

Stratigraphic Modeling of a Mix Siliciclastic-Carbonate System in a Passive Margin Setting: The Hettangian–Cenomanian Interval of the Shelburne Subbasin — Nova Scotia 2011 PFA SW Expansion*

Emerson Marfisi¹, Francky Saint-Ange¹, Adam MacDonald², Matt Luheshi³, and Laurent Cuilh¹

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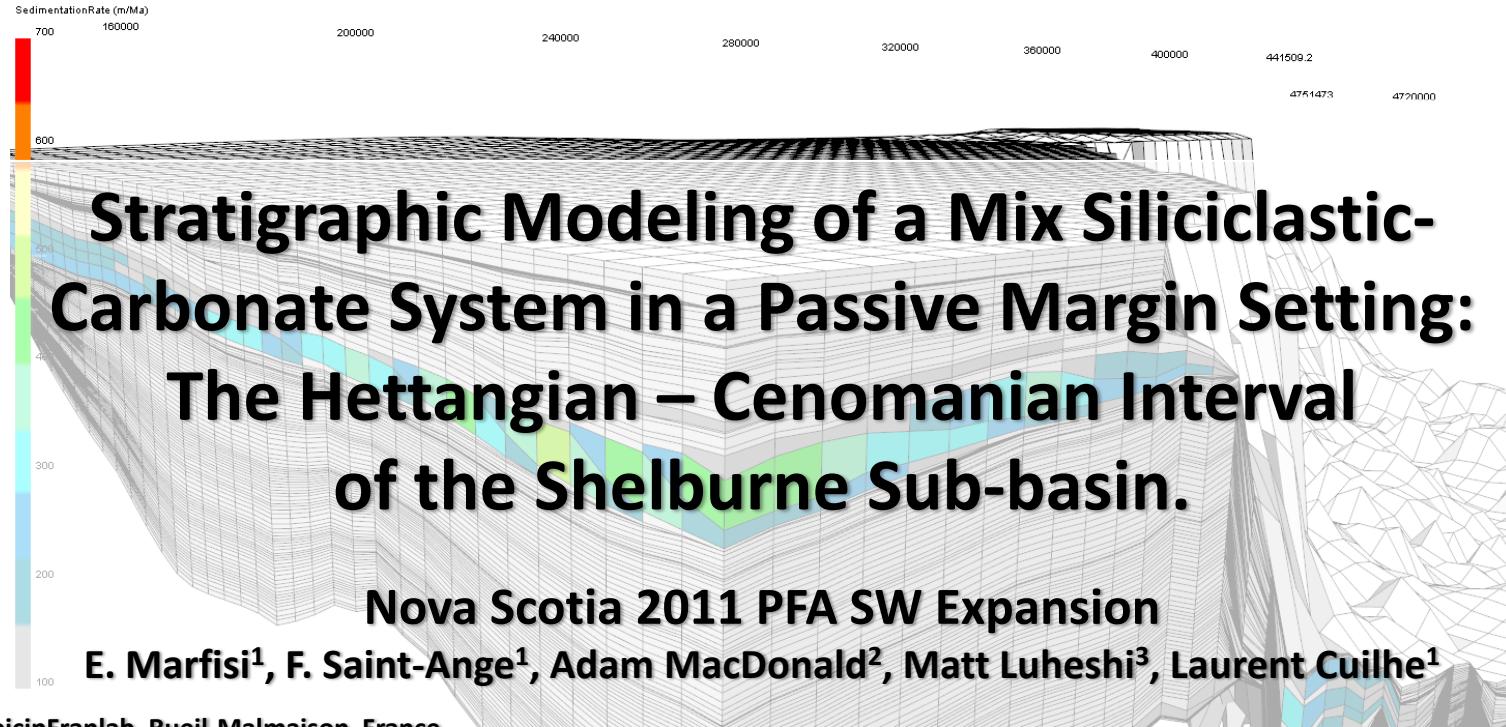
Abstract

As part of its ongoing projects on hydrocarbon resources assessment, the Department of Energy and the Offshore Energy Research Association (OERA) have published in 2015 an integrated exploration study which is an expansion of the 2011 Play Fairway Analysis (PFA). In this context, a forward stratigraphic model was generated to reproduce the alternating carbonate-siliciclastic deposits of Hettangian to Cenomanian age present in the Shelburne Subbasin. The sedimentary cover of this basin can reach 15 kilometers with basal Triassic synrift deposits overlain by a thick salt cover and Jurassic to present-day sediments. The stratigraphic model was performed using DionisosFlow® and contains 70×50 cells with 4×4 km of cell size covering 56000 km^2 . Four major tectono-sedimentary events were reproduced by this model spanning 106 My. A Hettangian – Callovian event characterized by the onset of a carbonate platform at the position of the present-day shelf break. The backreef area was dominated by aggrading shallow marine/continental deposits. An Oxfordian – Tithonian event corresponding to the Jurassic Shelburne Delta prograded basinward supplying sandy sediments to the turbiditic systems in the basin. The distribution of depocenters in the shelf and basin area was strongly impacted by salt tectonics during this period. A sensible decrease on the clastic supply and a reactivation of the carbonate sedimentation on the shelf marked the final stage of this event during the Tithonian MFS. An episode of aggradation of carbonate deposits on the shelf and siliciclastic deposits at the backreef position took place during the Upper Tithonian to Valanginian period. A new phase of deltaic progradation was active during the Valanginian to Cenomanian period. This episode corresponds to the Cretaceous Shelburne Delta that mostly provided an

important volume of potential reservoir facies to the basin area mainly represented by clastic and carbonatic turbidites. The model was calibrated using 2D seismic data and wells Bonnet P23 and Mohawk B93. The modeling results not only allowed a detailed 3D reconstruction of the margin evolution through time but also a prediction of the geometry and extension of reservoir facies in the still unexplored slope and basin areas. Facies distribution maps extracted from this model provided the stratigraphic framework for a petroleum system model generated for this promising new frontier basin (SW Nova Scotia 2011 PFA Expansion companion abstract).

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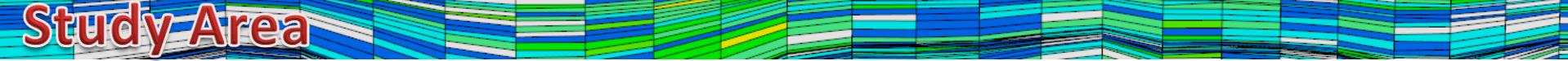
3. Leptis E & P Ltd., Gerards Cross, Buckinghamshire, United Kingdom.

Understanding for Modeling or Modeling for Understanding: two sides of the same coin.

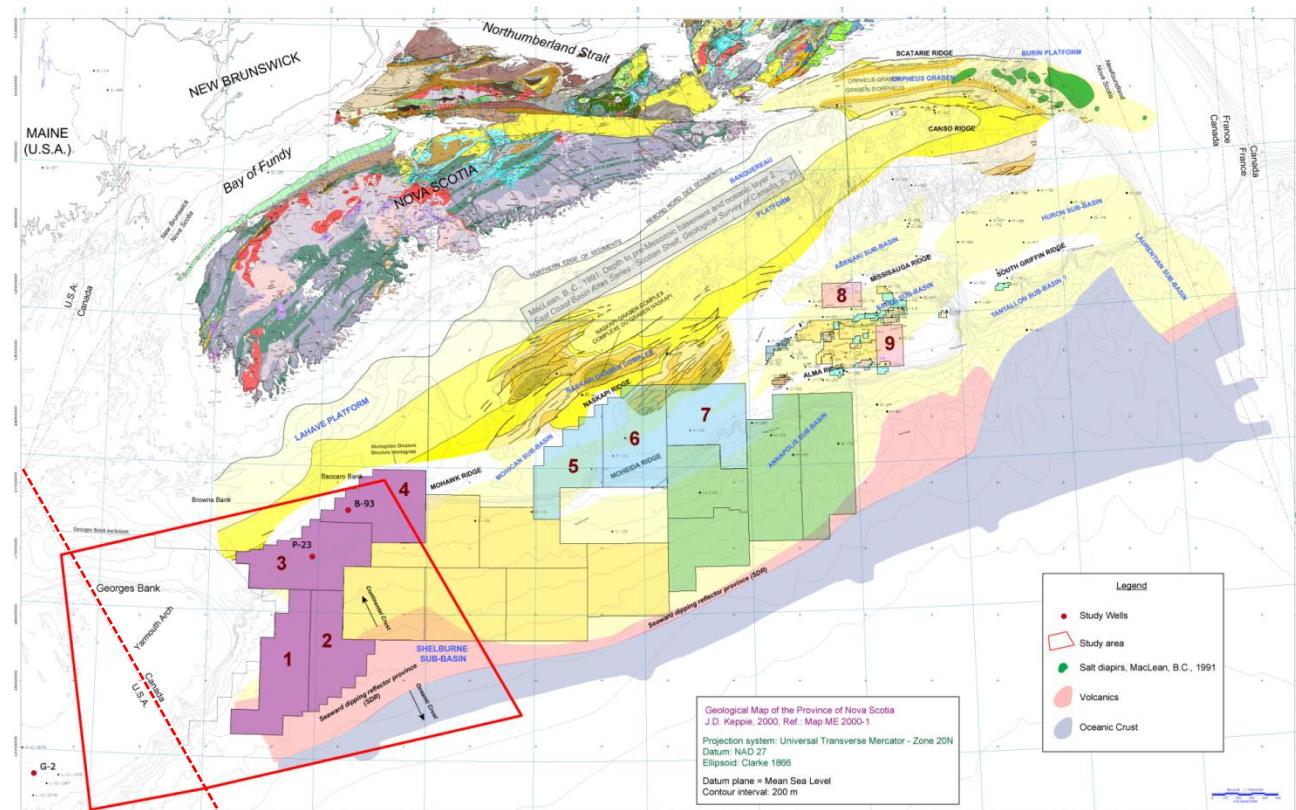


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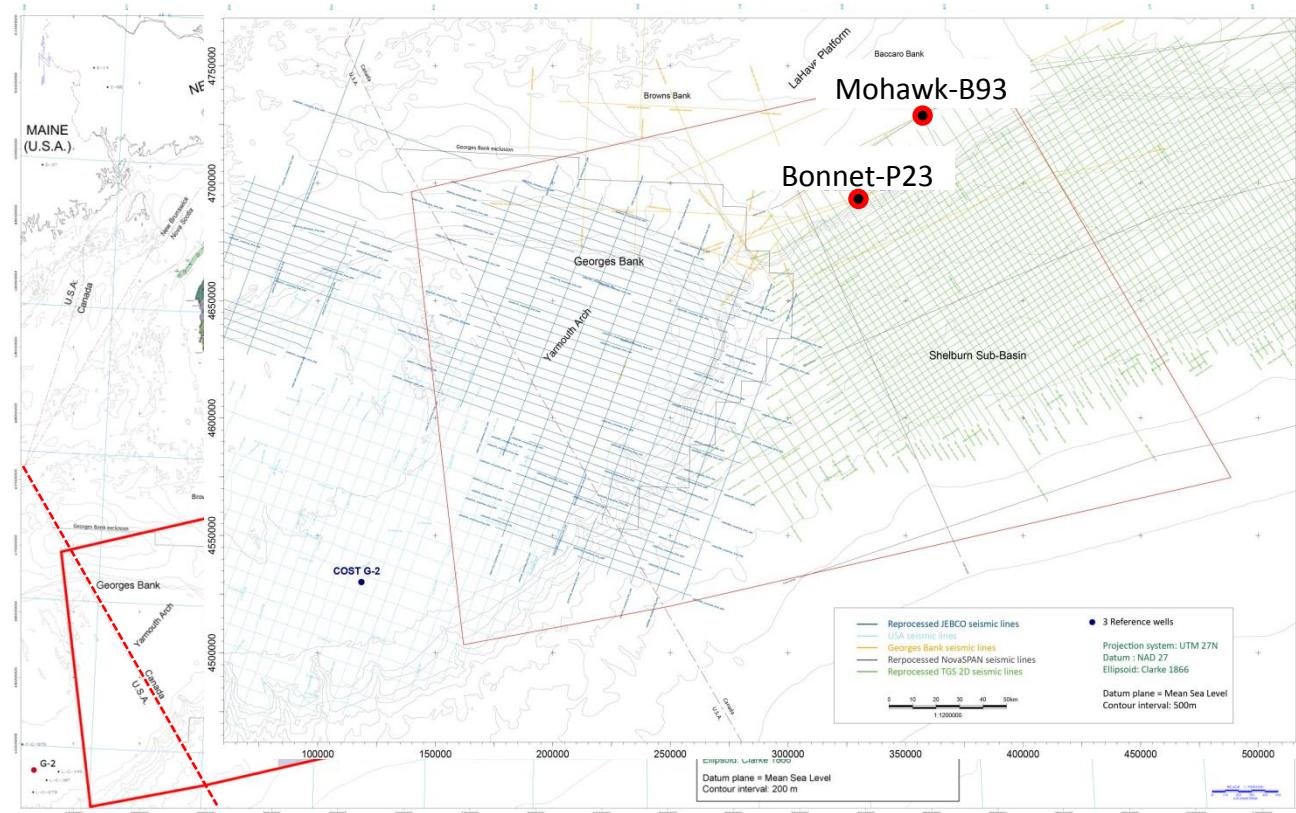
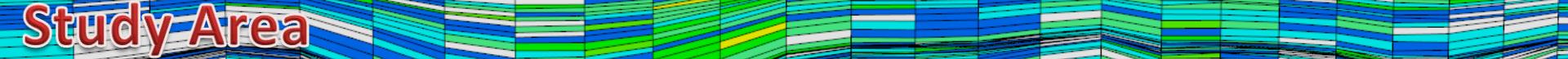
Study Area



Study Area

- ~56000 Km² Study area.
- SW Limit offshore Nova Scotia.
- Only two wells drilled.
- 2D seismic coverage.
- Up to 15 km of Triassic to Pleistocene sedimentary Record alternating siliciclastic and carbonatic deposits.
- Stratigraphic model containing 70 x 50 cells of 4 x 4 km 0.5 Ma time step.

Study Area



Study Area

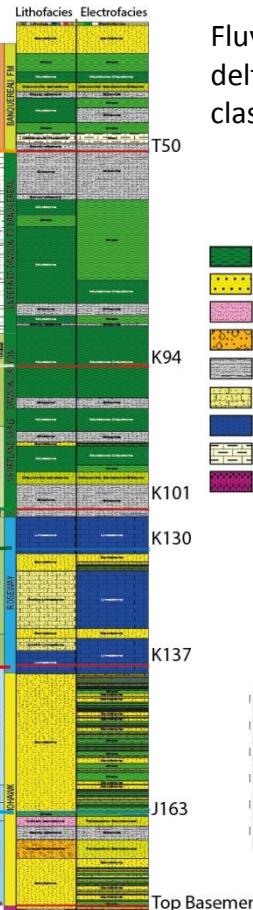
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Stratigraphy and Sedimentary Environments

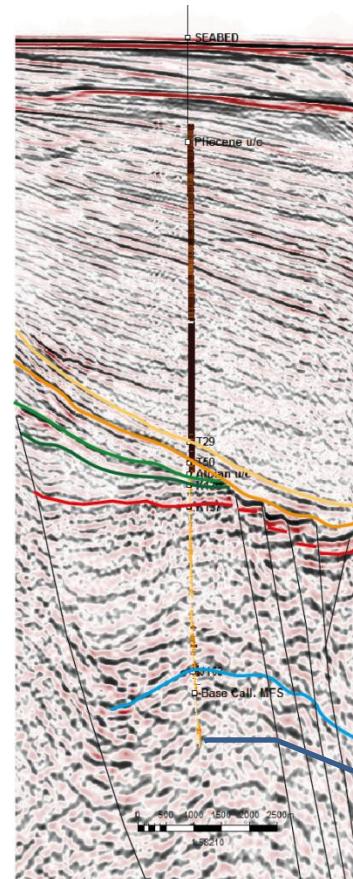
Mohawk-B93



Fluvial to
deltaic
clastic facies



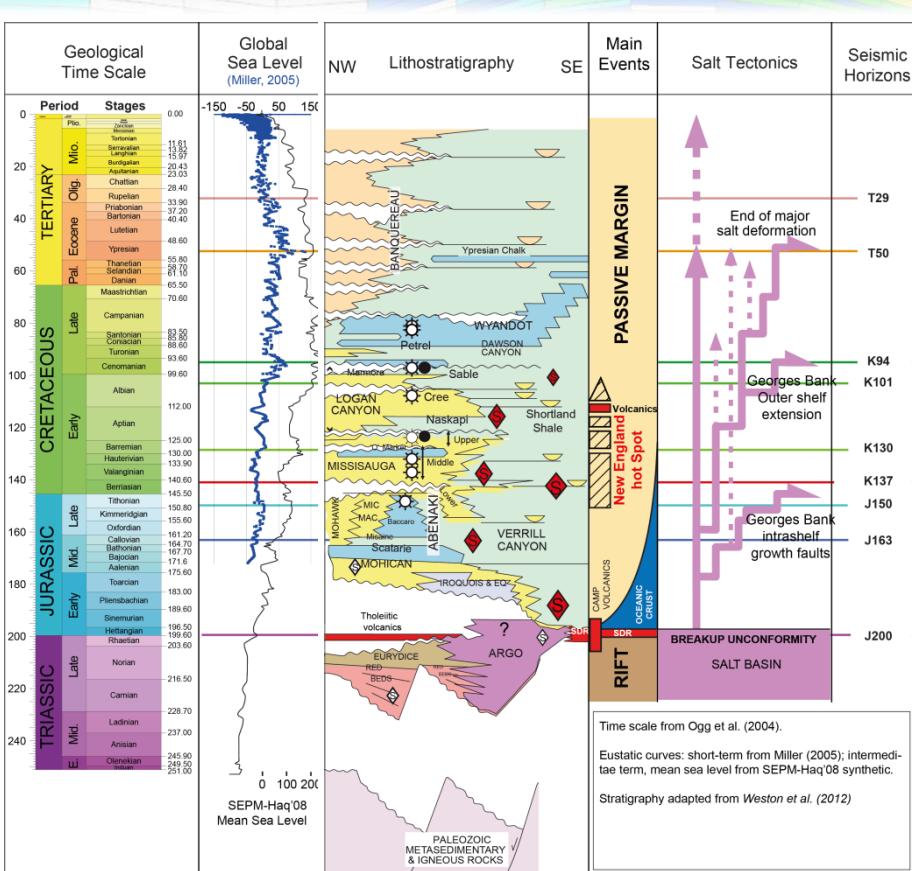
Bonnet-P23



2600 m of
carbonates
with minor
clastics
episodes

Lower
Jurassic to
Eocene

Stratigraphy and Sedimentary Environments



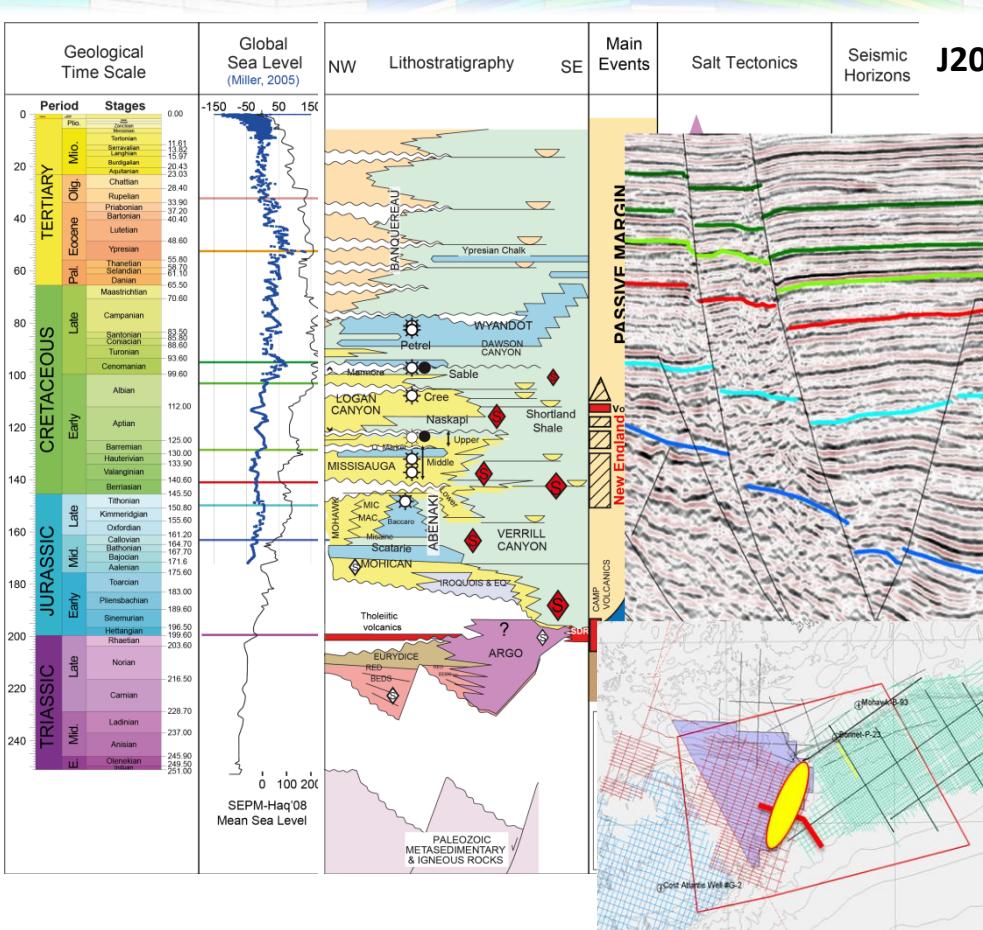
J200 - ~J163: Post-salt Siliciclastic and carbonate deposits of Mohican and Iroquois formations.

J163 – J150: Jurassic “Shelburne Delta” prograding complex and carbonate deposits (Mohawk – Mic Mac – Abenaki Fms).

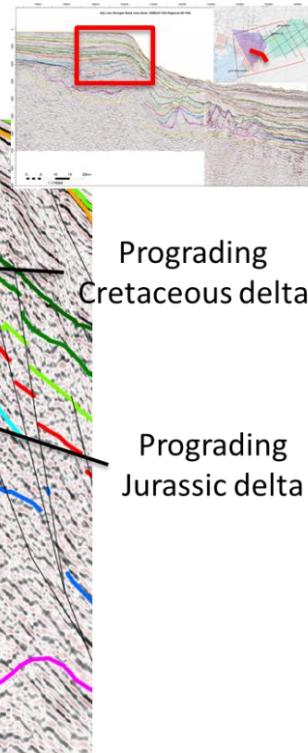
J150 – K130: Carbonate and Siliciclastic sedimentation (Missisauga Fm).

K130 – K94: Cretaceous “Shelburne Delta” prograding complex.

Stratigraphy and Sedimentary Environments



J200 - ~J163: Post-salt Siliciclastic and carbonate deposits of

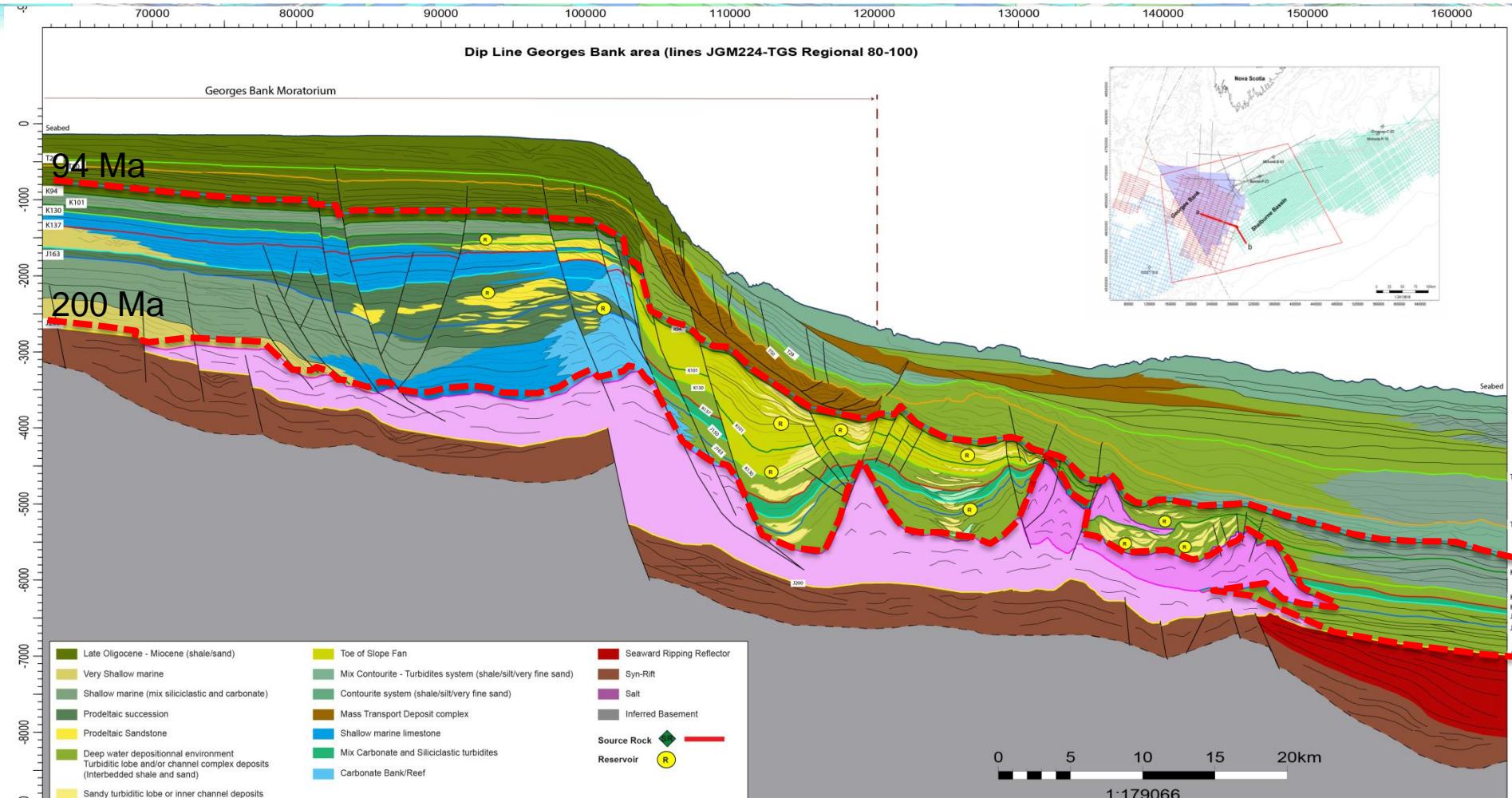


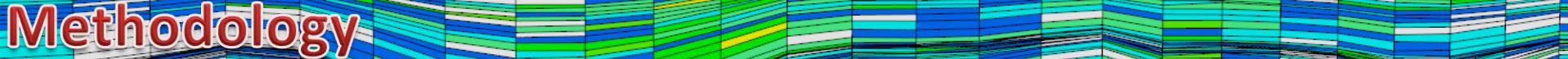
Prograding
Cretaceous delta

Prograding
Jurassic delta

Carbonate bank/reef

Stratigraphy and Sedimentary Environments





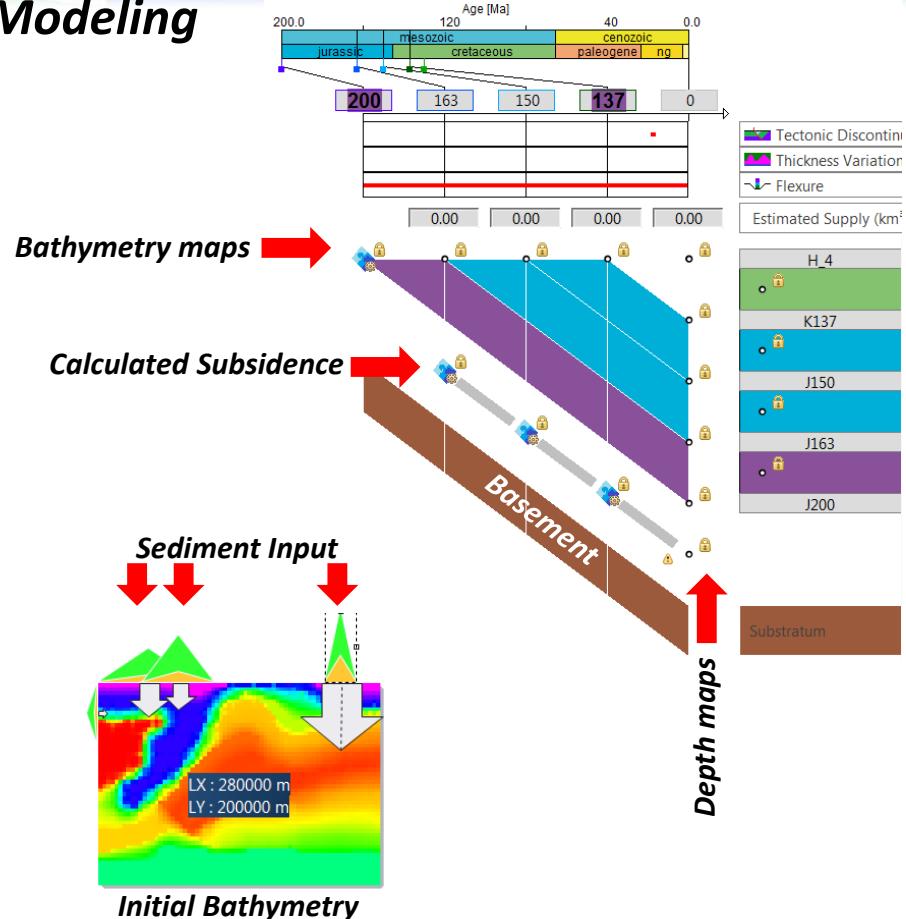
Methodology

Diffusion based Forward Stratigraphic Modeling

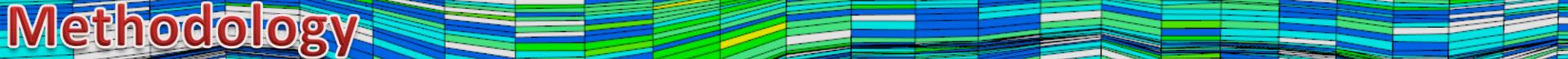
DionisosFlow®

Model Input Parameters:

- ✓ Paleo-bathymetry maps
 - Sedimentary facies and biostratigraphic data
- ✓ Depth maps:
 - J200 – J163 – J150 – K137 – K130 – K94
- ✓ Sea Level Curve.
 - Long term Haq et al 1988 Curve
- ✓ Location of Sediment Input
 - Seismic stratigraphy transects, GDE maps
- ✓ Sedimentary particles:
 - Introduced: **Sand – shale** ; Generated “in situ”: Carbonates,



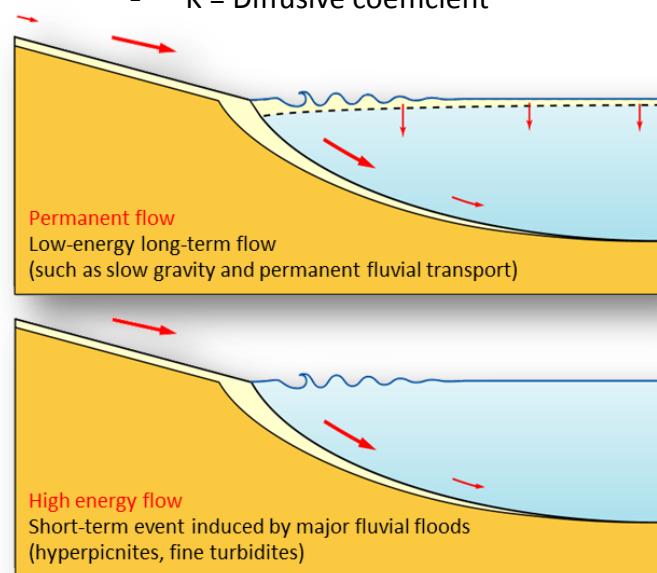
Methodology



The sediments transport rate is proportional to basin slope and water discharge:

$$Q_s = K Q_w S$$

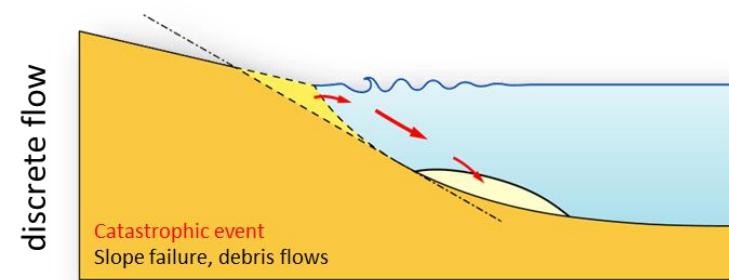
- Q_s = sediment inflow
- Q_w = Water flow
- S = depositional slope degree
- K = Diffusive coefficient



The transport can be also simulated by slope instability > triggers slumps and debris flows.

Newton's principle

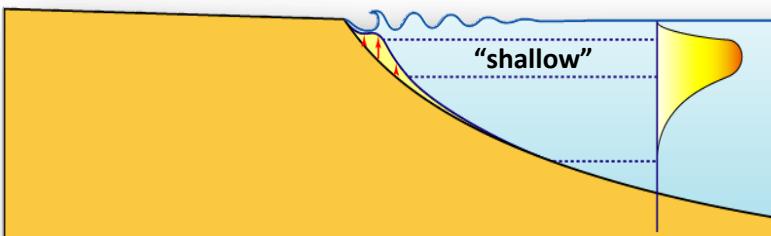
- Critical slope
- If slope > critical slope then sediments are unstable
- Acceleration = Gravity - Friction



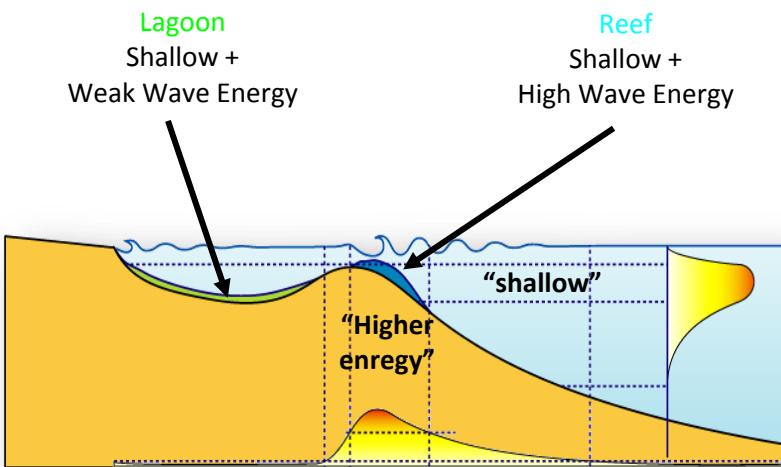
Methodology

Production rate is a function of:

1. water depth

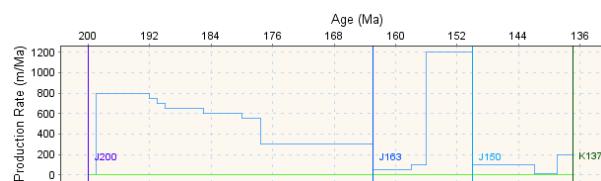


2. Water depth Vs wave energy



Carbonate factory

- Wave action
- Eustacy
- Prod rate/Ma
- Erosion
- Wave transport
- Gravity transport



Carbonate Production through time

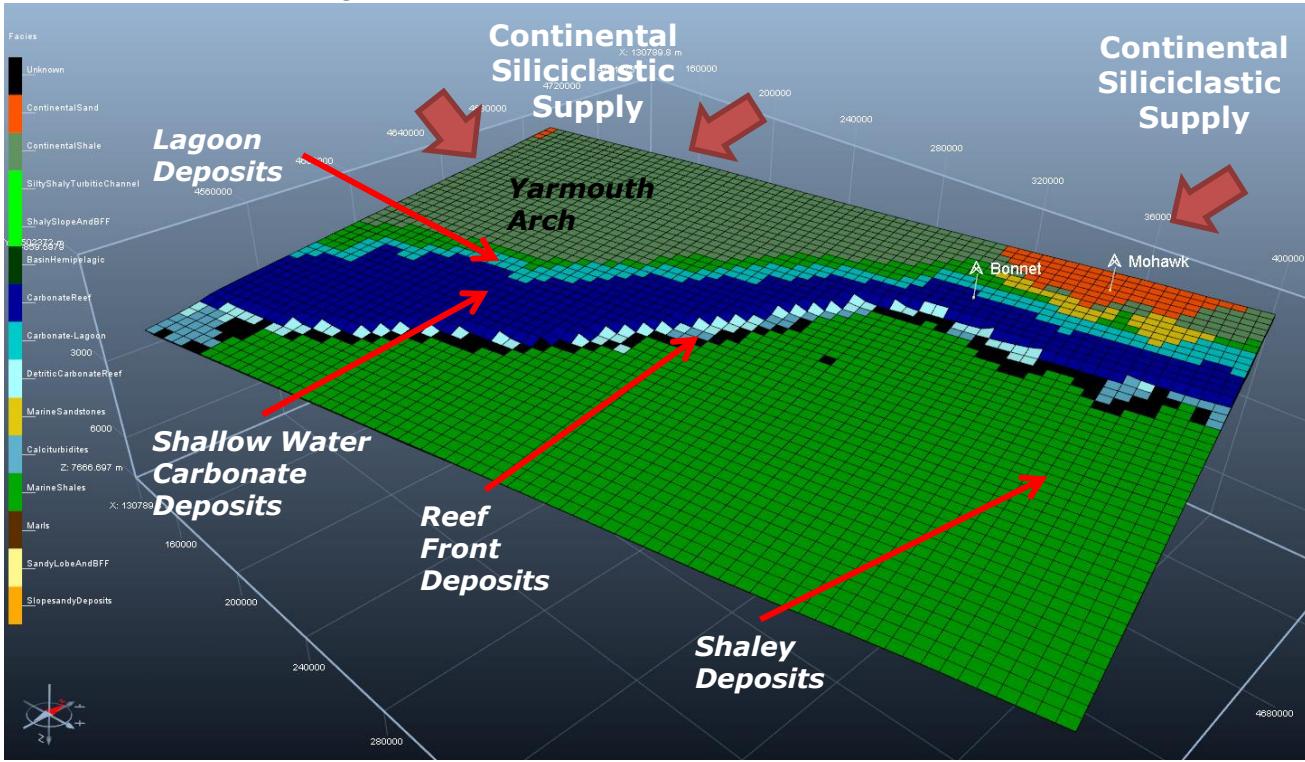
**Environmental conditions control
carbonate accumulation in DionisosFlow**



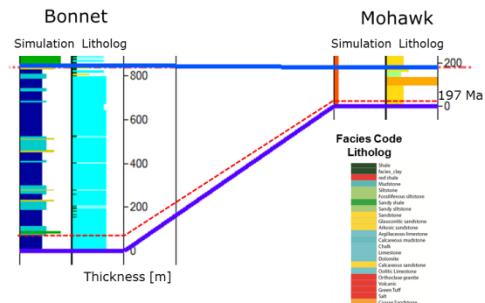
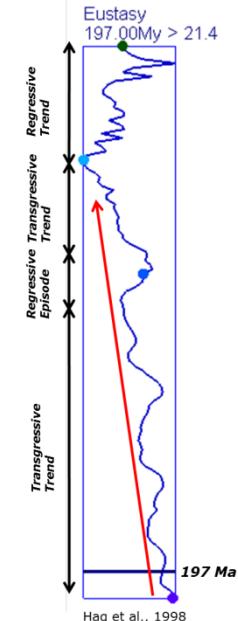
Results



197 Ma time step



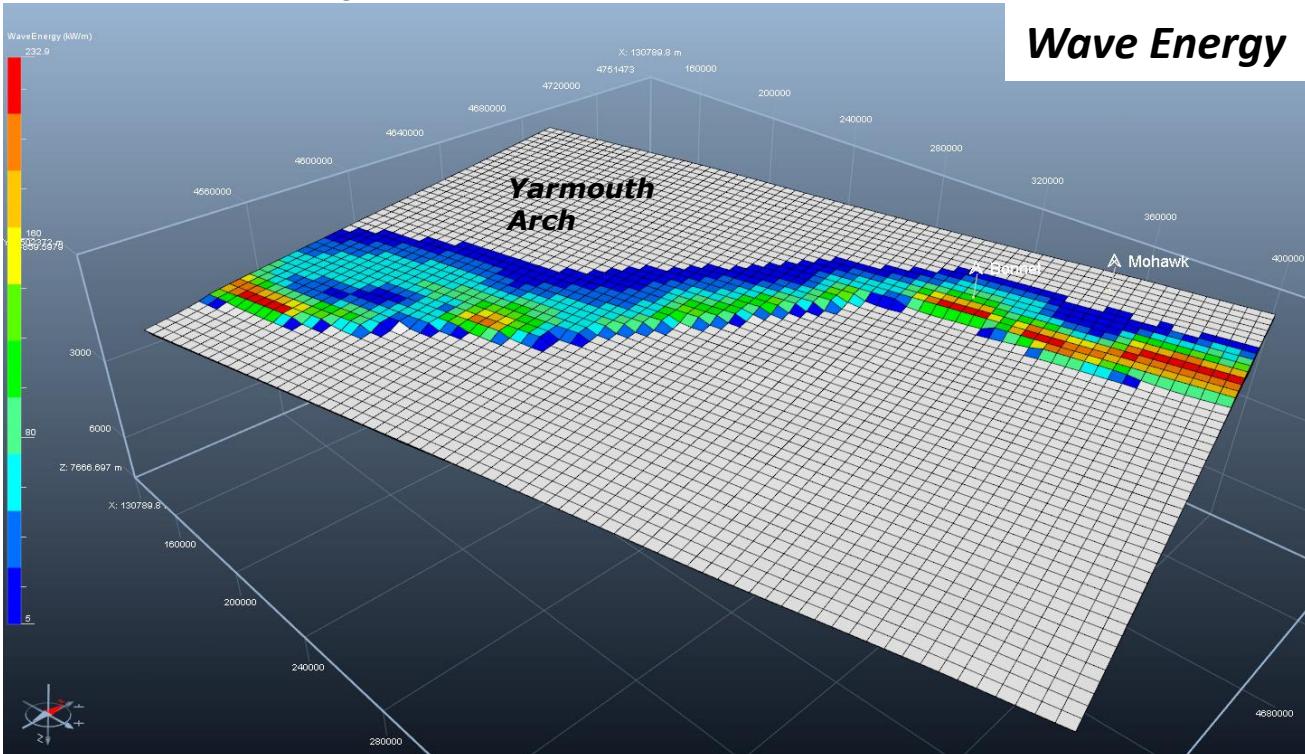
A full 4D Grid of lithology proportions and environmental parameters



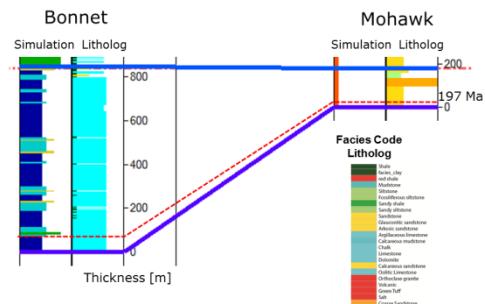
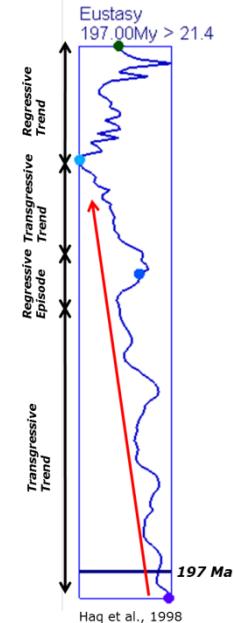
Results



197 Ma time step



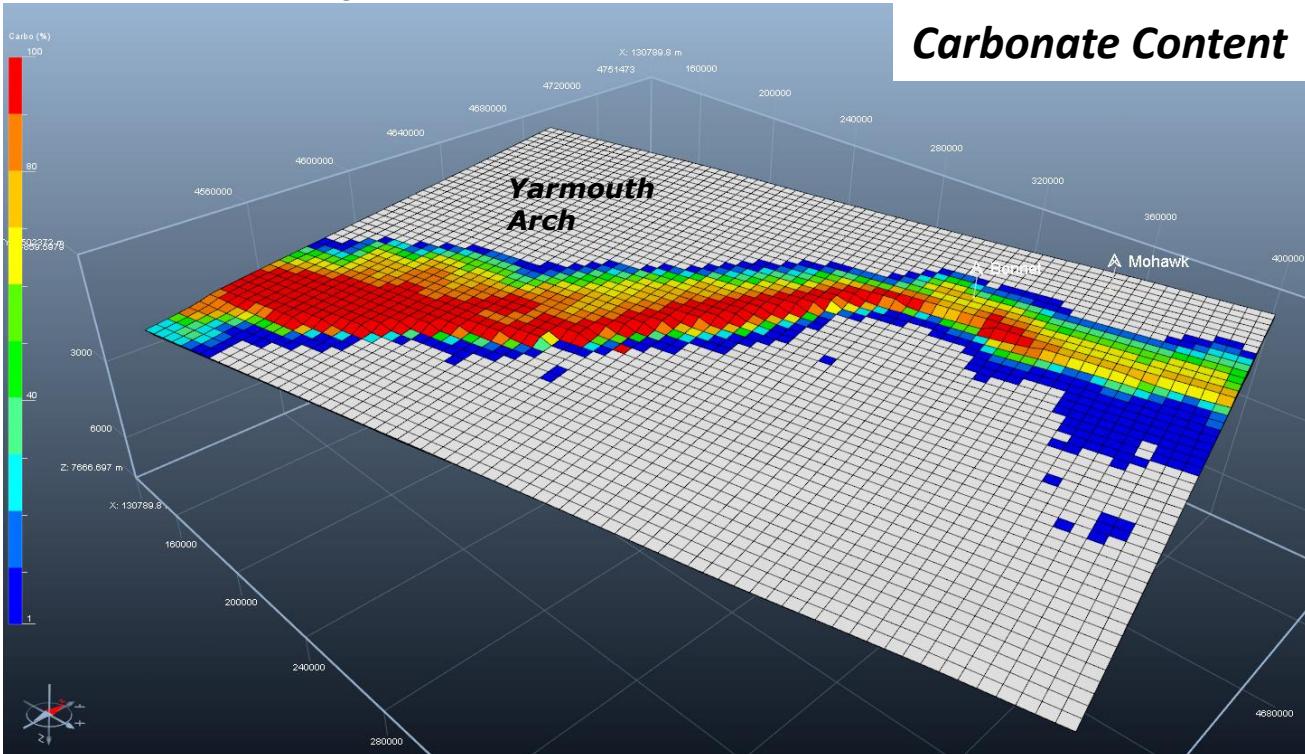
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Results

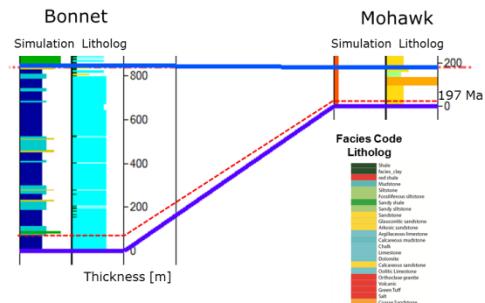
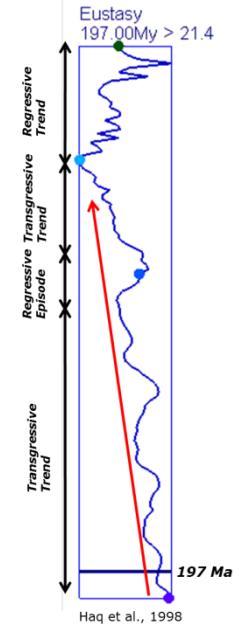


197 Ma time step



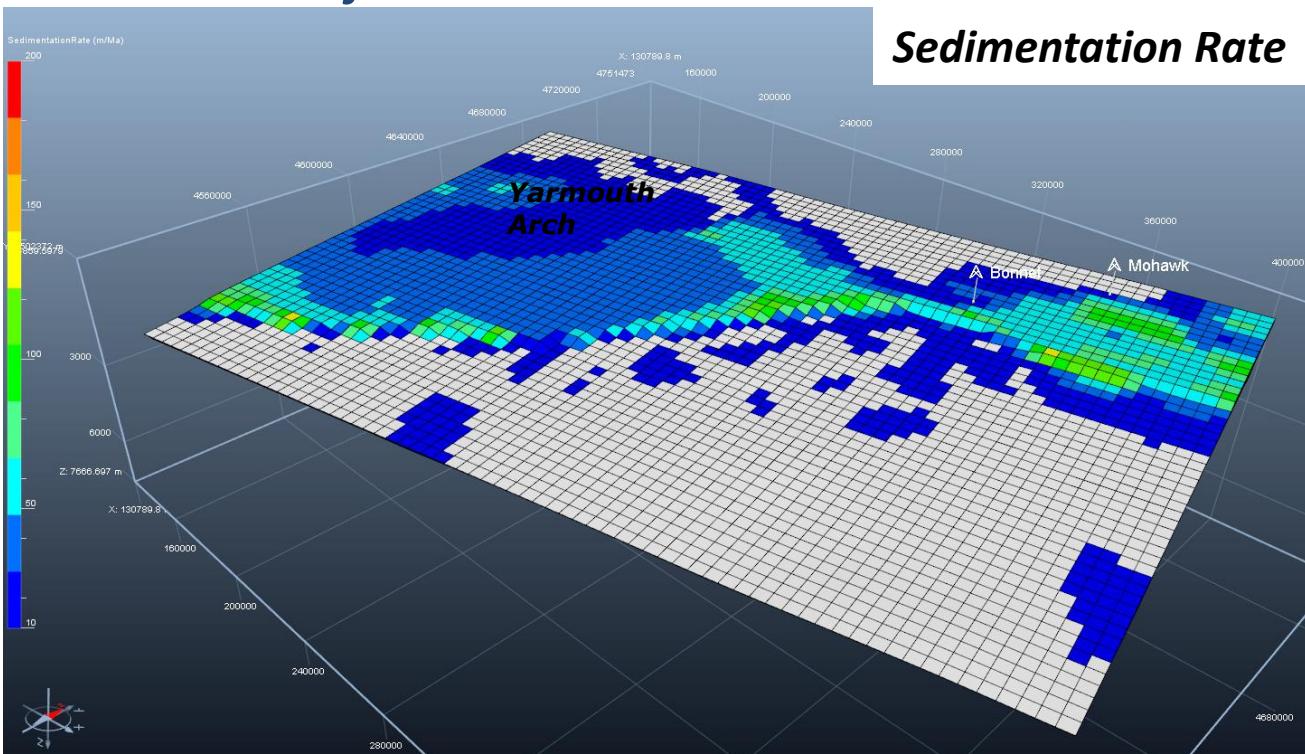
Carbonate Content

A full 4D Grid of lithology proportions and environmental parameters

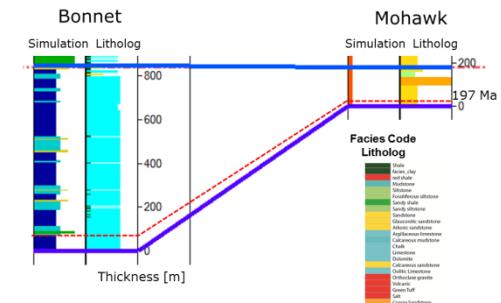
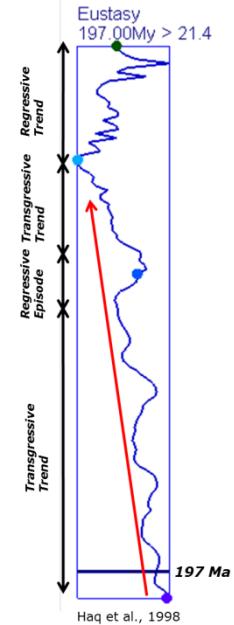


Results

Onset of the Carbonate Platform

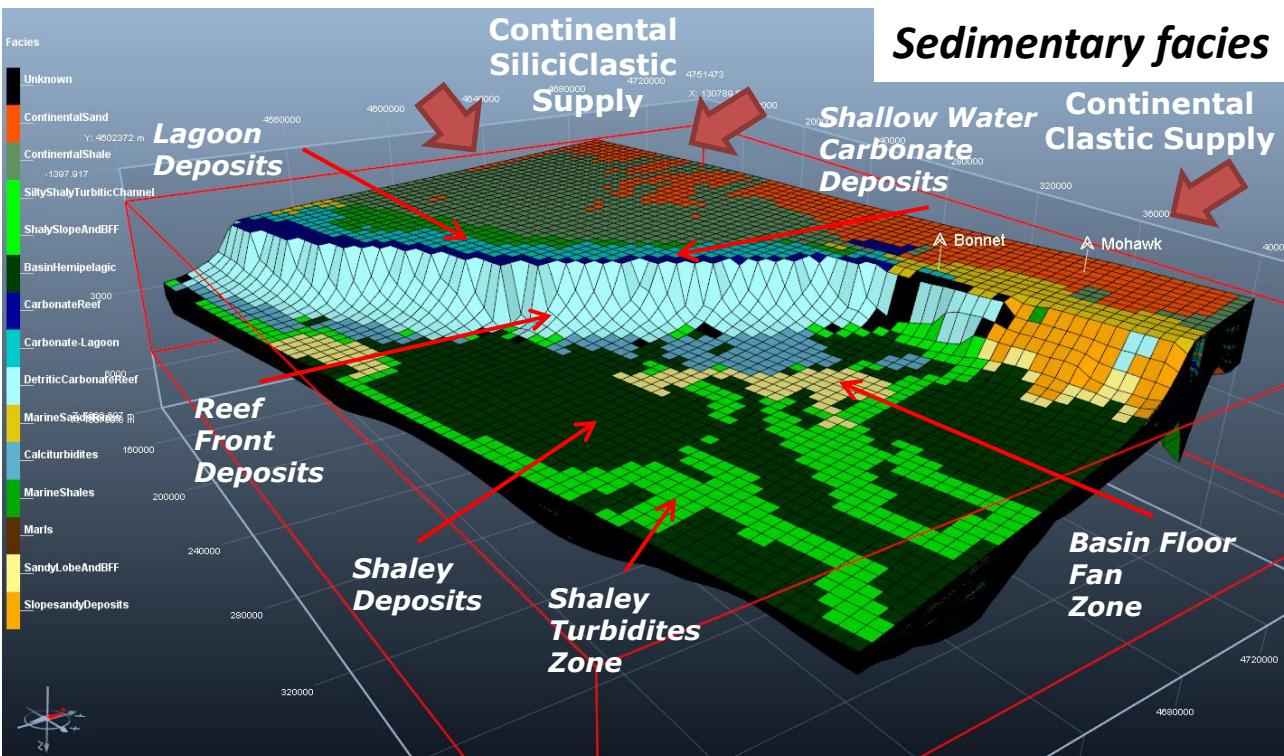


A full 4D Grid of lithology proportions and environmental parameters



Results

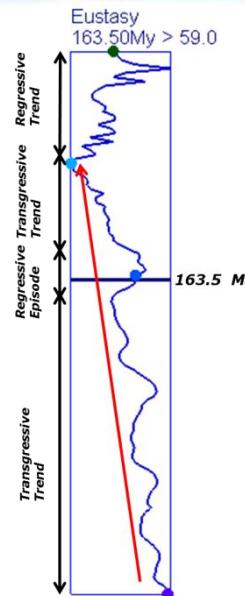
Carbonate Platform Keep-up



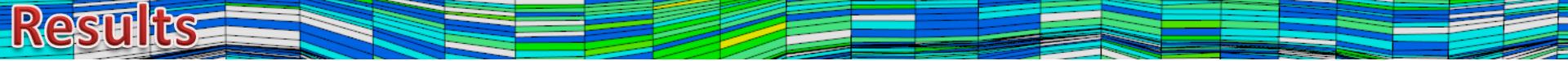
163,5 Ma time step

Sedimentary facies

Alternating siliciclastic and carbonate deposits on the shelf and MTD and turbrites in the basin area.



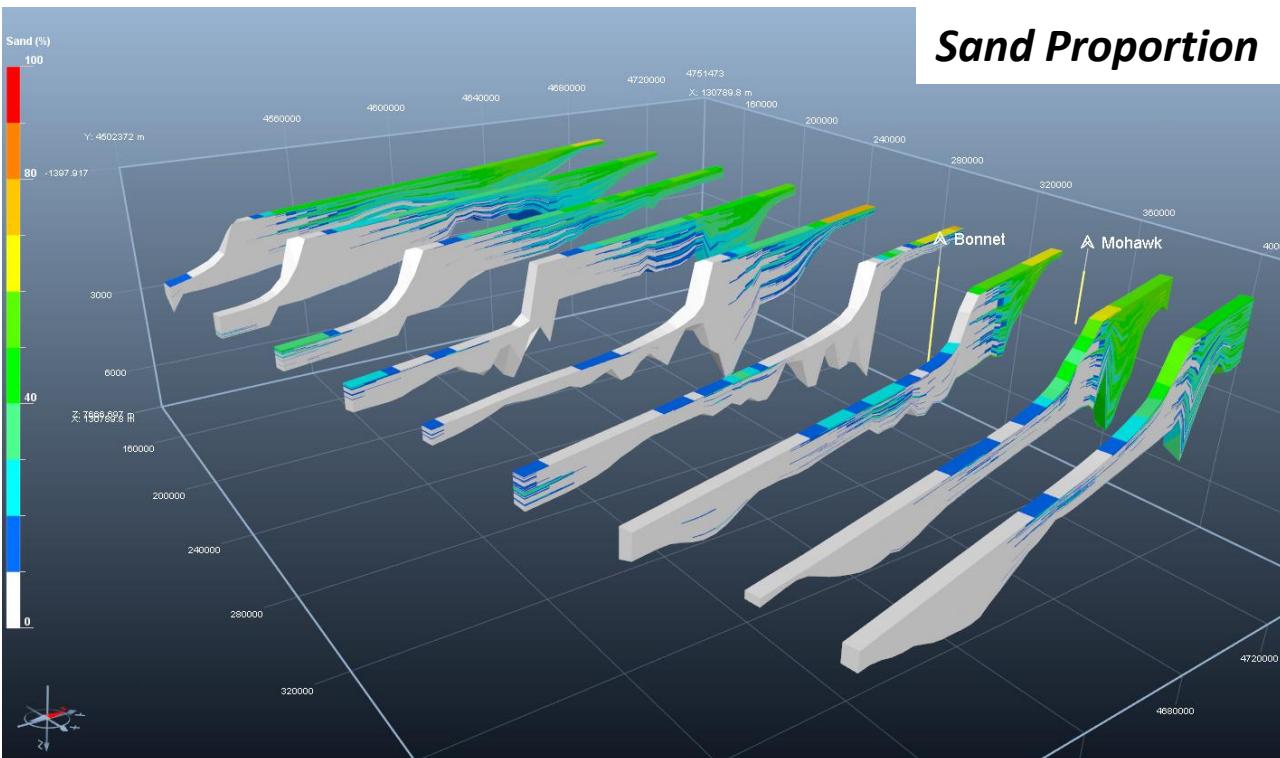
Results



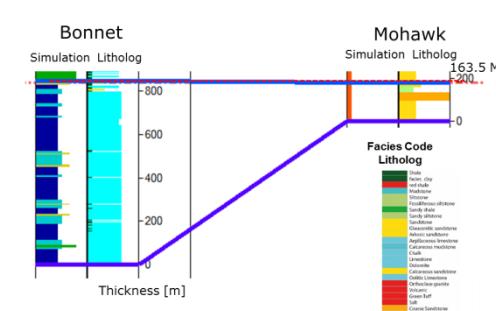
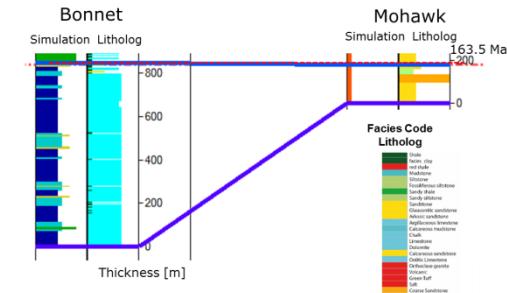
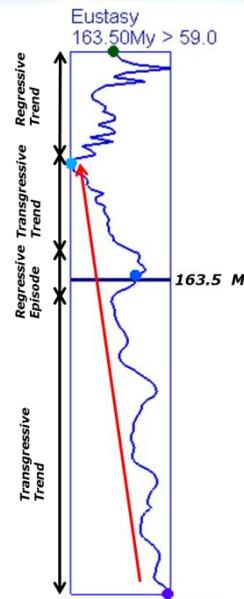
Carbonate Platform Keep-up

163,5 Ma time step

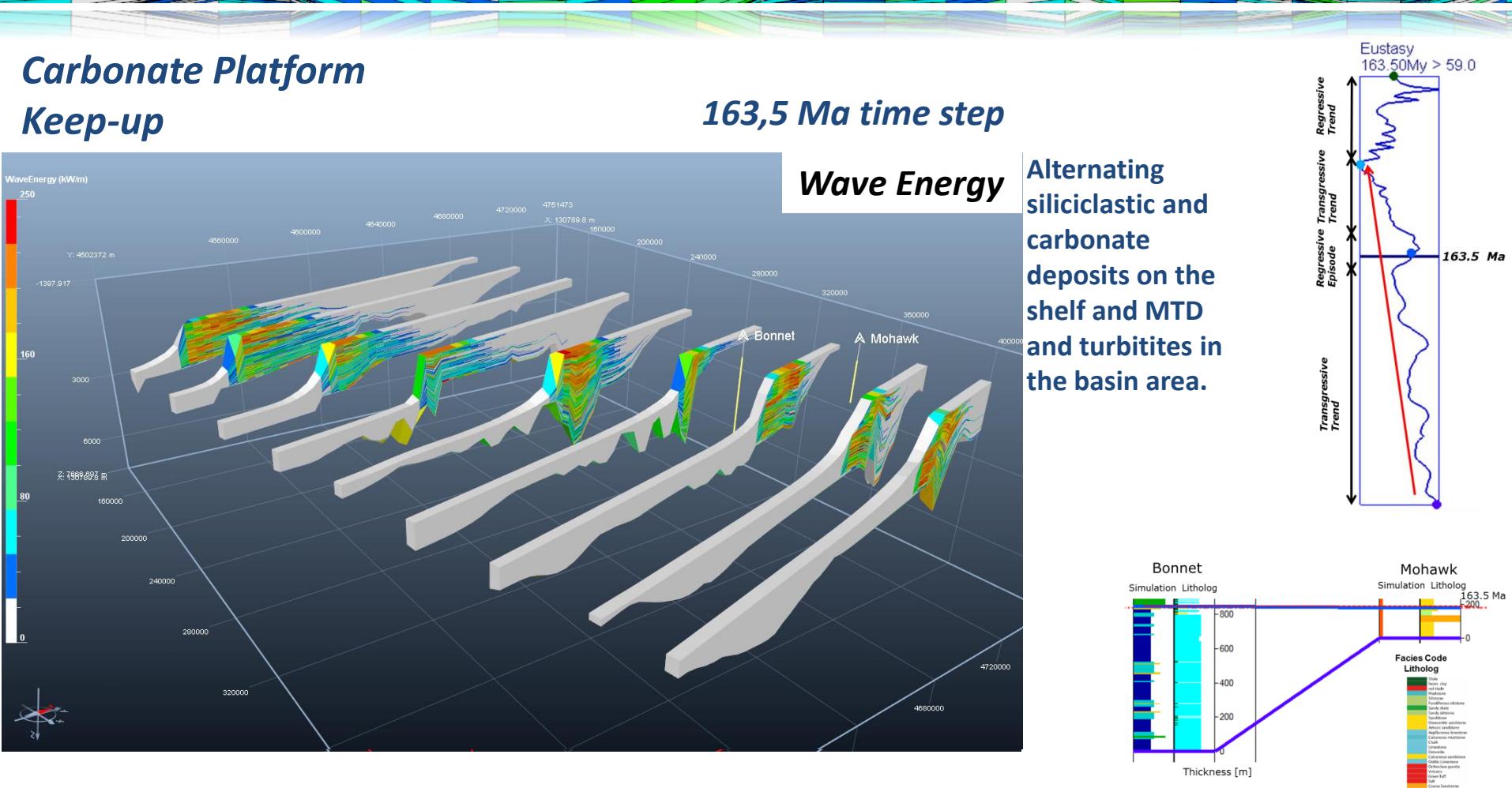
Sand Proportion



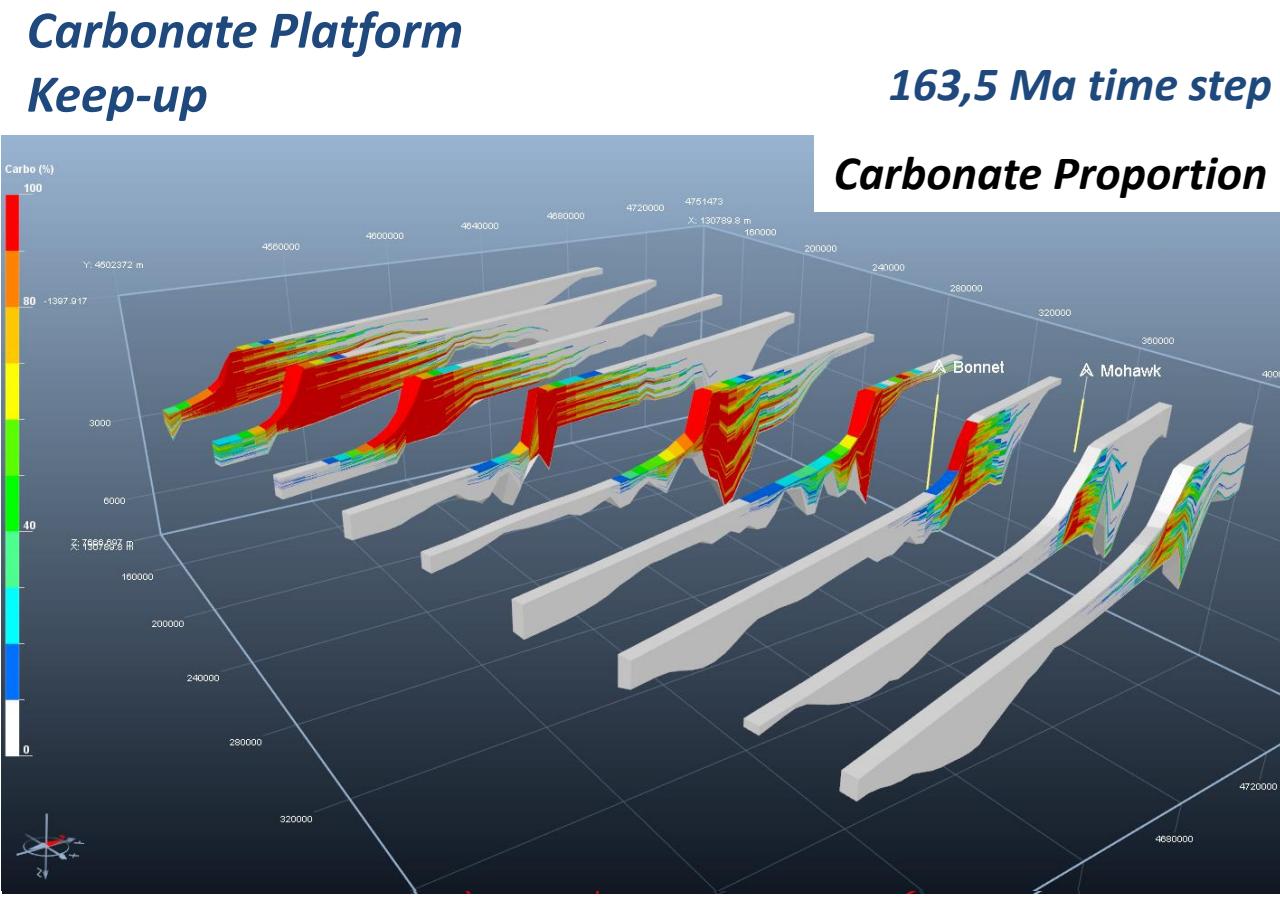
Alternating siliciclastic and carbonate deposits on the shelf and MTD and turbrites in the basin area.



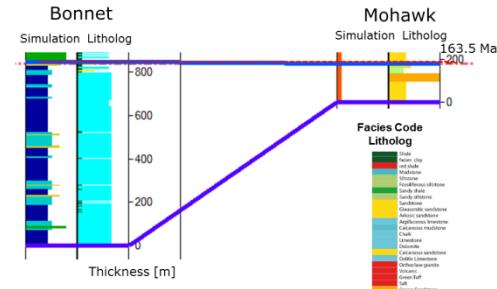
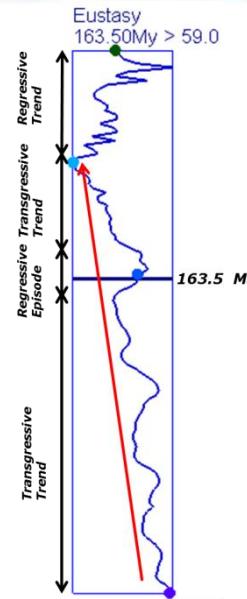
Results



Results



Alternating siliciclastic and carbonate deposits on the shelf and MTD and turbitites in the basin area.

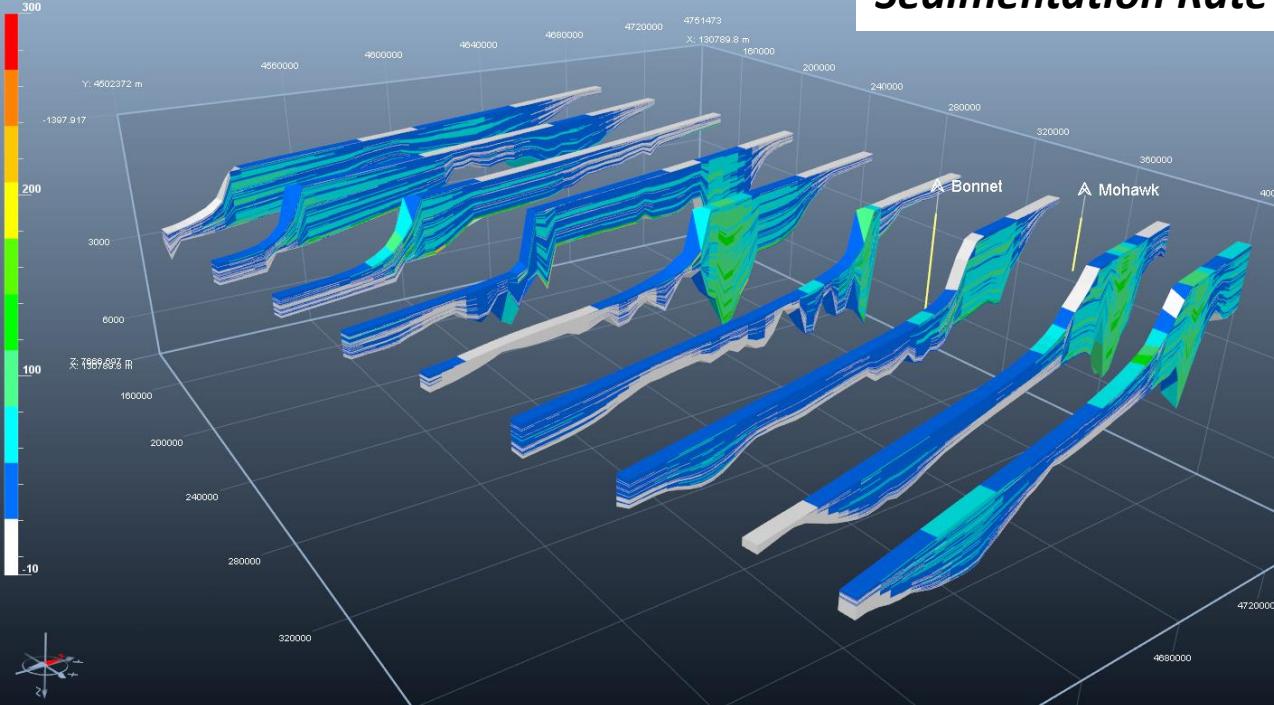


Results

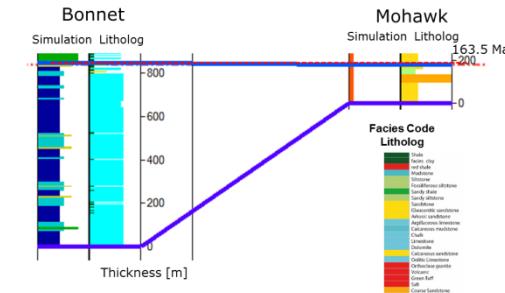
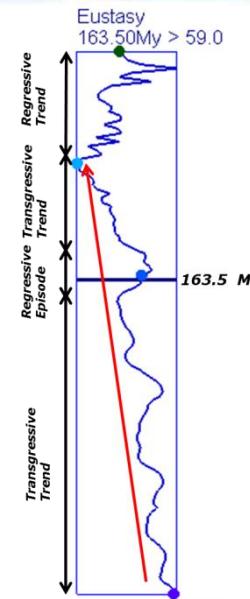
Carbonate Platform Keep-up

163,5 Ma time step

Sedimentation Rate

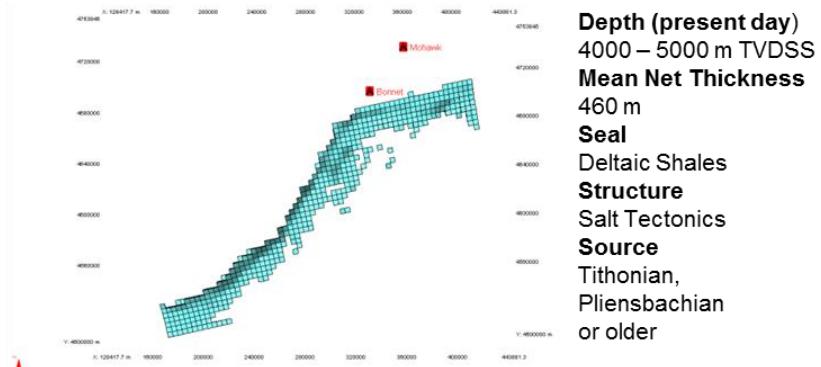


Alternating siliciclastic and carbonate deposits on the shelf and MTD and turbrites in the basin area.

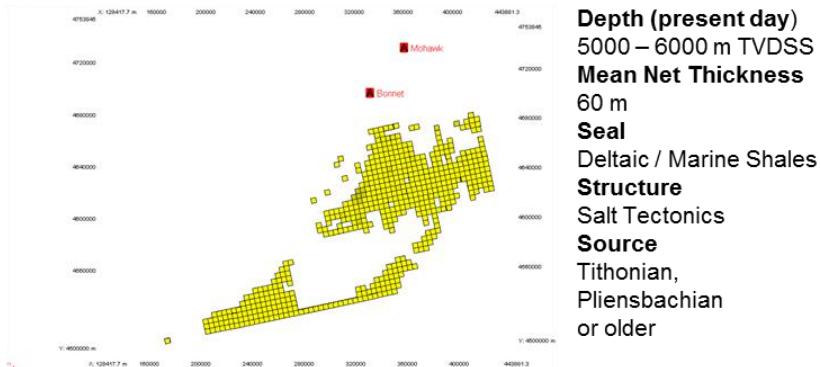


Results

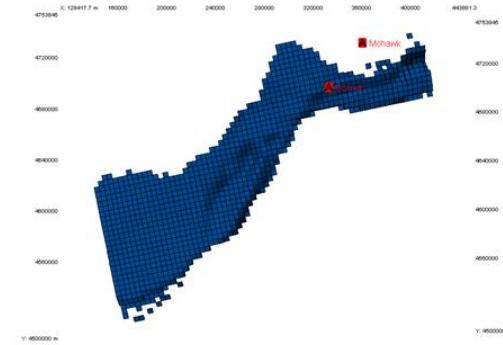
Carbonate Breccia and MTD 200 - 163 Ma



Sandy Turbidites and BFF 200 - 163 Ma



Shallow Water Carbonate 200 - 163 Ma



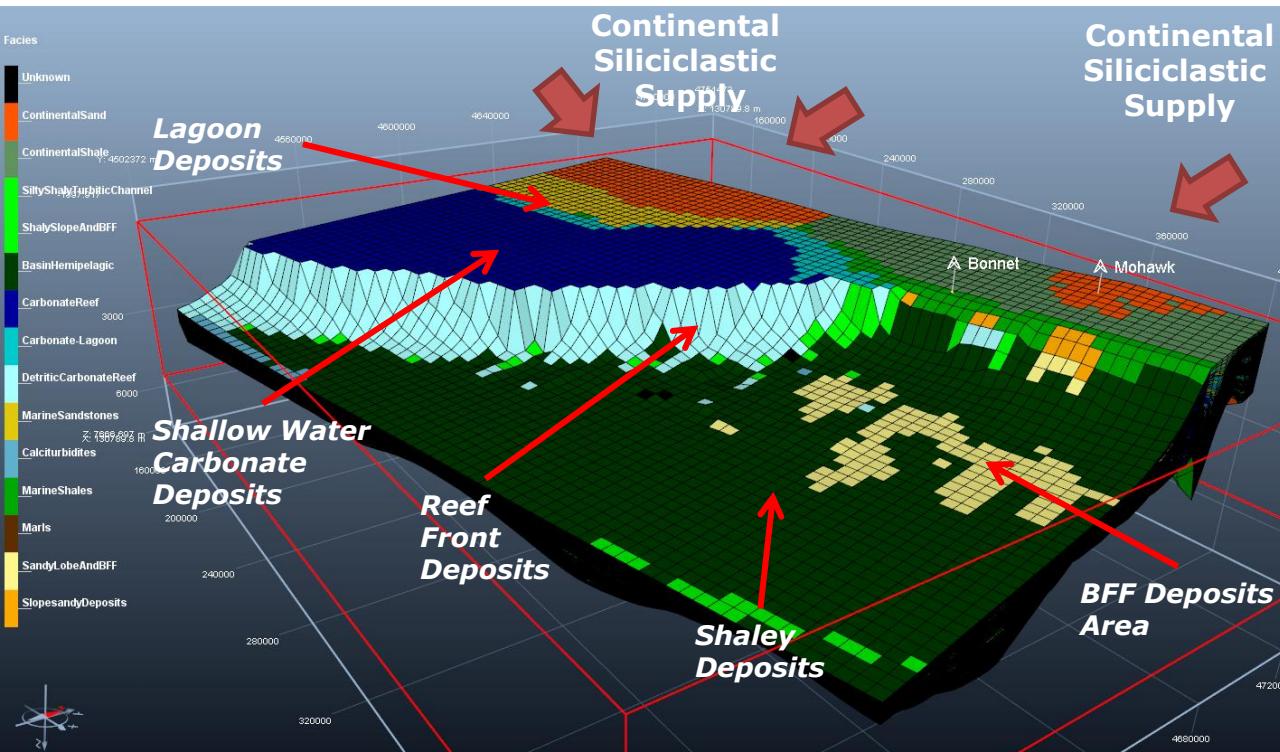
Marine Sandstone 200 - 163 Ma



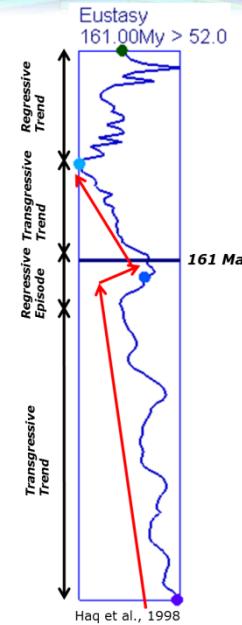
Results

Onset of the Tithonian Transgression

161 Ma time step



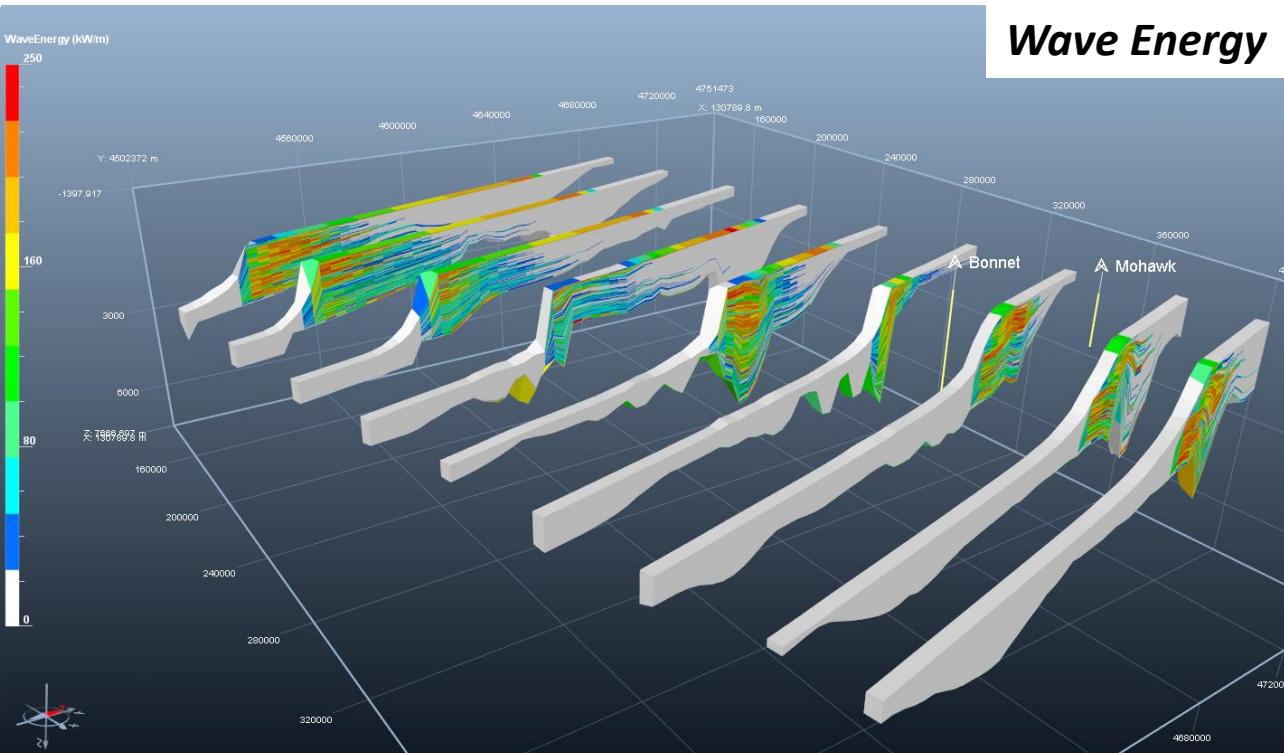
Carbonate deposits are dominant on the shelf area with siliciclastic retrogradation



Results

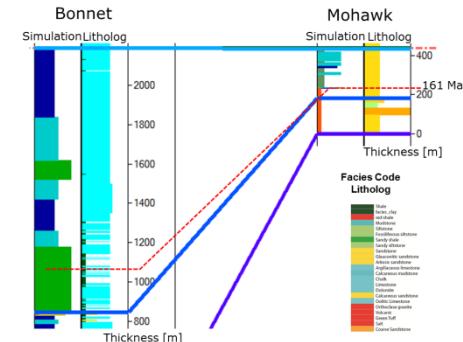
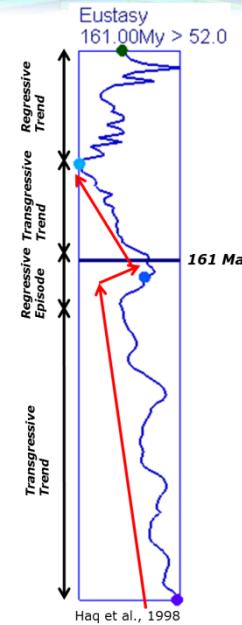
Onset of the Tithonian Transgression

161 Ma time step



Wave Energy

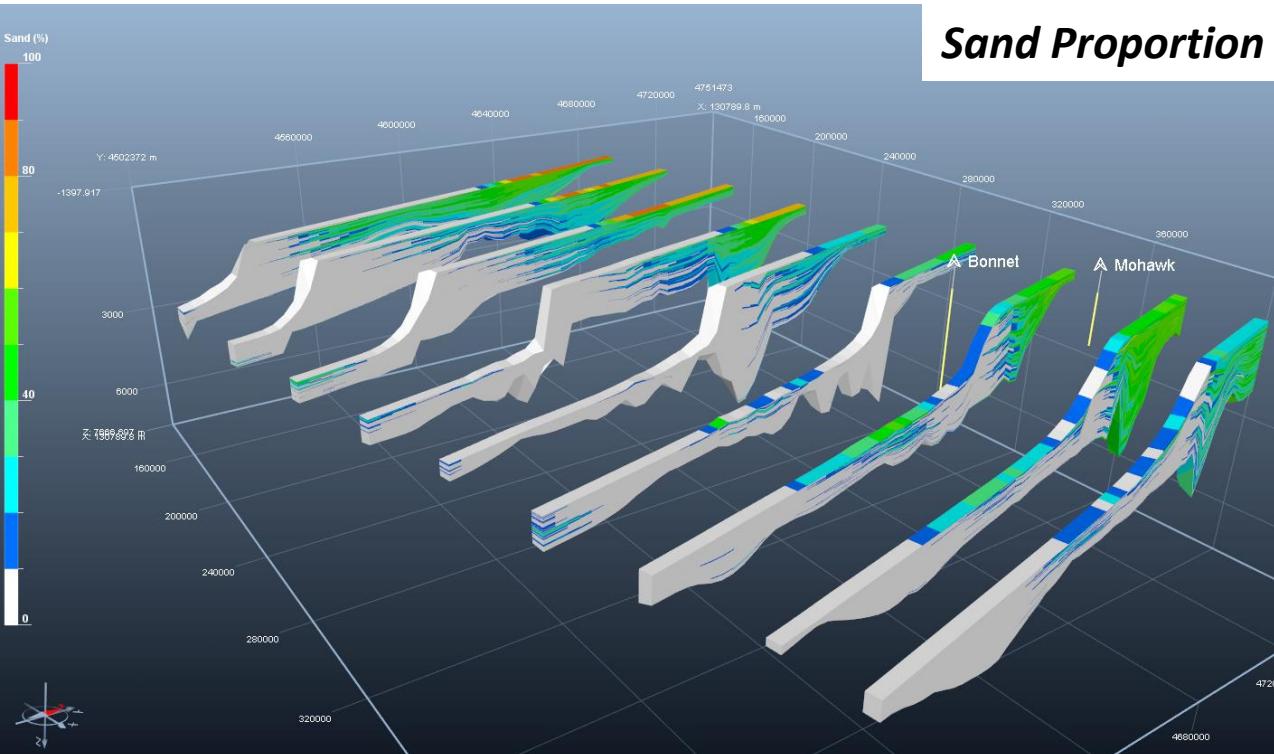
Carbonate deposits are dominant on the shelf area with siliciclastic retrogradation



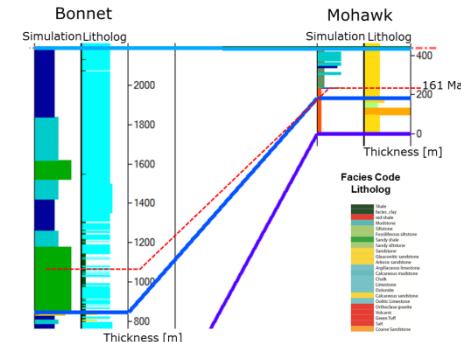
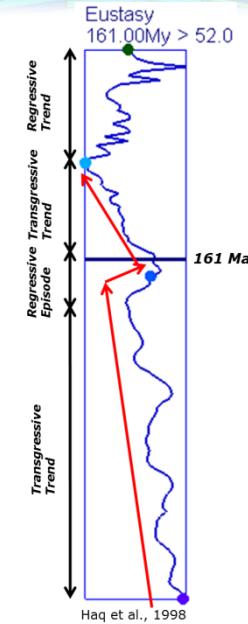
Results



161 Ma time step



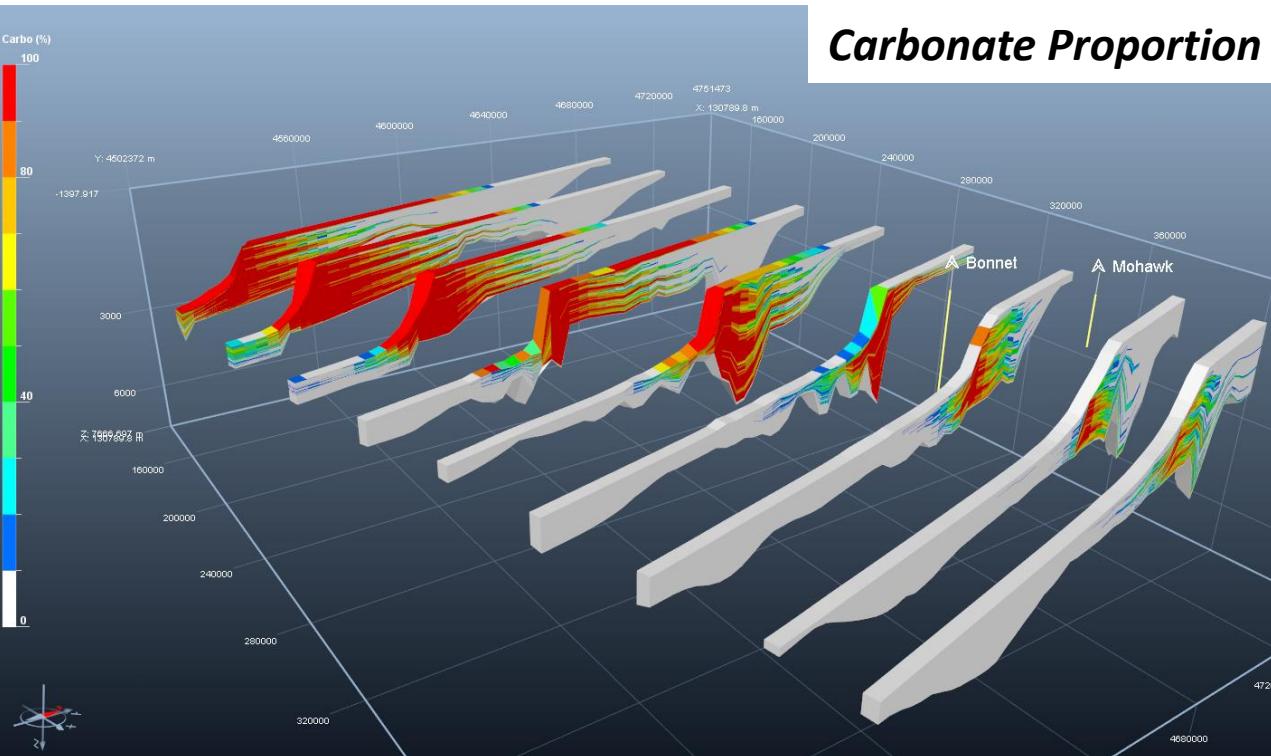
Carbonate deposits are dominant on the shelf area with siliciclastic retrogradation



Results

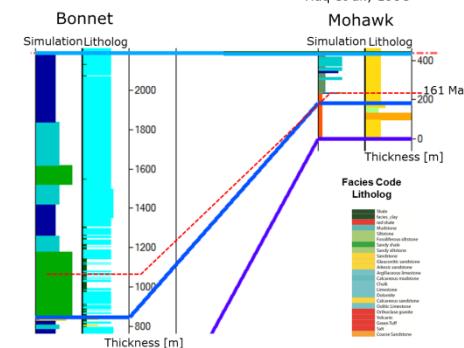
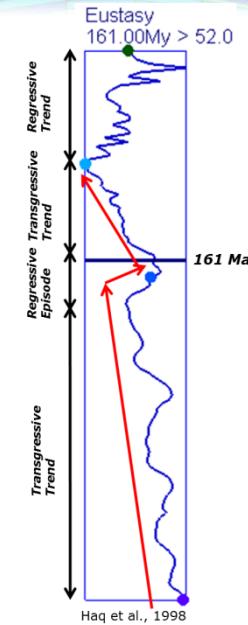


161 Ma time step

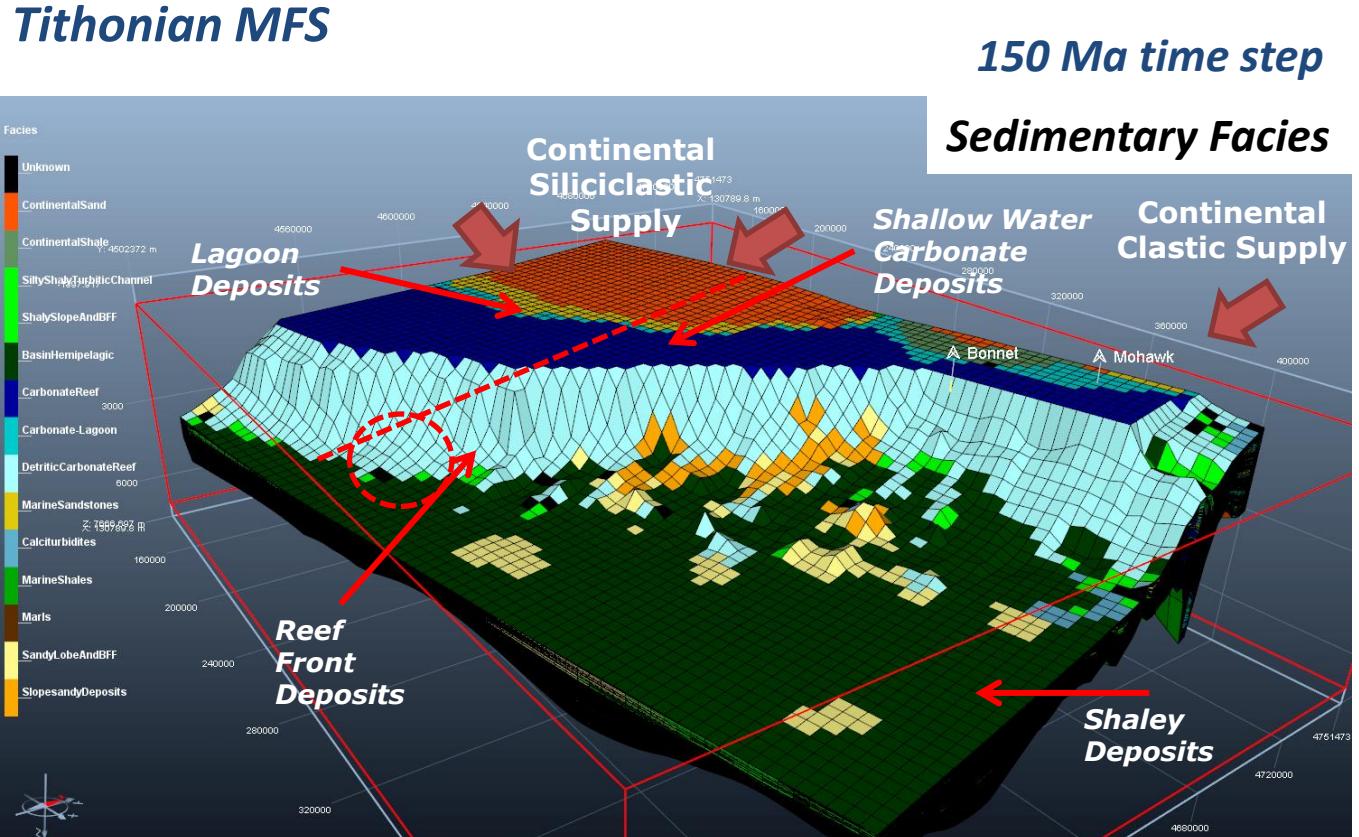


Carbonate Proportion

Carbonate deposits are dominant on the shelf area with siliciclastic retrogradation



Results

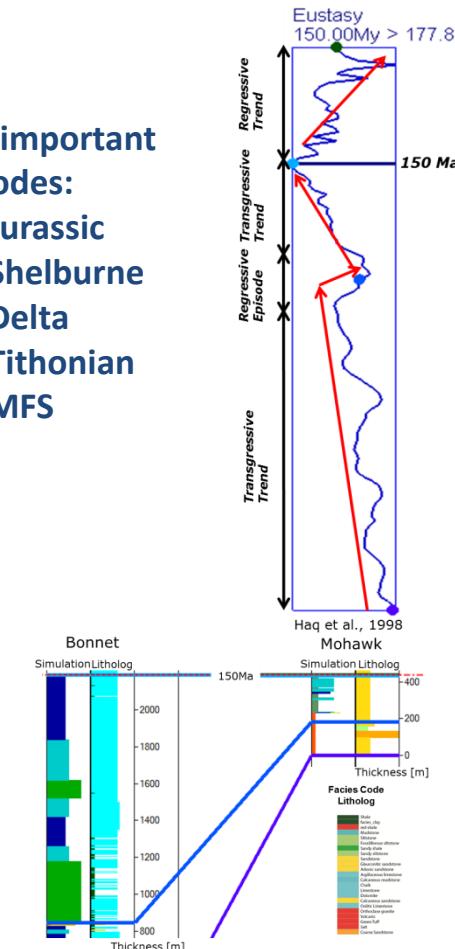


150 Ma time step

Sedimentary Facies

Two important episodes:

- Jurassic
Shelburne
Delta
 - Tithonian
MFS

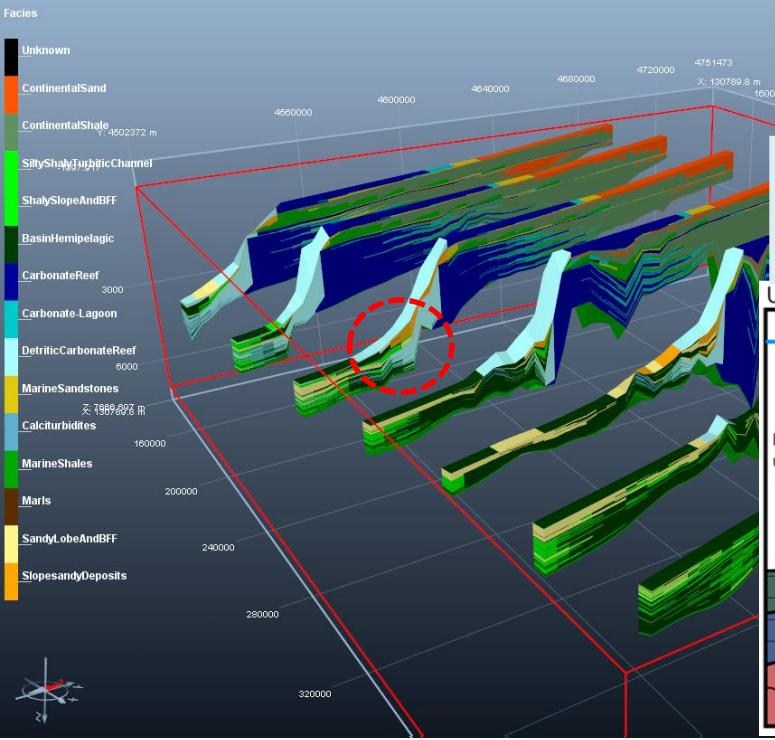


Results

Tithonian MFS

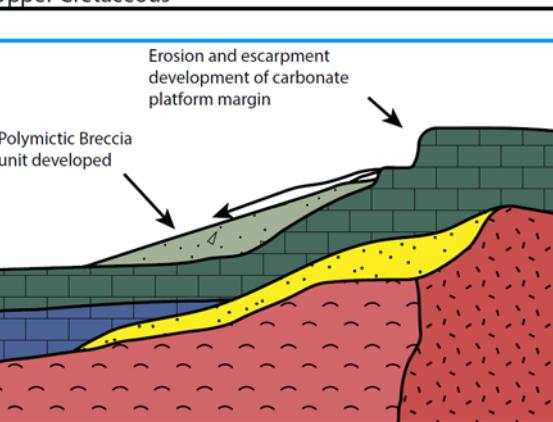
150 Ma time step

Sedimentary Facies

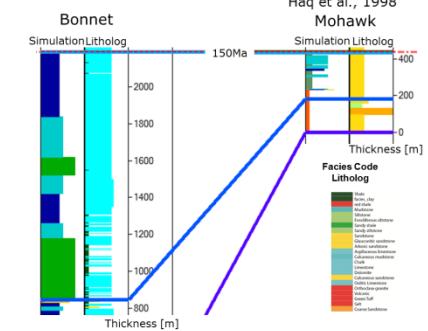
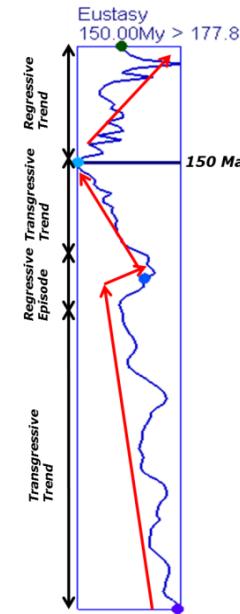


Western Yucatan Platform Cantarell Field

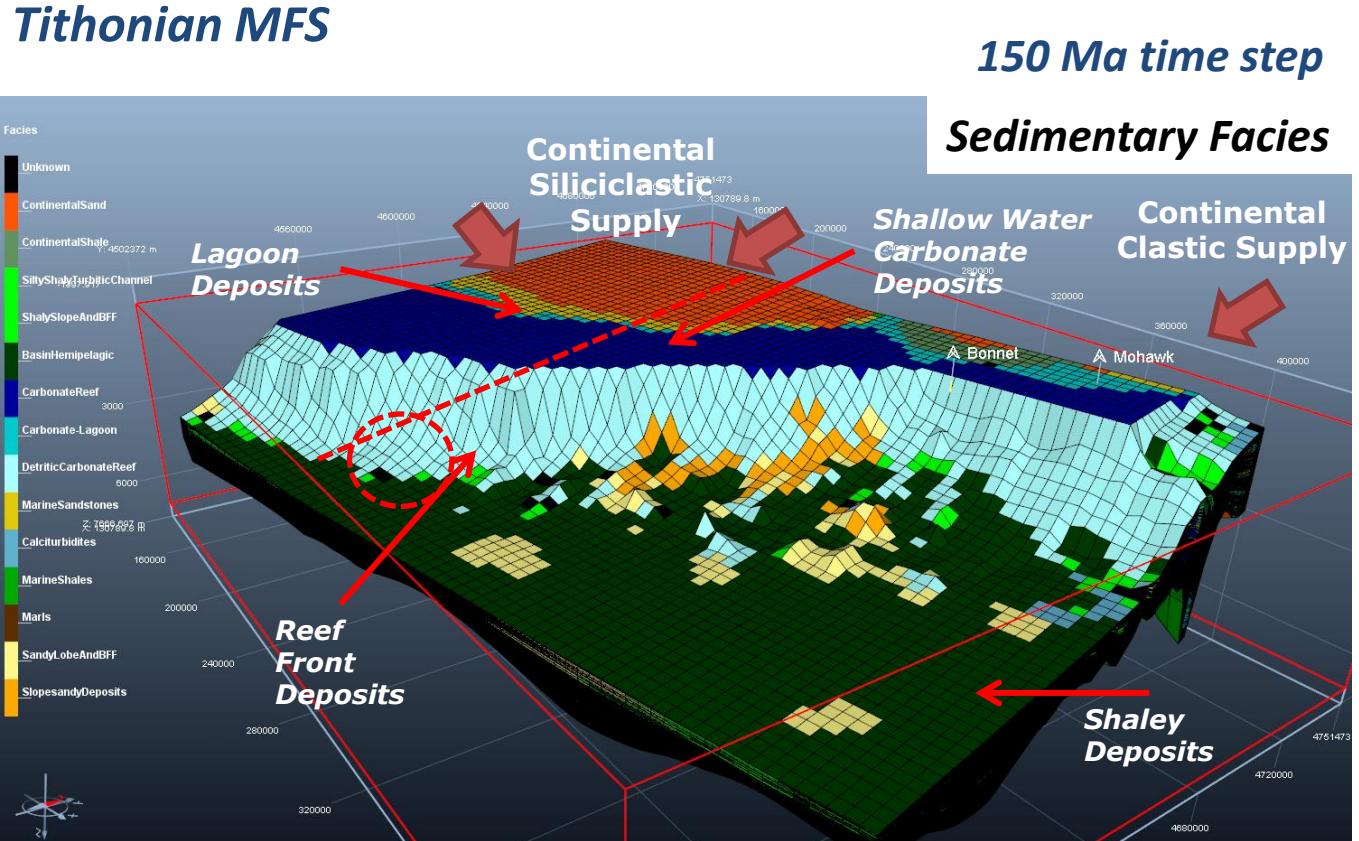
Upper Cretaceous



- Jurassic Shelburne Delta
 - Tithonian MFS



Results

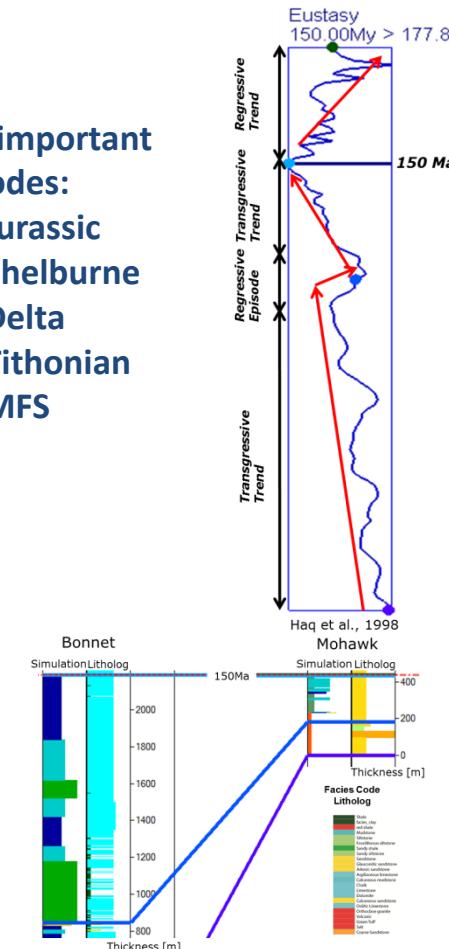


150 Ma time step

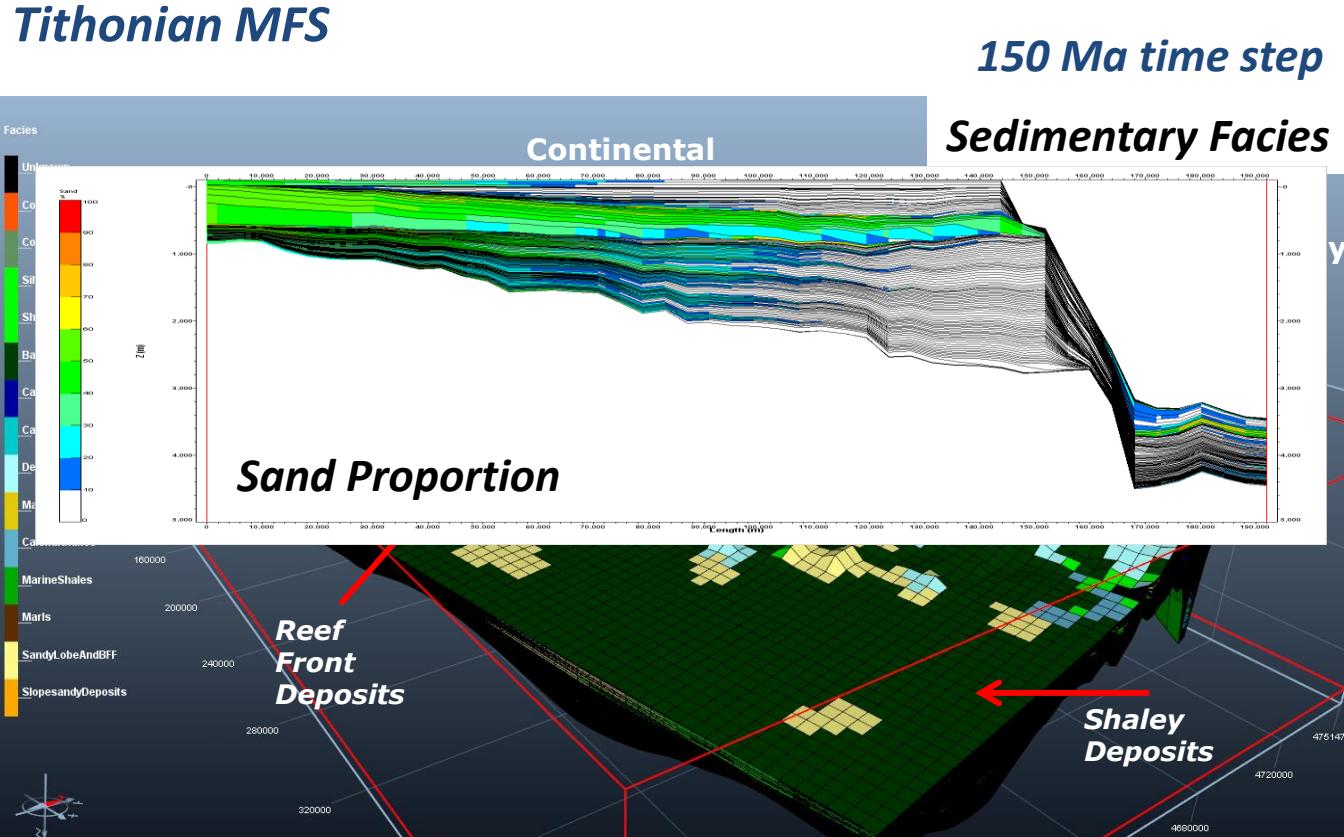
Sedimentary Facies

Two important episodes:

- Jurassic
Shelburne
Delta
 - Tithonian
MFS

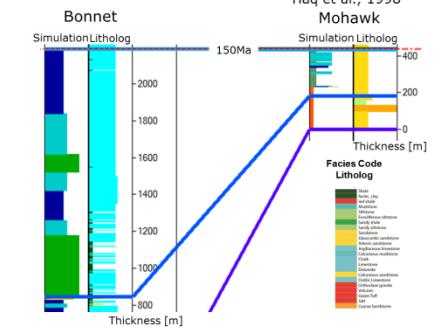
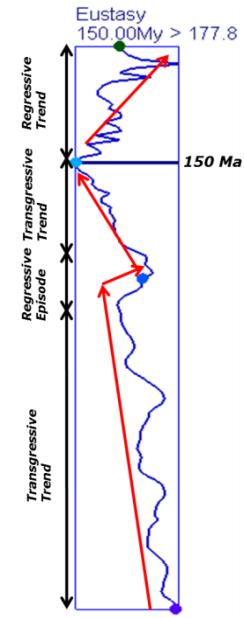


Results



150 Ma time step

- Jurassic Shelburne Delta
- Tithonian MFS

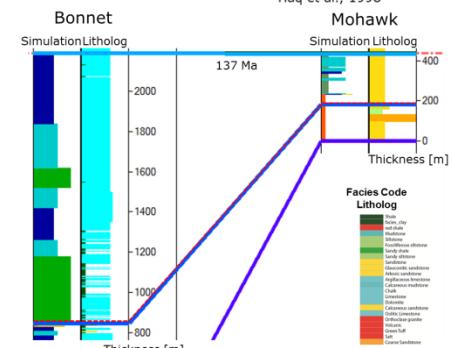
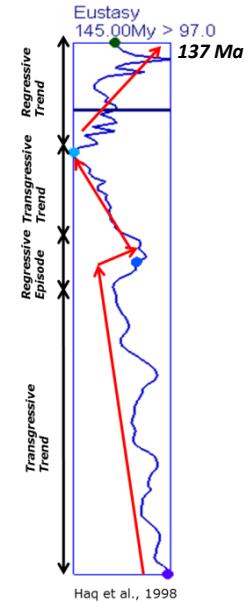
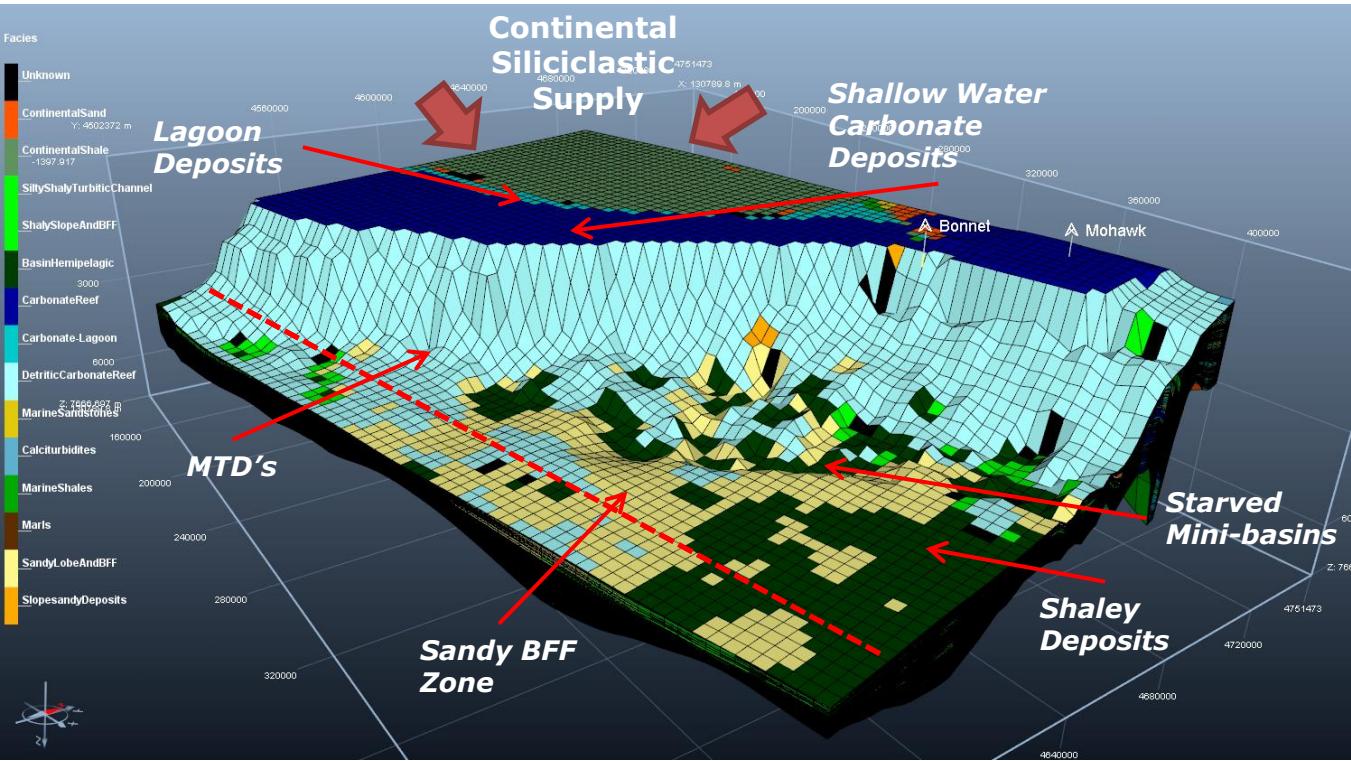


Results

Rhythmite Facies

Erosion on the Carbonate Platform

137 Ma time step

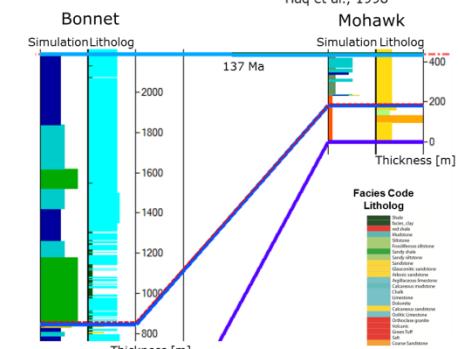
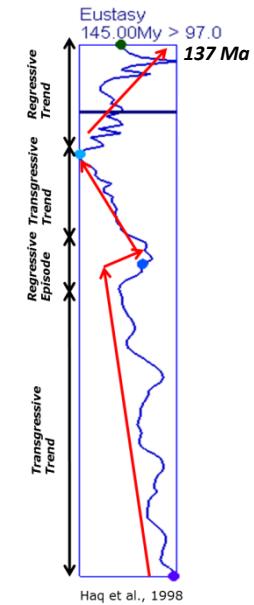
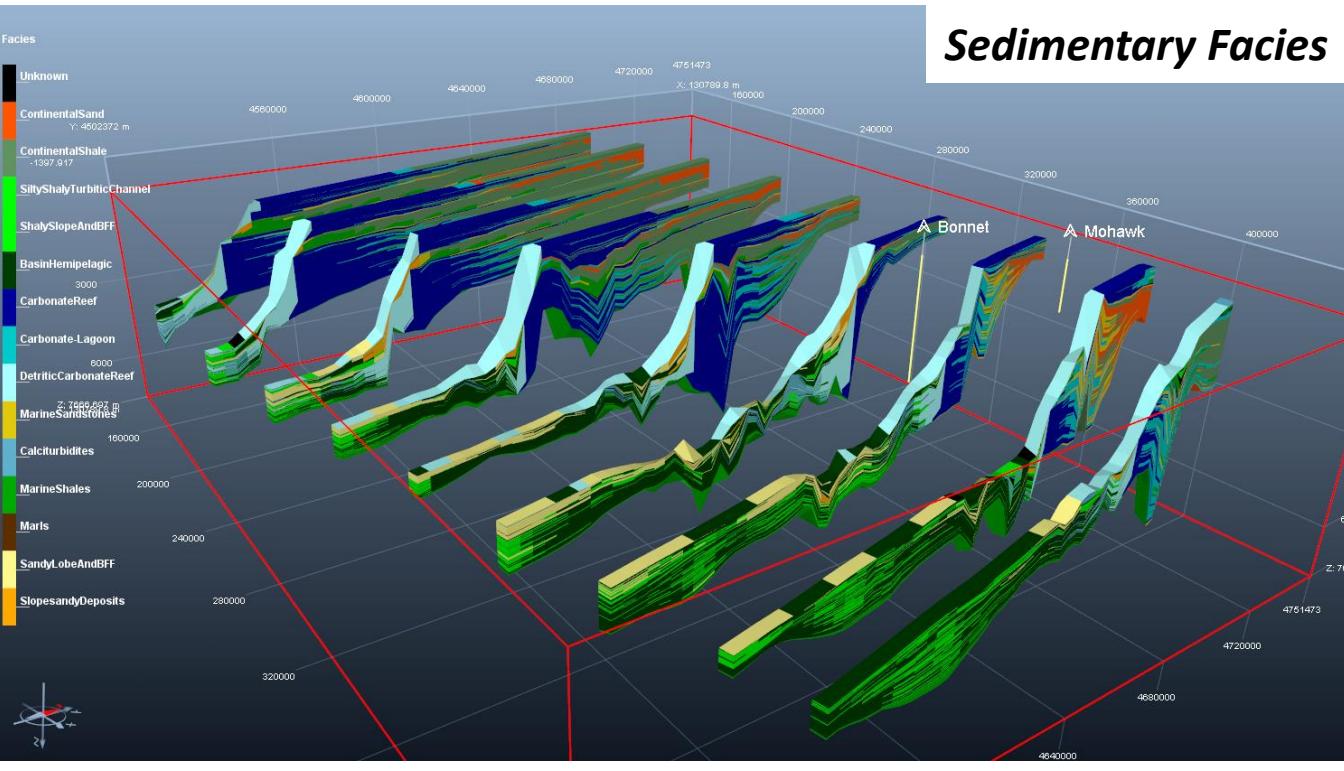


Results

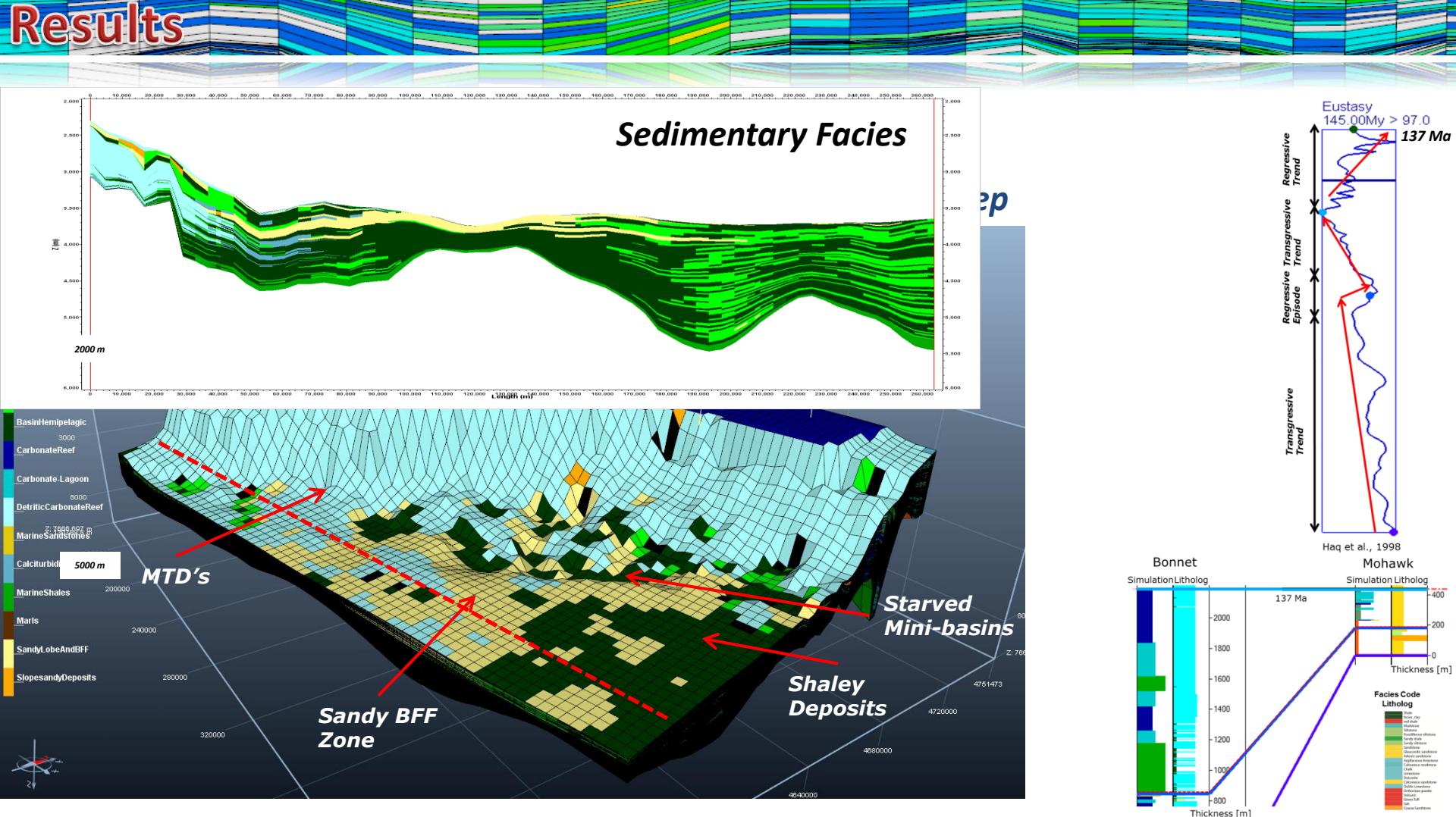
Retrogressive Episode Erosion on the Carbonate Platform

137 Ma time step

Sedimentary Facies

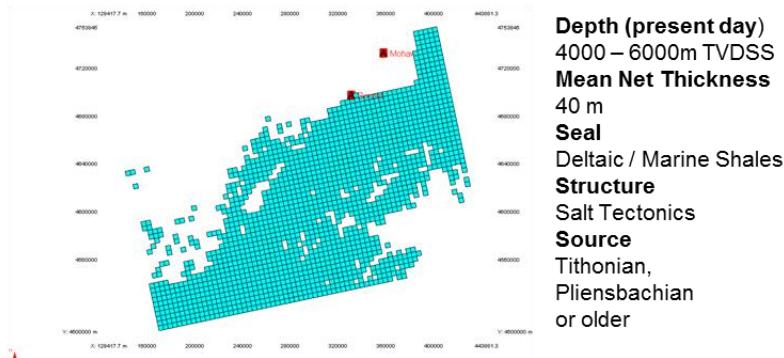


Results



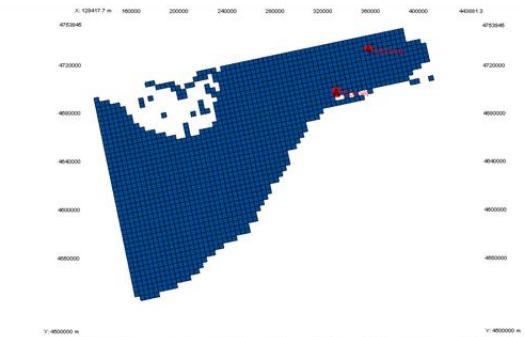
Results

Carbonate Breccia and MTD 163 - 137 Ma

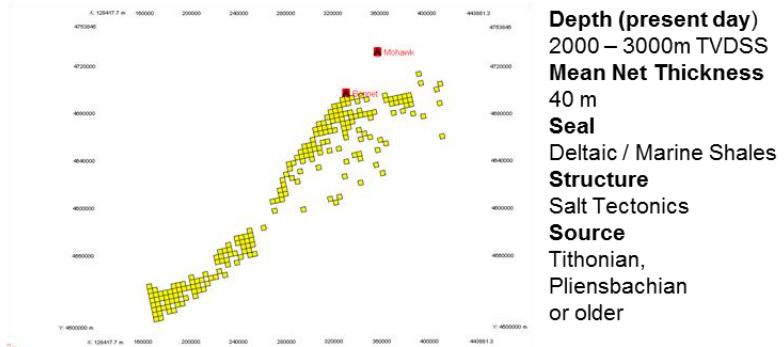


Depth (present day)
500 – 2000m TVDSS
Mean Net Thickness
300 m
Seal
Deltaic Shales
Structure
Salt Tectonics
Source
Tithonian,
Pliensbachian
or older

Shallow Water Carbonate Deposits 163 - 137 Ma

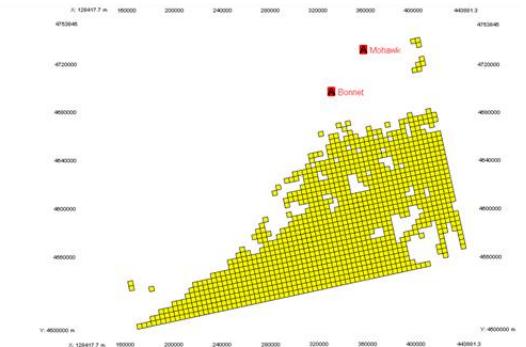


Slope sandstone 163 - 137 Ma



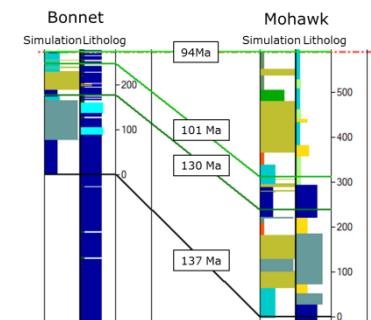
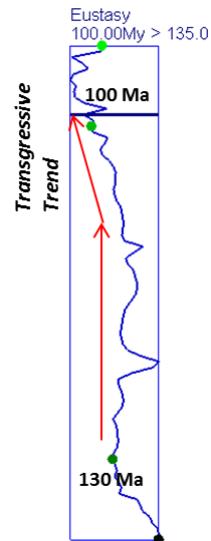
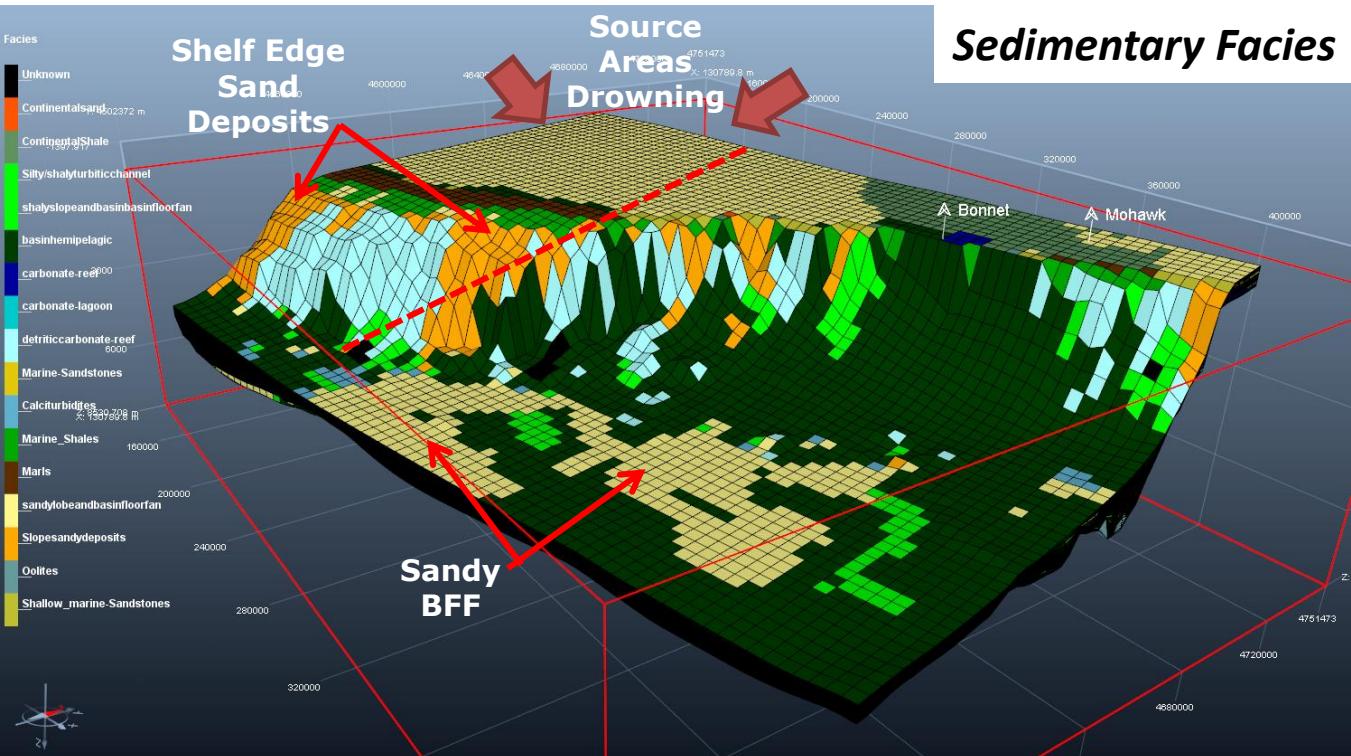
Depth (present day)
5000 - 6000m TVDSS
Mean Net Thickness
120 m
Seal
Deltaic Shales
Structure
Salt Tectonics
Source
Tithonian,
Pliensbachian
or older

Sandy Turbidites and BFF 163 - 137 Ma



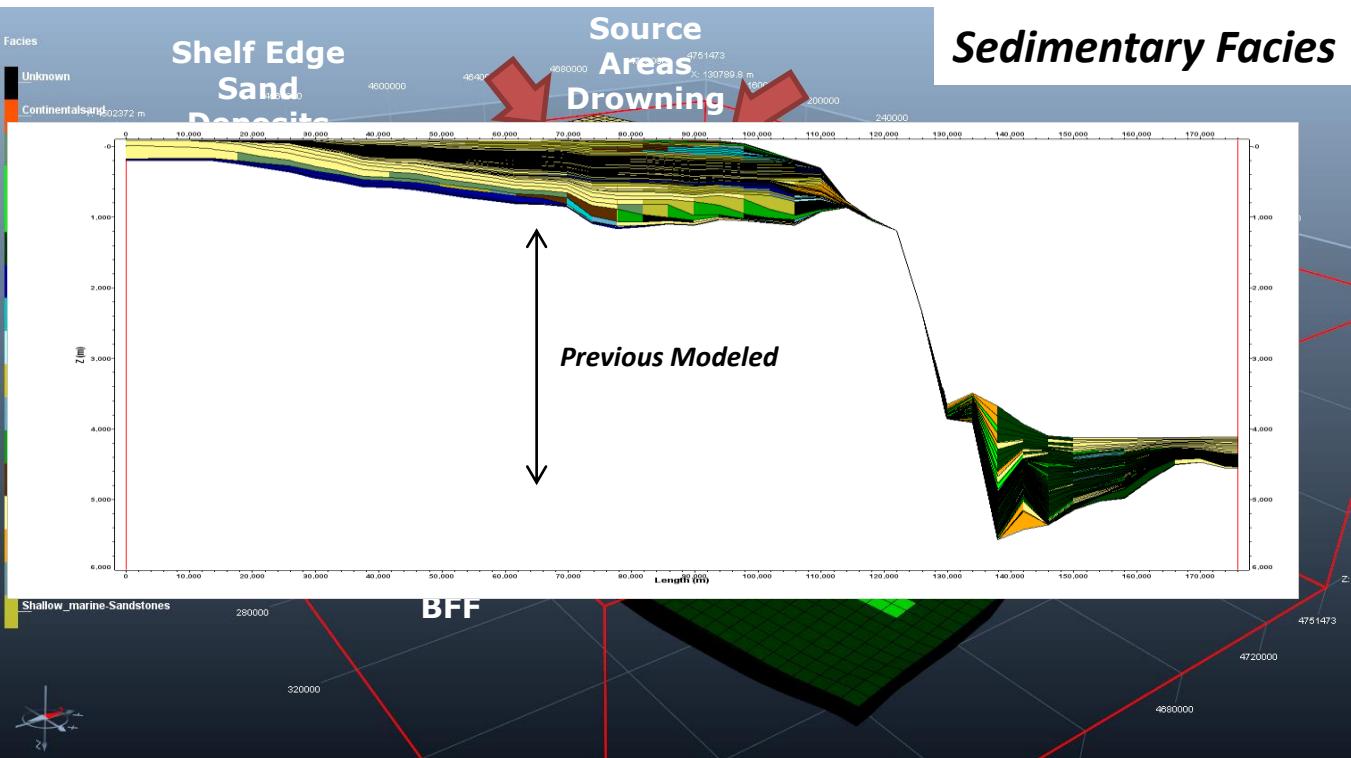
Results

*Decrease on
Sediment Supply*



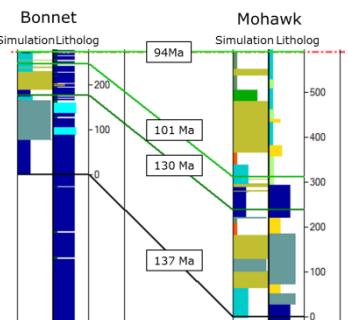
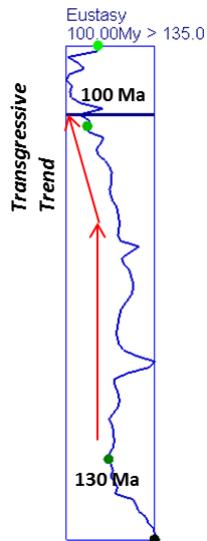
Results

*Decrease on
Sediment Supply*



94 Ma time step

Sedimentary Facies
Post – Cretaceous
Shelburne Delta



Conclusions

- A stratigraphic model integrating well and seismic data was generated for predicting the overall stratigraphic architecture of the Shelburne Sub-basin.
- Modeling results show the presence of promising reservoir – seal intervals in the **Jurassic and Cretaceous sequences** of the Shelburne Sub-basin.
- The reservoir targets are present in the shelf and basin areas:
 - **Shelf:** Carbonates and deltaic sandstones (eq Missisauga and L. Canyon Fm.)
 - **Basin:** Slope Sandstones, Carbonate Breccia, Calciturbidites, Sandy turbidites and Basin Floor Fan sandstones.

