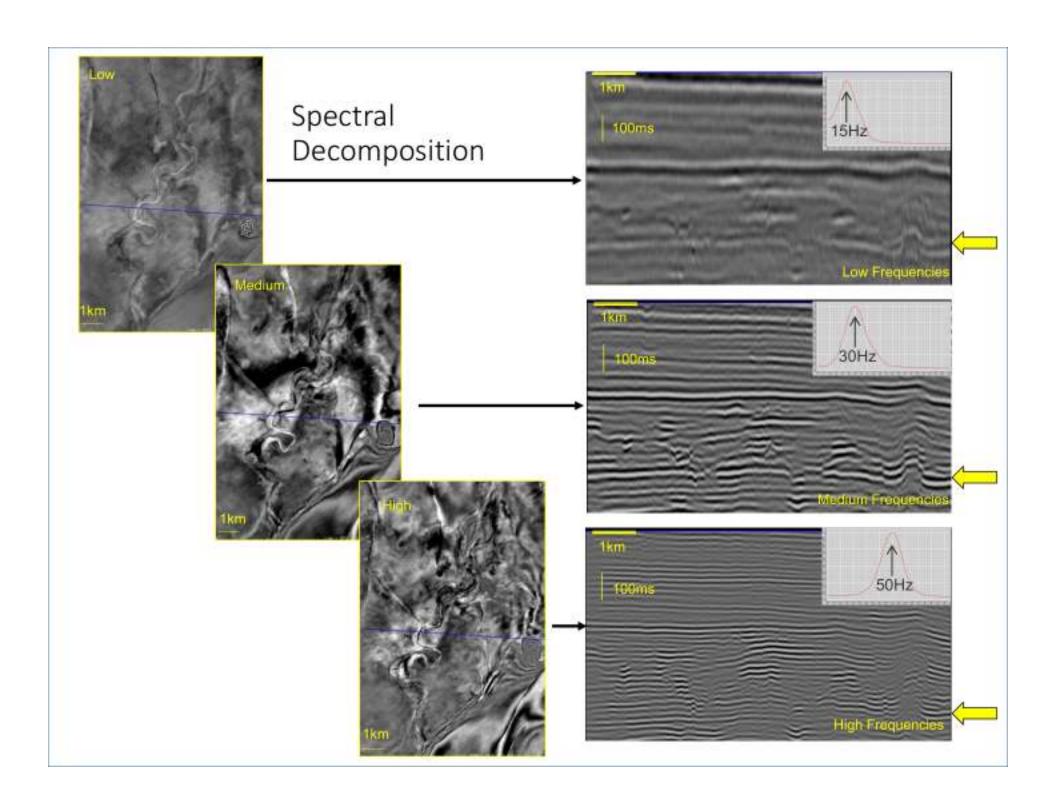


Thailand optical stack

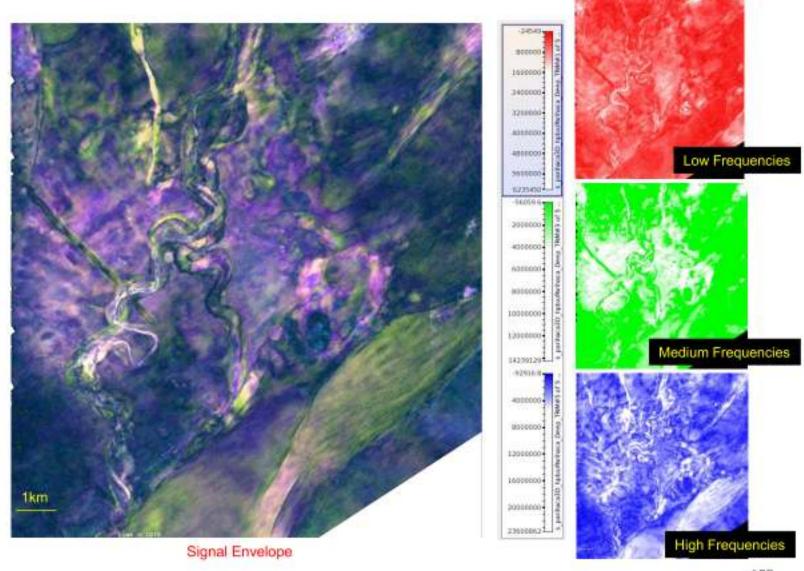


Workflows: Attribute Analysis

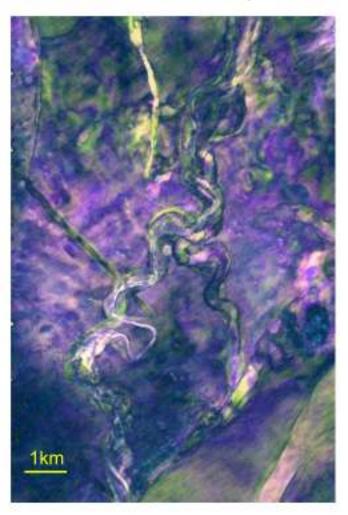


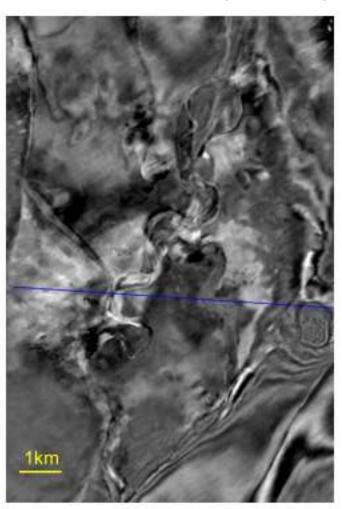


Co-Rendered Low/Medium/High Frequencies (Spectral Decomposition)

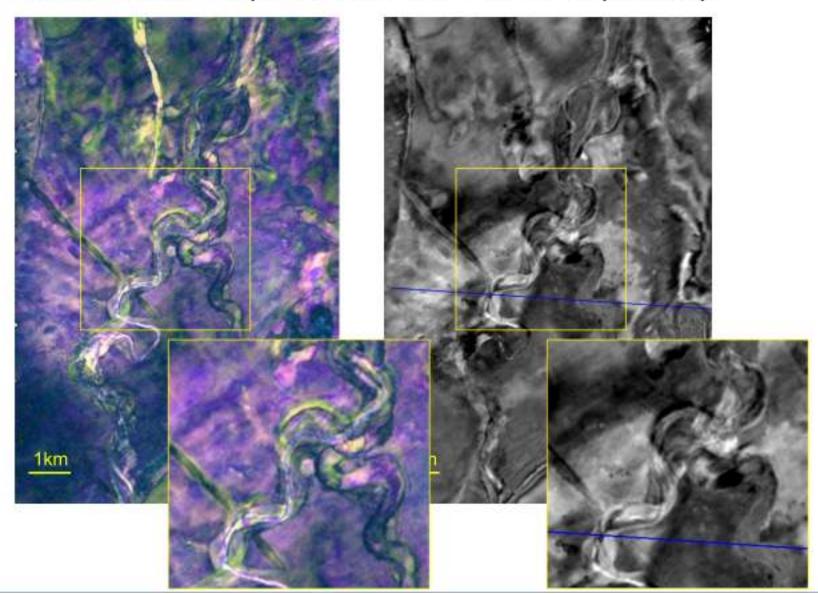


Spectral Decomposition vs. Full Frequency

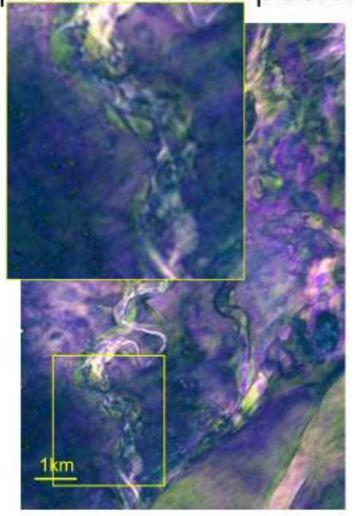


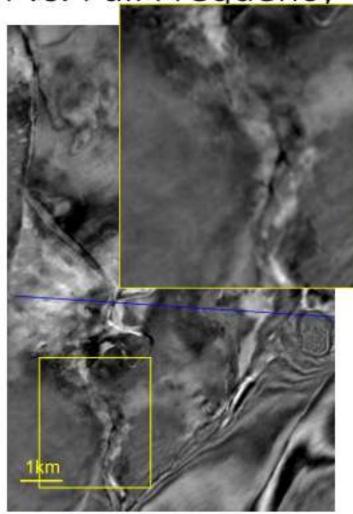


Spectral Decomposition vs. Full Frequency



Spectral Decomposition vs. Full Frequency



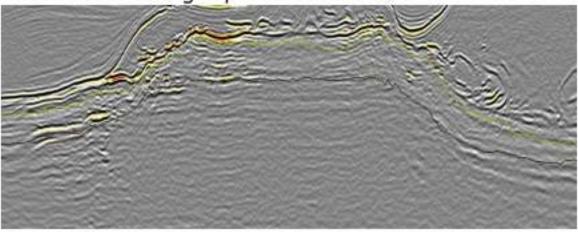


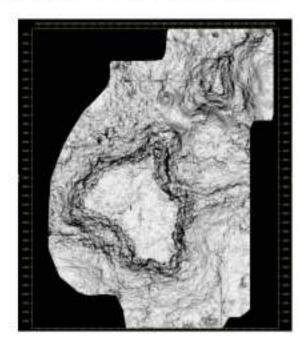


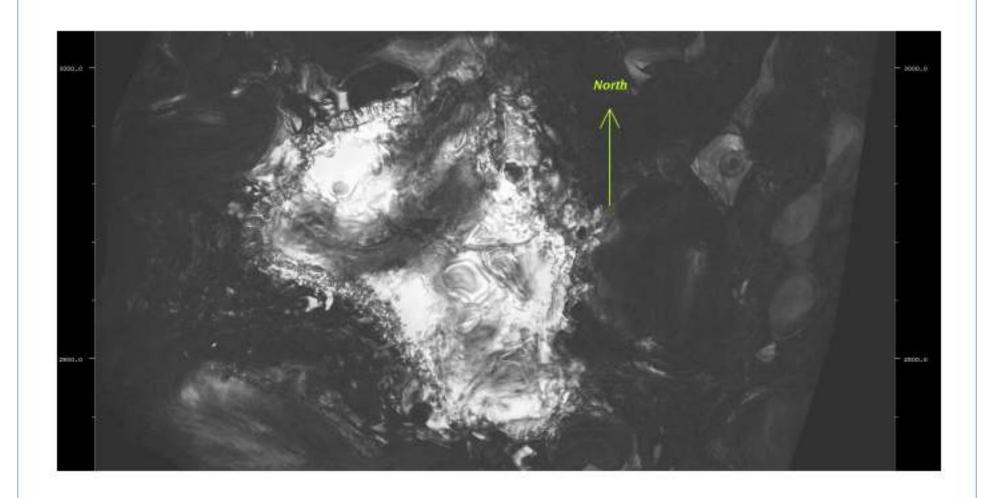
Top Bashkirian Dip Magnitude Map – Tengiz

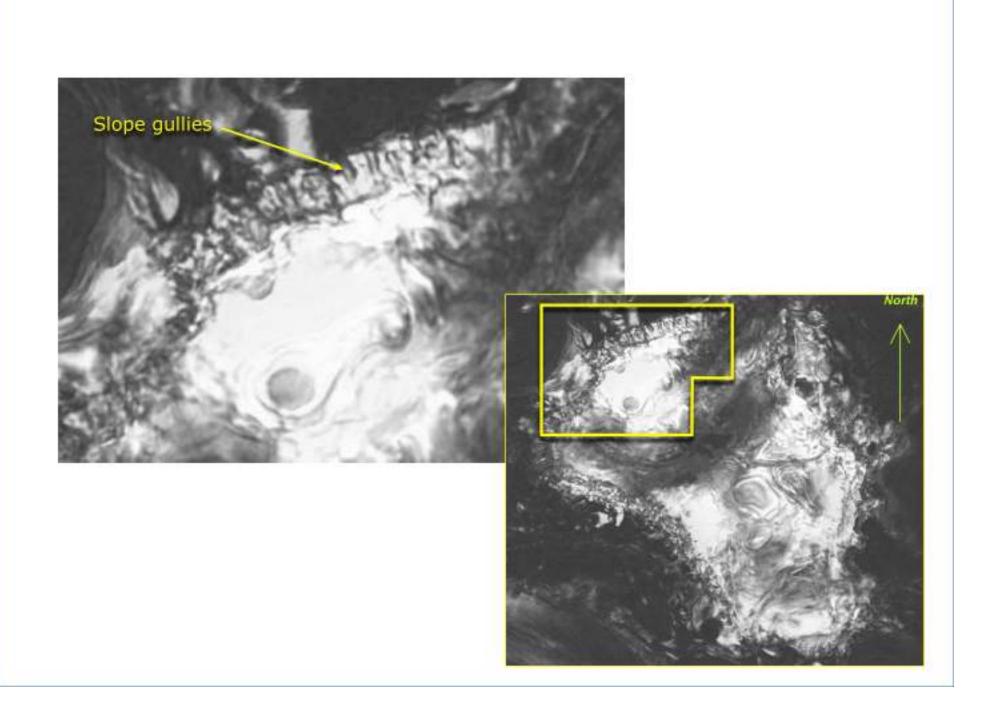


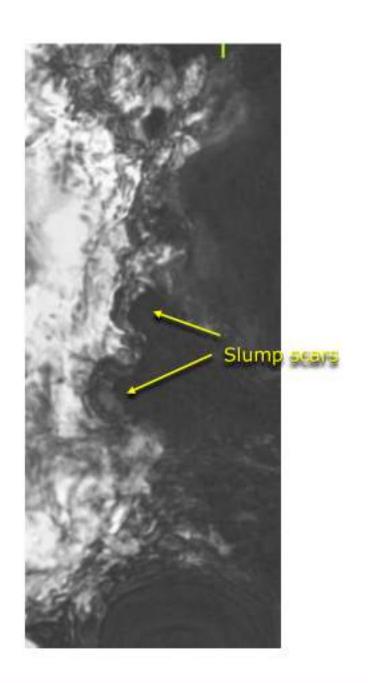
Transect showing top and base Unit 1

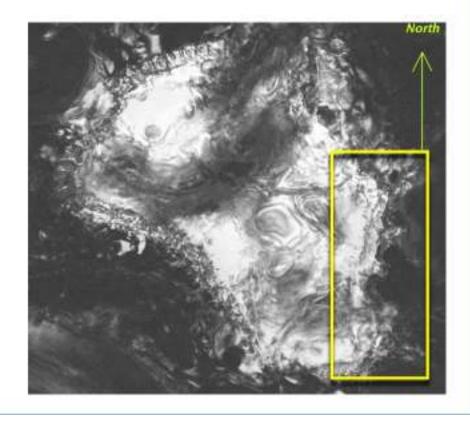




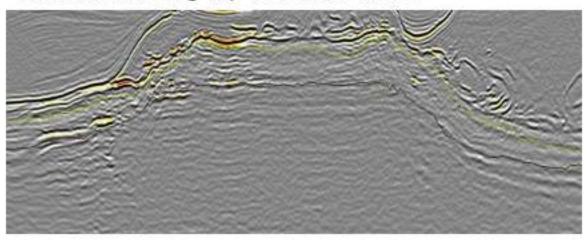








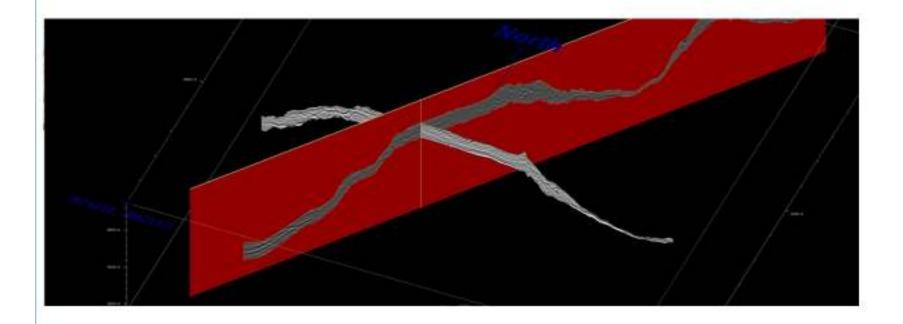
Transect showing top and base Unit 1

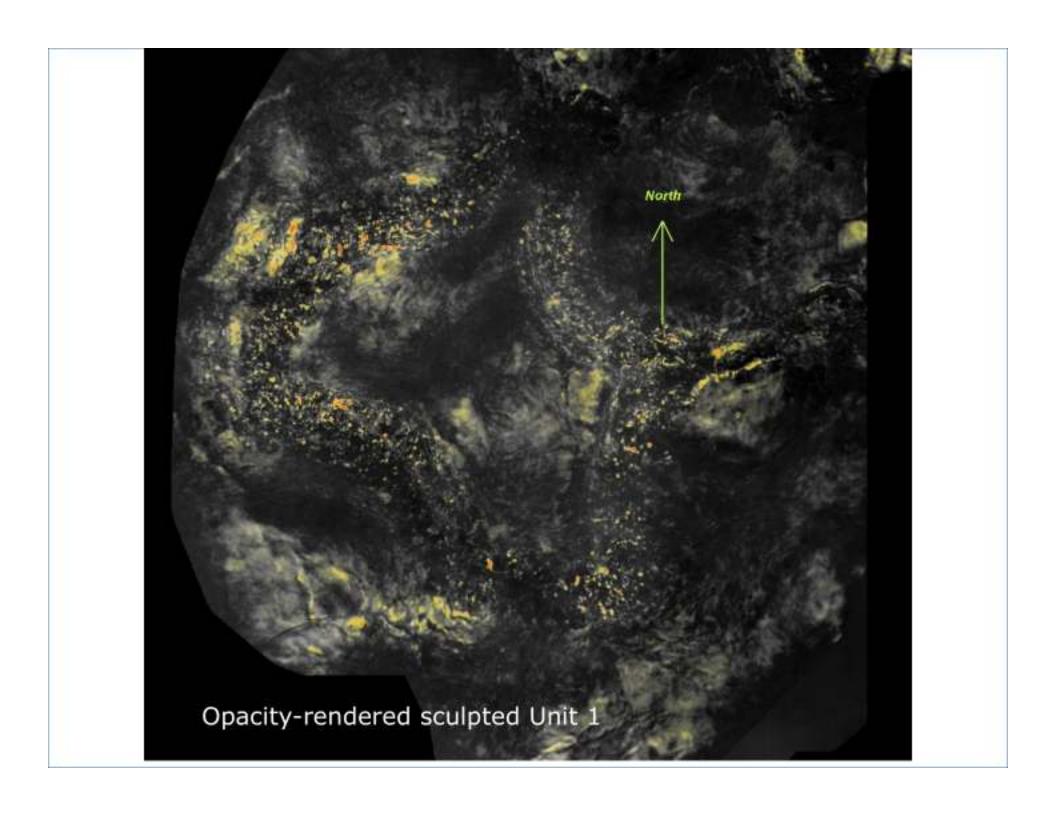


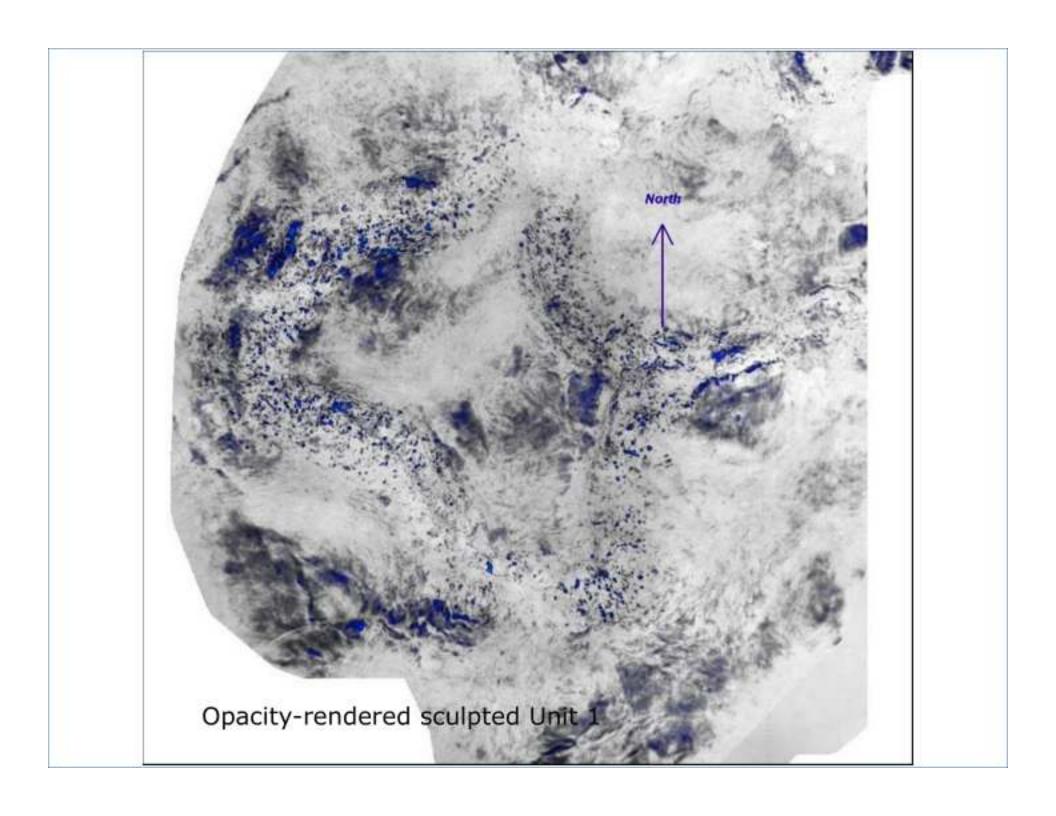
Formation sculpted Transect showing top and base Unit 1



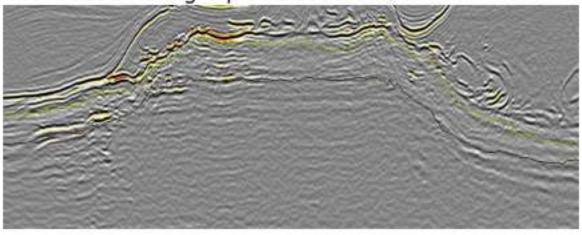
Sculpted Unit 1



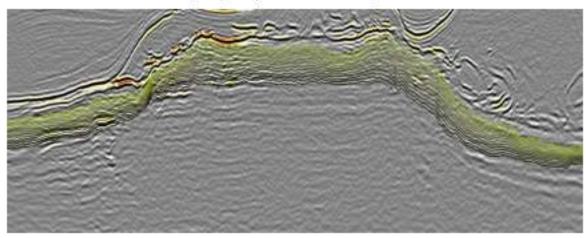


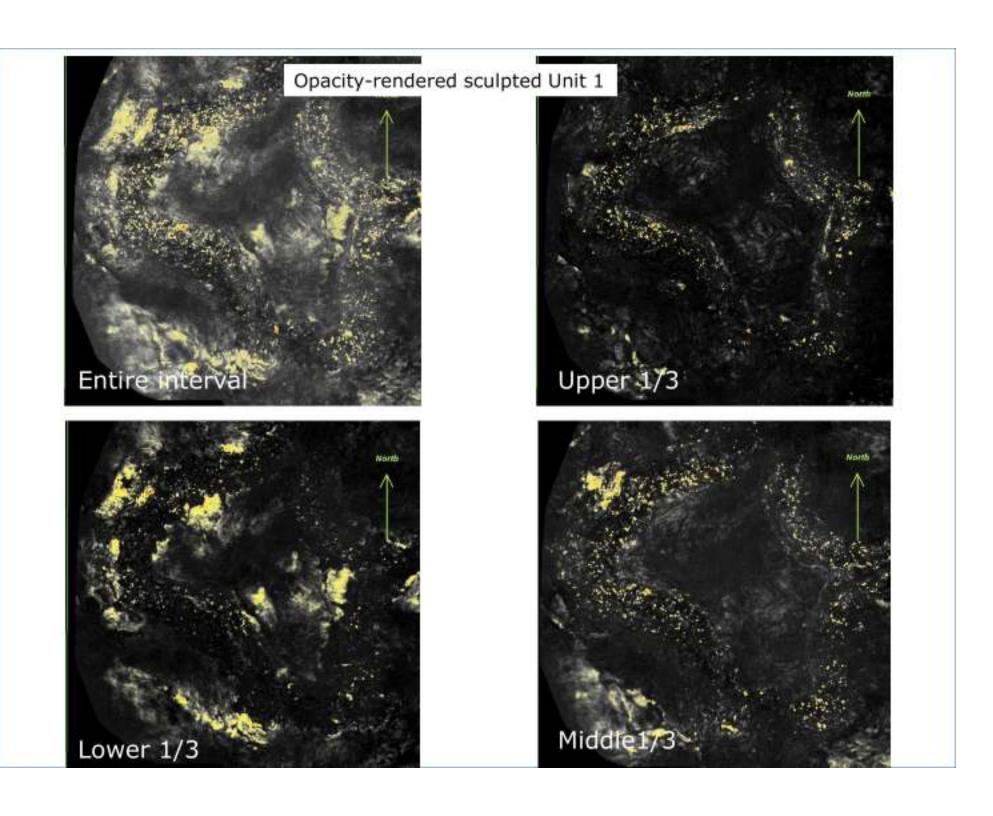


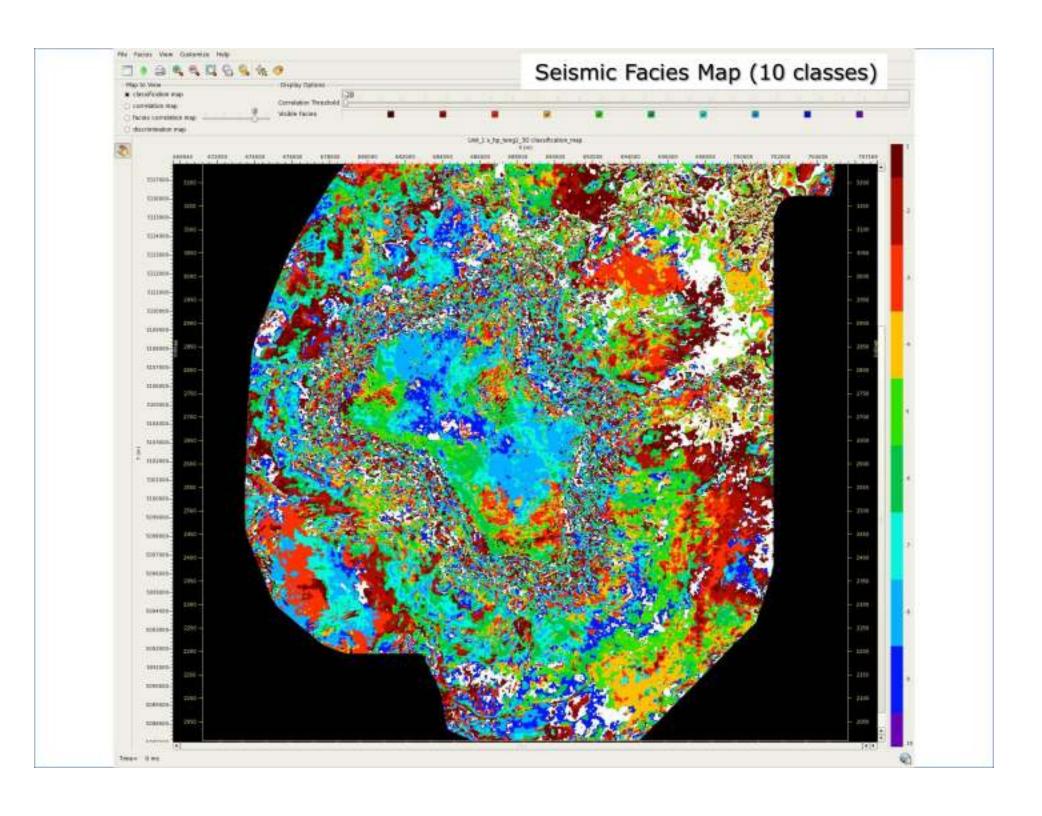
Transect showing top and base Unit 1



Transect showing "proportionately sliced" Unit 1

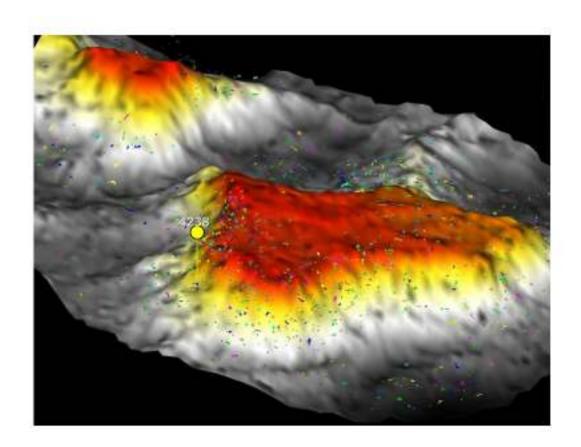


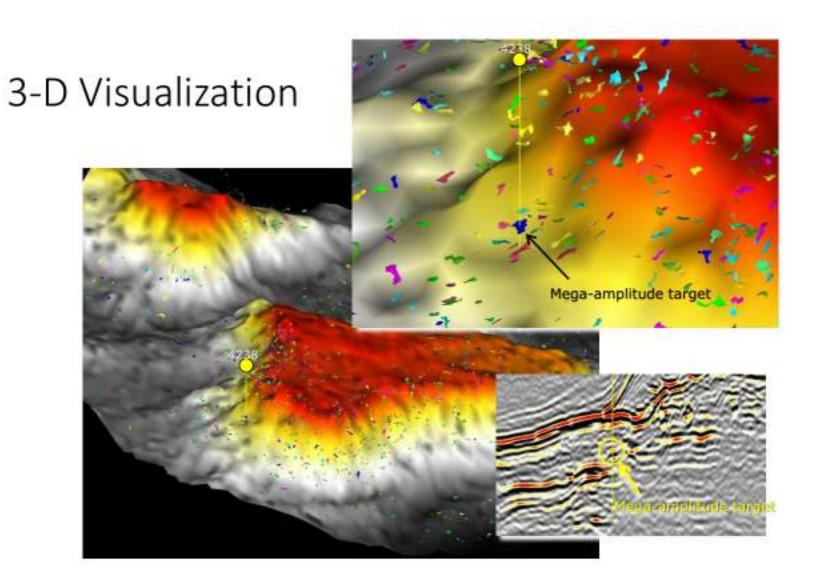




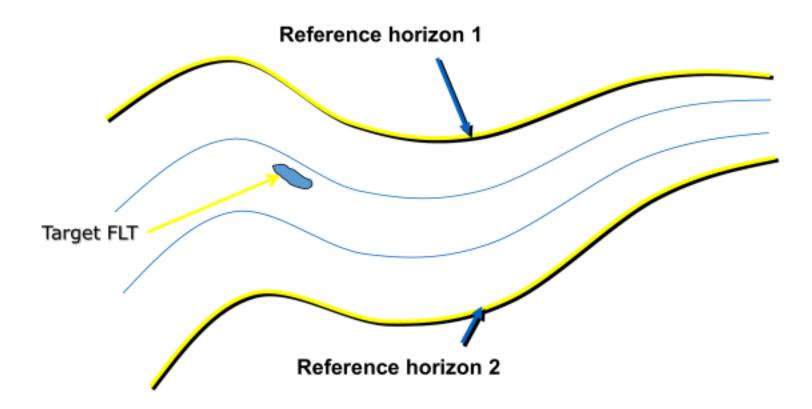


3-D Visualization

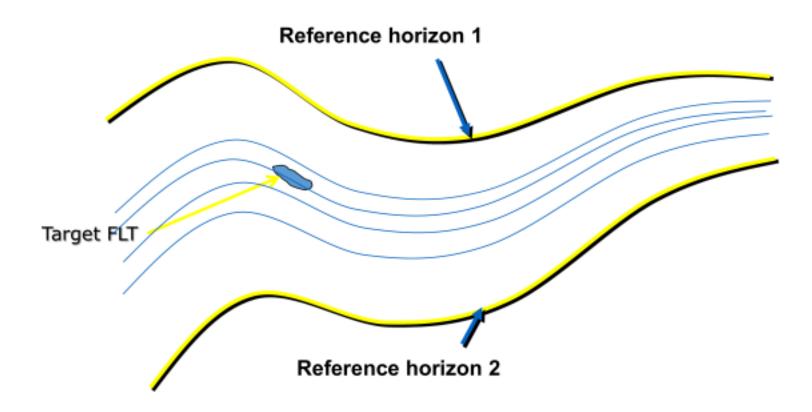




Proportional slicing through divergent seismic reflections

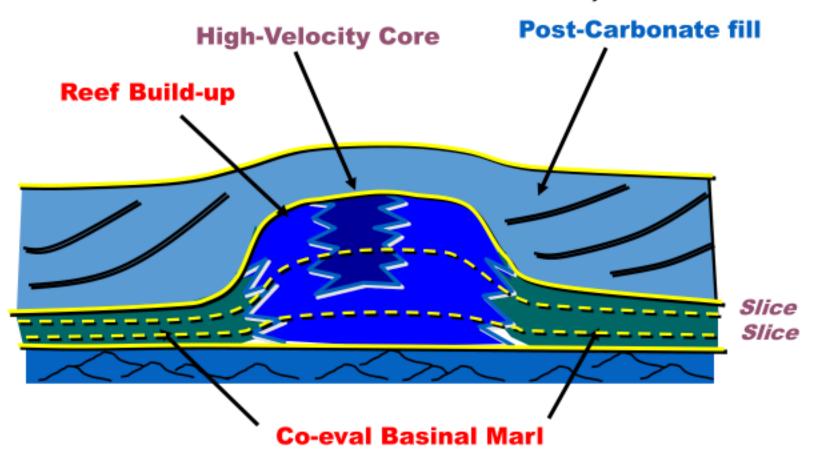


Proportional slicing through divergent seismic reflections



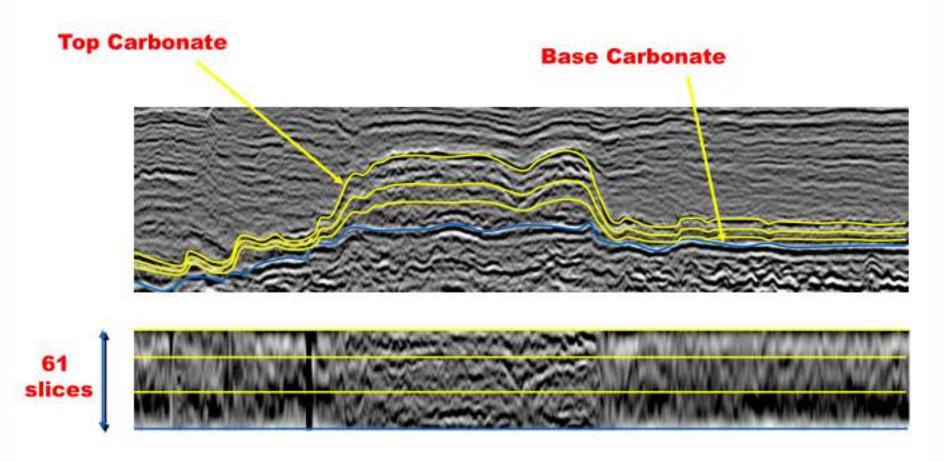
Horizon Slice

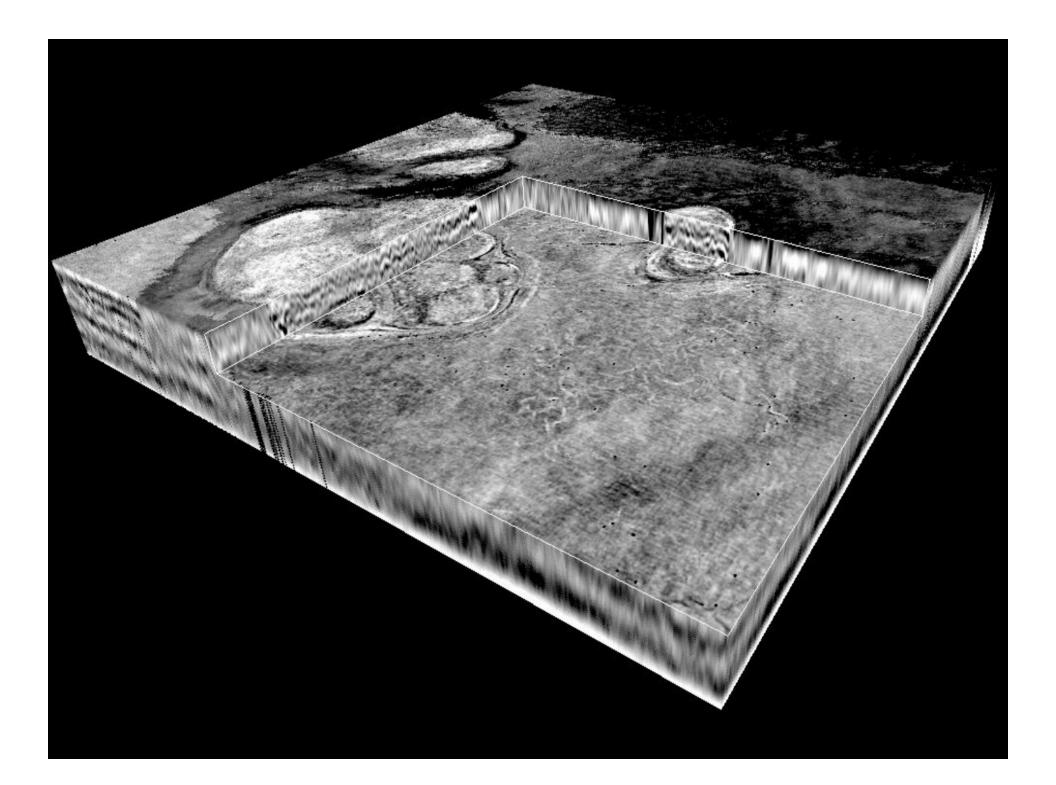
(Proportional Slice between Top and Base Carbonates)



Horizon Slice

(Proportional Slice between Top and Base Carbonates)



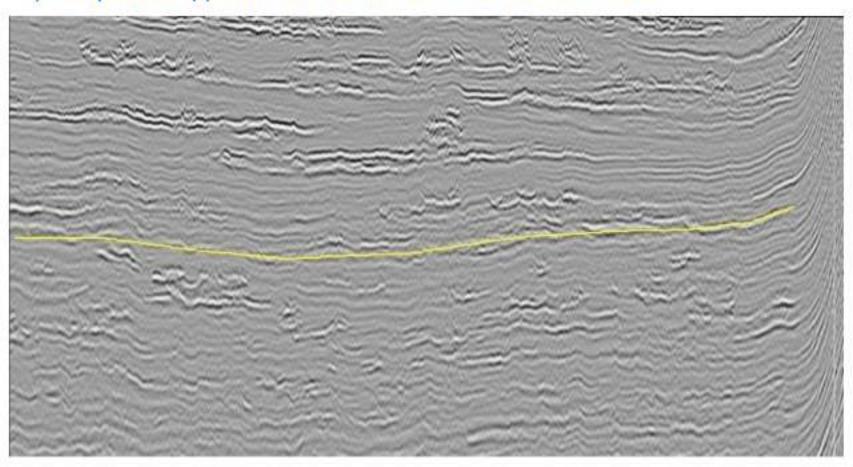


Workflow: Creative Datuming

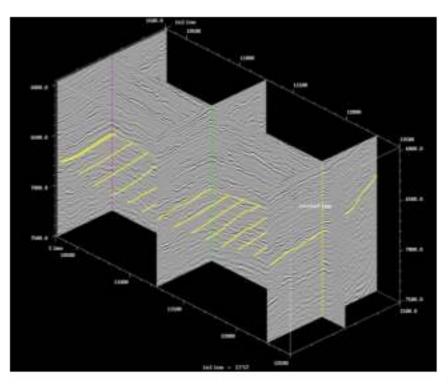
Or... what to do if no continuous horizon is available to pick on which to flatten

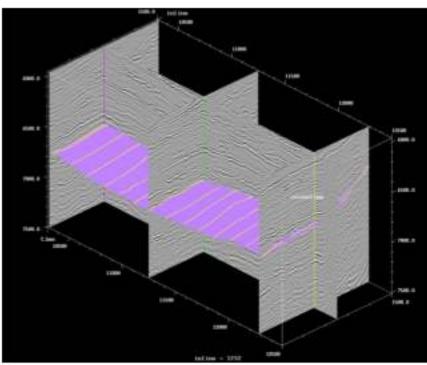
Slicing Techniques: "Creative" Datuming

1) Interpret an approximate horizon near the zone of interest



2a) Map this horizon across the study area



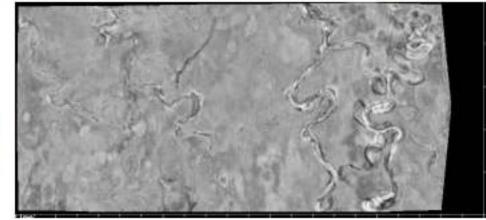


A. Interpret "forced" horizon onto a skeleton grid

B. Interpolate "forced" horizon pick

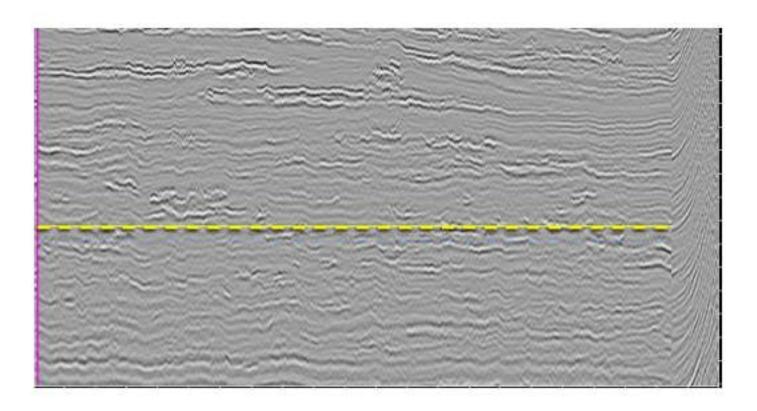
2b) Extract amplitude at this horizon

Interpolated "forced" horizon



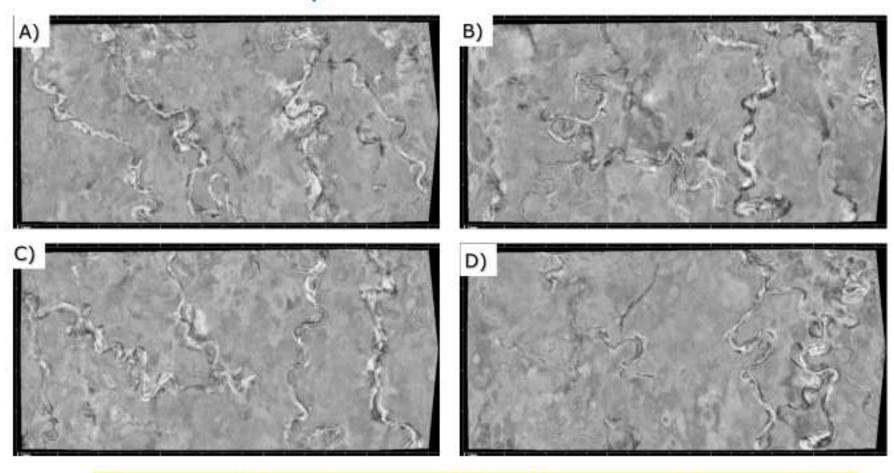
Amplitude extraction on "forced" horizon

3) Flatten on this horizon



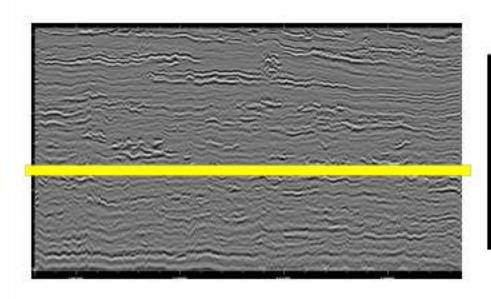
Flatten on interpreted "forced" horizon

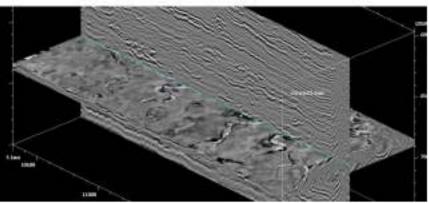
4) Generate horizon slices

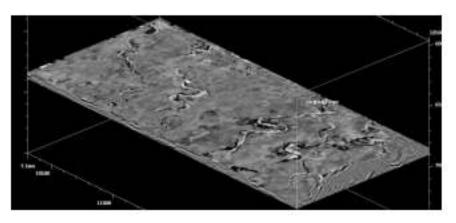


Slices parallel to interpreted "forced" horizon – horizon slices

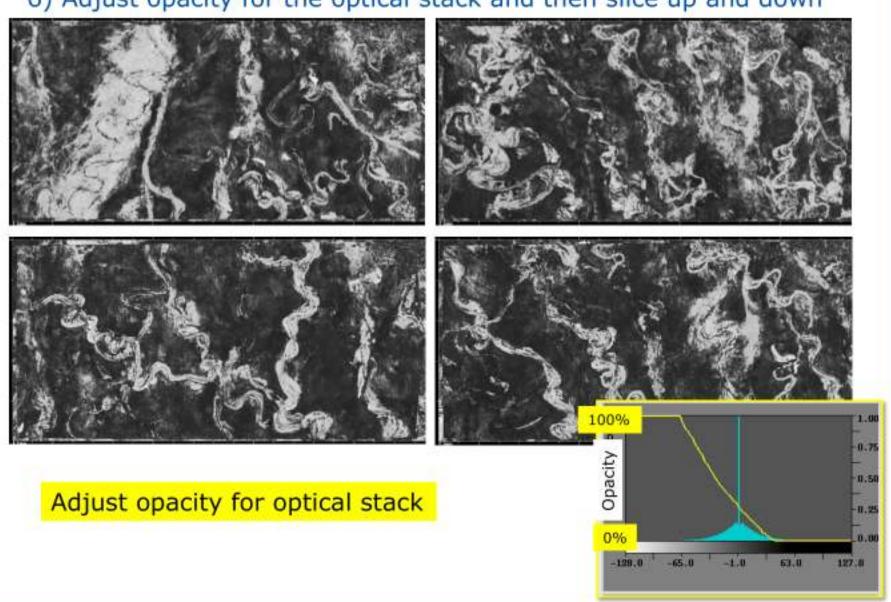
5) Create optical stack



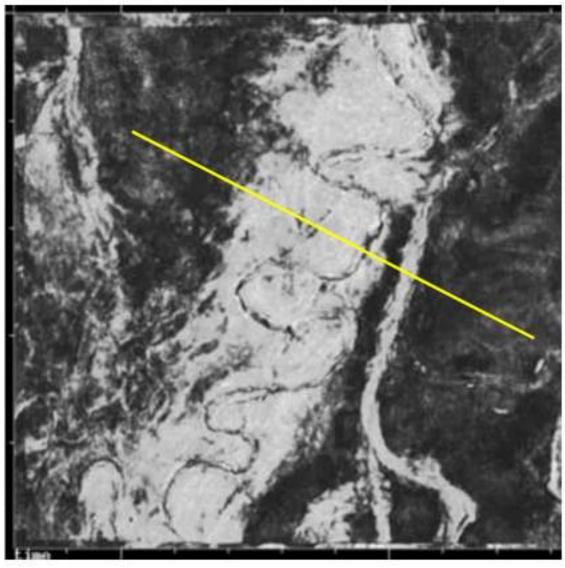


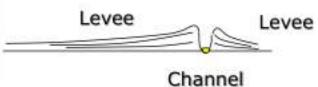


6) Adjust opacity for the optical stack and then slice up and down



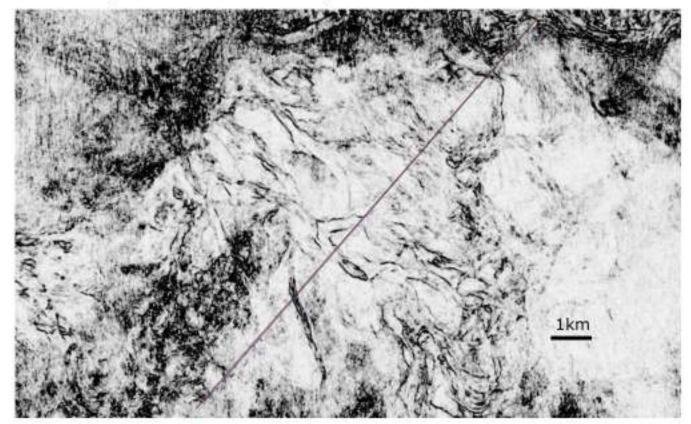
Leveed channel detail



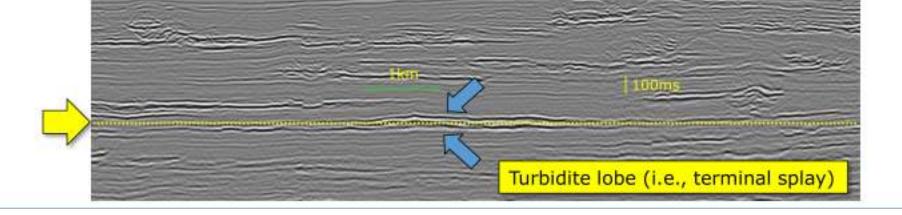


Levee is likely sand-poor; high amplitude probably related to silt content

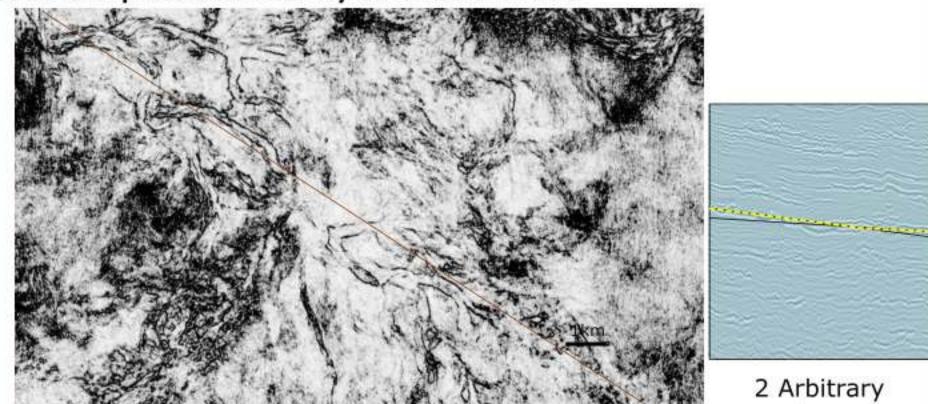
Seismic Expression of Weakly Confined Channels



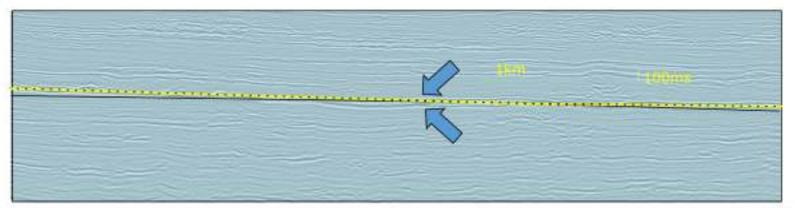
Time Slice

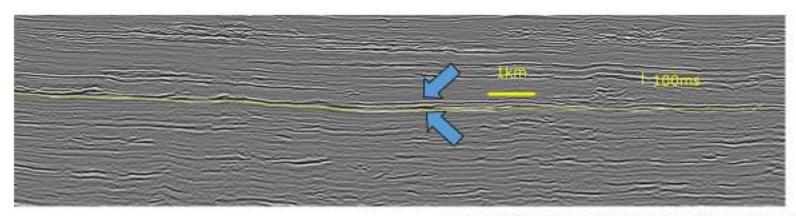


Seismic Expression of Weakly Confined Channels

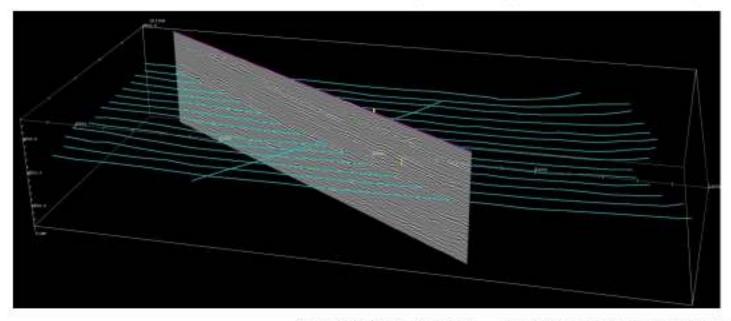


Planes

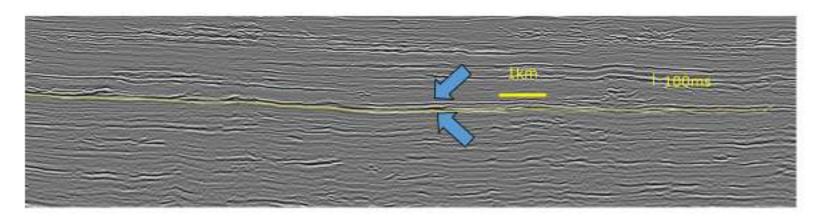


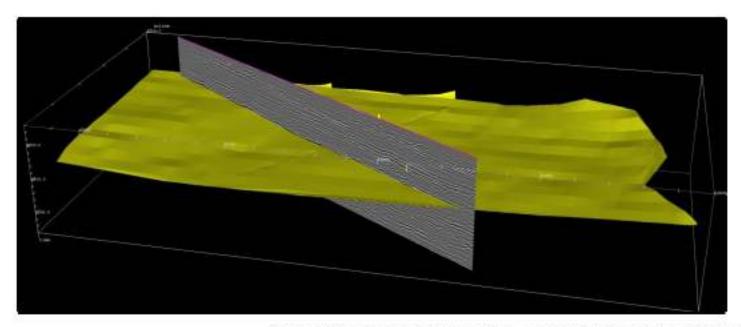


Step 1: Pick approximate base of target section

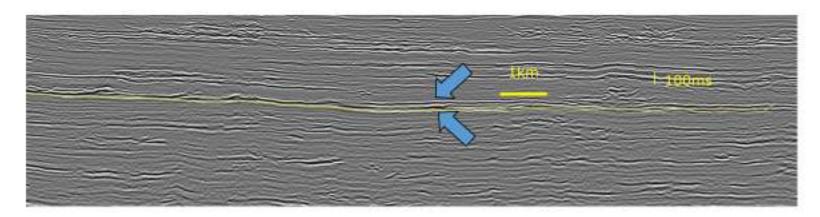


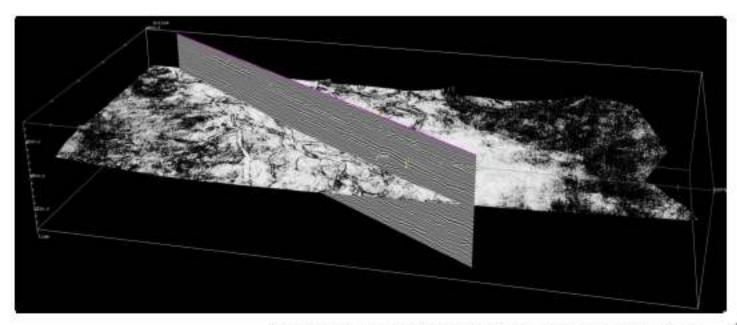
Step 2: Pick loose grid - approximate base of target section





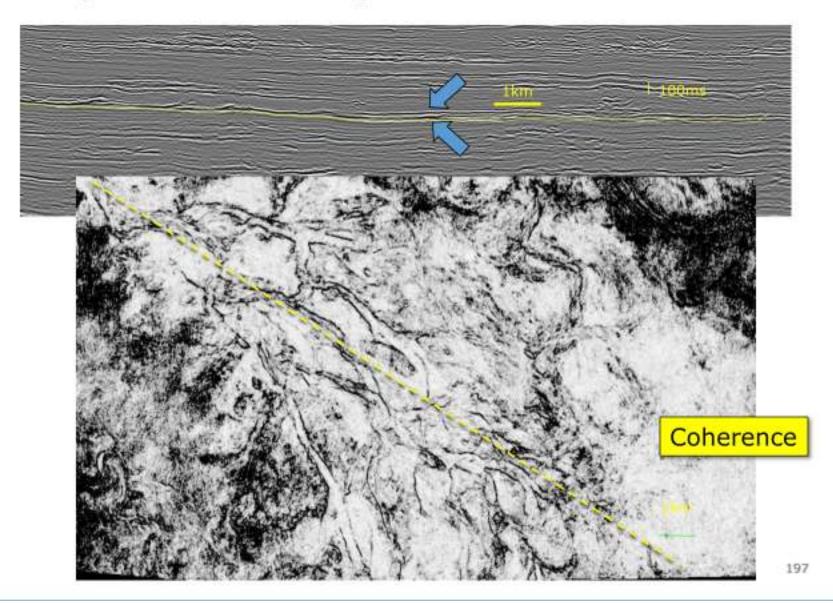
Step 3: Interpolate loose grid - approximate base of target section

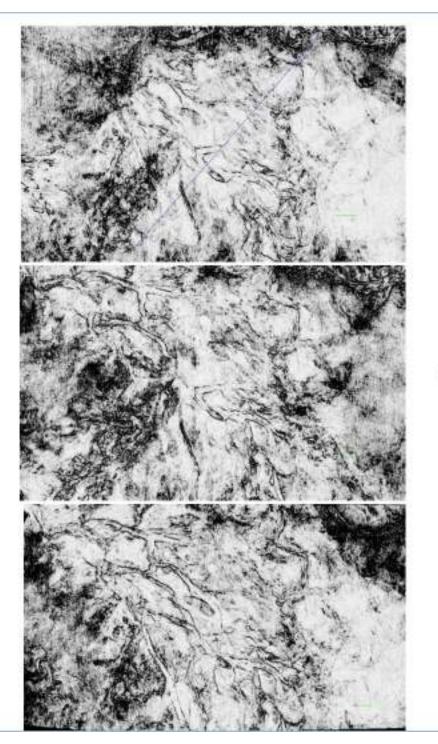




Step 4: Drape coherence values onto mapped horizon

Horizon Slice



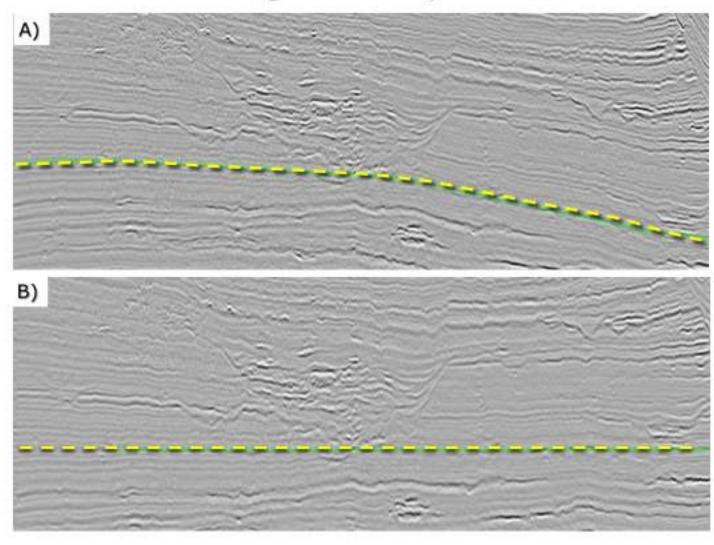


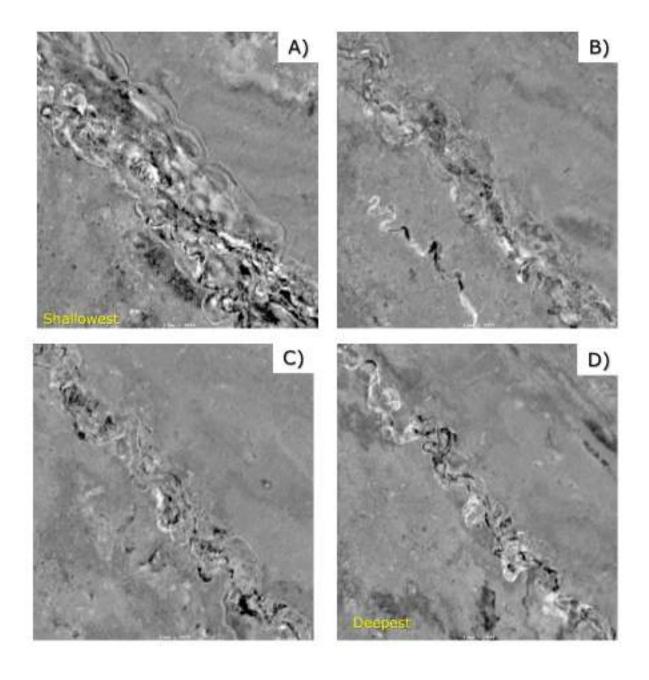
Time Slice

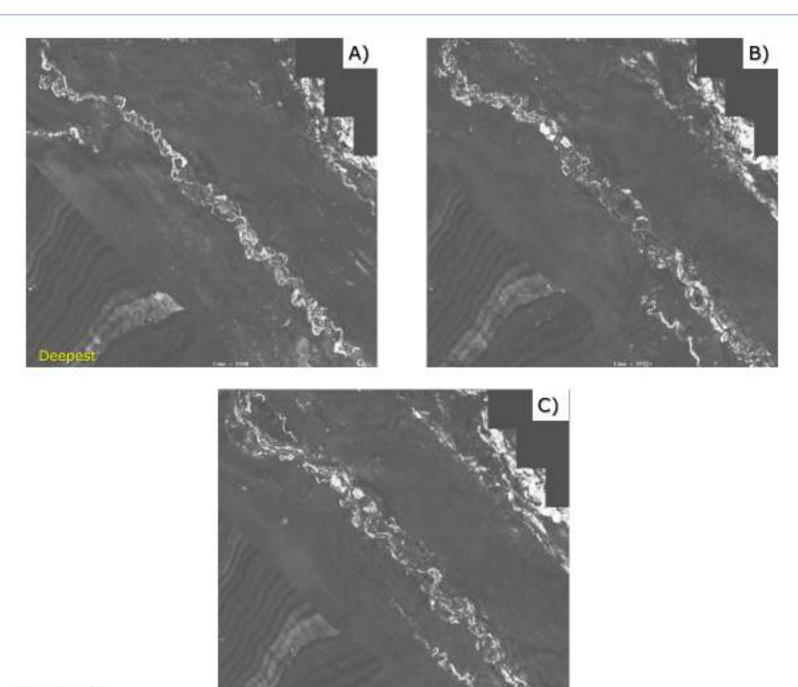
Tilted Planar Slice

Horizon Slice

Slicing techniques – 2



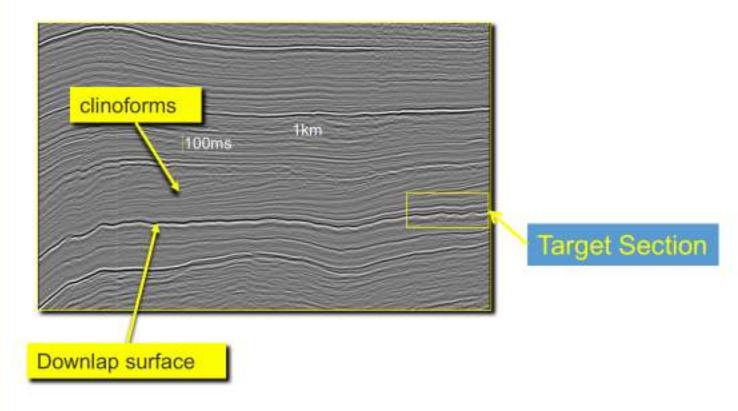




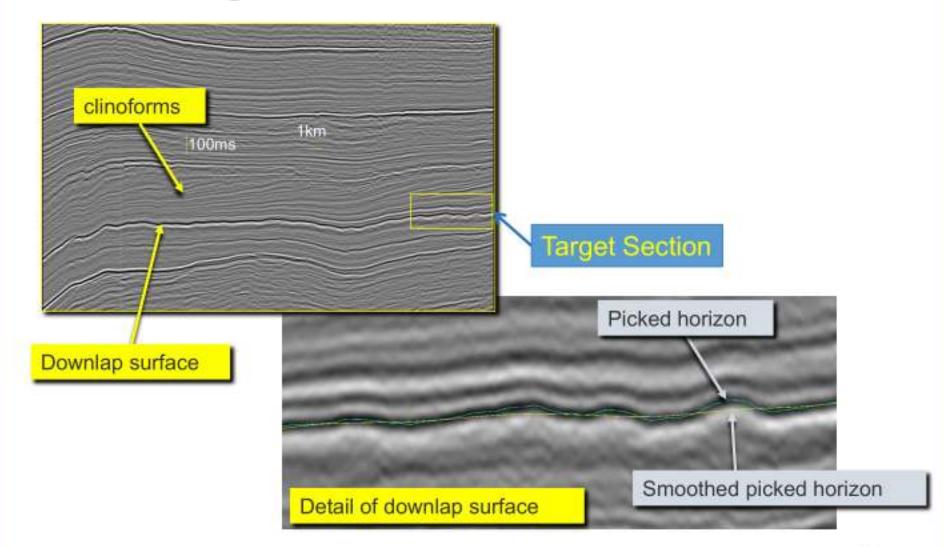
Shallowest

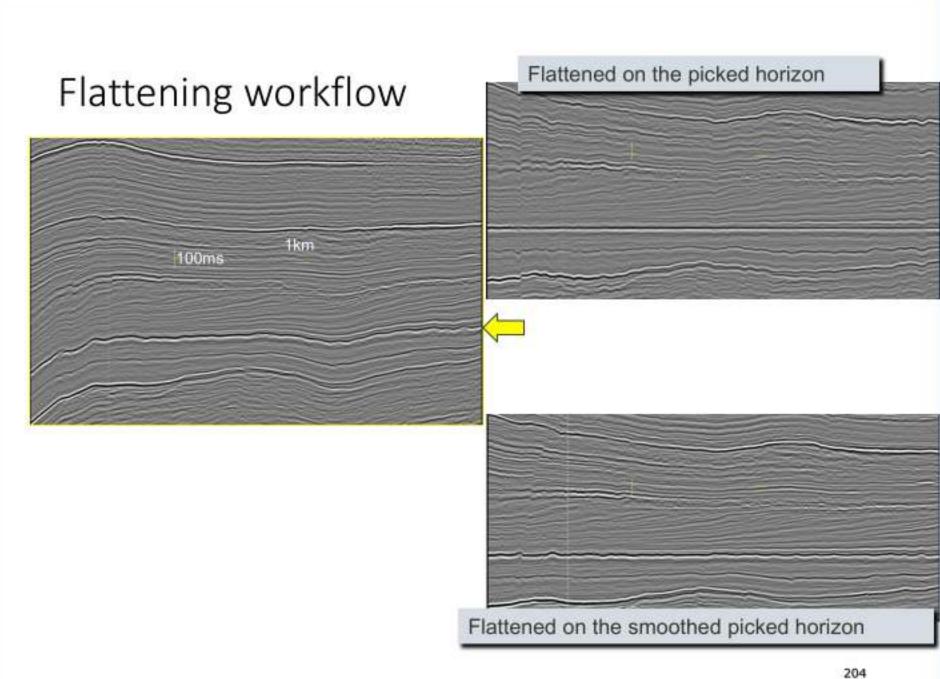
Figure 10

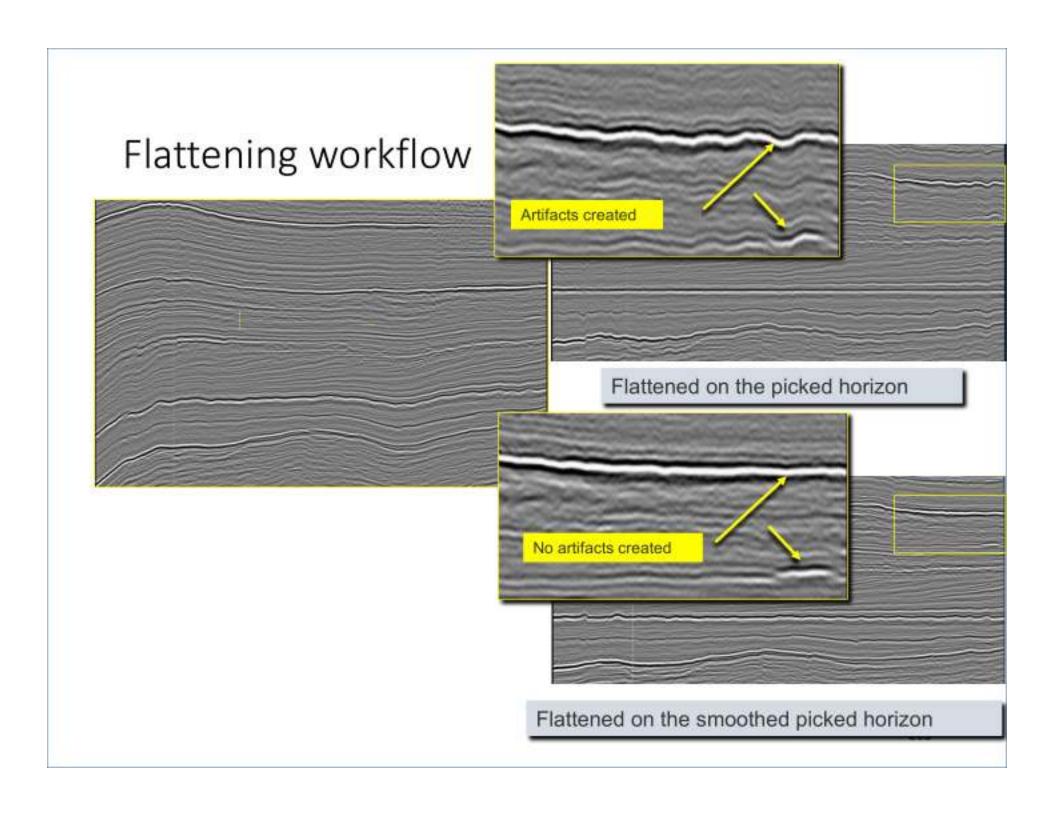
Flattening workflow

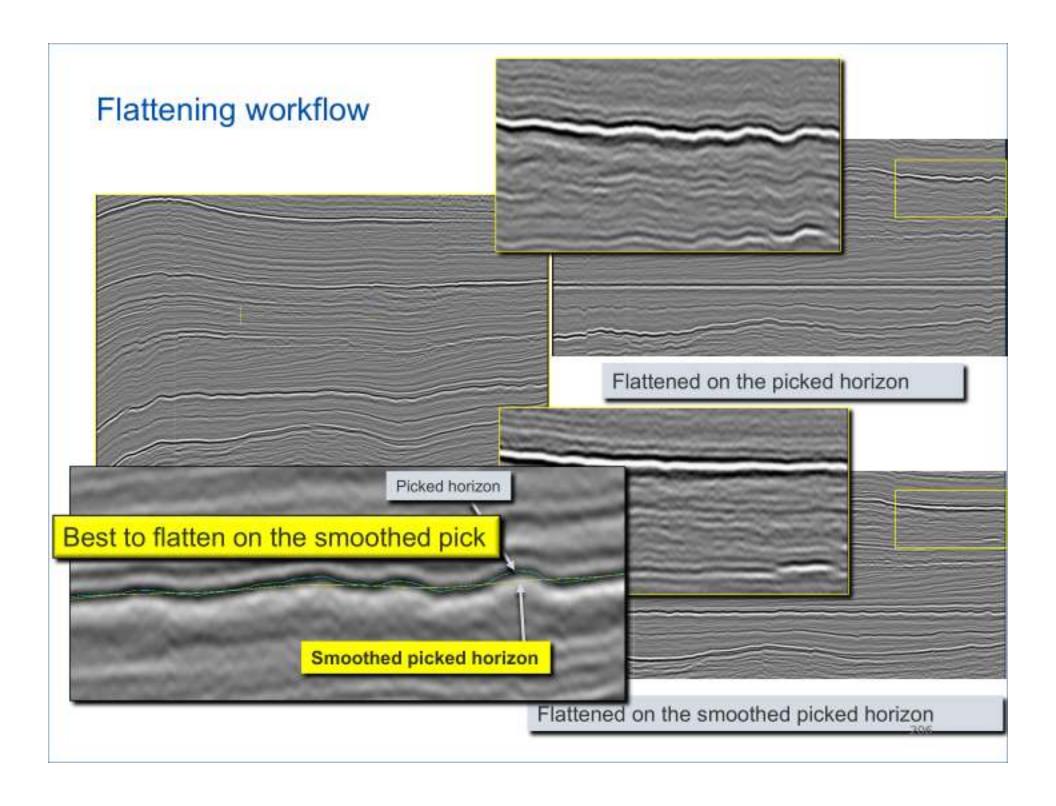


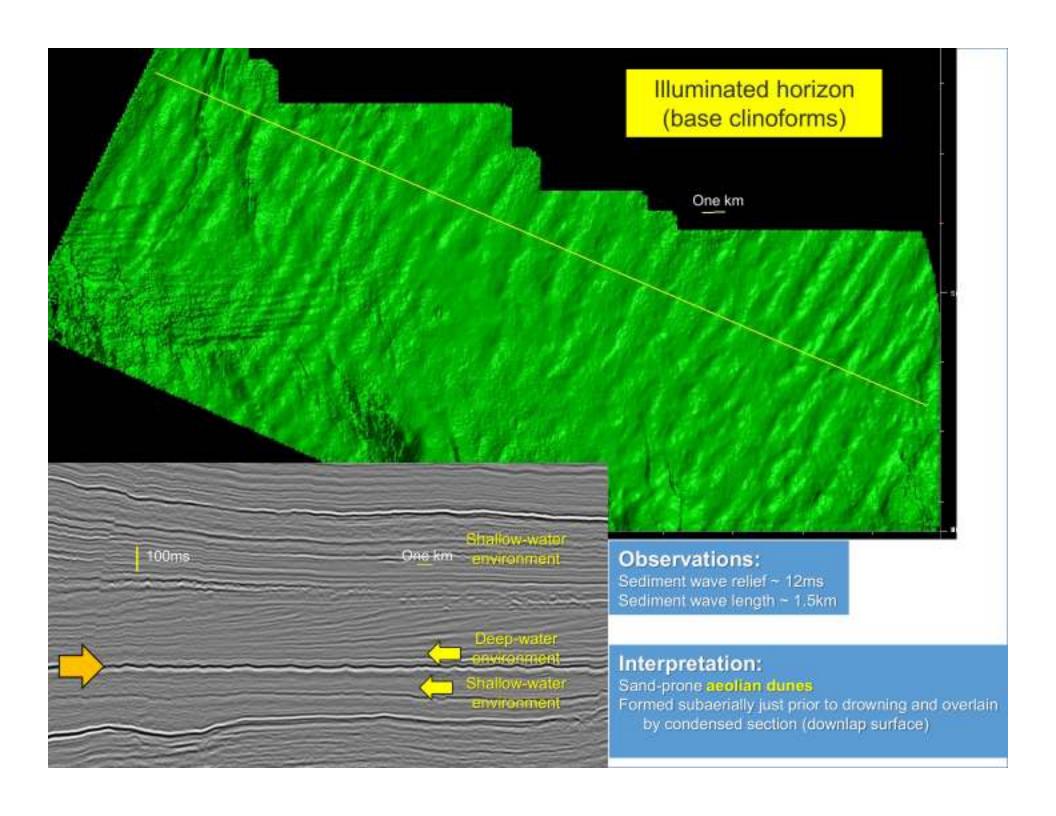
Flattening workflow

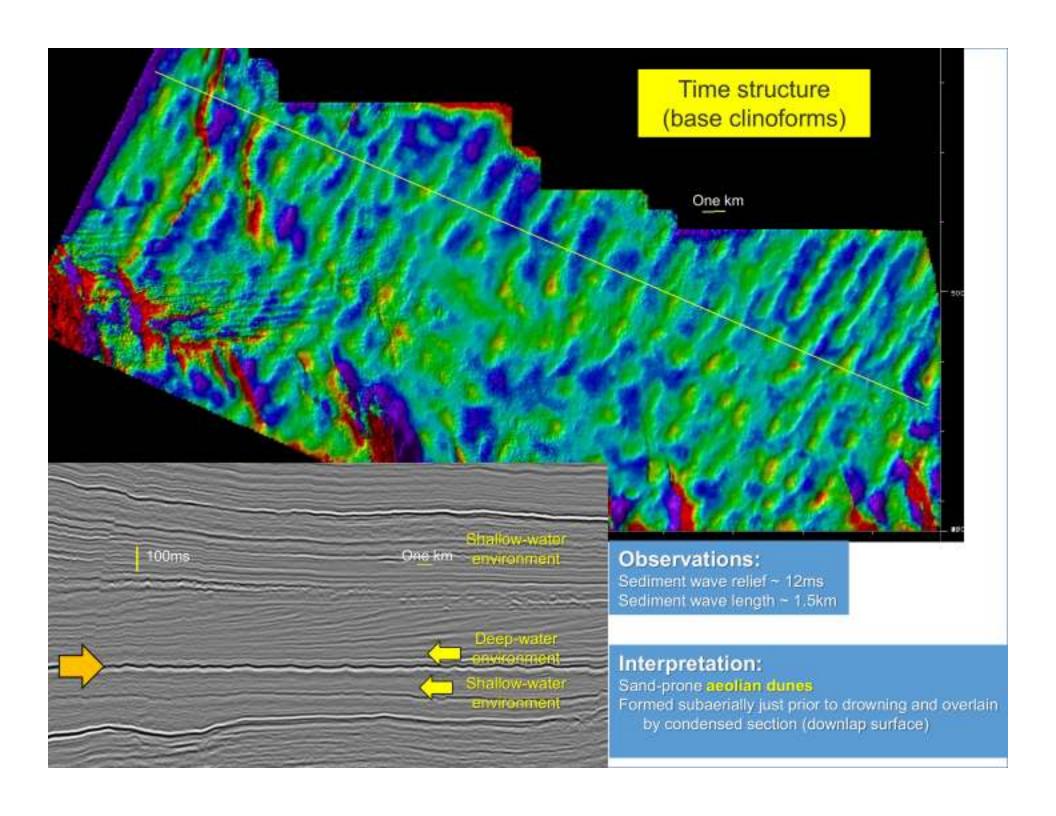


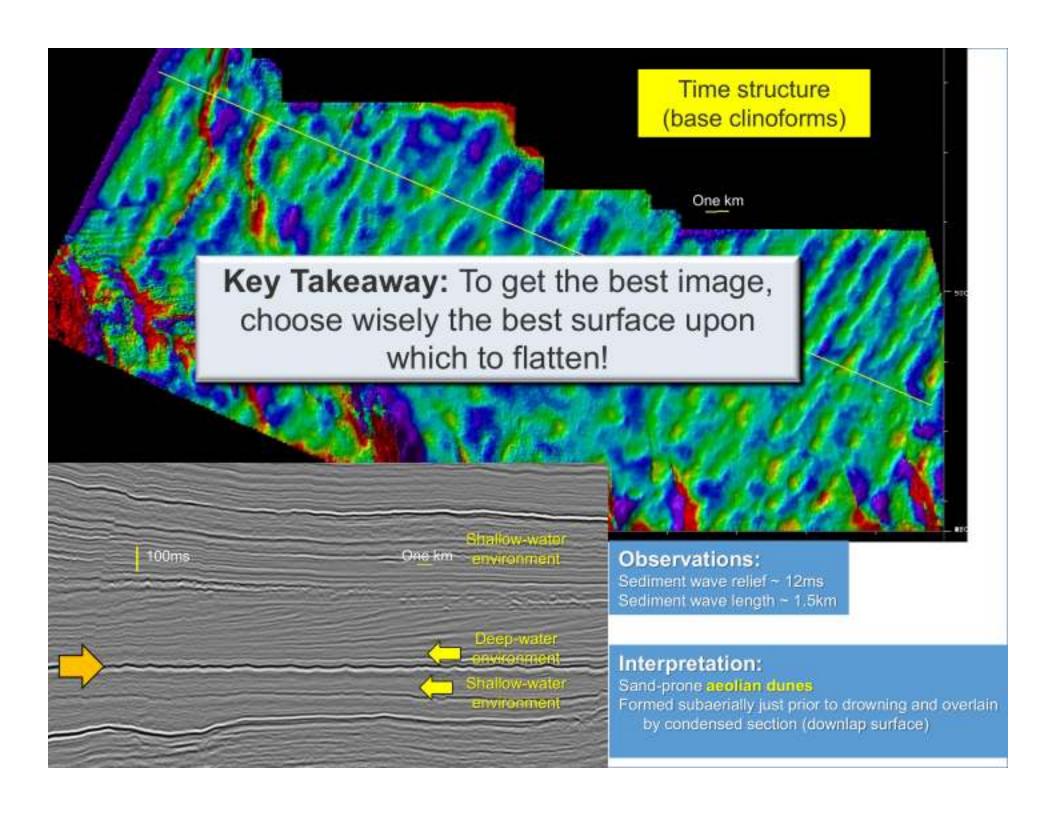


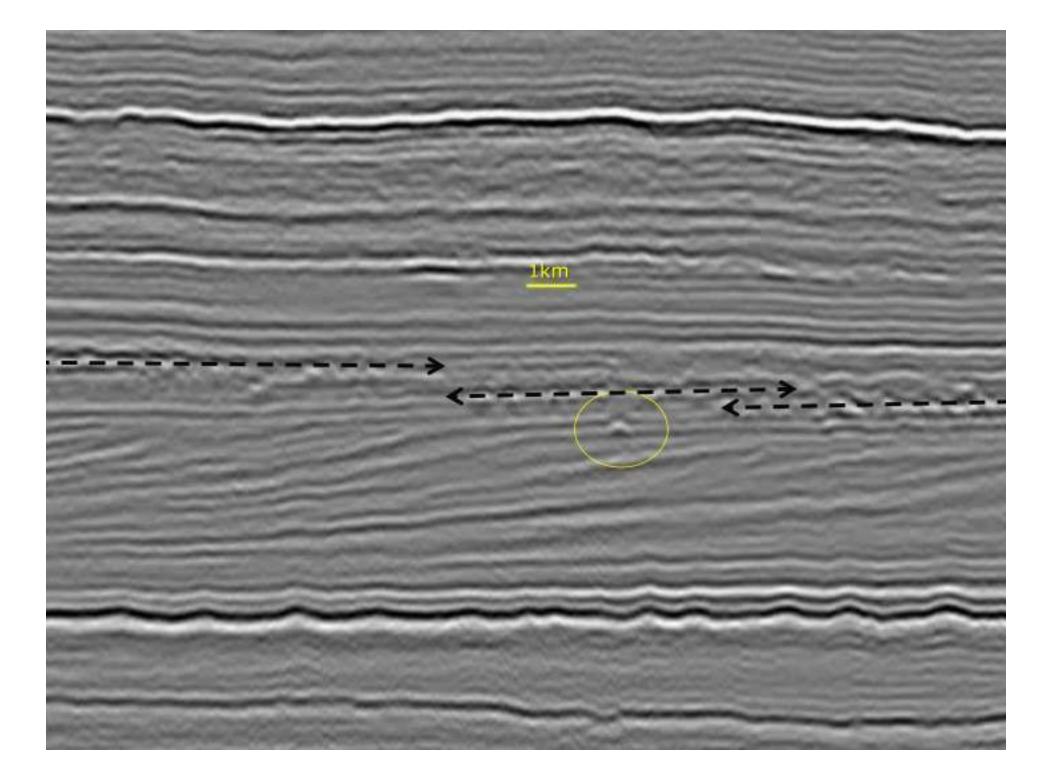


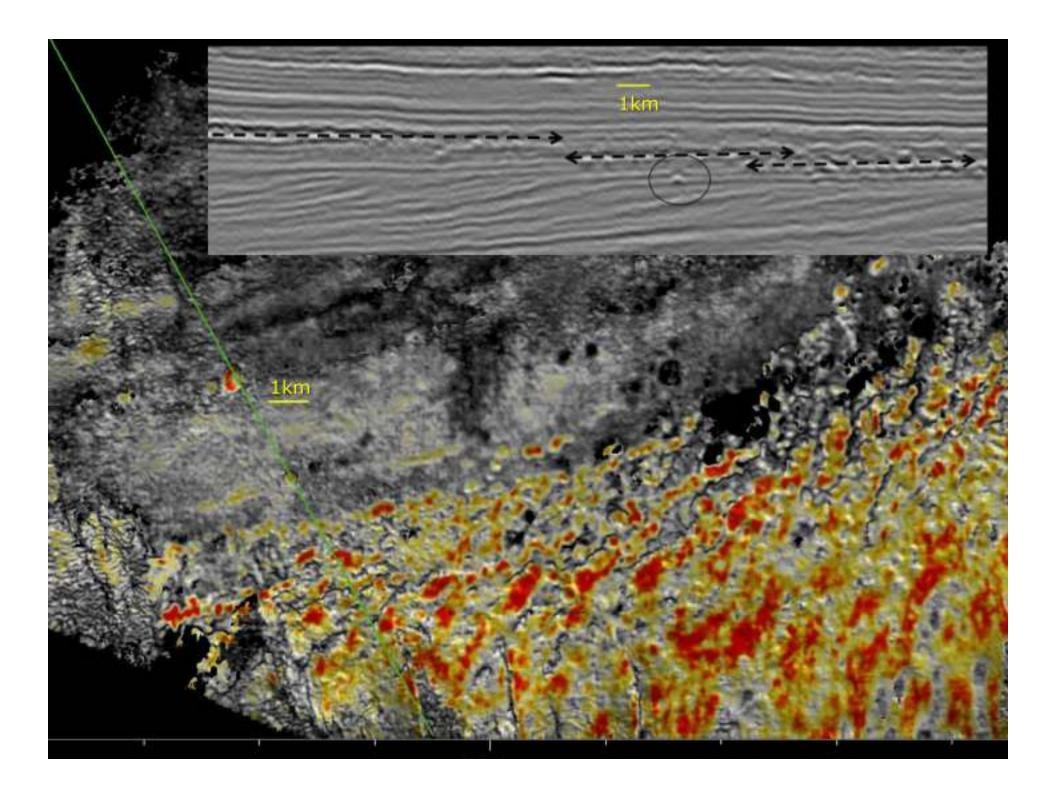


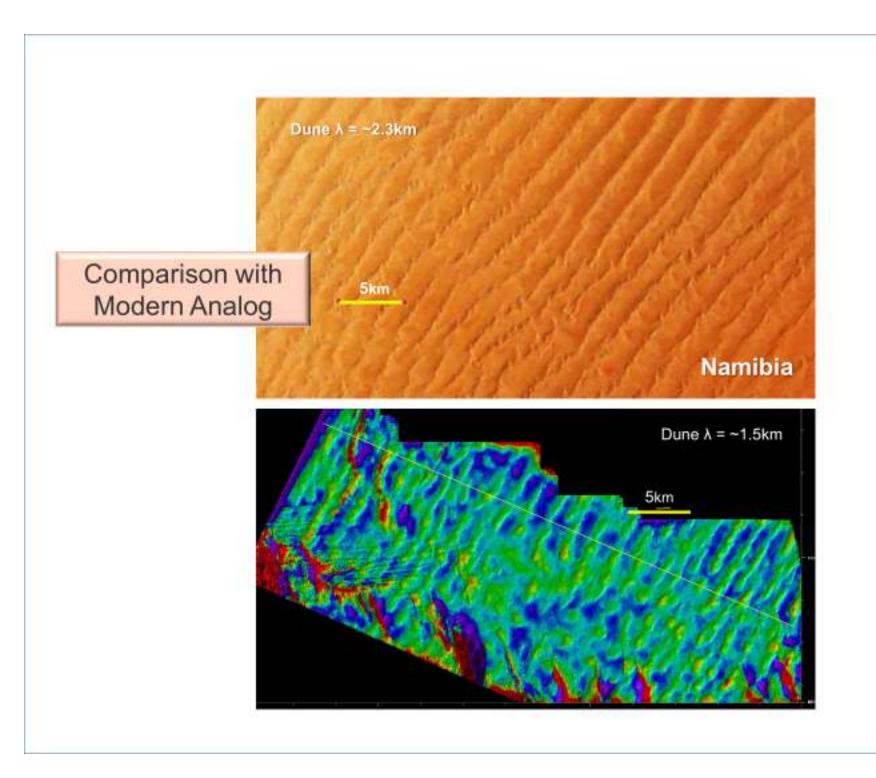




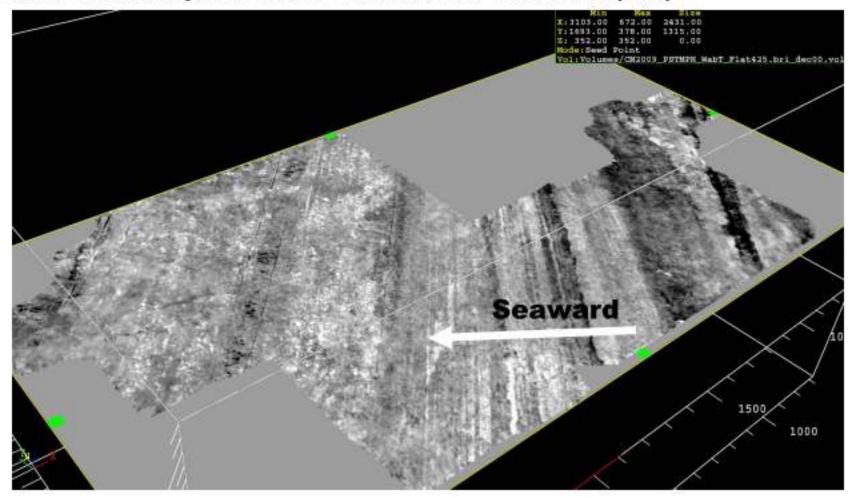


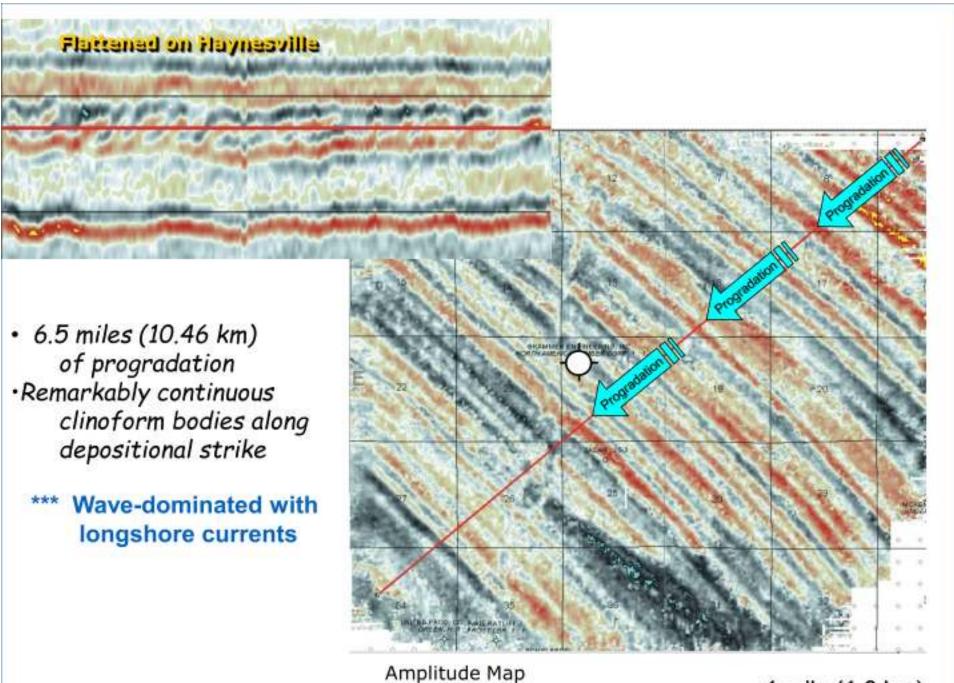






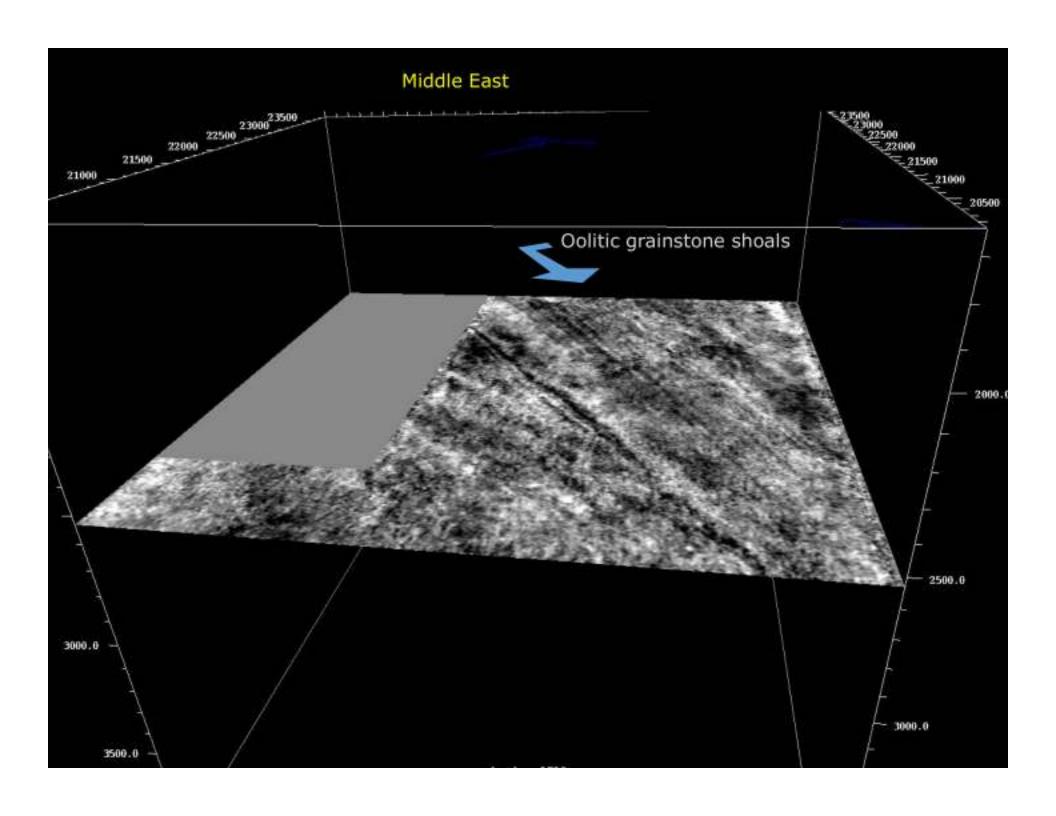
Flattened time slice showing strand plain deposits of the Lower Grand Rapids. Volume flattened on Wabiskaw (mfs)

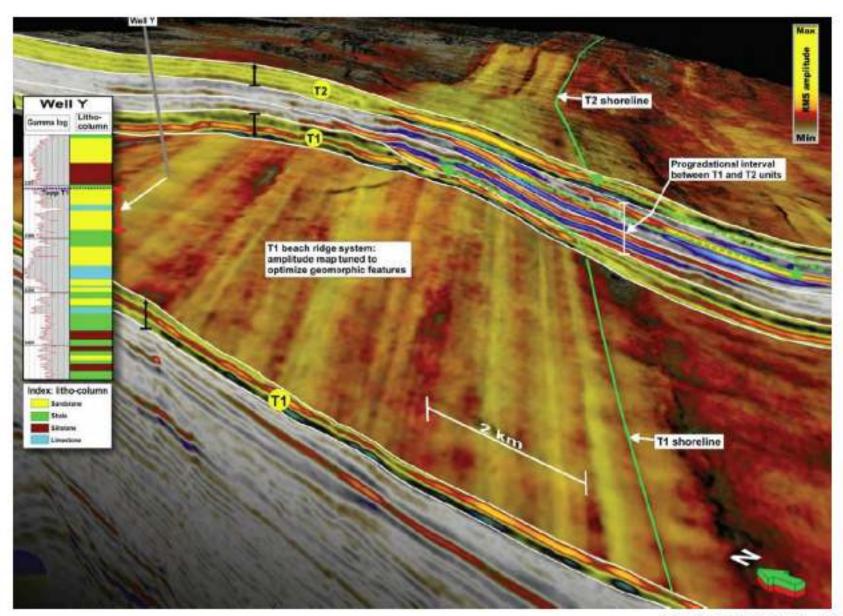




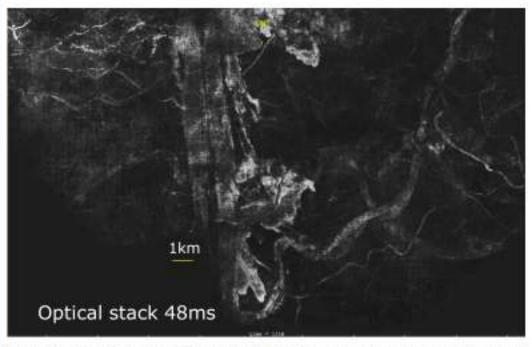
From Handford, 2004

1 mile (1.6 km)

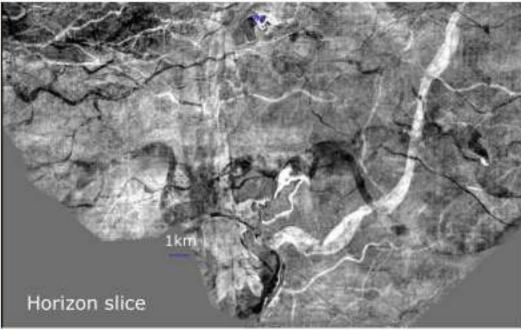


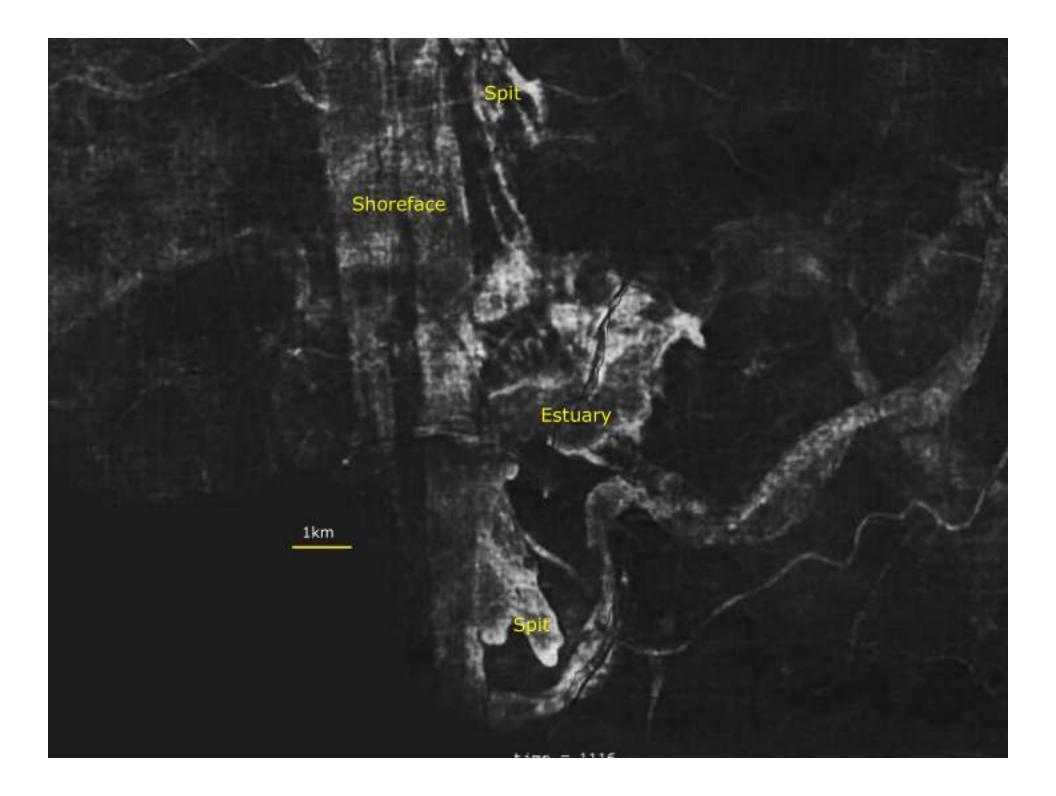


Hadler-Jacobsen et al., 2010



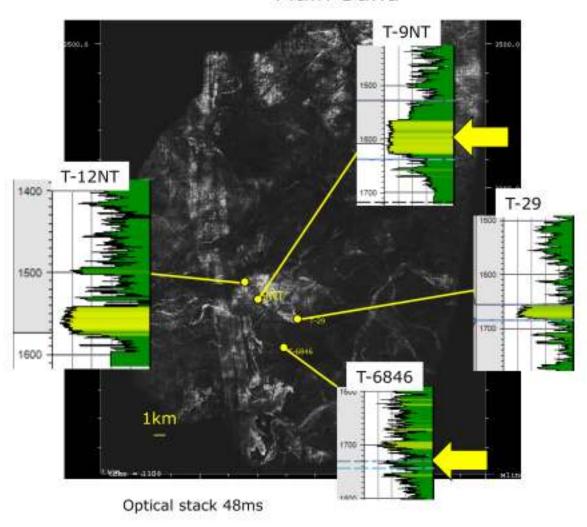
Shoreface and Associated Estuaries





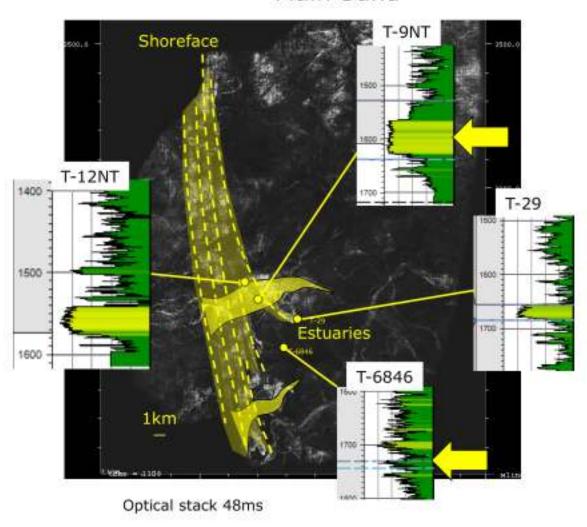
Shoreface and Associated Estuaries

Main Sand



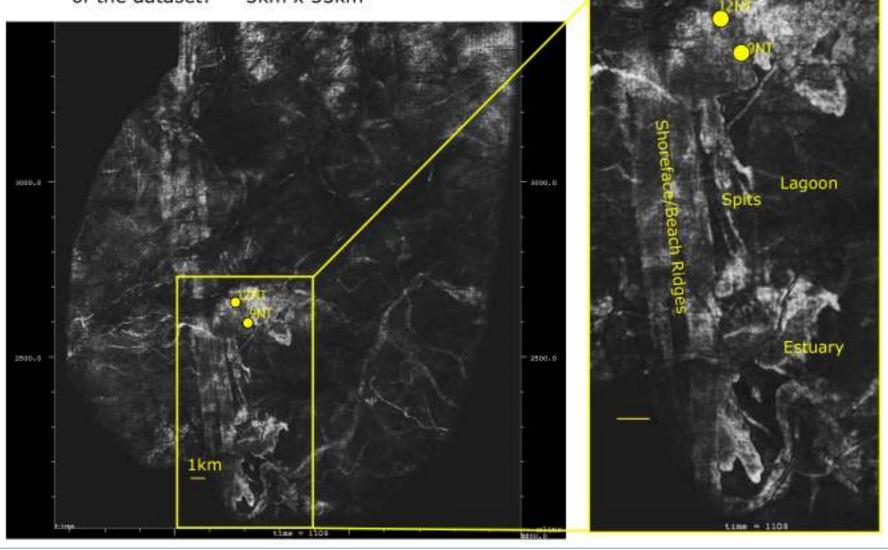
Shoreface and Associated Estuaries

Main Sand



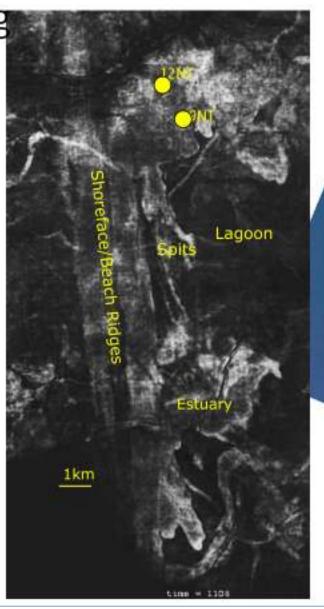
Lower Neocomian Main Sand – Optical Stack

Note that shoreface extends the length of the dataset: ~3km x 33km



Lower Neocomian Main Sand and Modern

Analog





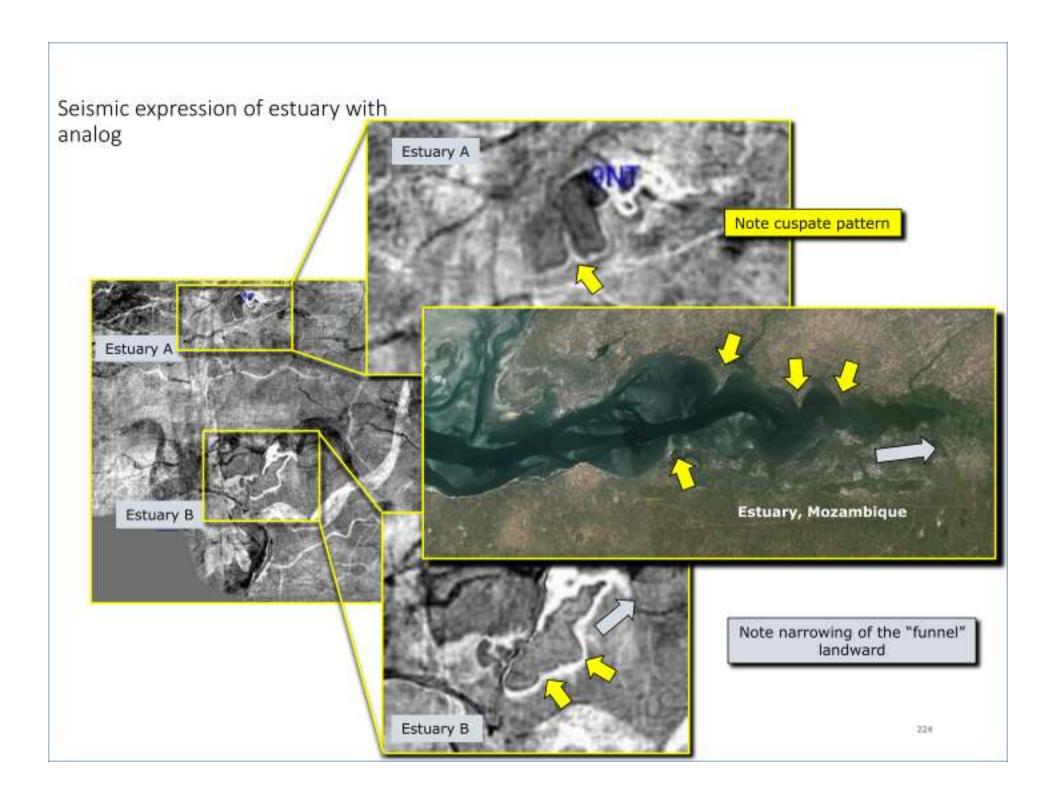
Shoreline of the Zambesi Delta, Mozambique

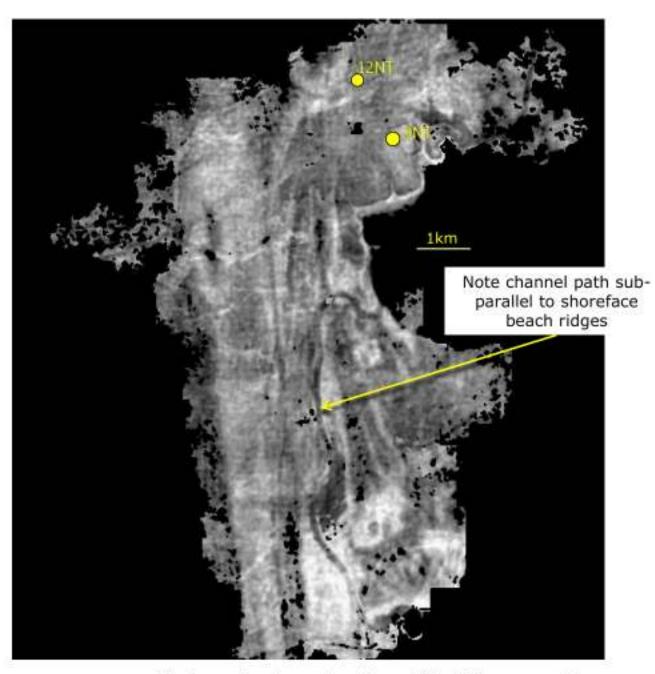
Note that scale is the same

Note that the **estuary is deepest where it crosses the shoreline**; At that location the estuary is narrowed by shoreface/spit growth across the estuary mouth. Flushing into and out of estuary by tidal currents can erode deeply into the substrate

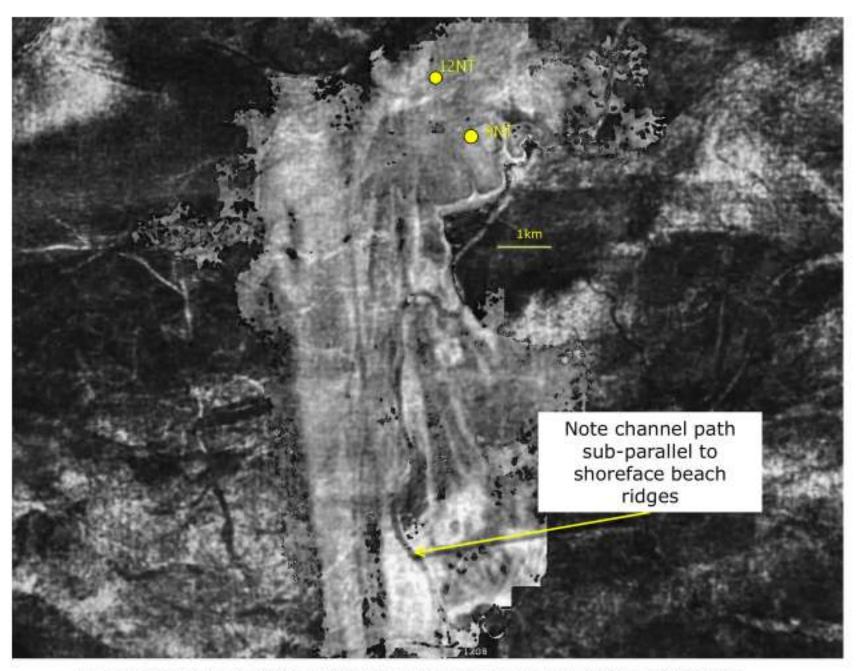


Modern estuary - Gulf of Carpentaria, Australia

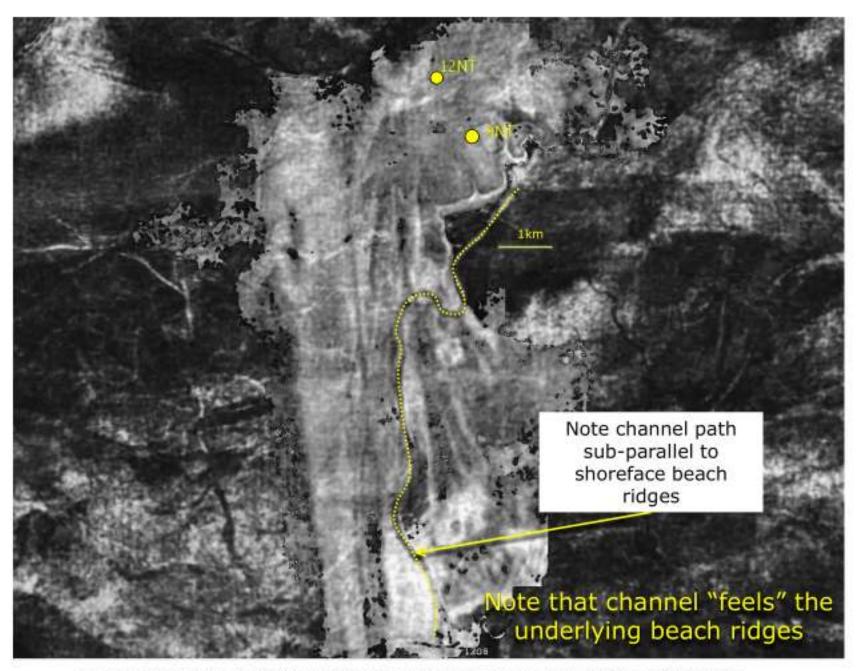




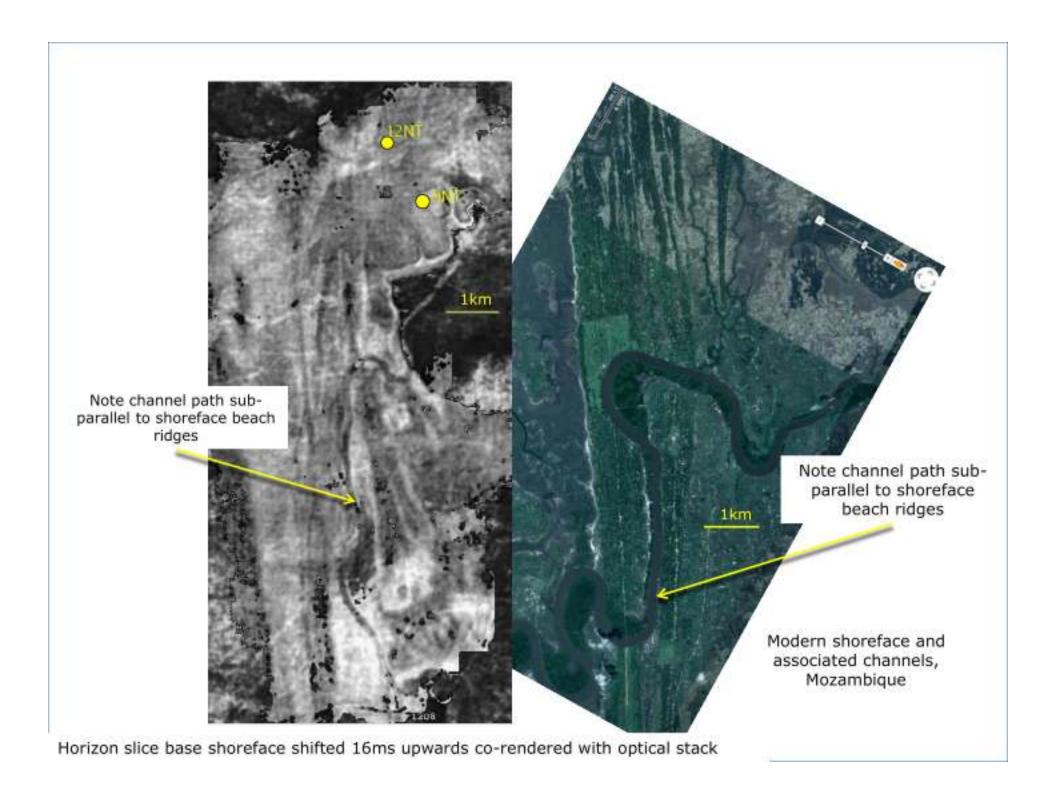
Horizon slice base shoreface shifted 16ms upwards

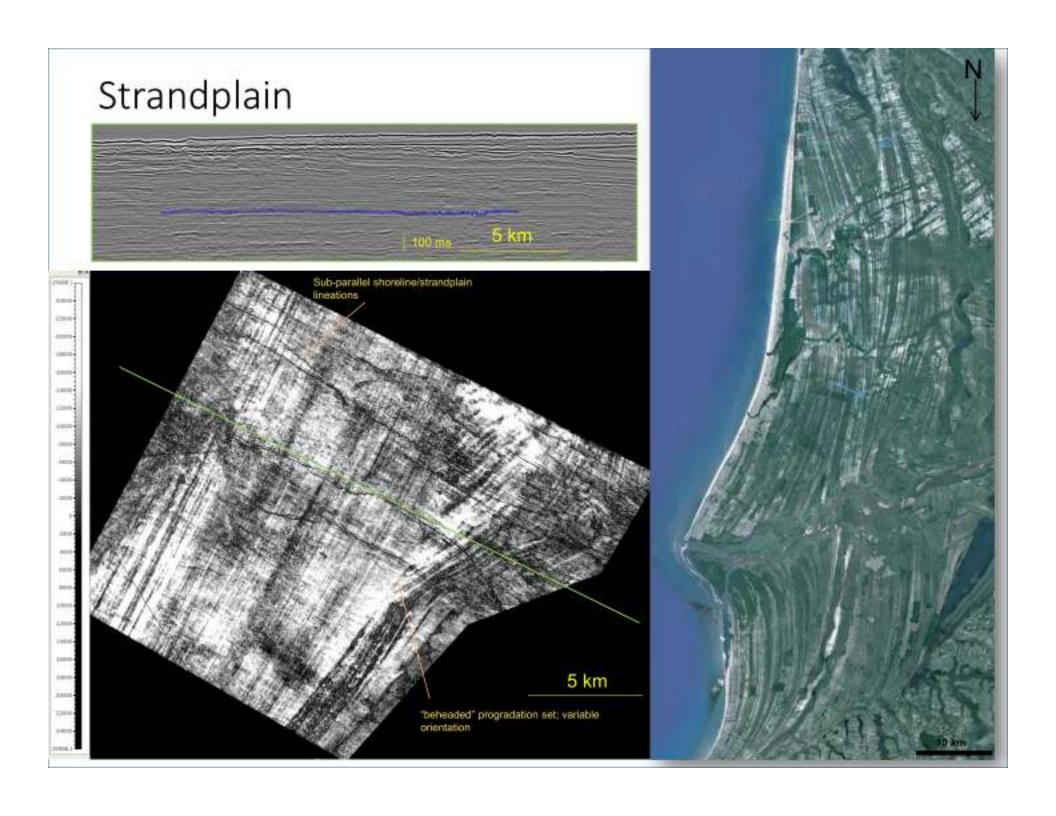


Horizon slice base shoreface shifted 16ms upwards co-rendered with optical stack

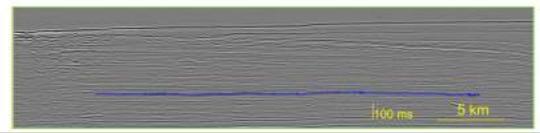


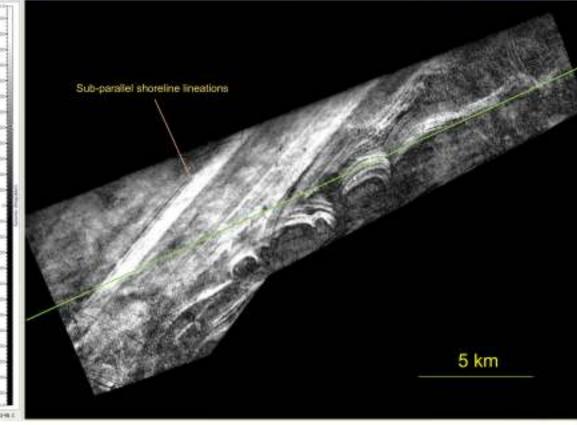
Horizon slice base shoreface shifted 16ms upwards co-rendered with optical stack





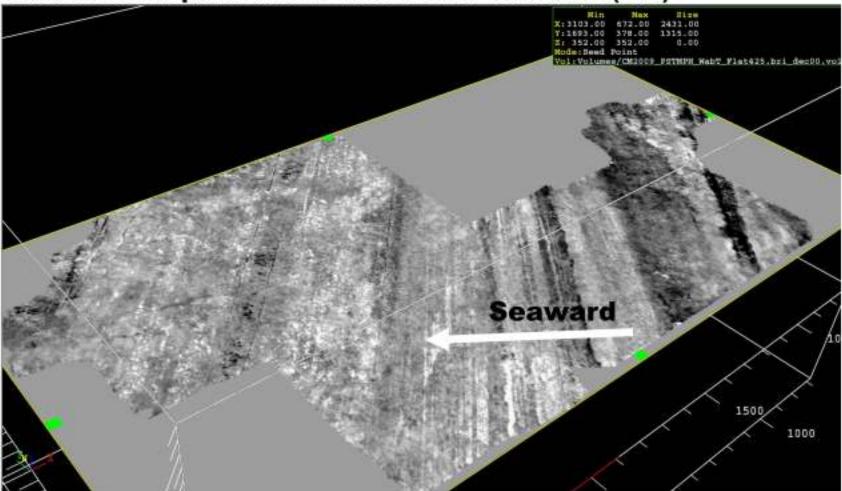
Strandplain

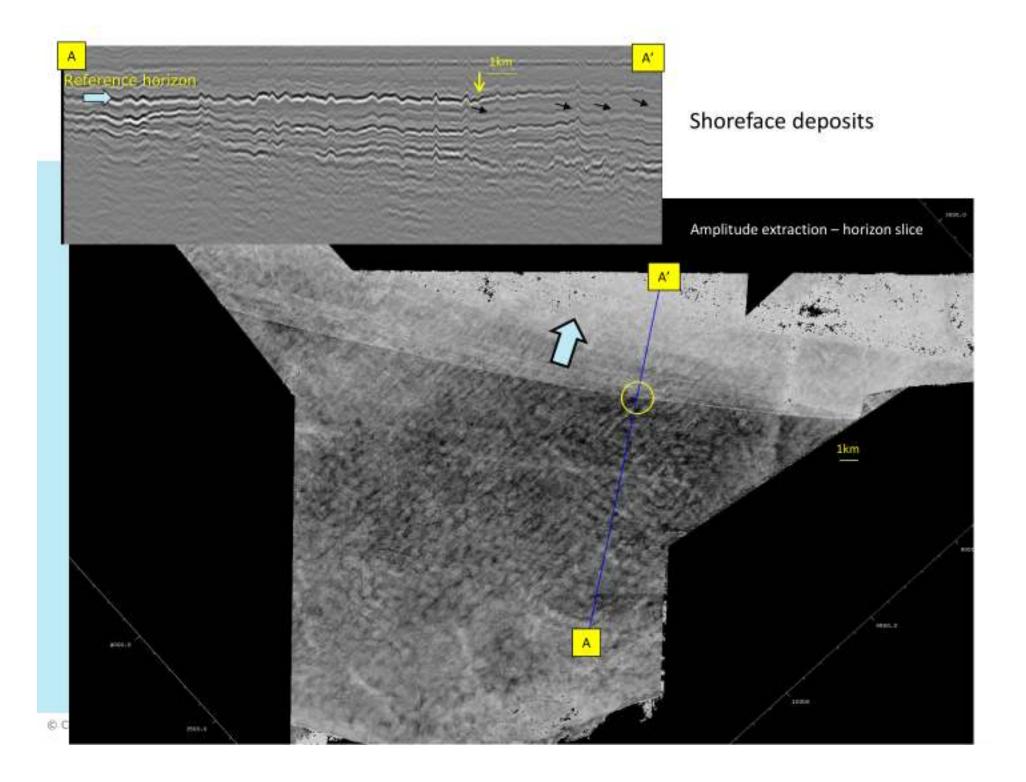


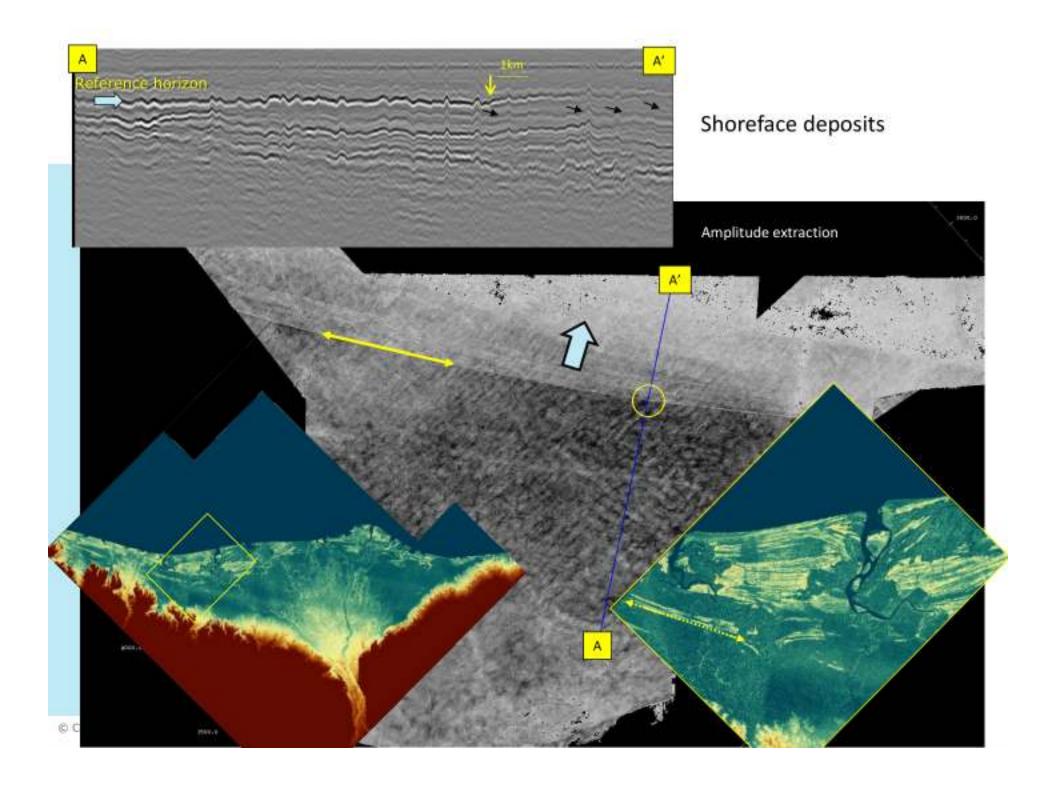


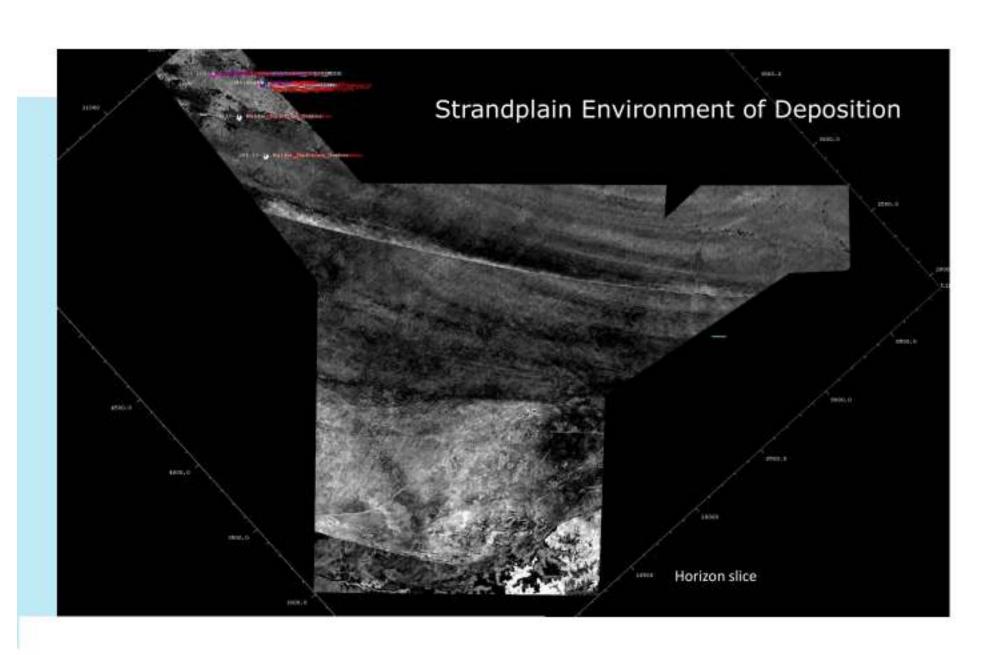


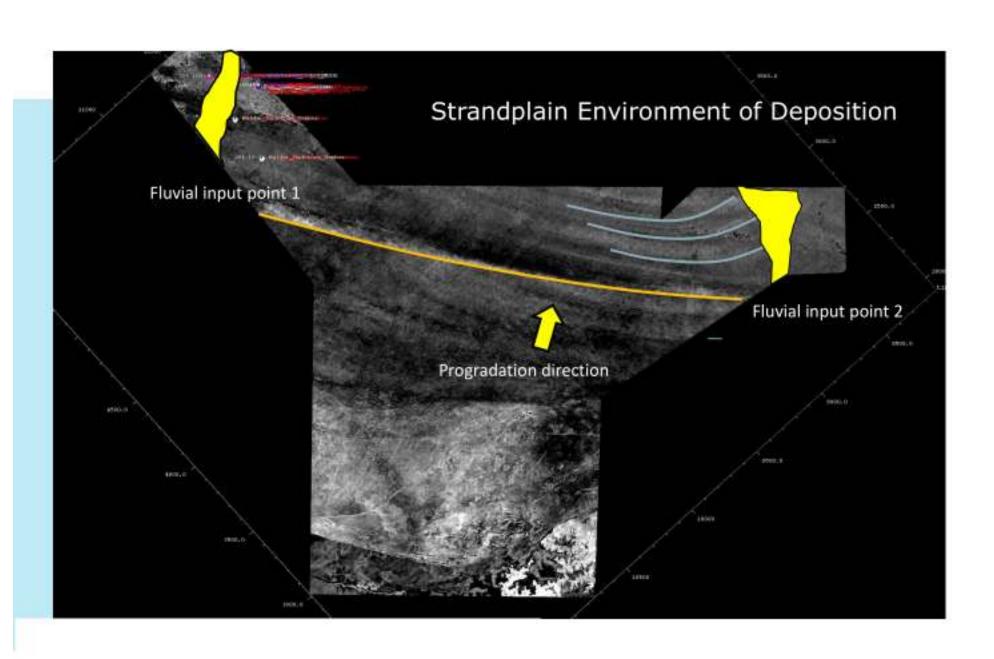
Flattened time slice showing strand plain deposits of the Lower Grand Rapids. Volume flattened on Wabiskaw (mfs)



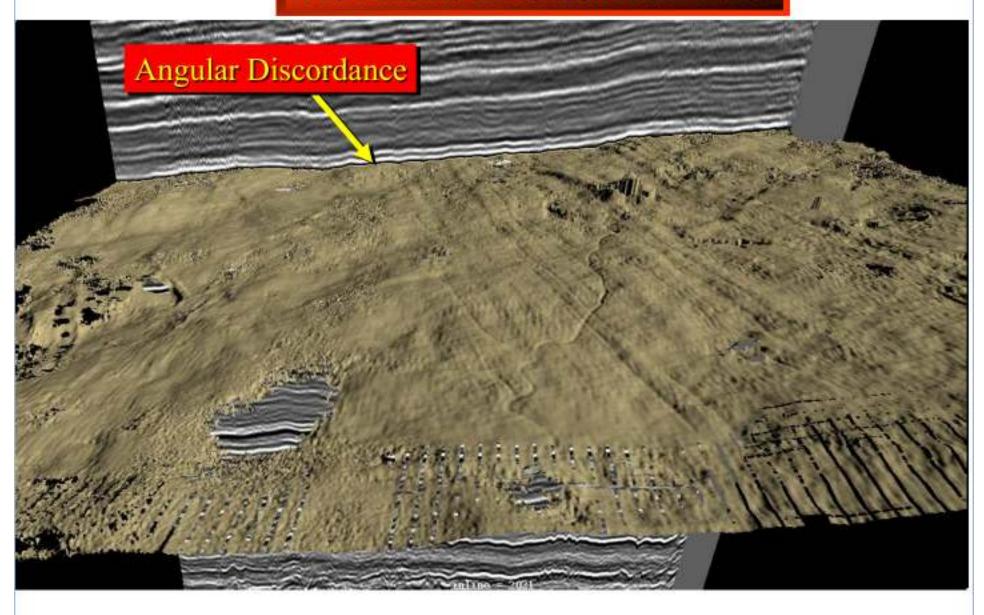




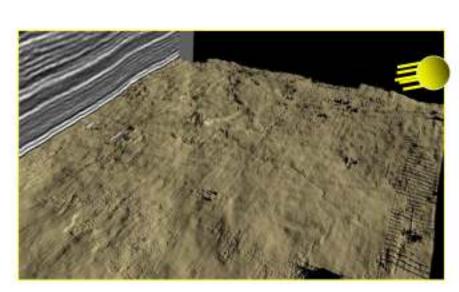




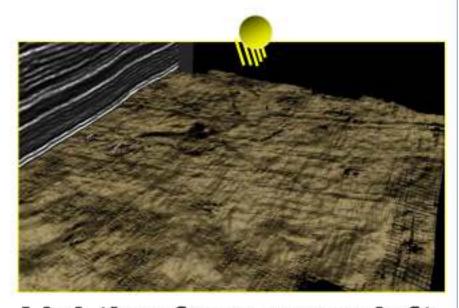
The Benefits of Horizon Illumination



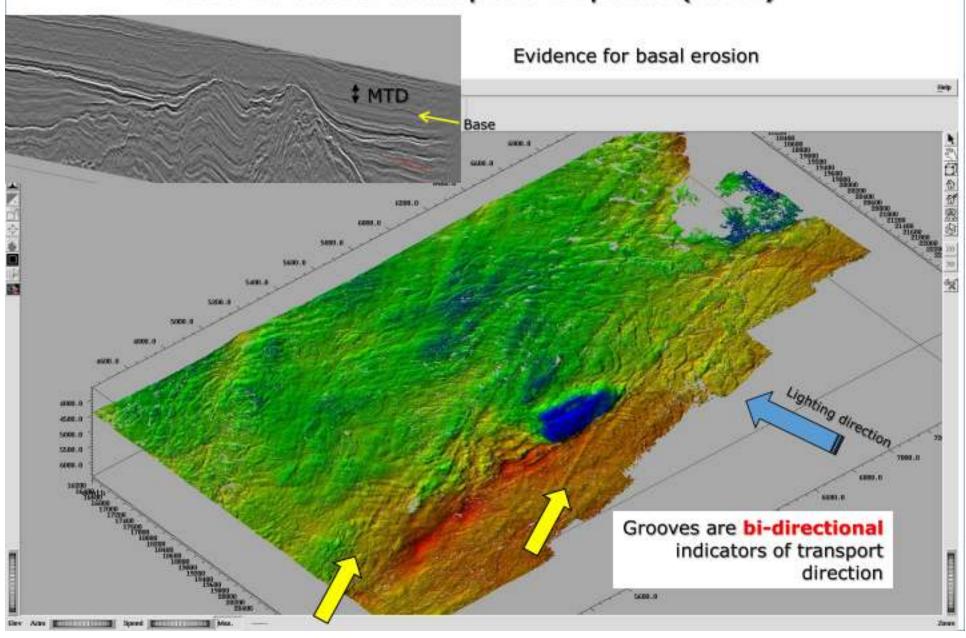
The Effect of Lighting Direction



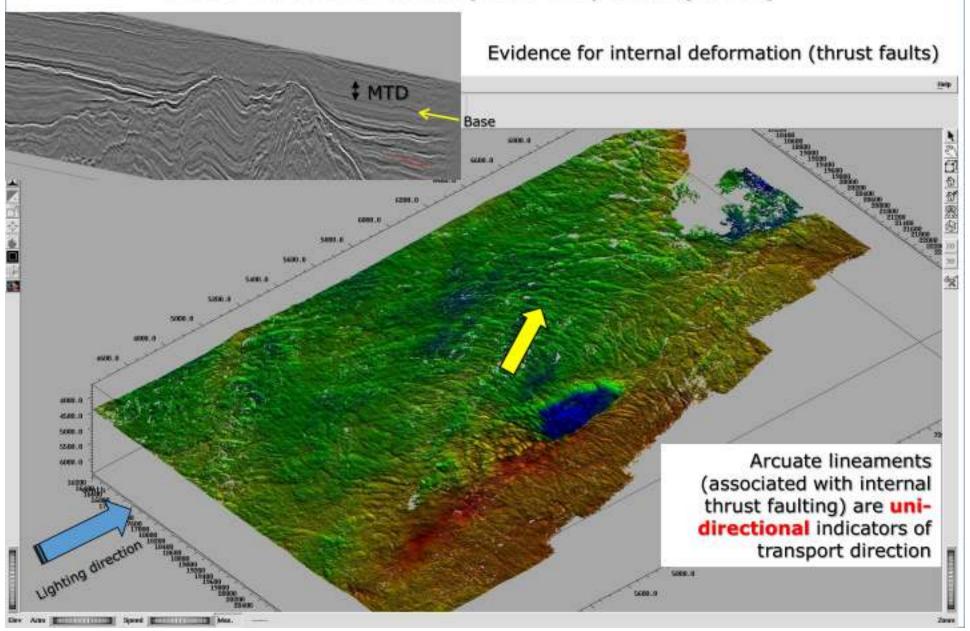
Lighting from upper right Lighting from upper left



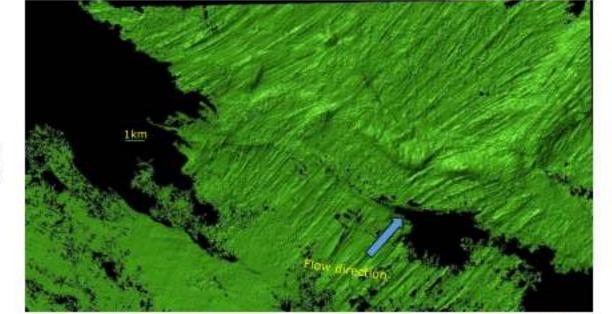
Base of Mass Transport Deposit (MTD)



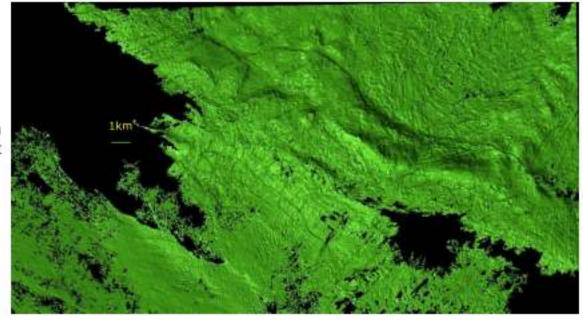
Base of Mass Transport Deposit (MTD)



Basal Grooves MTD - Brazil

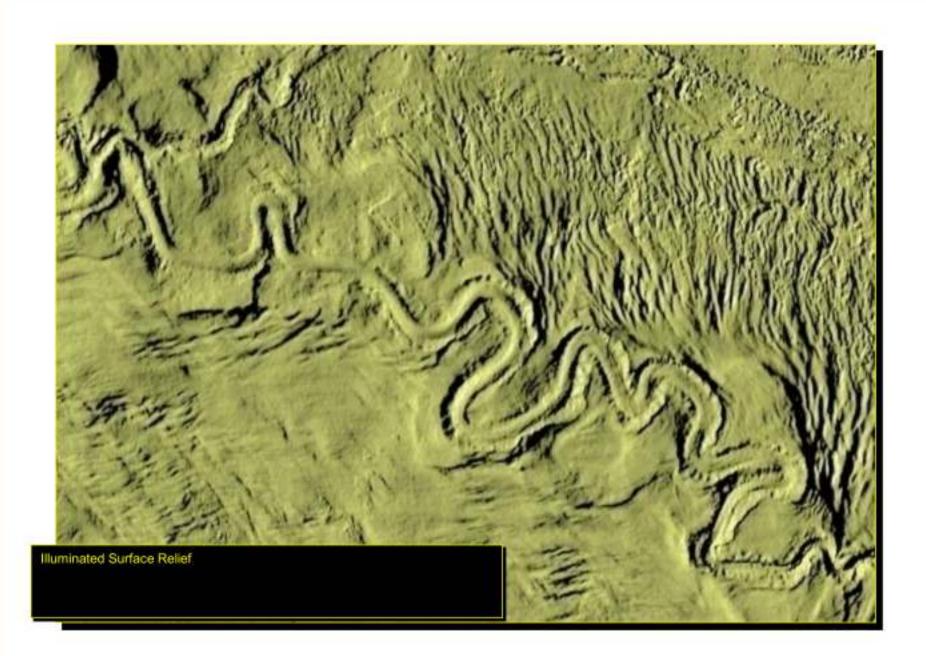


Lighting from lower right



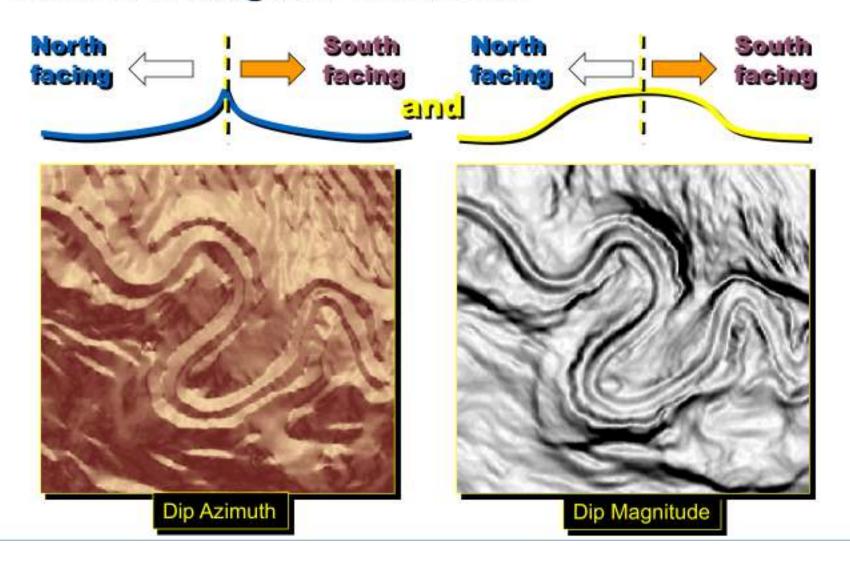
Lighting from lower left

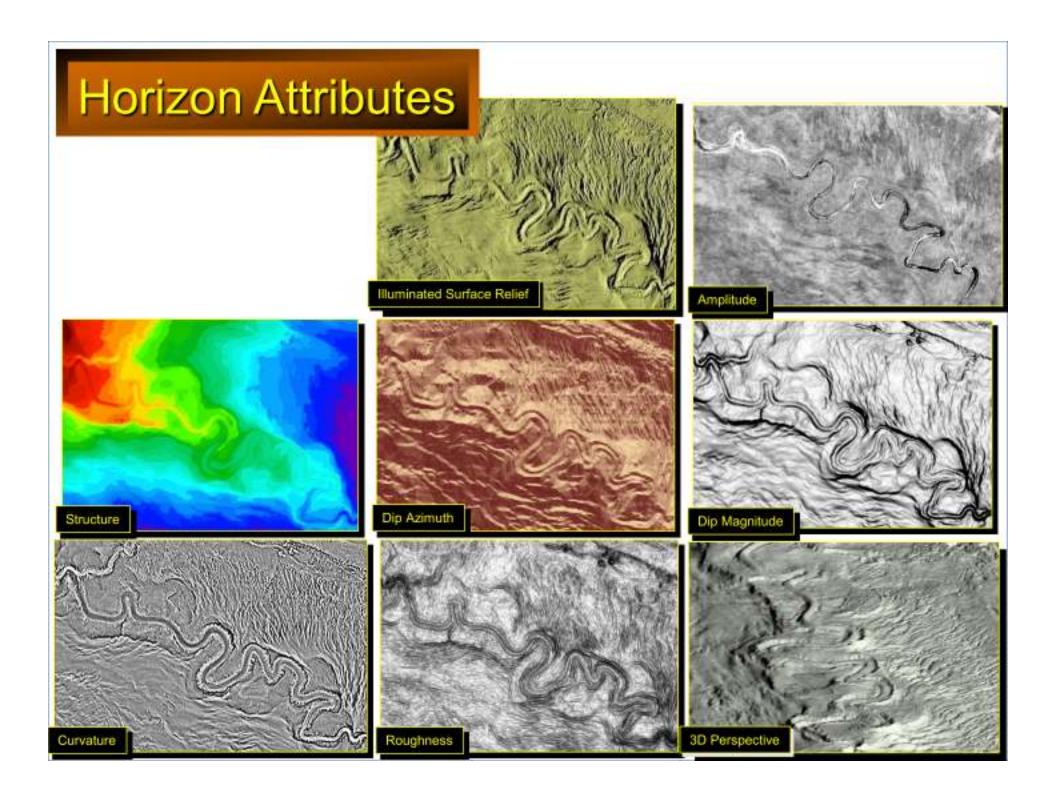
Horizon Attributes Structure

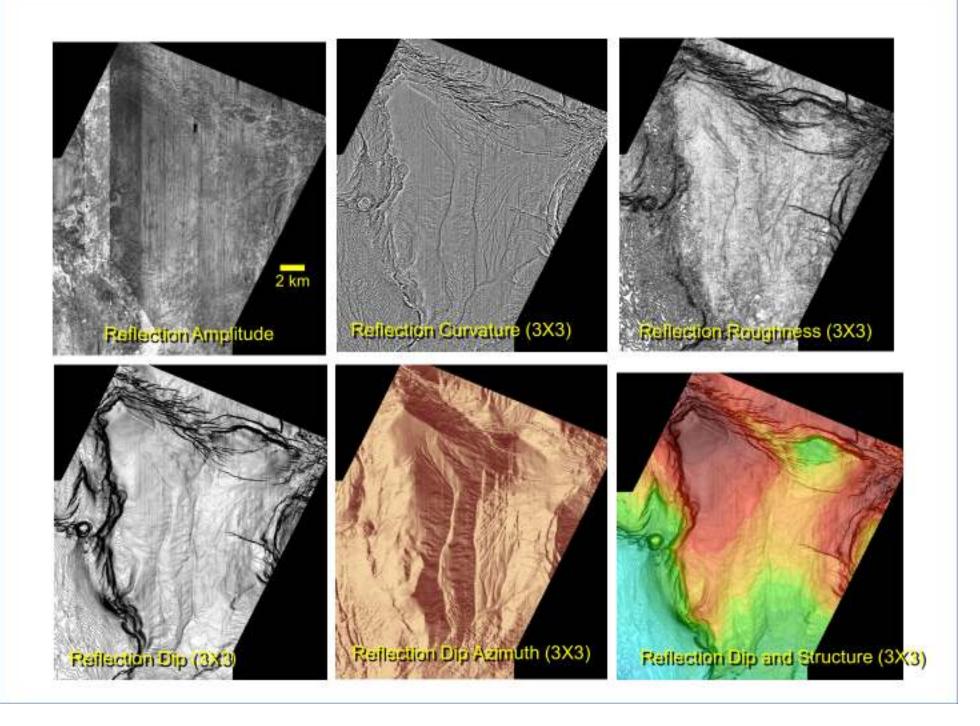


... a word about dip azimuth

Cannot distinguish between...

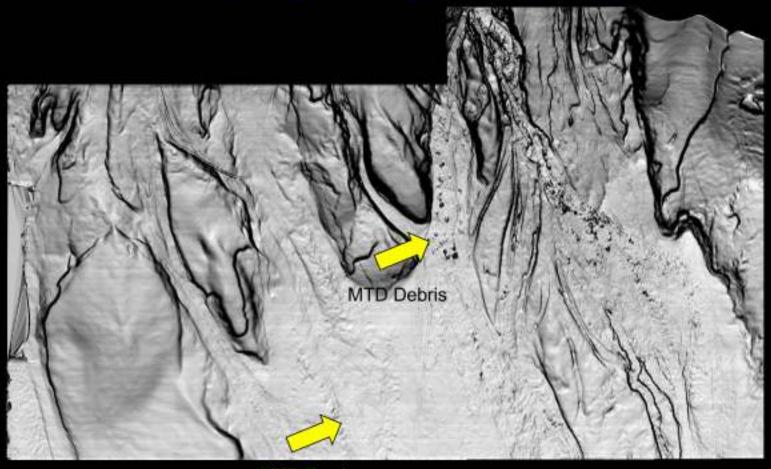






Horizon Attributes

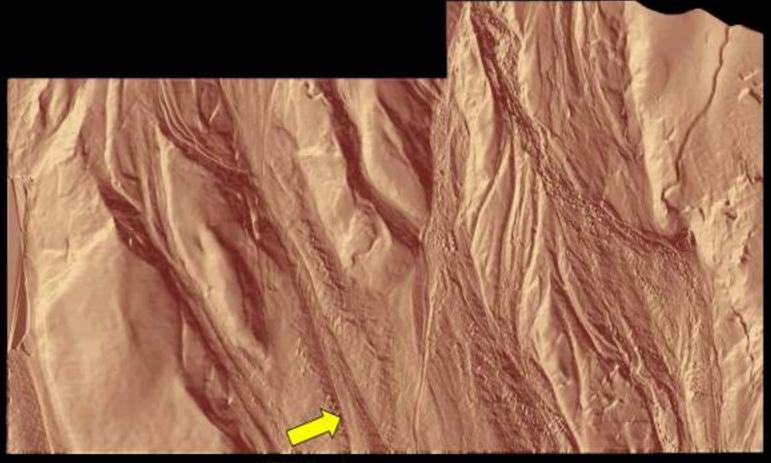
MTD on Slope - Dip Magnitude Attribute



MTD Track

Horizon Attributes

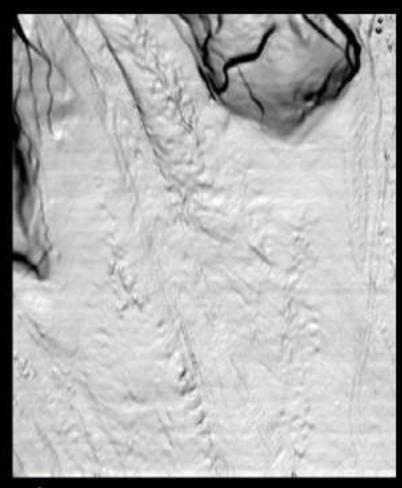
MTD on Slope - Dip Azimuth Attribute



MTD Track

Horizon Attributes

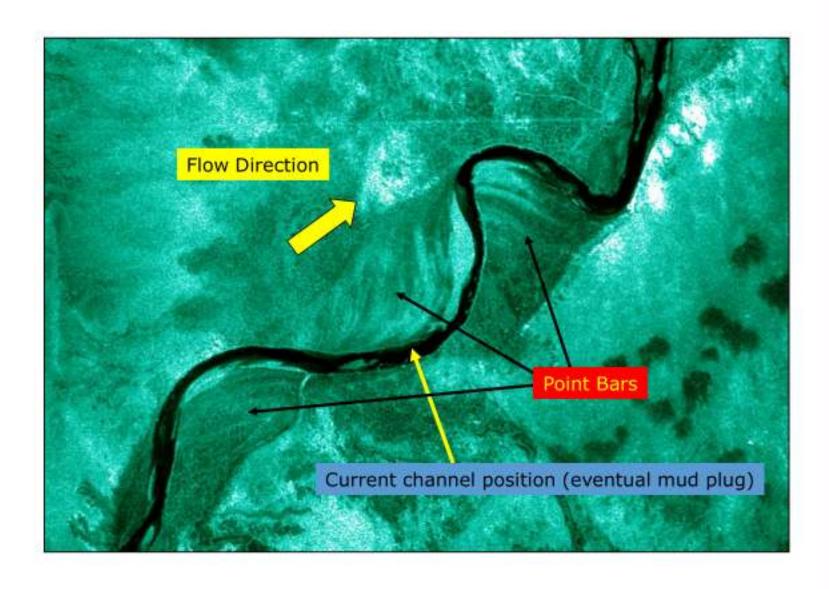
MTD on Slope - Dip Magnitude vs Dip Azimuth Attribute



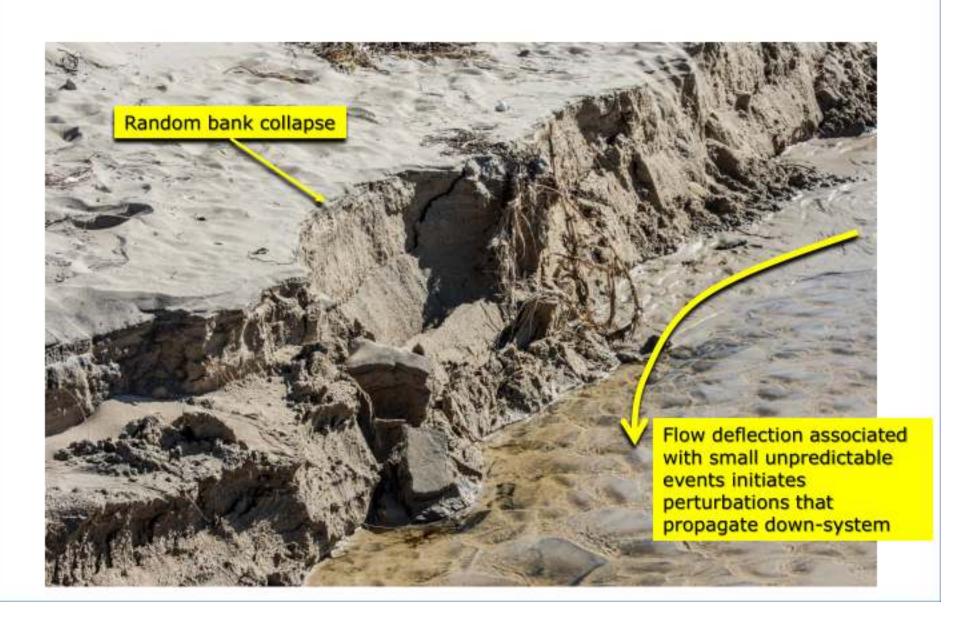




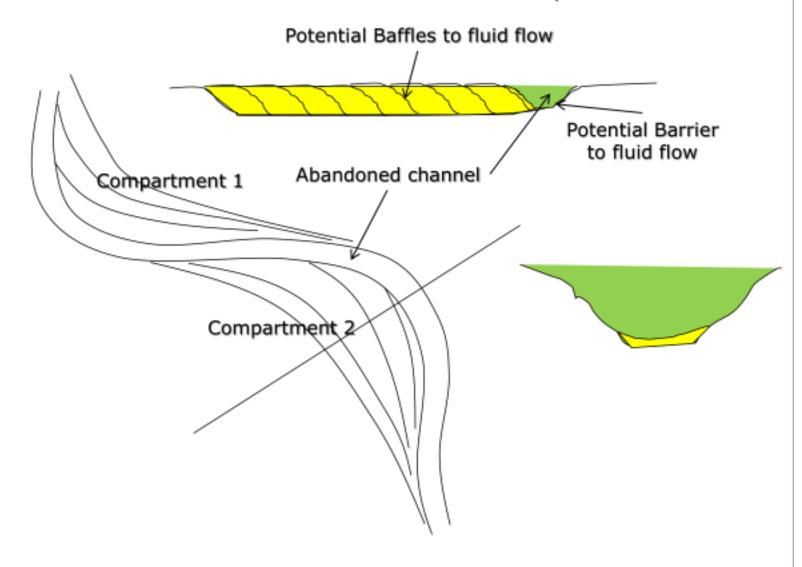
Modern Fluvial Channel - Wyoming



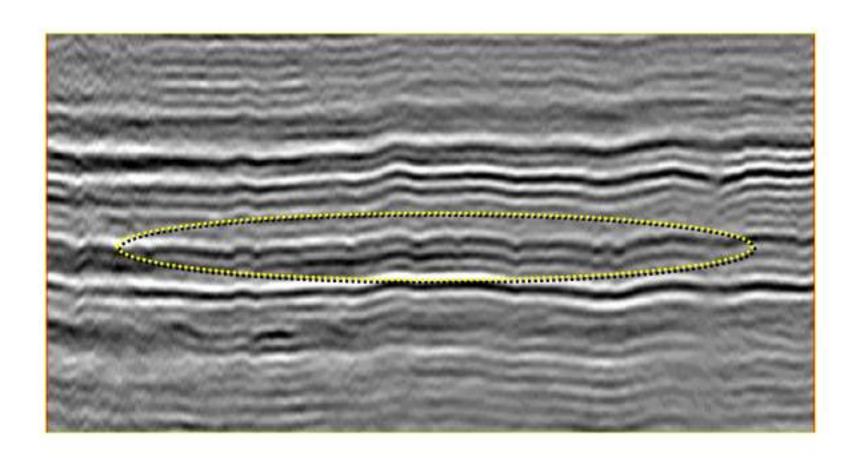
How is River Meandering Initiated

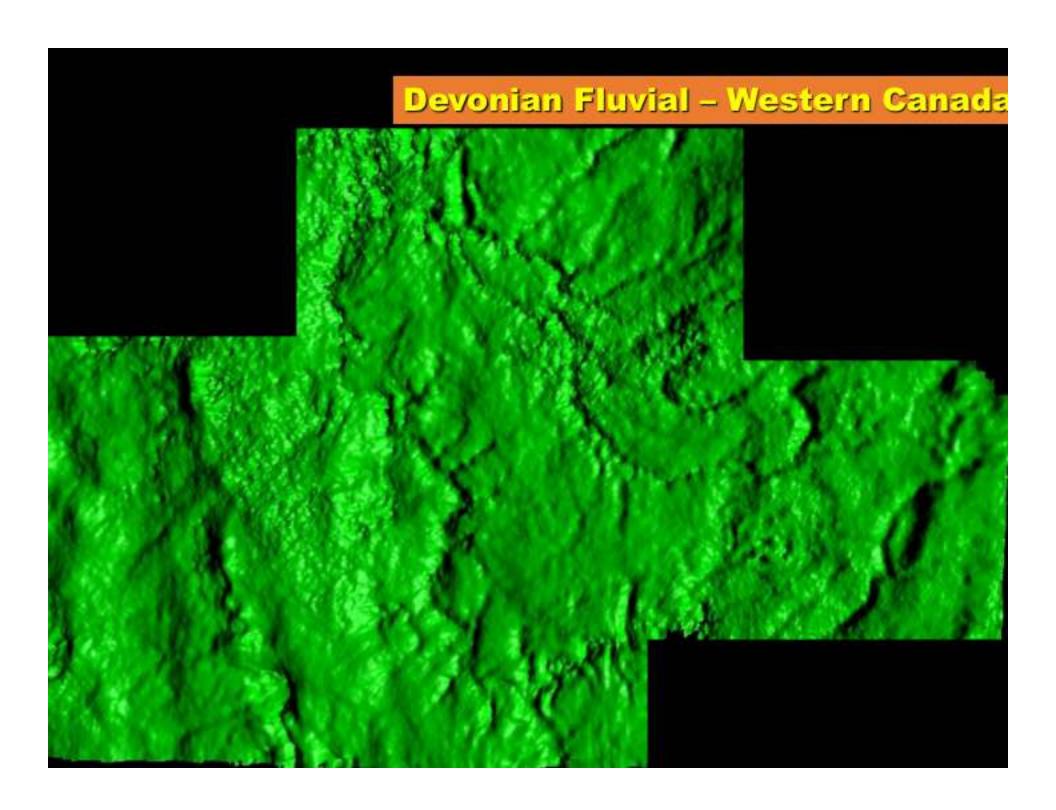


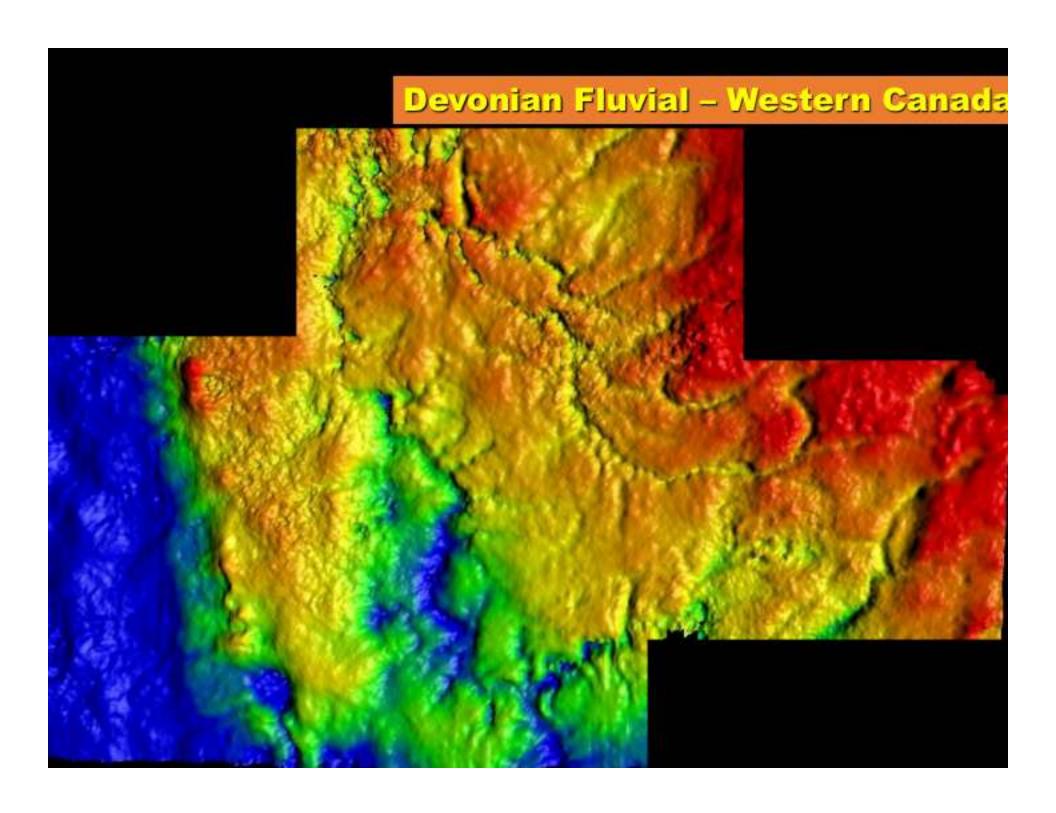
Baffles and Barriers within Fluvial Deposits

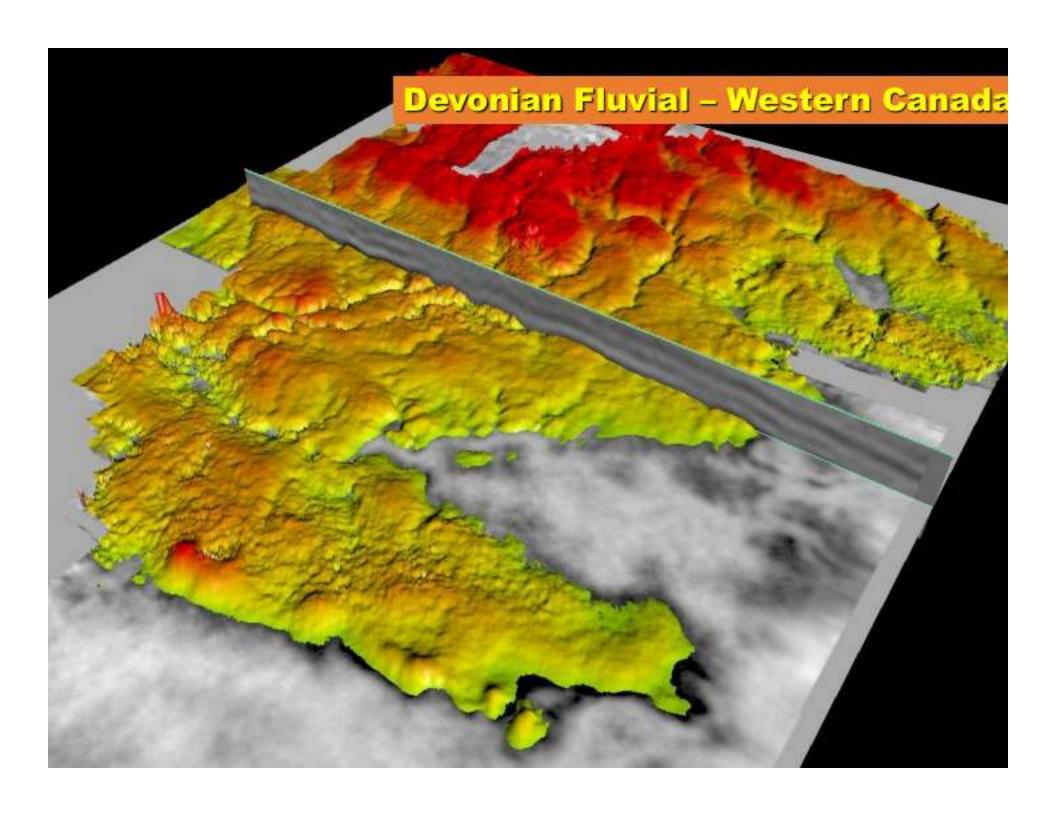


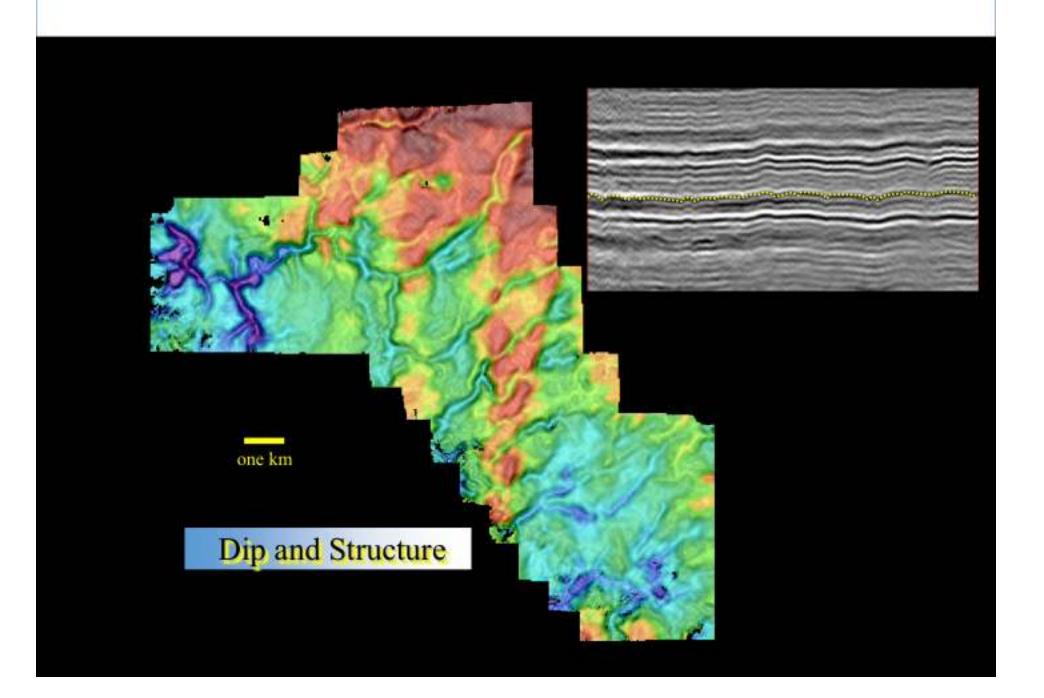
Can you identify the fluvial system?

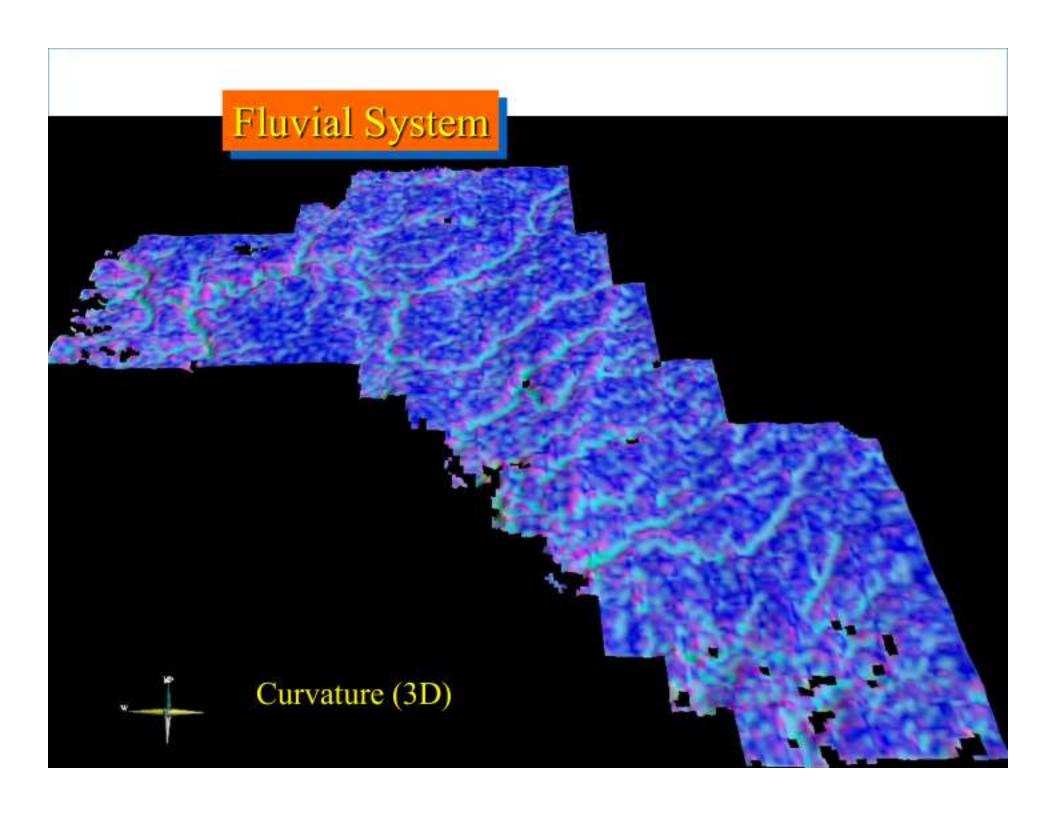


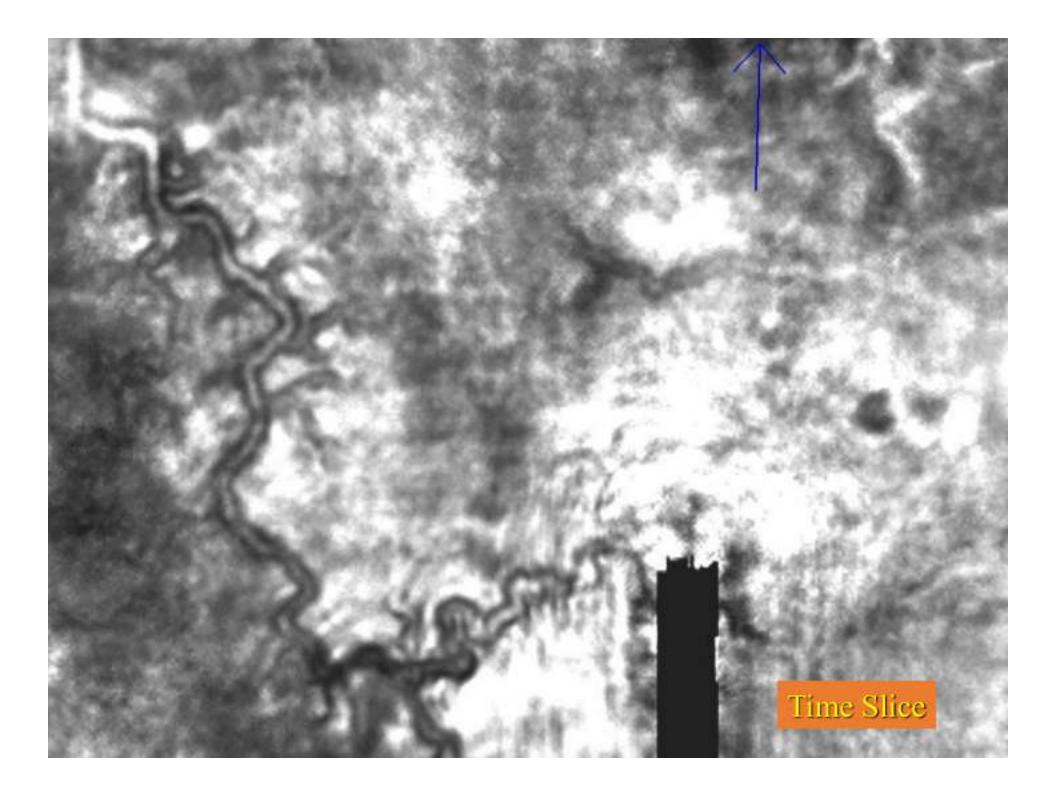


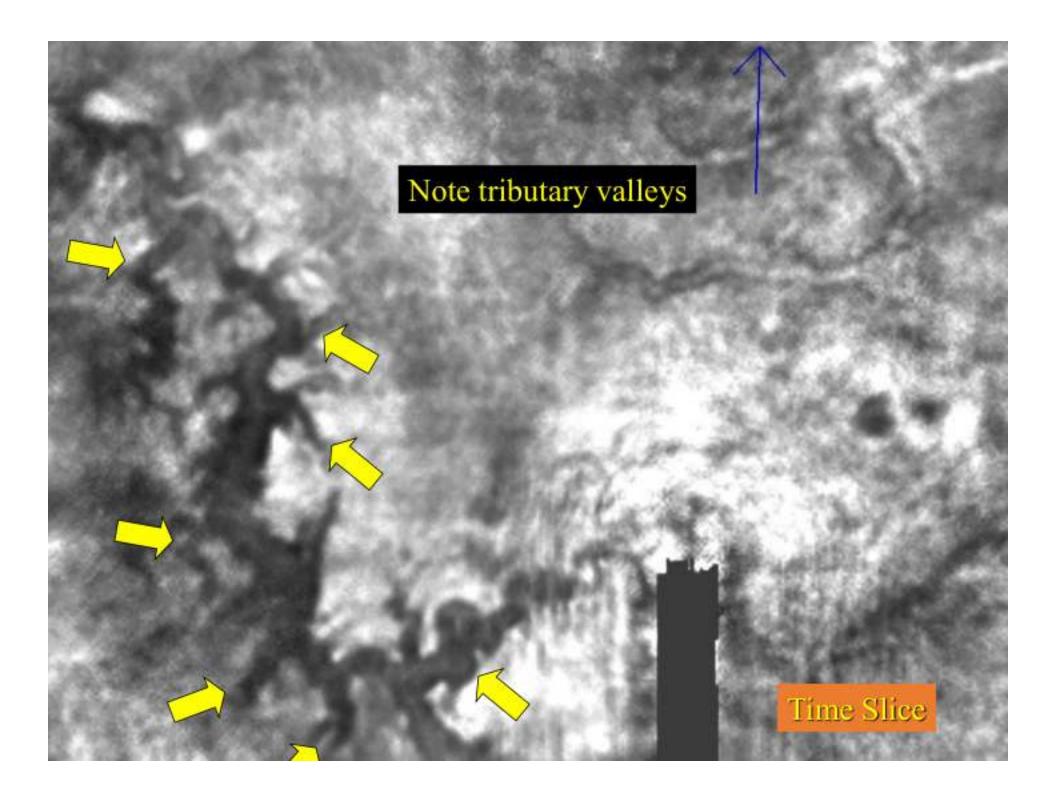




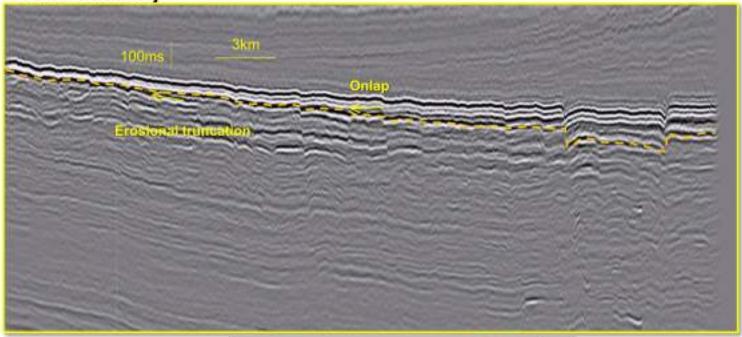


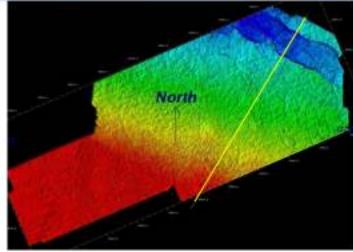






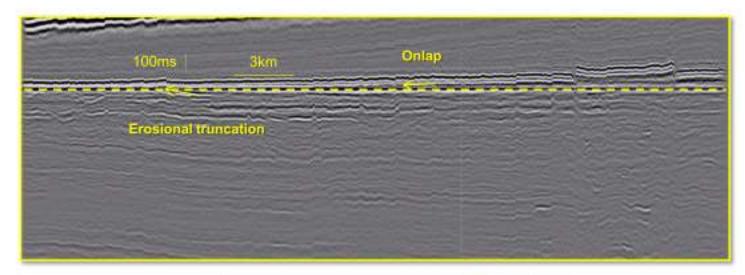
Stratigraphic Architecture related to Regional Unconformity

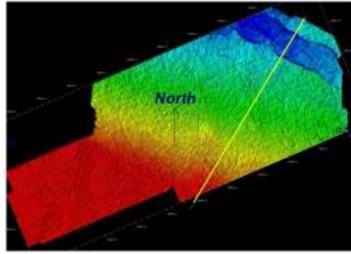




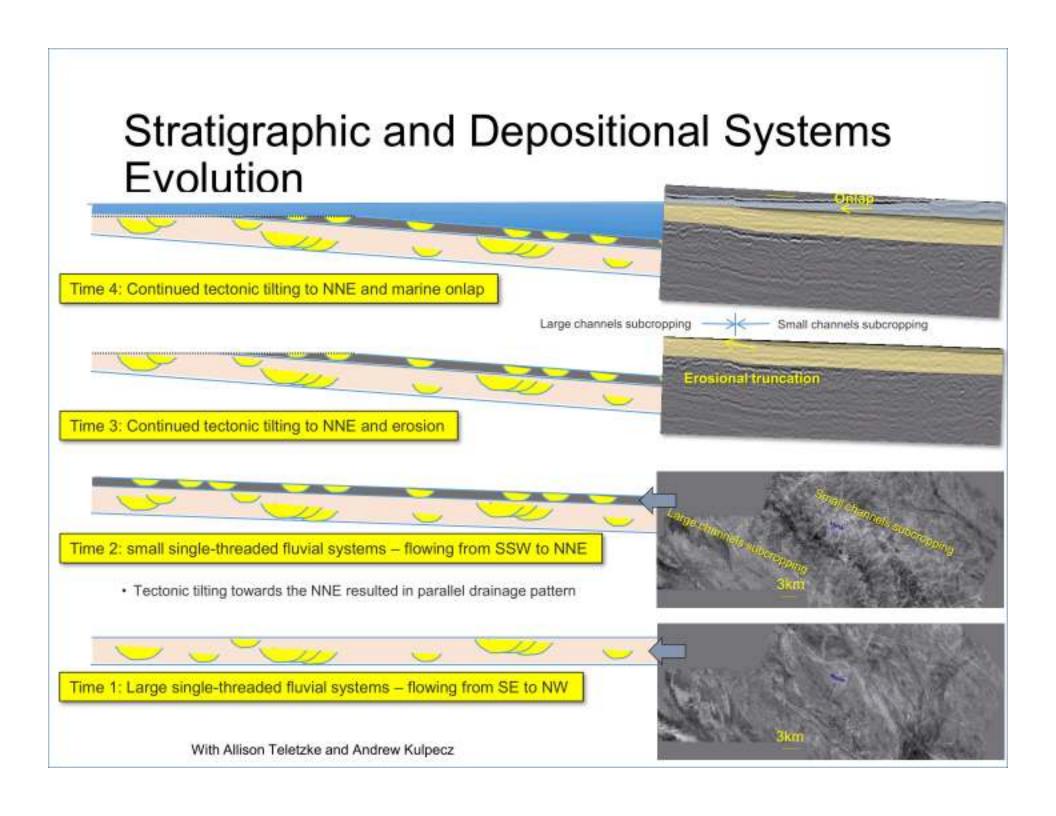
With Allison Teletzke and Andrew Kulpecz

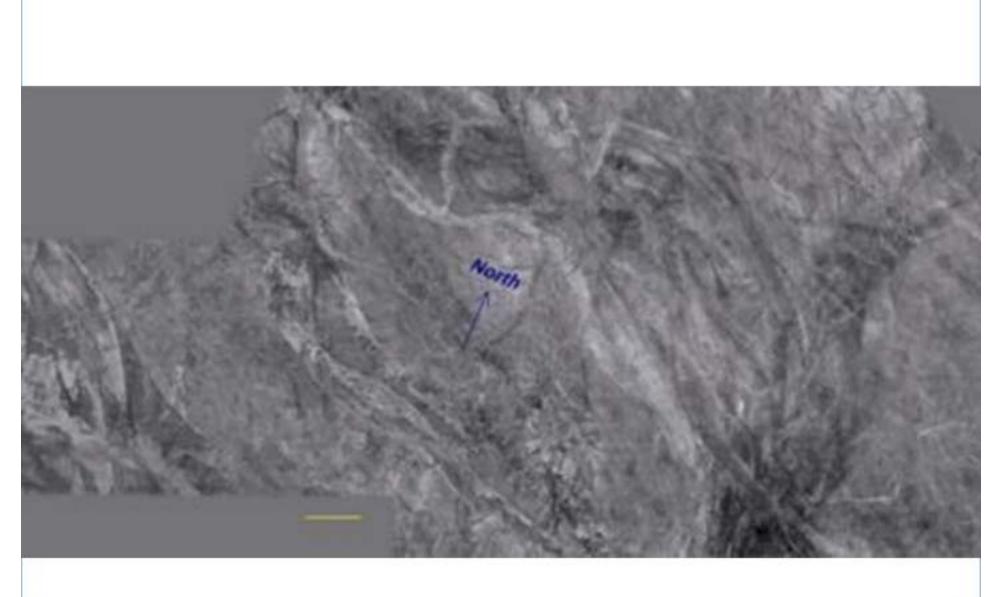
Stratigraphic Architecture related to Regional Unconformity

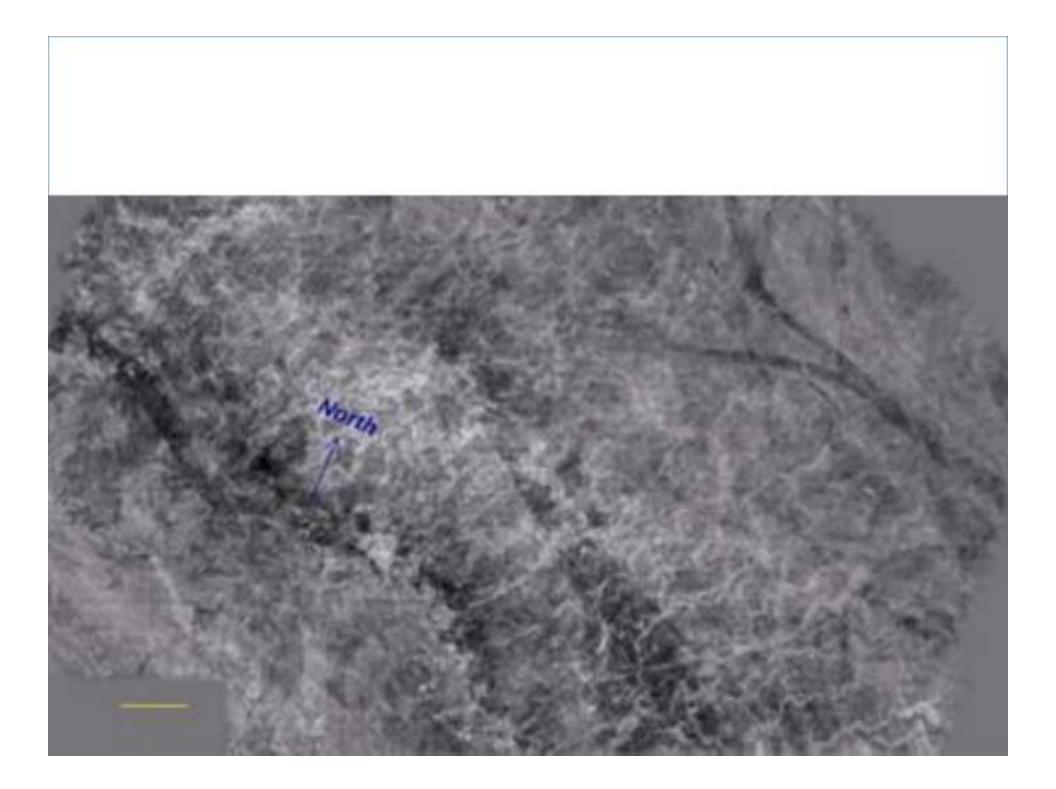




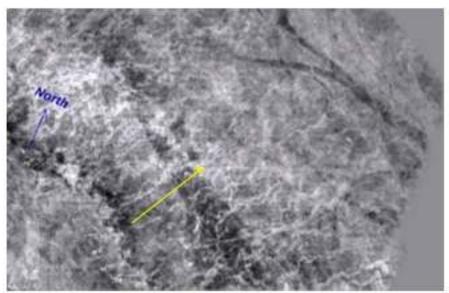
With Allison Teletzke and Andrew Kulpecz

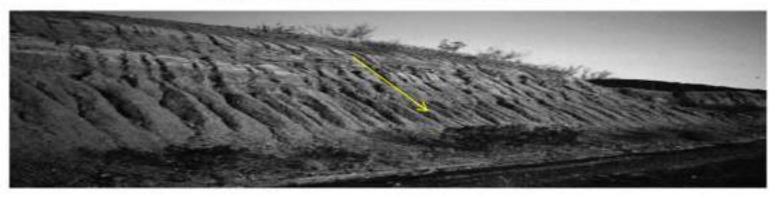




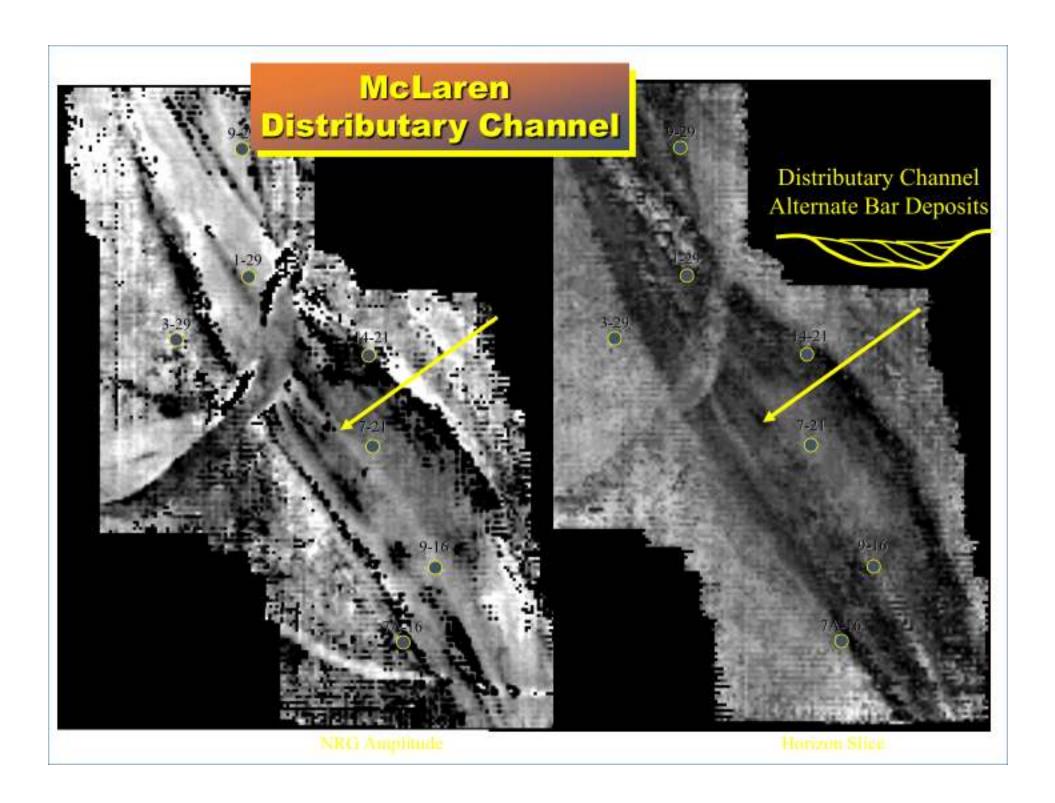


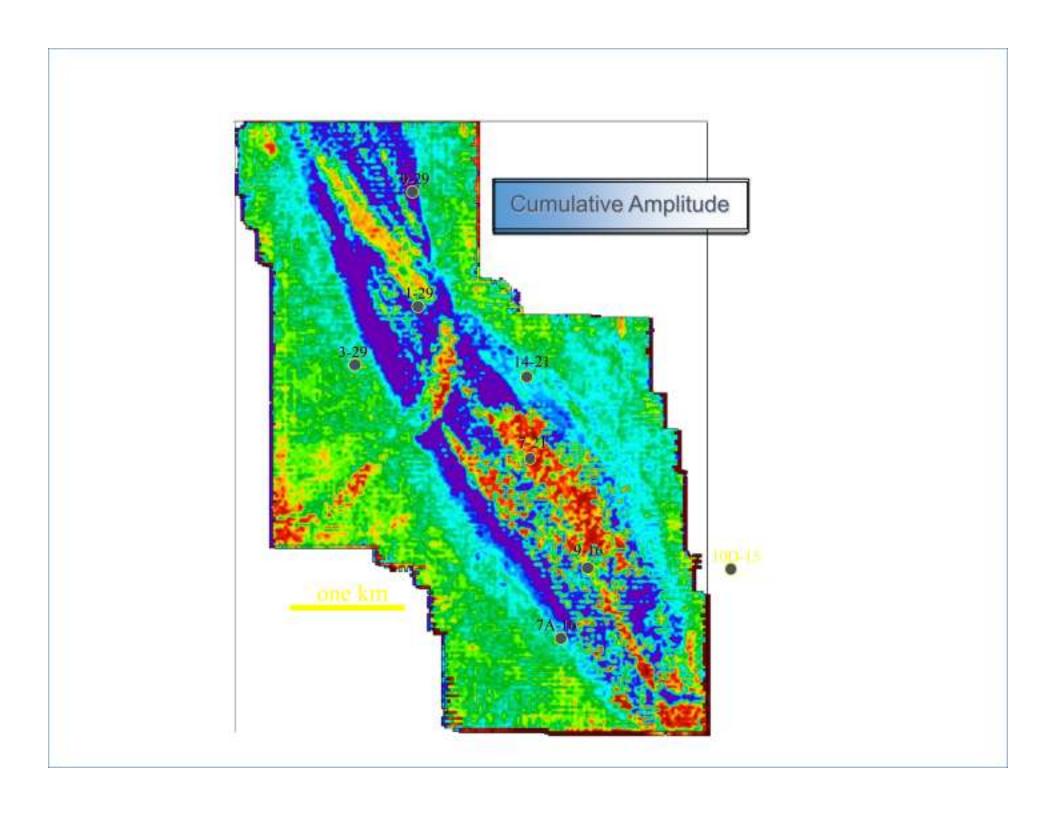
Parallel Drainage: Barents Sea vs. Analog

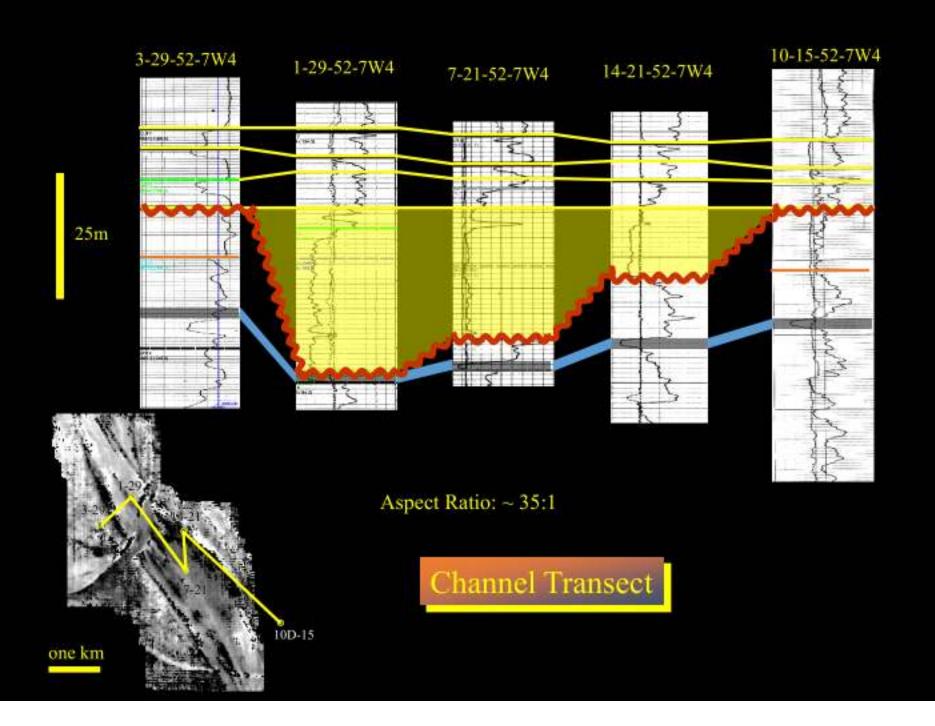


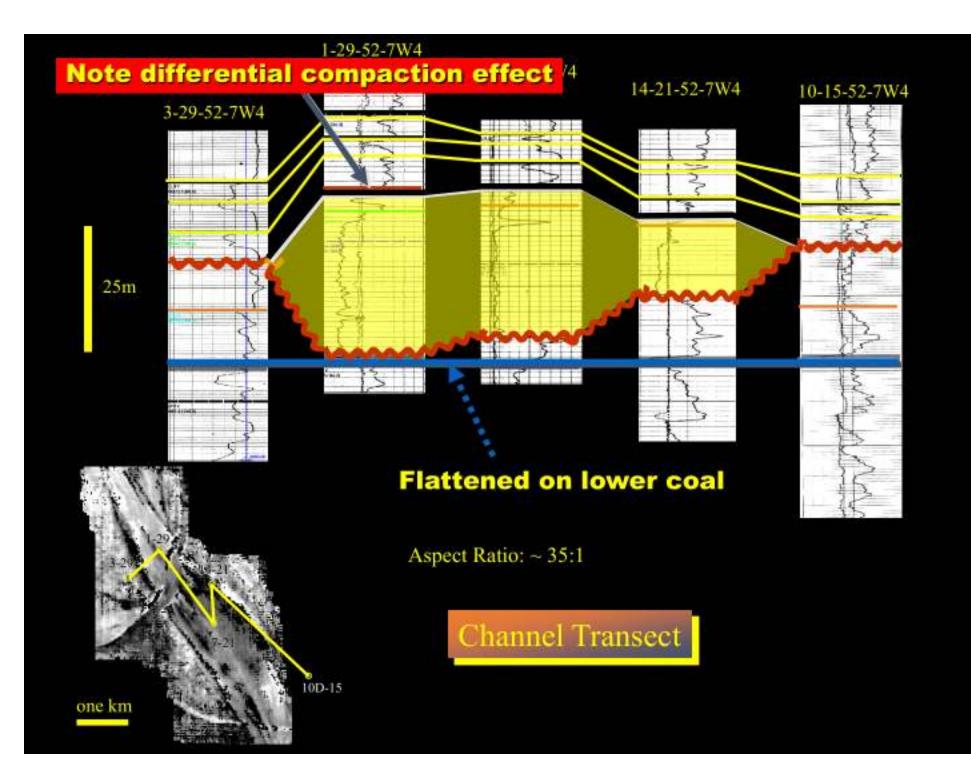


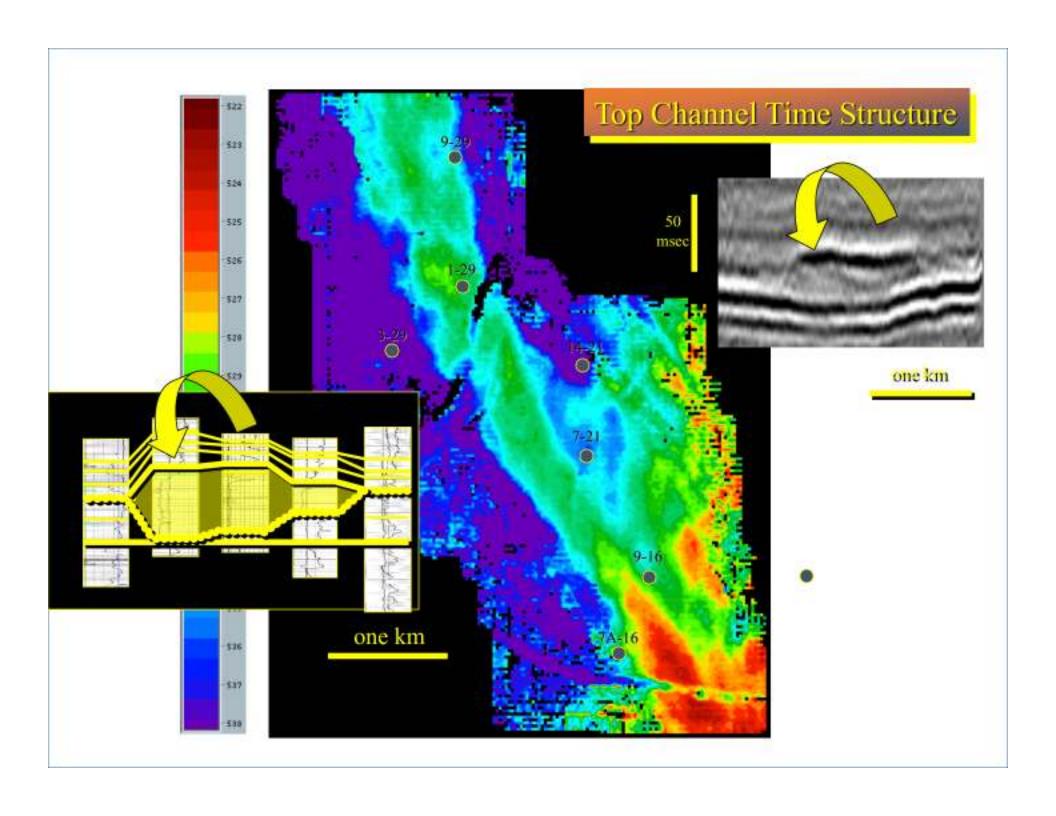
Example of parallel drainage on dipping surface







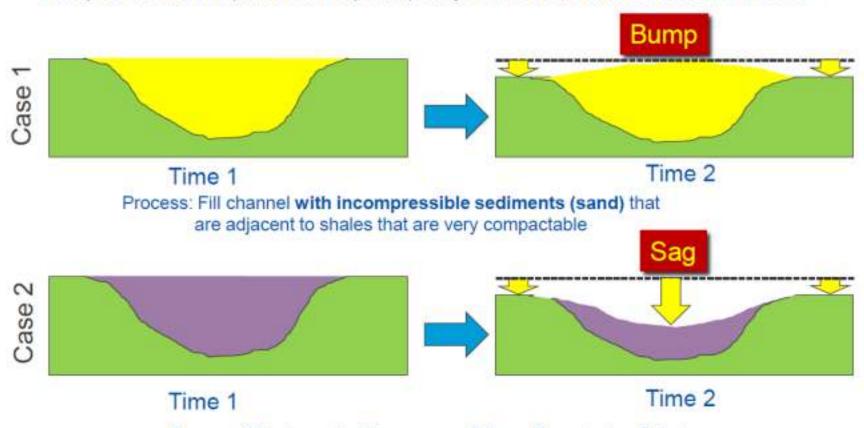




Channel-fill Patterns: Compaction Effects and Lithology prediction – sand-filled vs. mud-filled channels

Applies to any deposits that compact more (or less) than adjacent deposits

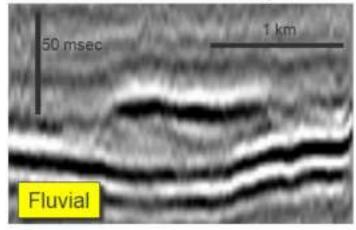
Examples: channel fills (fluvial and deepwater), canyon fills, reefs, barrier bars, sediment waves

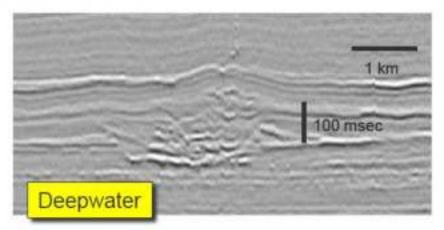


Process: Fill channel with compressible sediments (mud) that are adjacent to sediments that are less compactable

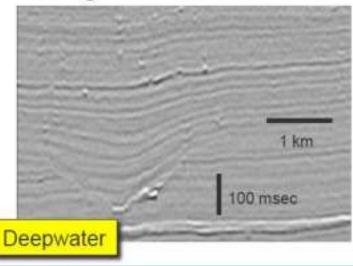
Channel-fill Patterns: Compaction Effects and Lithology prediction – sand-filled vs. mud-filled channels

Bump = sand-filled channel



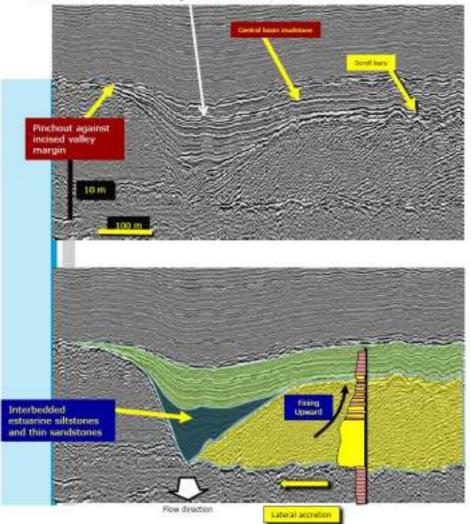


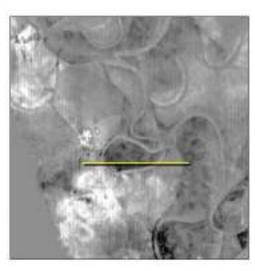
Sag = mud-filled channel



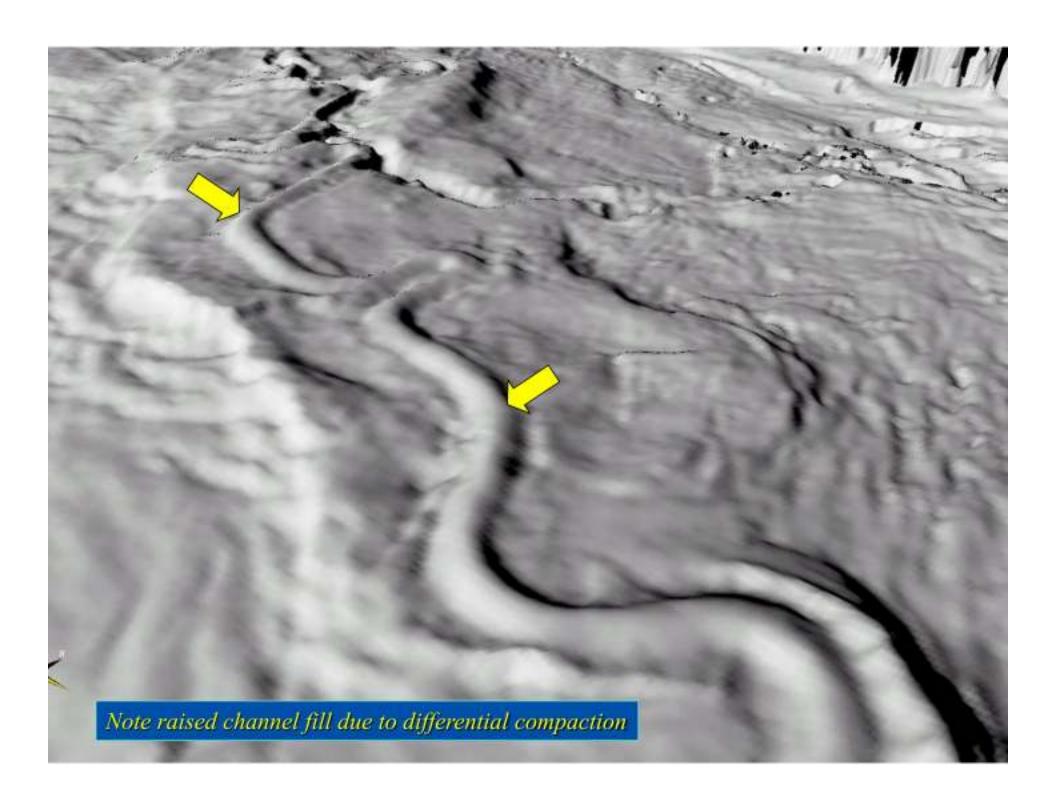
Channel-fill Patterns: Compaction Effects and Lithology prediction – sand-filled vs. mud-filled channels

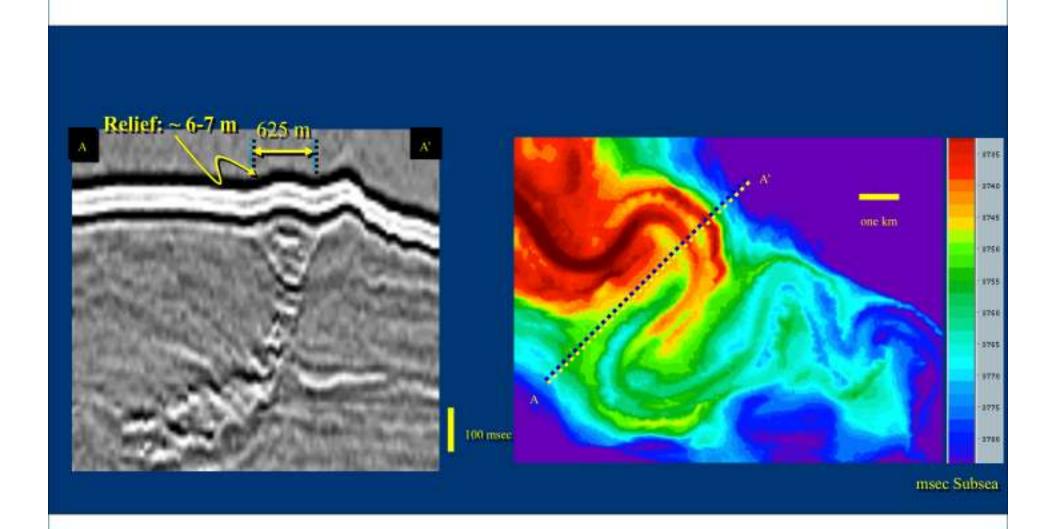
Differential compaction...in reverse



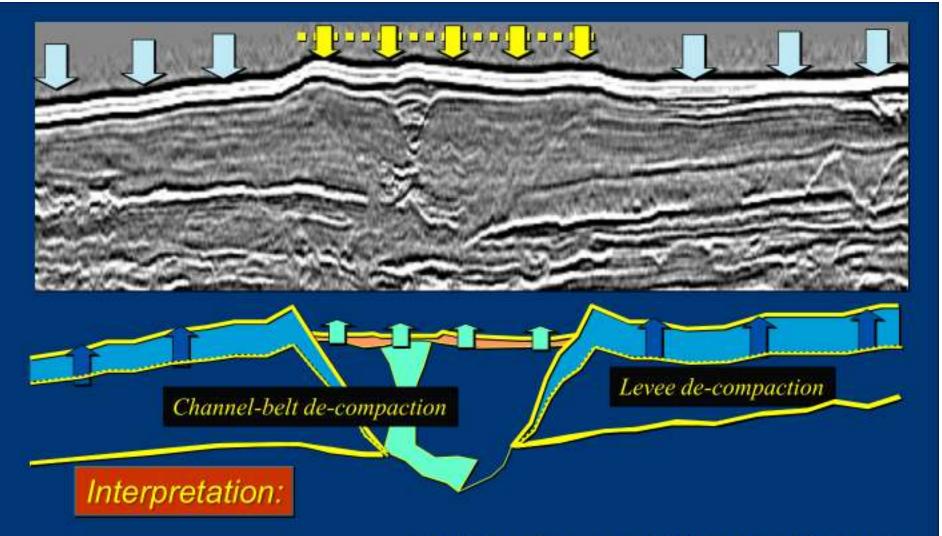


Clues to lithology: Note in addition to compaction... amplitude strength and continuity



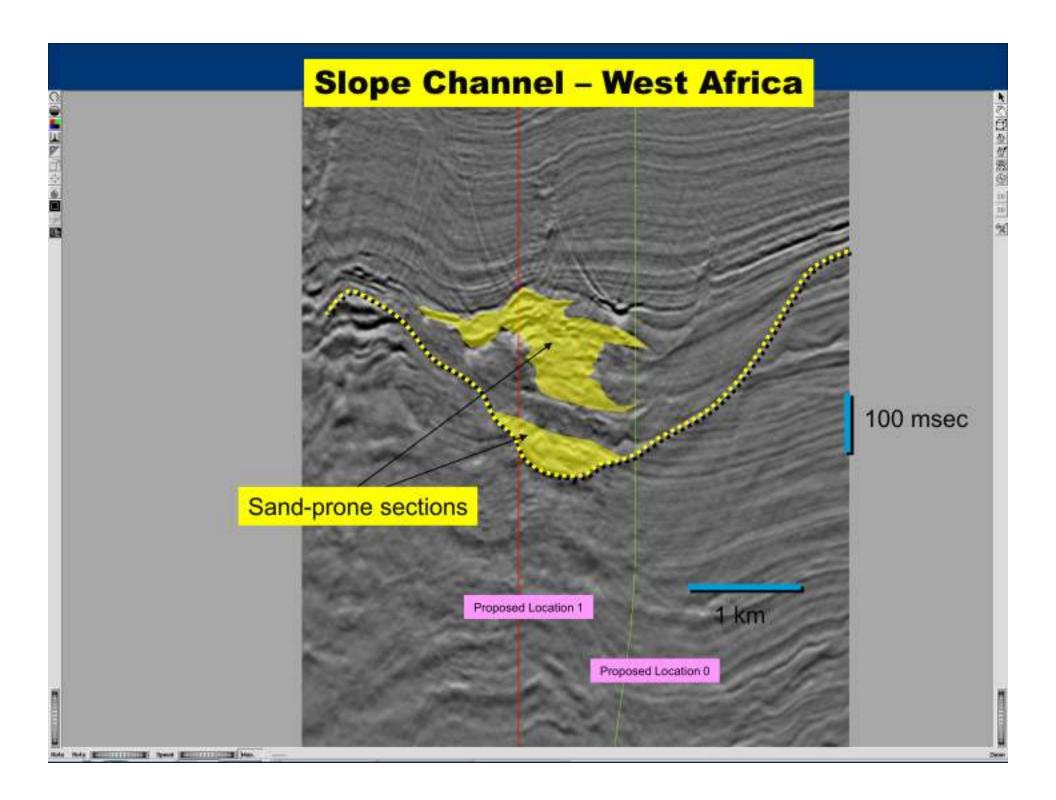


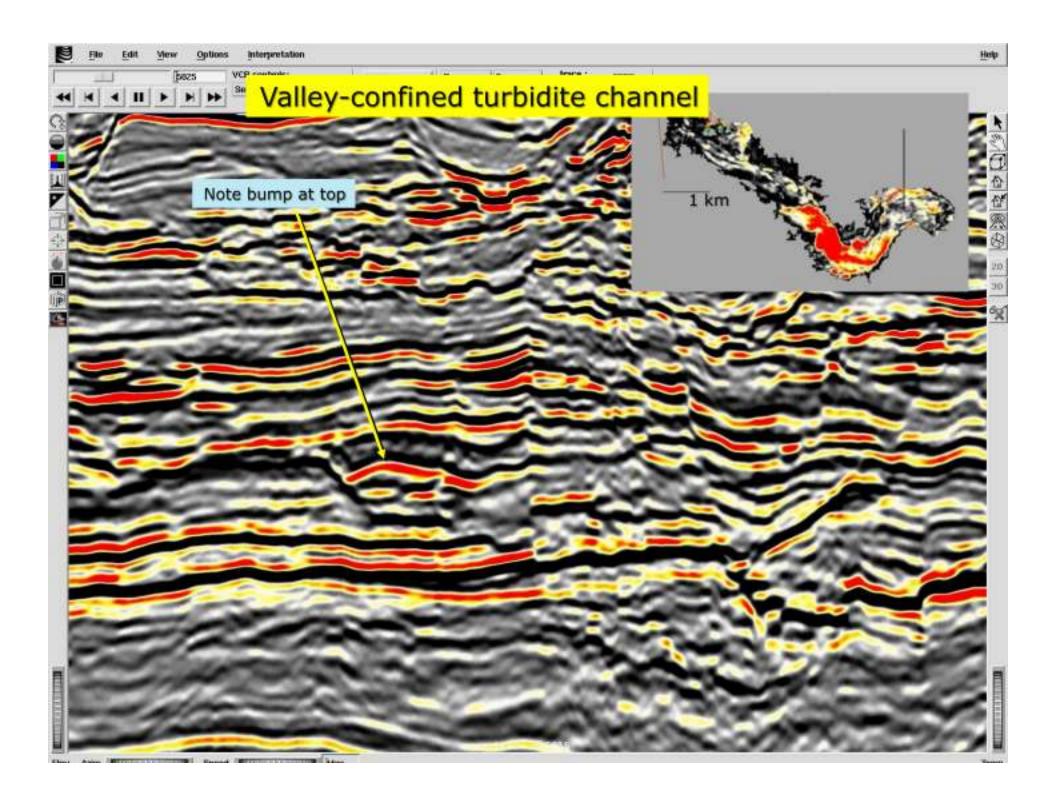
Time Structure Map

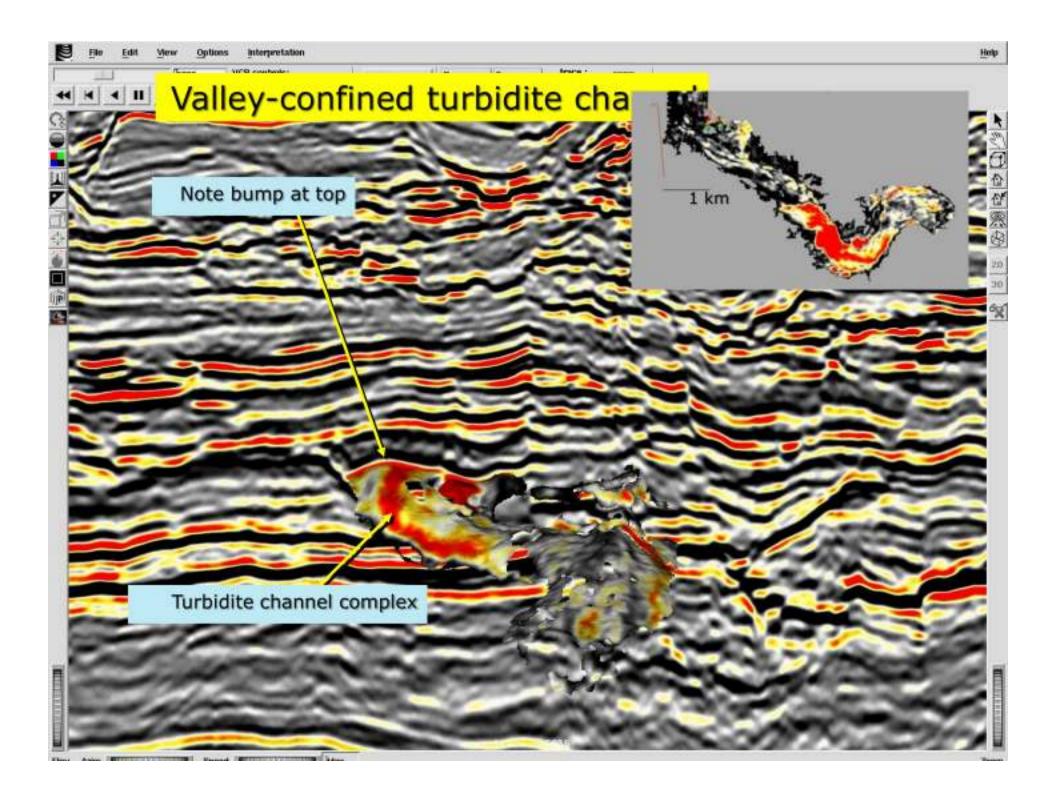


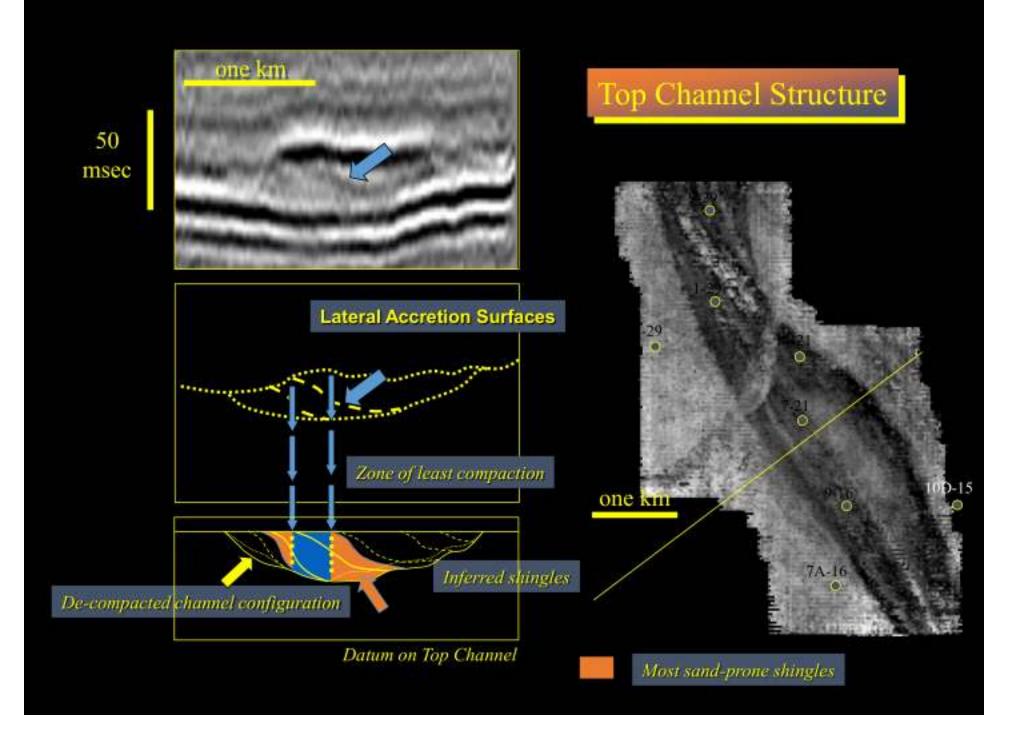
- Inversion of topography occurred over short time
- Levee deposits are more compactable (thin-bedded silts and muds); finer grained than channel belt deposits (thin-bedded sands and silts)
 - Channel belt deposits are more compactable (thin-bedded sands and silts) and therefore finer grained than channel deposits (sands)

Slope Channel - West Africa Note: convex-up profile and onlapping reflections - indicative of sand presence [associated differential compaction] 100 msec "Nested" Channels Base Slope Valley Complex Proposed Location 1 Proposed Location 0

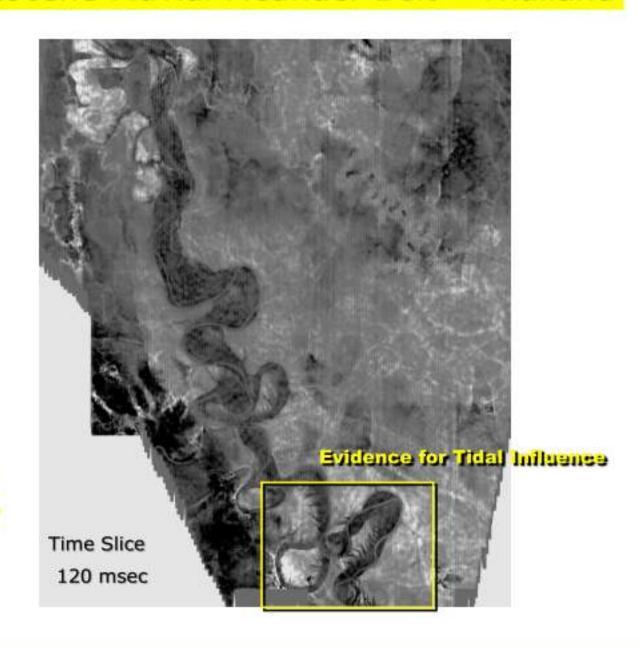




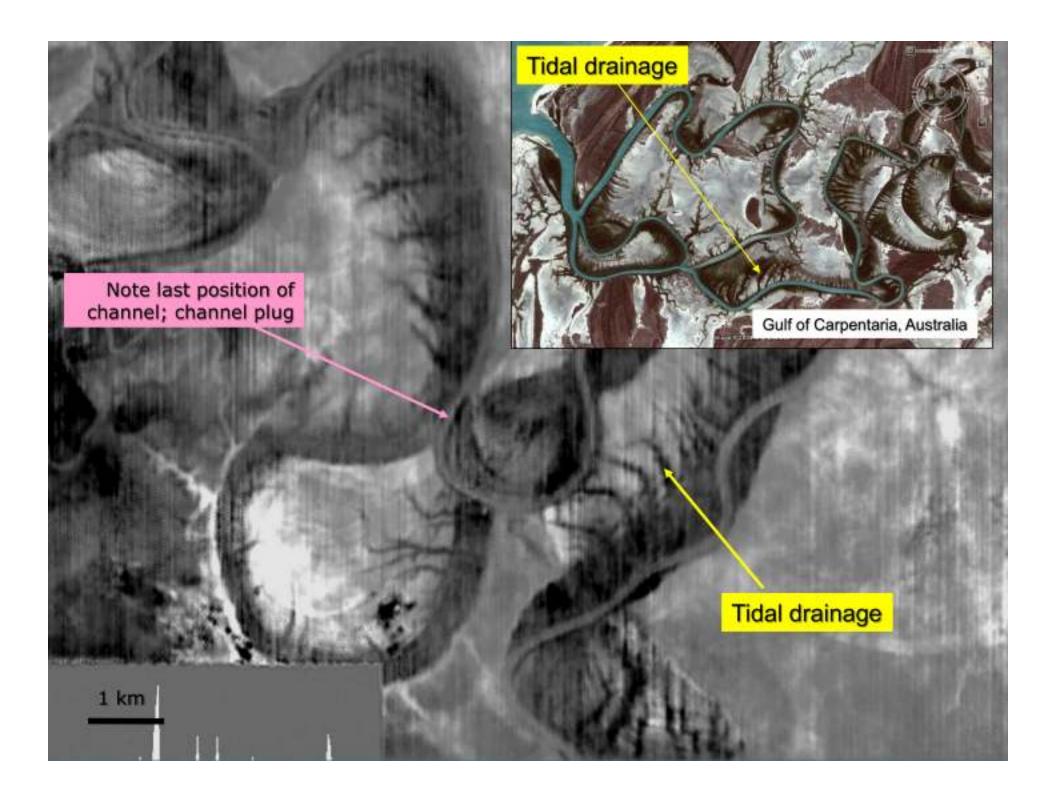


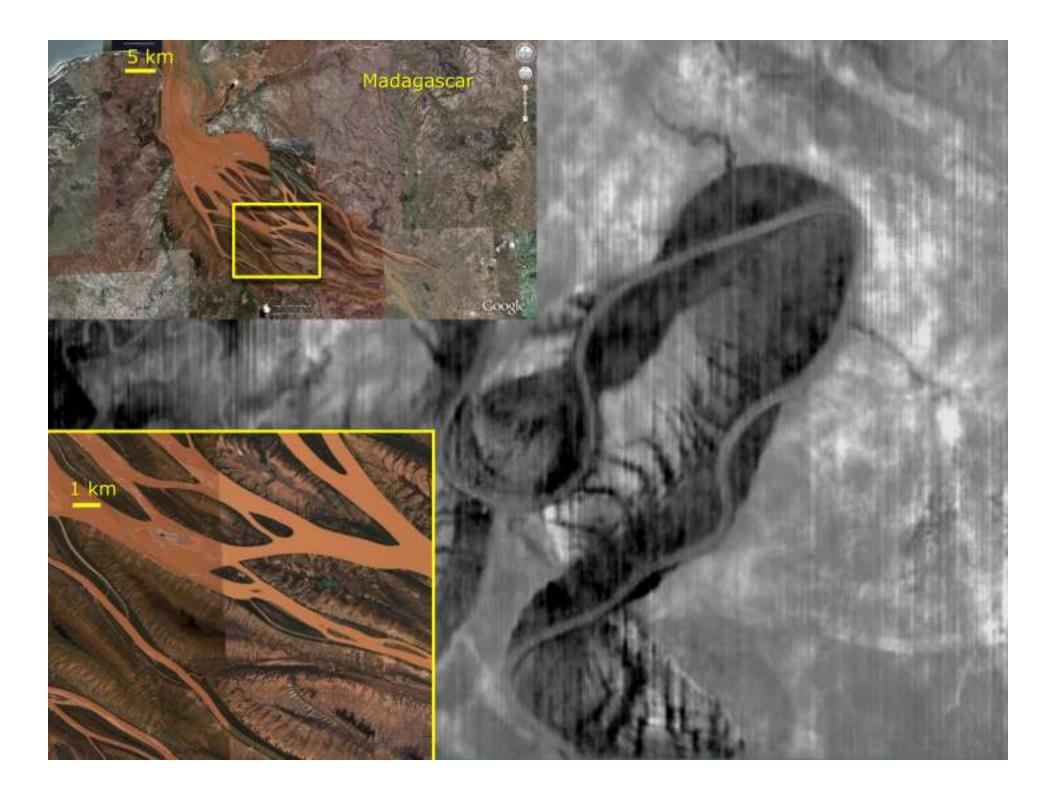


Pleistocene Fluvial Meander Belt - Thailand

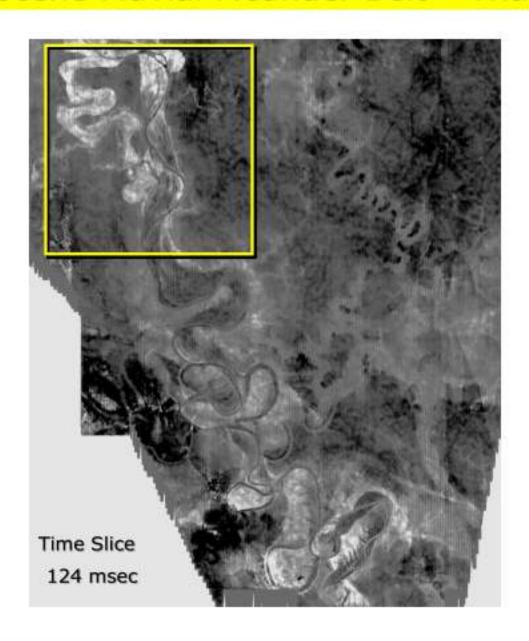


10 km



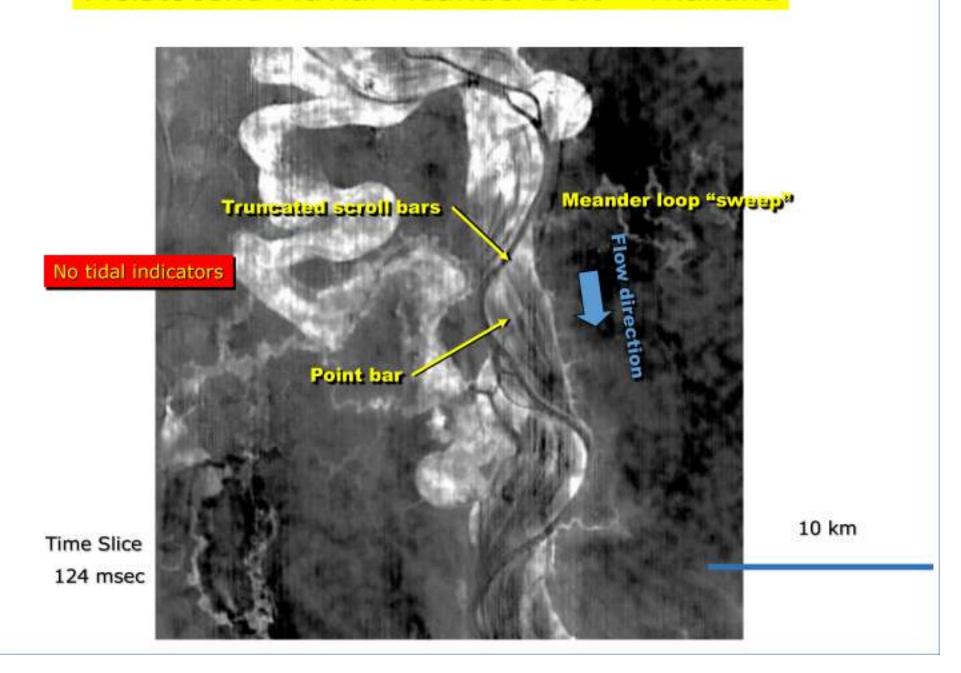


Pleistocene Fluvial Meander Belt - Thailand

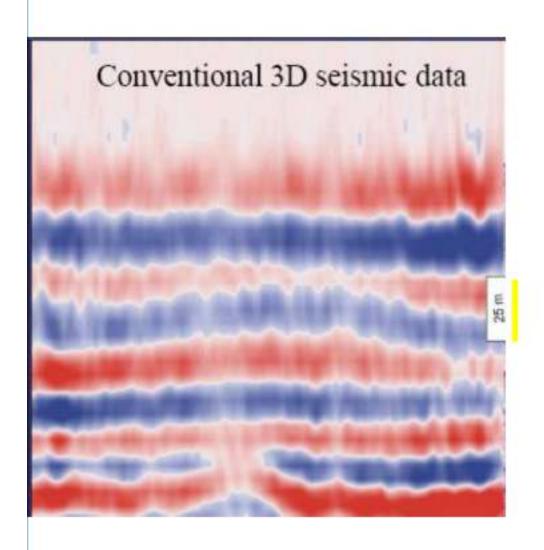


10 km

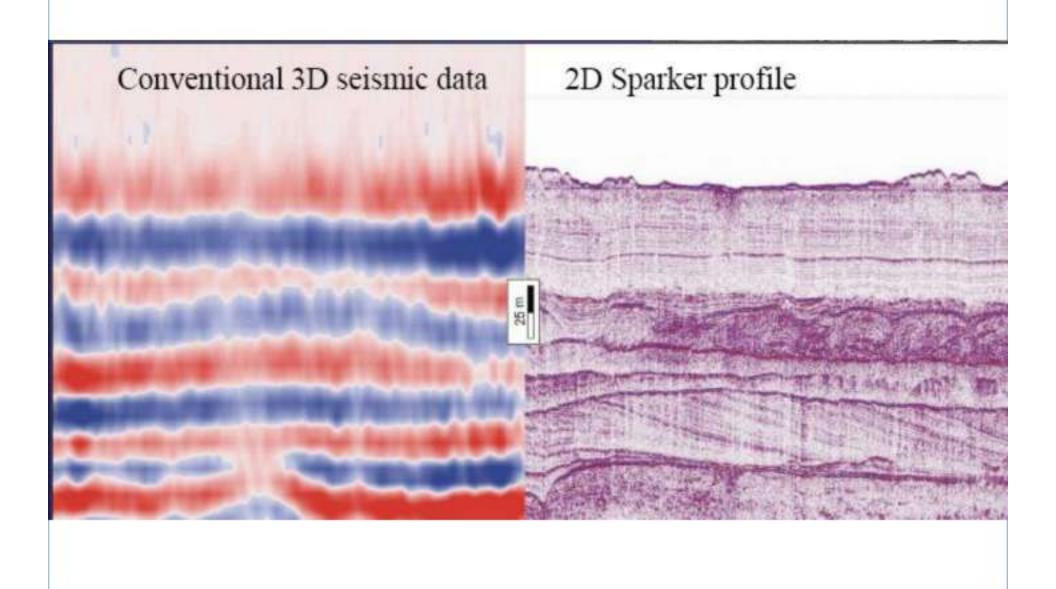
Pleistocene Fluvial Meander Belt - Thailand



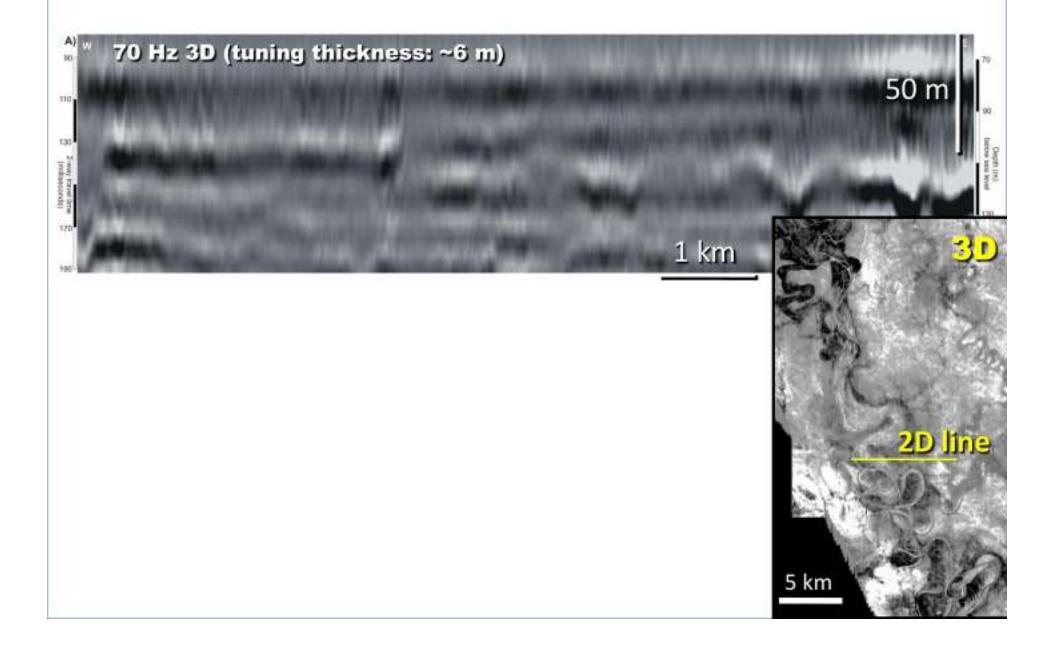
Integration of 3D with 2D High-Resolution Seismic Data



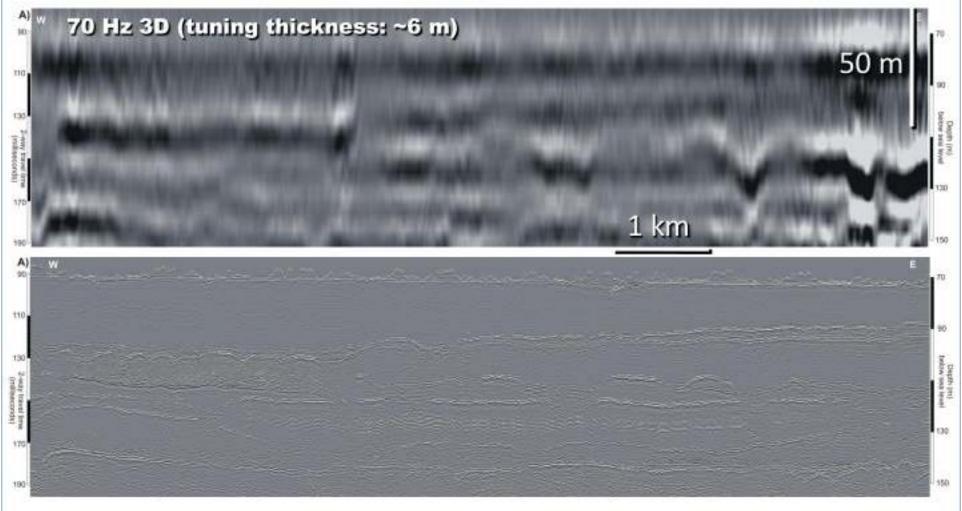
Integration of 3D with 2D High-Resolution Seismic Data



Conventional 3D Section and Time Slice

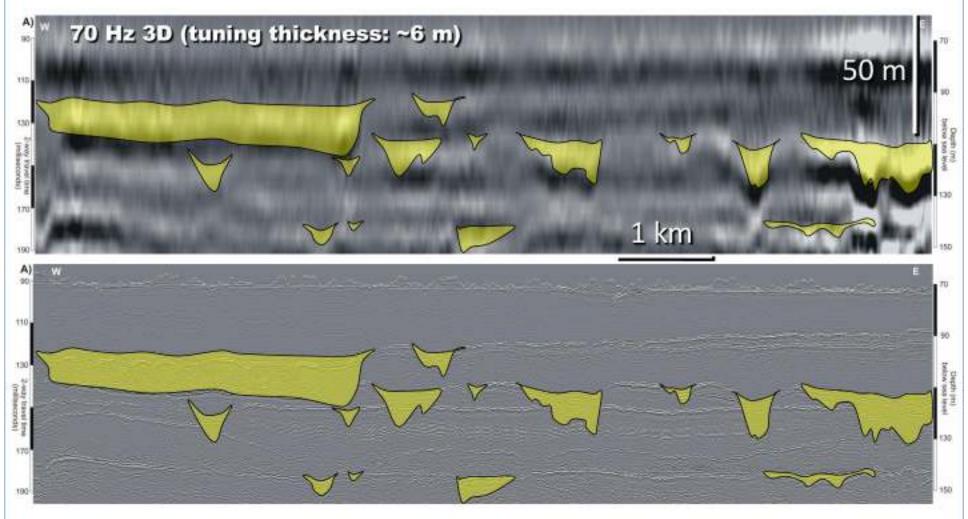


Conventional 3D Section and Hi-Res 2D Section

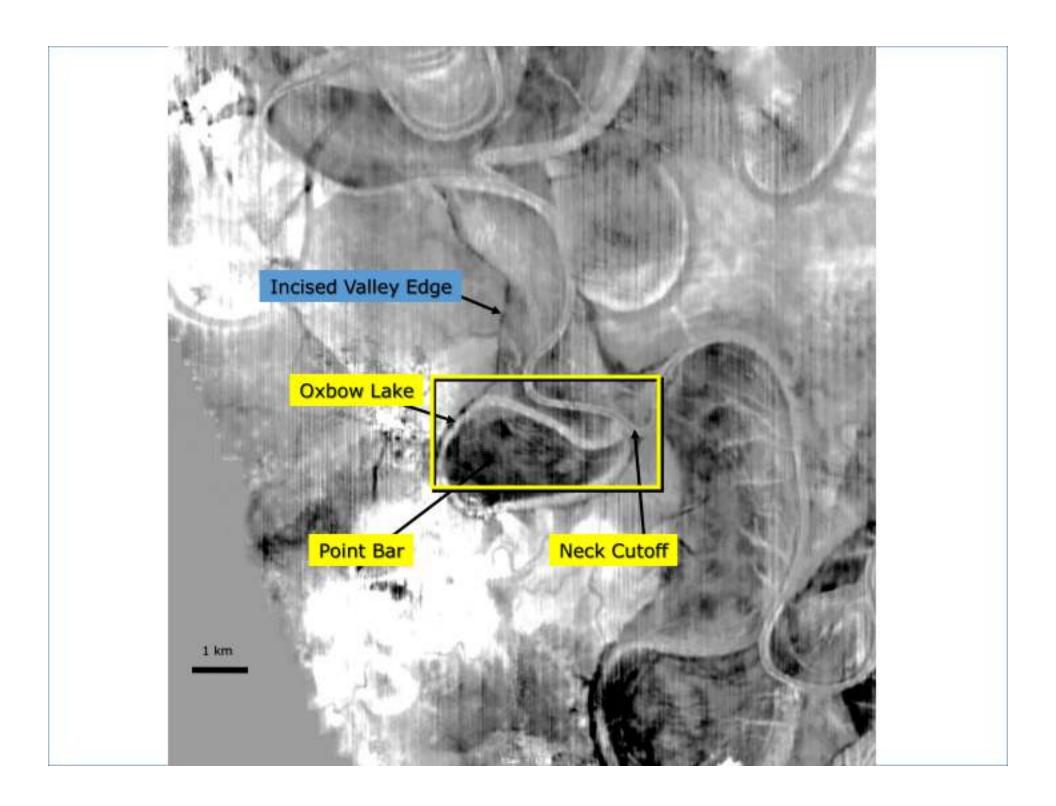


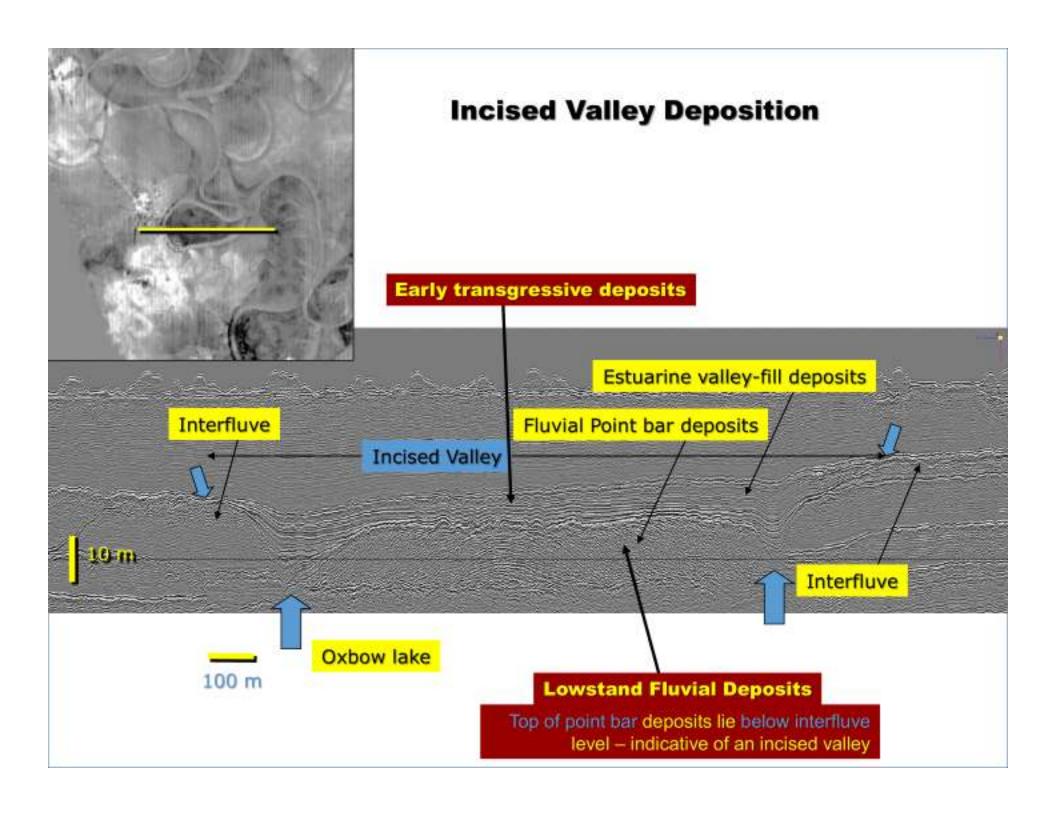
2000 Hz 2D (tuning thickness: ~25 cm)

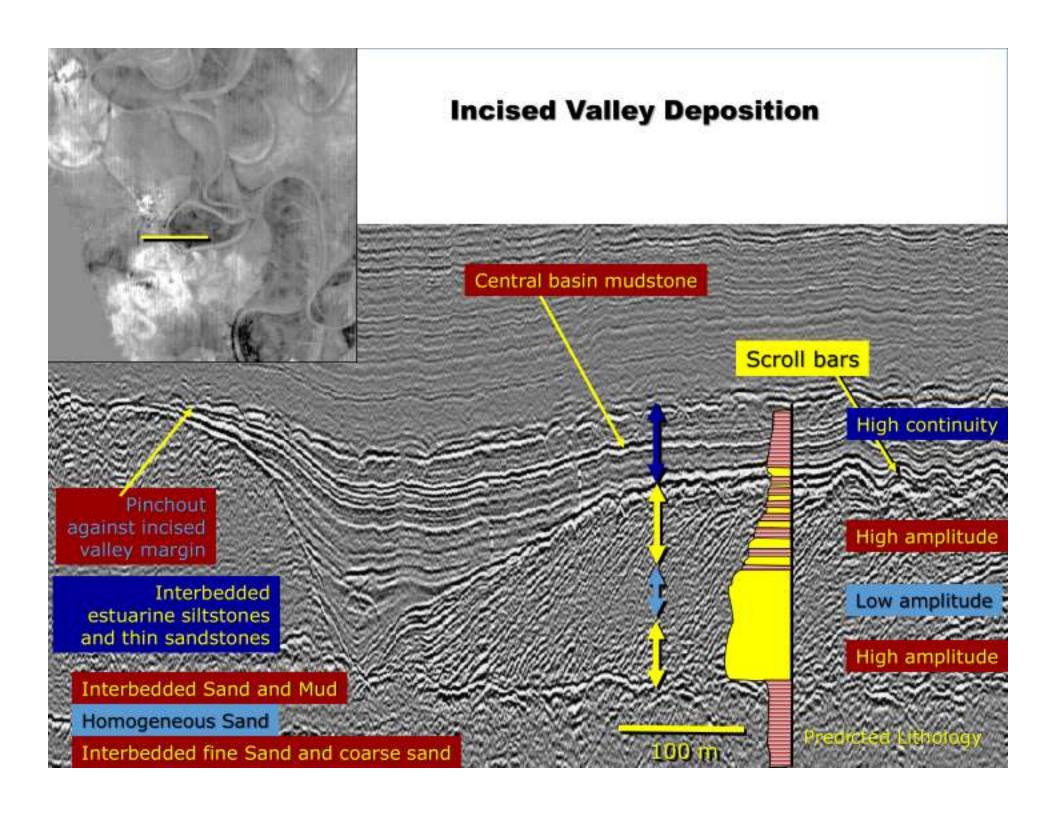
Conventional 3D Section and Hi-Res 2D Section



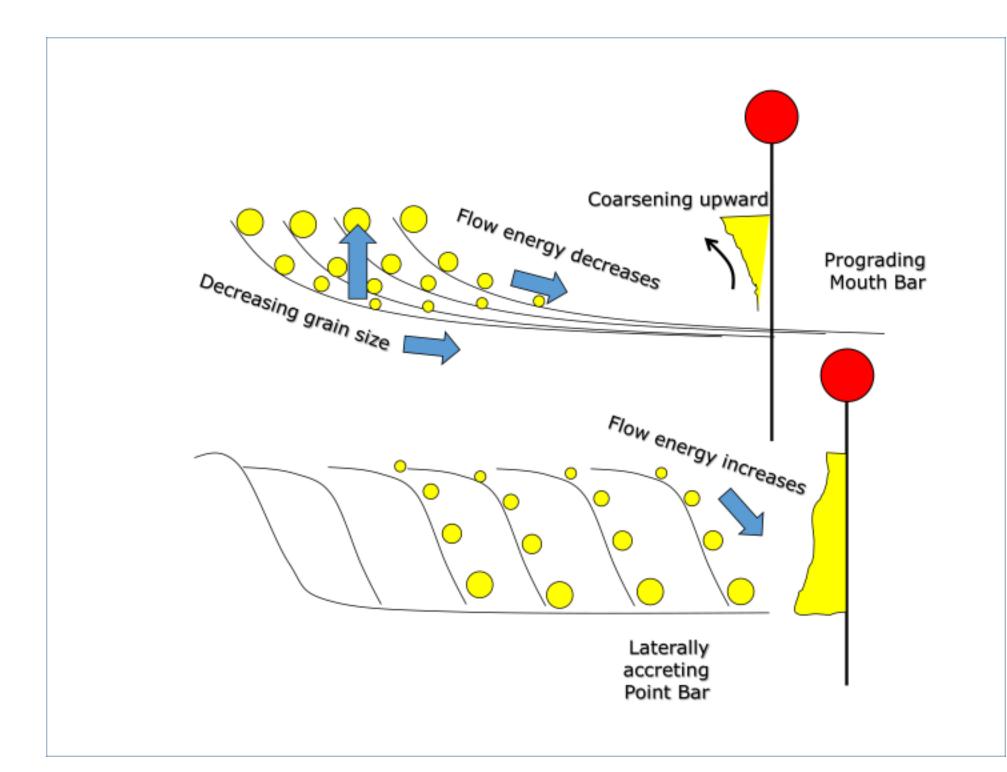
2000 Hz 2D (tuning thickness: ~25 cm)





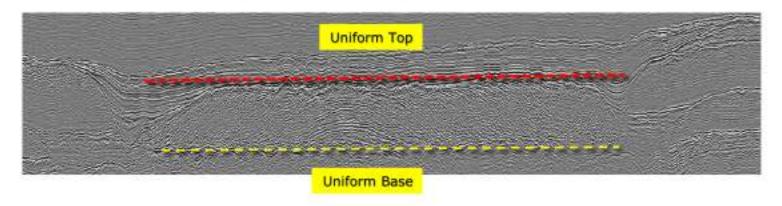


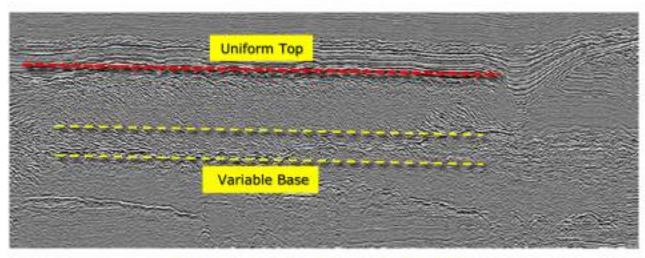
Facies architecture Strike View Dip View 116 msec Bidirectional downlap Incised valley margin Lateral accretion surfaces Interfluve Incised tributary valley



Variability of Point Bar Thickness

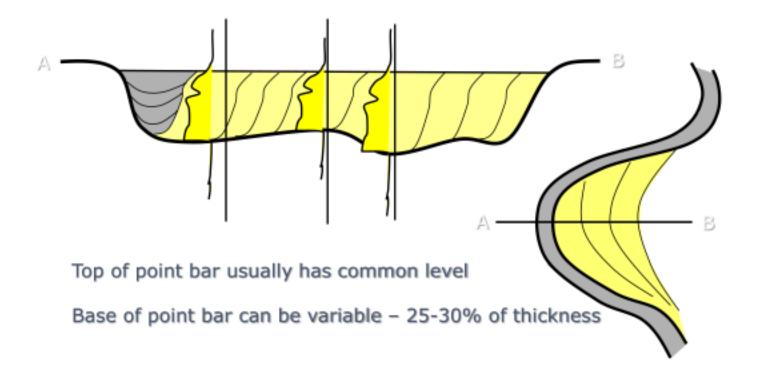
Tops are commonly horizontal (i.e., reasonable datum)

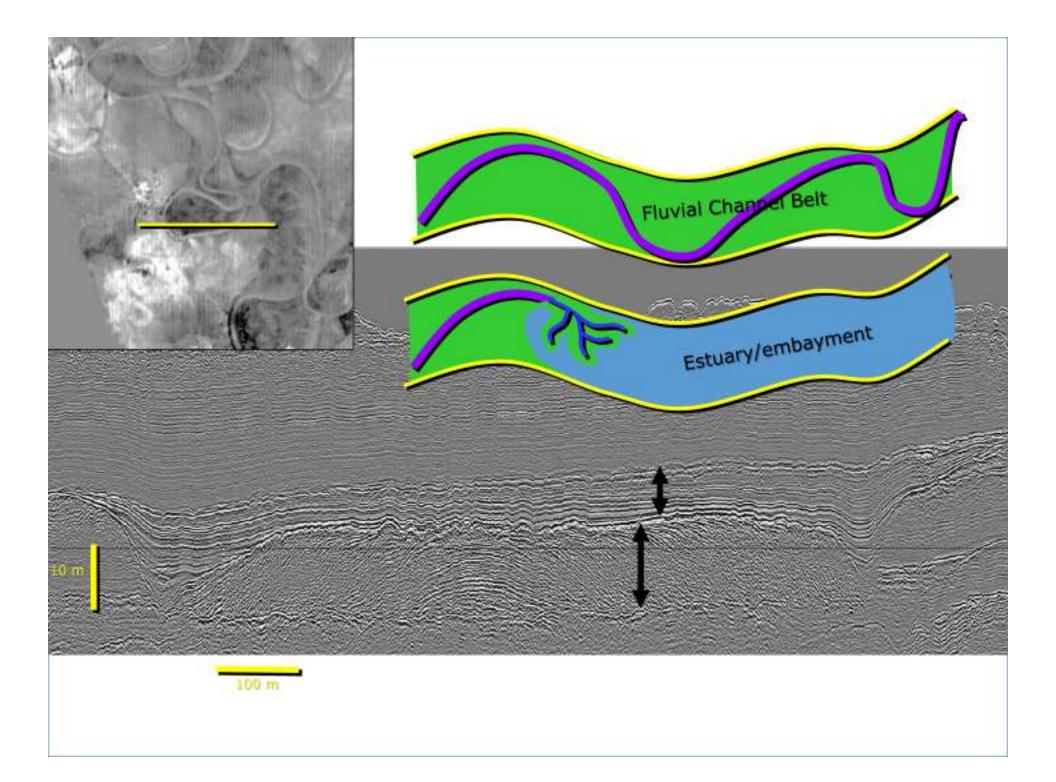




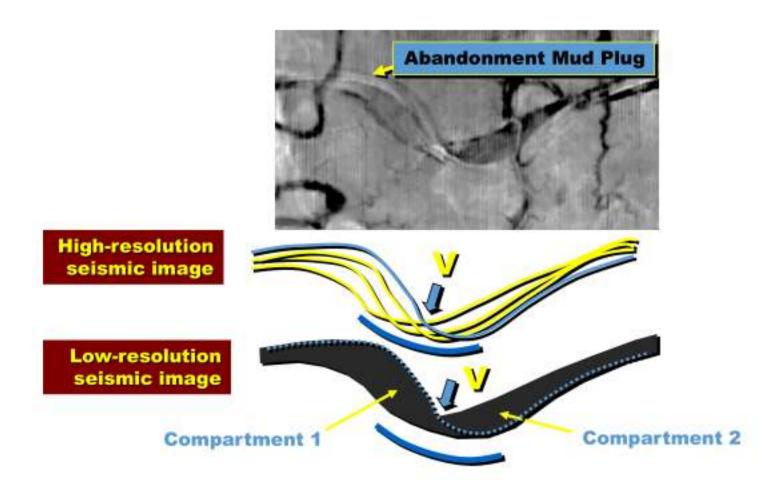
Bases can vary by up to 25-30%

Rules regarding correlation of well logs in fluvial settings



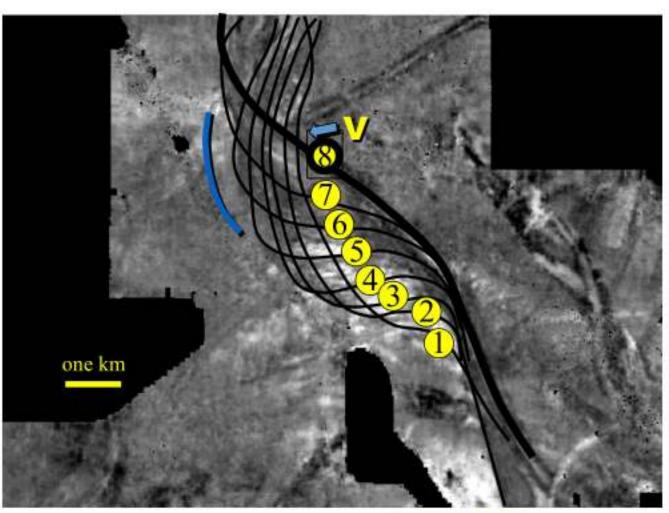


Indications of Fluvial Deposition: Rule of "V's"

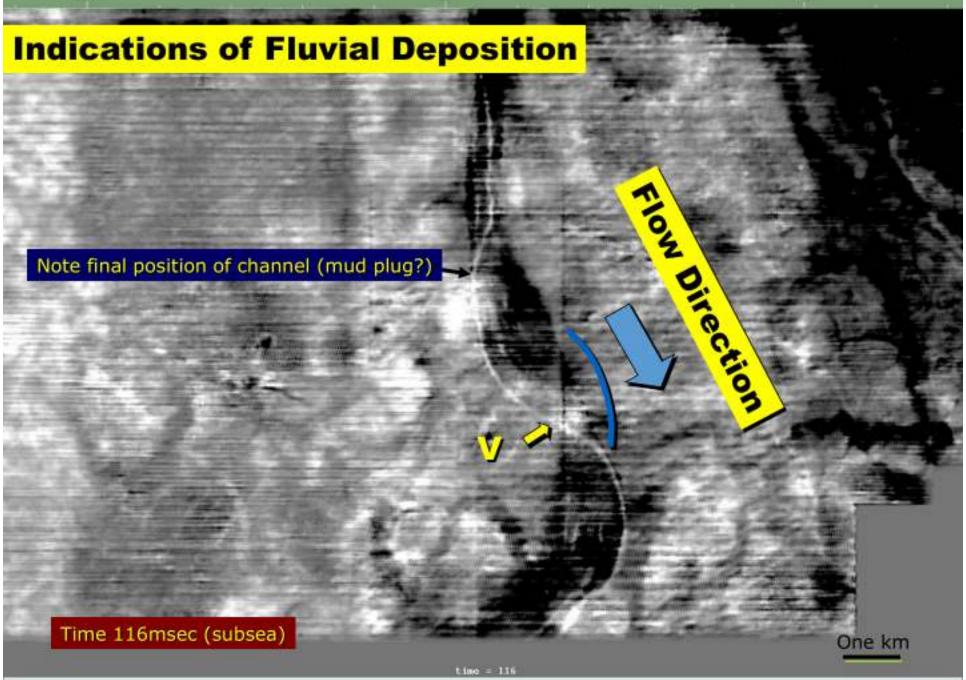


Note pinching and swelling of channel belt limit

Meandering Channel with Point Bars

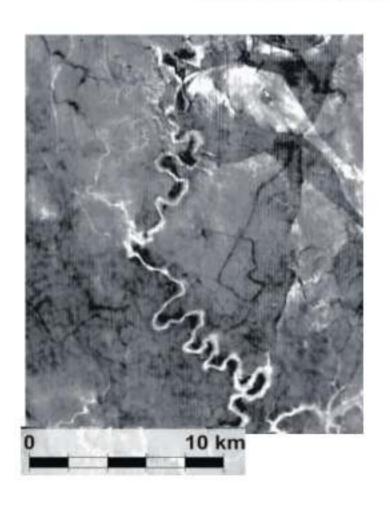


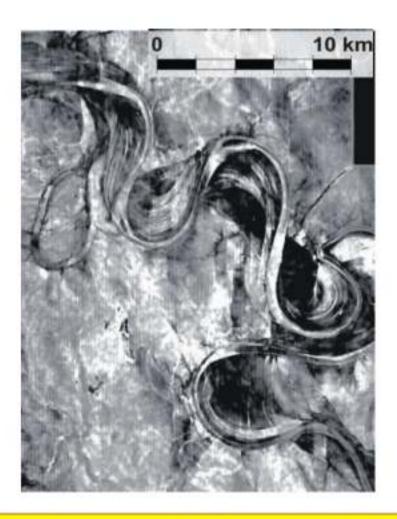
Horizon Stice-144





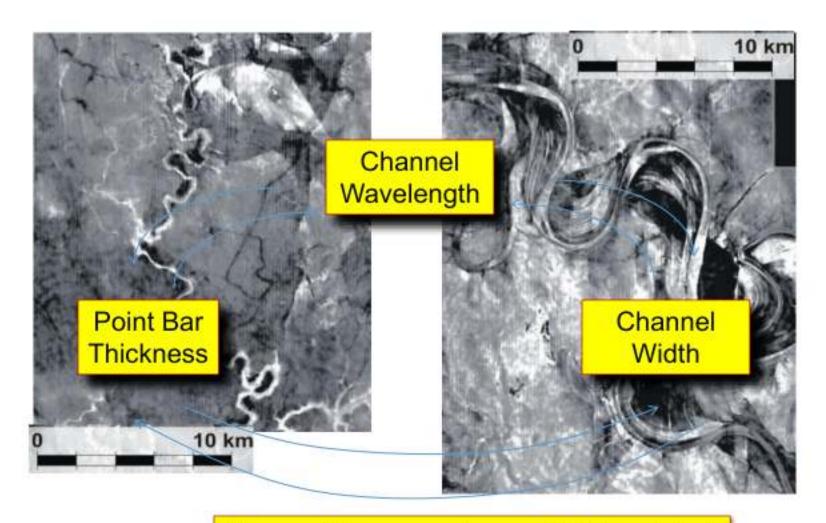
Point Bar Metrics





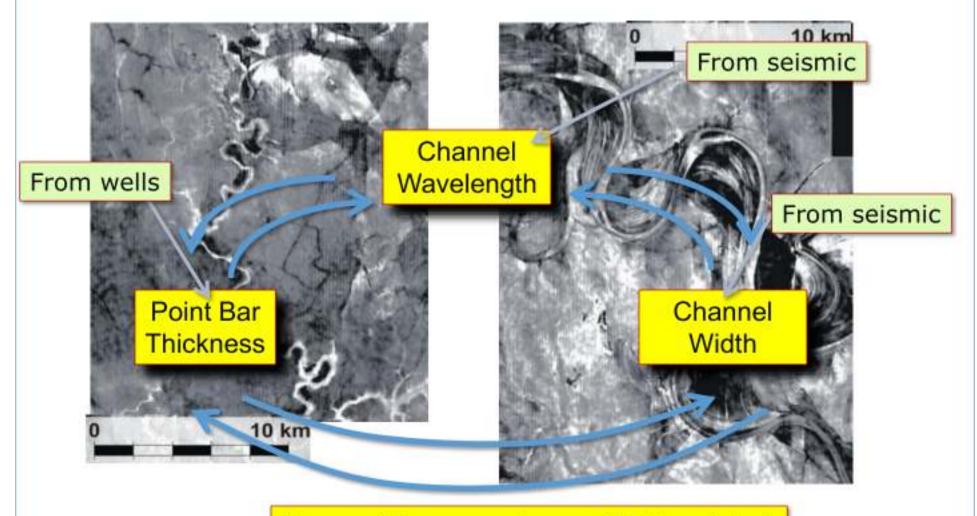
Big (i.e., wide) rivers have big (area and thickness) point bars

Point Bar Metrics



Measurable parameters - all interrelated

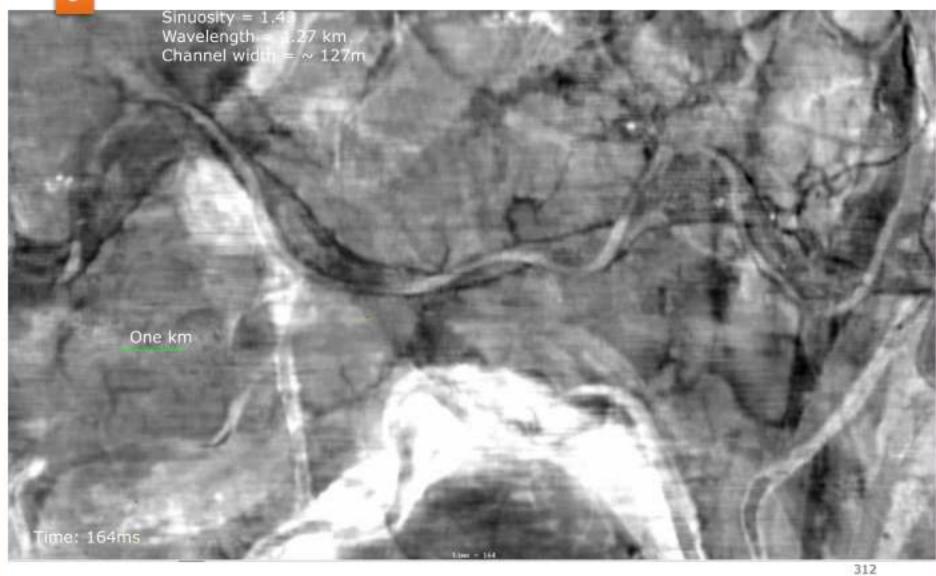
Point Bar Metrics

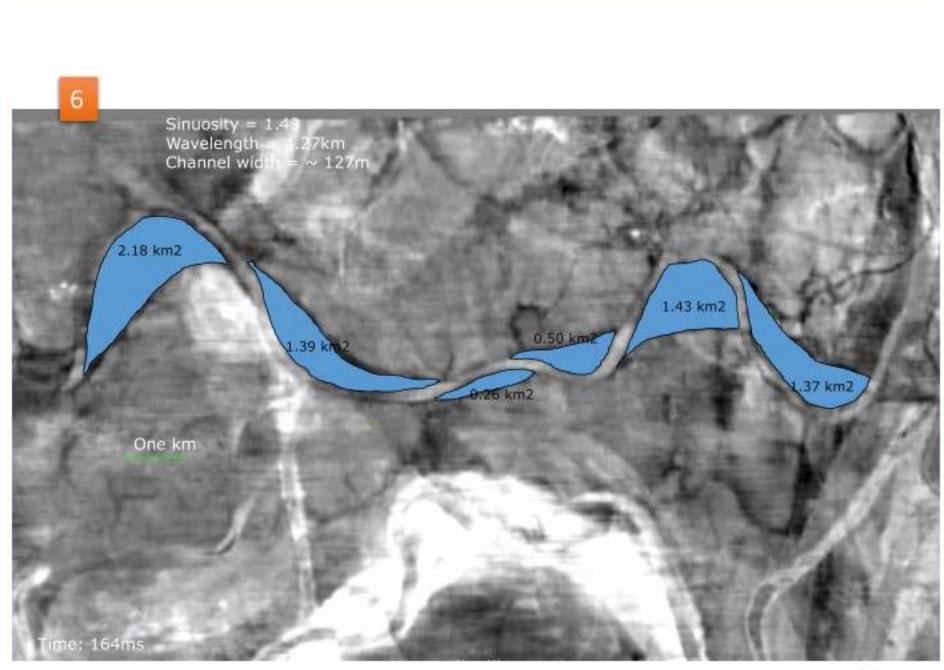


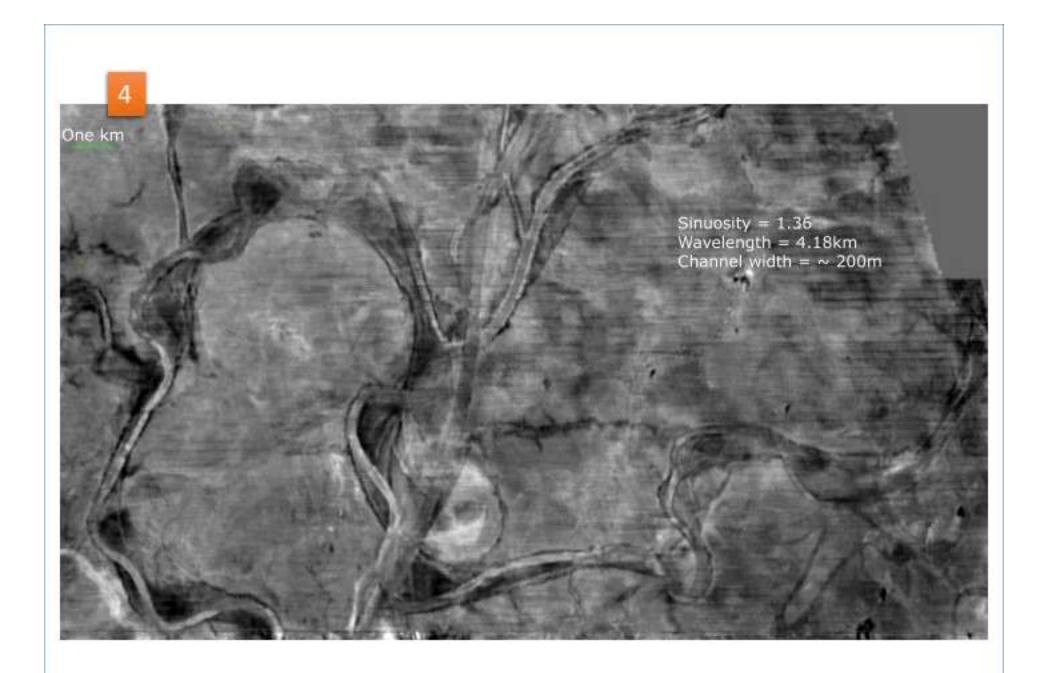
Measurable parameters - all interrelated

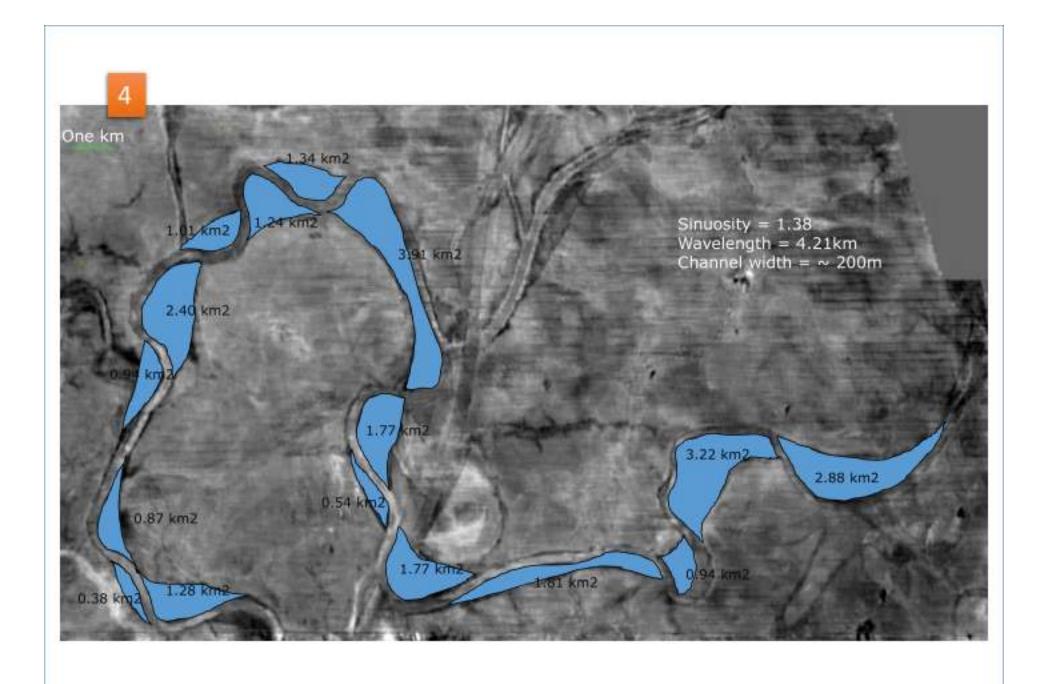


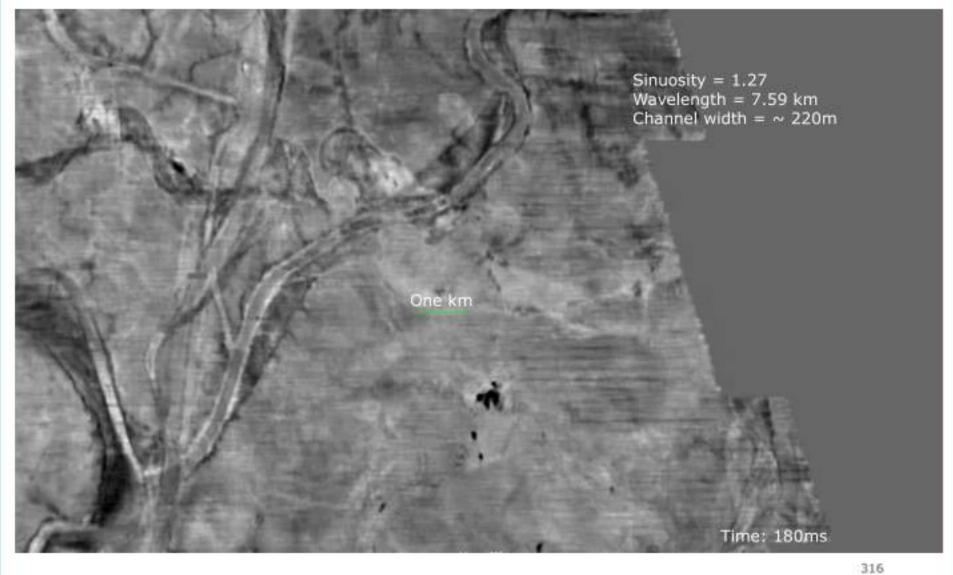


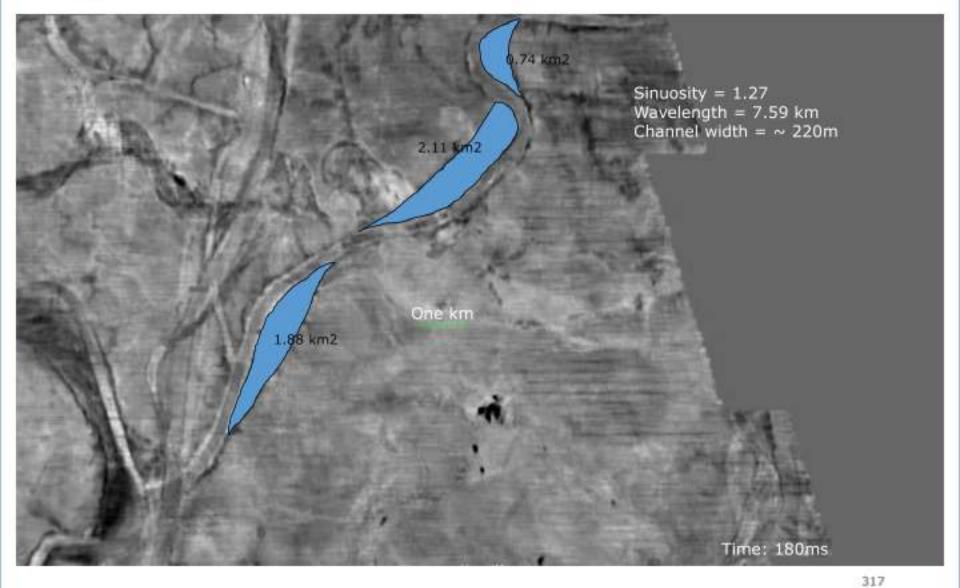


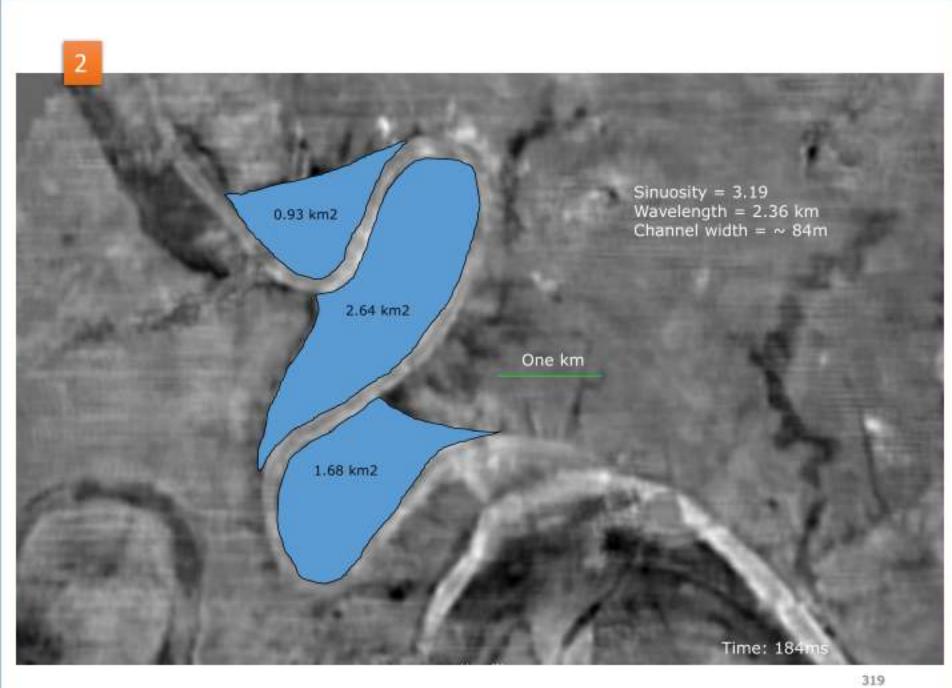


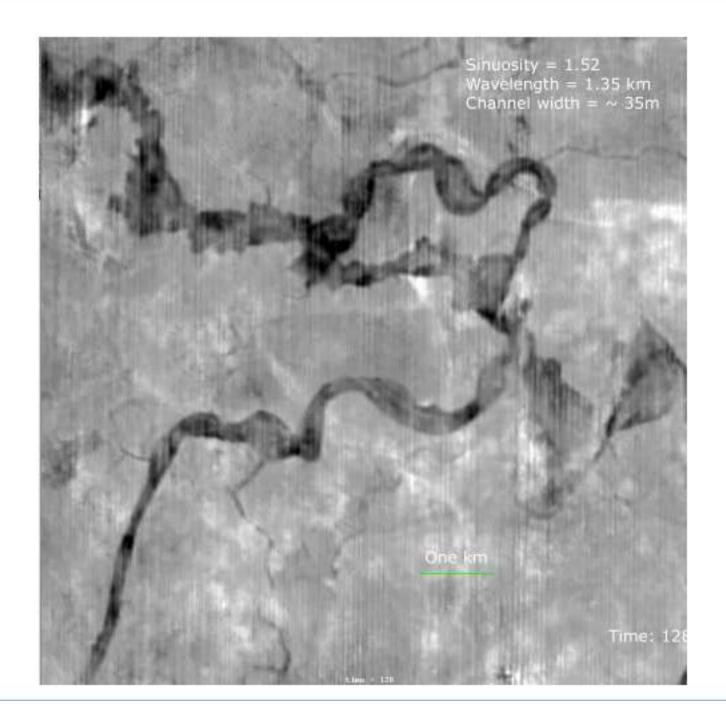


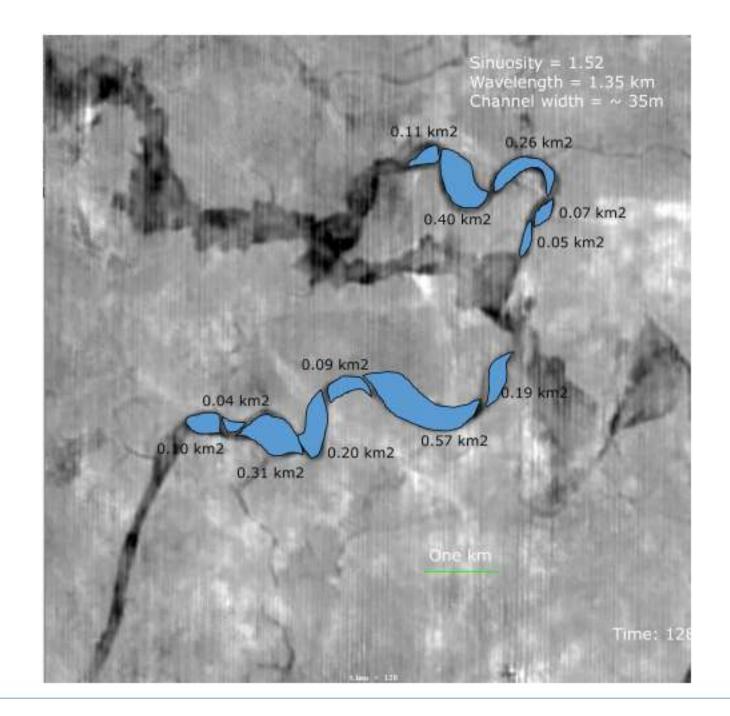


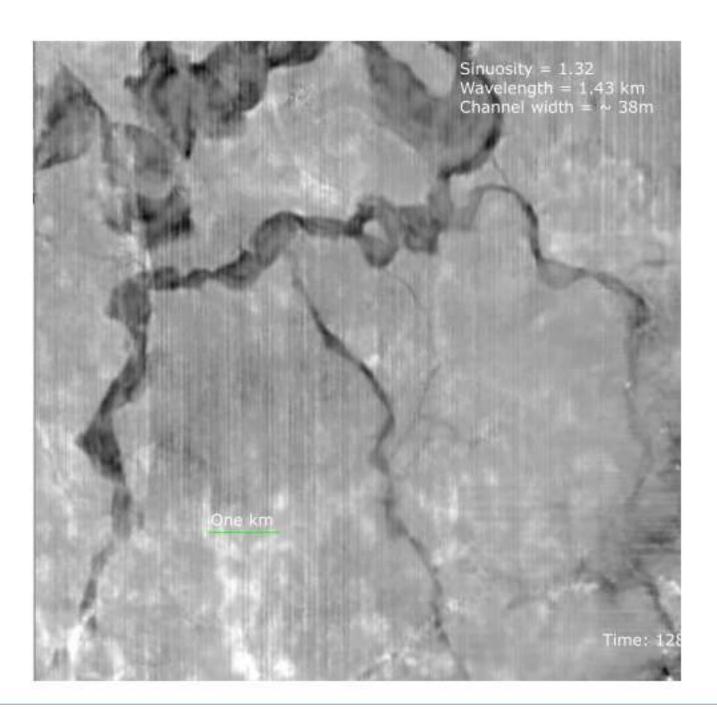


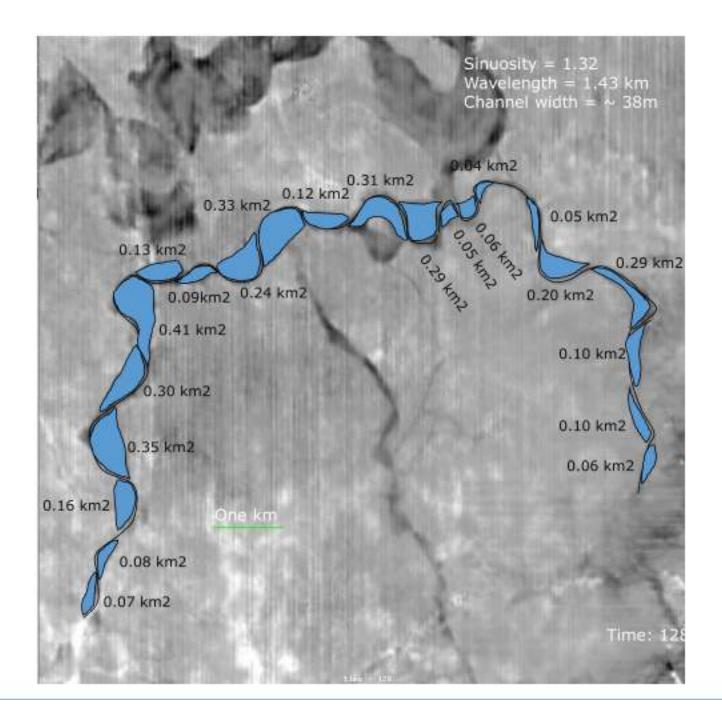


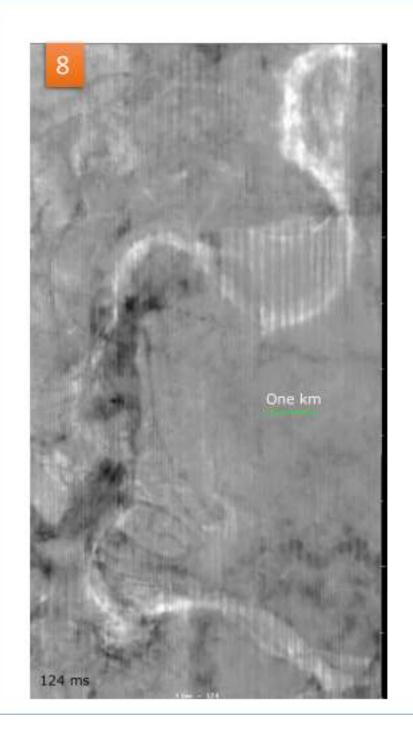


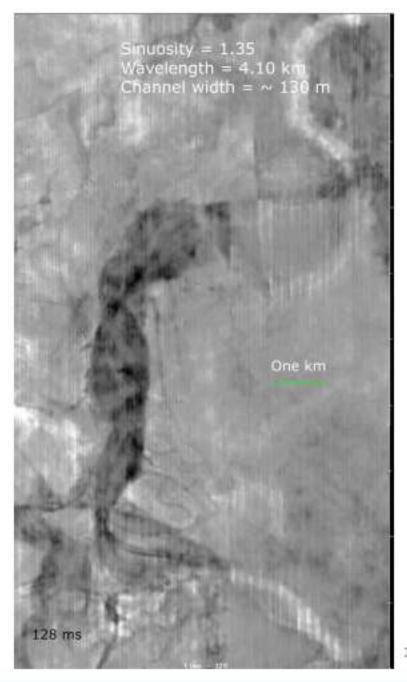


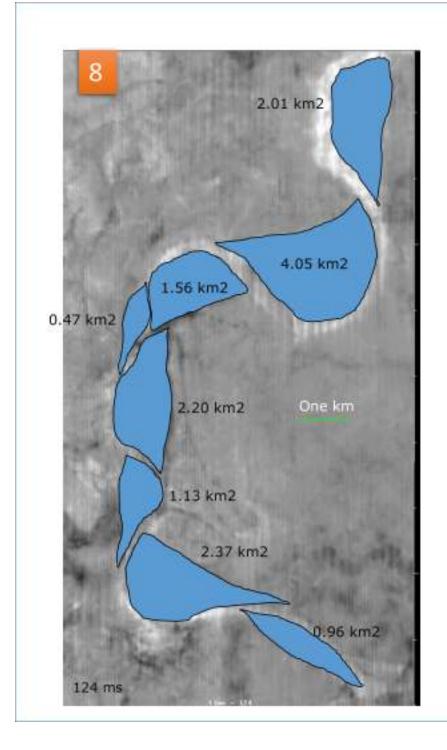


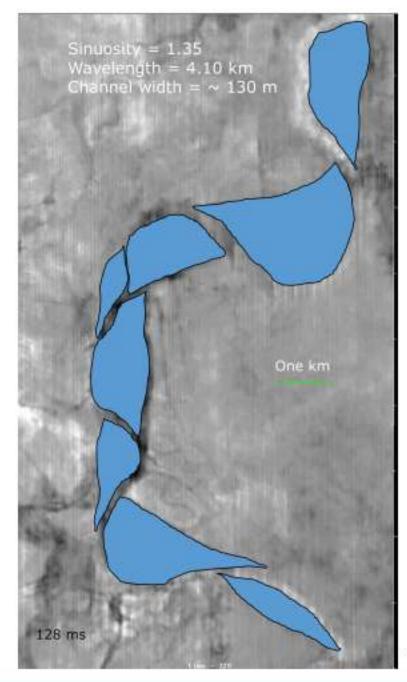




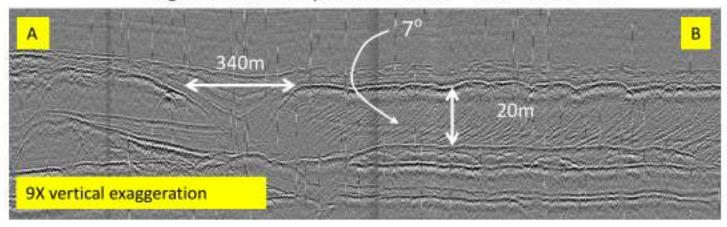


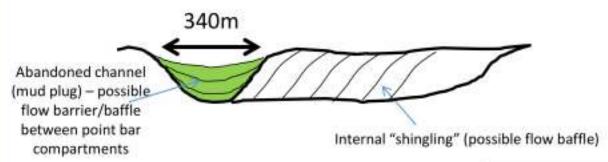


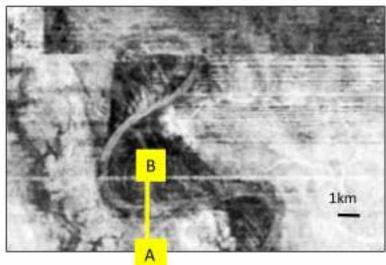


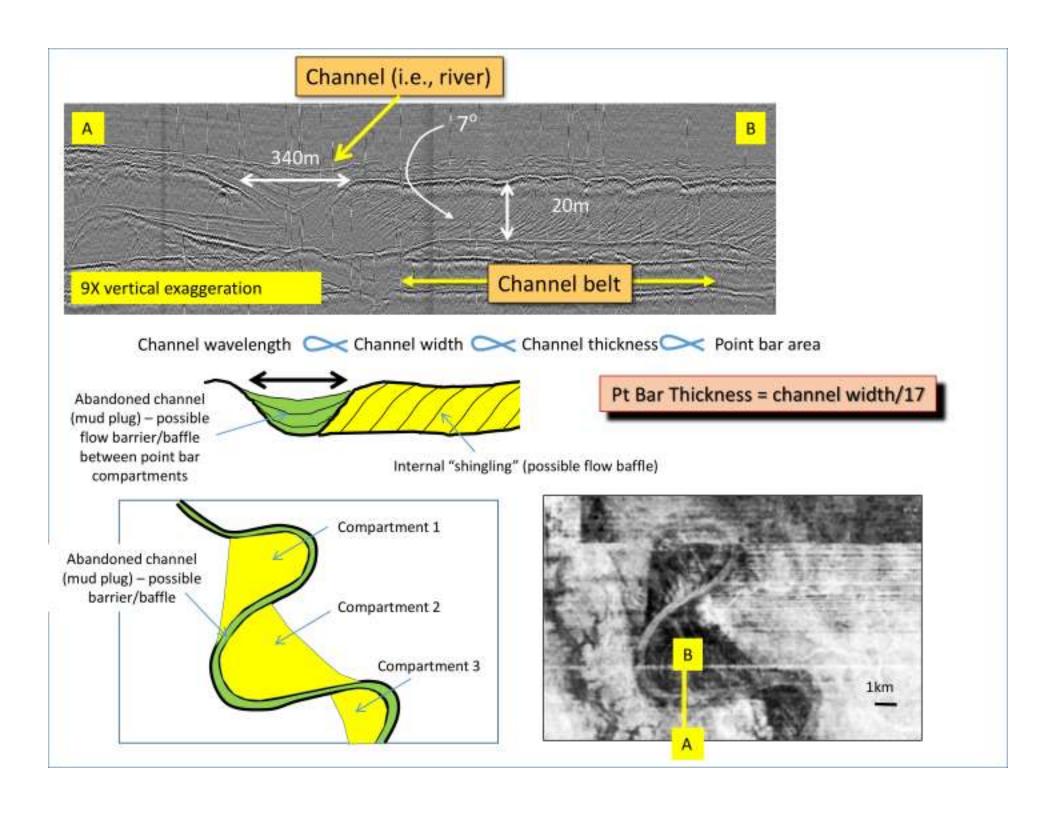


High-resolution sparker seismic - resolution <1m

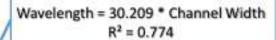


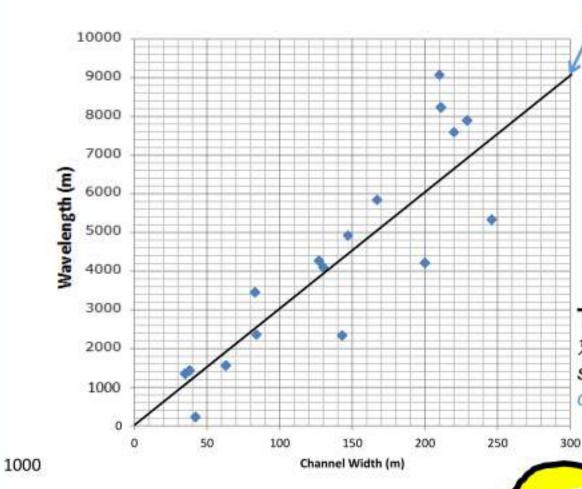






Relationship between Channel width and Channel Wavelength (based on Gulf of Thailand empirical observations)





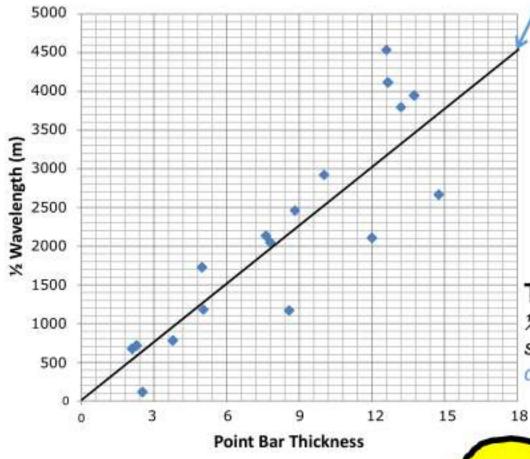
This is critical because:

1/2 WL

1/2 WL is a measure of the Pt Bar size, and Pt Bar thickness is derived directly from well logs

Big/deep rivers are associated with big/thick point bars

Relationship between Pt Bar Thickness and Channel Wavelength (based on Gulf of Thailand empirical observations)



Wavelength = 30.209 * Channel Width R² = 0.774

Channel Width = 17 * Point Bar Thickness

Wavelength = 30.209 * 17 * Point Bar Thickness

Point Bar Thickness = Wavelength / (30.209 * 17)

Point Bar Thickness = 1/2 Wavelength / 257

OF

1/2 Wavelength = 257 * Point Bar Thickness

This is critical because:

1/2 WL

1/2 WL is a measure of the Pt Bar size, and Pt Bar thickness is derived directly from well logs

Big/deep rivers are associated with big/thick point bars

1000

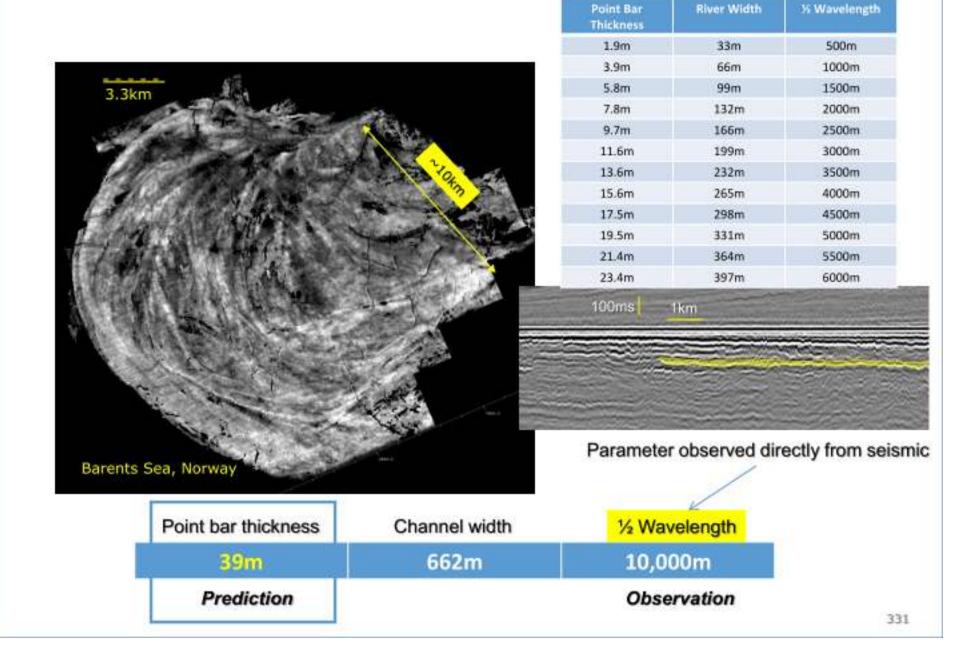
Relationship of Point Bar Thickness vs. River Size (width) vs. ½ Wavelength (Length of Point Bar) (based on Gulf of Thailand empirical observations)

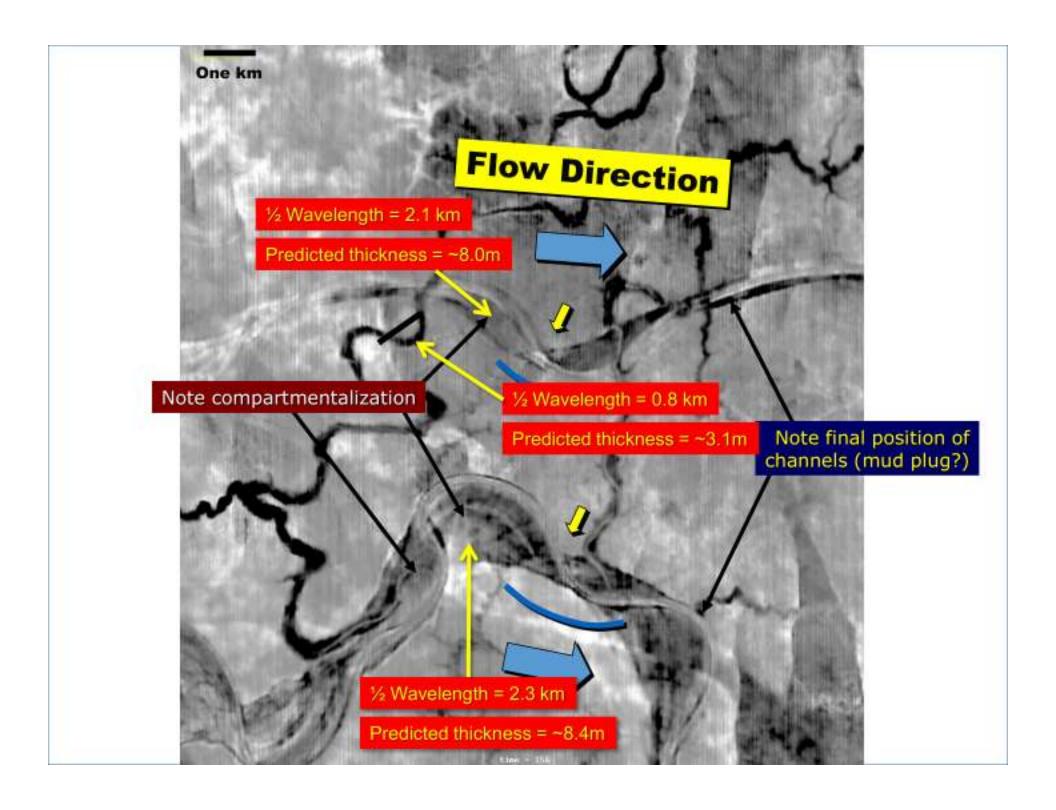
Point Bar Thickness	River Width	1/2 Wavelength	
1.9m	33m	500m	
3.9m	66m	1000m	
5.8m	99m	1500m	
7.8m	132m	2000m	
9.7m	166m	2500m	
11.6m	199m	3000m	
13.6m	232m	3500m	
15.6m	265m	4000m Pt	Bar Thickness
17.5m	298m	4500m	
19.5m	331m	5000m	
21.4m	364m	5500m	

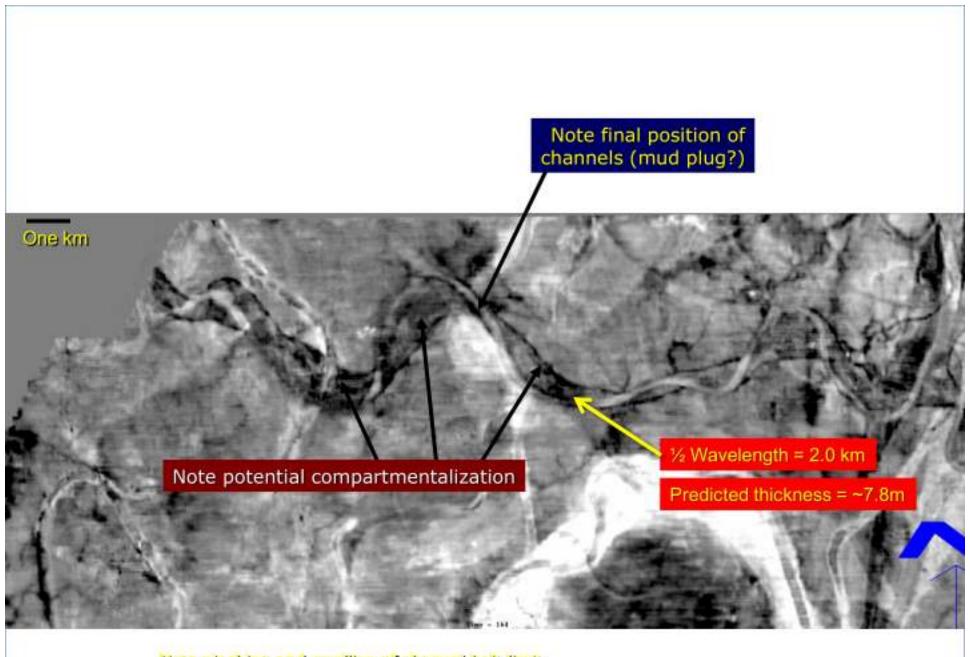
Big/deep rivers are associated with big/thick point bars

1/2 WL

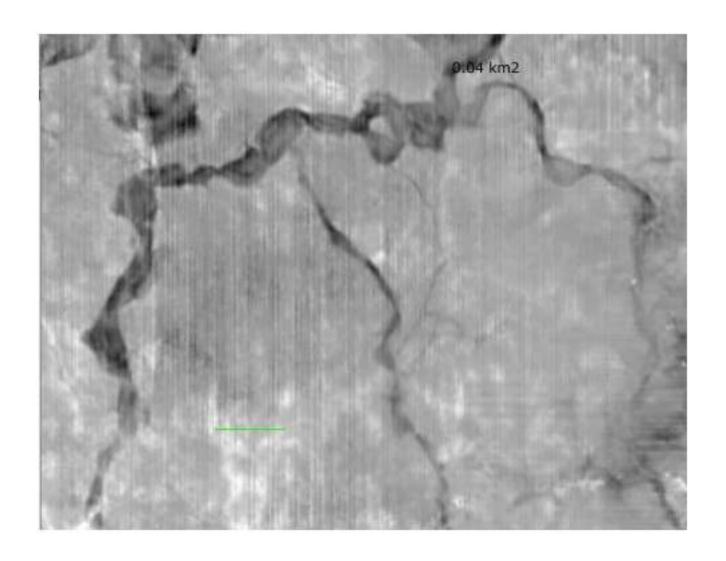
Point Bar Thickness Prediction

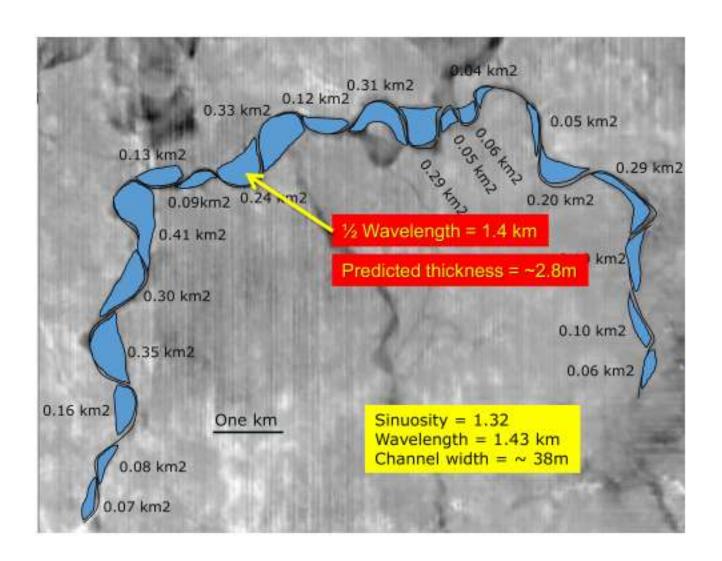


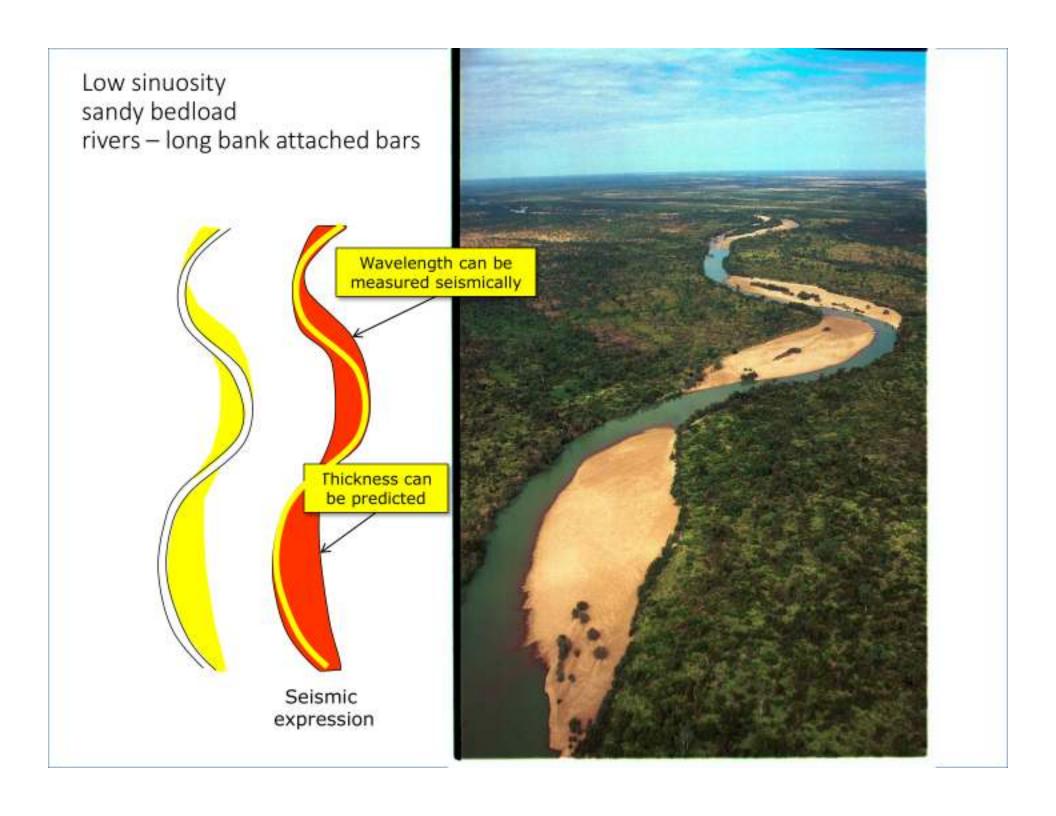


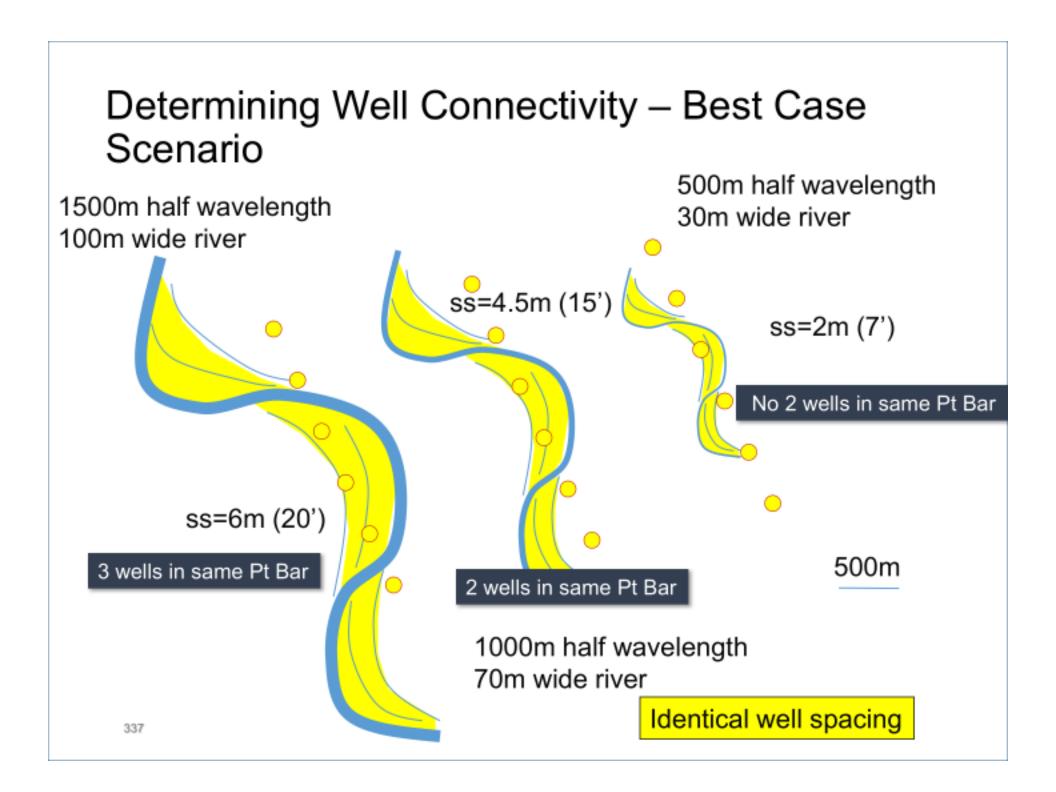


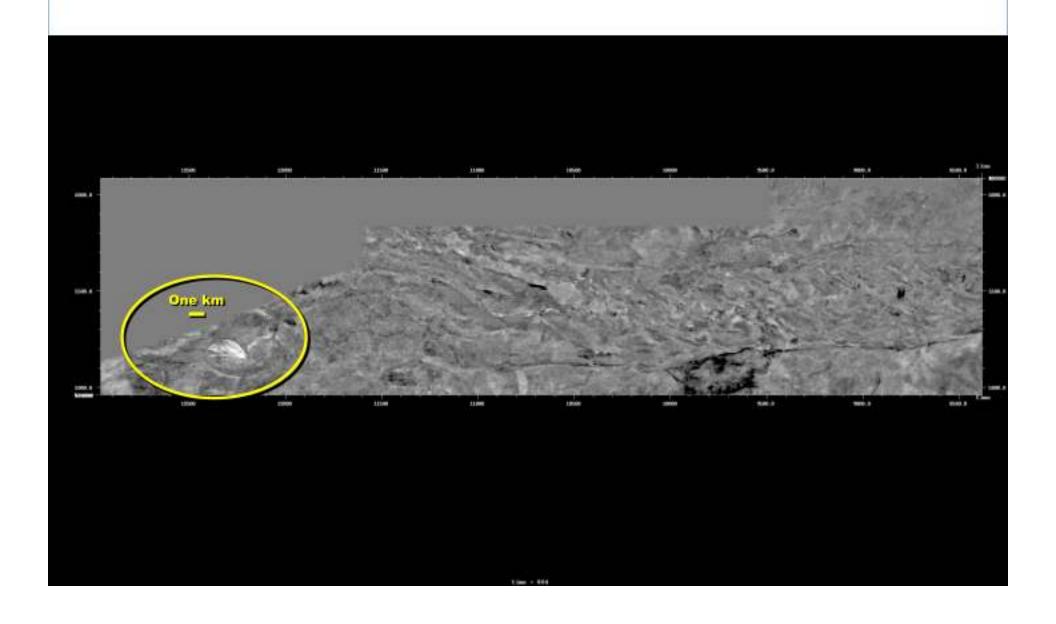
Note pinching and swelling of channel belt limit

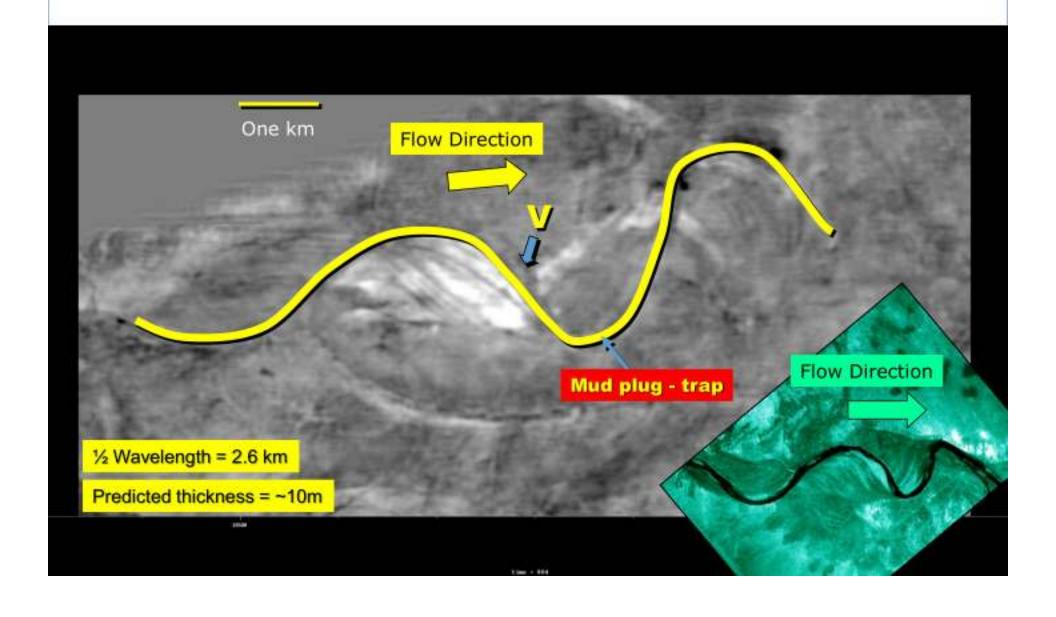


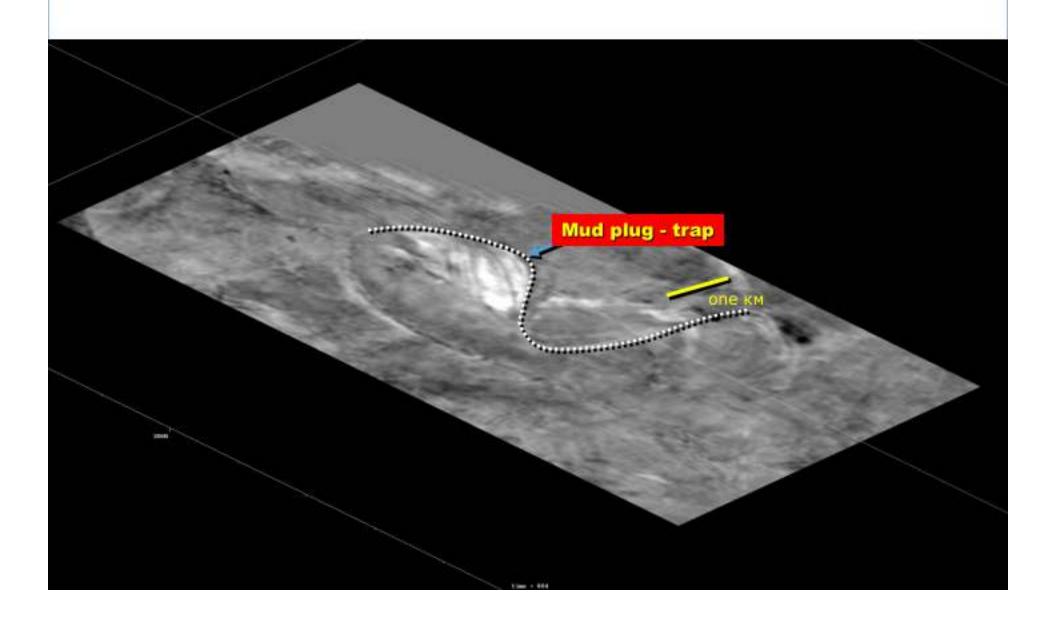


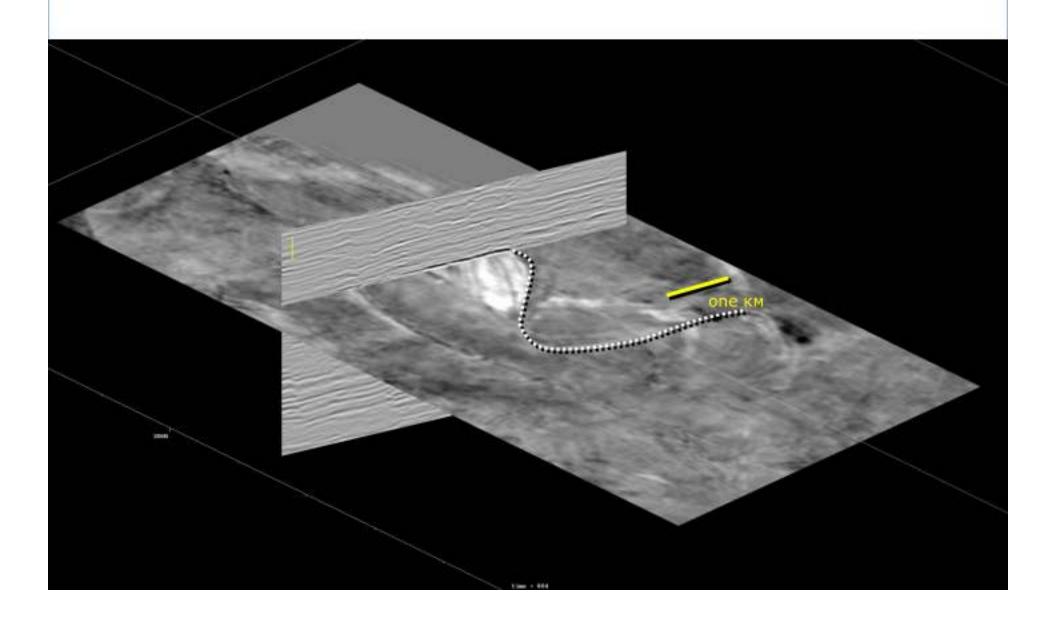


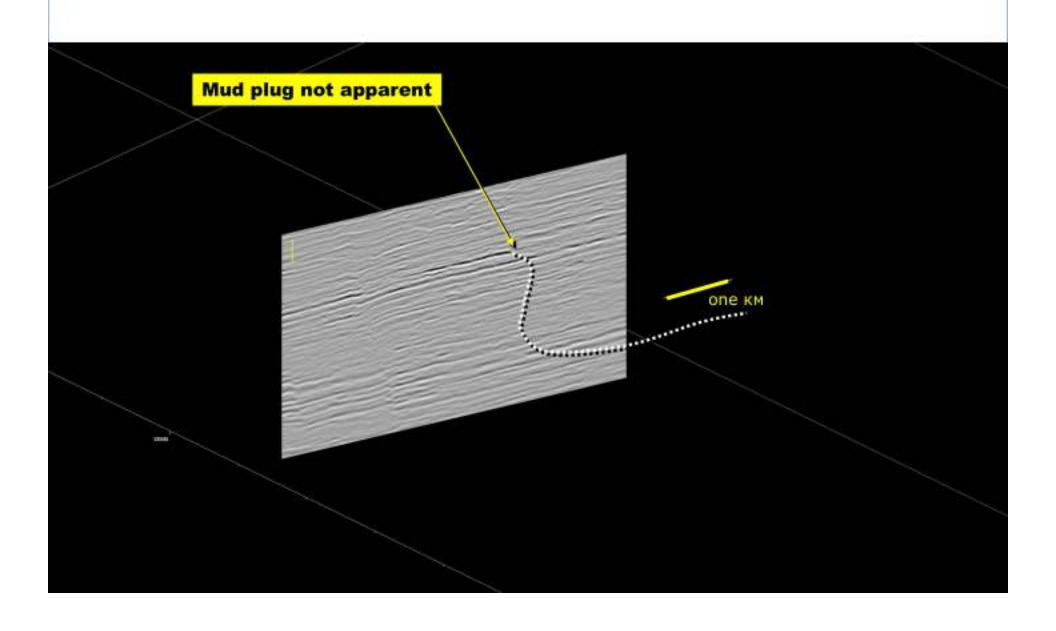






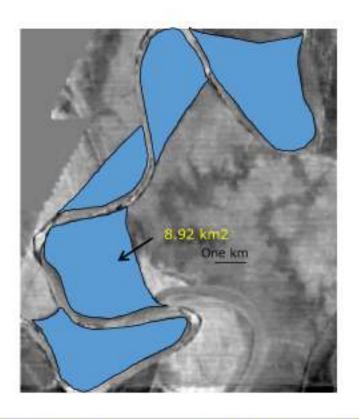


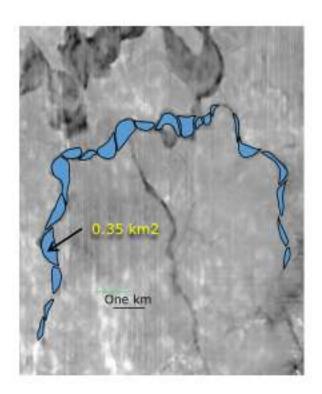




Stratigraphic Prediction

Key Question: How big is the point bar? or...How large is the compartment?

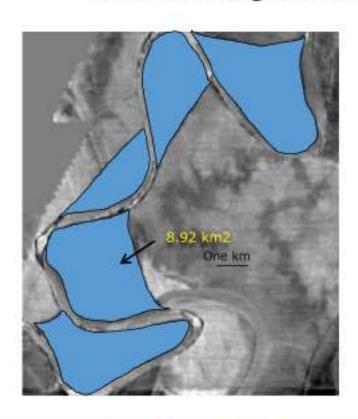


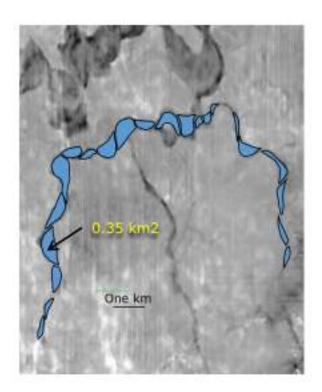


Big rivers have large point bars...little rivers have small point bars...

Stratigraphic Prediction

Key Question: How big is the point bar? or...How large is the compartment?

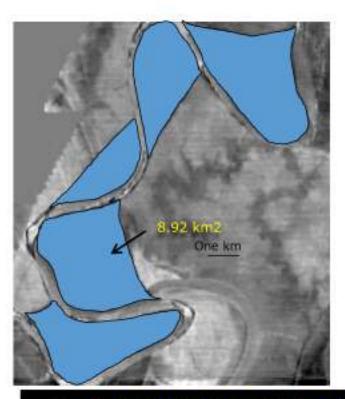


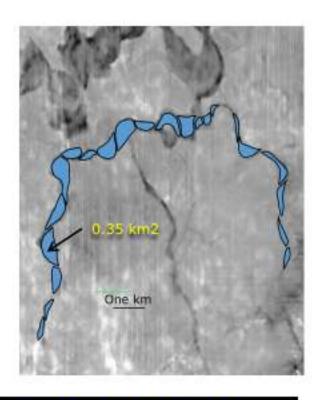


Big rivers have thick point bars...little rivers have thin point bars...

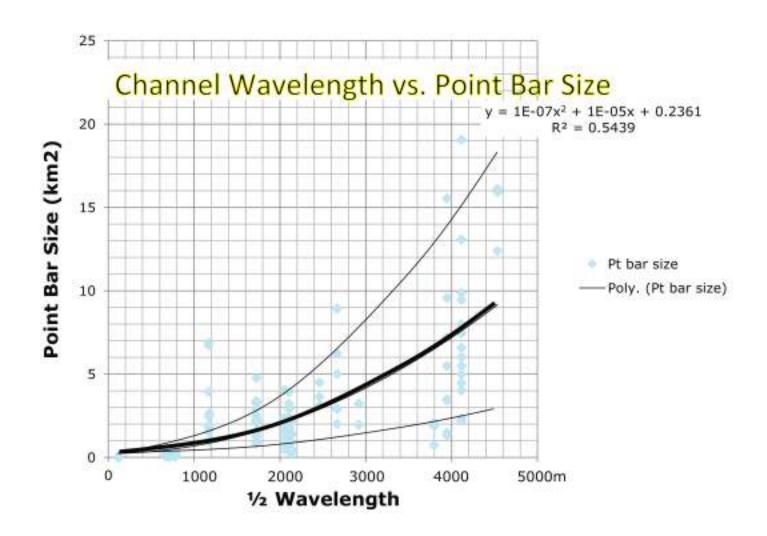
Stratigraphic Prediction

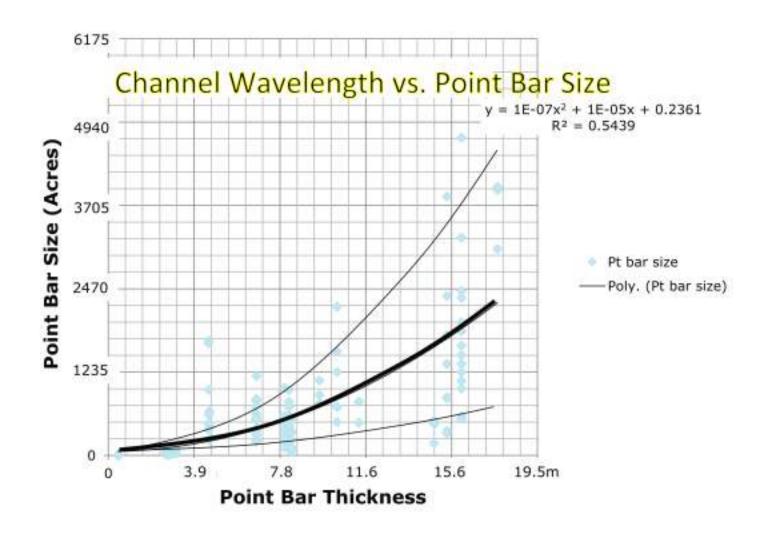
Key Question: How big is the point bar? or...How large is the compartment?



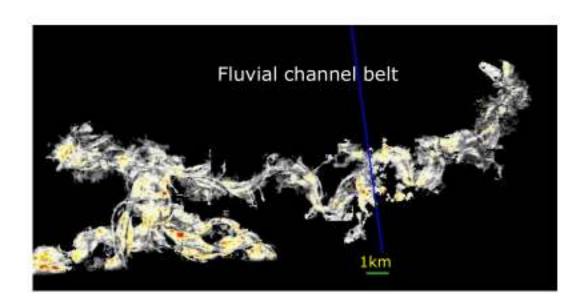


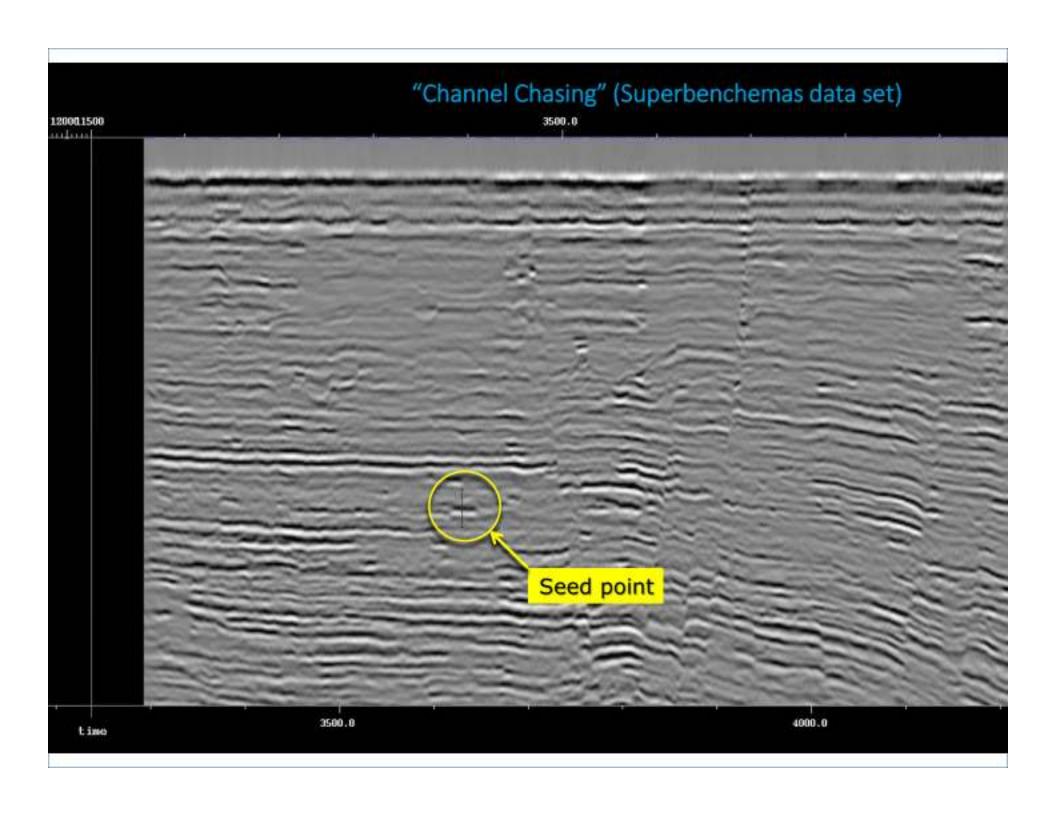
Well penetrations indicate point bar thickness... Can we predict the associated point bar size?

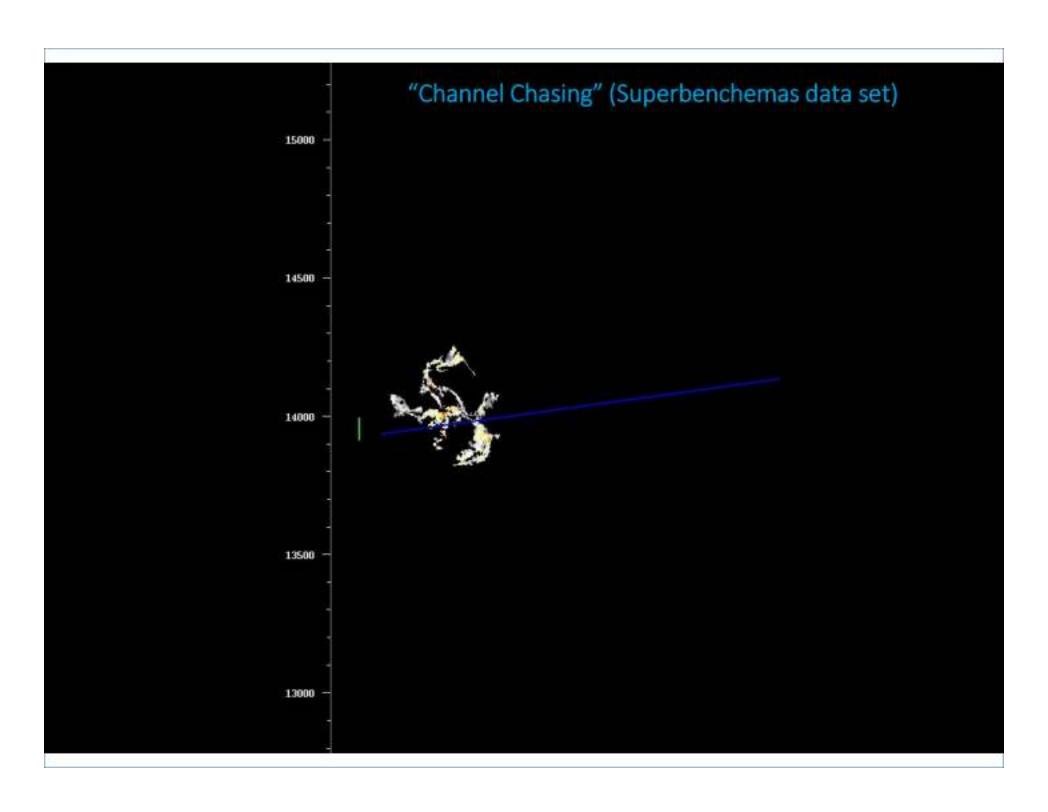


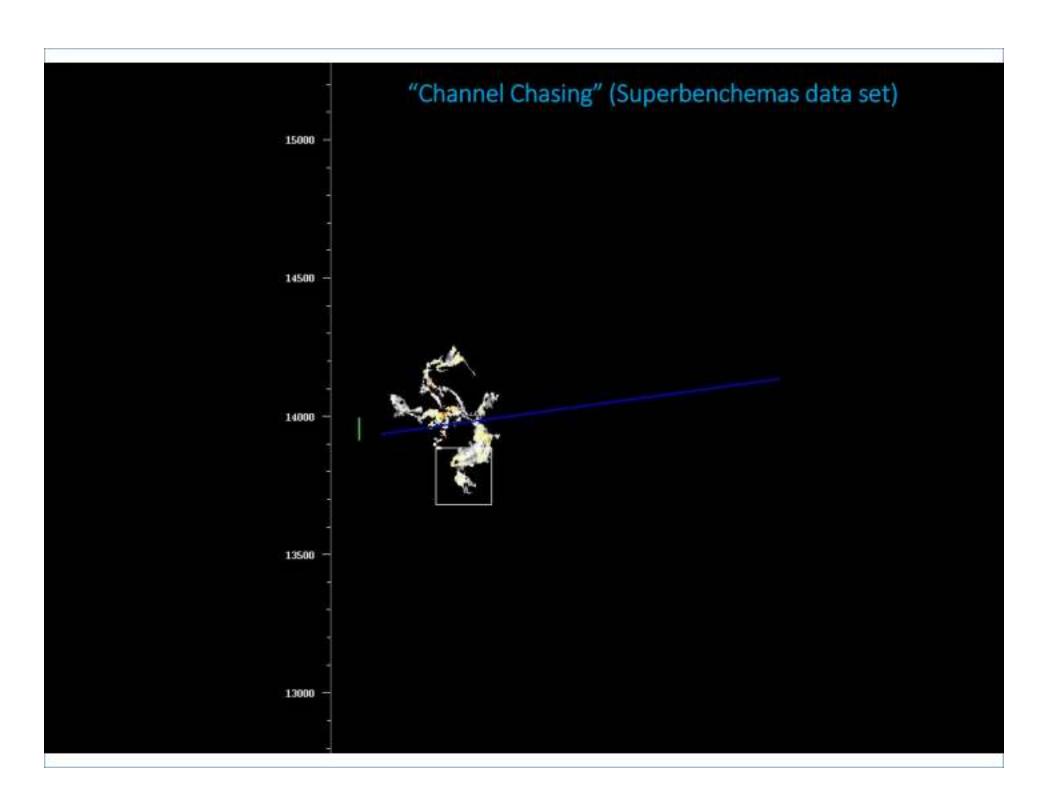


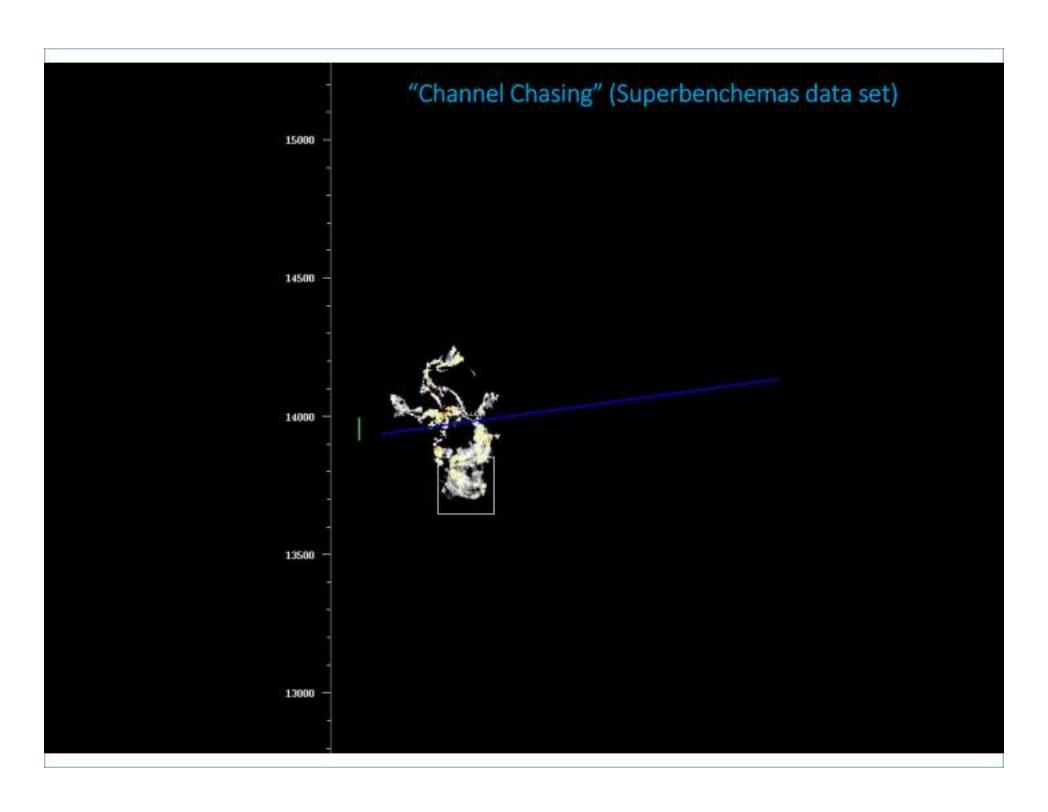
Workflow: Channel chasing

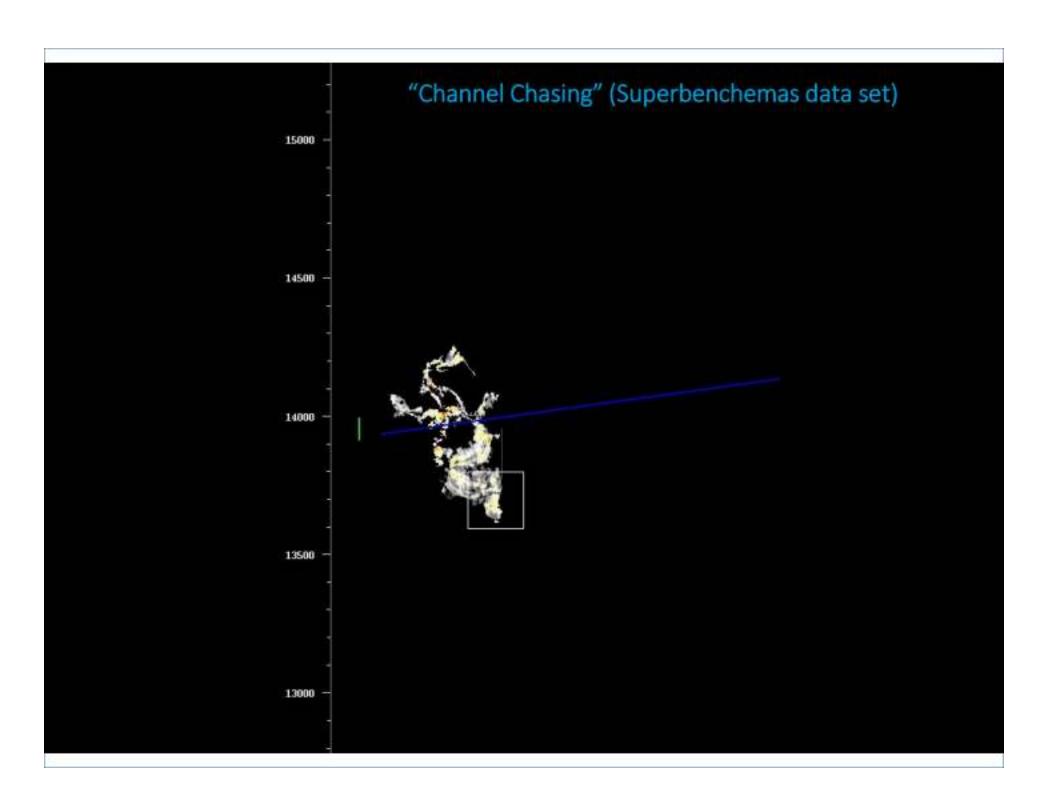


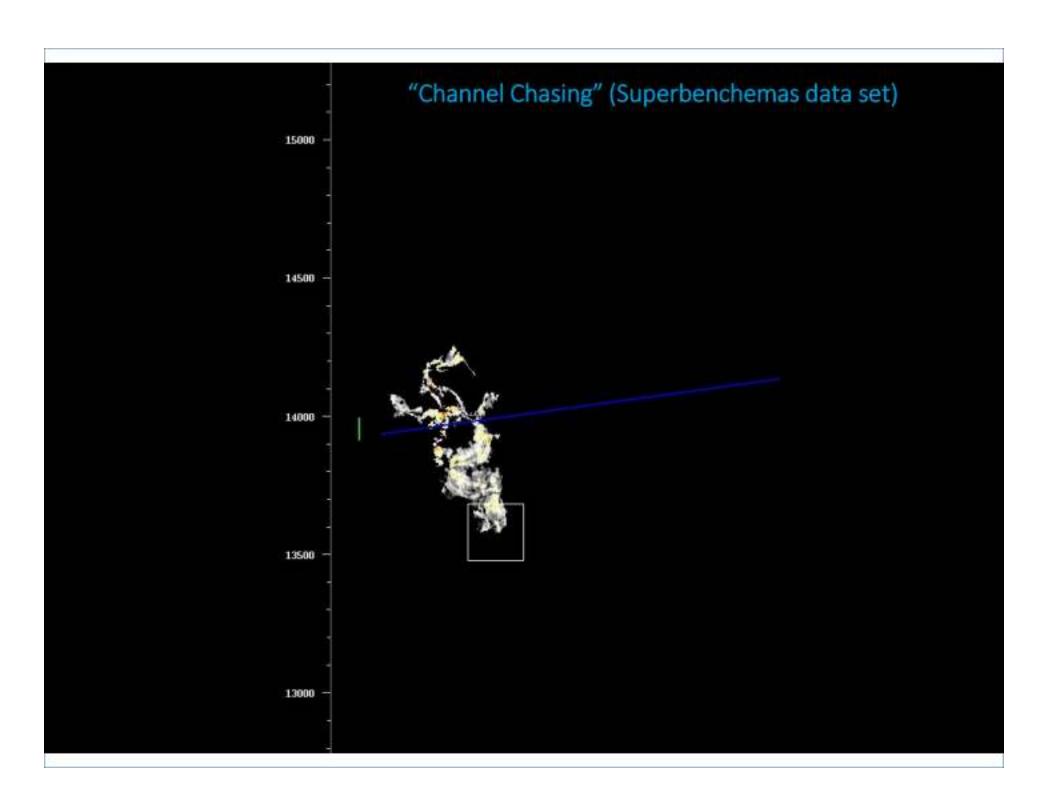


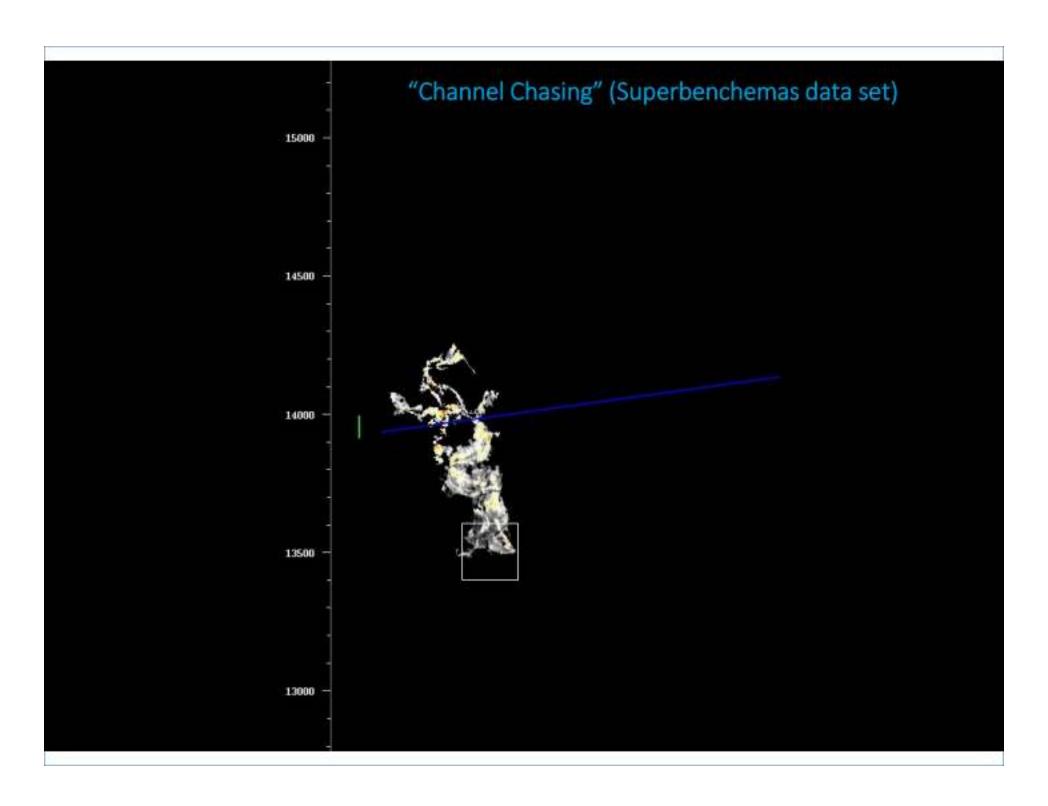


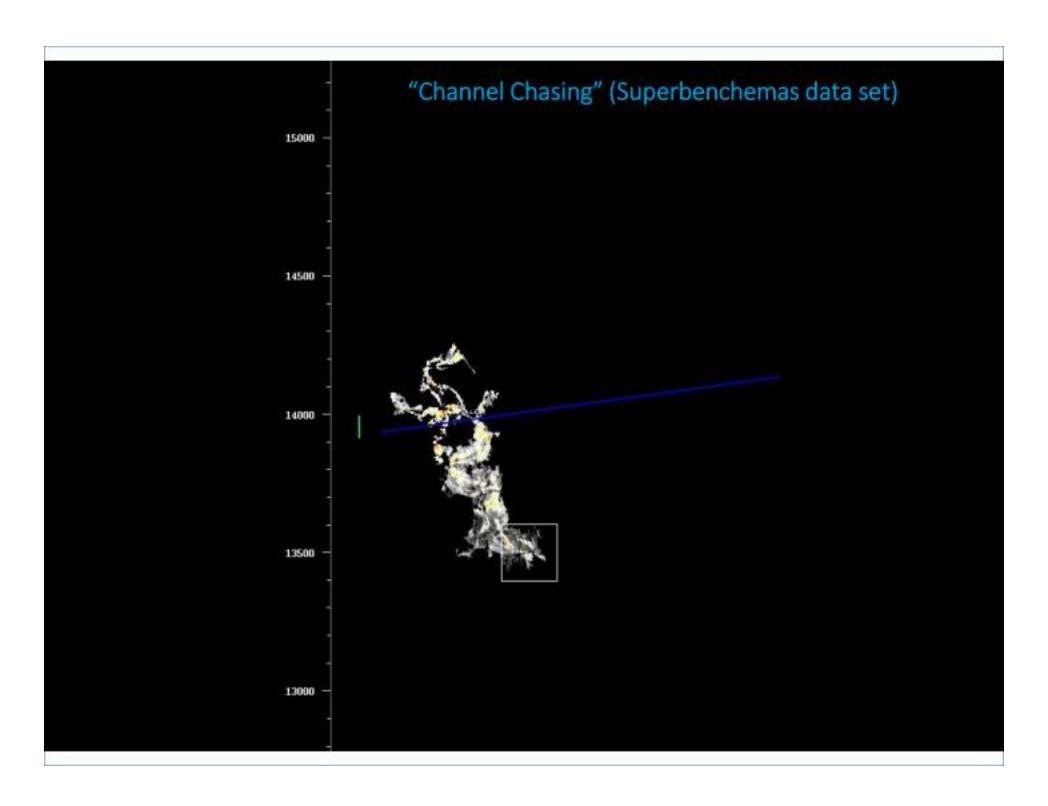


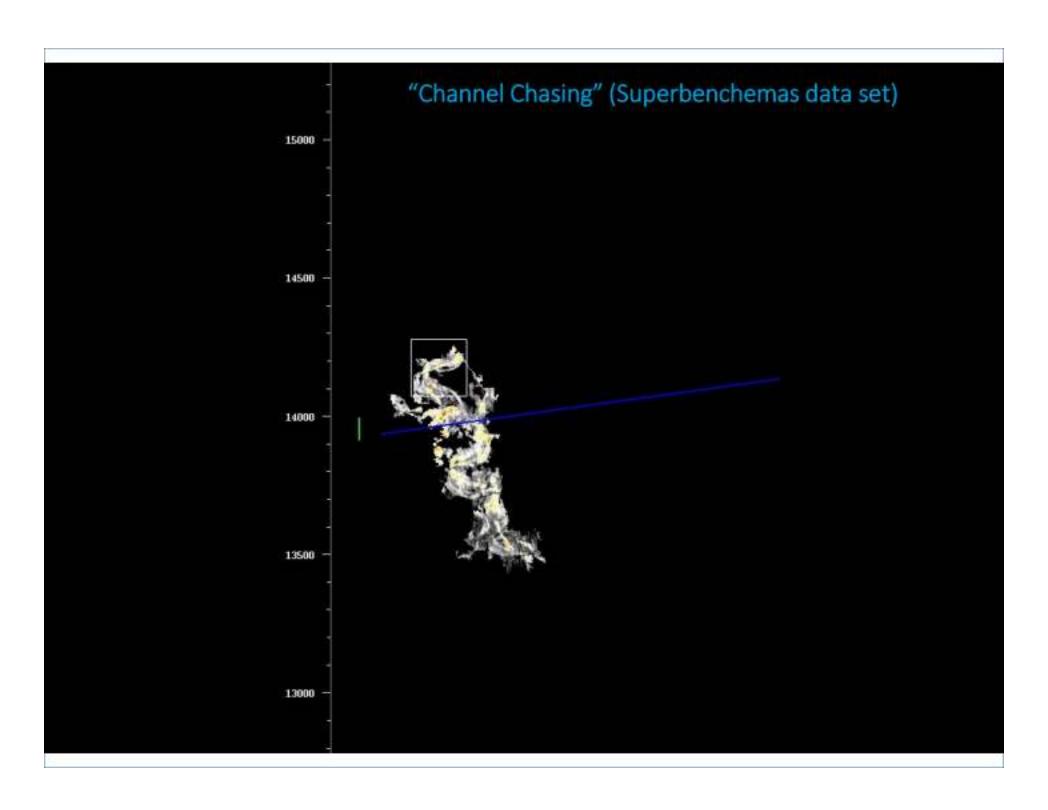


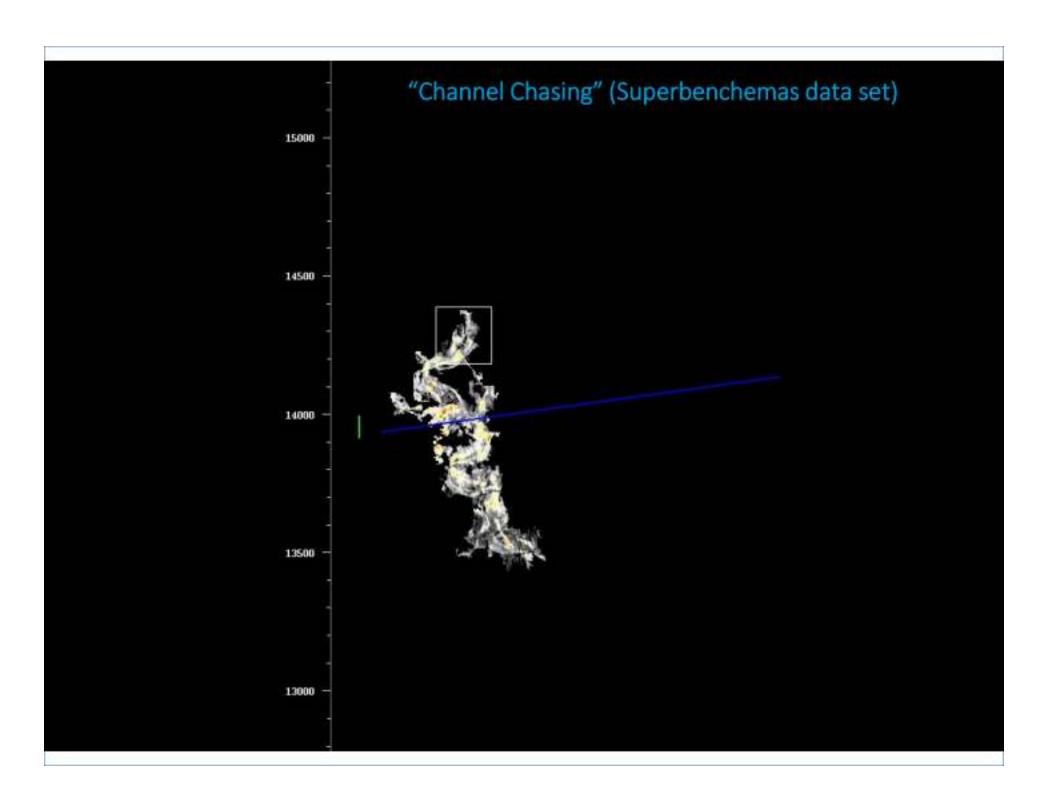


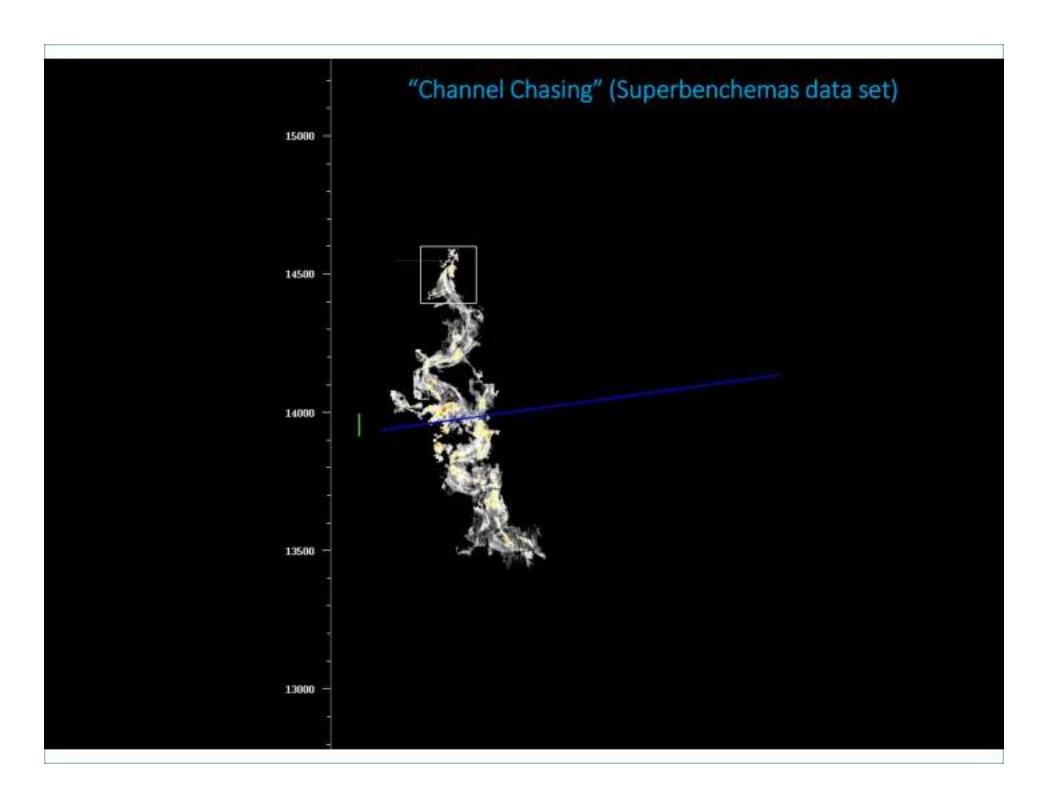


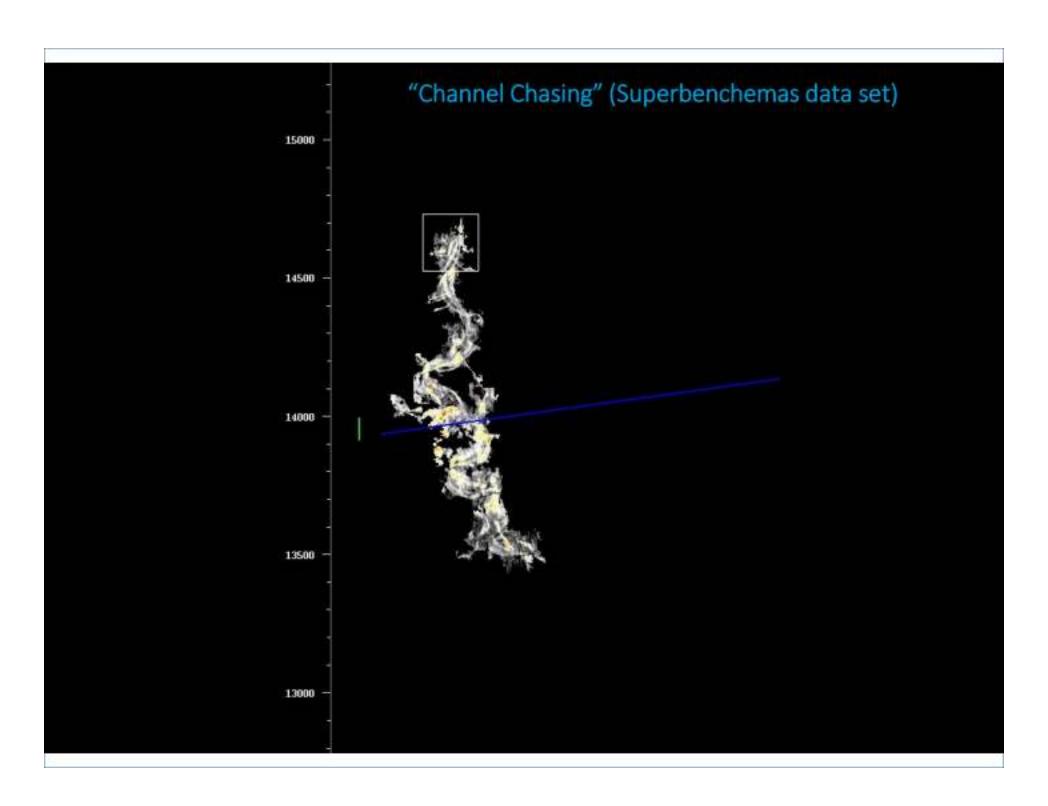


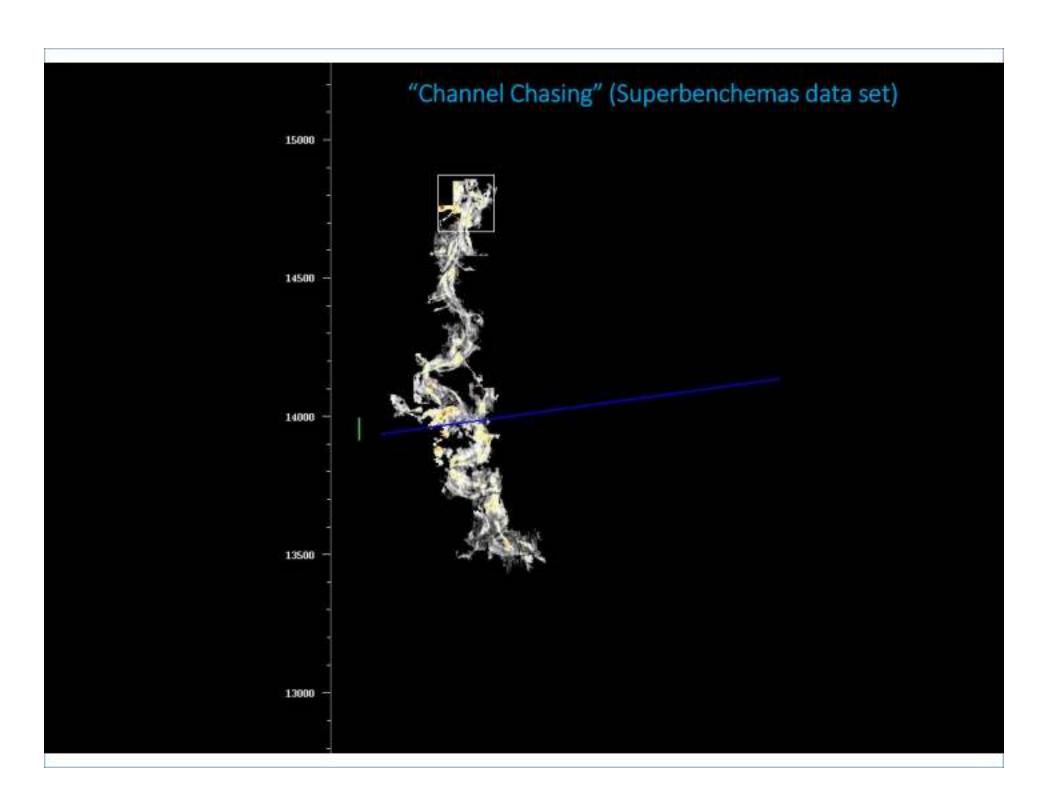


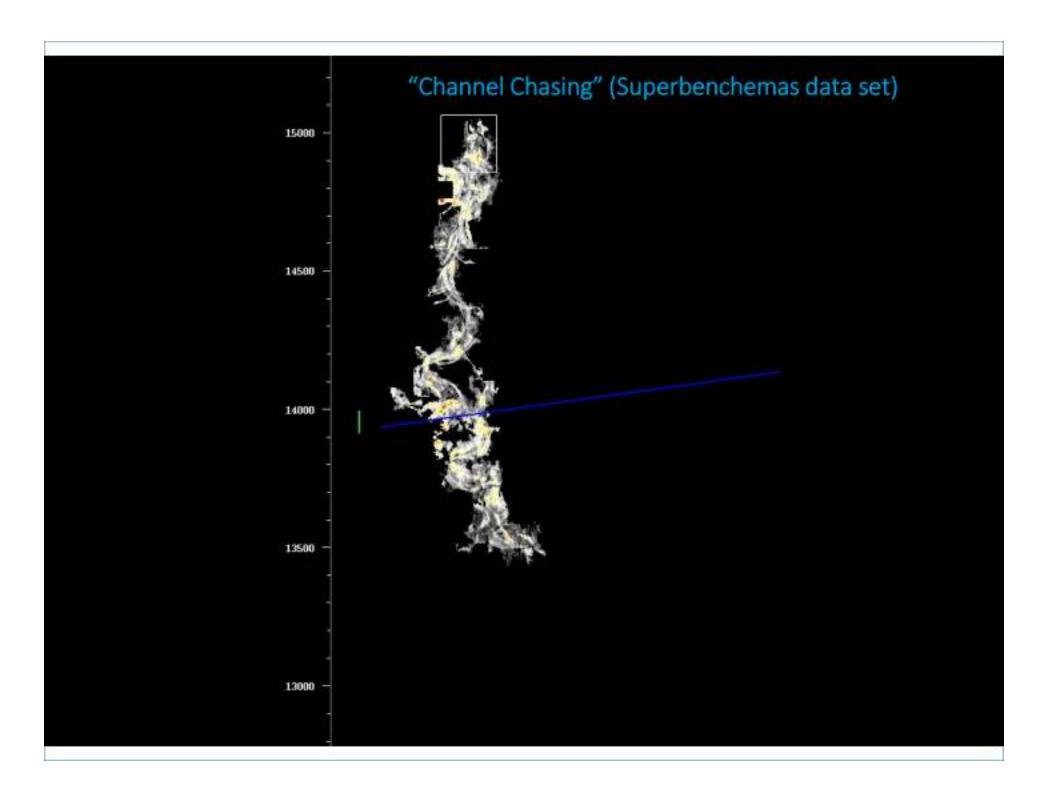


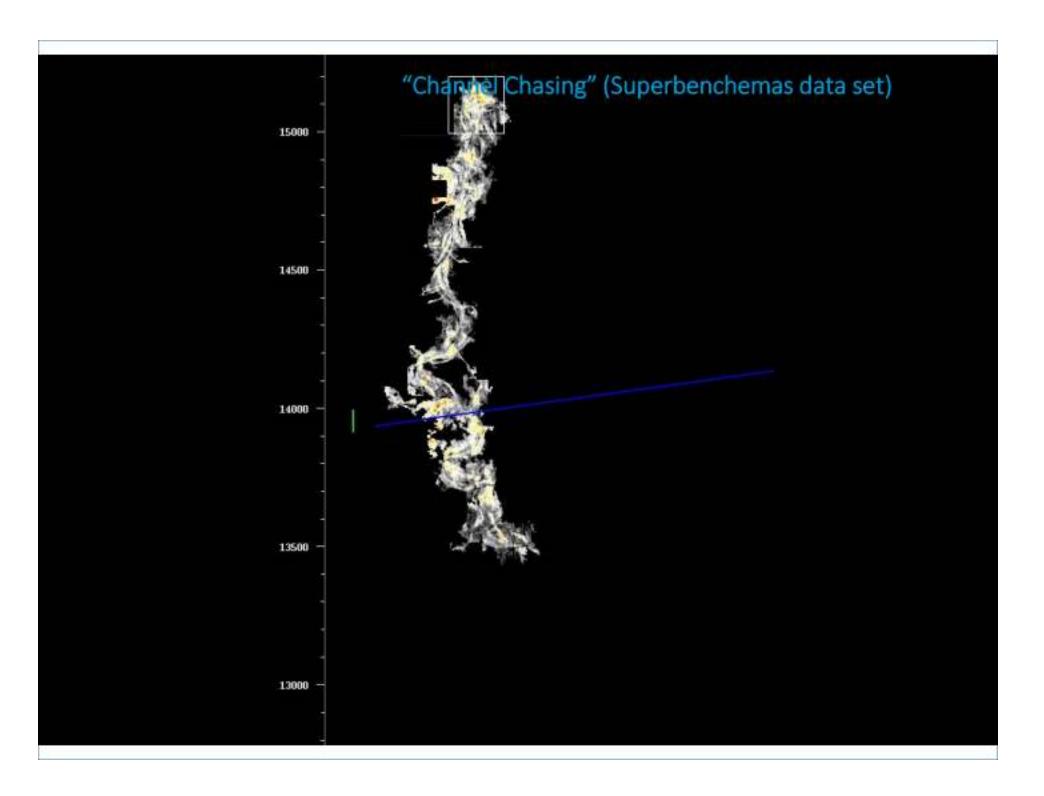


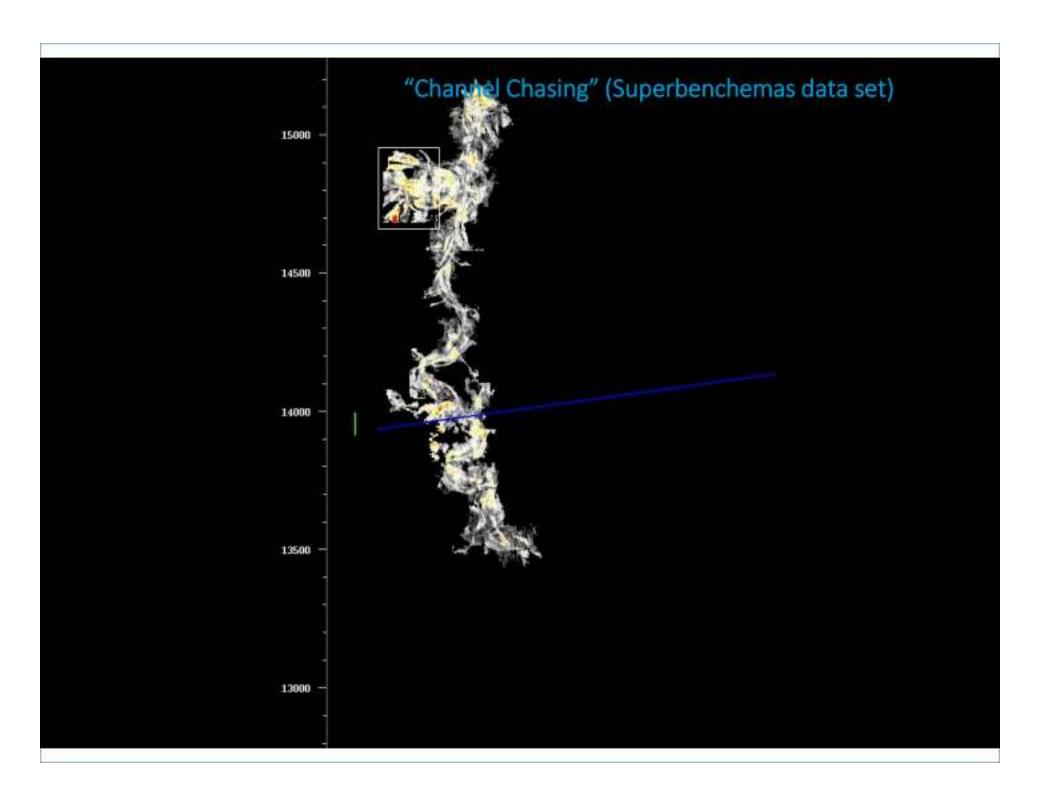


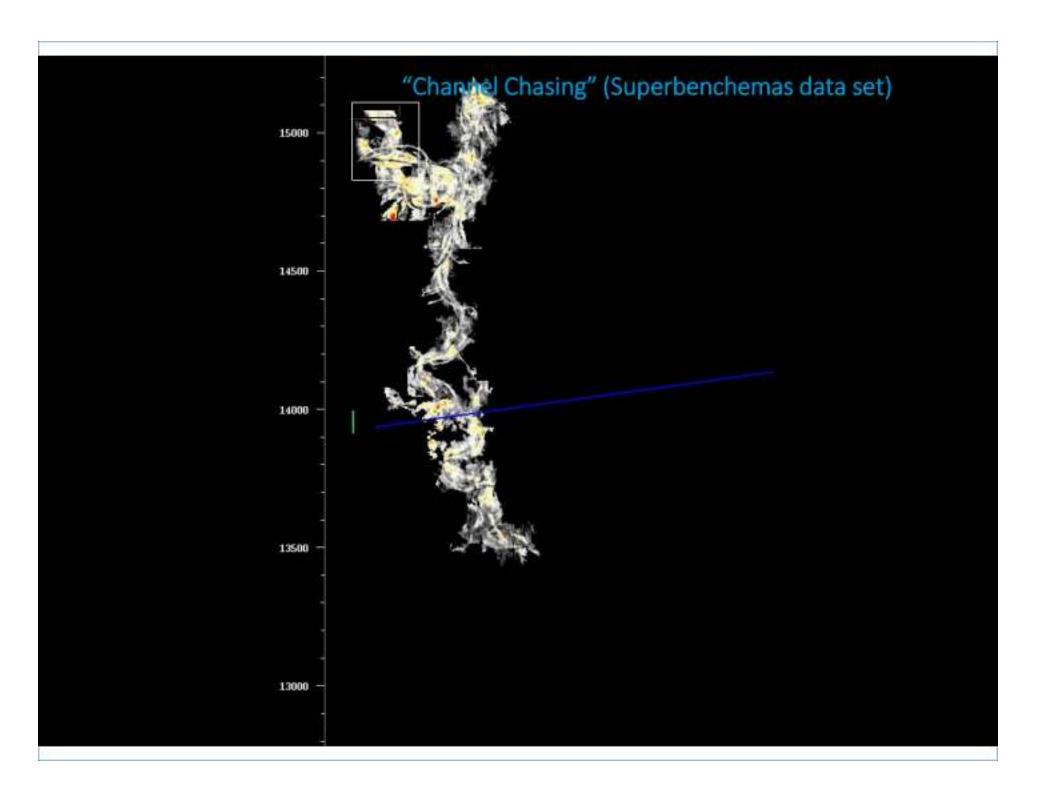


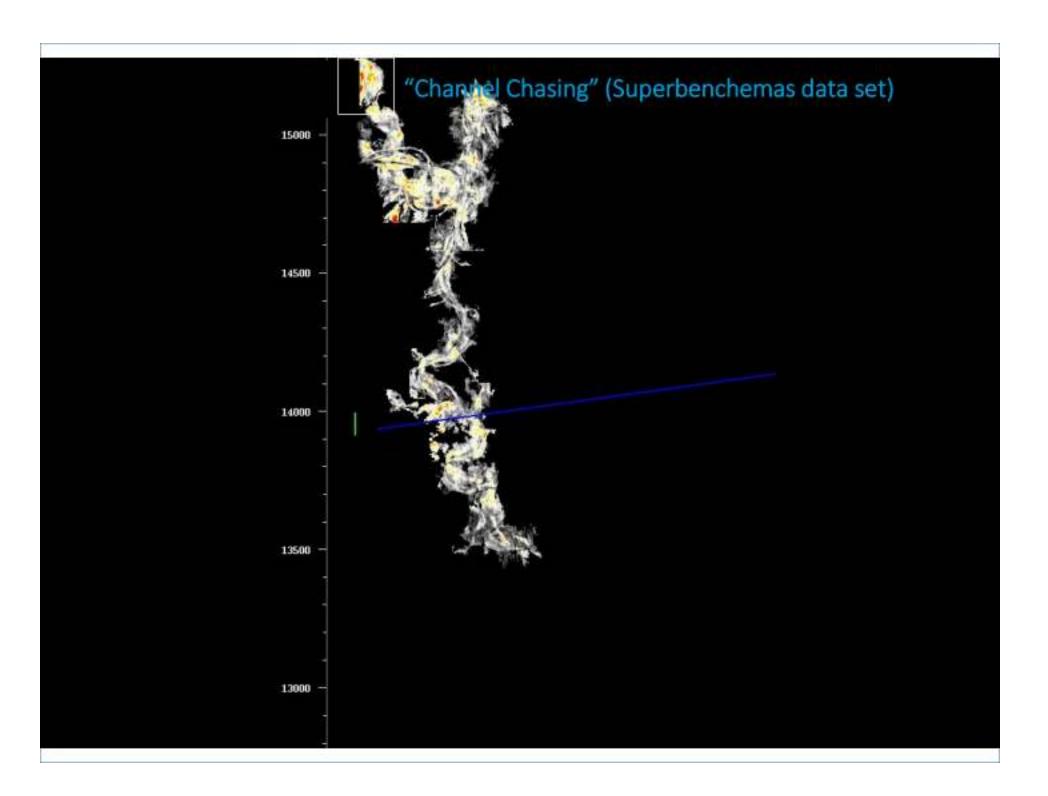


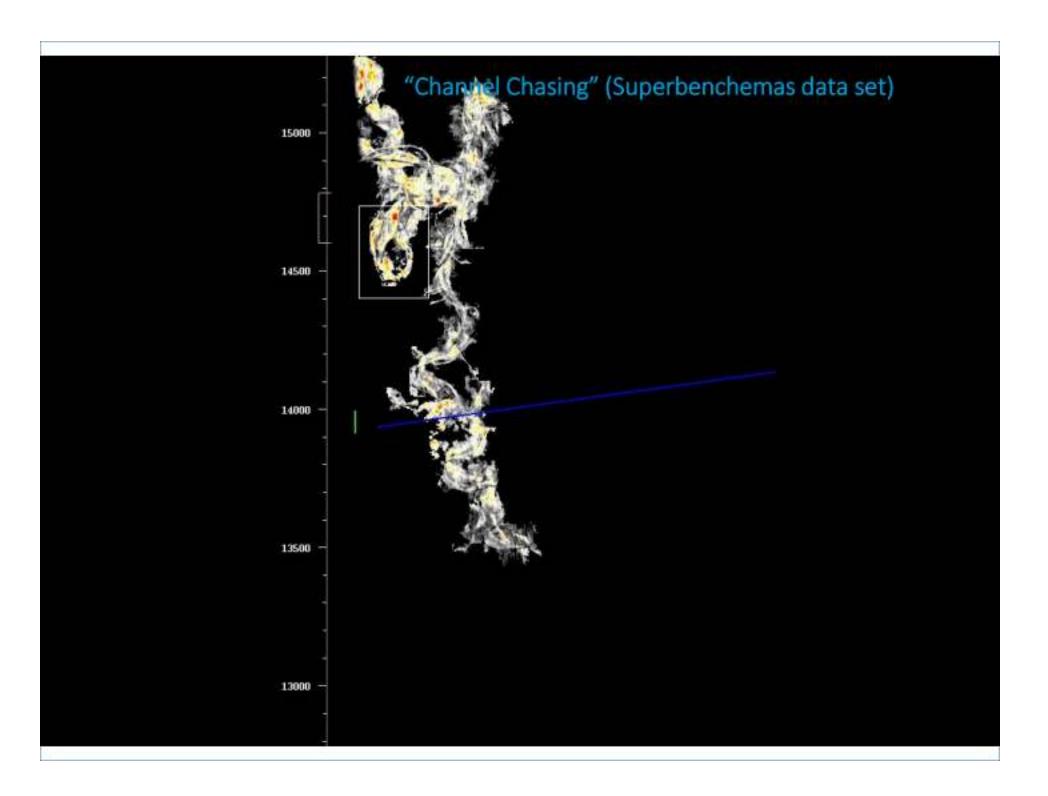


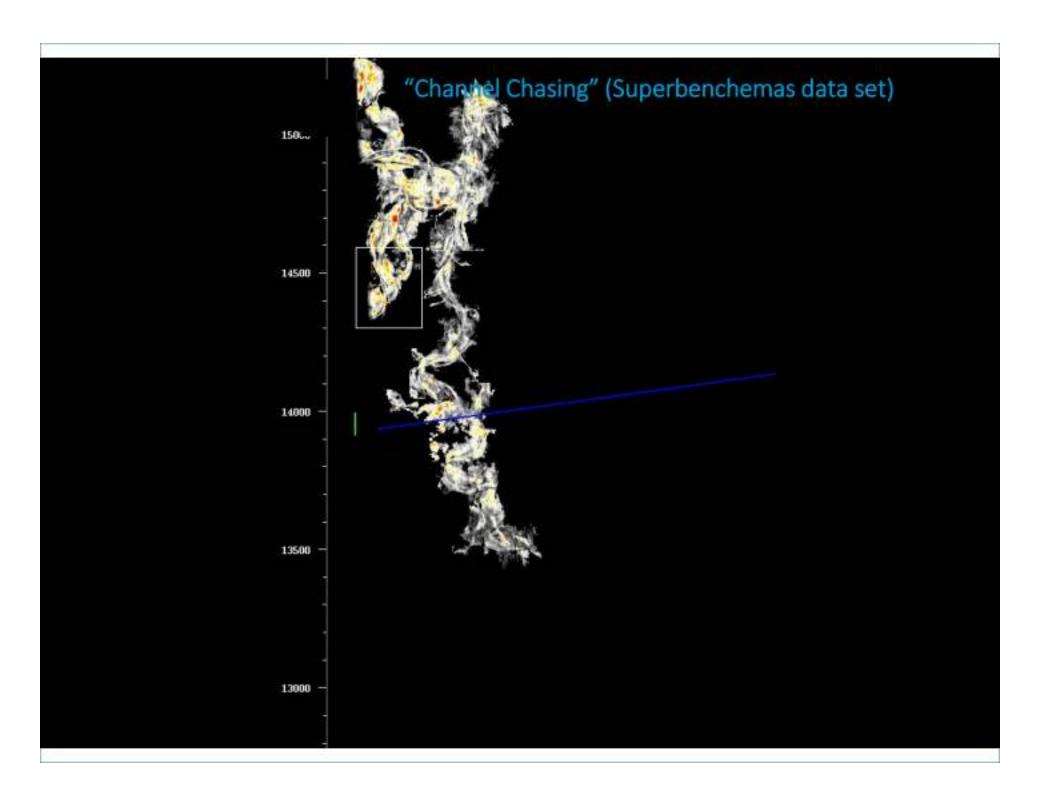


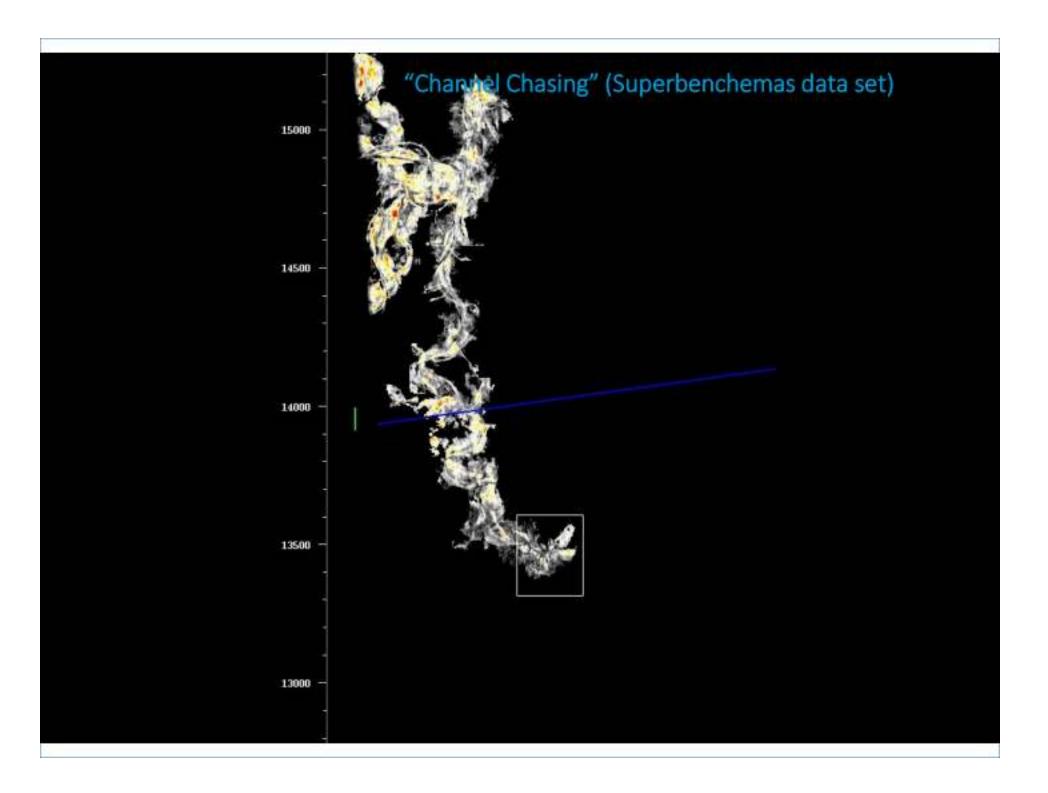


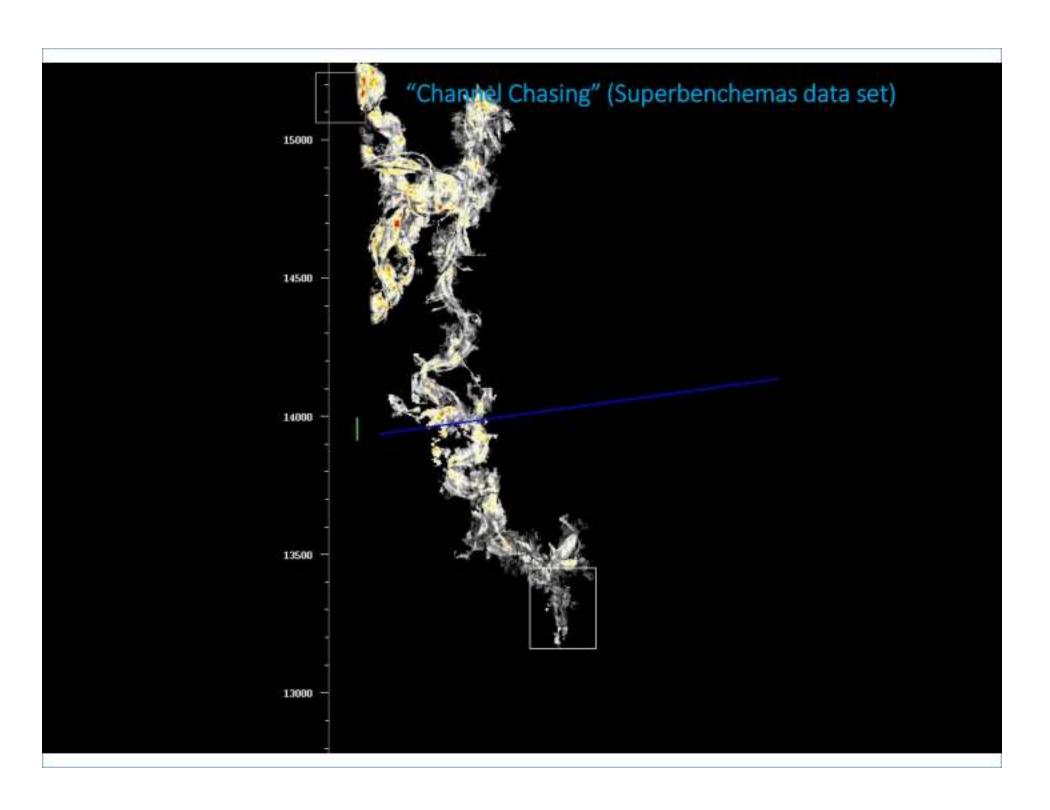


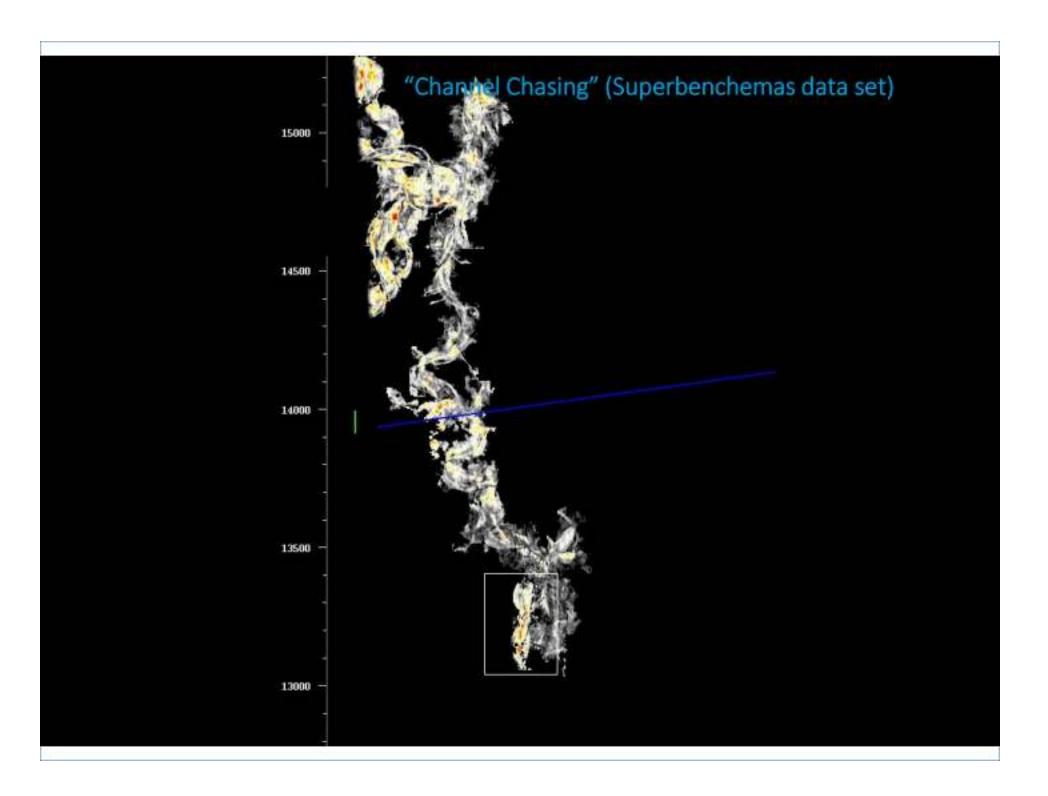


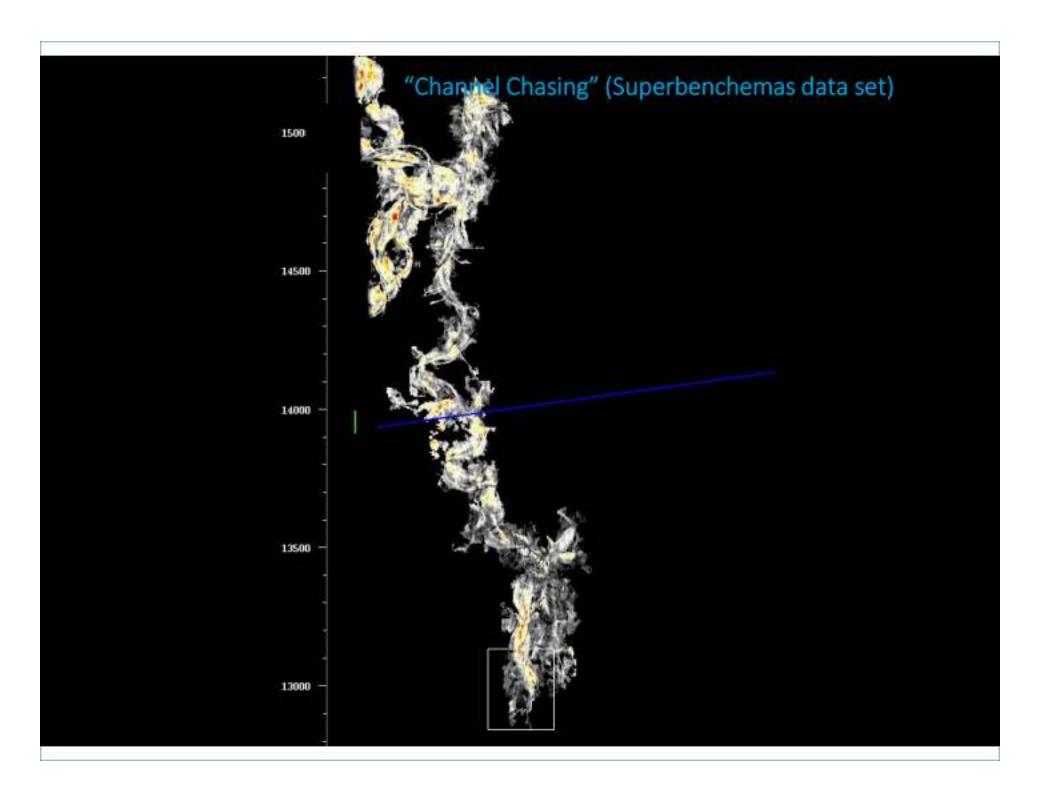




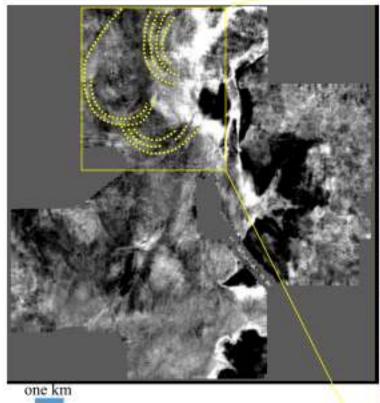






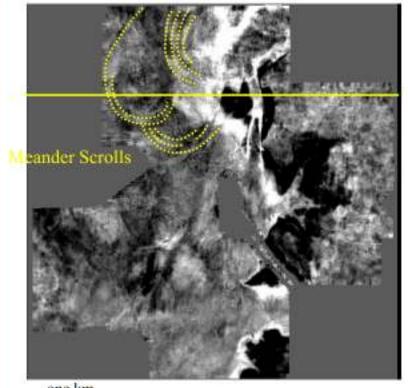


Meander Scrolls





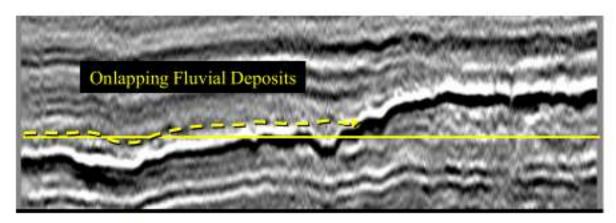
Base Cretaceous Fluvial Deposits



High-Sinuosity Fluvial Deposits Near Base Cretaceous Unconformity

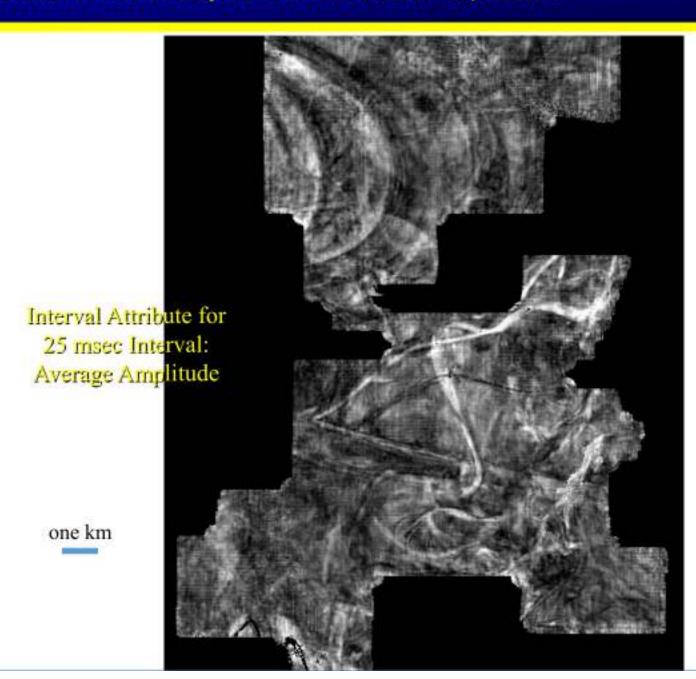
one km

20 msec

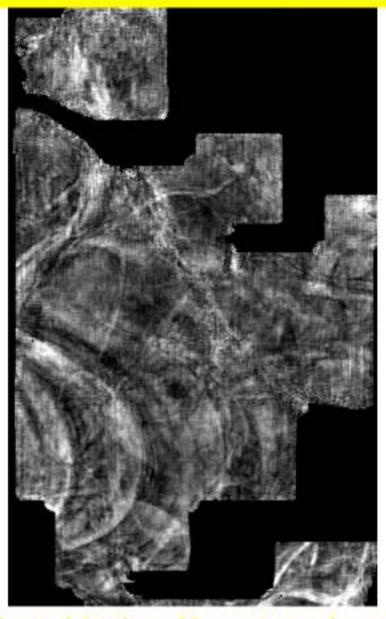


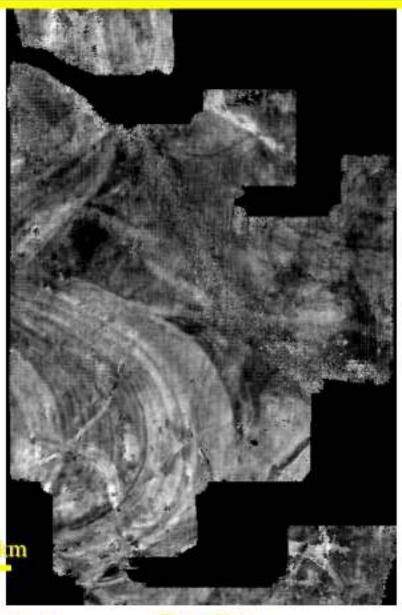


Cretaceous Channel Systems in the Cretaceous, Alberta



Cretaceous Channel Systems in the Cretaceous, Alberta

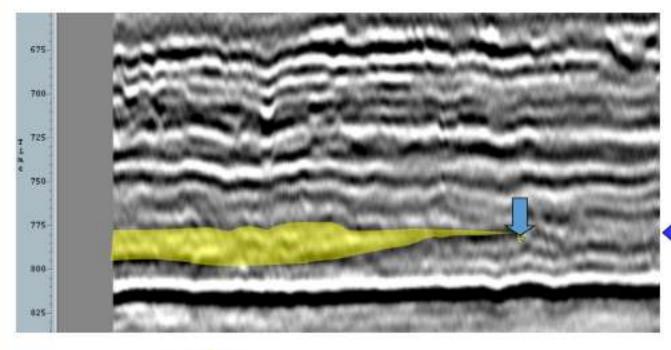


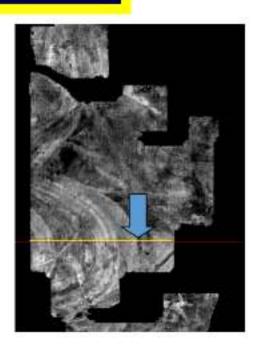


Interval Attribute: 25 msec interval average amplitude

Time Slice

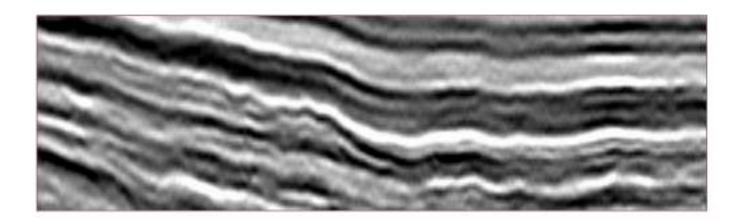
High-Sinuosity Channel System with Scroll Bars in the Cretaceous, Alberta





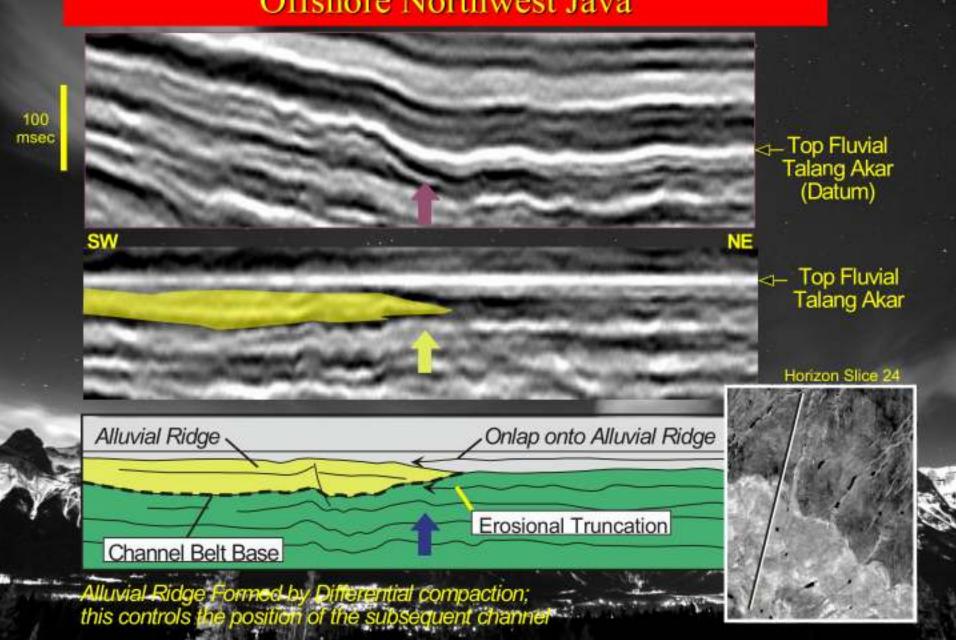
Horizon Slice

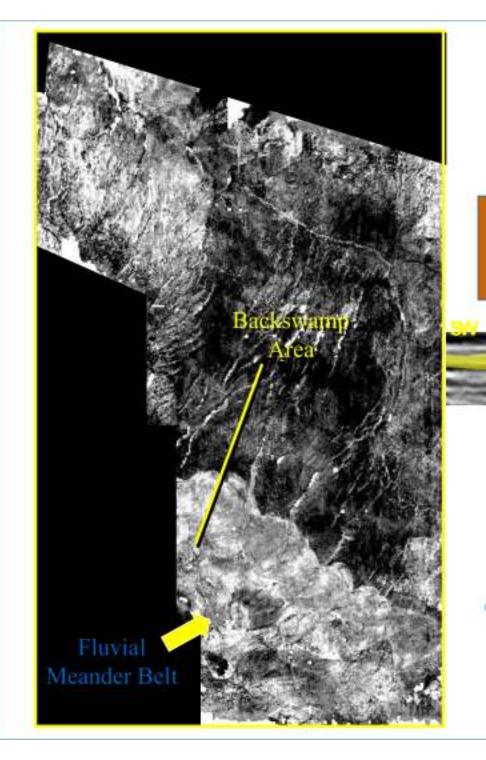
one ka



Can you identify the fluvial channel belt?

Talang Akar High-Sinuosity Fluvial Channel Belt Offshore Northwest Java

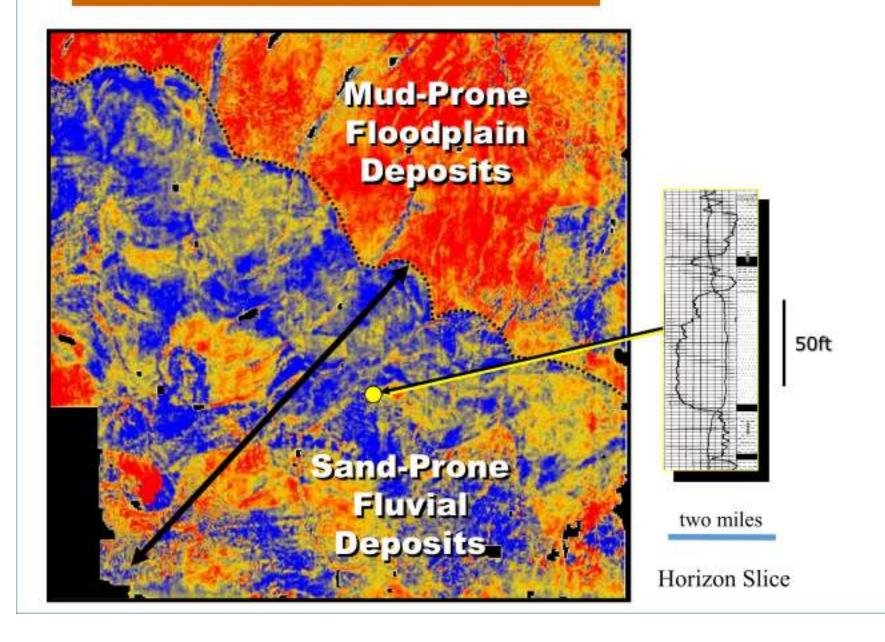


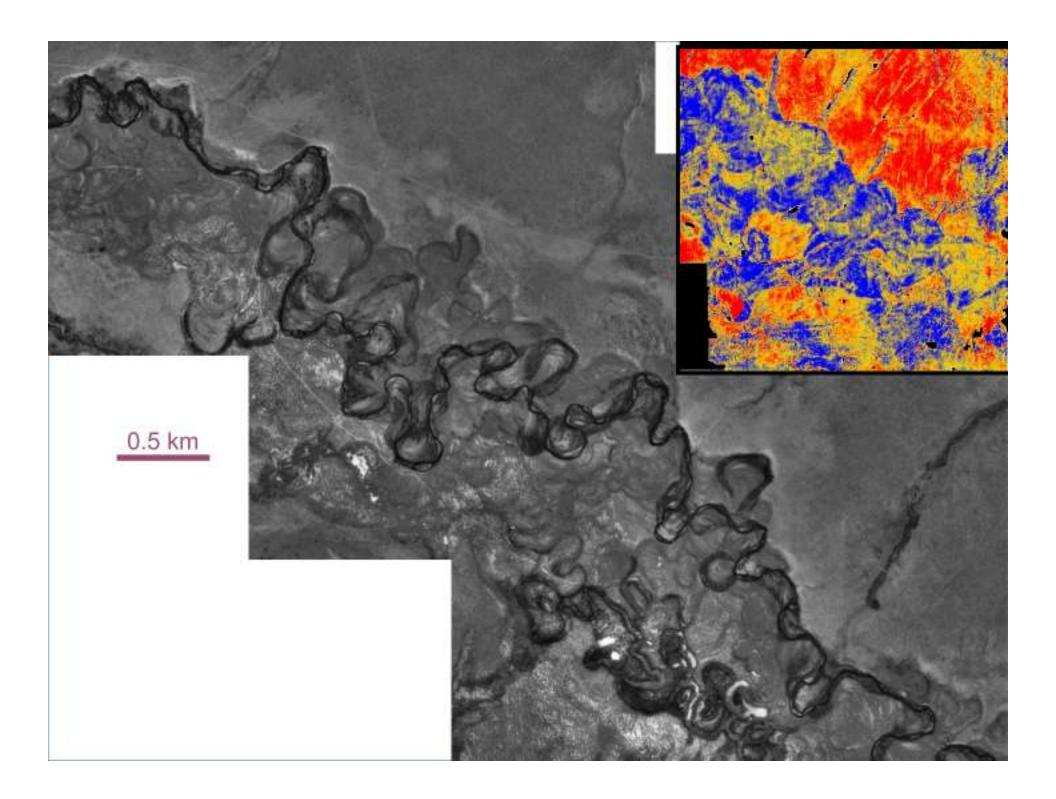


Meander Belt with Backswamp Area

5 km

Meander Belt with Backswamp Area

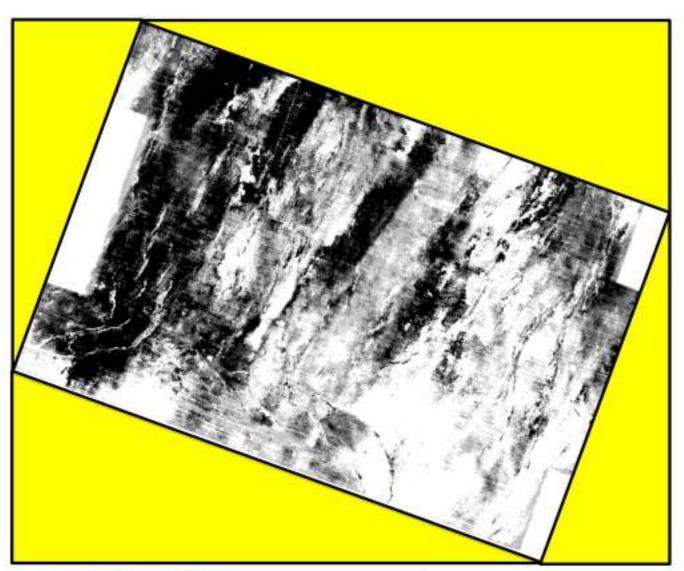




Case Study

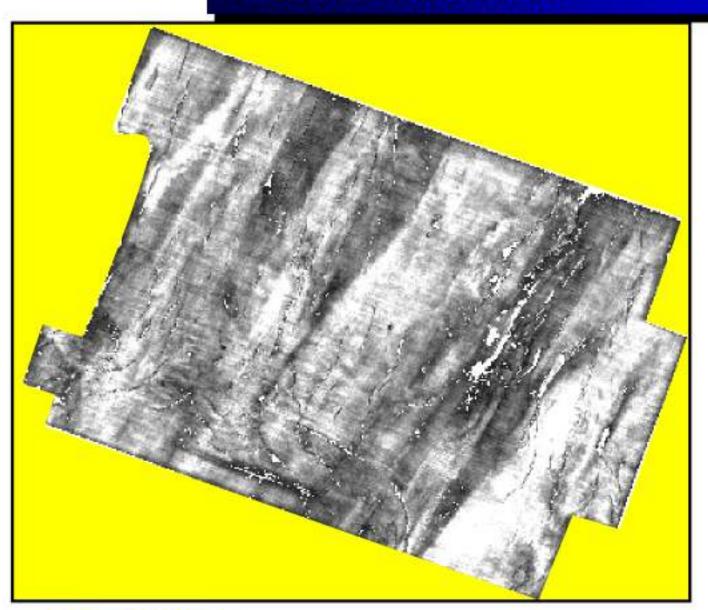
Shelf Ridges Offshore Indonesia (Miocene)

Offshore Indonesia 5 km



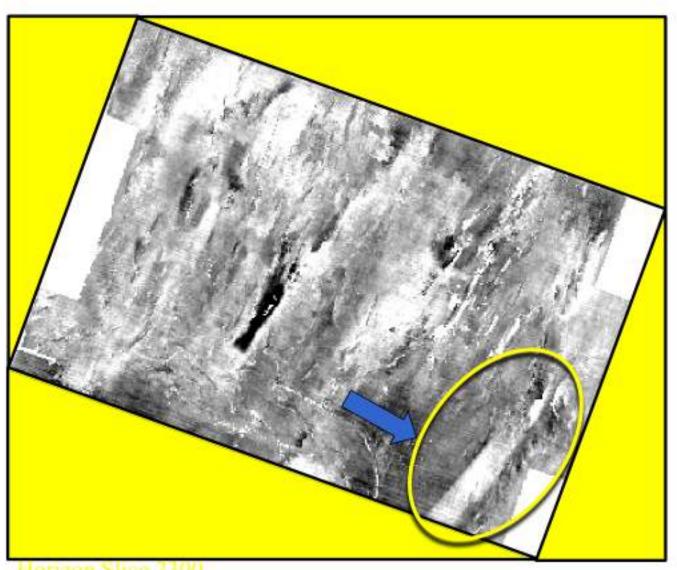
5 km

Horizon Slice 2320

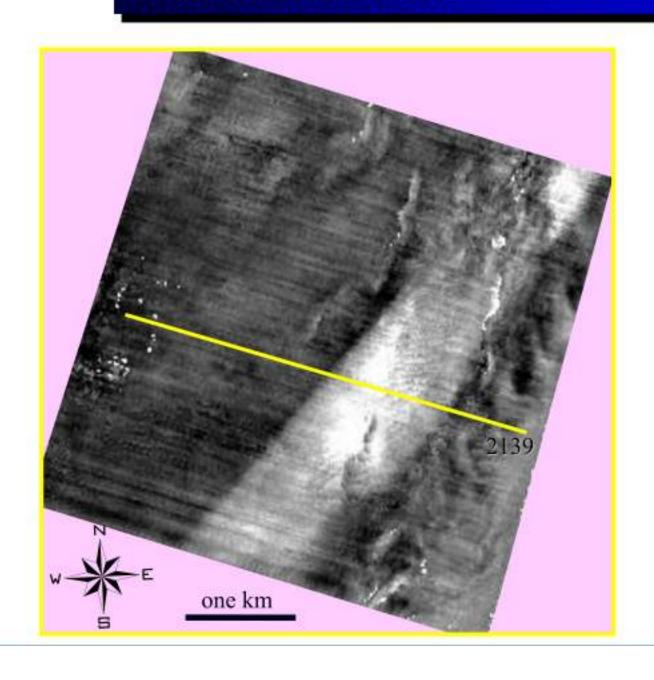


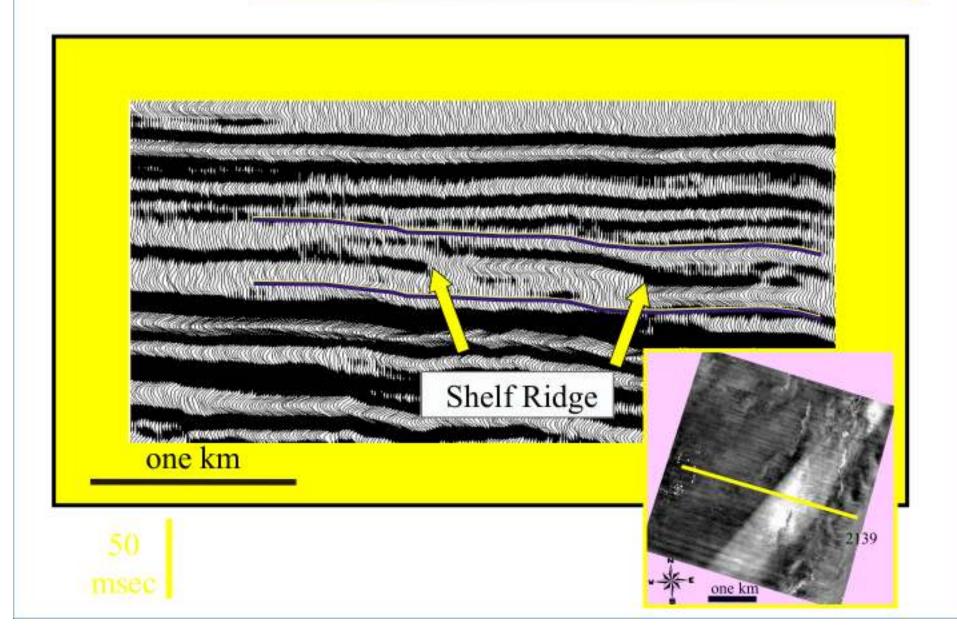
5 km

Horizon Slice 2480

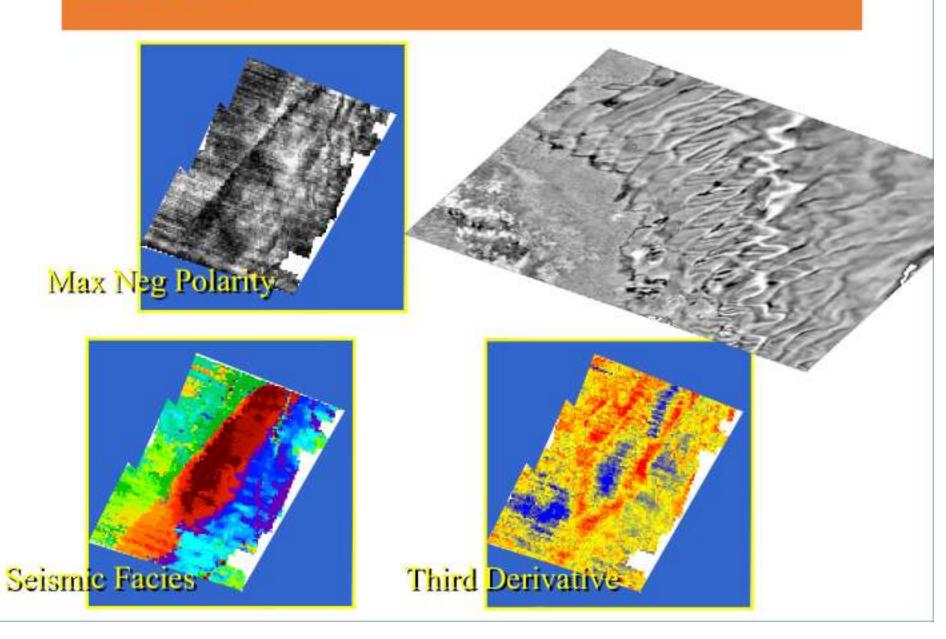


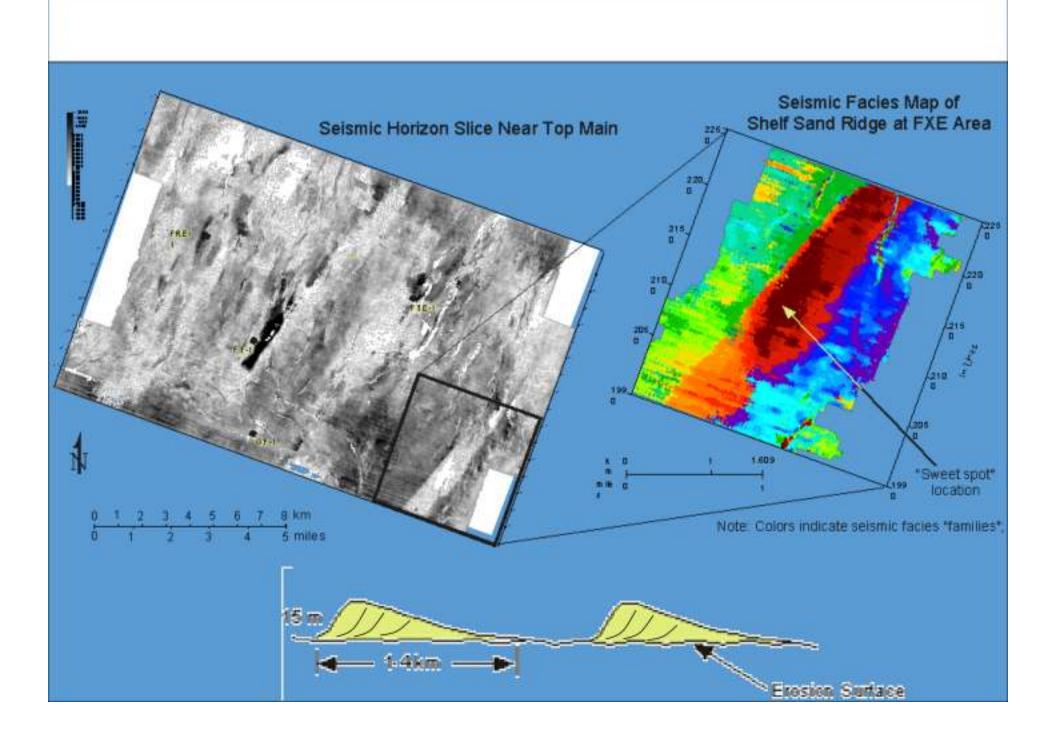
5 km

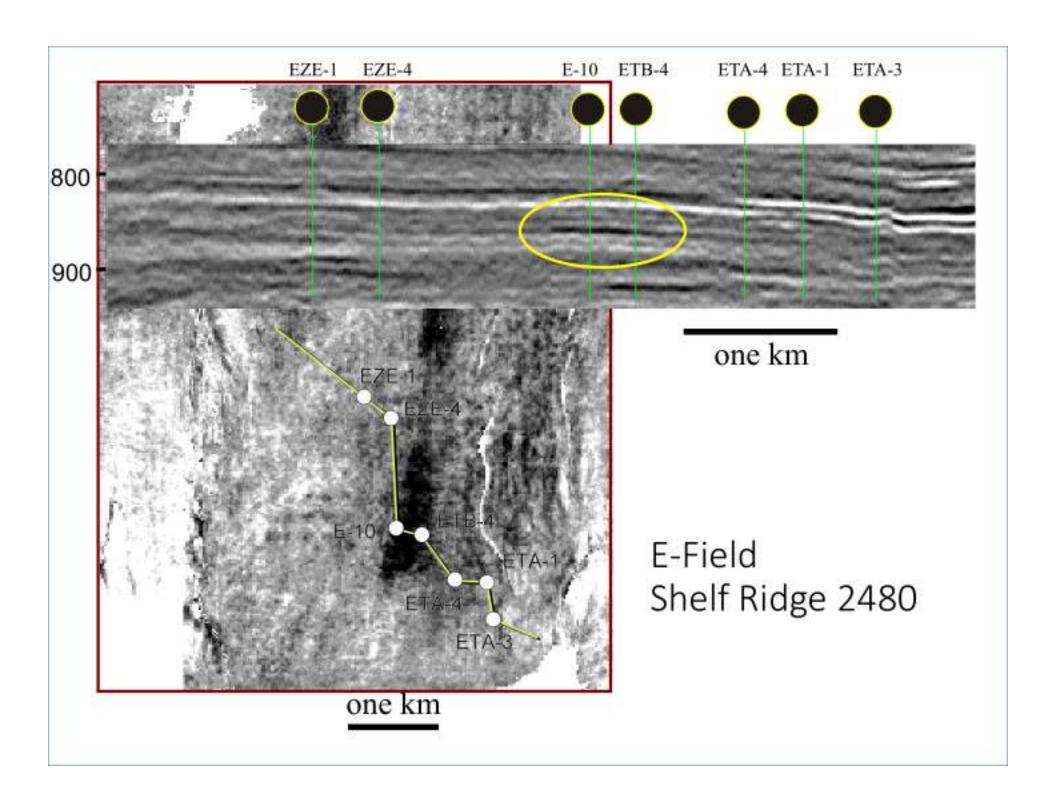




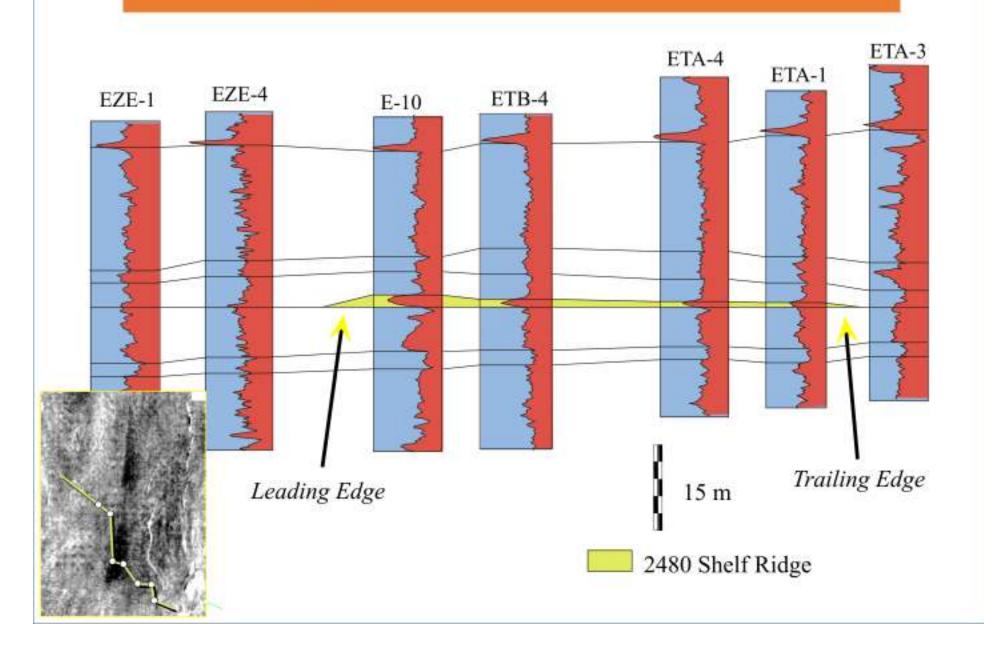
FXE Area - Shelf Ridge Interval Attributes



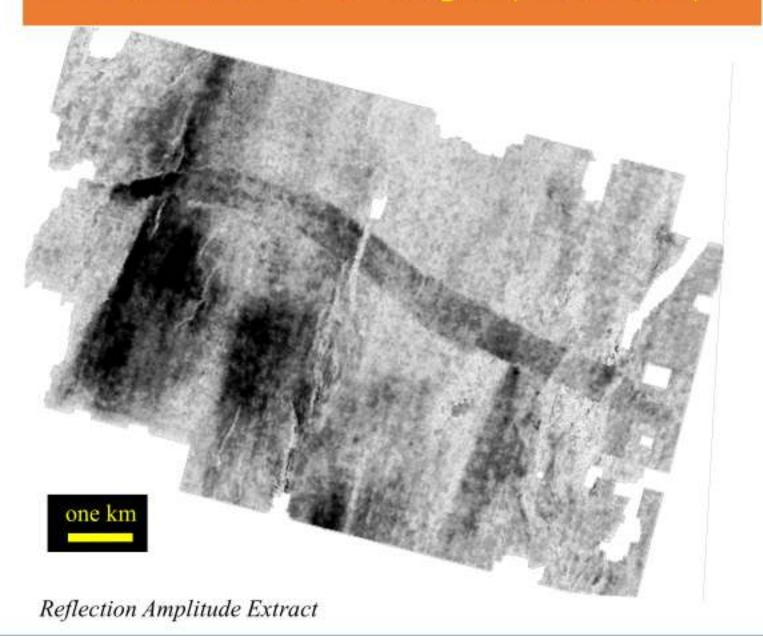




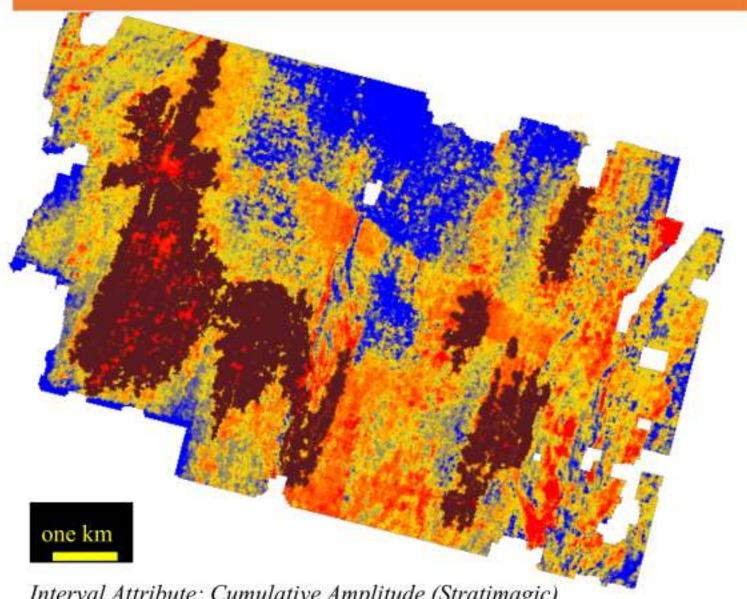
E-Field - Shelf Ridge 2480



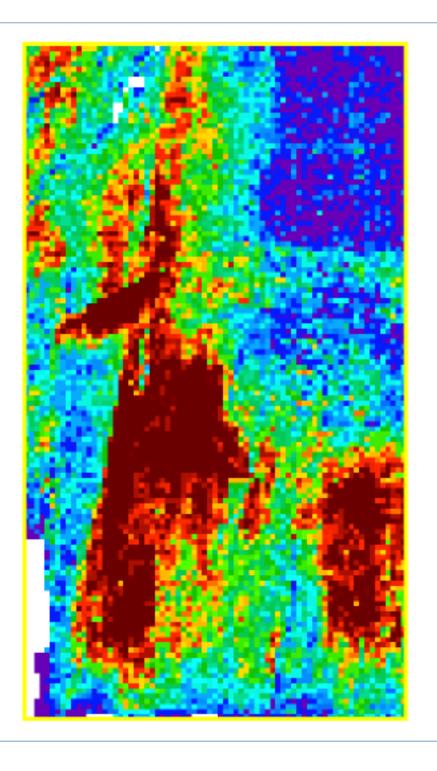
E-Field - 2732 Shelf Ridges (Indonesia)



E-Field - 2732 Shelf Ridges (Indonesia)

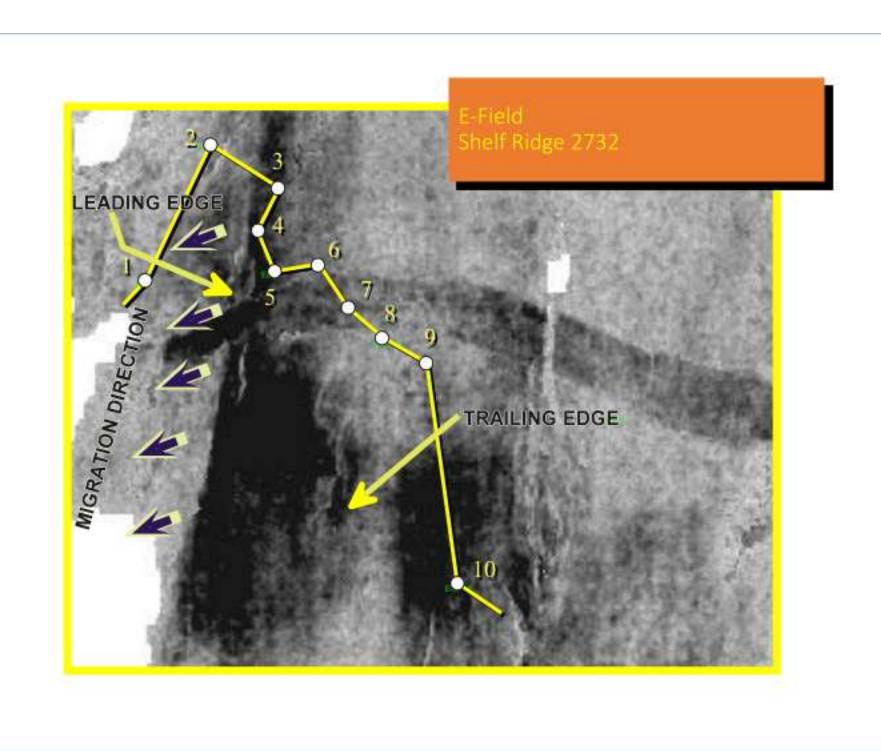


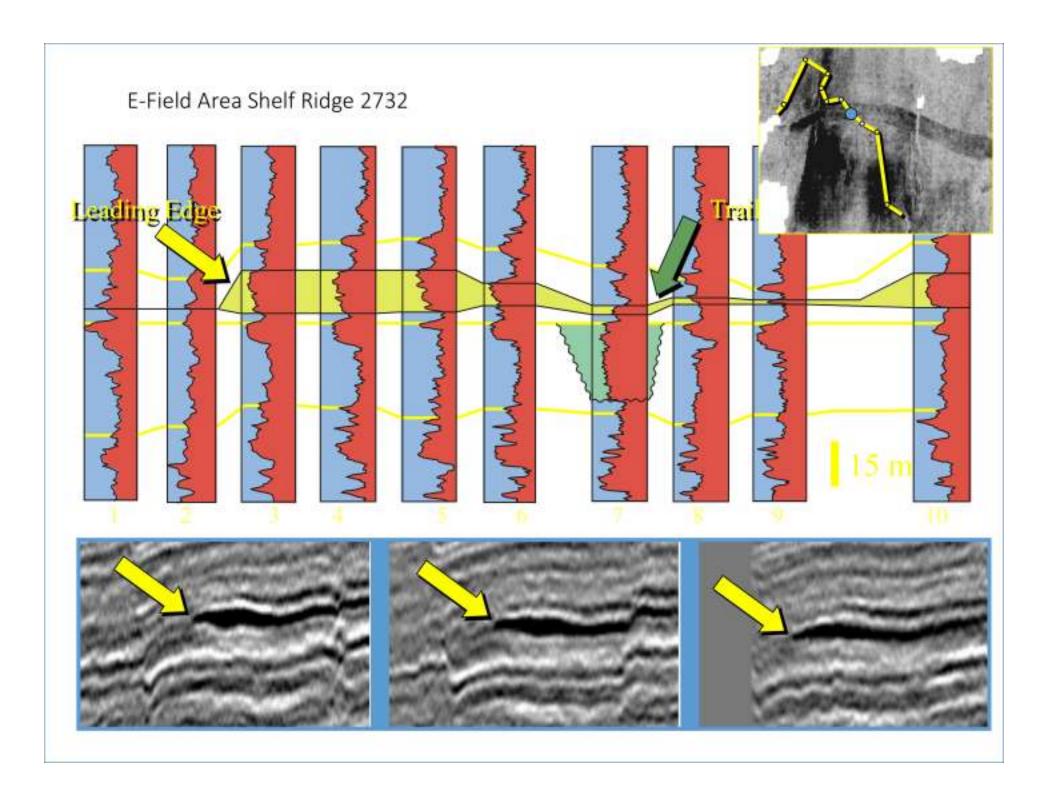
Interval Attribute: Cumulative Amplitude (Stratimagic)



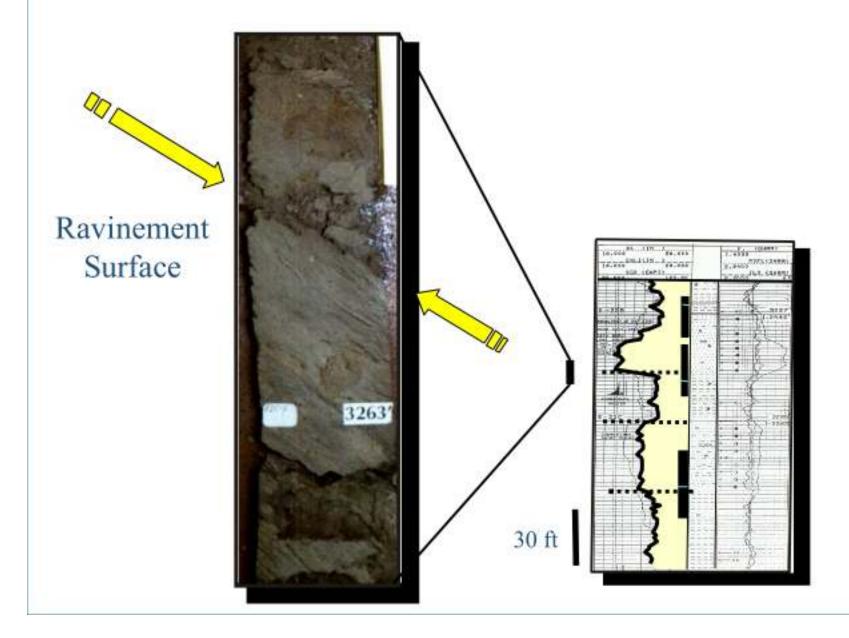
E-Field Shelf Ridge 2528

one km





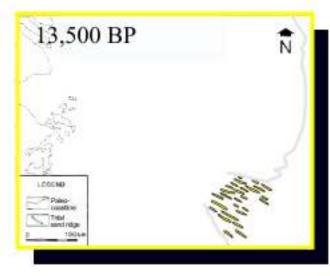
Shelf Ridge - Basal Boundary

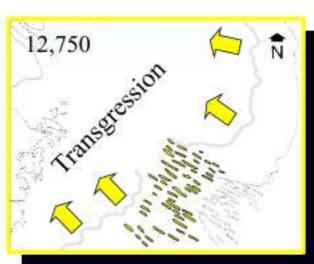


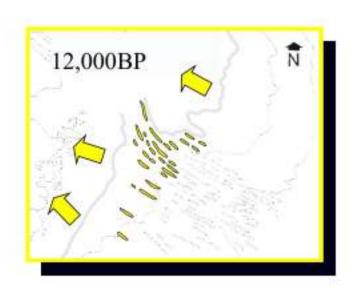
Shelf Ridges - East China Sea

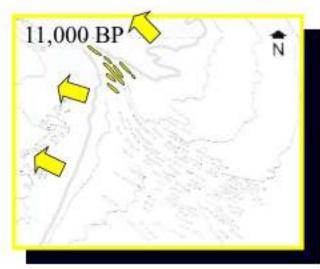


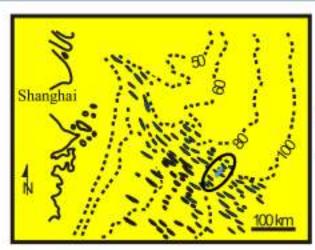
Shelf Ridges - East China Sea



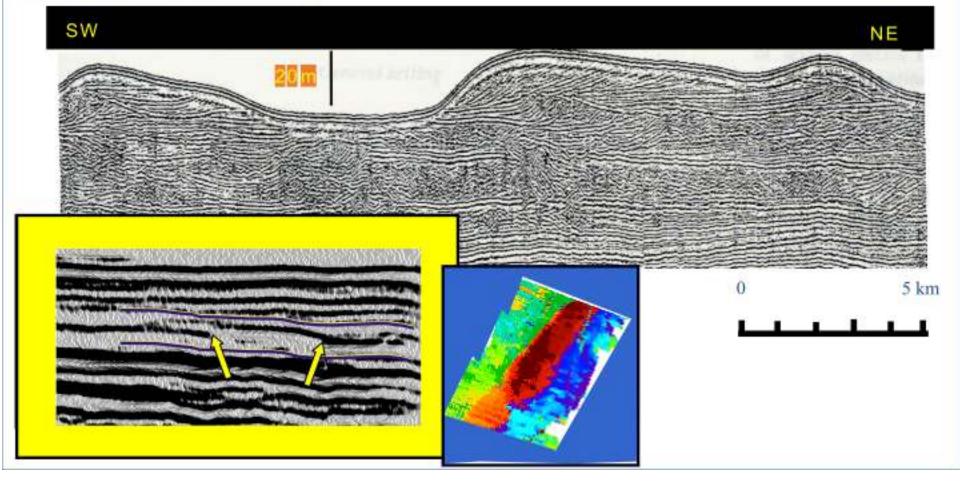




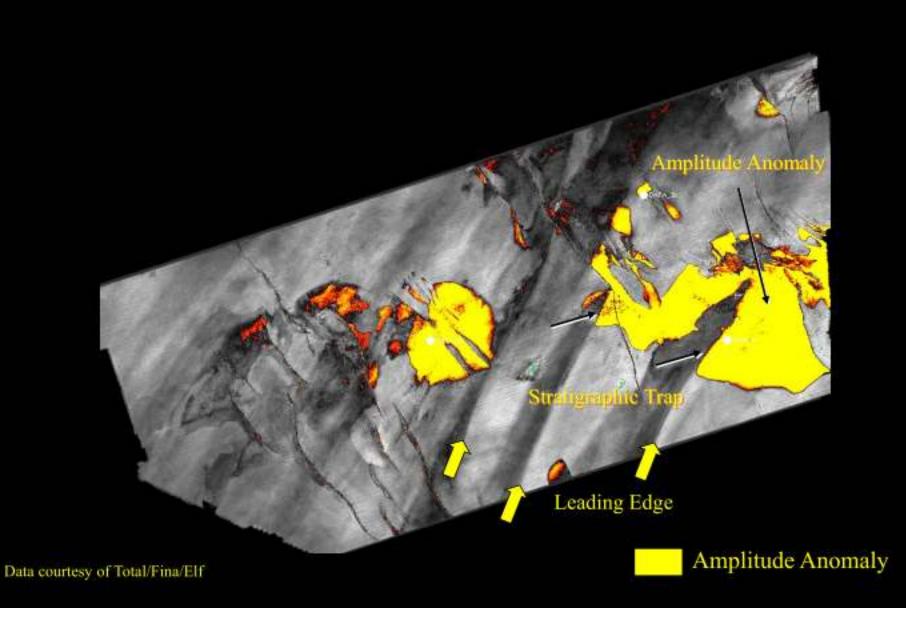




Shelf Ridge Transverse Section - East China Sea



Shelf Ridge - Natuna Sea (Miocene)



- Methodology -

- Integration of seismic stratigraphy and seismic geomorphology
- Pattern recognition recognition of what "look" like geologically significant patterns
- Efficient workflows and creative analytical techniques

- Final Thoughts -

Significant stratigraphic information can be extracted from 3D seismic volumes

Recommended workflow:

- Slice and Dice (geologist MUST get involved)
- Examine in 3D (visualization)
- Tie wells for calibration of stratigraphic features and evaluate exploration significance
- Evaluate additional attribute volumes

There is no cookbook approach - creativity is the key!!

Conclusions

Benefits of
Seismic stratigraphy/seismic geomorphology
Prediction of lithology
Prediction of compartmentalization
Prediction of reservoir architecture
Insights into process sedimentology

Identify Depositional system/depositional element ...and then predict lithofacies distribution

Image the Depositional Element

Interpretation Procedure: Integration of

Seismic Geomorphology

Seismic Stratigraphy

Process Sedimentology

Depositional Systems Analysis



Analysis:

- 1. Reconnaissance
- 2. Detailed evaluation
 - Slice/dice
 - Perspective
 - Opacity
 - Seismic facies
 - Etc.



Keys to Success

- Robust catalogue of geologic patterns
- Good working knowledge of interpretation software
- Good understanding of strengths and weaknesses of geophysical data