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OFFSHORE PETROLEUM BOARD

Sediment Transportation

Sable Delta → Deep Water

October 24, 20011
AAPG Milan

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*Canada Nova Scotia Offshore Petroleum Board

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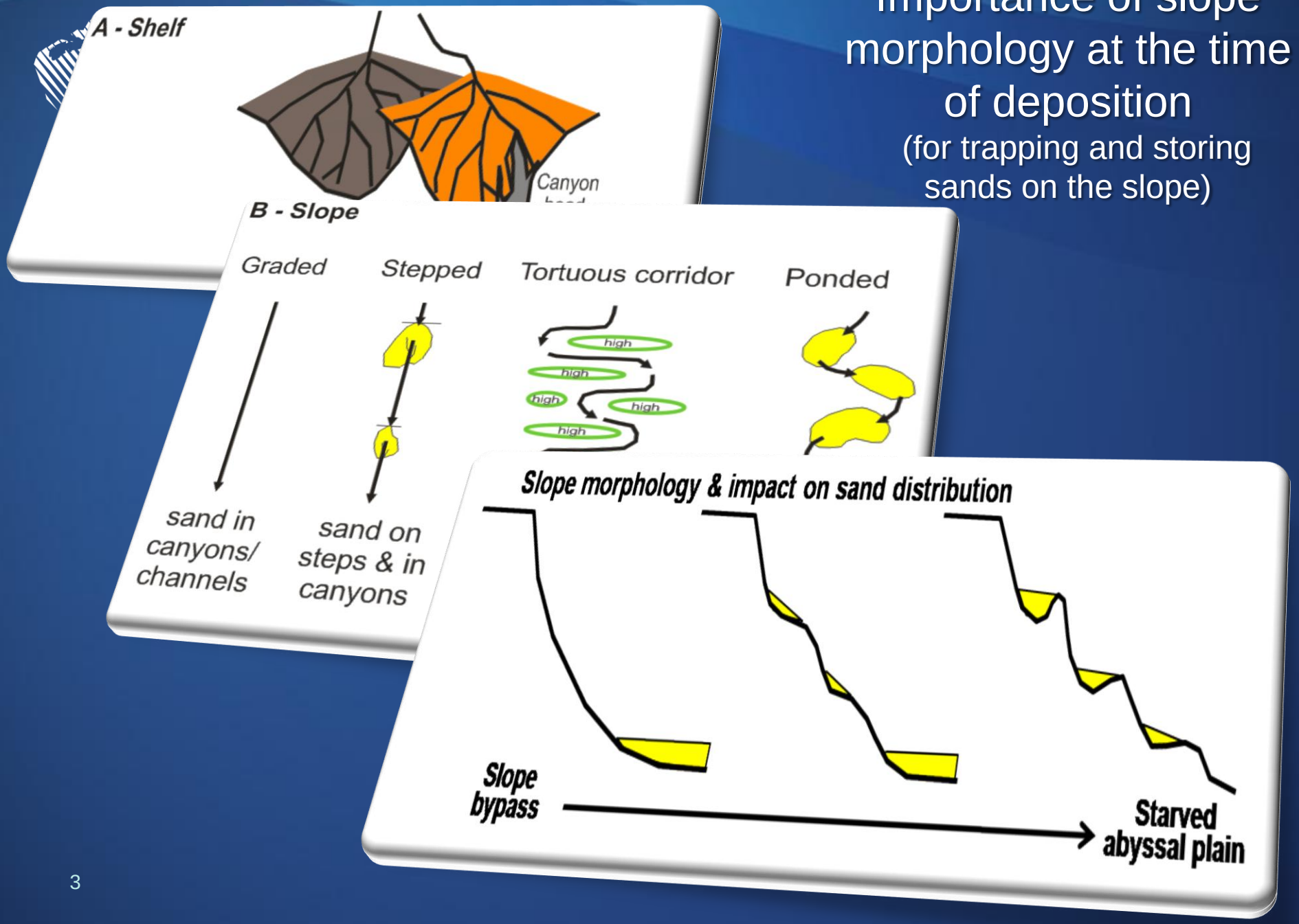
Talk Outline

- Evidence for presence and transport of sand
  - Abundant Jurassic and Cretaceous sand on shelf
  - Sand transport across shelf → channel complexes
  - Sand transport across slope → canyon systems
- Show paleogeography maps to illustrate
- Discuss well results → Annapolis and Crimson
- Discuss undrilled structures outboard Sable delta

Importance of slope morphology at the time of deposition

(for trapping and storing sands on the slope)



Sand Does Exist in Deep Water

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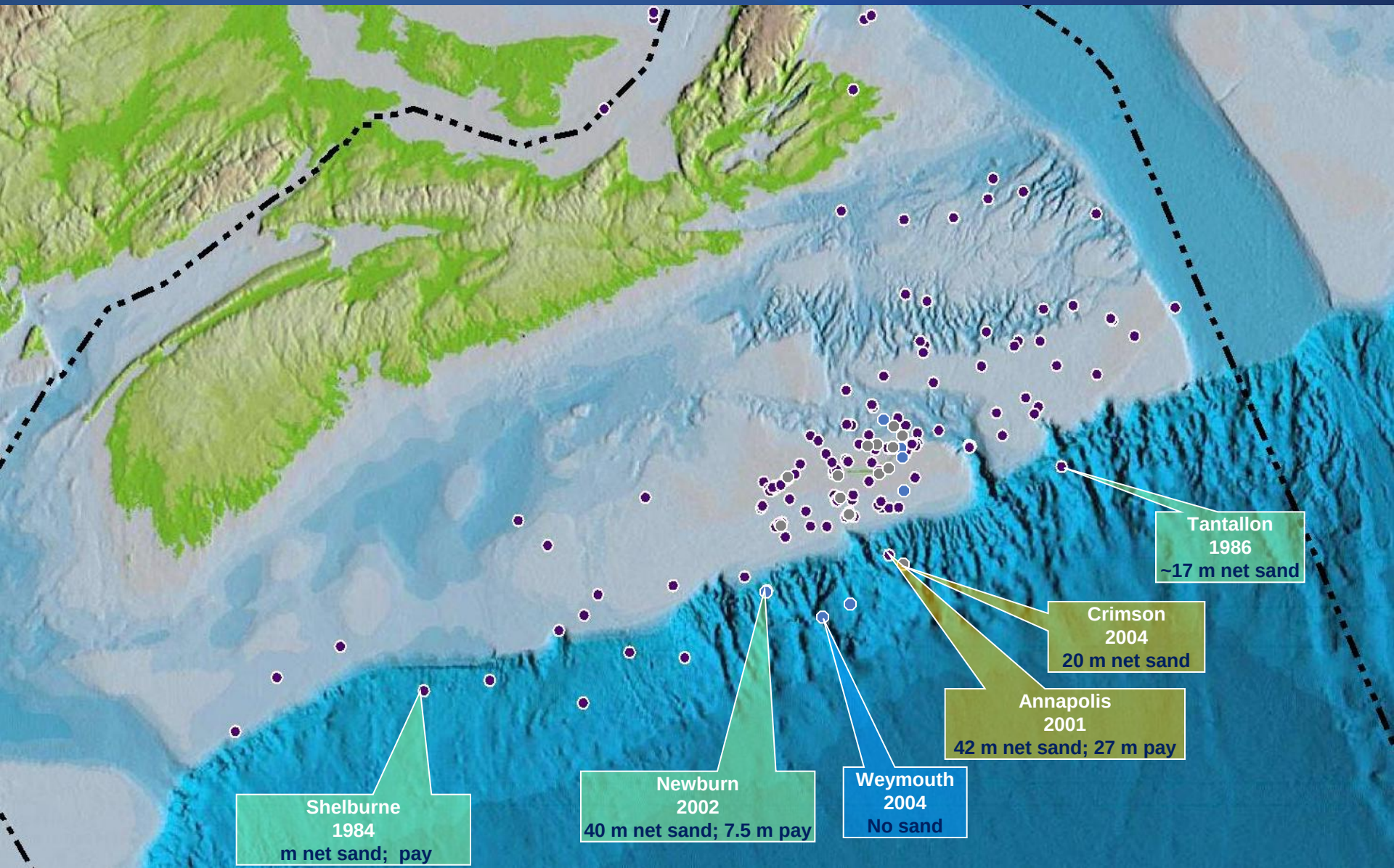

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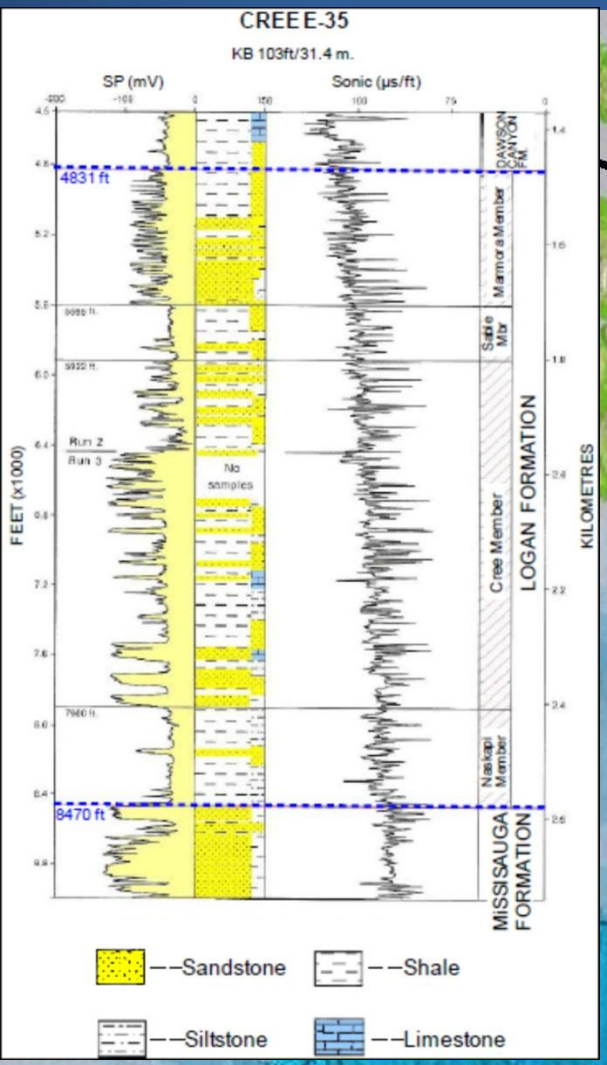
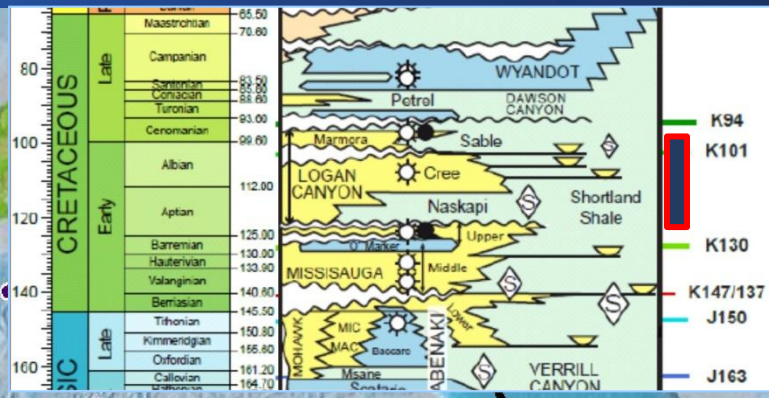
Cree Well
1100 m Sand Prone Logan Canyon





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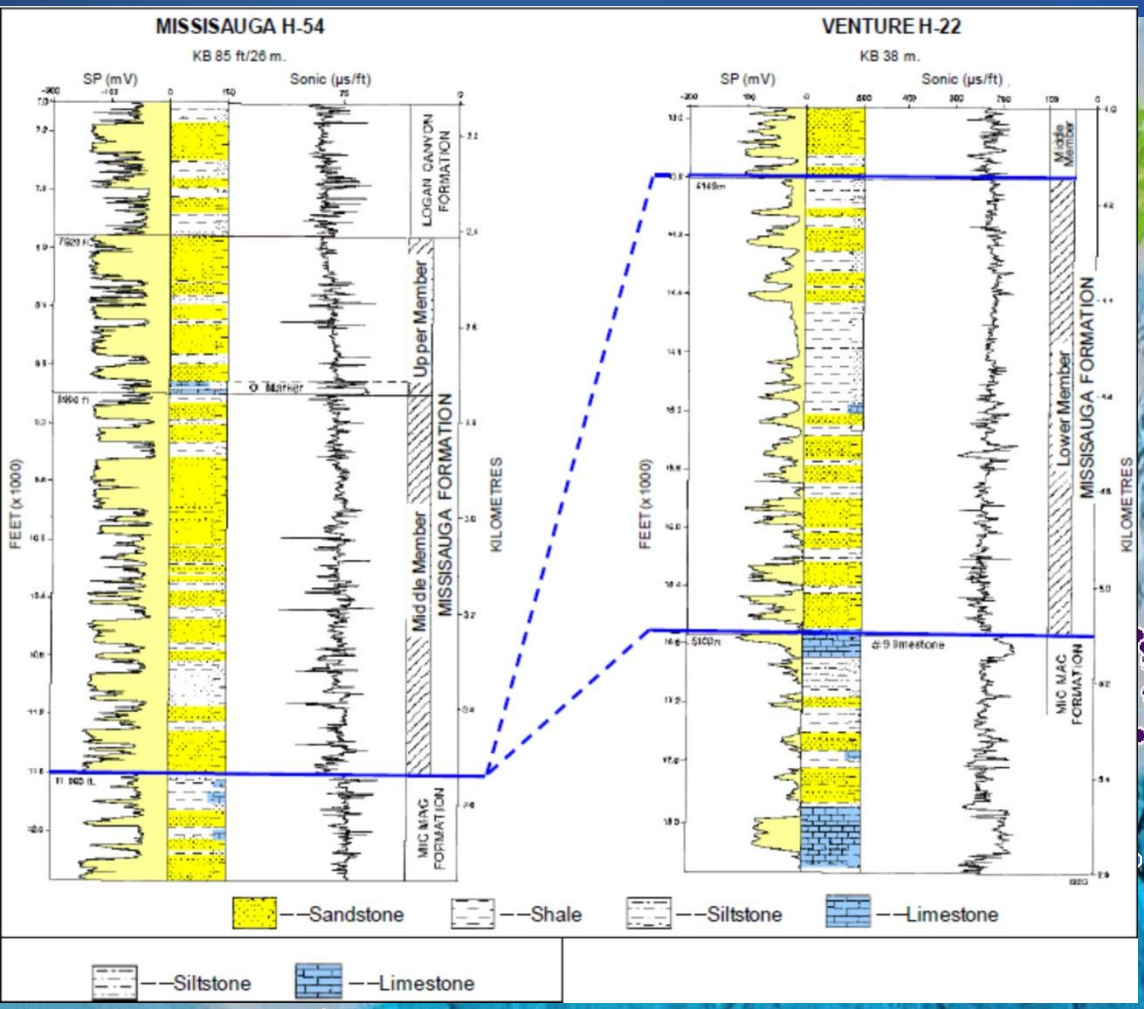
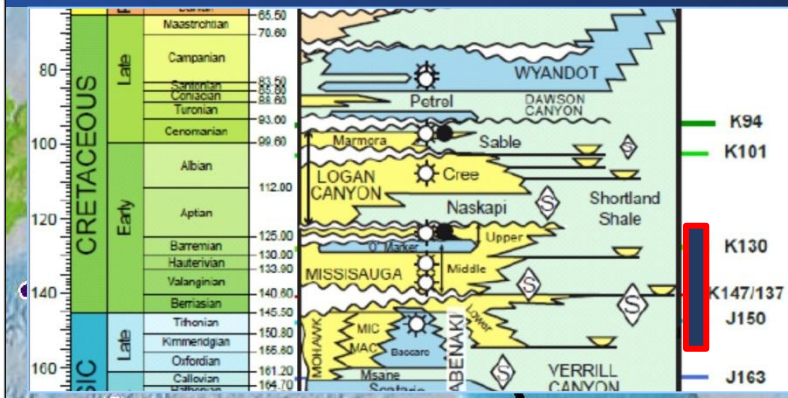
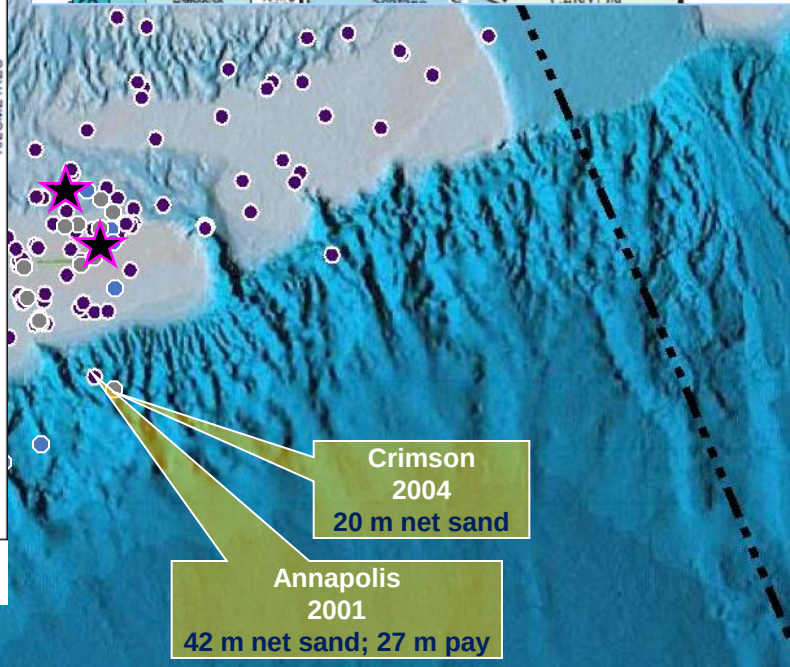
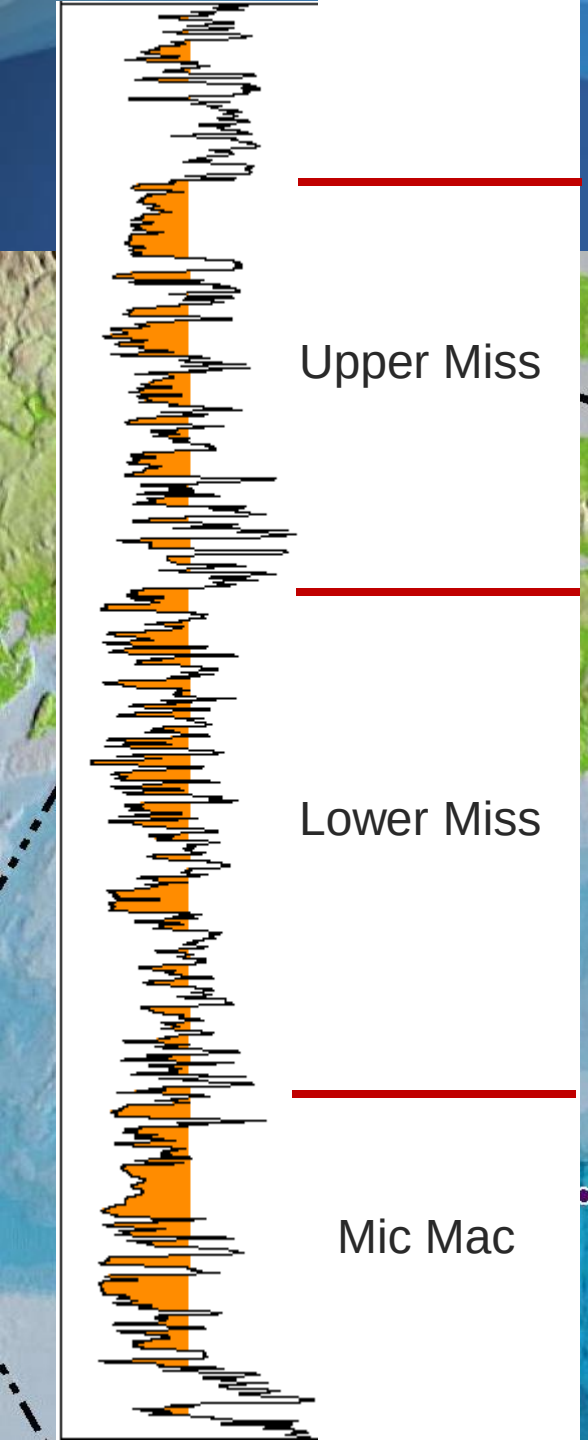
Missisauga Well - 1200 m Sand Prone U & M Missisauga
Venture H-22 Well - 900 m Sand Prone L Missisauga added in only 40 km



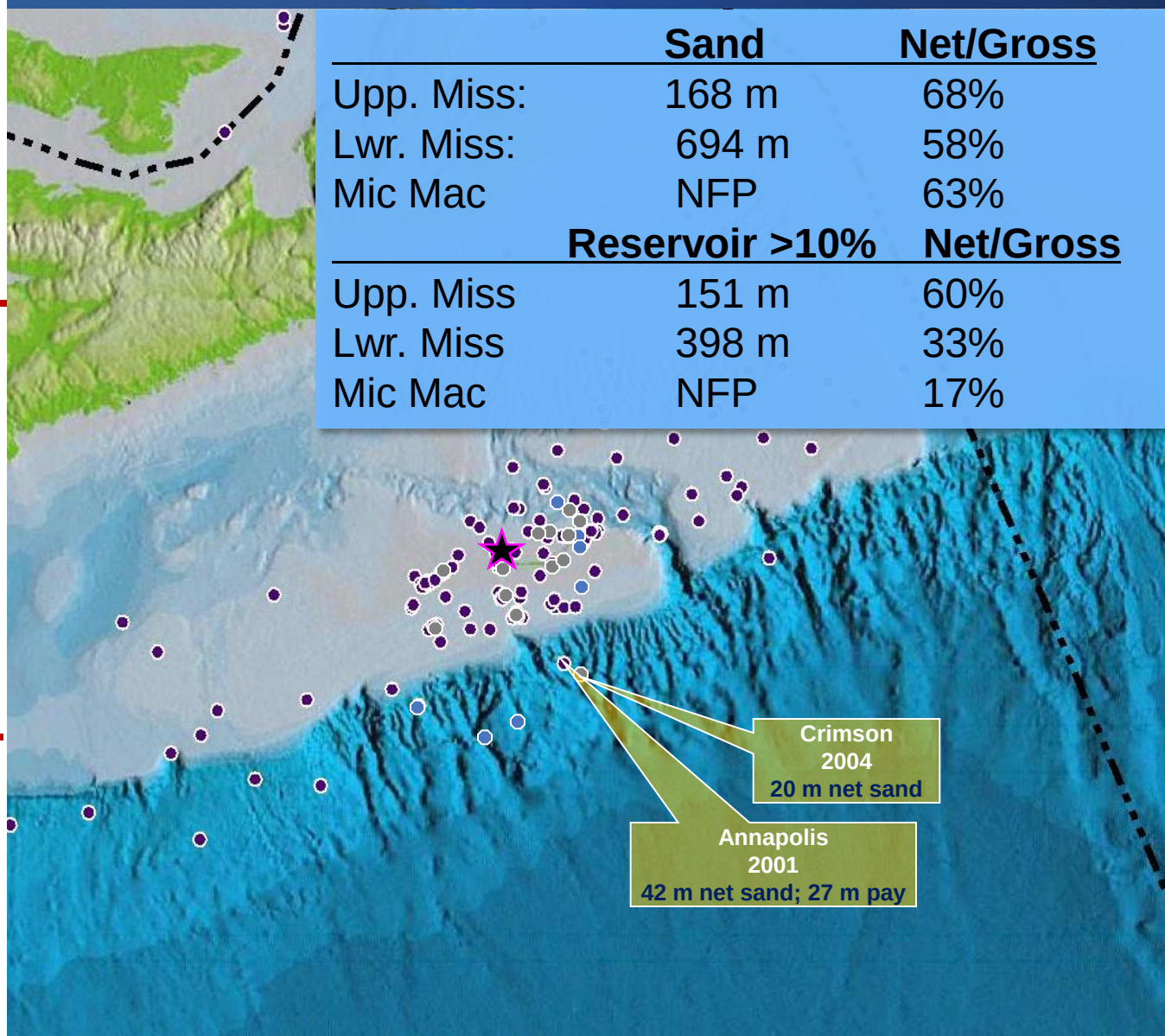




Migrant N-20 Sand Content



	Sand	Net/Gross
Upp. Miss:	168 m	68%
Lwr. Miss:	694 m	58%
Mic Mac	NFP	63%
	Reservoir >10%	**Net/Gross**
Upp. Miss	151 m	60%
Lwr. Miss	398 m	33%
Mic Mac	NFP	17%



Shelf Systems

Shelf Systems

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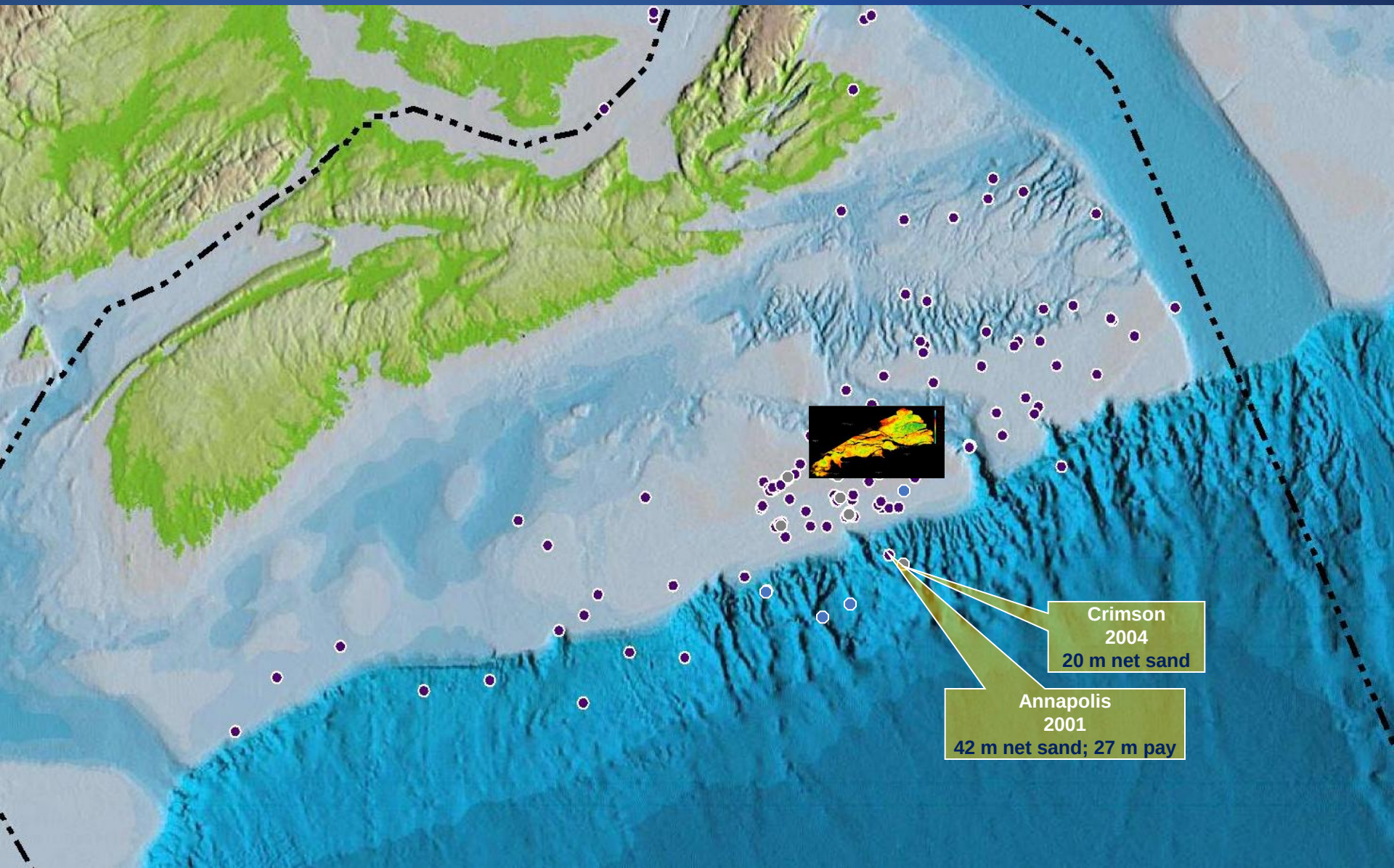
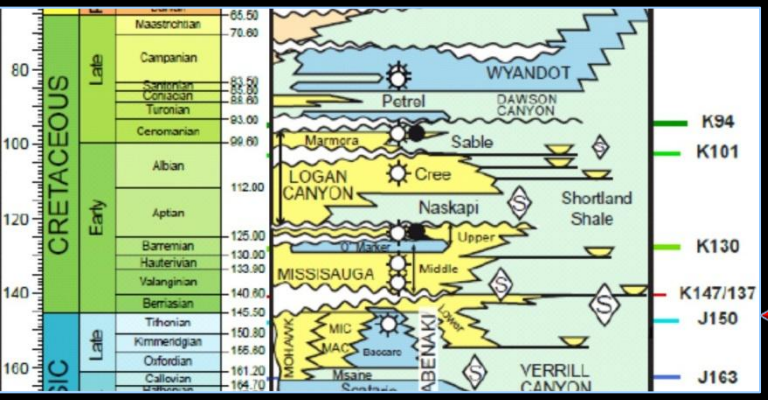
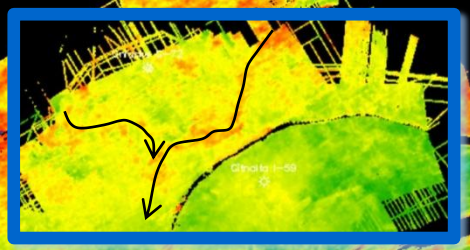
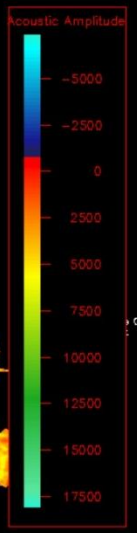


Top Jurassic Amplitude with Tithonian Clastic Channel Overlay in Box

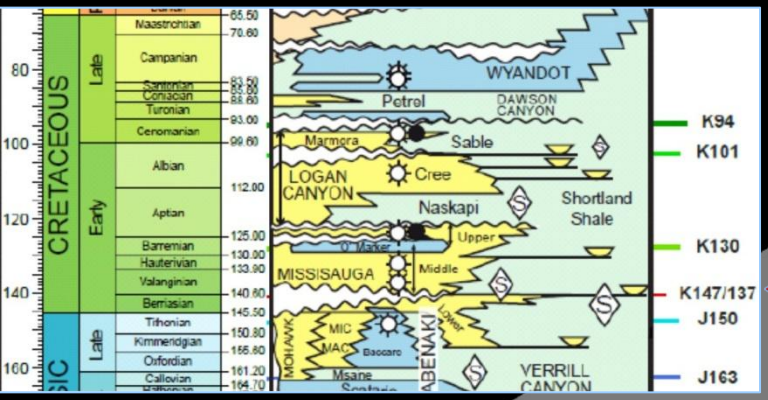




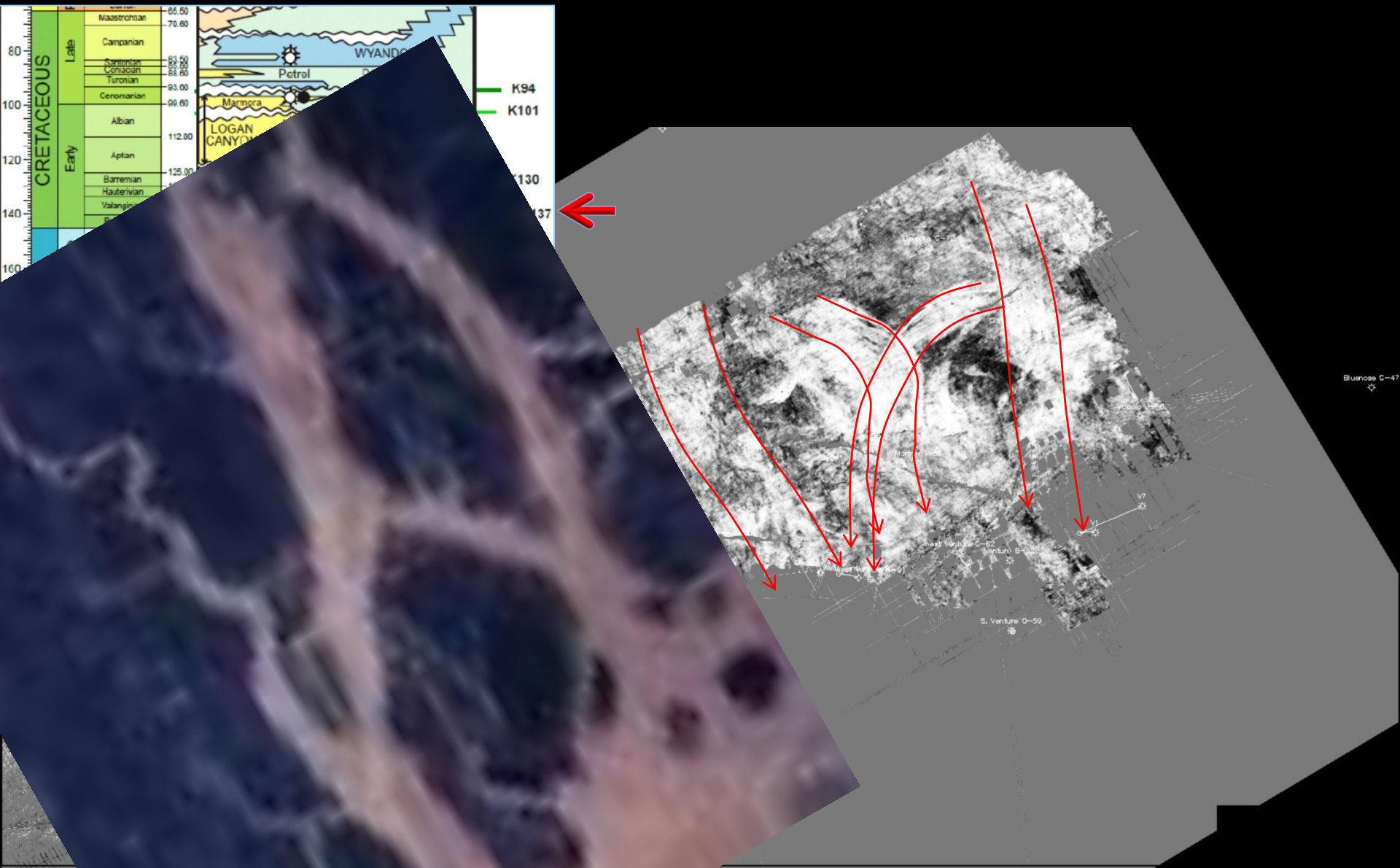


Penobscot B-41
Penobscot L-30
Glenelg I-59
Marquis L-35
Marquis L-38A
Migrant N-70
Sable Island O-47
Adamant N-97
Thebaud C-74
South Sable B-44
West Venture C-62
Venture B-52
S. Venture O-59

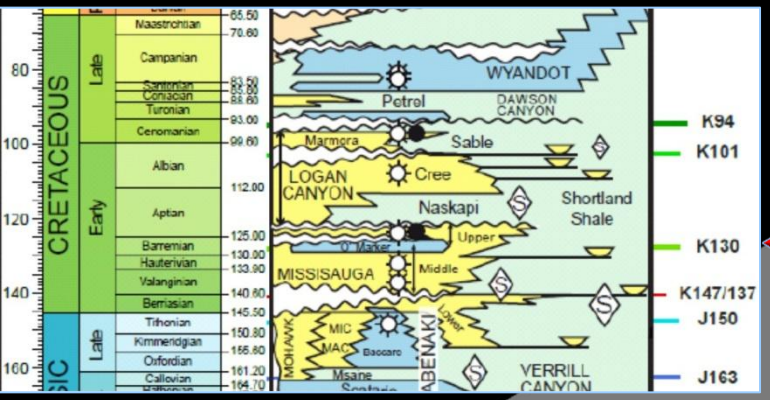
Berriasian Channel Systems on Flattened Time Slice



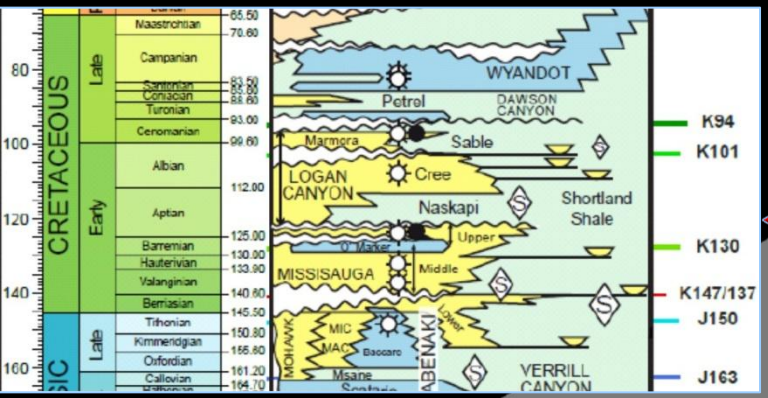
Berriasian Channel Systems
Shown With Present Day Ganges for Scale



Barremian (K130) Channel Systems

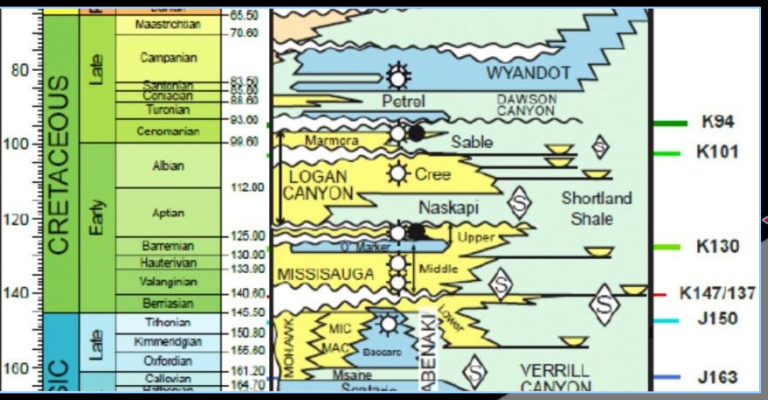


Aptian
Channel Systems

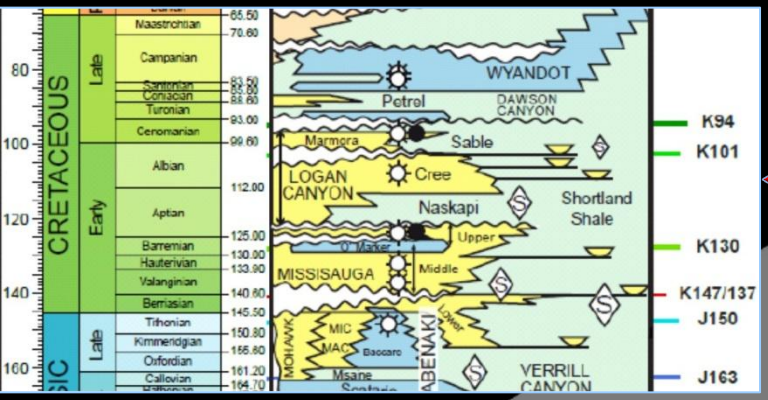


Channel next to previously detailed Migrant well

Aptian
Channel Systems Slightly Higher



Albian (K101)
Channel Systems



Submarine Canyons

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- **Major conduit for sediment transport from continent to deep sea.**

- **Define slope break at specific point in time.**

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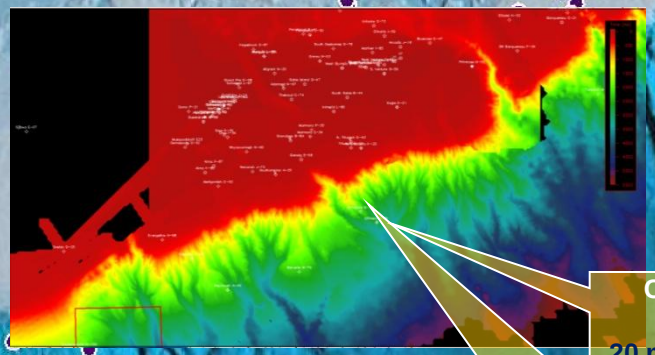
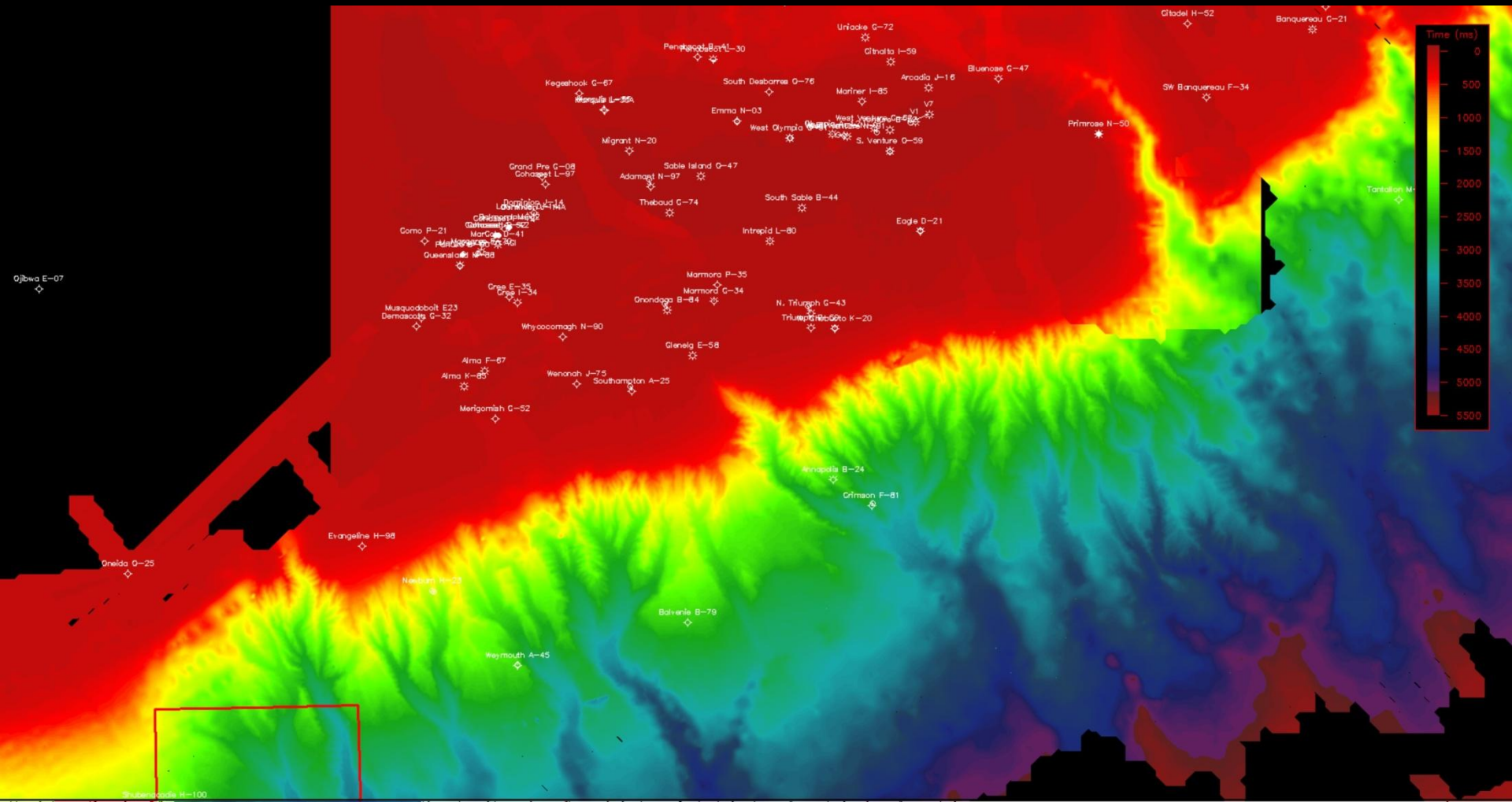
Submarine Canyons
Present Day Seafloor



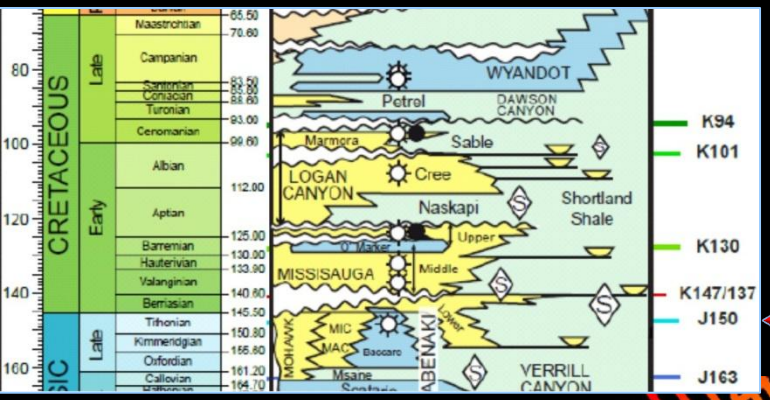
Crimson
2004
20 m net sand

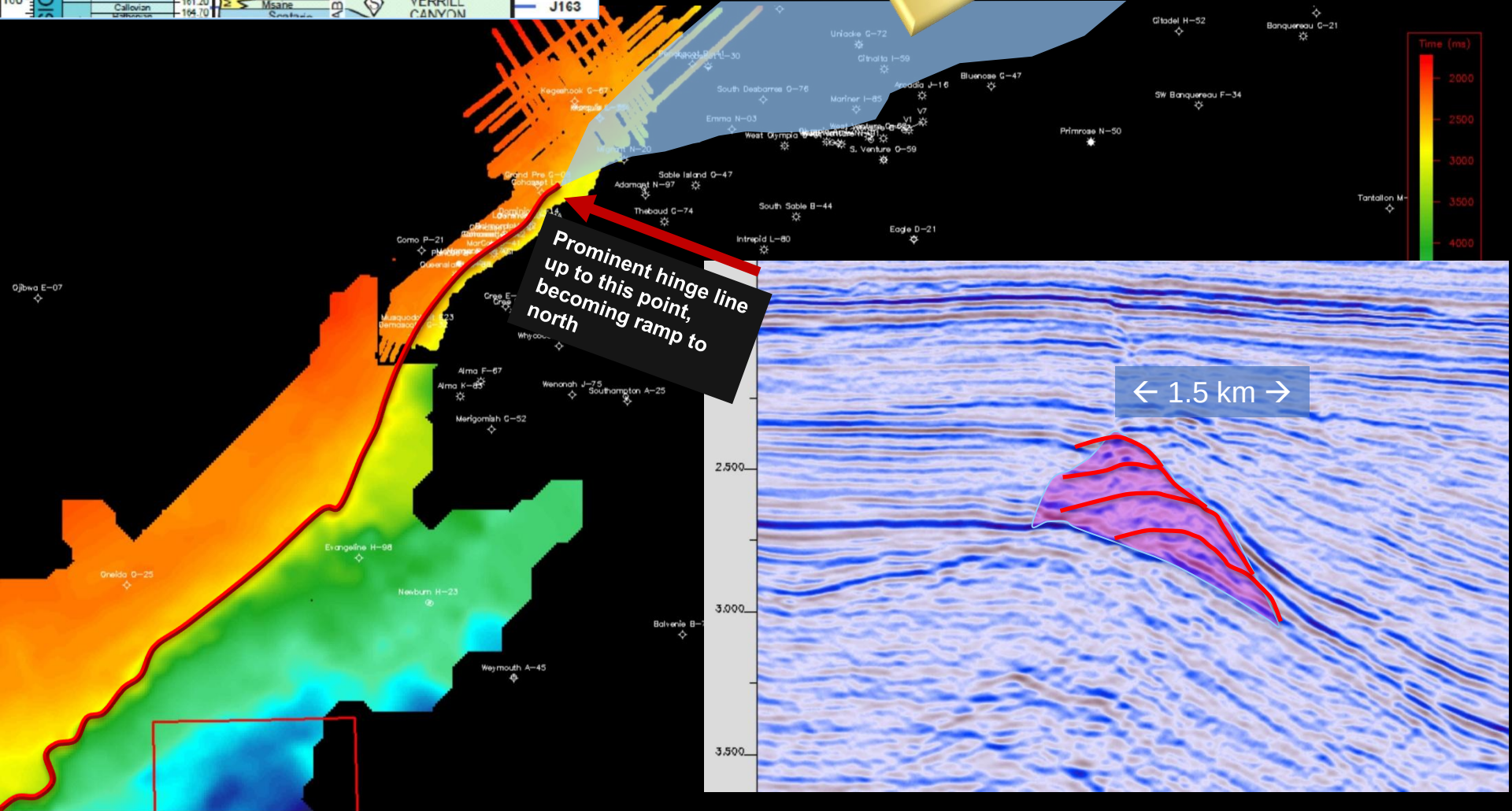
Annapolis
2001
42 m net sand; 27 m pay

Seafloor Canyons

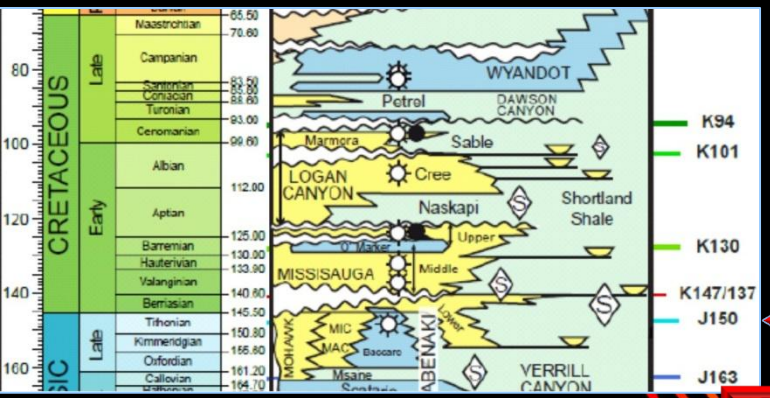


Top Jurassic (J150) Carbonate Shelf Break

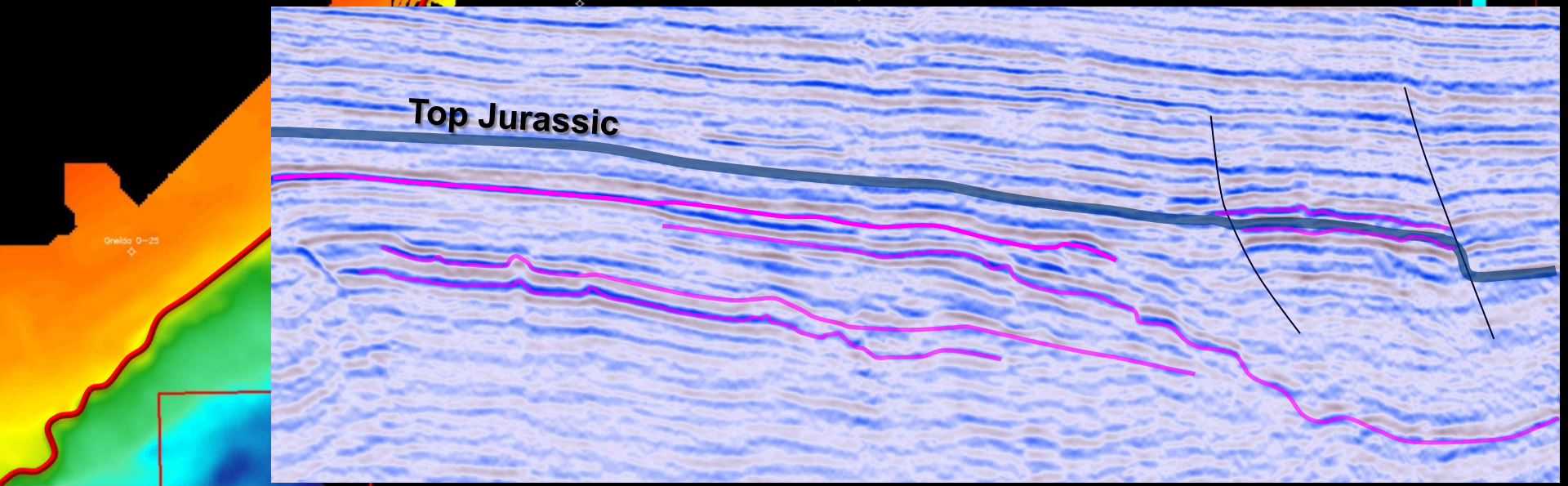




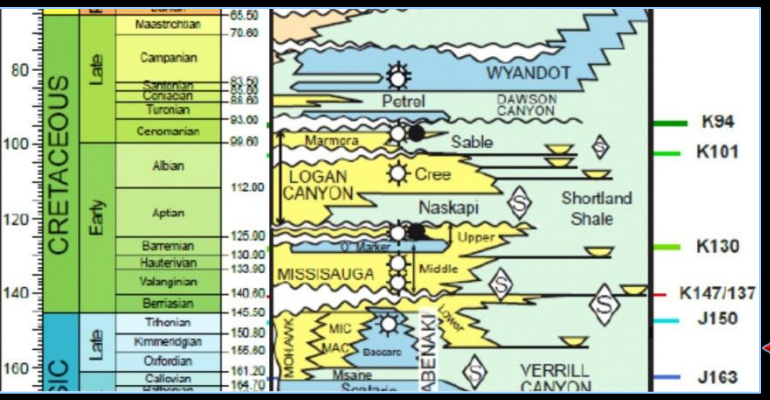
Top Jurassic (J150) Carbonate Shelf Break

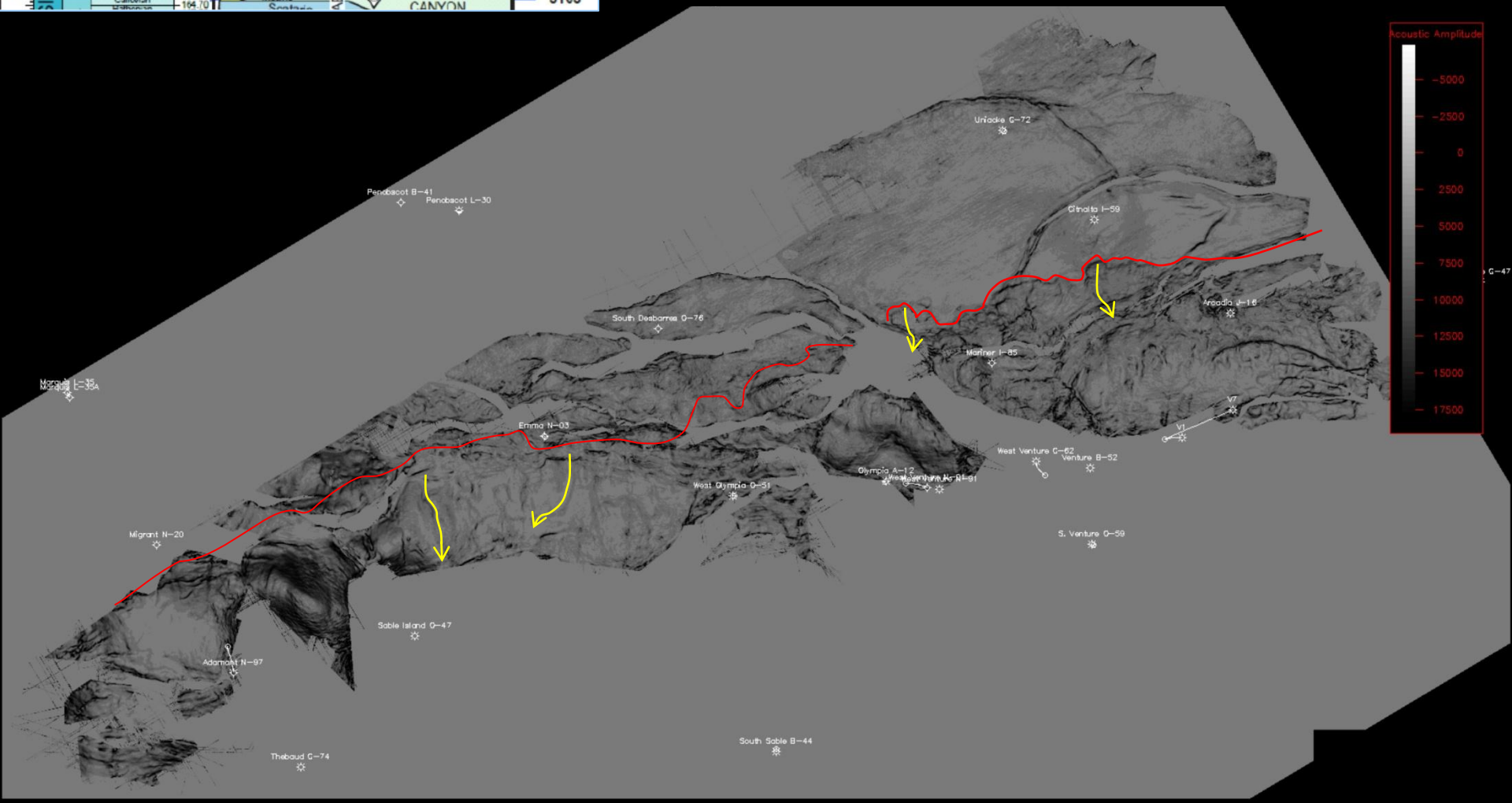


Carbonate production on ramp influenced by periodic influx of Mic Mac clastics from NE

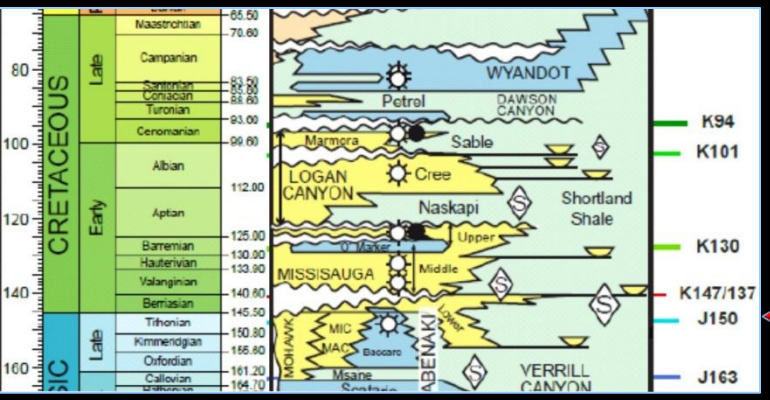


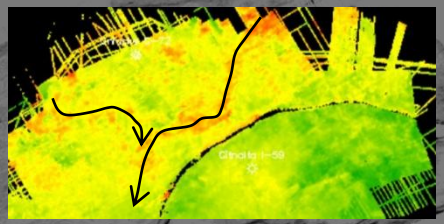
Upper Jurassic Carbonate Shelf Break



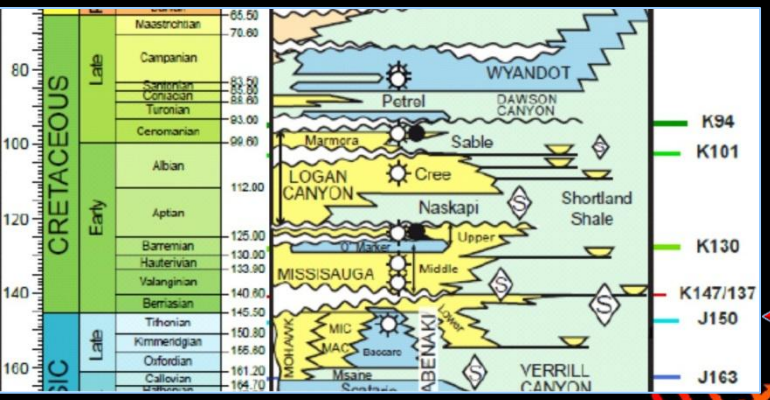


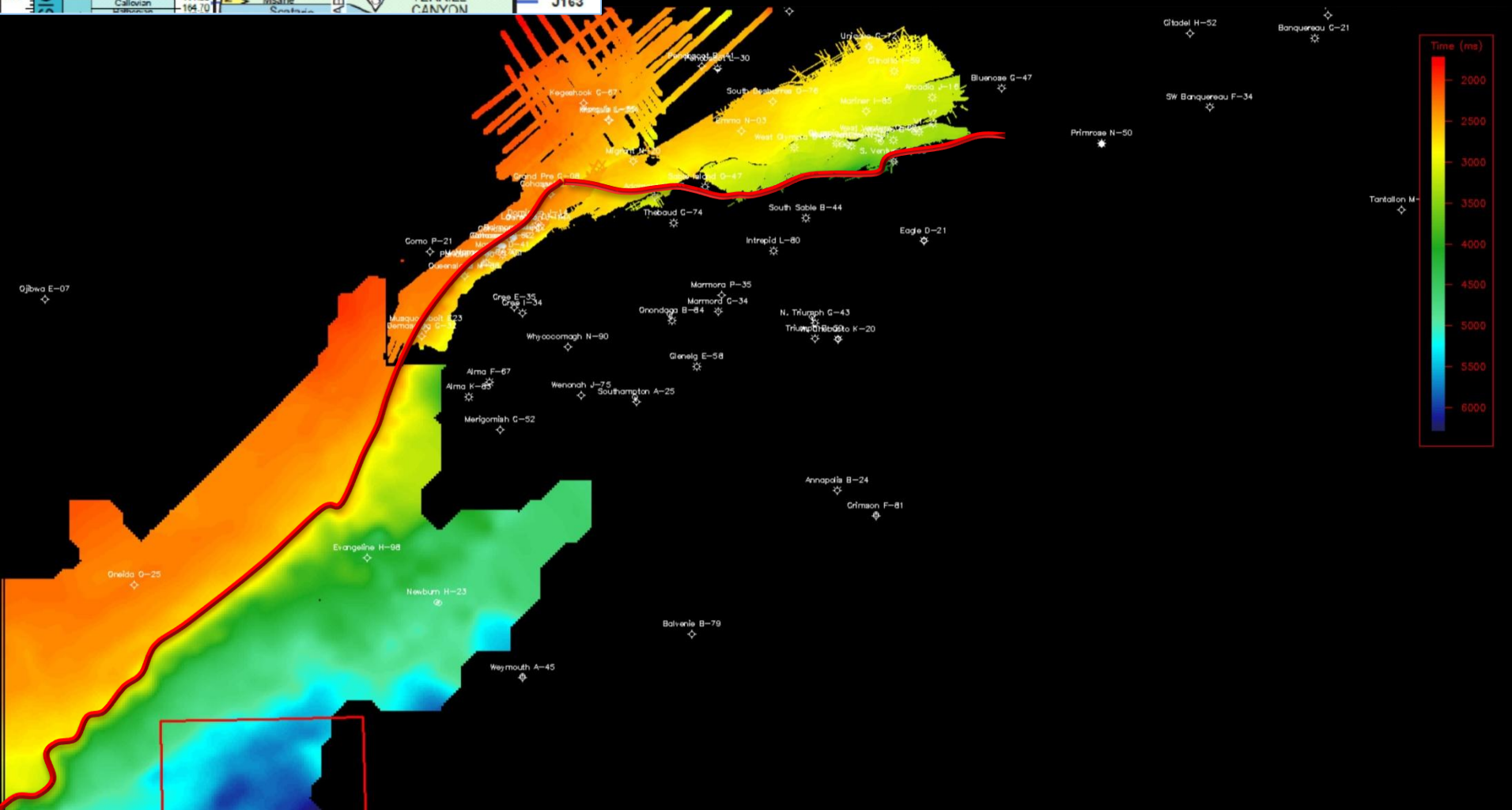
Tithonian Channel Systems Above Carbonate

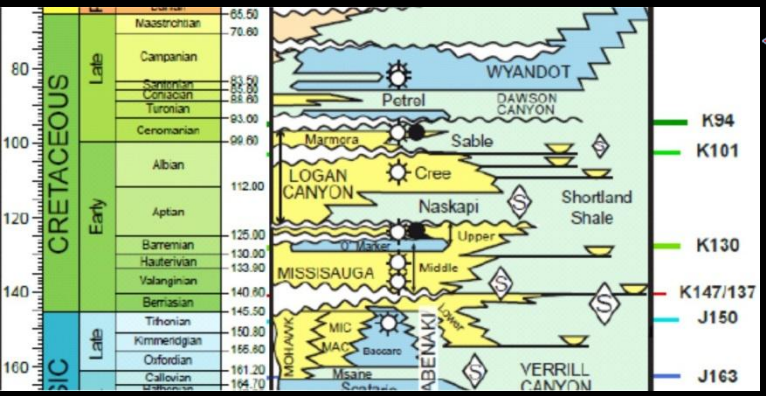




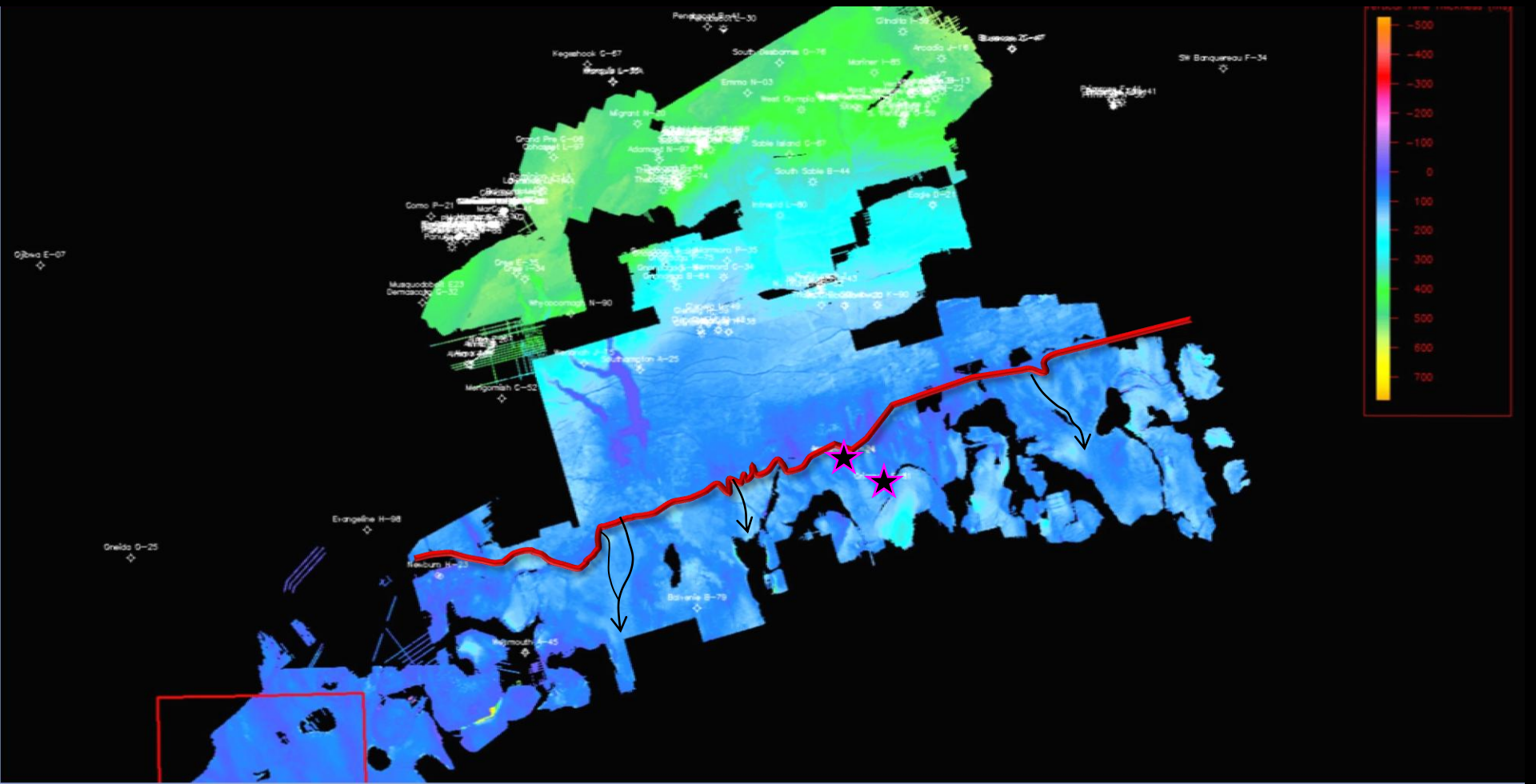
Upper Jurassic Shelf Break



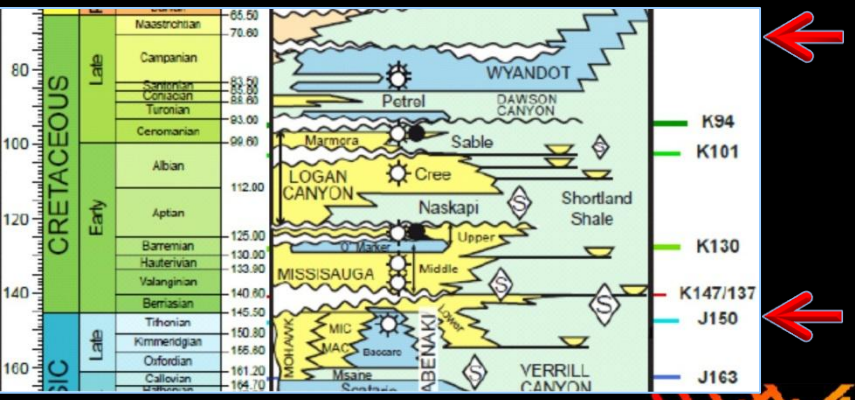


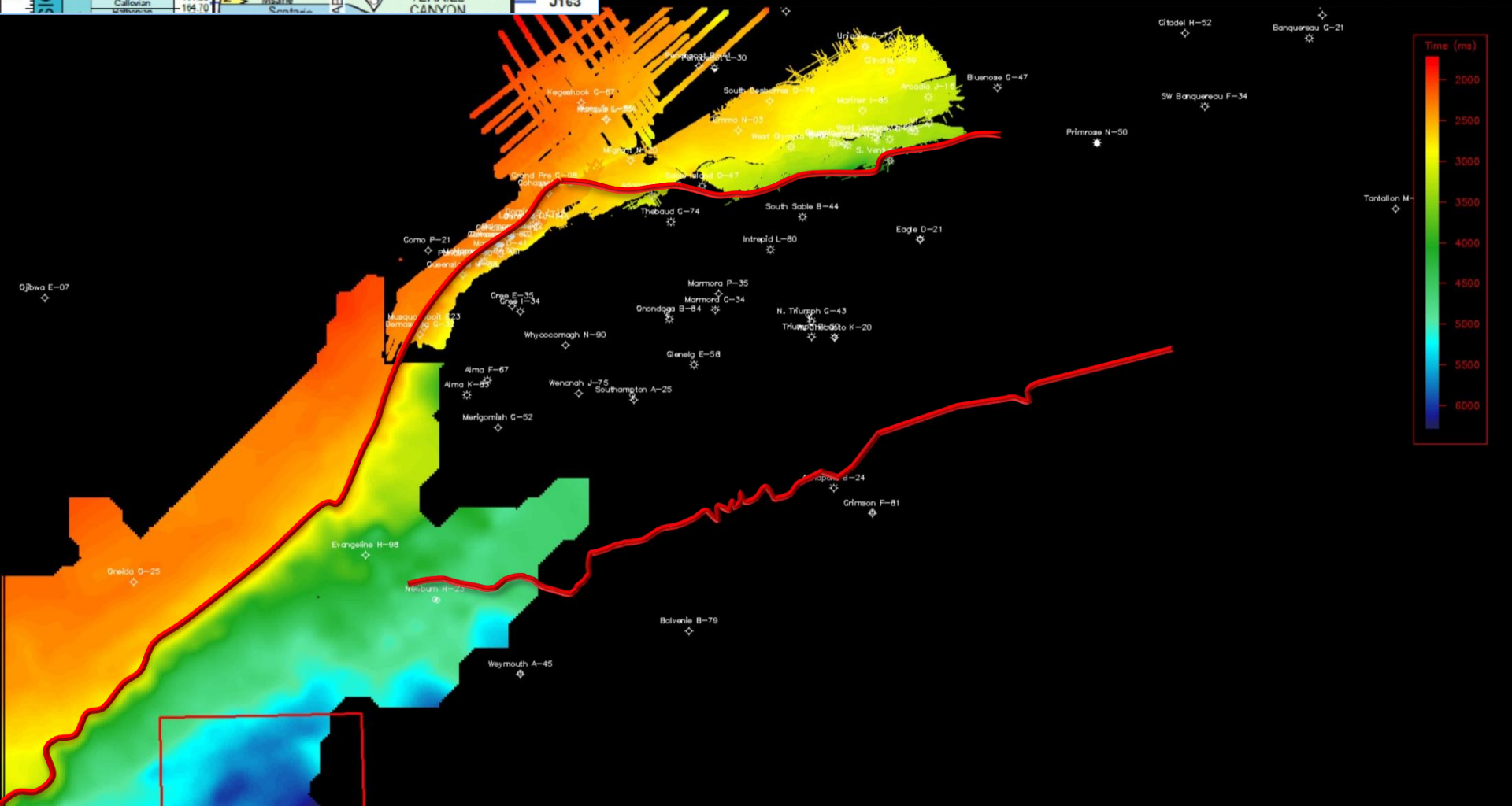


Late Cretaceous Isochron Maximum Regression

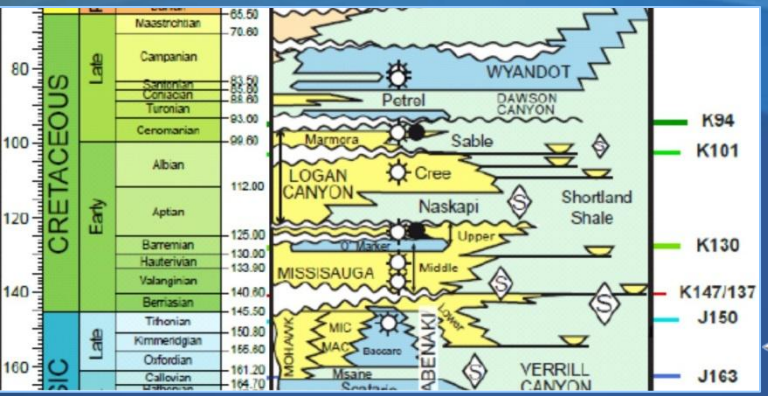


Upper Jurassic & Late Cretaceous Shelf Breaks

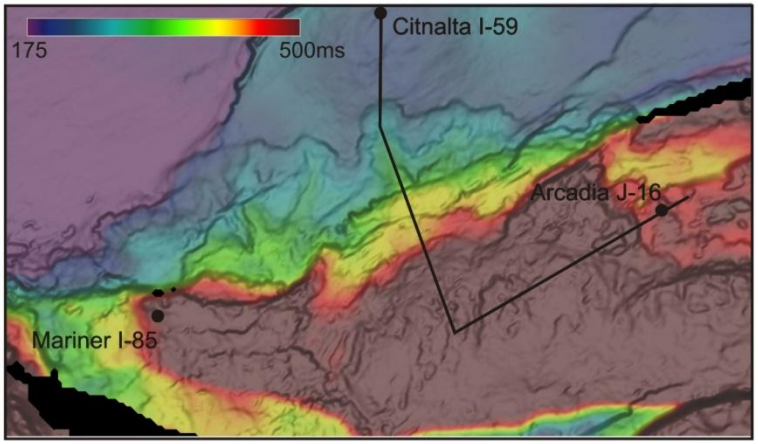


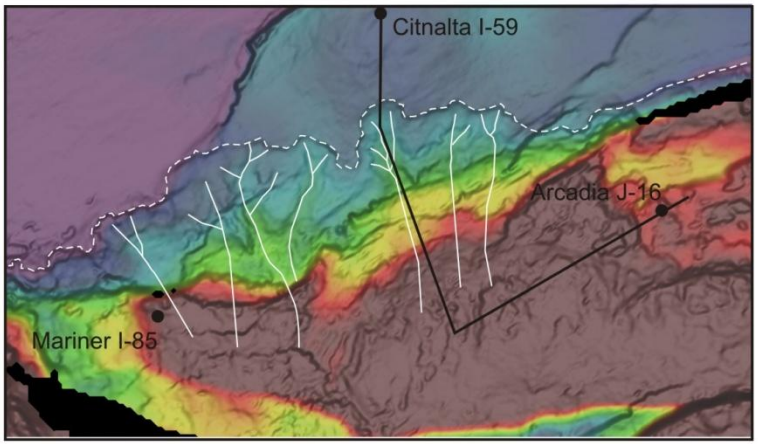


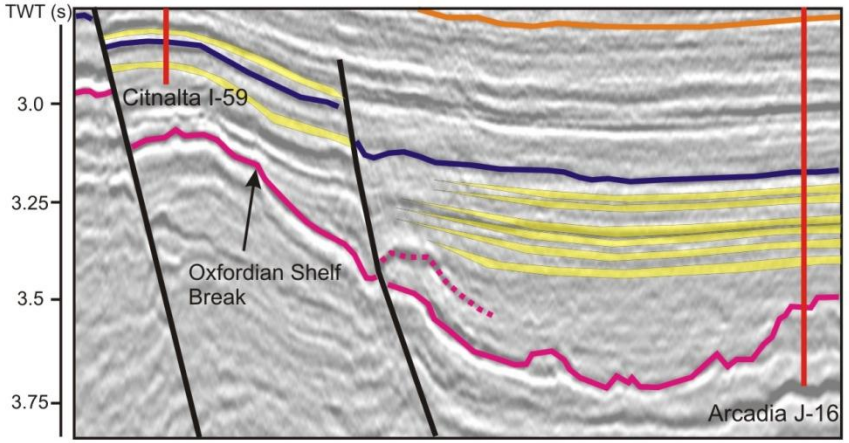
Late Jurassic Canyon



Late Jurassic

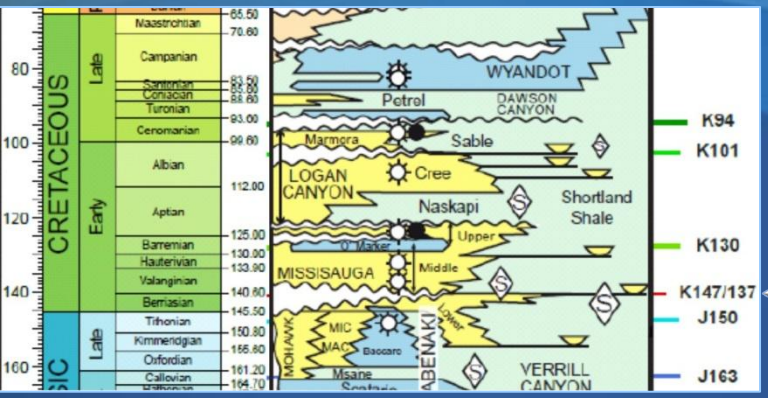




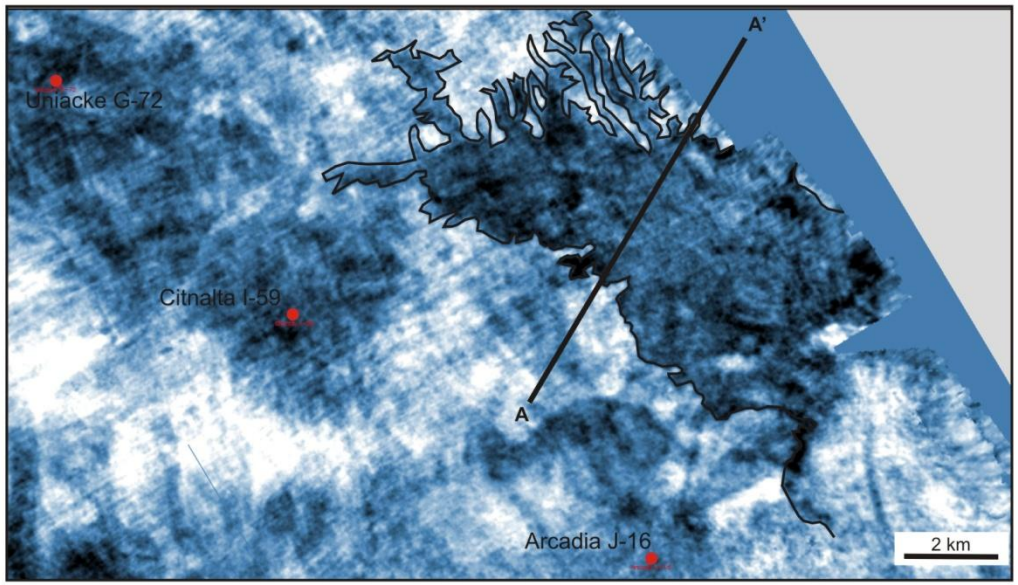


(Above left) Time structure grid of the XX seismic horizon interpreted to represent an Oxfordian aged carbonate of the Baccaro formation. This grid is draped by a XX to XX isochron, and is interpreted to represent the time thickness of the Mic Mac formation in this area. (Left) An Oxfordian shelf edge trajectory is traced in the dashed white line, and potential canyon erosion into the carbonate is also noted (solid white lines). (Above) Seismic section from Citnalta to Arcadia showing the shelf break location in section view. Also noted is the isochron thick and pay intervals at both Citnalta and Arcadia are schematically shown at their intersection with the borehole

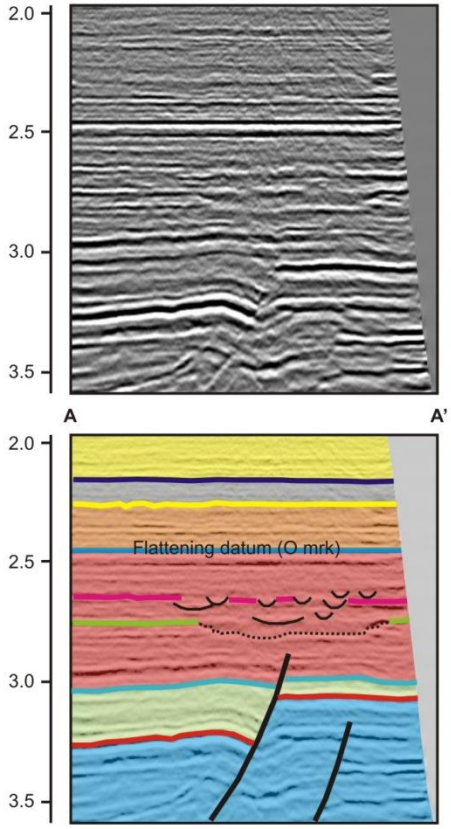
Early Cretaceous
L Missisauga Canyon



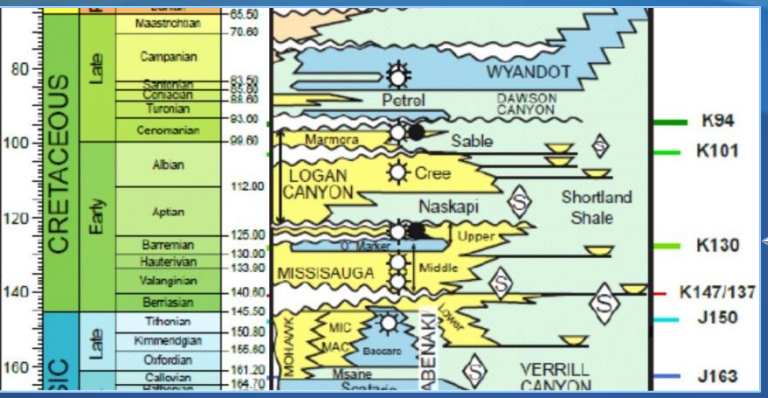
E. Cretaceous - Lwr. Miss.



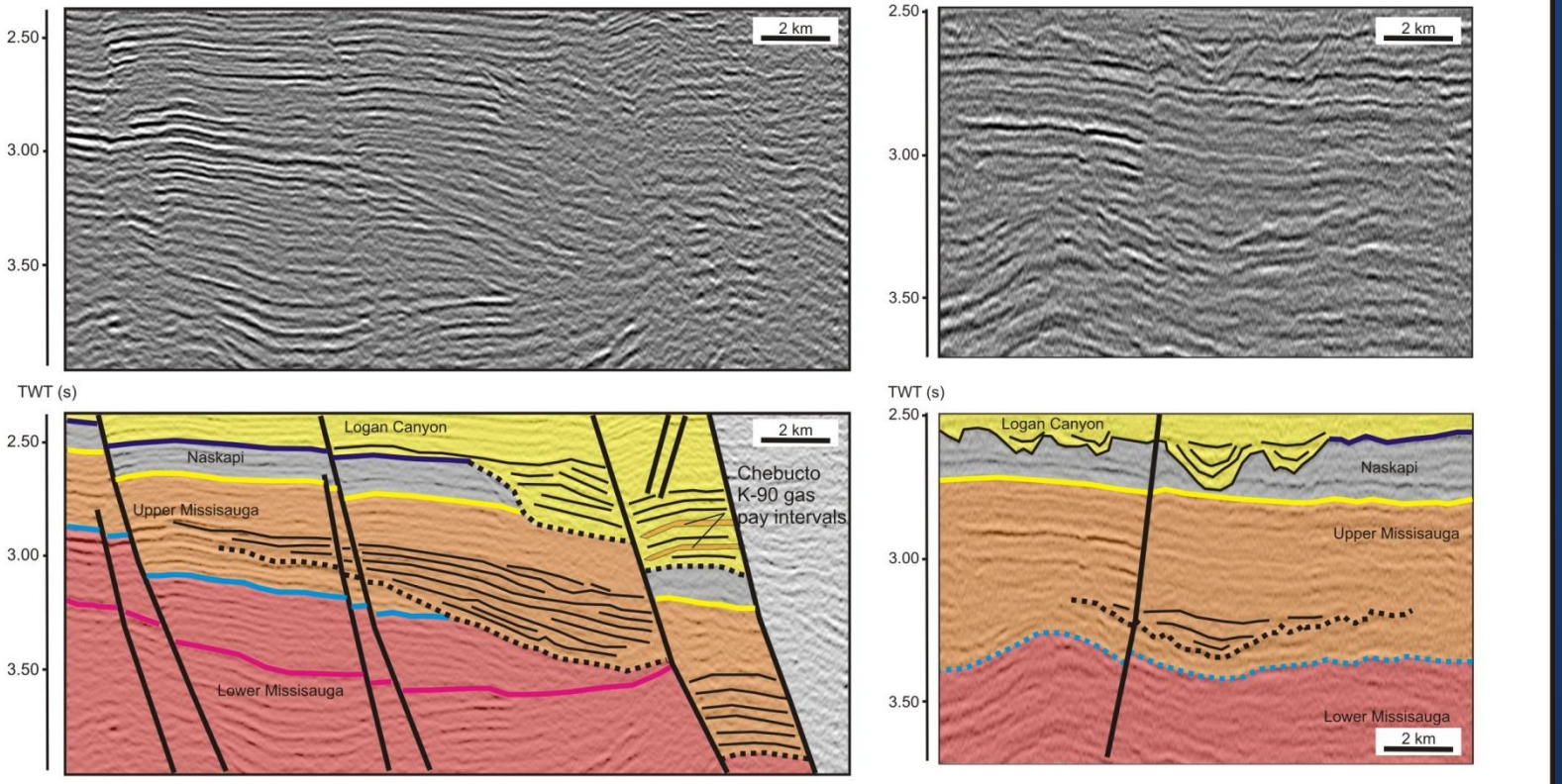
3D seismic volume flattened on the 'o' marker and sliced through an interpreted lower Missisaugua canyon head (above). Corresponding interpreted and uninterpreted seismic transects A-A' also flattened on the 'o' marker (right).



Early Cretaceous
U. Missisauga Canyons

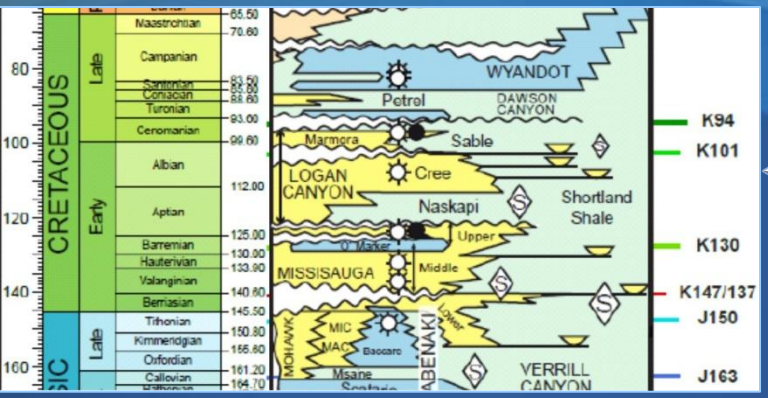


E. Cretaceous - Up Miss.

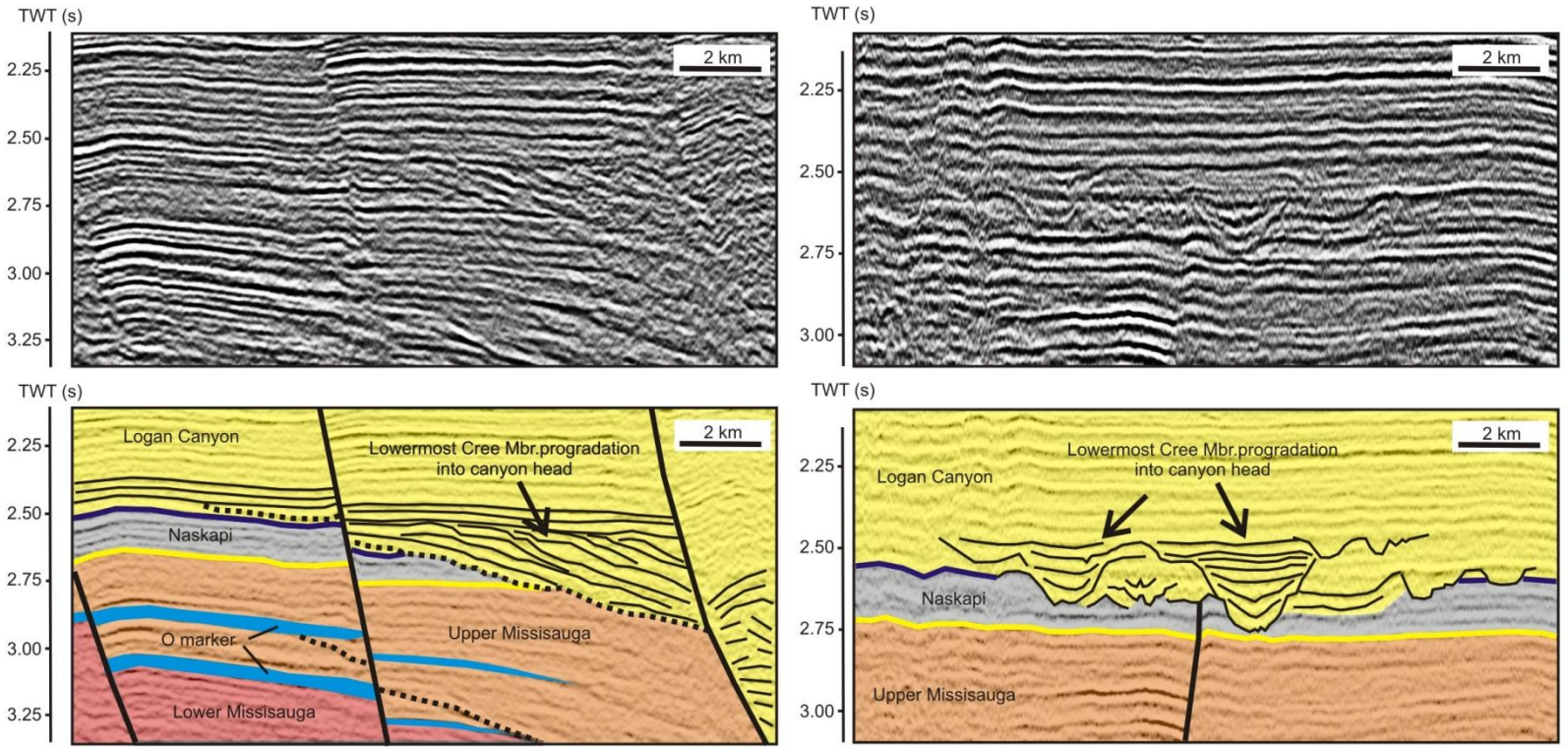


Uninterpreted and interpreted strike (right) and dip (left) seismic profiles of an Upper Missisauga canyon head adjacent to a salt cored high near Chebucto K-90.

Early Cretaceous Cree Canyons



E. Cretaceous - Cree Mbr



Uninterpreted and interpreted strike (right) and dip (left) seismic profiles of lowermost Cree member progradation into a late Aptian/early Albian canyon head. The upper Missisaugua canyon head is also visible deeper in the section.

Linked Late Jurassic Systems

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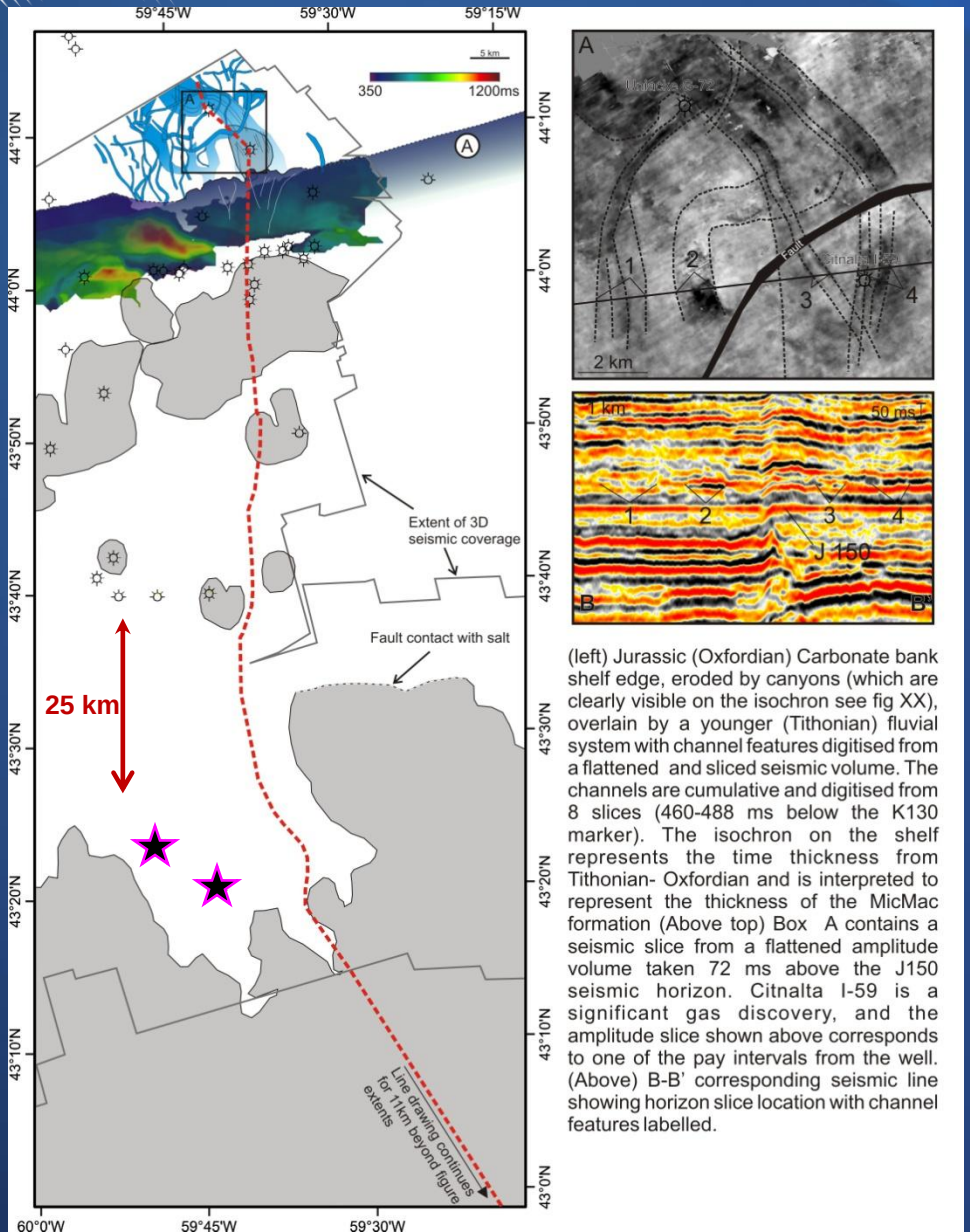
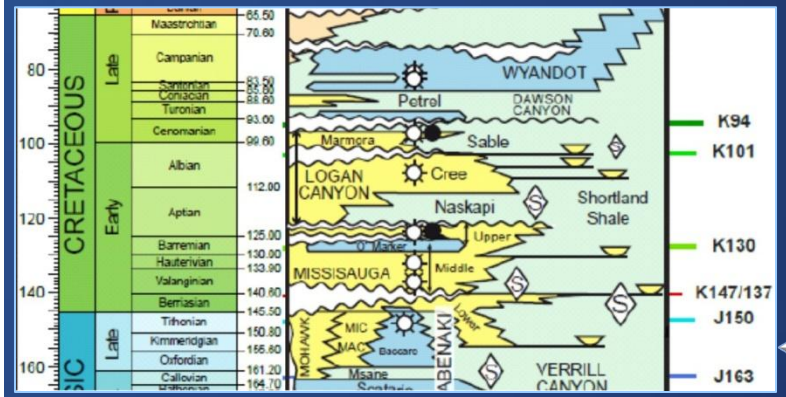


(left) Jurassic (Oxfordian) Carbonate bank shelf edge, eroded by canyons (which are clearly visible on the isochron see fig XX), overlain by a younger (Tithonian) fluvial system with channel features digitised from a flattened and sliced seismic volume. The channels are cumulative and digitised from 8 slices (460-488 ms below the K130 marker). The isochron on the shelf represents the time thickness from Tithonian- Oxfordian and is interpreted to represent the thickness of the MicMac formation (Above top) Box A contains a seismic slice from a flattened amplitude volume taken 72 ms above the J150 seismic horizon. Citnalta I-59 is a significant gas discovery, and the amplitude slice shown above corresponds to one of the pay intervals from the well. (Above) B-B' corresponding seismic line showing horizon slice location with channel features labelled.



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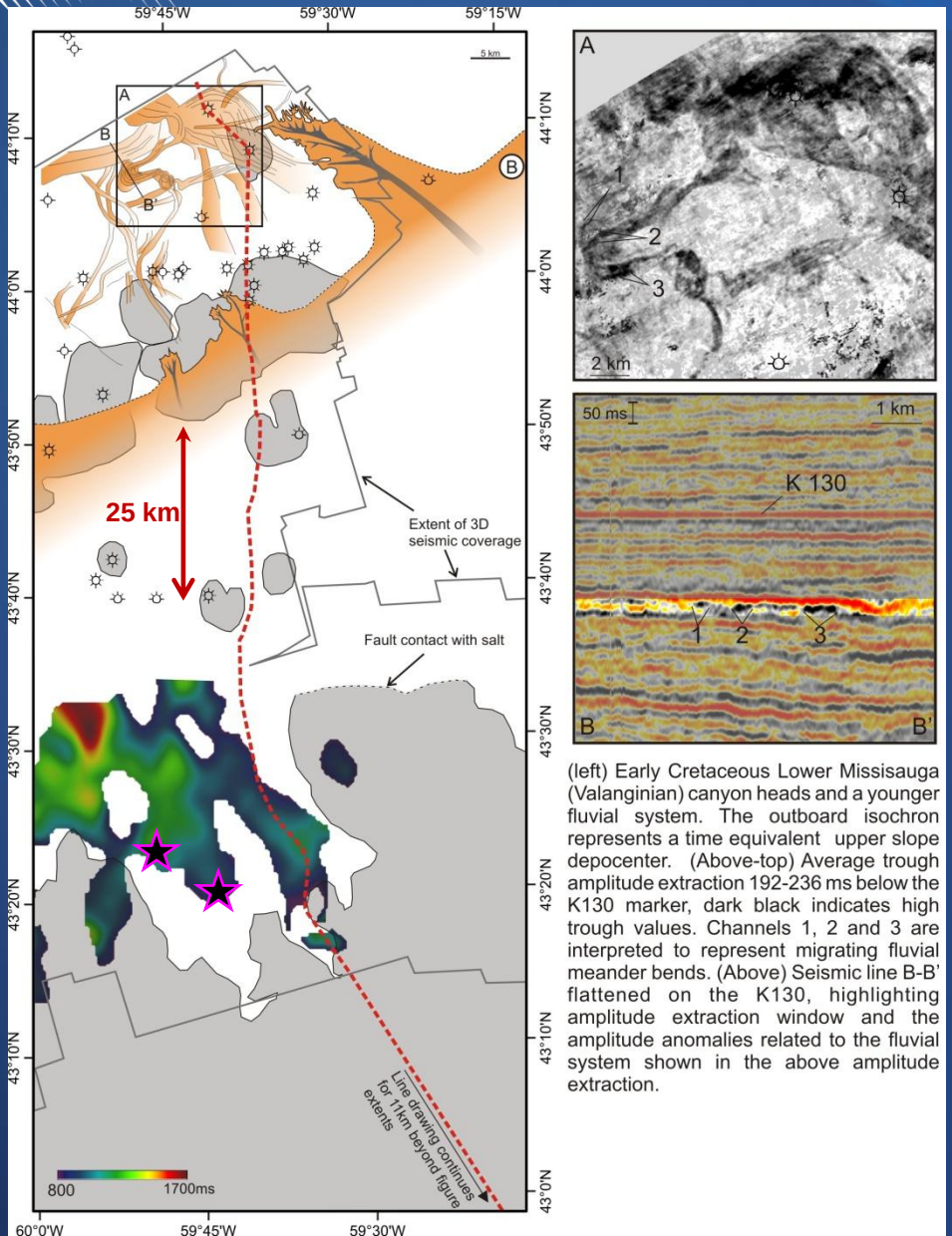
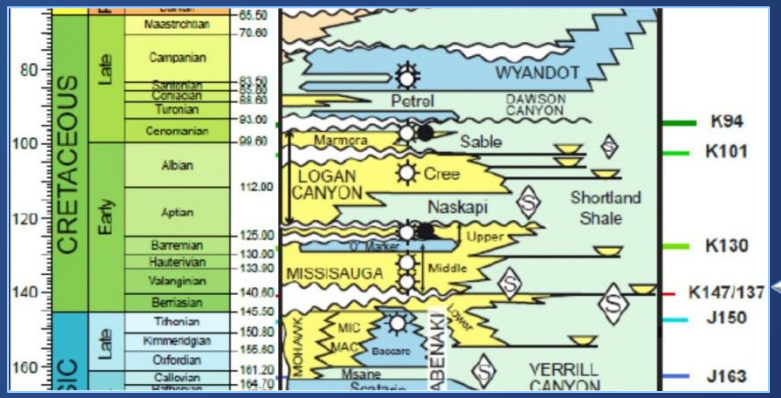
Early Cretaceous Lower Missisauga Systems



(left) Early Cretaceous Lower Missisauga (Valanginian) canyon heads and a younger fluvial system. The outboard isochron represents a time equivalent upper slope depocenter. (Above-top) Average trough amplitude extraction 192-236 ms below the K130 marker, dark black indicates high trough values. Channels 1, 2 and 3 are interpreted to represent migrating fluvial meander bends. (Above) Seismic line B-B' flattened on the K130, highlighting amplitude extraction window and the amplitude anomalies related to the fluvial system shown in the above amplitude extraction.



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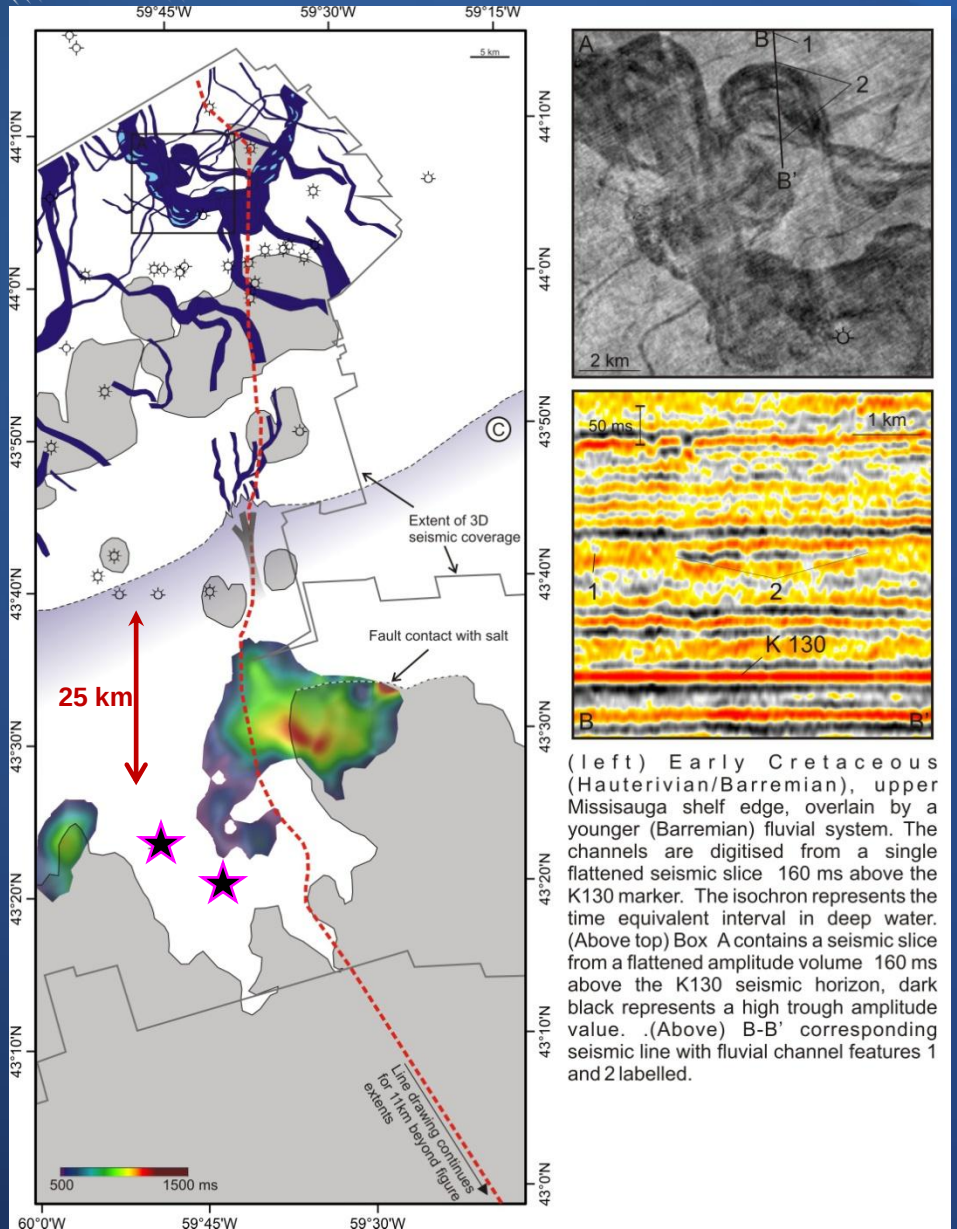
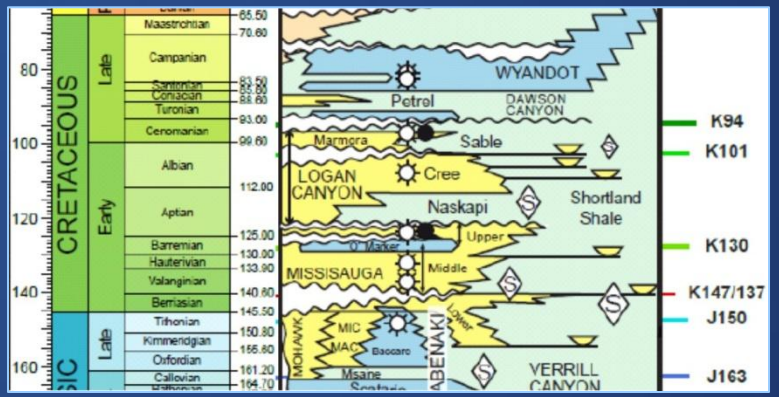
Early Cretaceous Upper Missisauga Systems



(left) Early Cretaceous (Hauterivian/Barremian), upper Missisauga shelf edge, overlain by a younger (Barremian) fluvial system. The channels are digitised from a single flattened seismic slice 160 ms above the K130 marker. The isochron represents the time equivalent interval in deep water. (Above top) Box A contains a seismic slice from a flattened amplitude volume 160 ms above the K130 seismic horizon, dark black represents a high trough amplitude value. .(Above) B-B' corresponding seismic line with fluvial channel features 1 and 2 labelled.



Early Cretaceous Cree Systems

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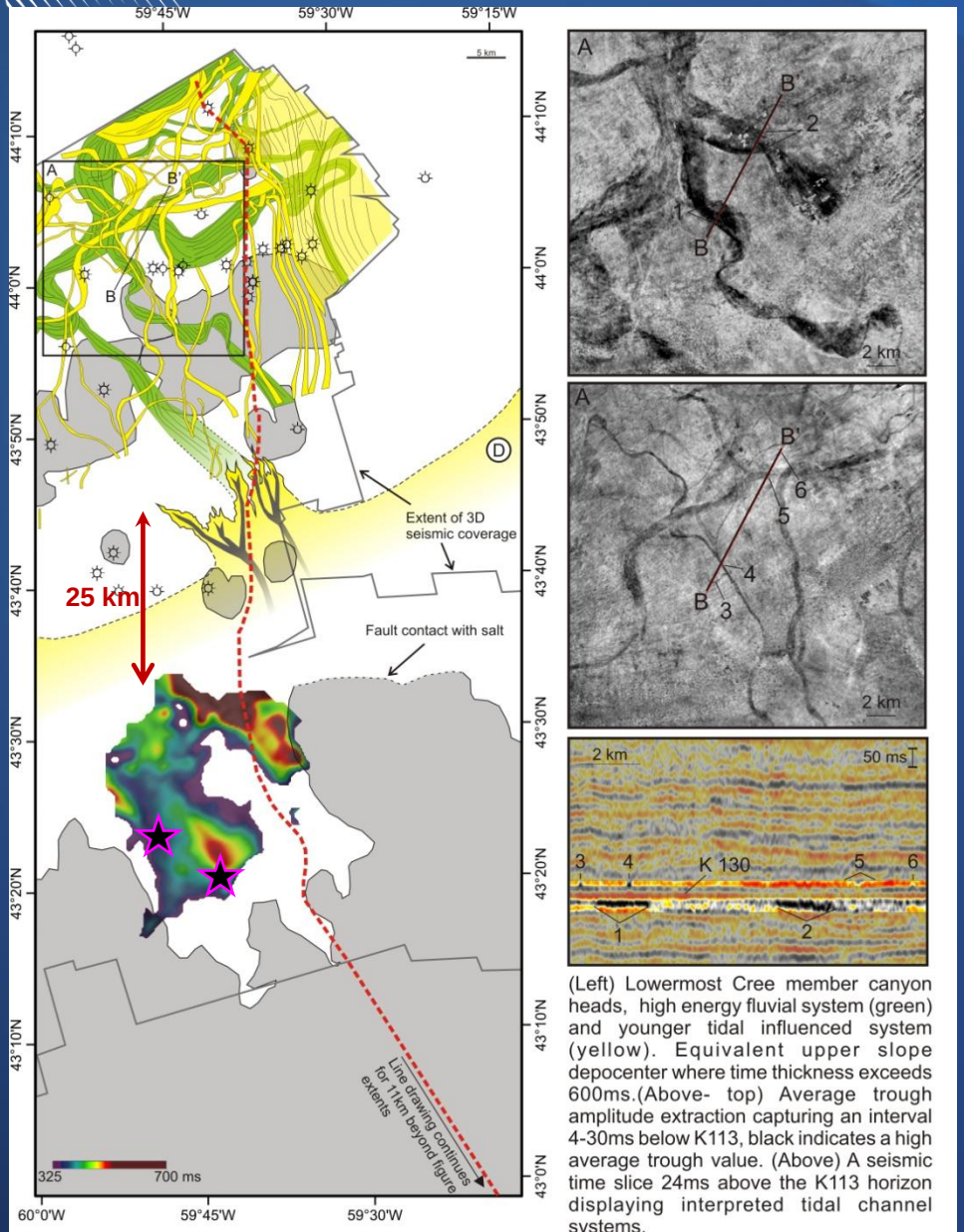
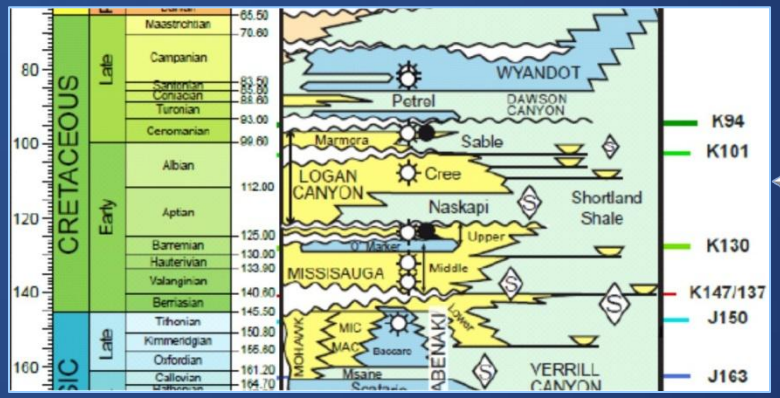


(Left) Lowermost Cree member canyon heads, high energy fluvial system (green) and younger tidal influenced system (yellow). Equivalent upper slope depocenter where time thickness exceeds 600ms.(Above- top) Average trough amplitude extraction capturing an interval 4-30ms below K113, black indicates a high average trough value. (Above) A seismic time slice 24ms above the K113 horizon displaying interpreted tidal channel systems.



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Annapolis & Crimson Well Results Explained With Current Interpretation

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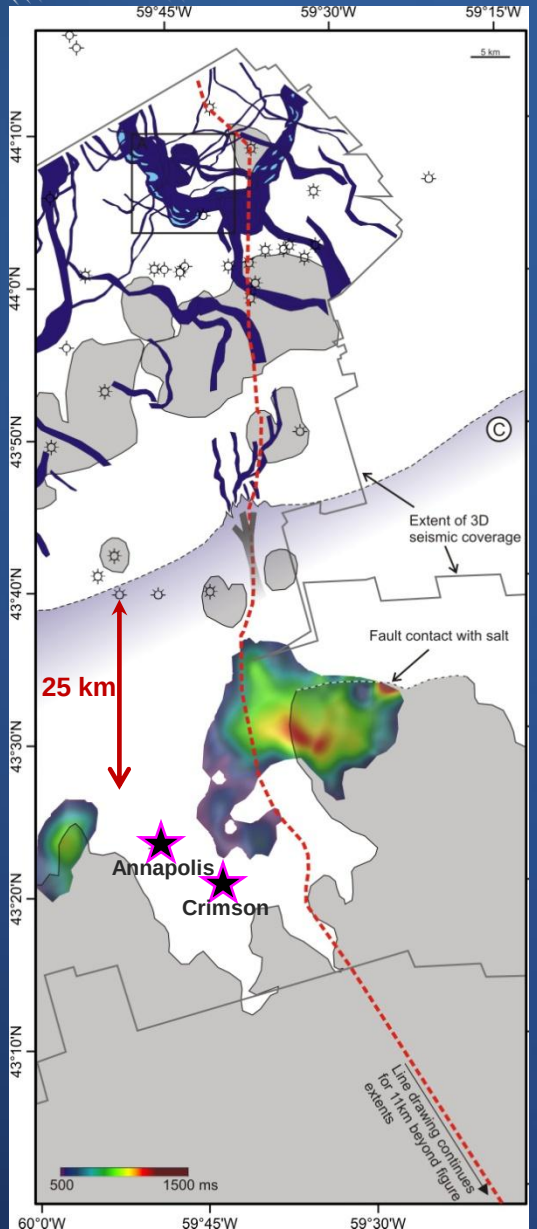
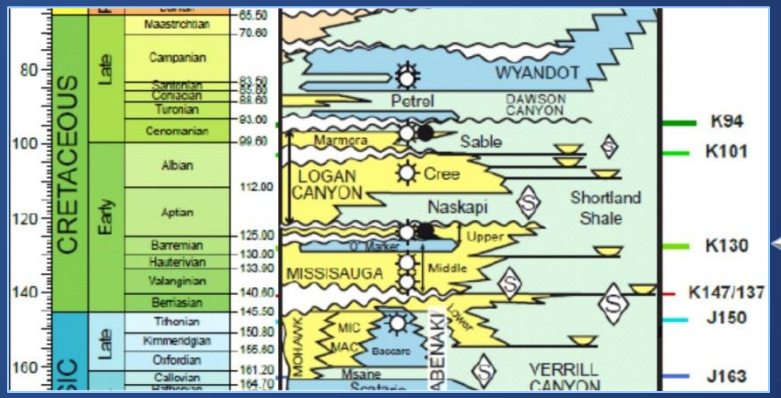
Early Cretaceous
U. Missisauga Systems





Hauterivian –Barremian Isochron

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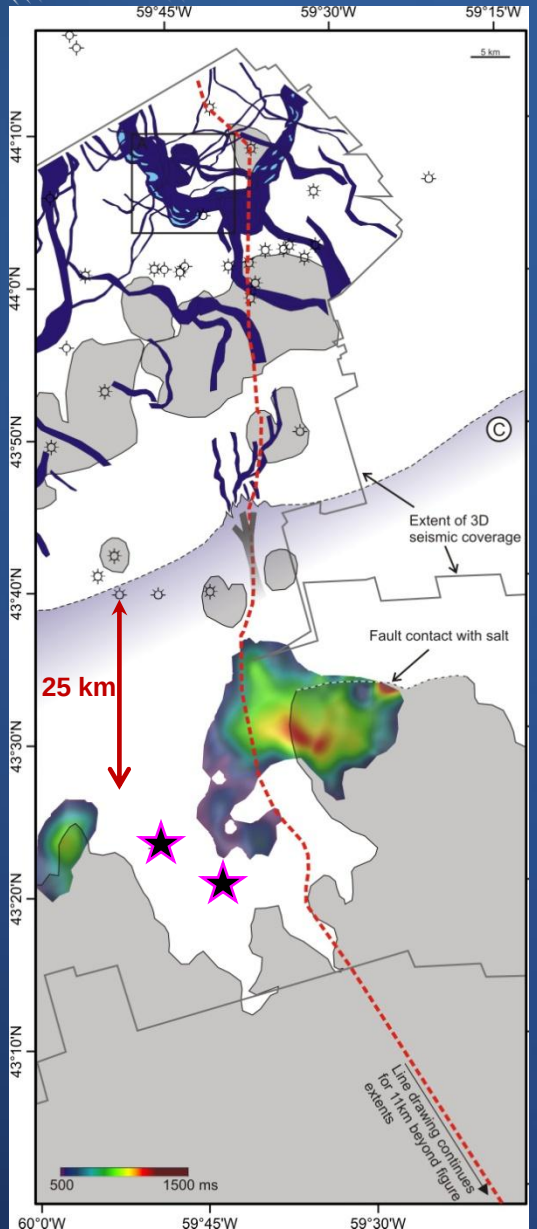

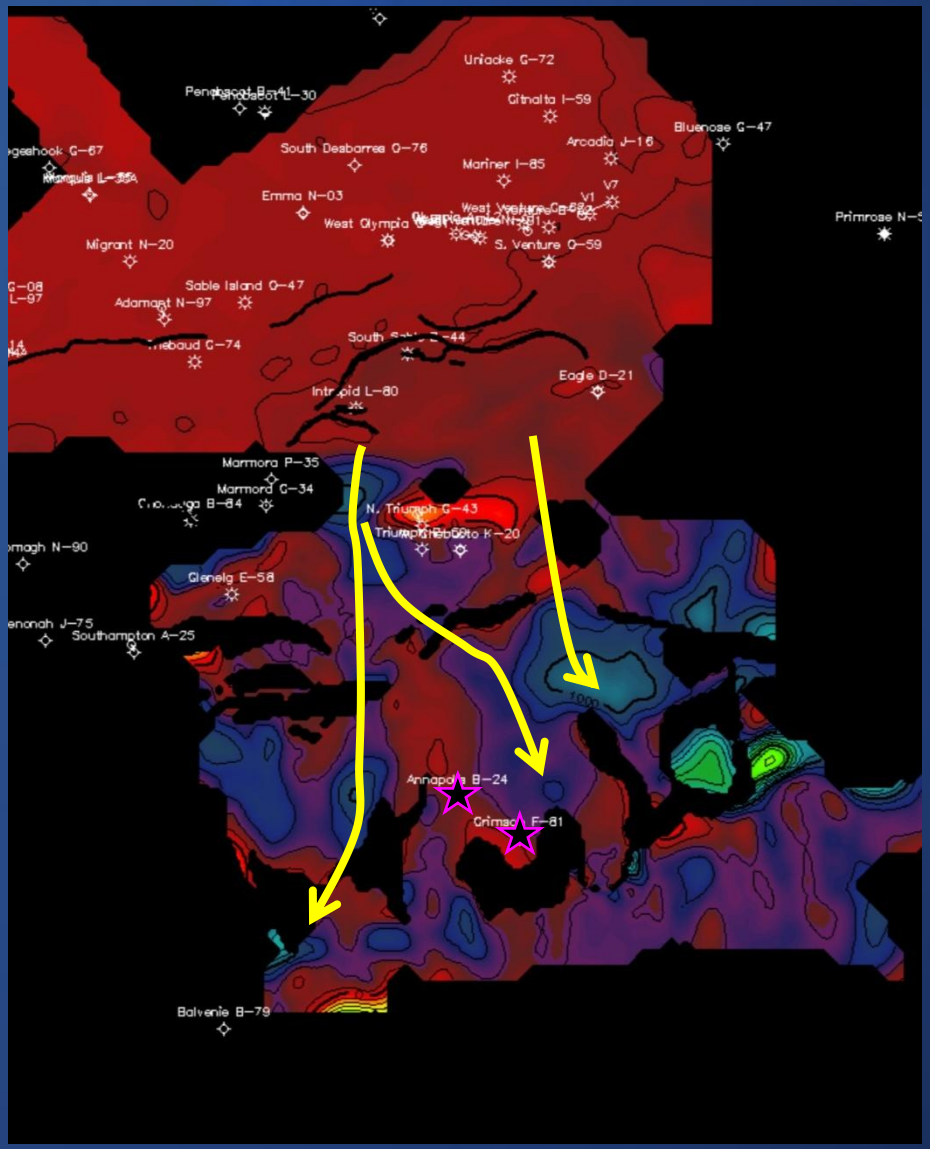

Hauterivian –Barremian Isochron

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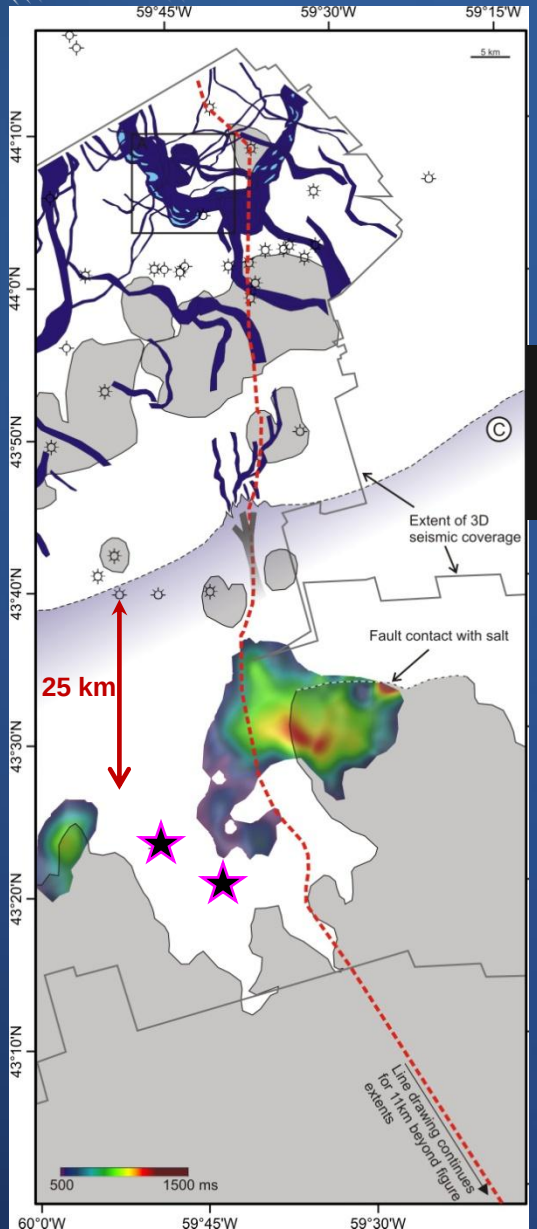
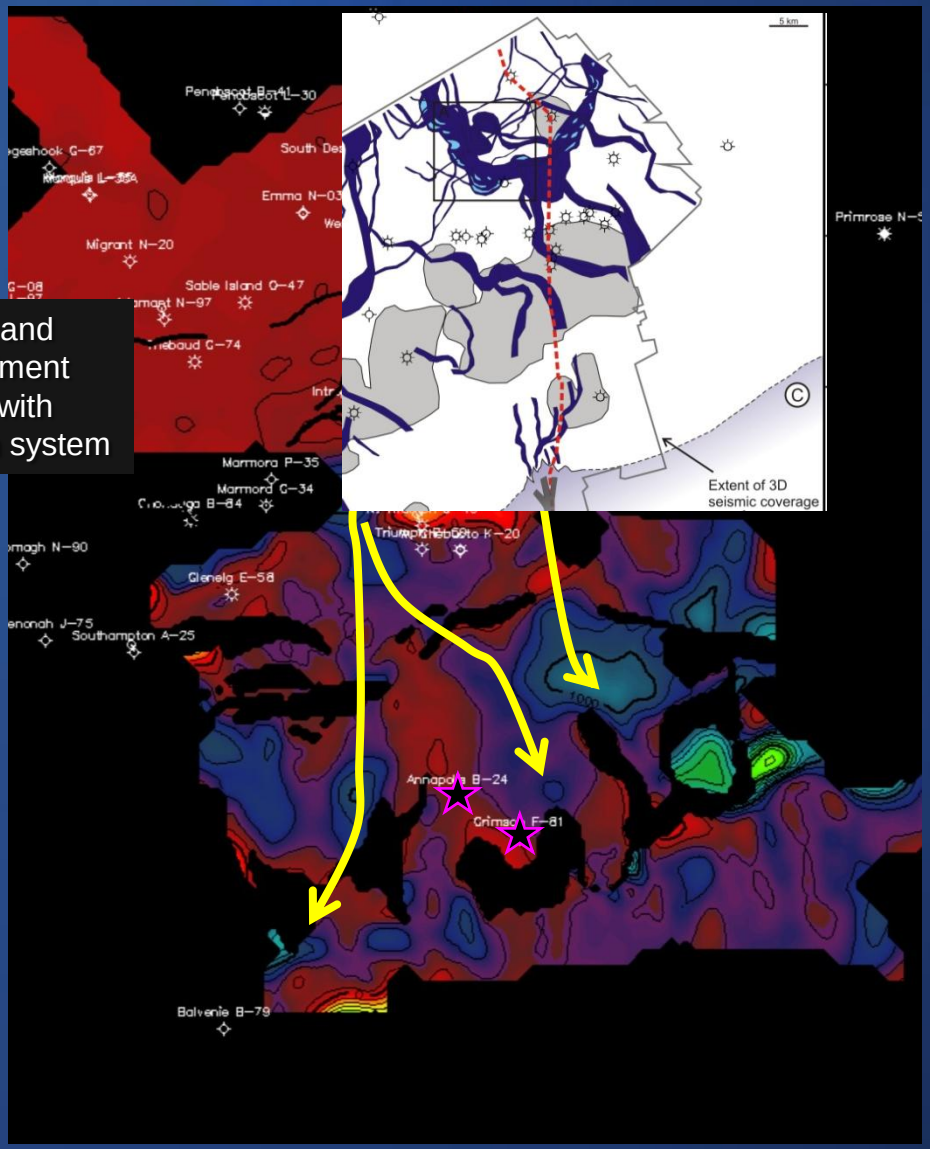


Isochron thick and interpreted sediment fairway aligns with interpreted canyon system



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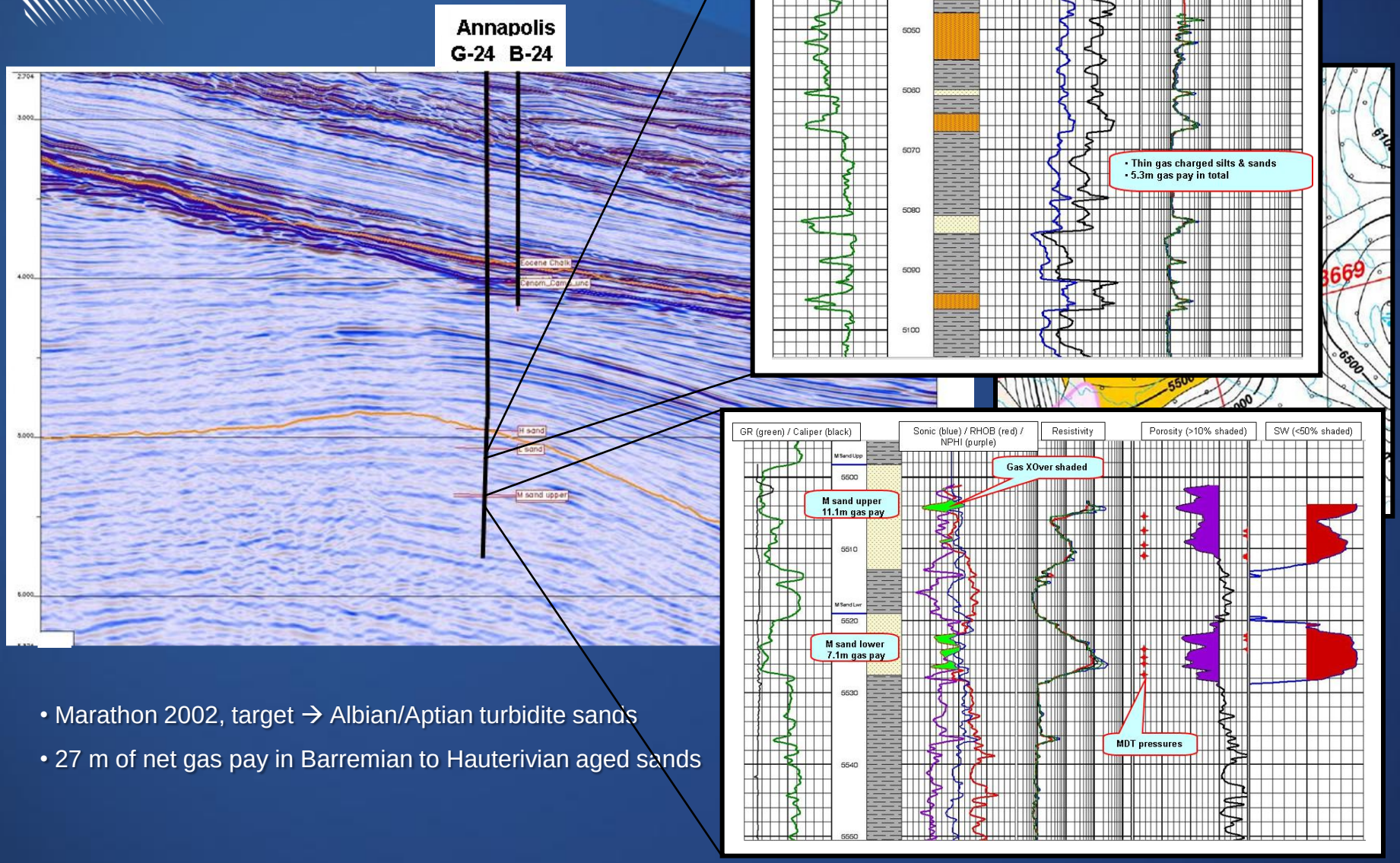
A



- Marathon 2002, target → Albian/Aptian turbidite sands
- 27 m of net gas pay in Barremian to Hauterivian aged sands

(Kidston et. al, 2007)

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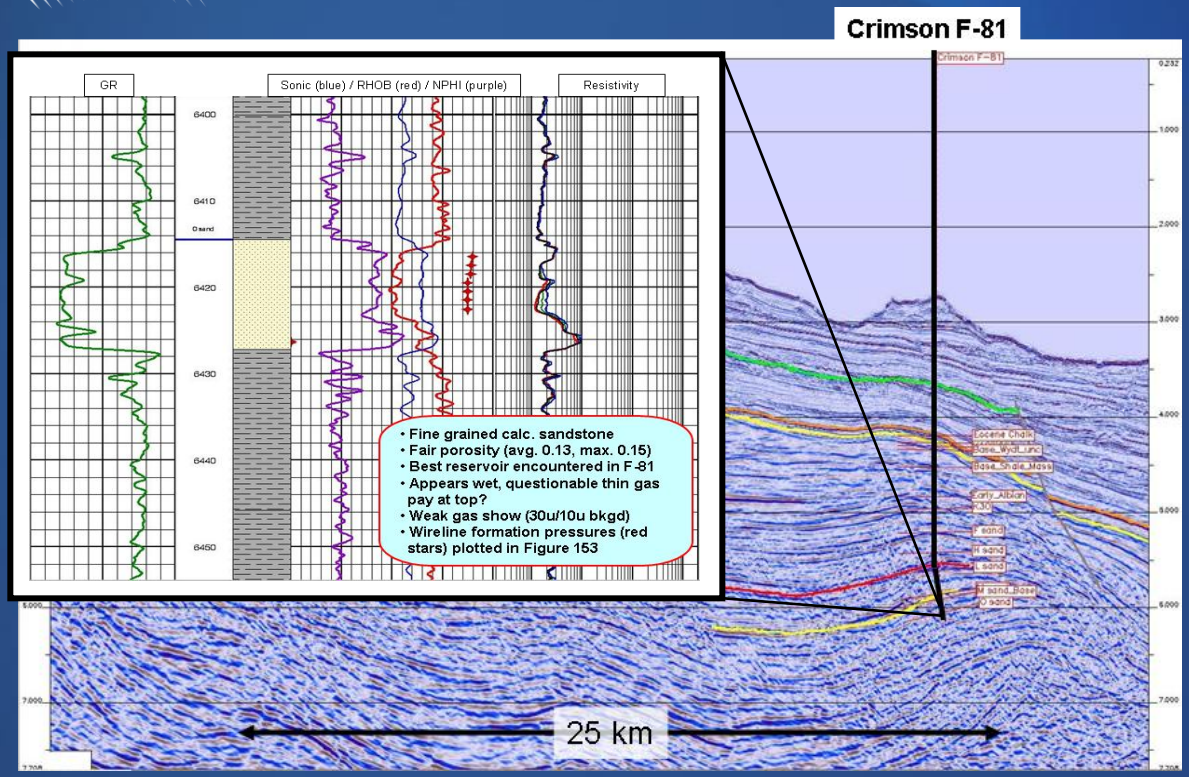
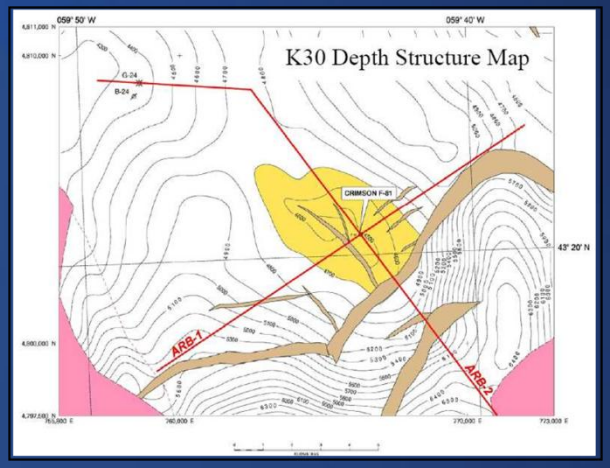
Crimson F-81





Structure dependant on closure against a rollover fault to the southeast

- Marathon 2004
- H, L and M sands poorly developed
- Deeper sand (O sand ~ 13 m thick) penetrated.
- No hydrocarbon charge

(Kidston et. al, 2007)

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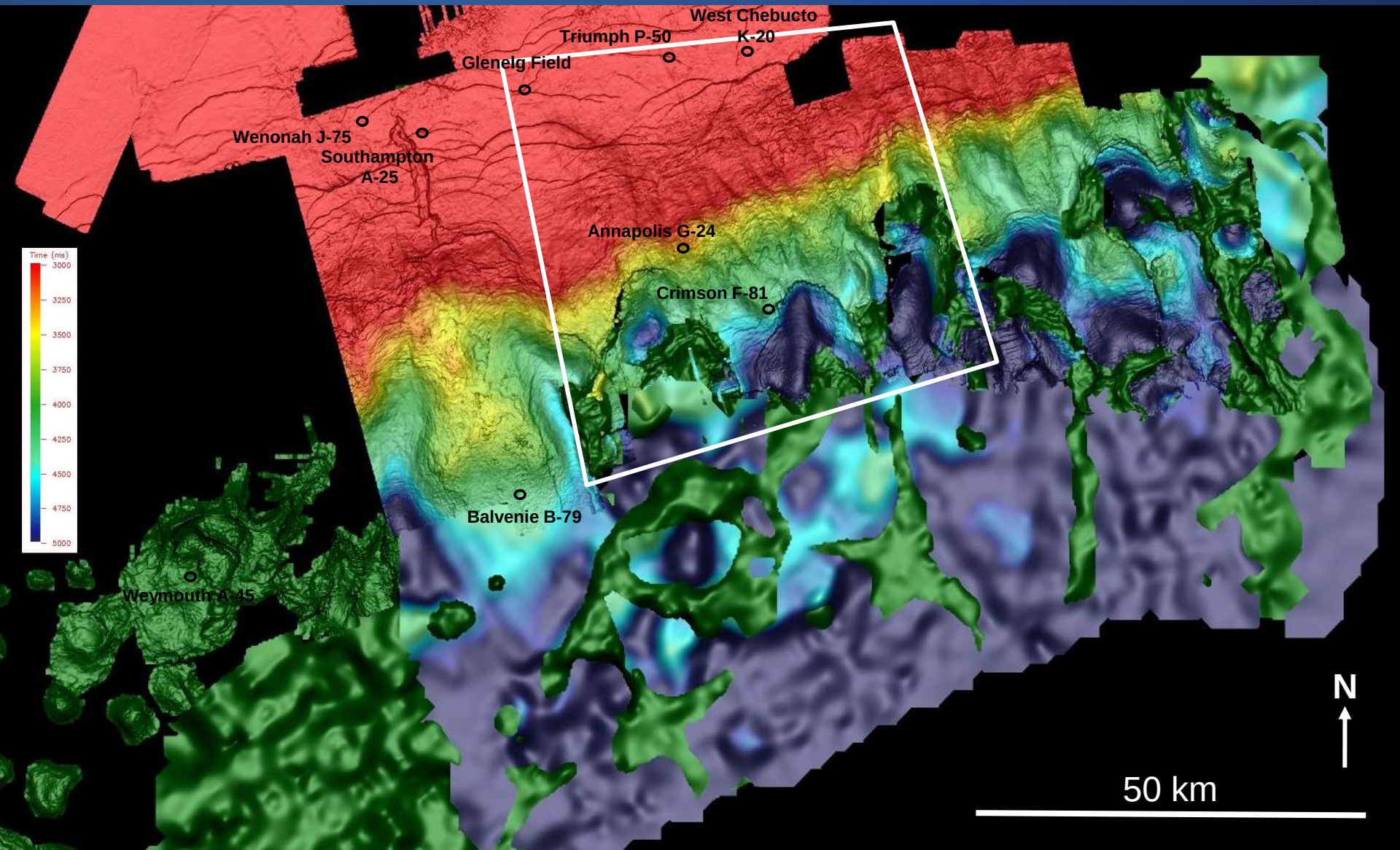
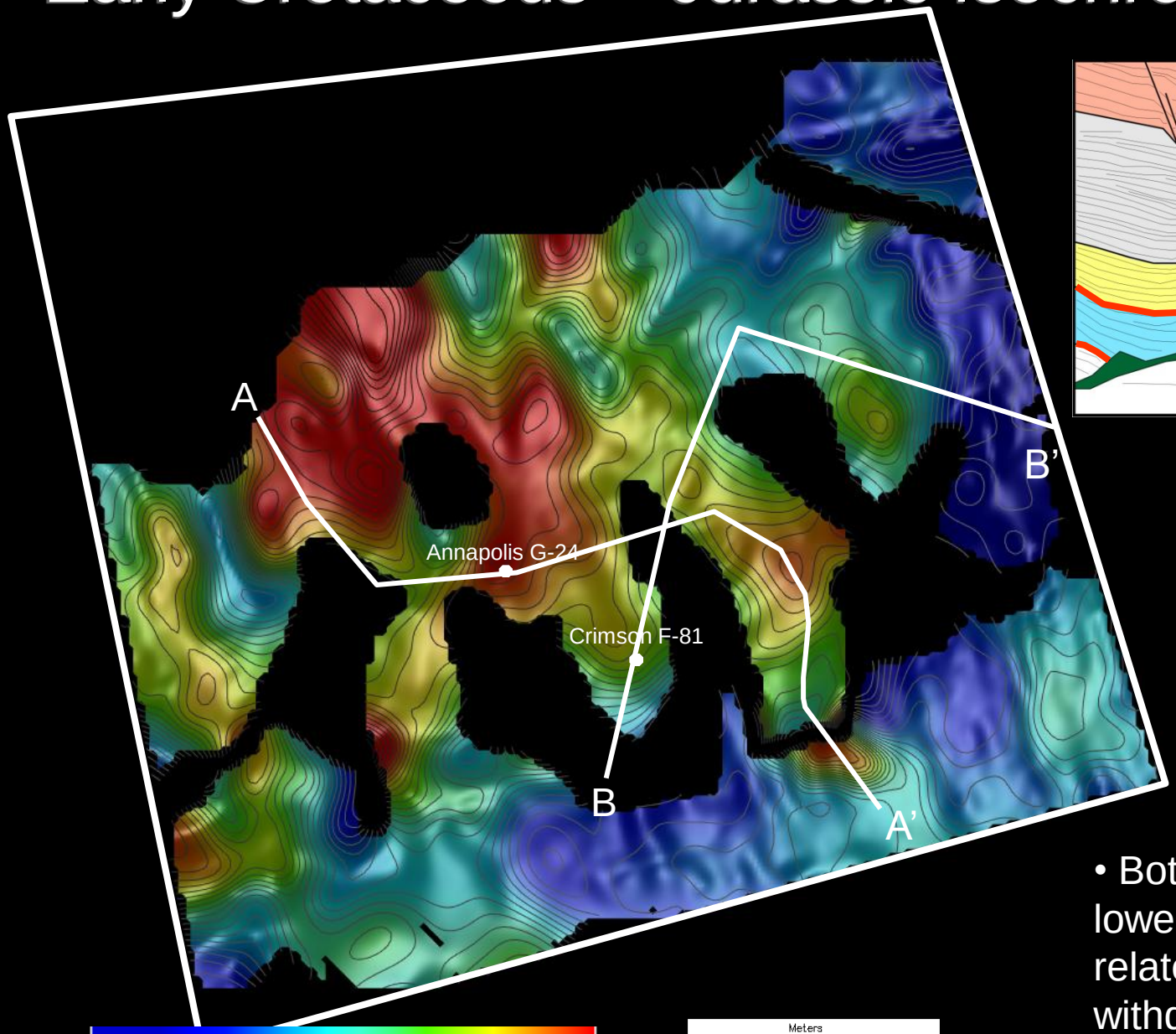
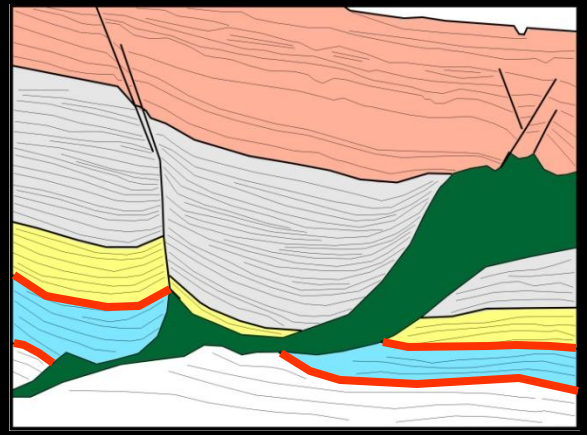
Late Cretaceous with Salt



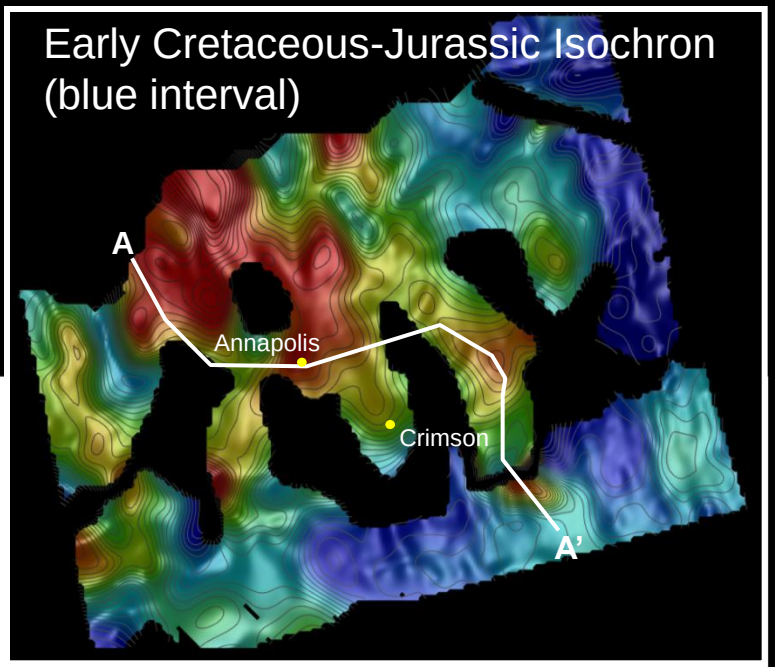
Early Cretaceous – Jurassic Isochron (blue)

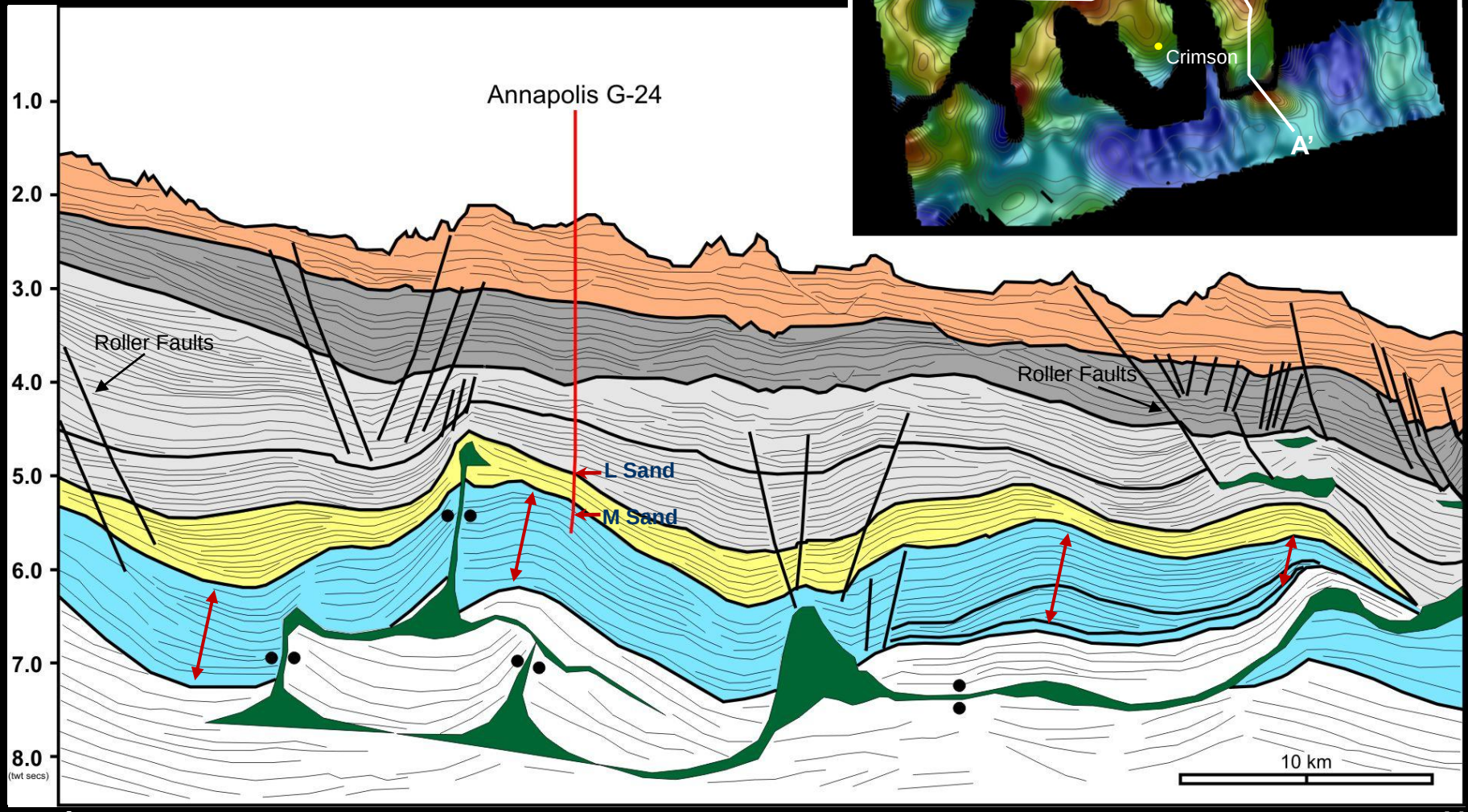




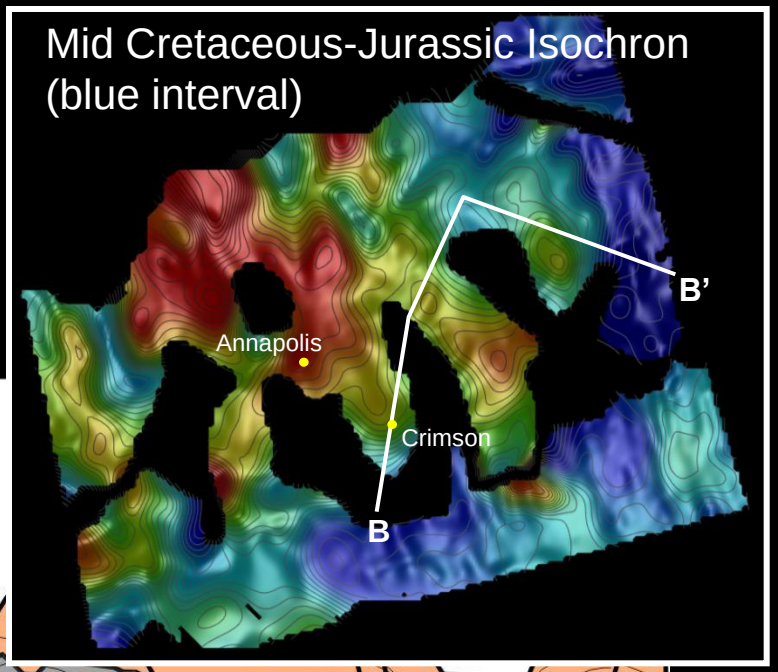
- Both wells drilled lower Cretaceous <u>thicks</u> related to early salt withdrawal

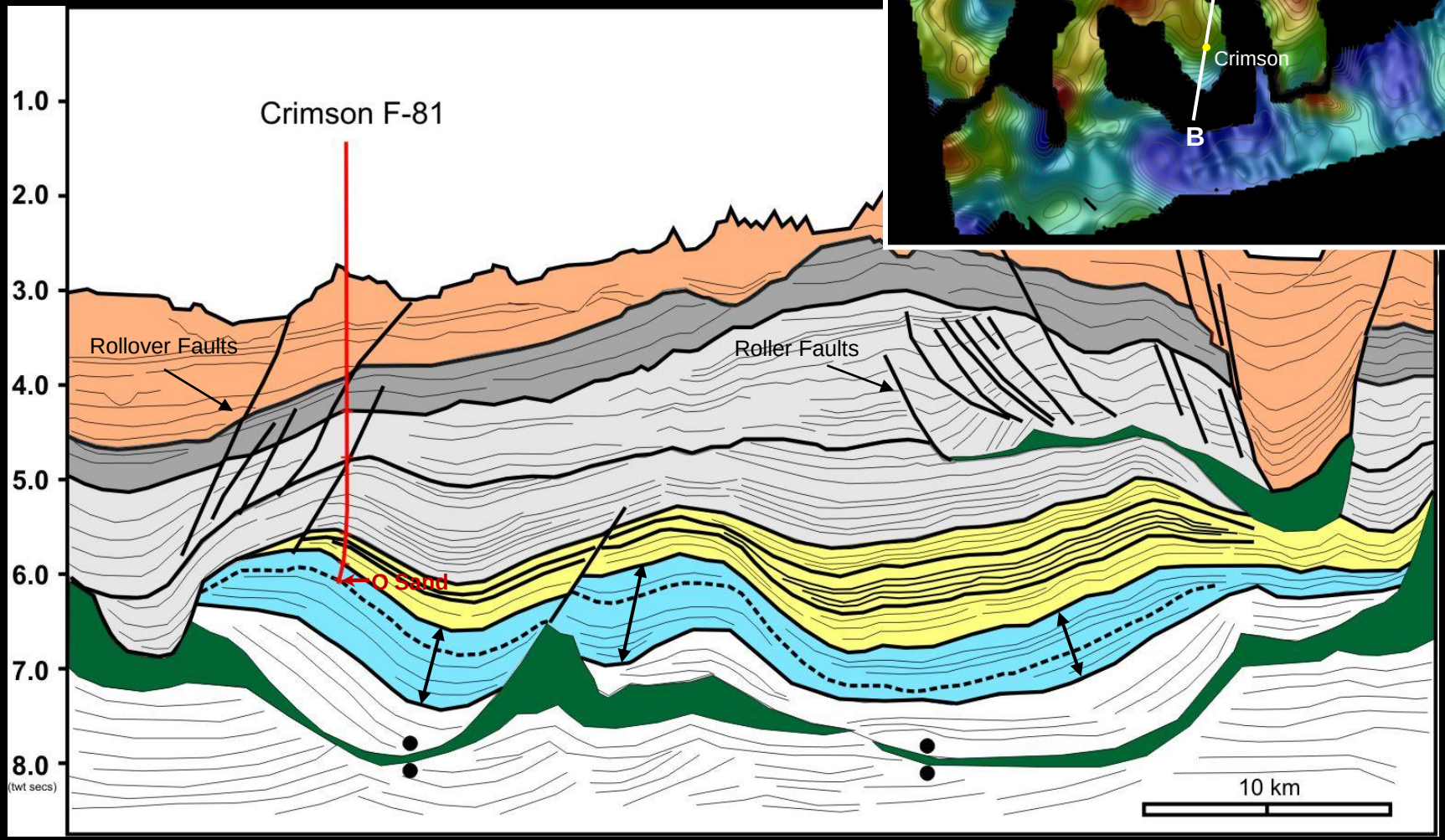
- Annapolis only penetrated the very upper 100-200 m this interval
- Excellent reservoir sands (M sands 18 m net pay) are penetrated at this well location



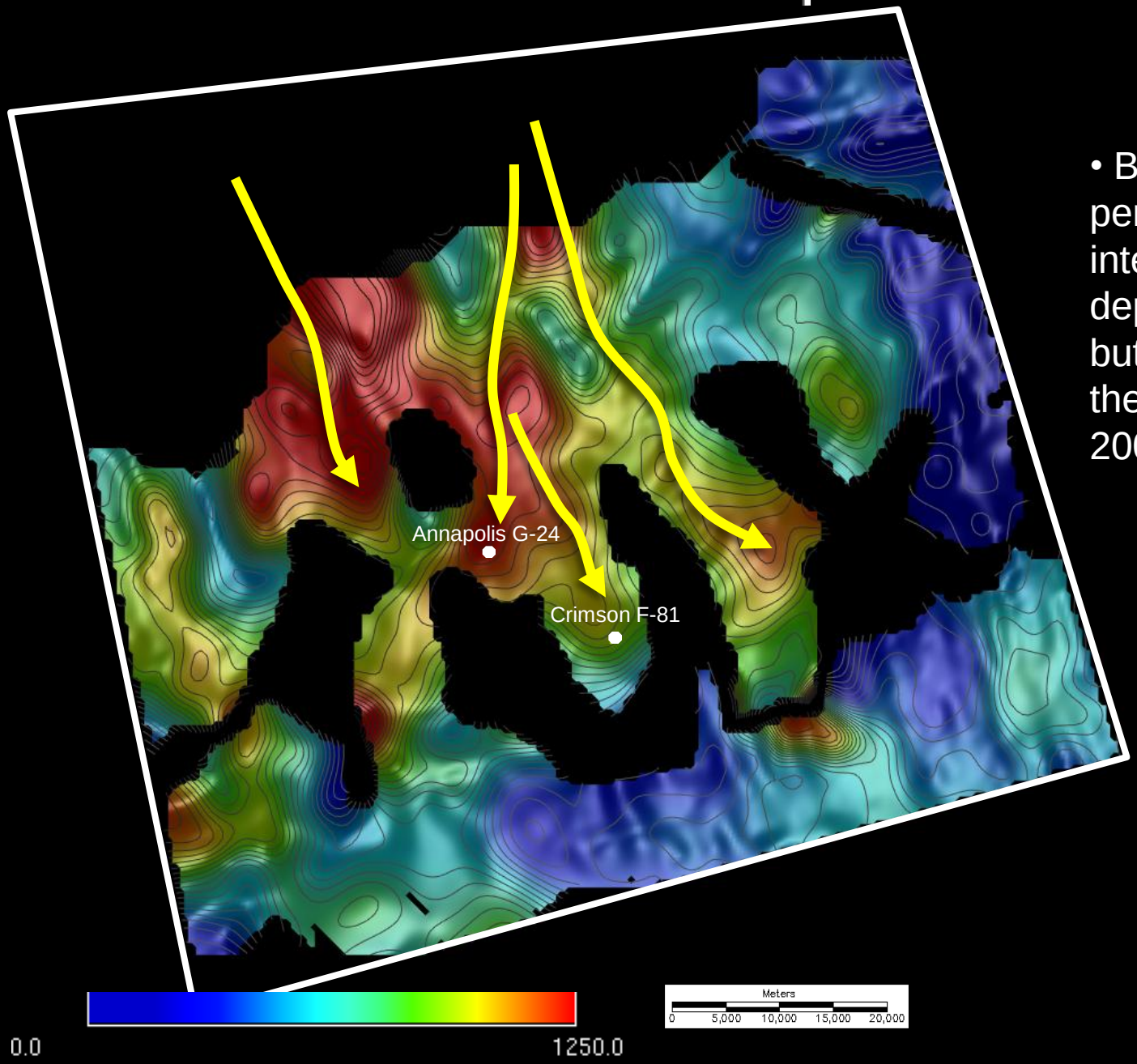


- M sand penetrated at Annapolis is not present here
- A deeper (but wet) sand is encountered, the O sand approx 13 m thick.





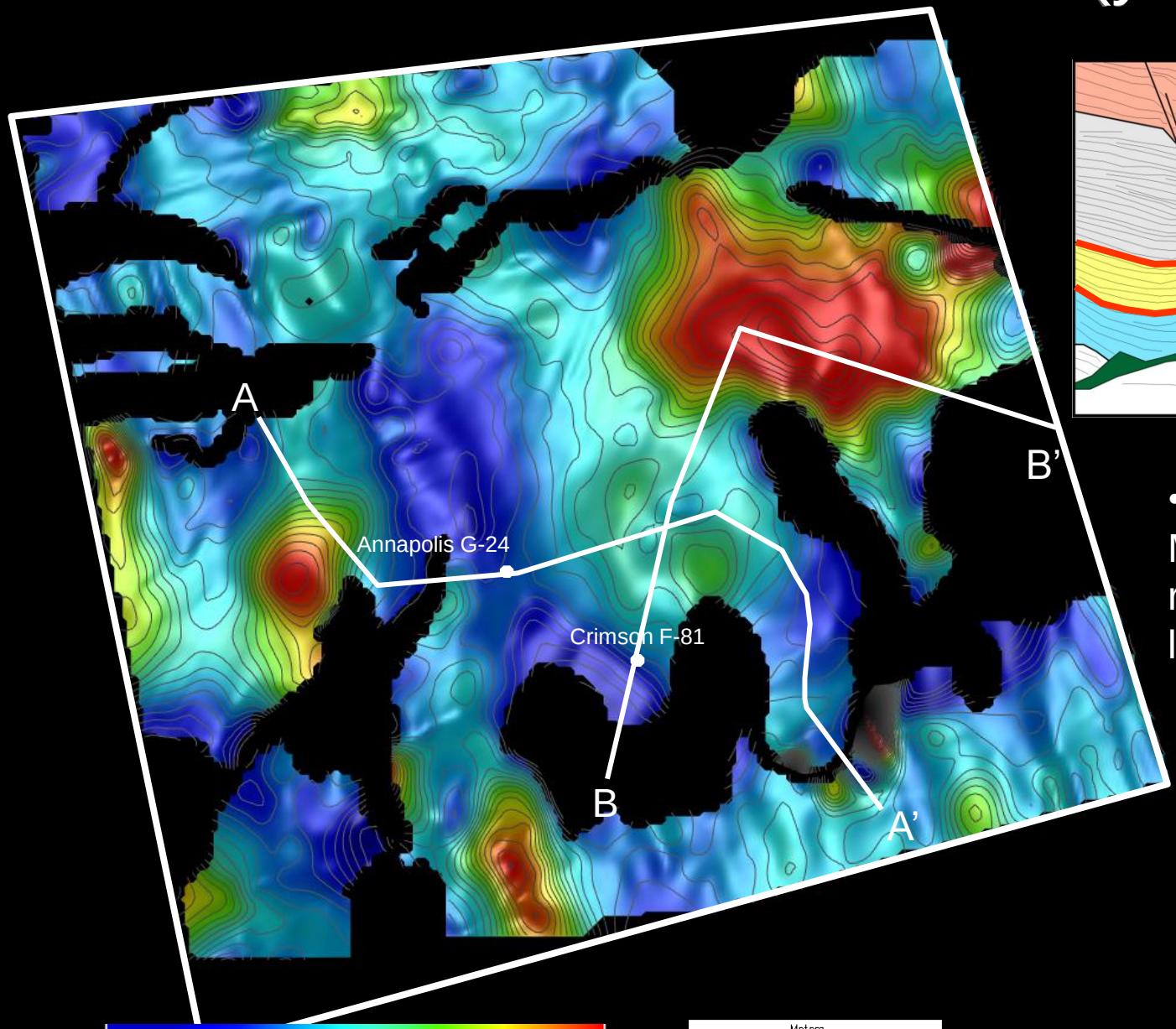
Lower Cretaceous Depositional Corridors

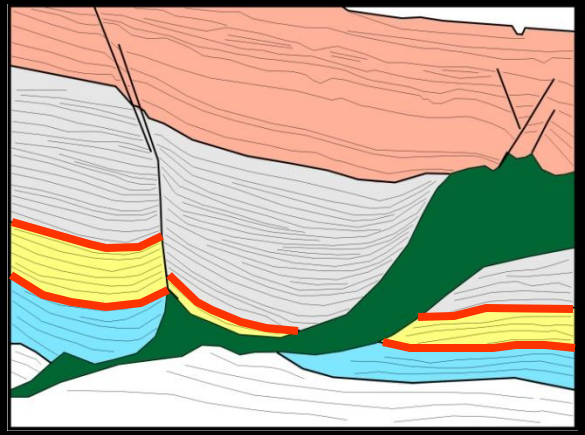


- Both wells penetrate an interpreted depositional corridor, but only penetrate the uppermost 100 - 200 m section

- M sand at Annapolis and O sand at Crimson are the thickest sands encountered to date in deepwater

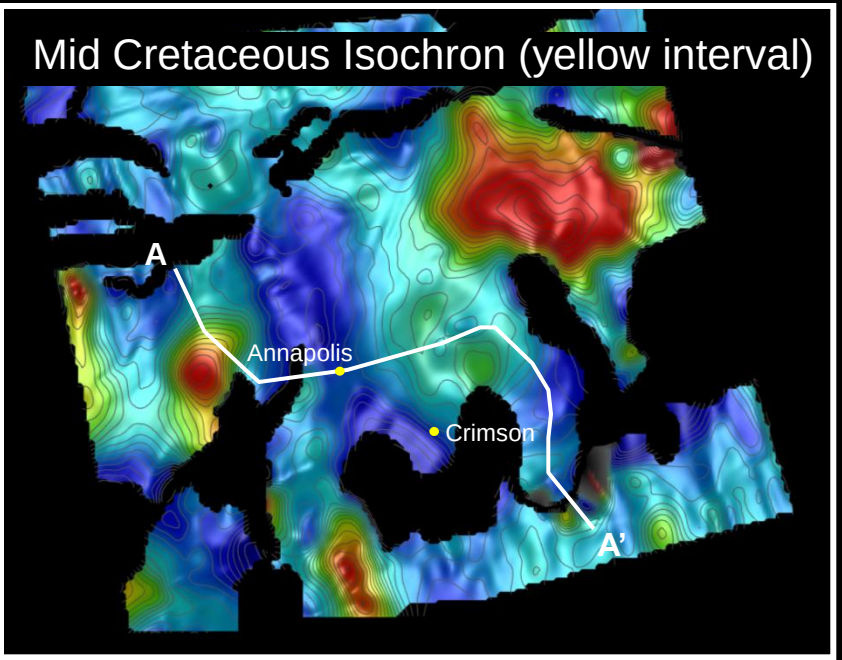
Mid Cretaceous Isochron (yellow)

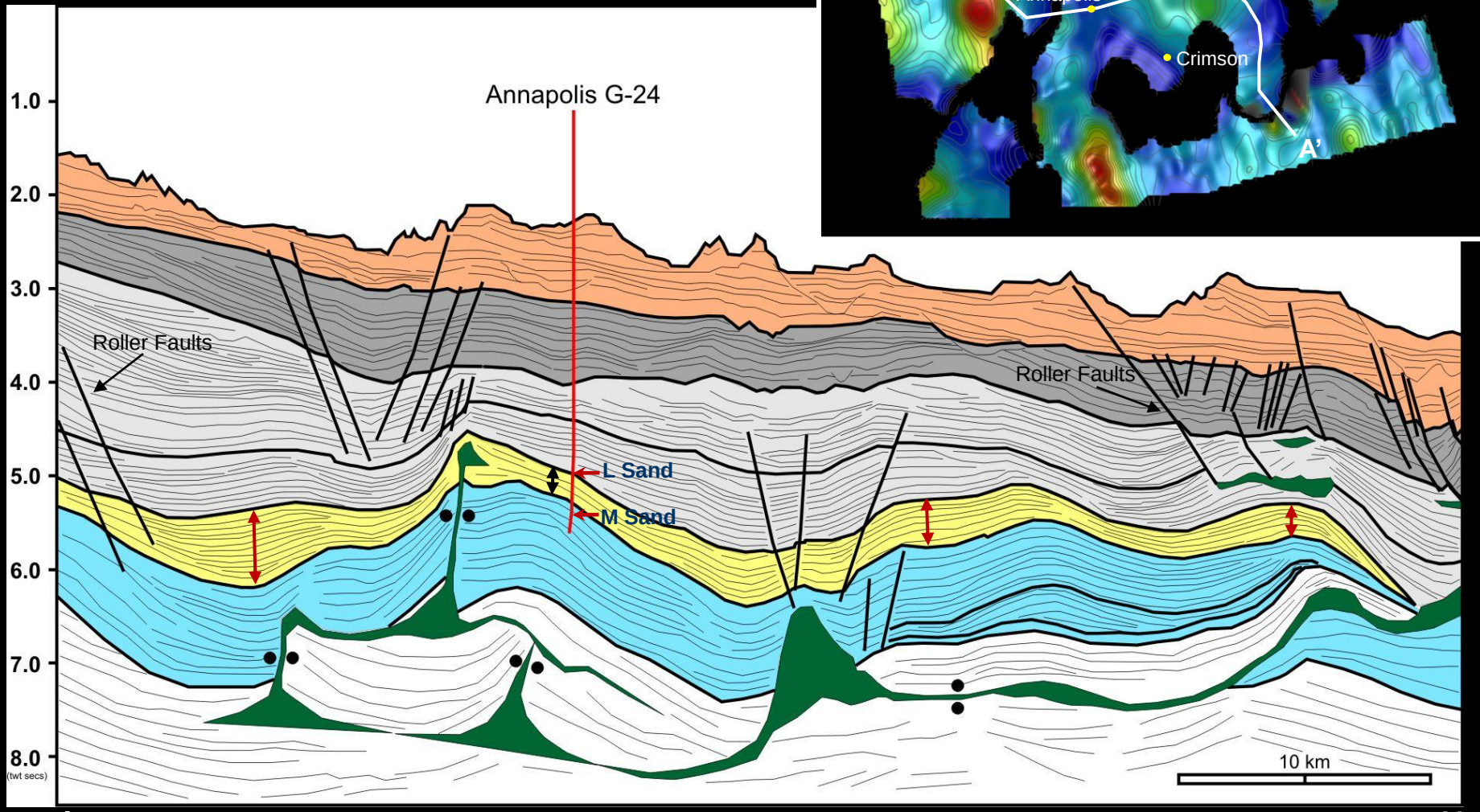




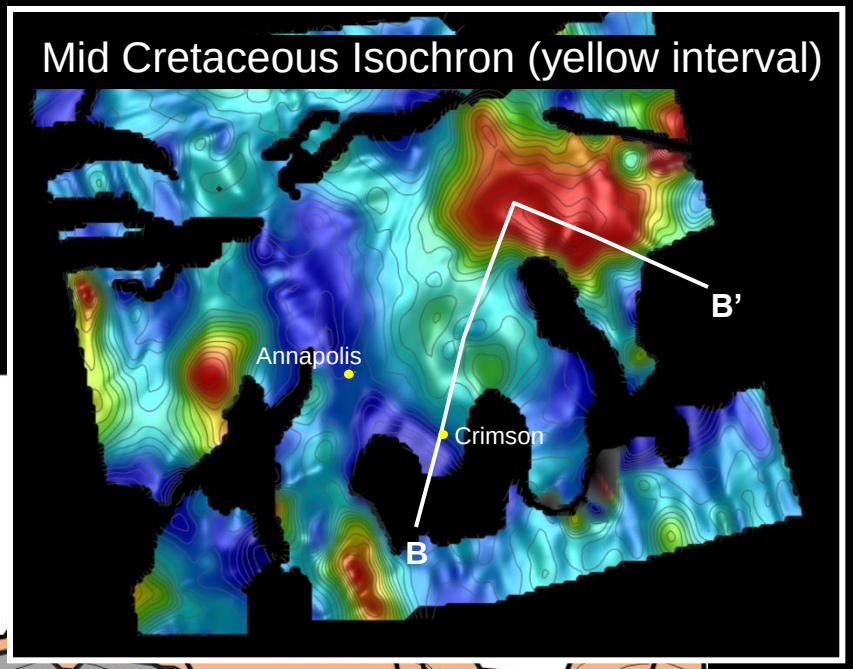
- Both wells drilled Mid Cretaceous <u>thins</u> relative to other locations

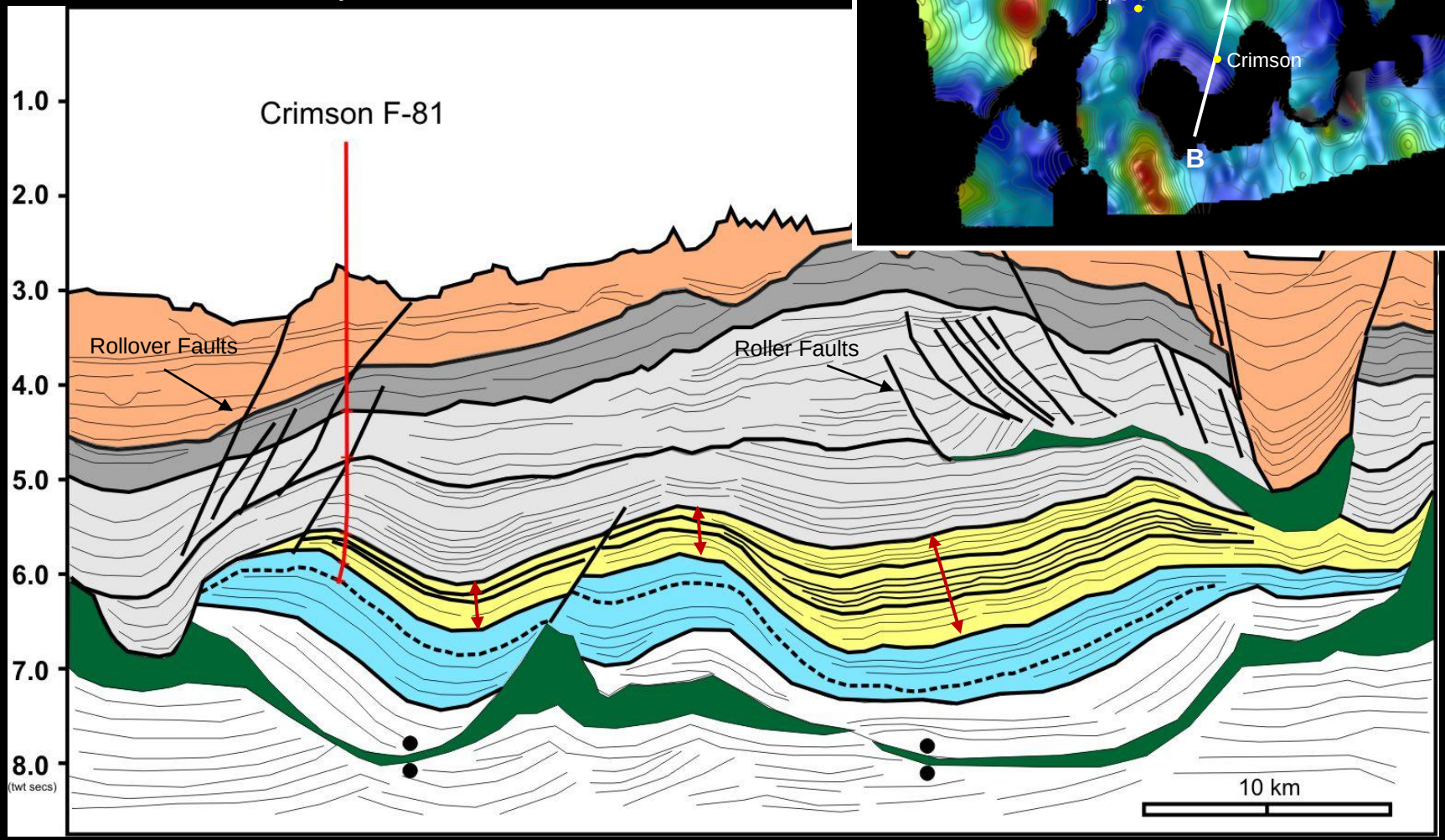
- Annapolis penetrated thinnest sections of this interval
- Encountered both the H and L sands within this interval



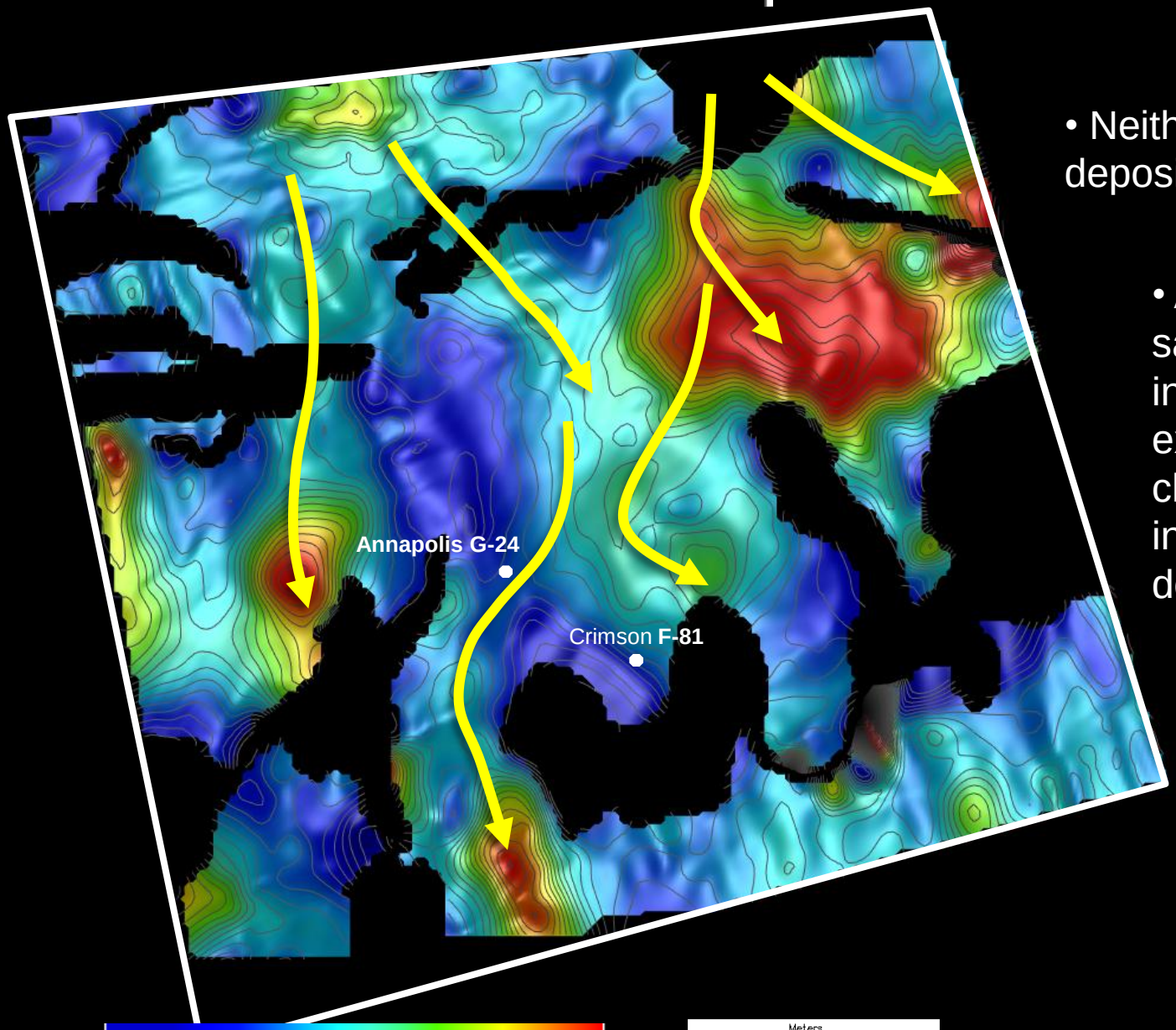


- Sand not present within this interval at Crimson
- Expands in thickness to the northeast (approx. 300 m at borehole to greater than 1000 m in the NE)

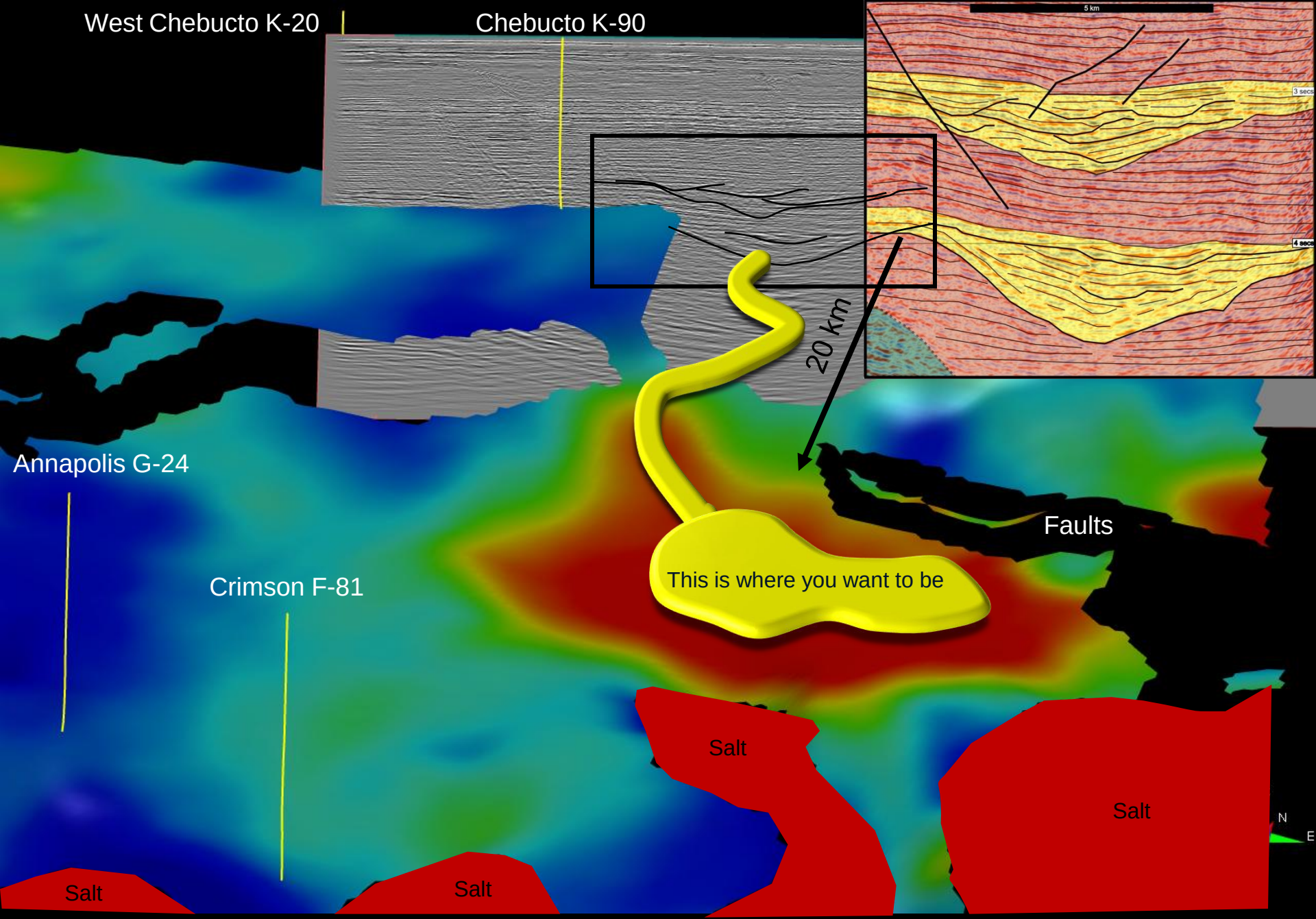




Mid Cretaceous Depositional Corridors



- Neither well penetrates depositional corridor
- Annapolis' H and L sands within this interval, and may be explained by being in close proximity to the interpreted depositional corridor
- Thickest mid Cretaceous depocenters have not been penetrated


West Chebucto K-20
Chebucto K-90
5 km
3 secs
4 secs
20 km
Annapolis G-24
Crimson F-81
Faults
This is where you want to be
Salt
Salt
Salt
Salt
N
E

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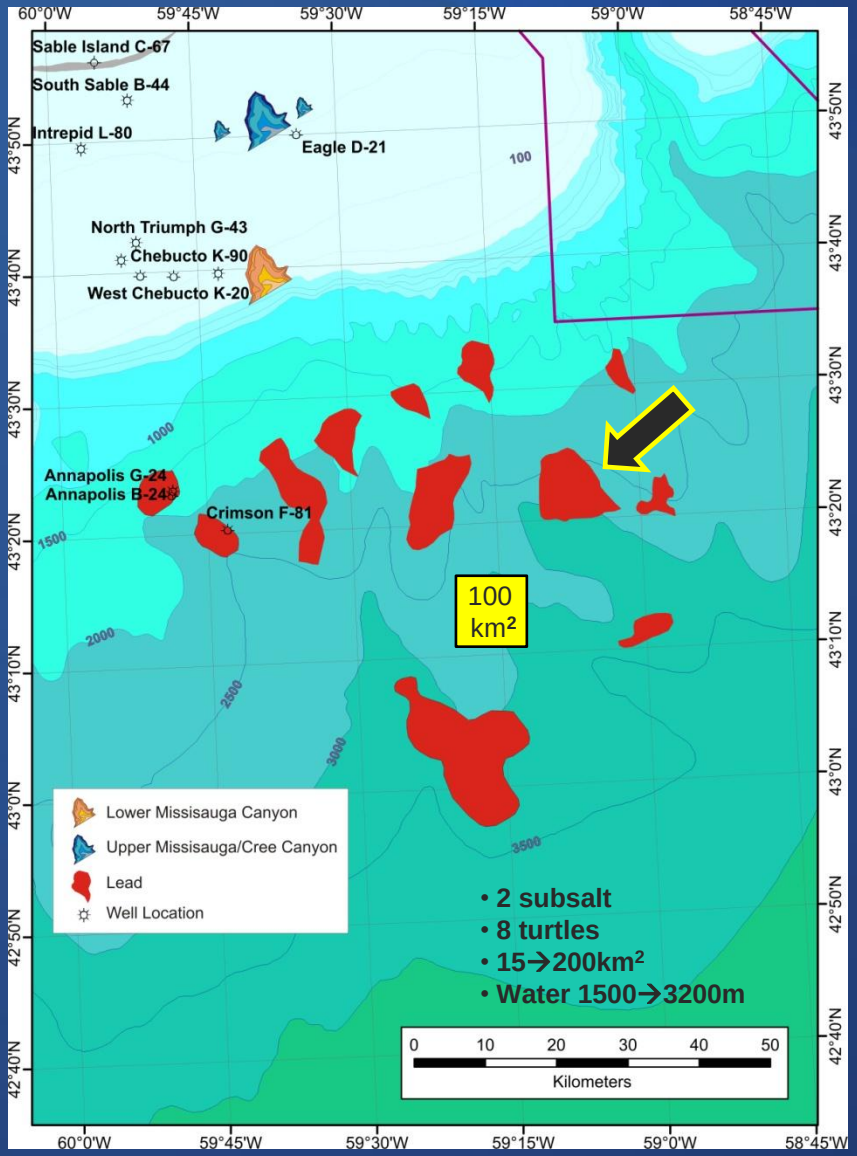
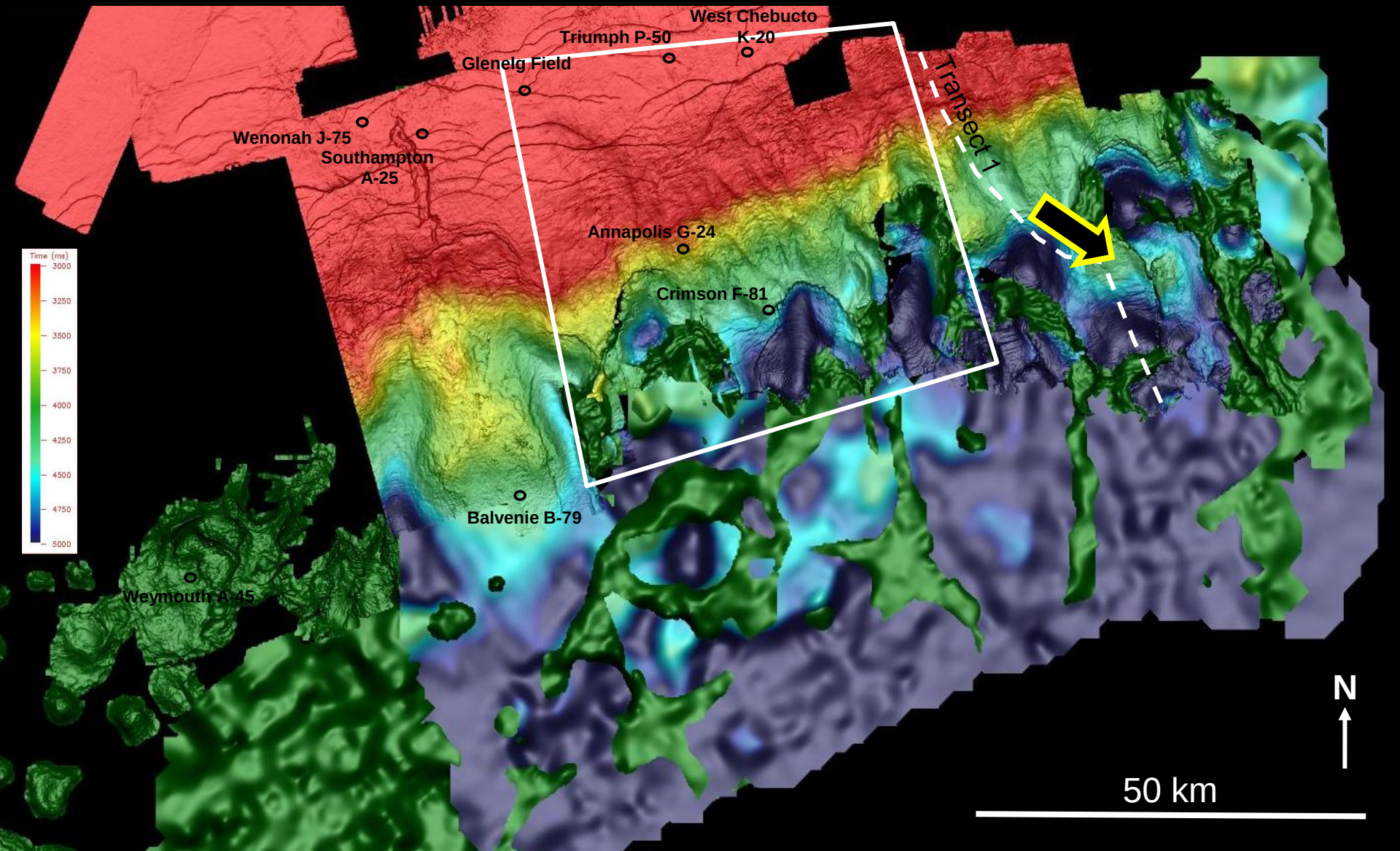
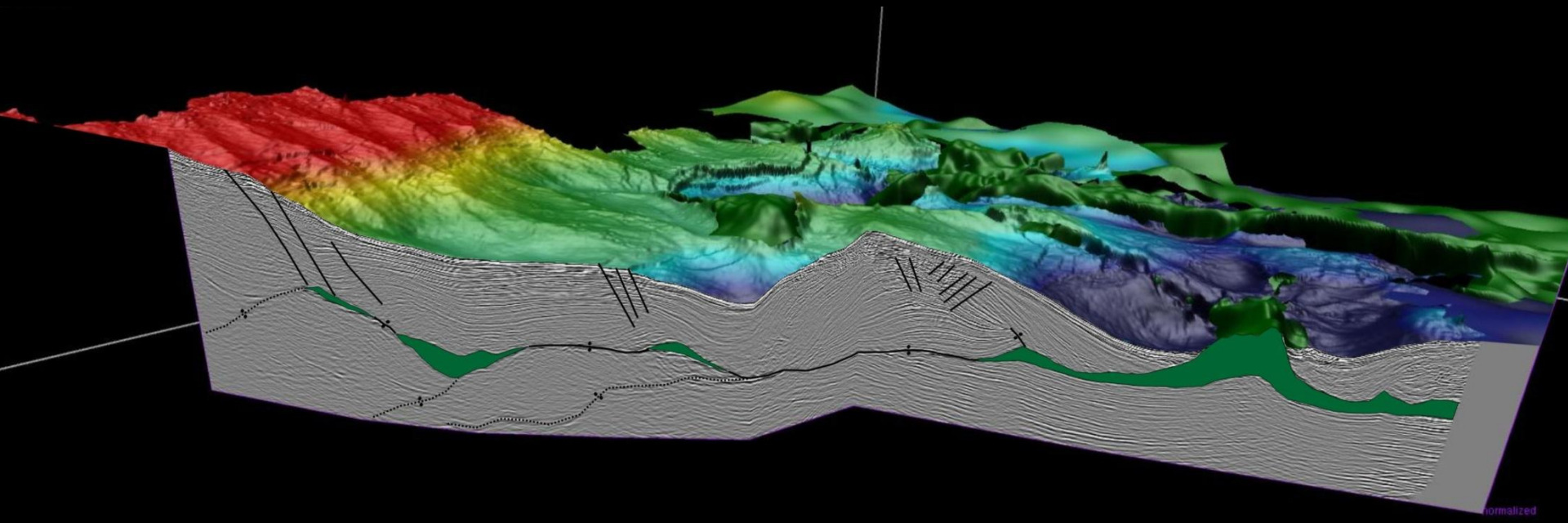
CNSOPB Leads



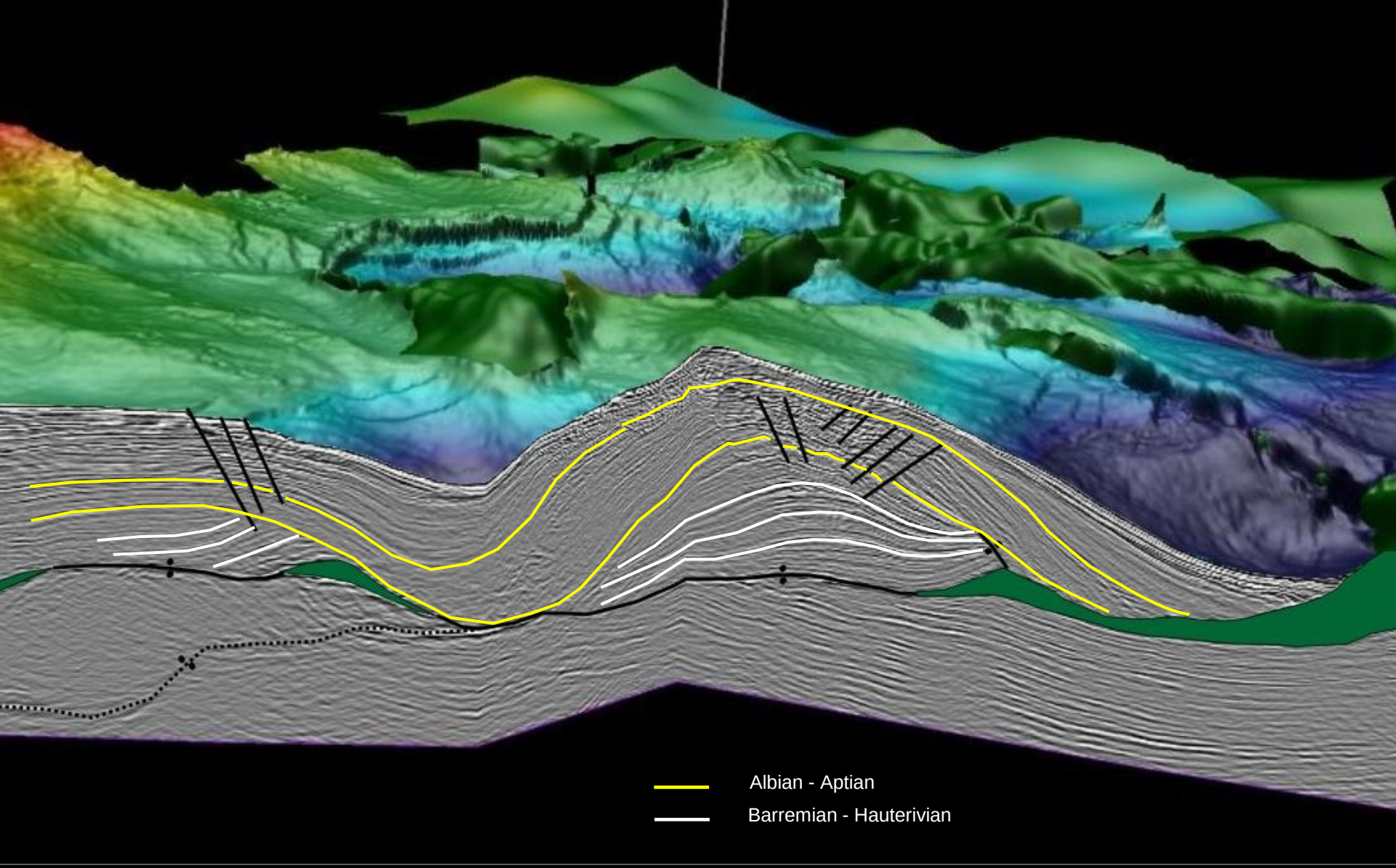
Late Cretaceous Structure Map with Salt (green)



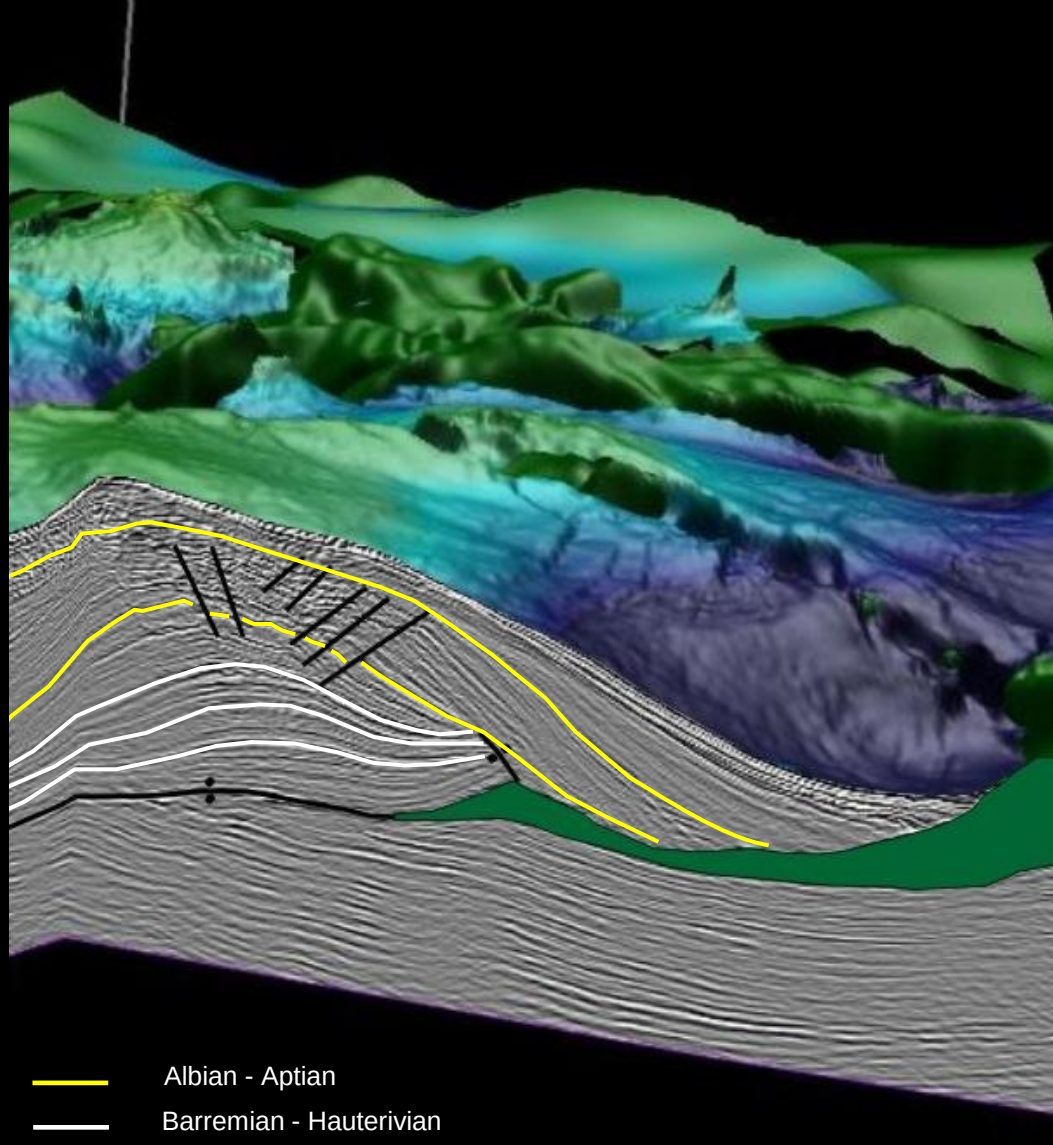
Transect 1 – Canopy loading/Detachment



Defining features: multiple welded salt feeders, turtle structure, salt withdrawal minibasins, salt nappe and minor amounts of detachment.


Albian - Aptian
Barremian - Hauterivian

- **Closures** 25 → 80 km²
- **P50 Area** 31 km²
- **P50 Net Pay** 50 m
- **P50 Porosity** 22 %
- **Mean In Place** 4.3 tcf



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Conclusions

- Abundance of Jurassic and Cretaceous sand on the shelf.
- Active sediment transport system present
  - Numerous canyon systems mapped
  - Linked to shelf channel complexes
  - Sand is being transported to deep water.
- Where Annapolis and Crimson encountered thin sand
  - demonstrated to be on thinned edge of mini basin.
- Where Annapolis and Crimson encountered thicker sand
  - demonstrated to have just penetrated top of mini basin.
- Numerous undrilled structures in prospective areas.