CHAPTER 6

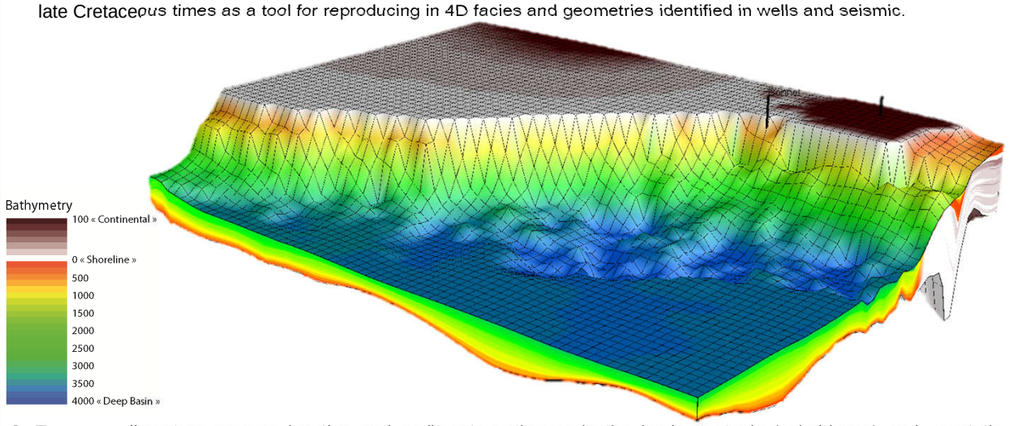
STRATIGRAPHIC MODELING

CHAPTER 6.1

DIONISOS WORKFLOW

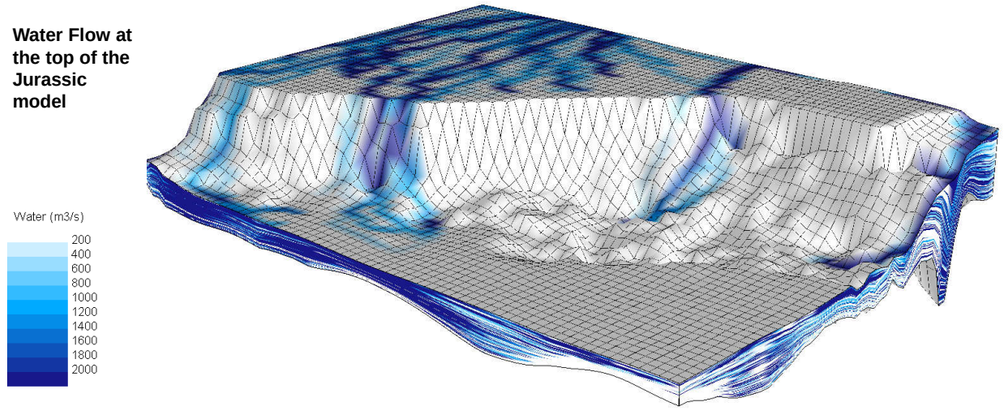
Objectives of the direct forward modeling using Dionisos®

1. To provide a 4D geological reconstruction of the SW Nova Scotia margin (Georges Bank area) from Lower Jurassic to late Cretaceous times as a tool for reproducing in 4D facies and geometries identified in wells and seismic.



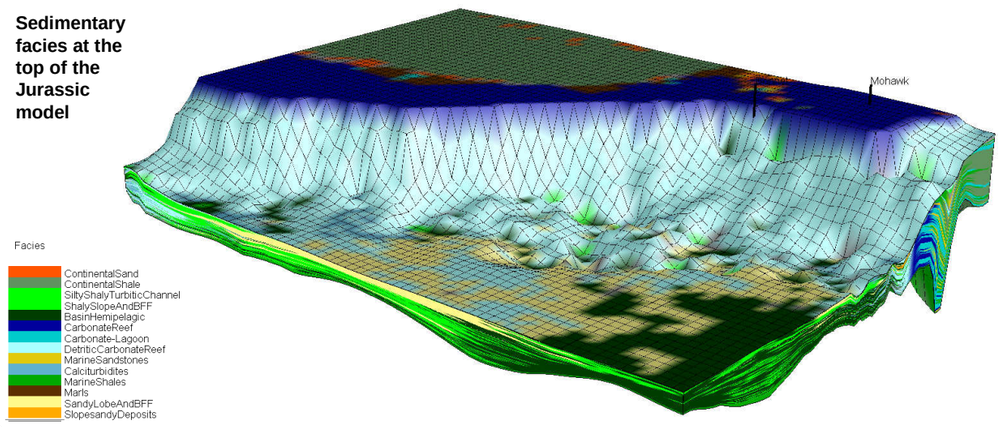
2. To test sedimentary sources location and sediments pathways in the basin, tectonic (subsidence) and eustatic changes impact on sedimentation.

Water Flow at the top of the Jurassic model



3. To provide a probable distribution of sedimentary facies in the basin.

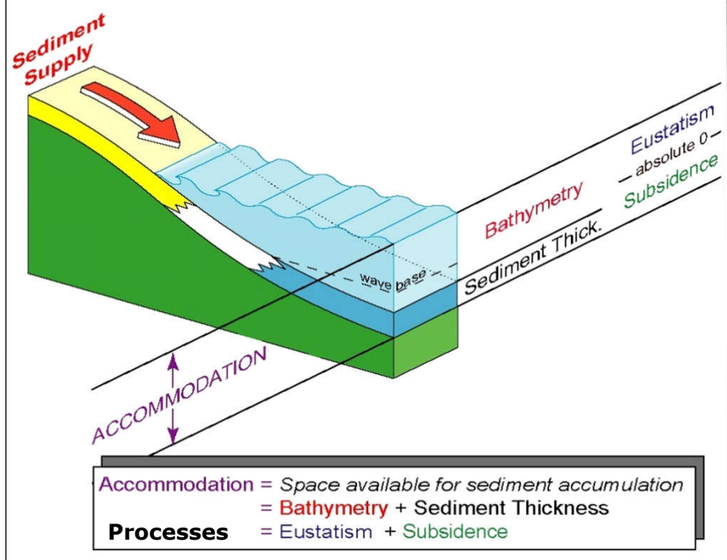
Sedimentary facies at the top of the Jurassic model



Dionisos® principles

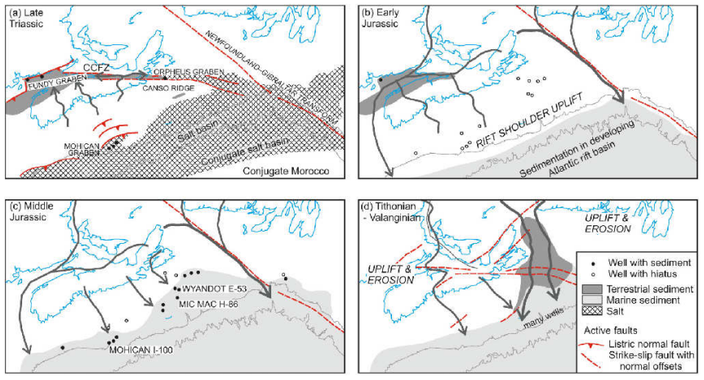
The main principle of DionisosFlow® is to simulate sedimentation constrained by the **A/S** ratio:

A : Accommodation (The available space)



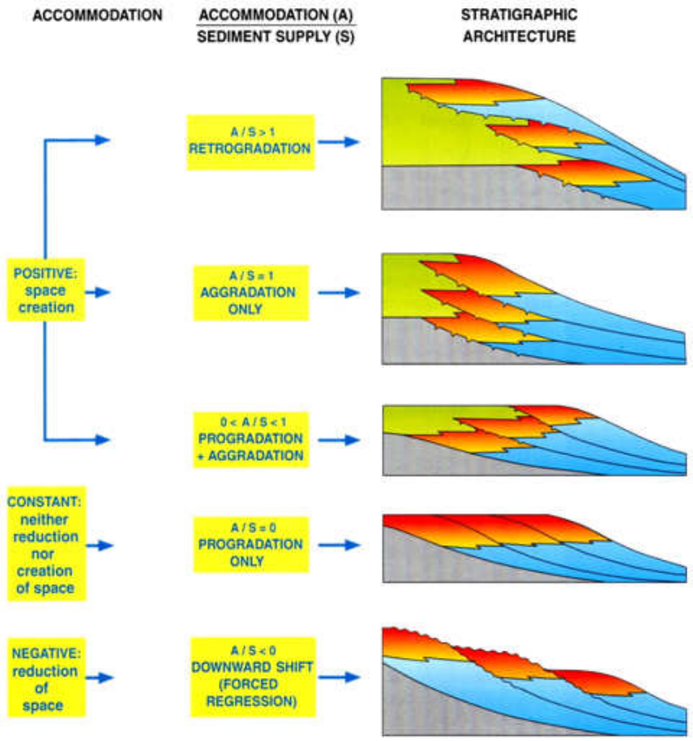
S: Sediment supplies

Probable location of sediment sources from Triassic to Jurassic times integrated in Dionisos.

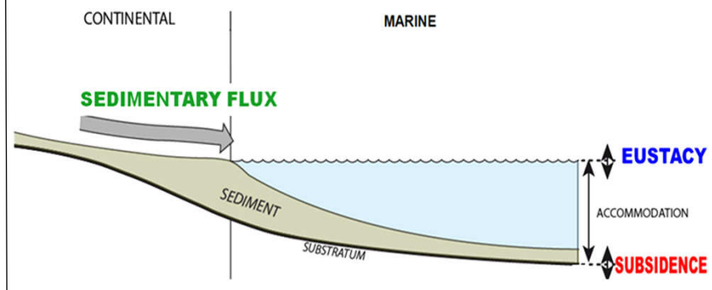


Map showing the structural and geomorphic evolution of the Scotian Basin and its hinterland from late Triassic to early Cretaceous: (a) late Triassic; (b) early Jurassic; (c) middle Jurassic; (d) Tithonian–Valanginian. (From Li et al., 2012). Futher details are provided in the Stratigraphy chapter.

The A/S ratio controls and reflects the stratigraphic architecture and spatial distribution of sediments through time.



The main input parameters in Dionisos® are:
- Sequence thickness
- Paleo-bathymetries
- Sediments flux
- Eustacy
- Environmental parameters (diffusion coefficient)



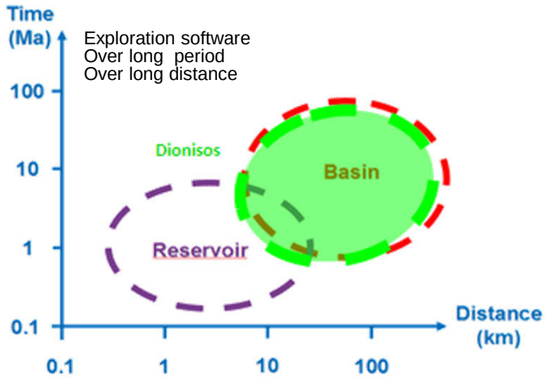
modified after Robin and al, 1995

STRATIGRAPHIC MODELING – DIONISOS WORKFLOW

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

DionisosFlow® concepts

The Dionisos simulation is basin oriented and mostly dedicated to exploration.
The sediment distribution and deposition are simulated through a simple diffusion law.



References:

Granjeon, D., 1996. Modelisation stratigraphique deterministe
— conception et applications d'un modele diffusif 3D multilithologique.
Memoires Geosciences Rennes, PhD Dissertation.
Geosciences Rennes, Rennes, France, 189 pp.

Granjeon, D., Joseph, P., 1999. Concepts and applications of a 3-D multiple lithology, diffusive model in stratigraphic modeling. Numerical experiments in stratigraphy: recent advances in stratigraphic and sedimentologic computer simulations.
SEPM Spec. Publ. 62, 197– 210.

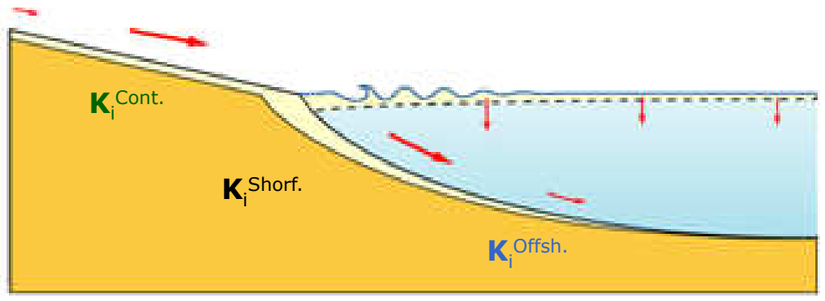
Granjeon, D., 2009. 3D stratigraphic modeling of sedimentary basins.
AAPG Search and Discovery Article #90090©2009 A
APG Annual Convention and Exhibition, Denver, Colorado, June 7-10, 2009.

Somme, T.O., Helland-Hansen, W., Granjeon, D., 2009. Impact of eustatic amplitude variations on shelf morphology, sediment dispersal, and sequence stratigraphic interpretation: Icehouse versus greenhouse systems. Geology 37, 587-590

Diffusion equation:

$$Q_s = K\, Q_w\, S$$

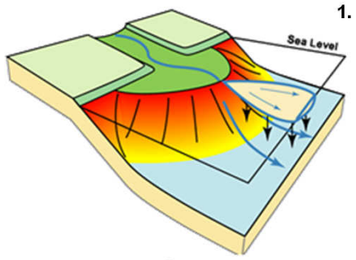
Q_s = sediment flow
K = diffusive coefficient for each environment
Q_w = water flow
S = slope



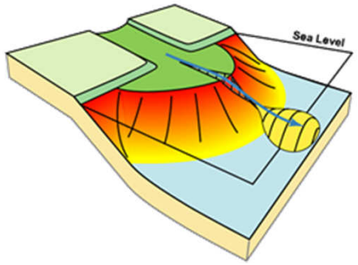
Considered Transport:

1. Water driven

a. Long Term
Low Energy
(permanent transport)

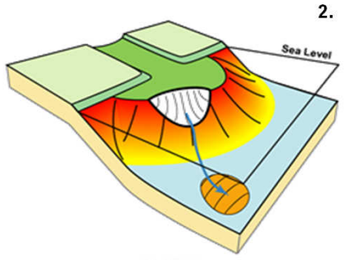


b. Short Term
High Energy
(Turbiditic events)

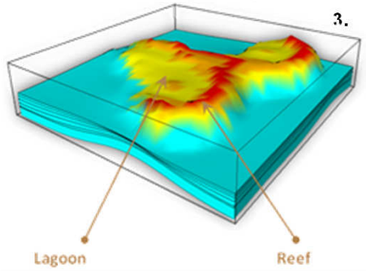


2. Gravity Driven

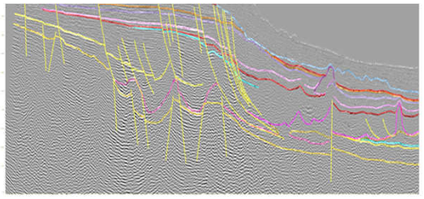
Slope failure
(triggers slumps and debris flows)



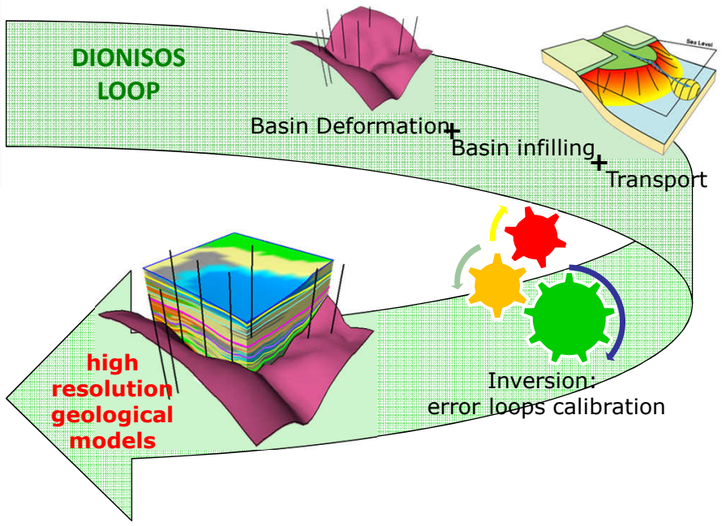
3. Carbonate production
Environment energy
Bathymetry
Ecological processes

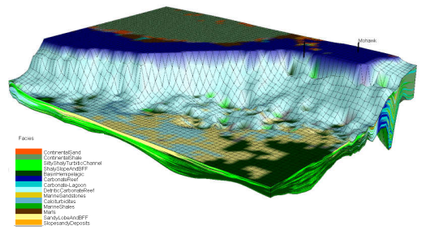


DionisosFlow® workflow



Seismic Data + Geological Concepts





Sedimentologic and stratigraphic modeling

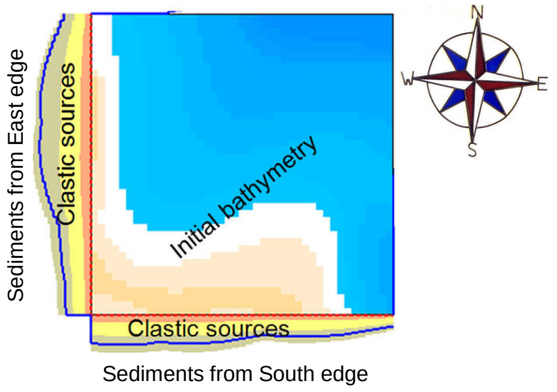
1. Estimation of accommodation space

Thickness of the sequence + final bathymetry – initial bathymetry

2. Definition of sediment supplies, clastic transport or/and carbonate production

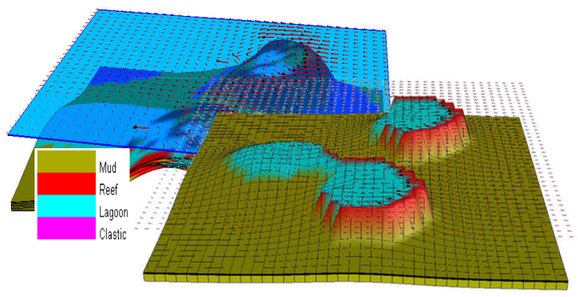
a. Define *lateral* clastic sources

b. Define *in situ* carbonate production



Constrain clastic supplies as a function of :
- Localization of each sediment source
- Width of the source
- Quantity of sediments by source
- Fluvial discharge of each source

$$Q_S = K_i\, Q_w\, S$$



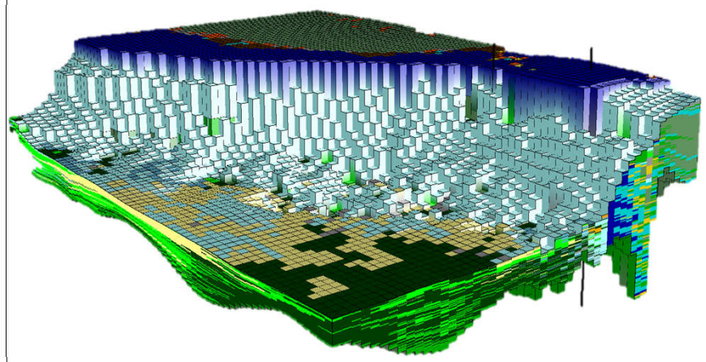
Constrain carbonate production as a function of:
- bathymetry
- wave energy
- ecology processes

$$Prod = f(bathy, E_{wave}\ldots)$$

STRATIGRAPHIC MODELING – DIONISOS WORKFLOW

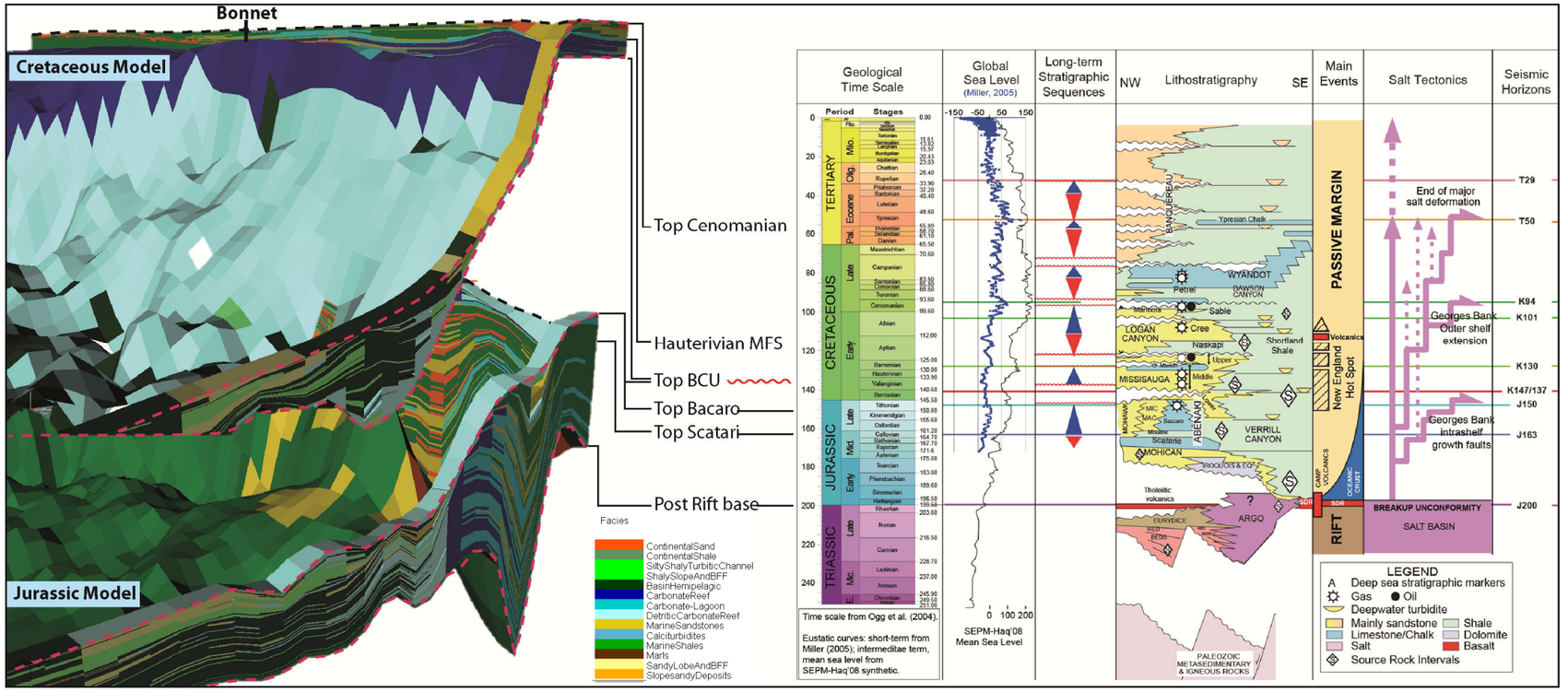
SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

3. Computation and calibration



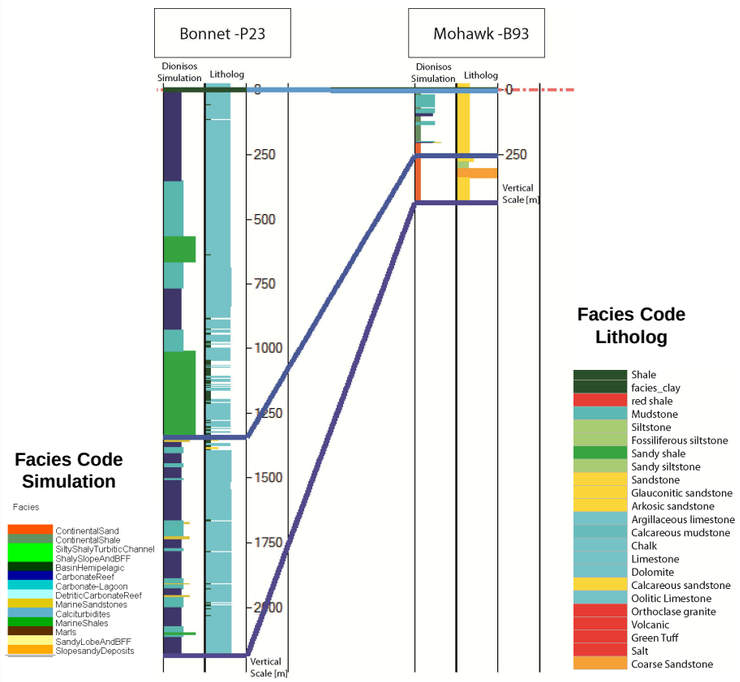
Basin size	X = 280 km y = 200 km
Griding size	4 km x 4 km
Origin (UTM)	X = 170 000 m Y = 4 500 000 m
Angle with horizontal	12°
Forward simulation from 200 My (Jurassic) to 94 My (Cretaceous)	
Time step	0.5 My

Geometrical parameters of the simulation



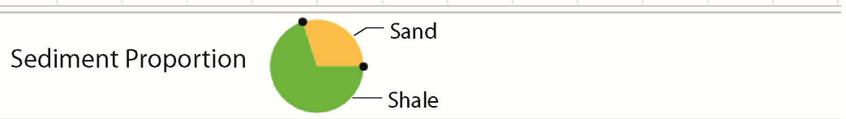
Dionisos calibration : sequence stratigraphy

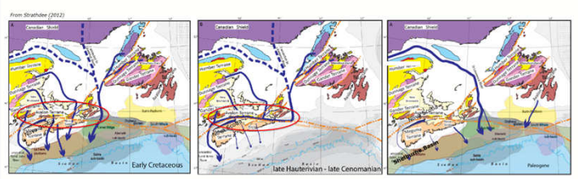
Main sequence boundaries defined for the Georges Bank area were taken into account for the Dionisos simulation



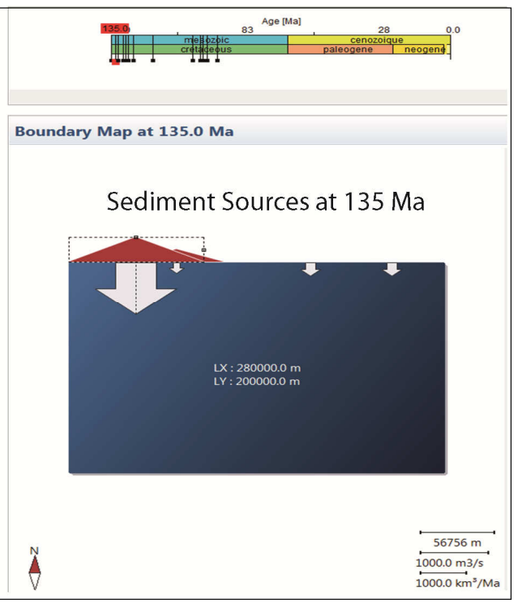
Example of Dionisos® calibration : simulated facies at well vs litholog

	Average													
Age (Ma)		137.0	135.0	134.0	132.0	131.0	130.0	128.0	120.0	104.0	101.0	100.0	98.0	94.0
Supply (km³/Ma)	544.65	0.0	2800.0	2000.0	100.0	100.0	10.0	400.0	400.0	400.0	800.0	800.0	800.0	400.0
Fluvial Discharge (m3/s	1162.79	0.0	4000.0	4000.0	1000.0	1000.0	200.0	800.0	800.0	800.0	2000.0	2000.0	2000.0	800.0
Sediment class														
Sand		30.0	30.0	30.0	30.0	25.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Shale		70.0	70.0	70.0	70.0	75.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
Carbo		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0





The sedimentary sources distribution on the Dionisos stratigraphic models are based on paleogeographic reconstructions showed in detail in the stratigraphy chapter of this atlas.

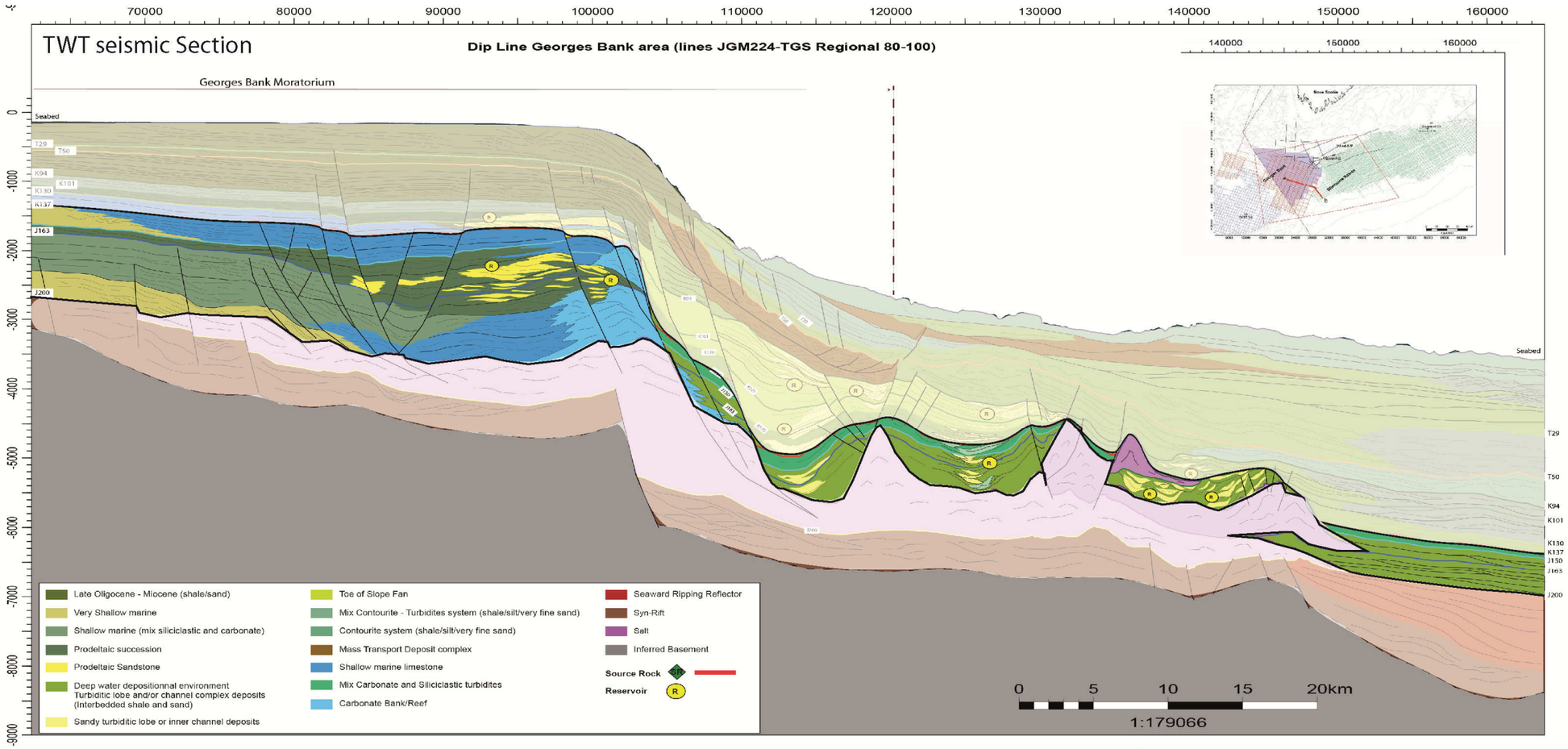


Sediment supply and sources distribution through time

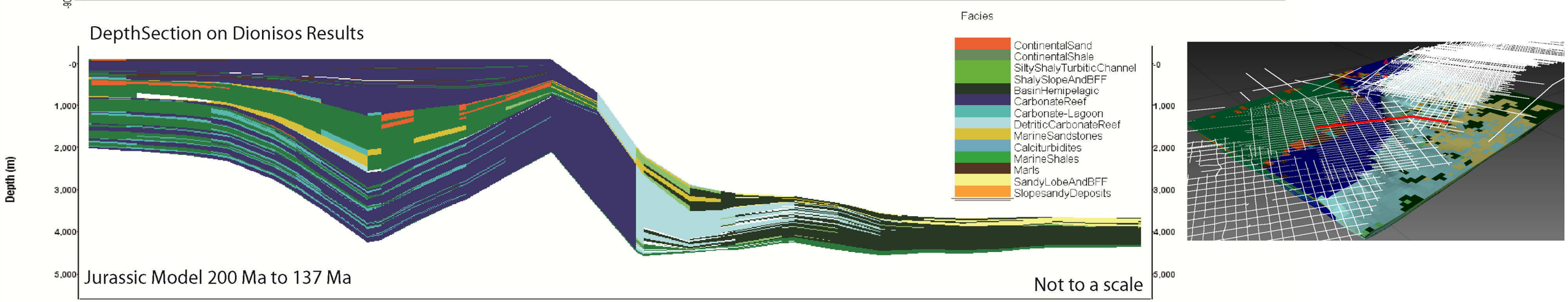
Dionisos Calibration : Lithofacies – Sequence Stratigraphy – Sources Distribution

PL. 6.1.3

Comparison between 2D Interpreted Seismic Lines and Dionisos Simulations



This seismic line shows the transition between the Yarmouth sub- platform area and the Shelburne Basin.



CHAPTER 6.2

STRATIGRAPHIC MODELLING
HETTANGIAN-OXFORDIAN SEQUENCE

South West Nova Scotia

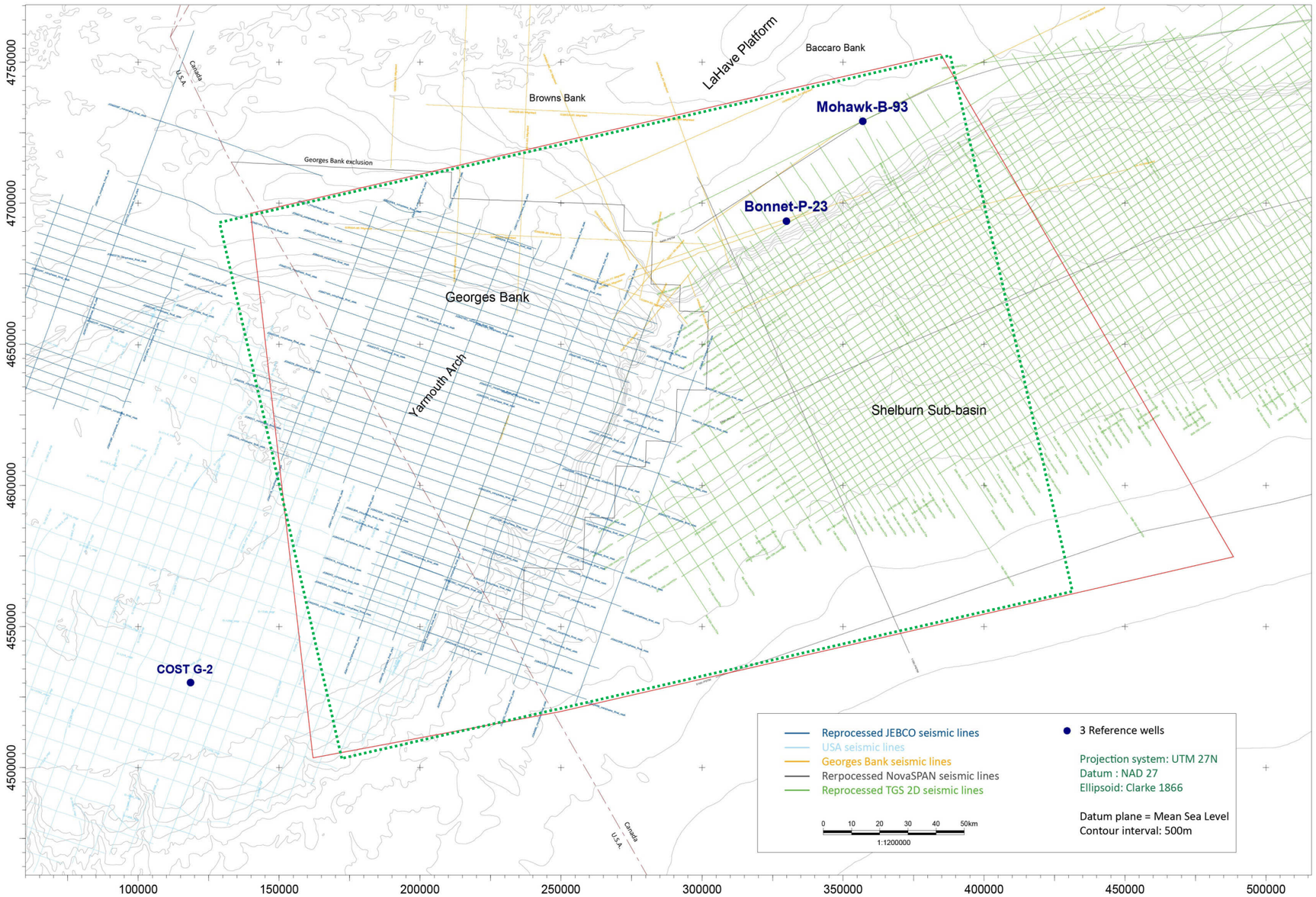


Figure 1. Location map of the study area including seismic surveys and present-day bathymetry. A continuous red line is delimiting the study area and a segmented green one is showing the Dionisos model extension.

STRATIGRAPHIC MODELLING - HETTANGIAN-OXFORDIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

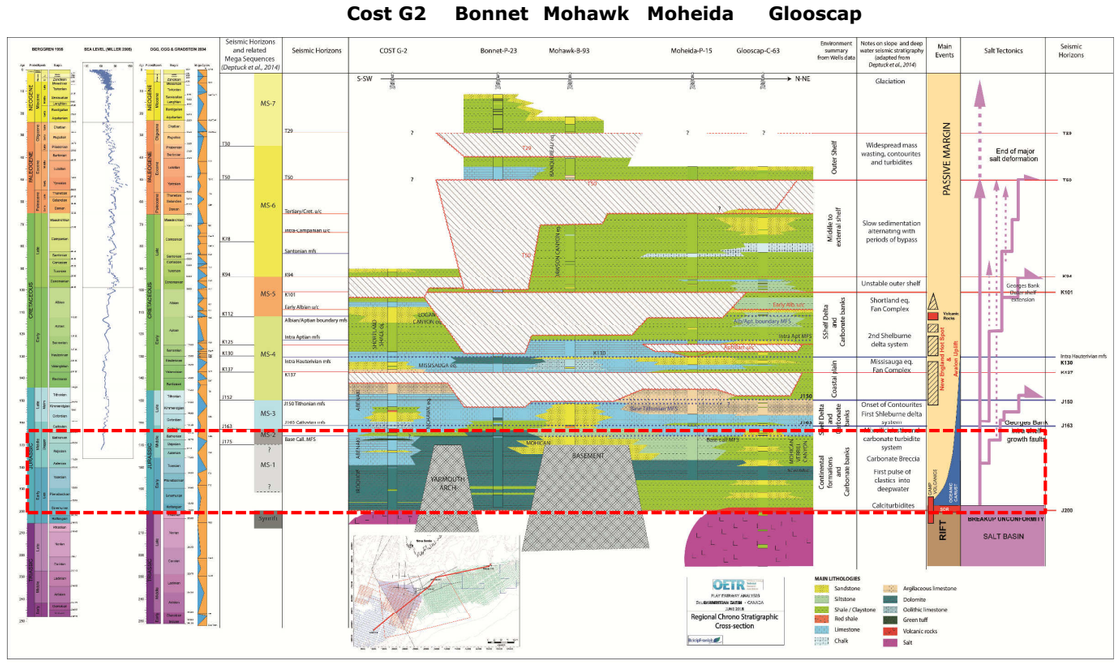


Figure 2. Stratigraphic Cross-Section across the study area. Dotted red line represents the period of time showed in this section.

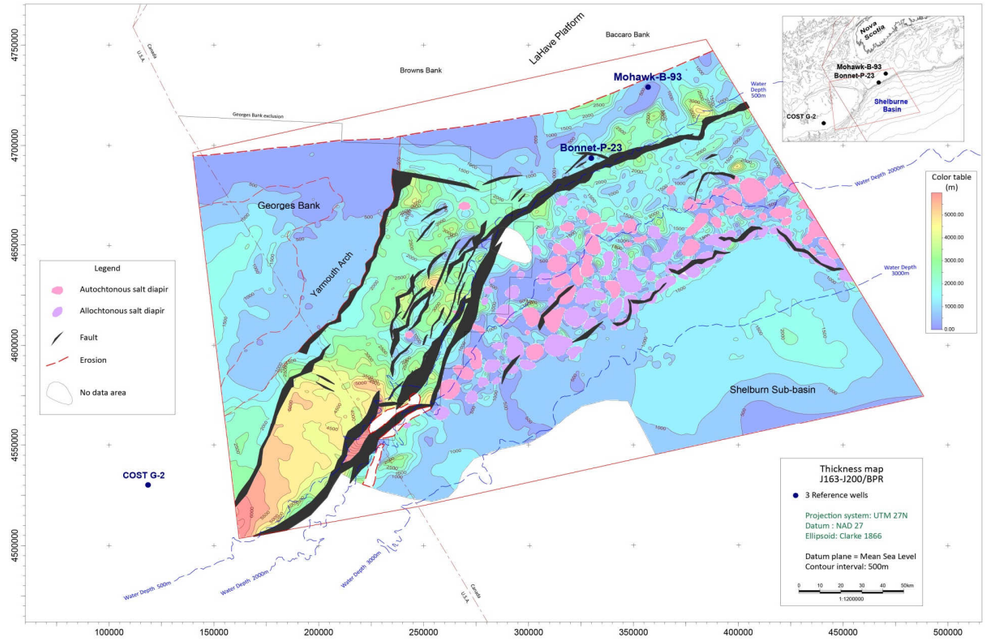


Figure 3. Isopach map J200 – J163.

The interval J200–J163 encompasses the Lower to middle Jurassic sediments lying just above the autochthonous salt. On the sediment thickness map, strong local variations are shown providing information on the distribution of depocenters during the postrift and until Callovian times. In this map, an important sediment accumulation seems to be present to the southwest of the Yarmouth Sub-Platform. The presence of this depocenter is uncertain due to the poor data quality in this area and it would need to be review in the future.

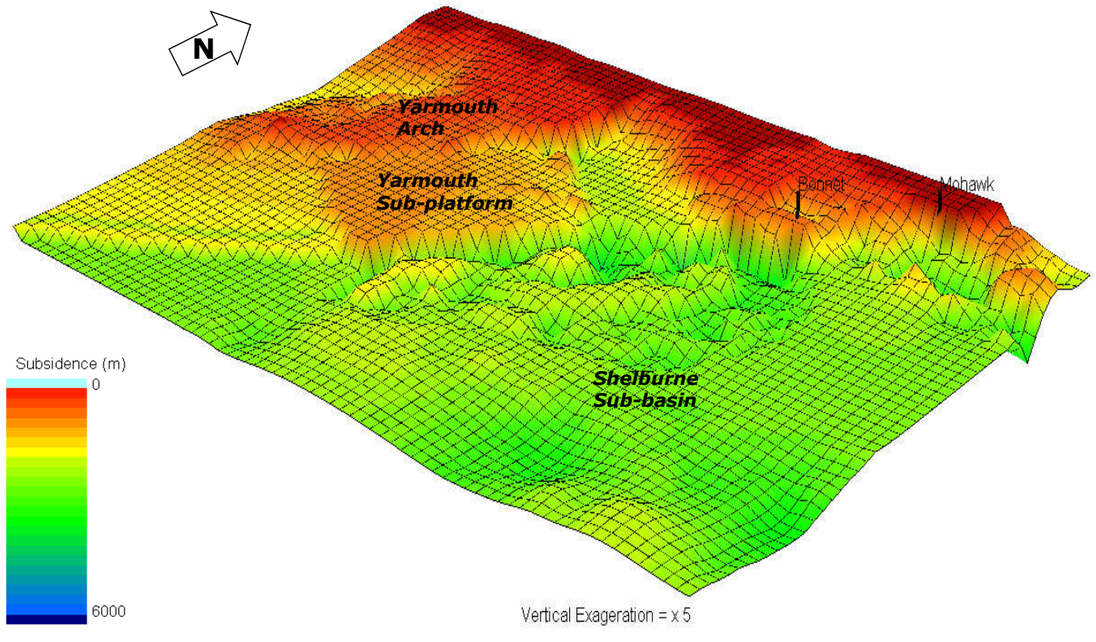


Figure 4. Subsidence map 200 Ma – 163 Ma; The total subsidence at this age was estimated following this formula: $Total\ Subsidence = Subidence\ (t-1) + SedThick(t) + Bathy\ (t) - Bathy\ (t-1)$; t=163 Ma; (t-1)=200

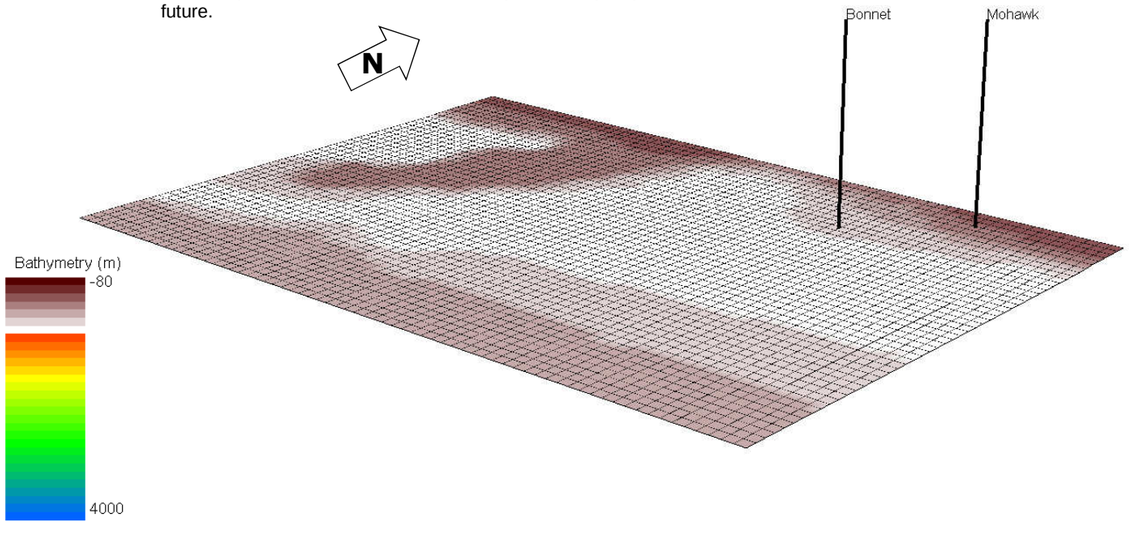


Figure 5. Initial Bathymetry for Dionisos at 200 Ma.

PL. 6.2.2 **J200 – J163 Interval**

STRATIGRAPHIC MODELLING - HETTANGIAN-OXFORDIAN SEQUENCE

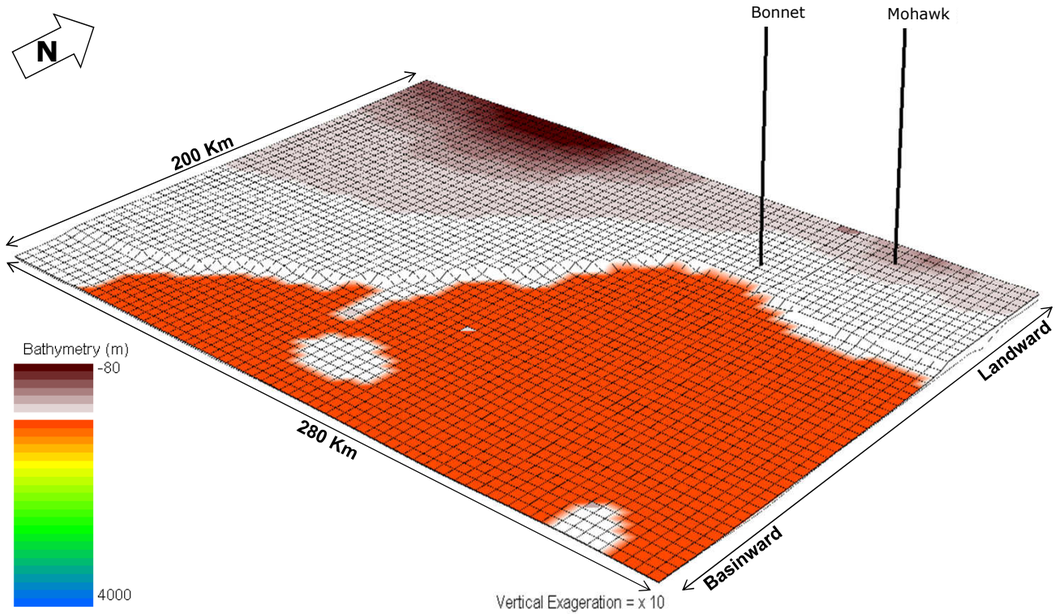
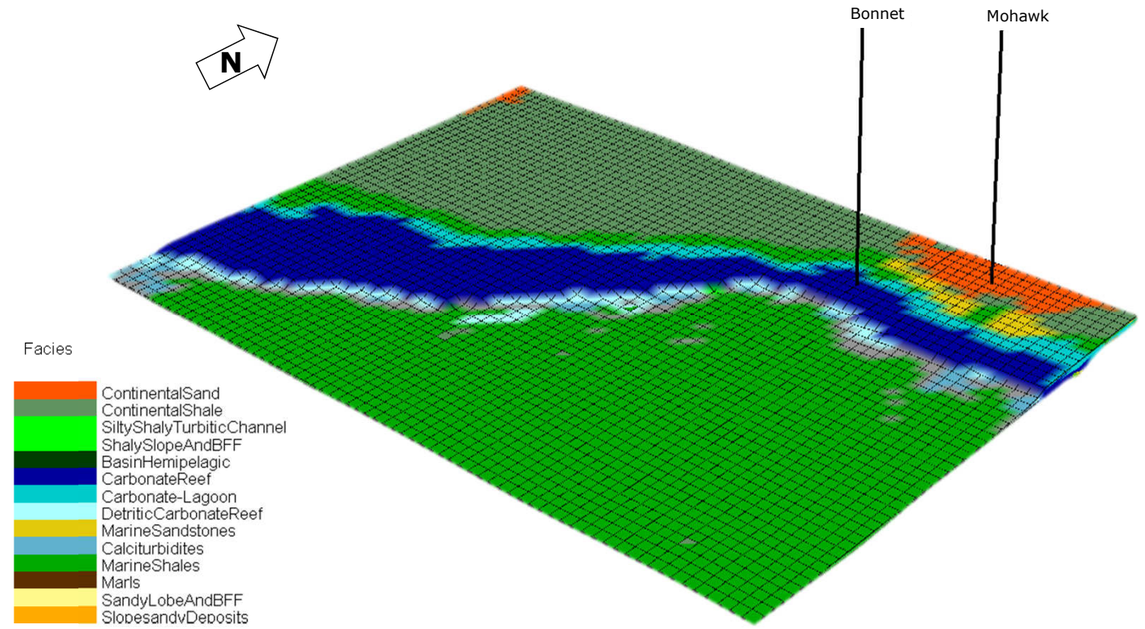


Figure 6. Bathymetry map at 197 Ma



This time step represent an early stage on the carbonate platform aggradation, but a differentiation between the future shelf and basin areas is already present.

Figure 7. Facies distribution at 197 Ma

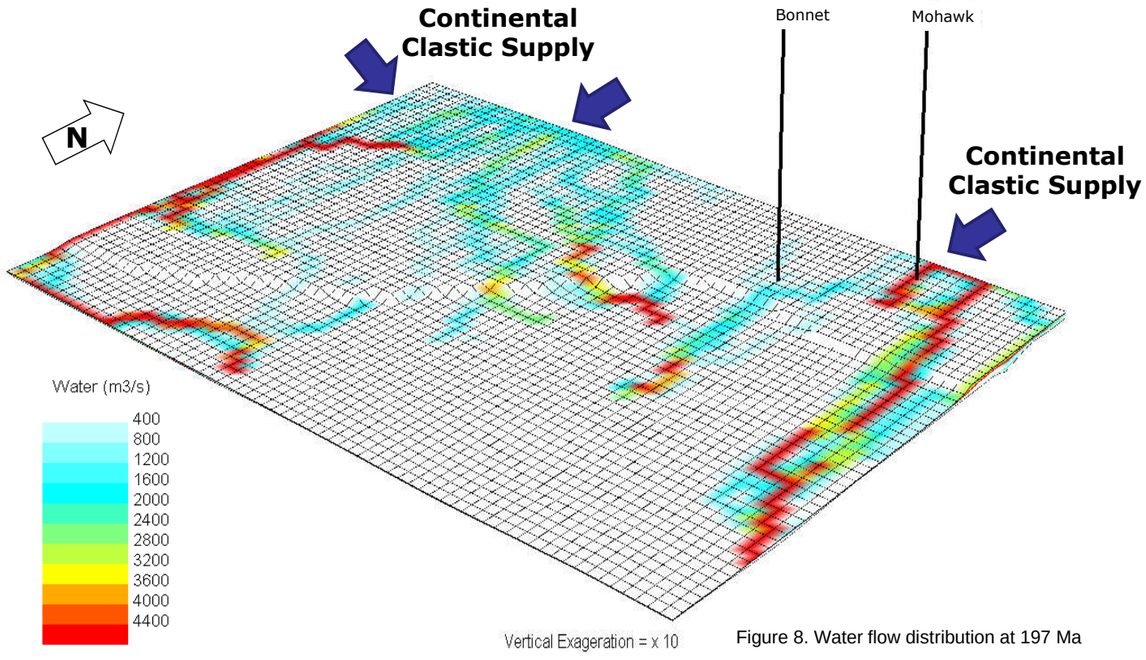


Figure 8. Water flow distribution at 197 Ma

✓ Sequence simulated: Post rift to Callovian

✓Age represented: Sinemurian.

✓Stratigraphic event: Transition from continental to marine conditions.

✓ The deposits are mainly representative of continental to marine water environments during the Sinemurian times. The aggradation of carbonates facies keeping pace with subsidence and eustatic changes allowed the onset of differentiation between the shelf and basin area.

✓The sediment supplies at this time correspond to fluvial systems located to the north of the simulation being preferentially concentrates to the northwest border of the model and close to the Mohawk Well position (Figure 8).

The average sand content of the sediment sources ranged from 20% to 35% in average.

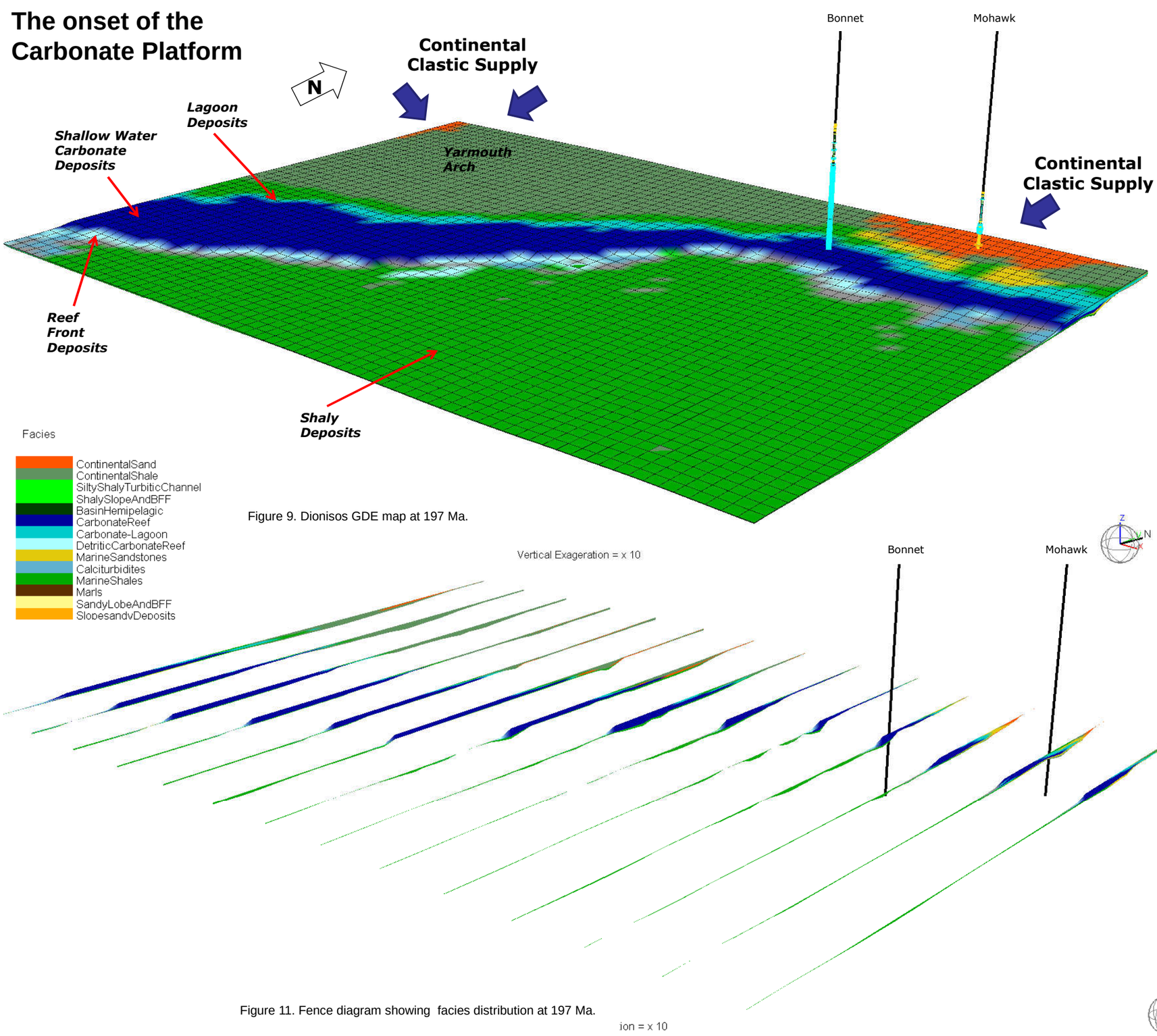


Figure 9. Dionisos GDE map at 197 Ma.

Figure 11. Fence diagram showing facies distribution at 197 Ma.

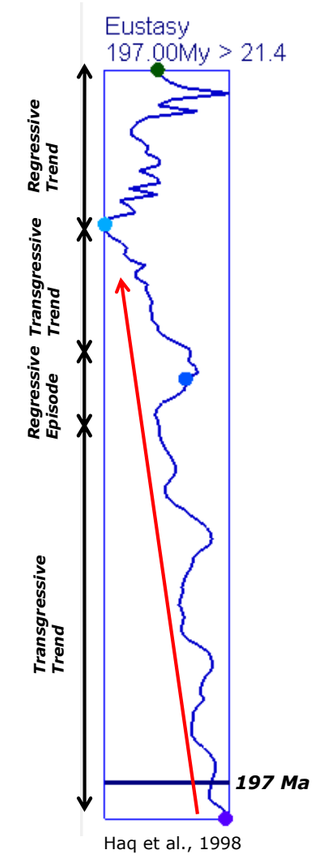


Figure 10. Eustatic curve at 197 Ma.

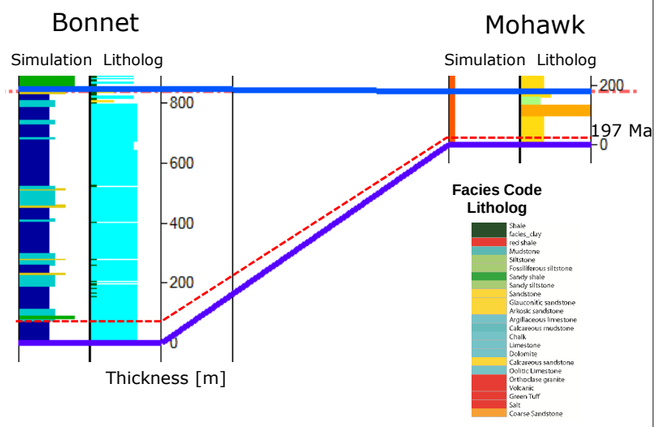


Figure 12. Well correlation between wells Bonnet and Mohawk at 197 Ma.

PL. 6.2.4 **GDE Maps and Dionisos Results : Fence Diagram and 3D View – Age 197 Ma**

STRATIGRAPHIC MODELLING - HETTANGIAN-OXFORDIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

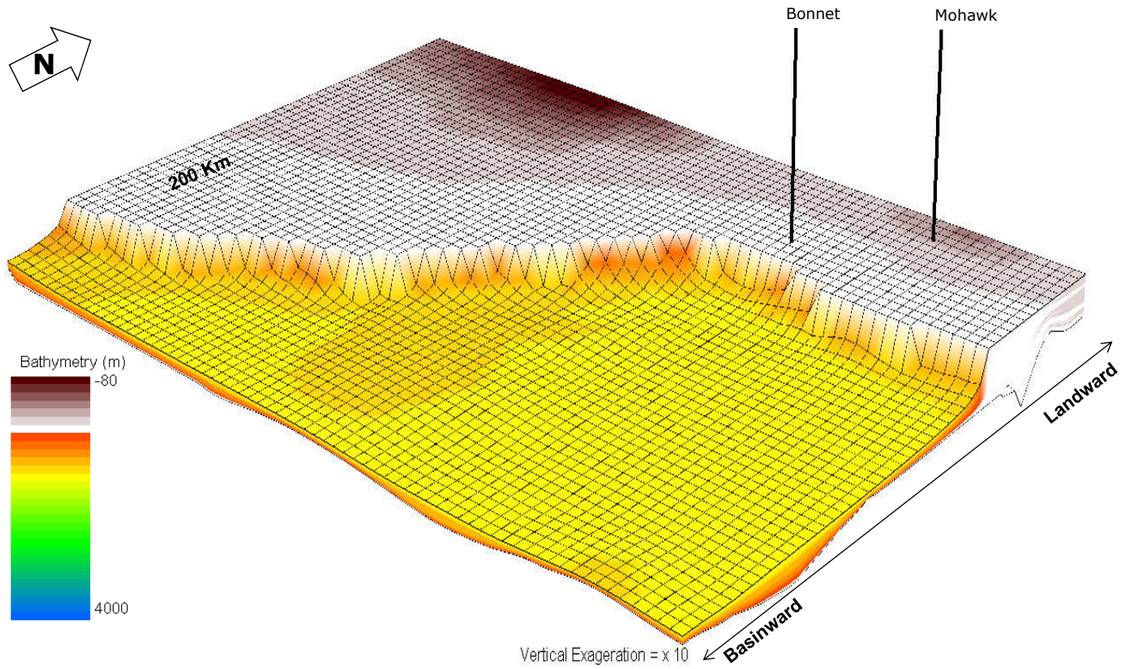


Figure 13. Bathymetry map at 181.5 Ma

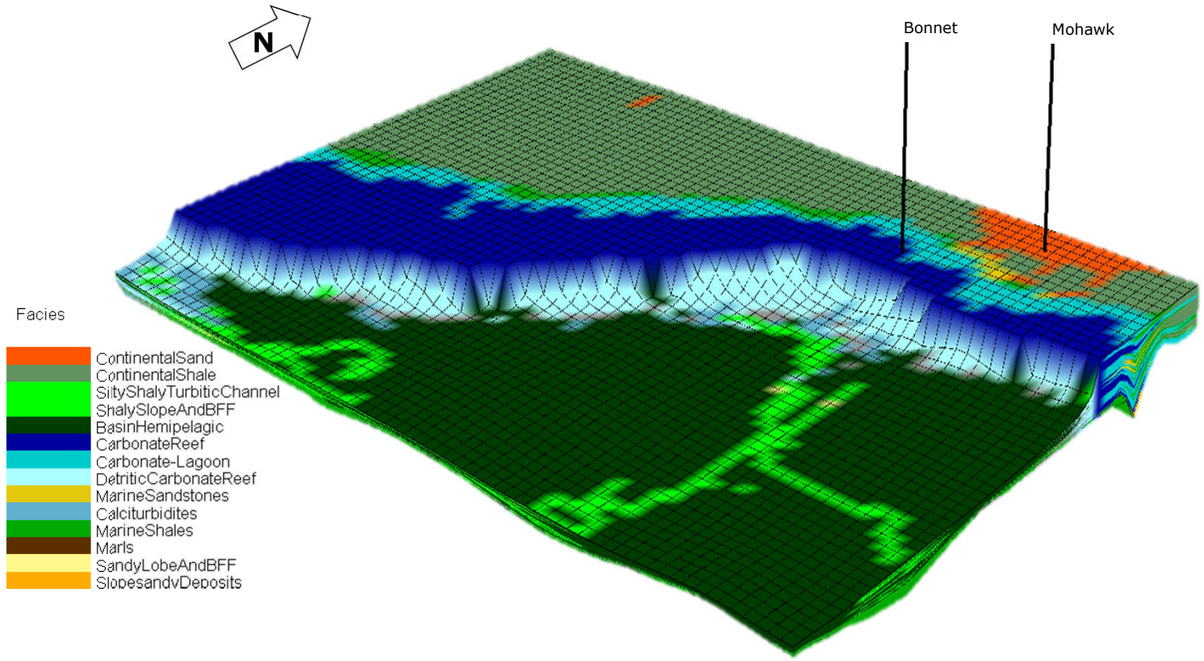


Figure 14. Facies distribution at 181.5 Ma

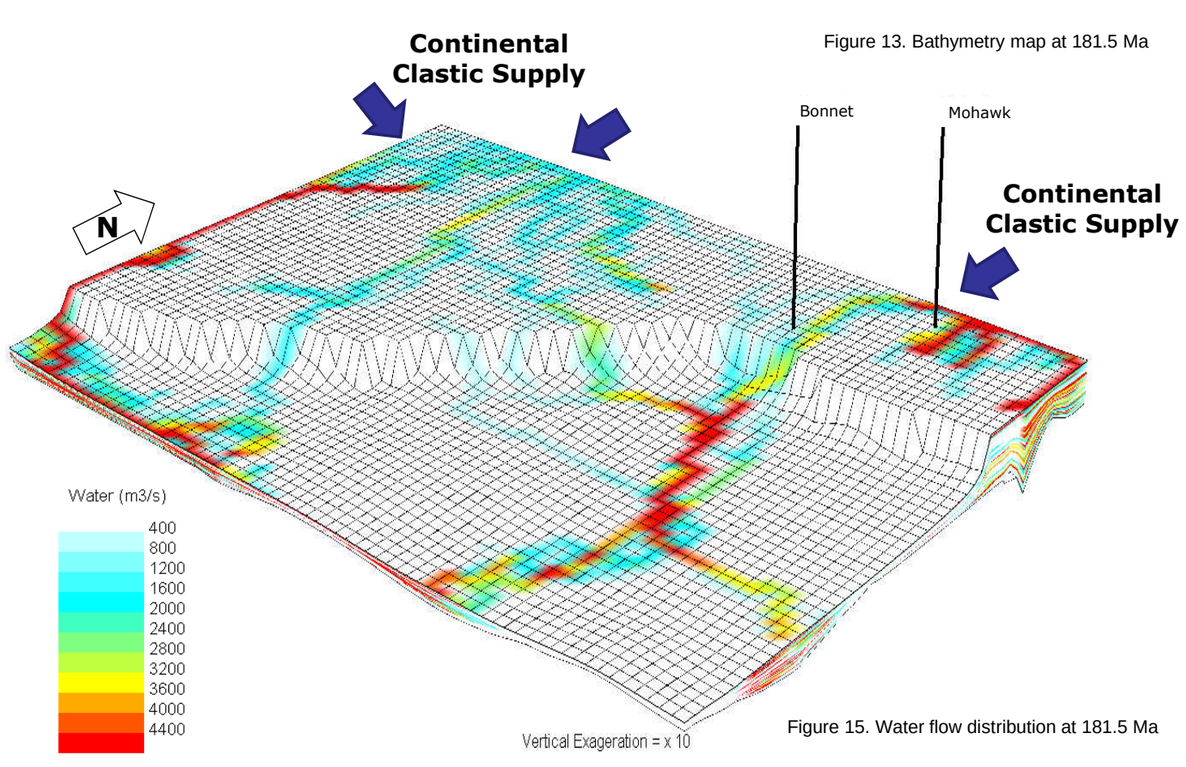


Figure 15. Water flow distribution at 181.5 Ma

✓ Sequence simulated: Post rift to Toarcian

✓Age represented: Toarcian.

✓Stratigraphic event: Carbonate shelf aggradation and shaly turbidites supply to the Shelburne Sub-basin.

✓ The deposits are mainly representative of continental to shallow marine facies in the back reef. The aggradation of carbonates facies kept pace with subsidence and marine transgression.

✓The sediment supplies at this time correspond to fluvial systems located to the north of the simulation being preferentially concentrates to the northwest border of the model and close to the Mohawk Well position (Figure 15).

The average sand content of the sediment sources ranged from 20% to 35% in average.

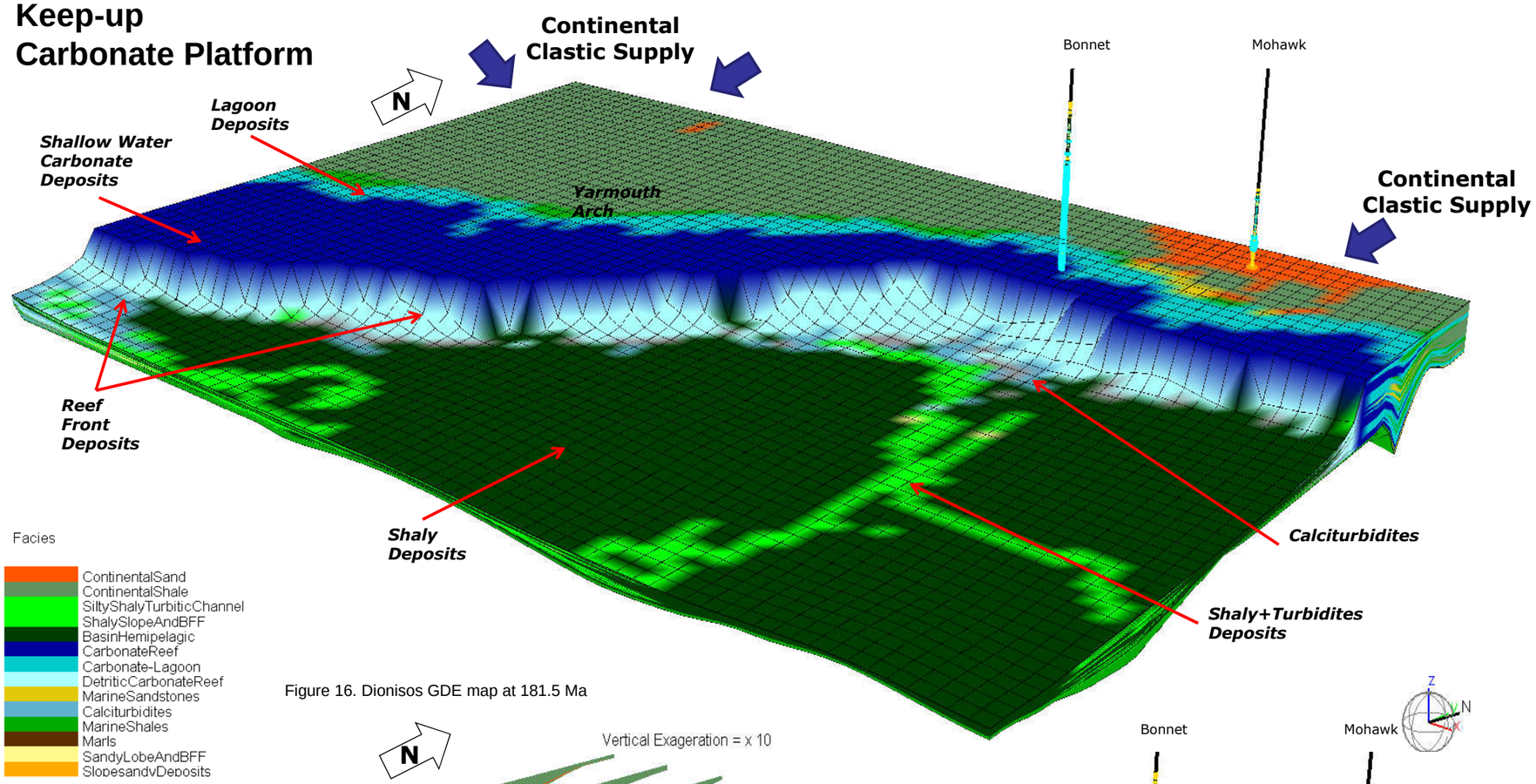


Figure 16. Dionisos GDE map at 181.5 Ma

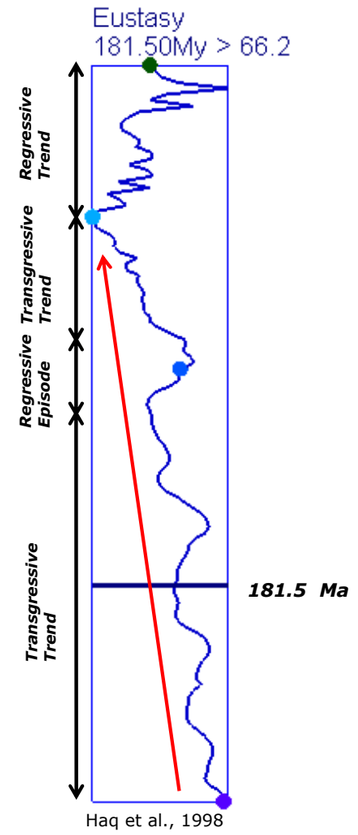


Figure 17. Eustatic curve at 181.5 Ma.

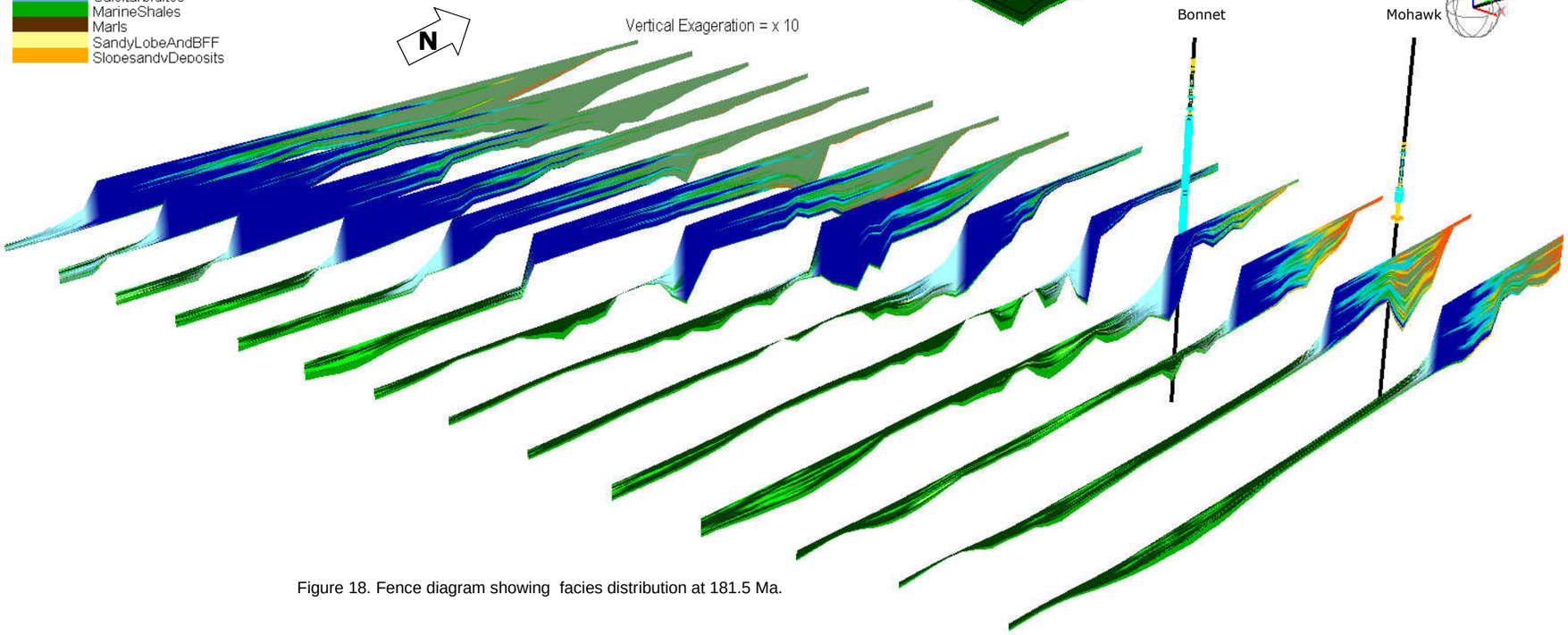


Figure 18. Fence diagram showing facies distribution at 181.5 Ma.

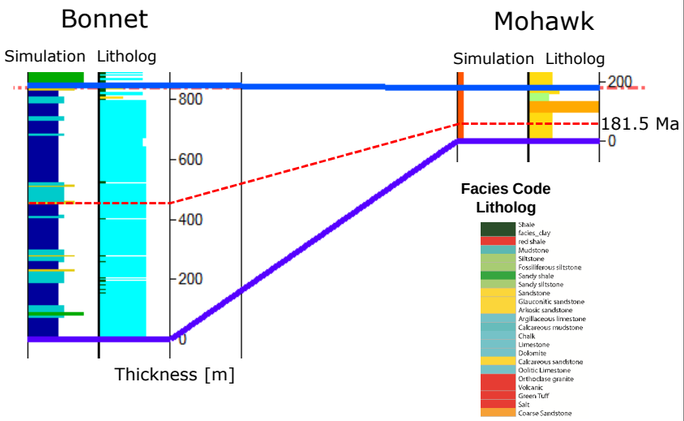


Figure 19. Well correlation between wells Bonnet and Mohawk at 181.5 Ma.

PL. 6.2.6 **GDE Maps and Dionisos Results : Fence Diagram and 3D View – Age 181.5 Ma**

STRATIGRAPHIC MODELLING - HETTANGIAN-OXFORDIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

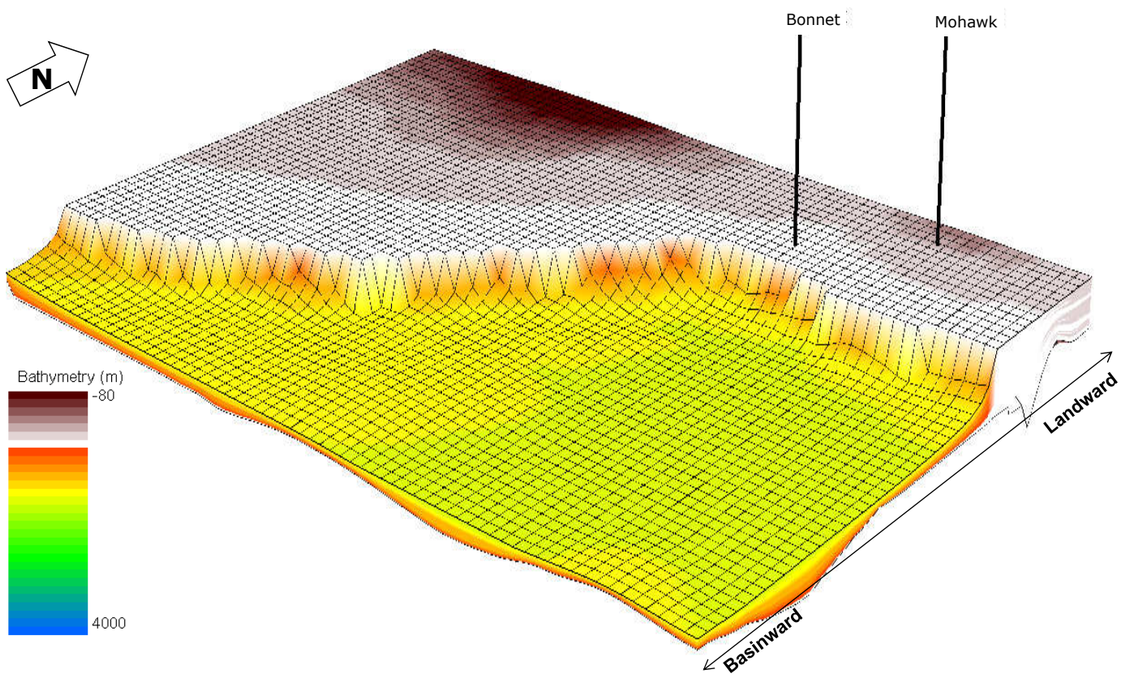


Figure 20. Bathymetry map at 179 Ma

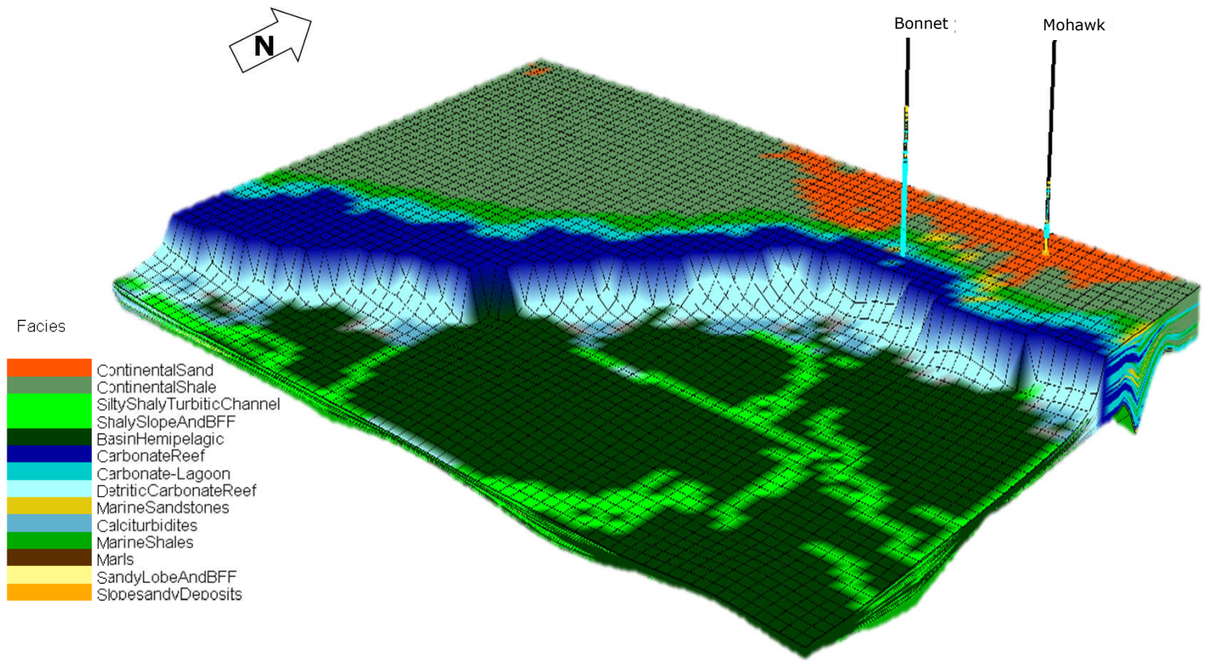


Figure 21. Facies distribution at 179 Ma

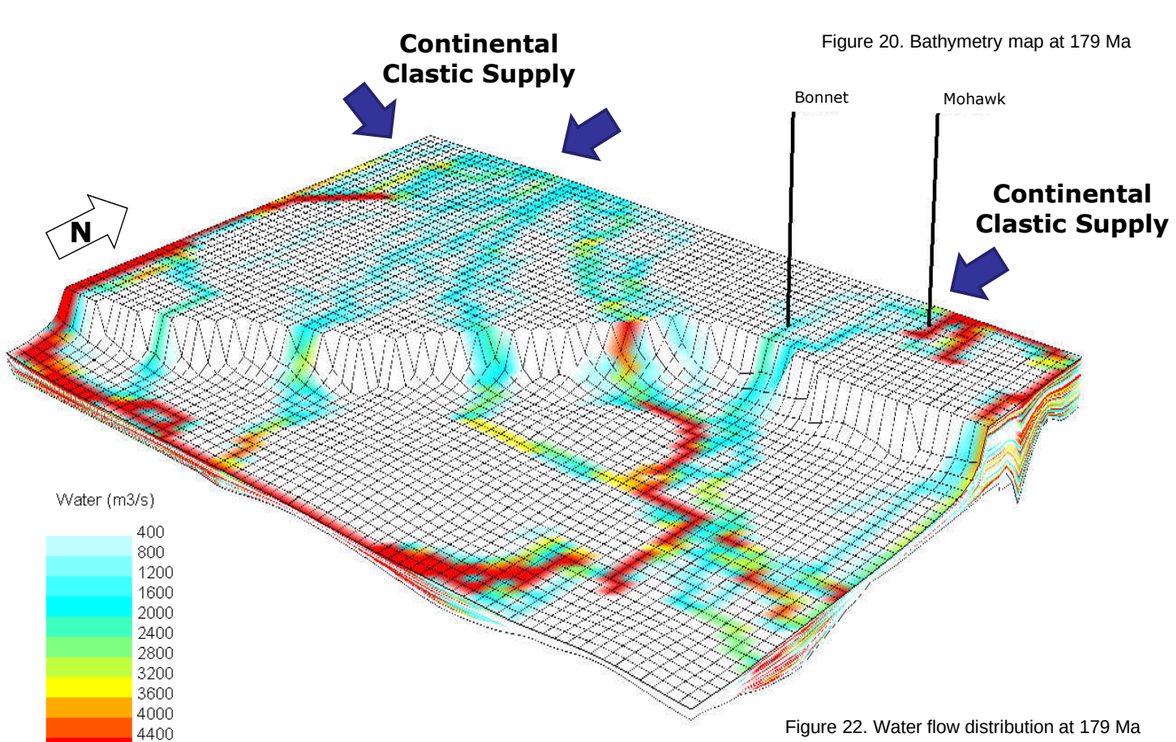


Figure 22. Water flow distribution at 179 Ma

✓ Sequence simulated: Post rift to Toarcian

✓Age represented: Toarcian.

✓Stratigraphic event: Carbonate shelf aggradation and shaly turbidites supply to the Shelburne Sub-basin.

✓ The deposits are mainly representative of continental to shallow marine facies in the back reef area. The aggradation of carbonates facies kept pace with subsidence and marine trangression.

✓The sediment supplies at this time correspond to fluvial systems located to the north of the simulation being preferentially concentrates to the northwest border of the model and close to the Mohawk Well position (Figure 22).

The average sand content of the sediment sources ranged from 20% to 35% in average.

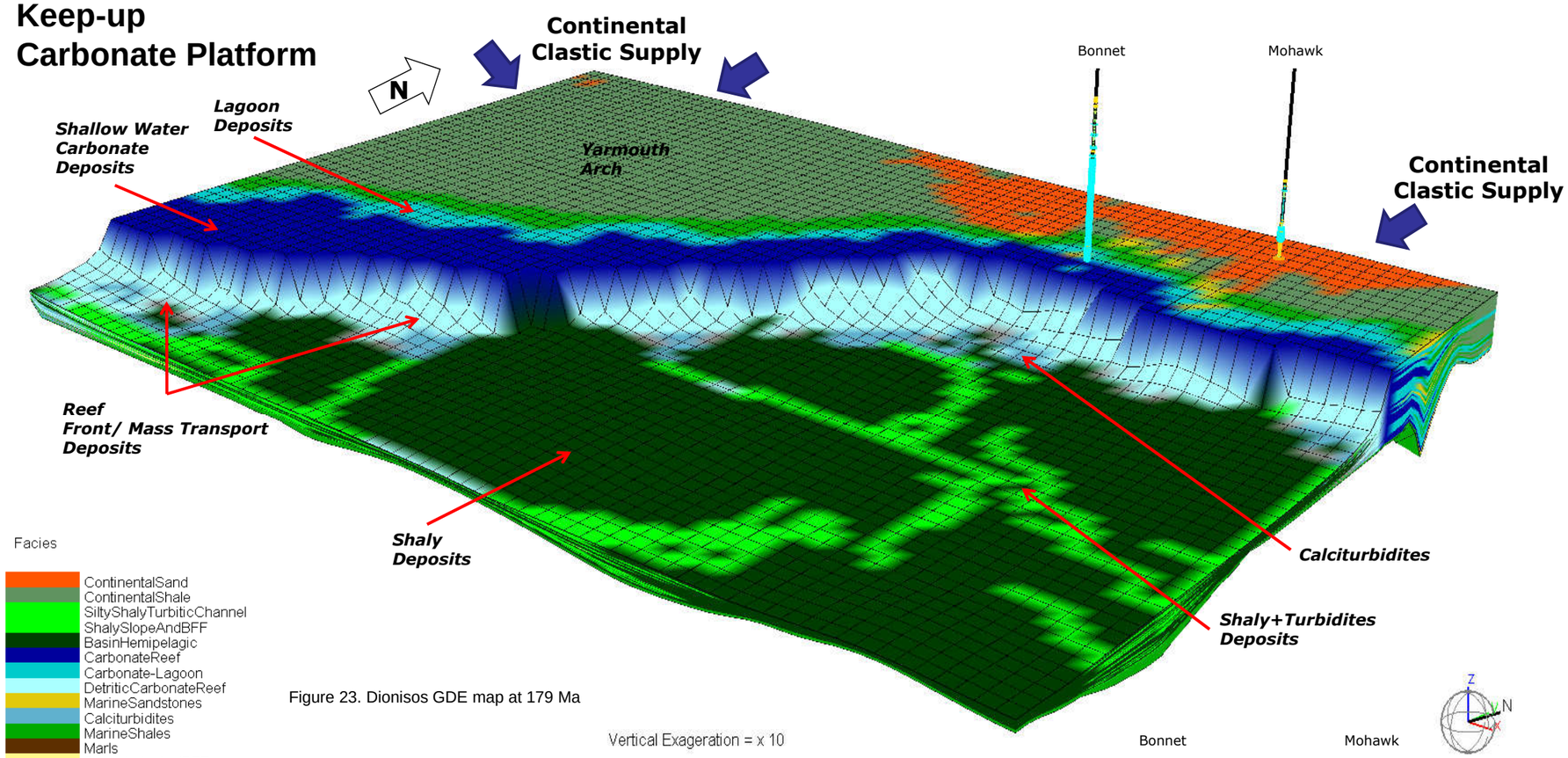


Figure 23. Dionisos GDE map at 179 Ma

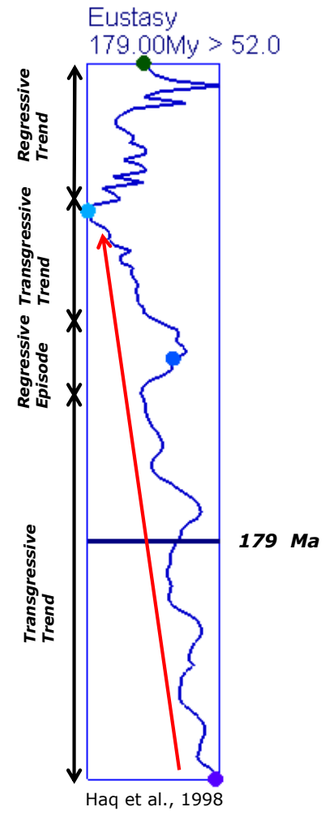


Figure 24. Eustatic curve at 179 Ma.

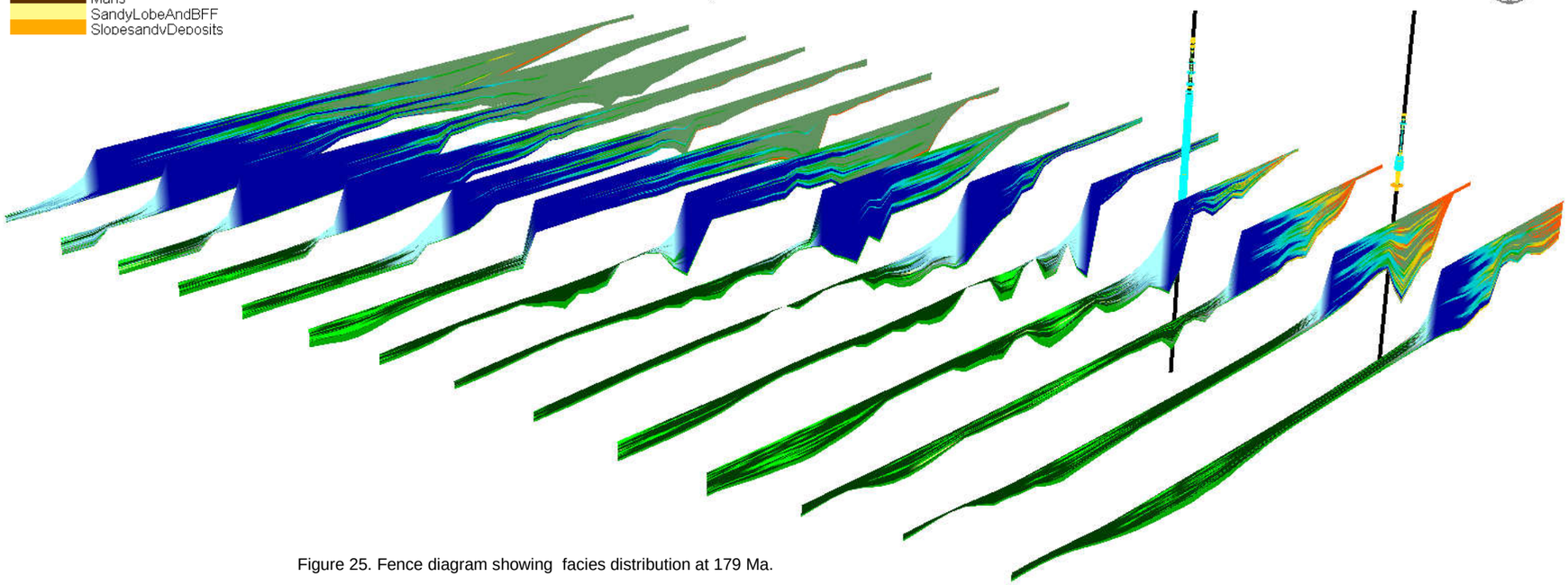


Figure 25. Fence diagram showing facies distribution at 179 Ma.

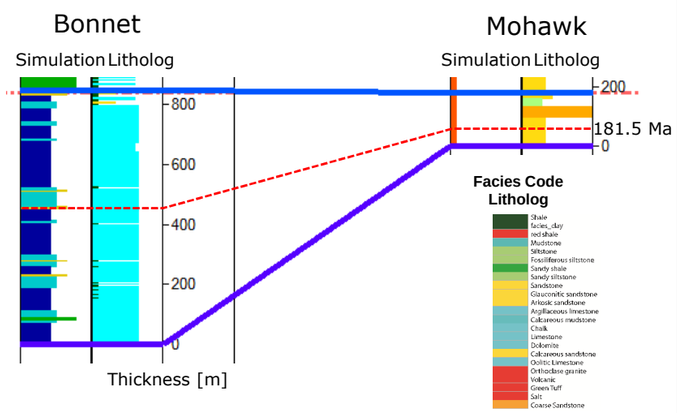


Figure 26. Well correlation between wells Bonnet and Mohawk at 179 Ma.

PL. 6.2.8 **GDE Maps and Dionisos Results : Fence Diagram and 3D View – Age 179 Ma**

STRATIGRAPHIC MODELLING - HETTANGIAN-OXFORDIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

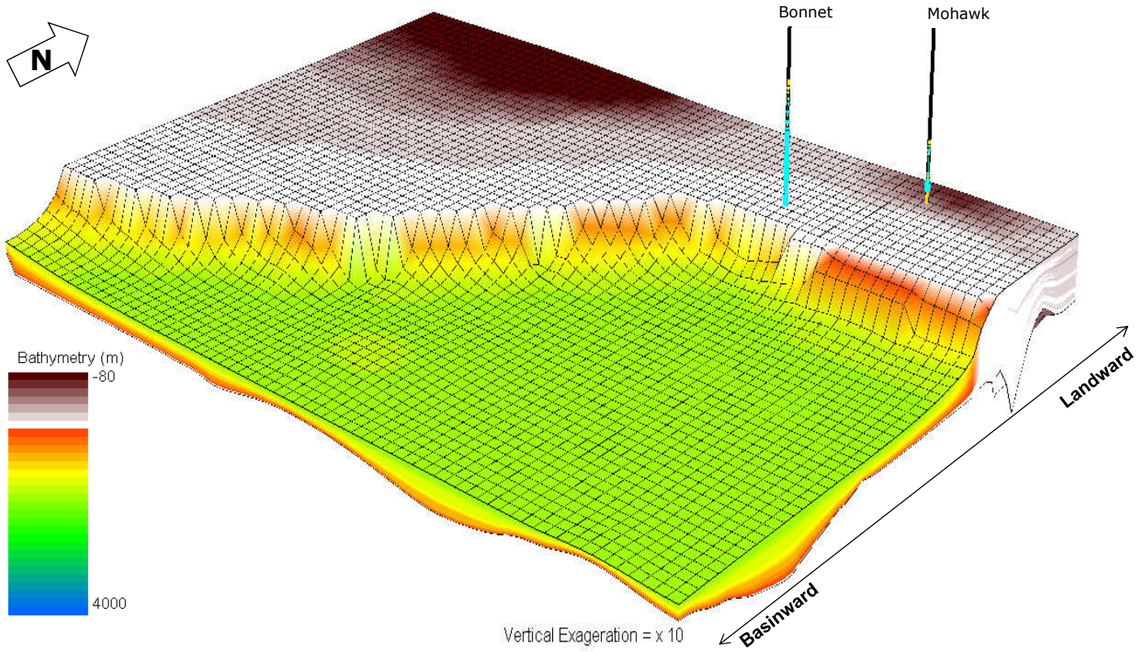


Figure 27. Bathymetry map at 170 Ma

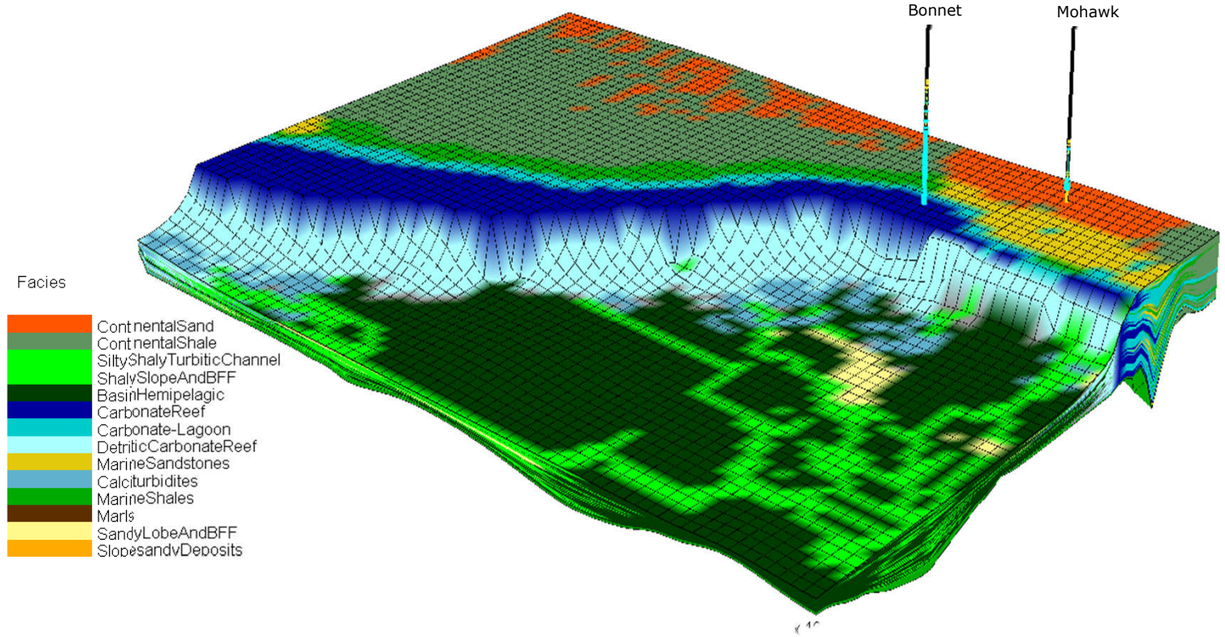


Figure 28. Facies distribution at 170 Ma

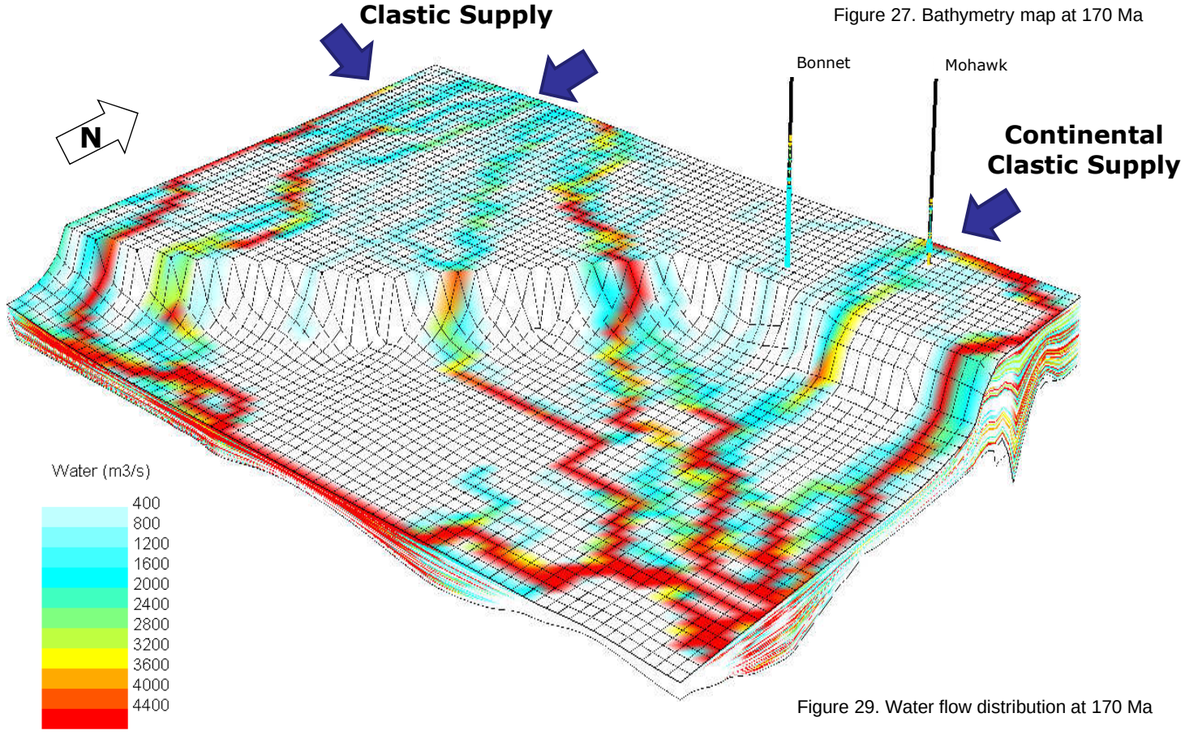


Figure 29. Water flow distribution at 170 Ma

✓ Sequence simulated: Post rift to Bajocian

✓Age represented: Bajocian.

✓Stratigraphic event: Carbonate shelf aggradation and shaly turbidites supply to the Shelburne Sub-basin.

✓ The deposits are mainly representative of continental to shallow marine facies in the back reef area. The aggradation of carbonates facies kept pace with subsidence and marine transgression. First sandy turbidites start to be present in the basin area (Figure 28)

✓The sediment supplies at this time correspond to fluvial systems located to the north of the simulation being preferentially concentrates to the northwest border of the model and close to the Mohawk Well position (Figure 29).

The average sand content of the sediment sources ranged from 20% to 35% in average.

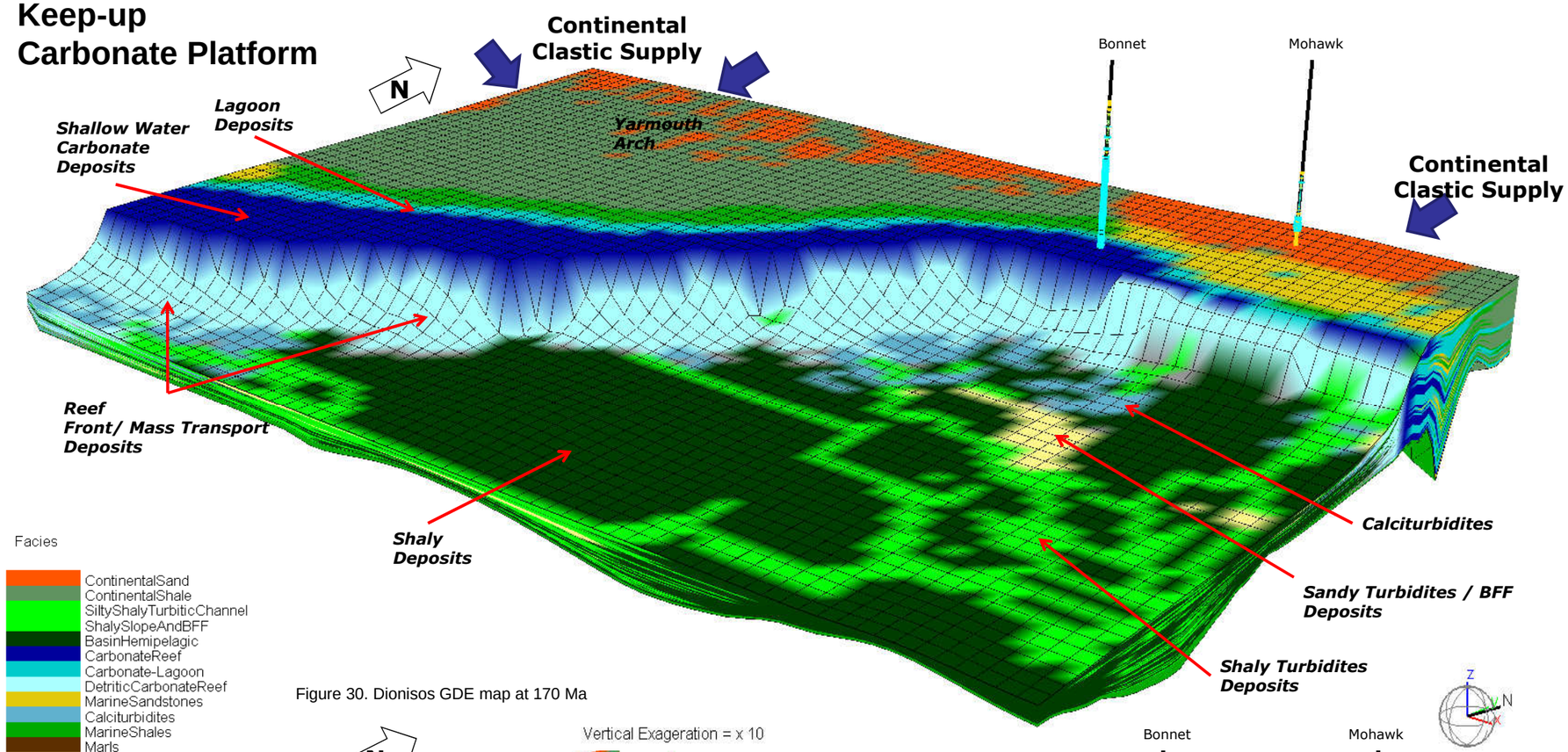


Figure 30. Dionisos GDE map at 170 Ma

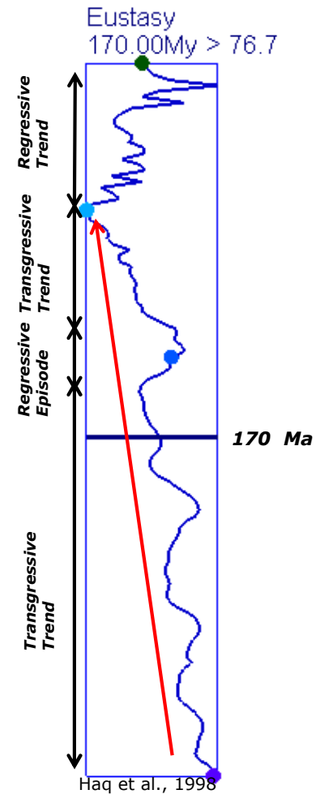


Figure 31. Eustatic curve at 170 Ma.

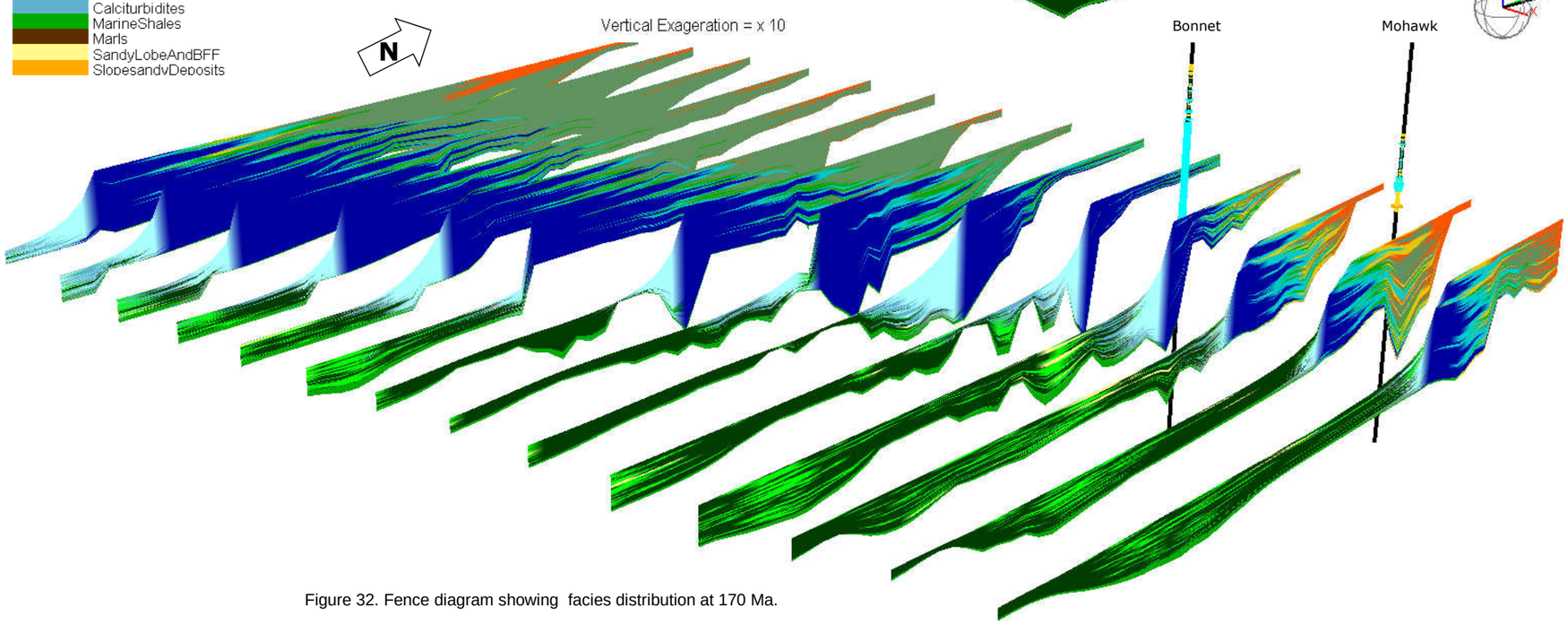


Figure 32. Fence diagram showing facies distribution at 170 Ma.

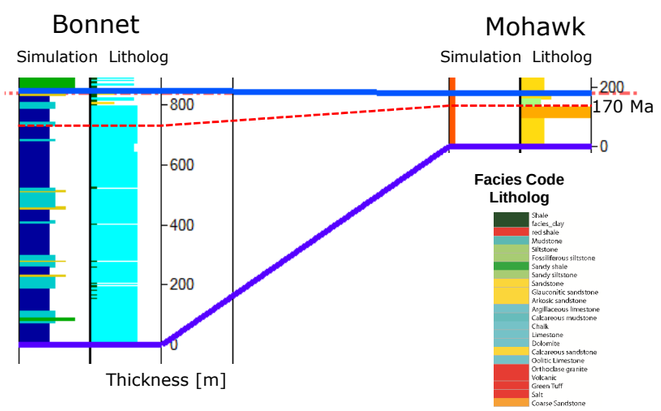


Figure 33. Well correlation between wells Bonnet and Mohawk at 170 Ma.

STRATIGRAPHIC MODELLING - HETTANGIAN-OXFORDIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

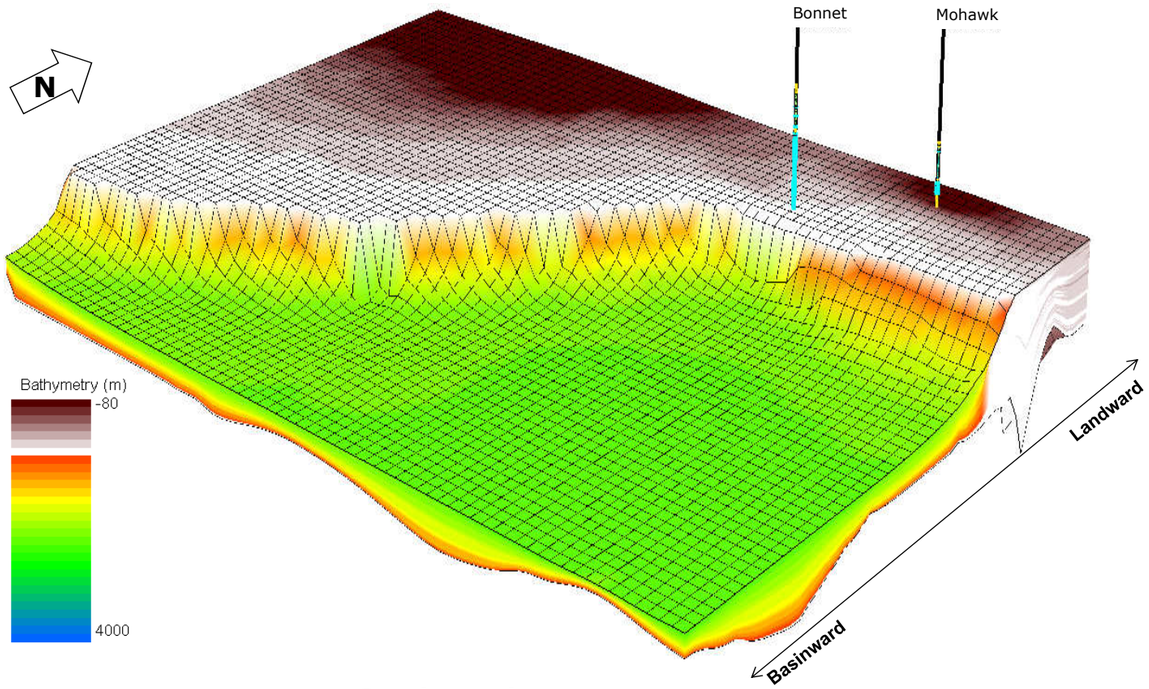


Figure 34. Bathymetry map at 163.5 Ma

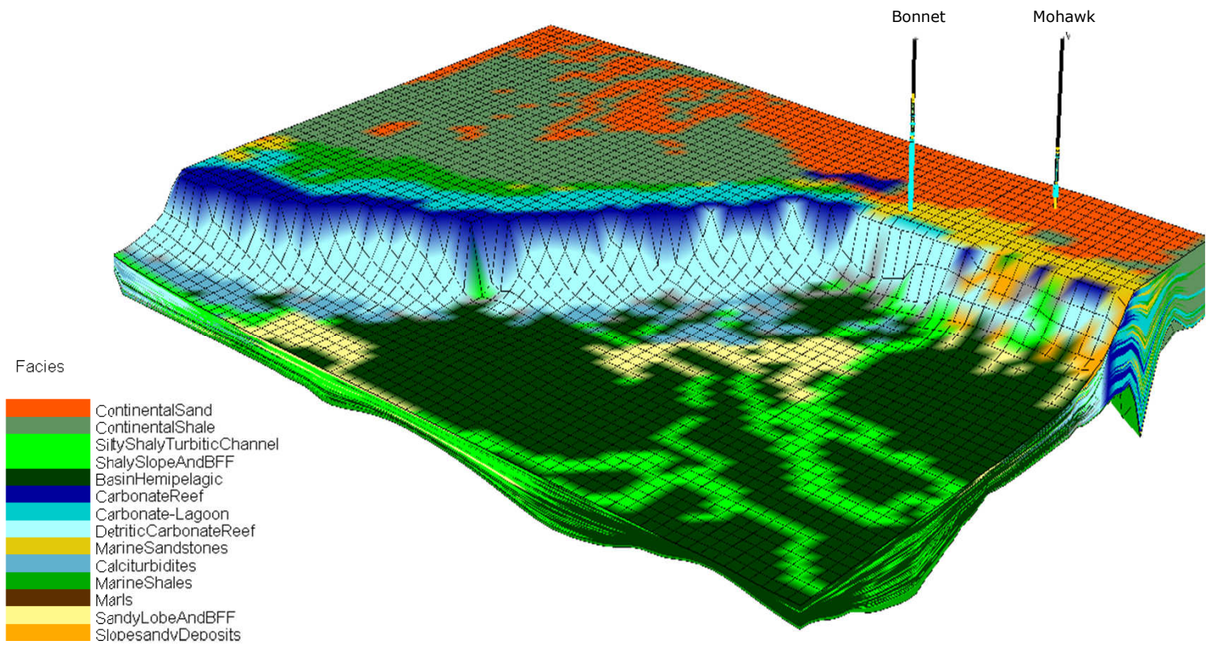


Figure 35. Facies distribution at 163.5 Ma

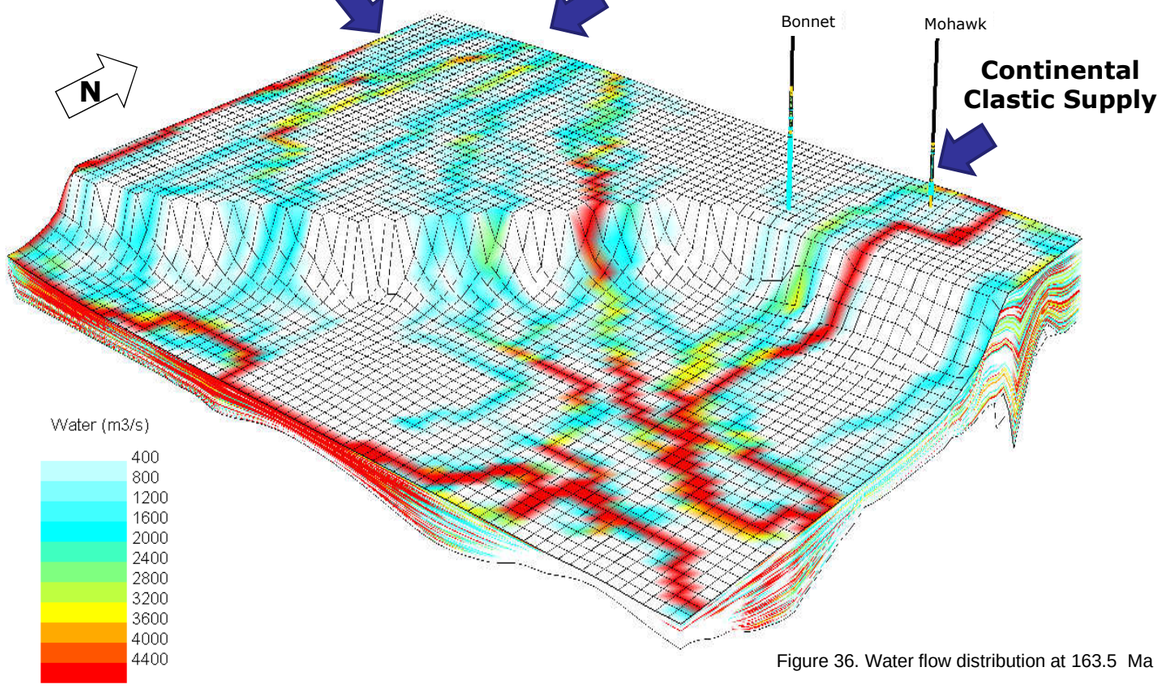


Figure 36. Water flow distribution at 163.5 Ma

✓ Sequence simulated: Post rift to Oxfordian

✓Age represented: Oxfordian.

✓Stratigraphic event: Carbonate shelf aggradation and turbidites supply to the Shelburne Sub-basin.

✓ The deposits are mainly representative of continental to shallow marine facies in the back reef area. The aggradation of carbonates facies kept pace with subsidence and marine transgression. Sandy turbidites and calciturbidites start to extend all along the base of the slope – basin floor (Figure 35)

✓The sediment supplies at this time correspond to fluvial systems located to the north of the simulation being preferentially concentrates to the northwest border of the model and close to the Mohawk Well position (Figure 36).

The average sand content of the sediment sources ranged from 20% to 35% in average.

STRATIGRAPHIC MODELLING - HETTANGIAN-OXFORDIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

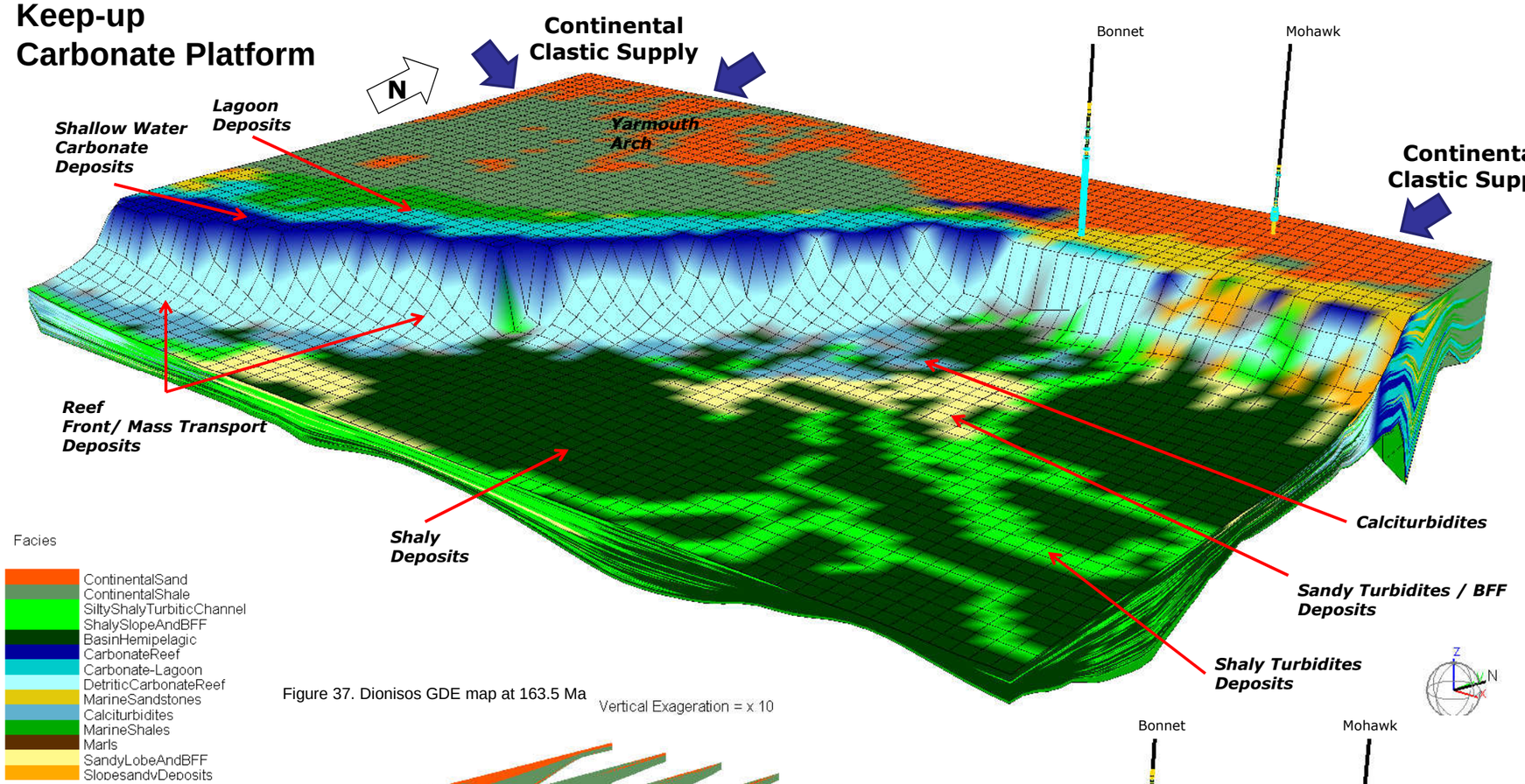


Figure 37. Dionisos GDE map at 163.5 Ma

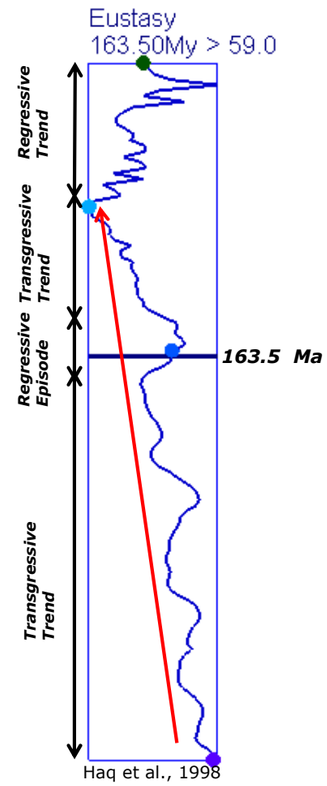


Figure 38. Eustatic curve at 163.5 Ma.

Figure 39. Fence diagram showing facies distribution at 163.5 Ma.

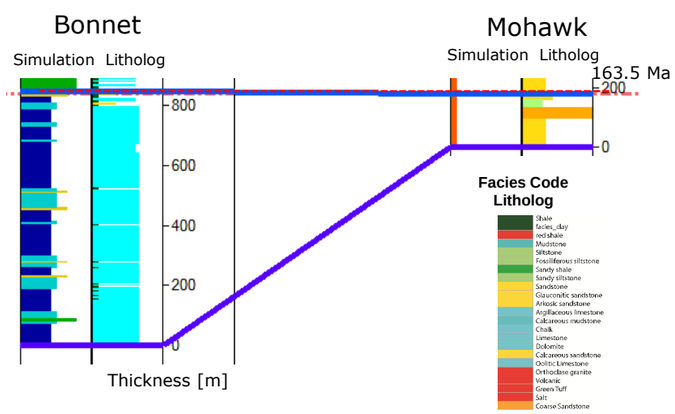


Figure 40. Well correlation between wells Bonnet and Mohawk at 163.5 Ma.

PL. 6.2.12 **GDE Maps and Dionisos Results : Fence Diagram and 3D View – Age 163.5 Ma**

CHAPTER 6.3

STRATIGRAPHIC MODELING
OXFORDIAN-TITHONIAN SEQUENCE

STRATIGRAPHIC MODELLING- CALLOVIAN-TITHONIAN SEQUENCE

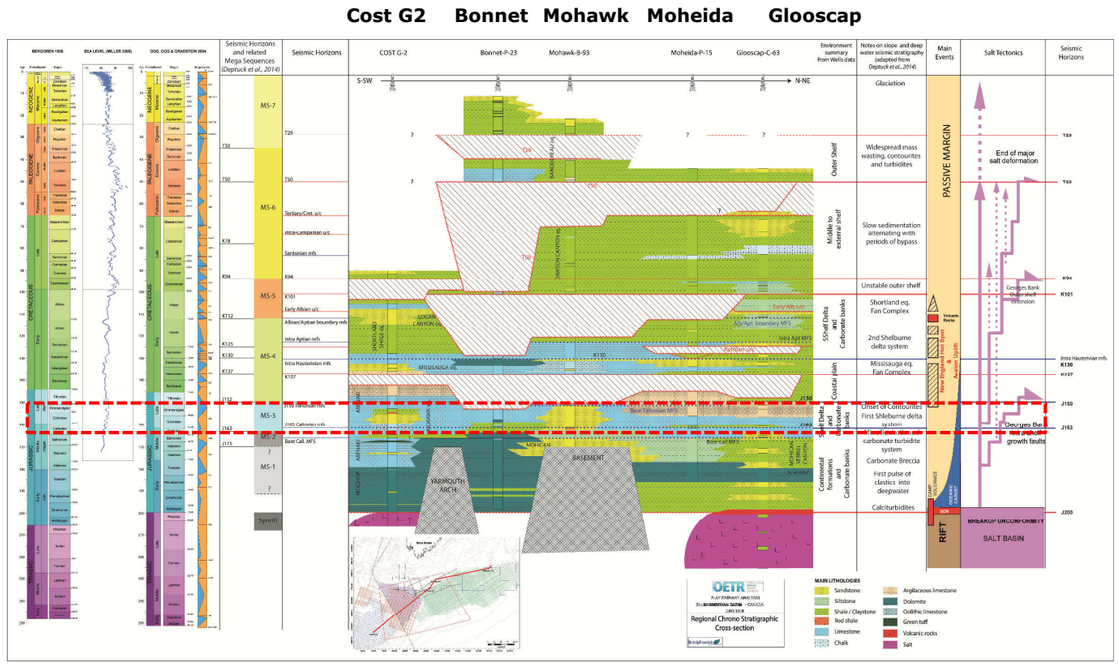


Figure 41. Stratigraphic Cross-Section across the study area. Dotted red line represents the period of time showed in this section.

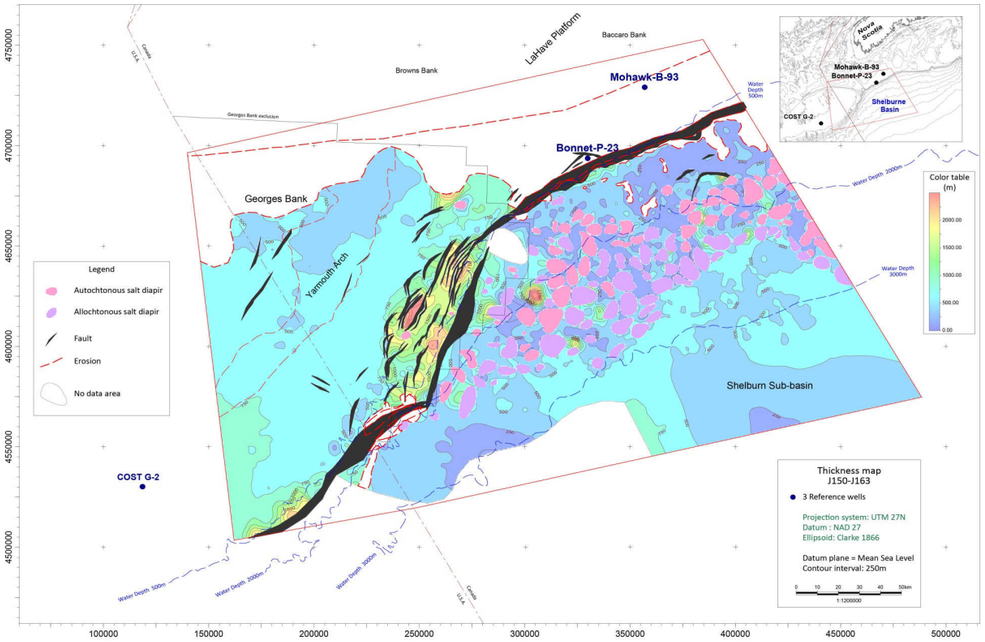


Figure 42. Isopach map J163 – J150.

The interval J163–J150 encompasses the middle to upper Jurassic. The top and bottom of this interval correspond to the position of the Callovian and Tithonian source rocks. During this period of time an important siliciclastic flux reached the shelf area. These deposits correspond to deltaic facies named "Shelburne Jurassic Delta". The main depocenter was located in the western side of the Yarmouth Sub-platform filling the space generated by an active listric fault system in this area

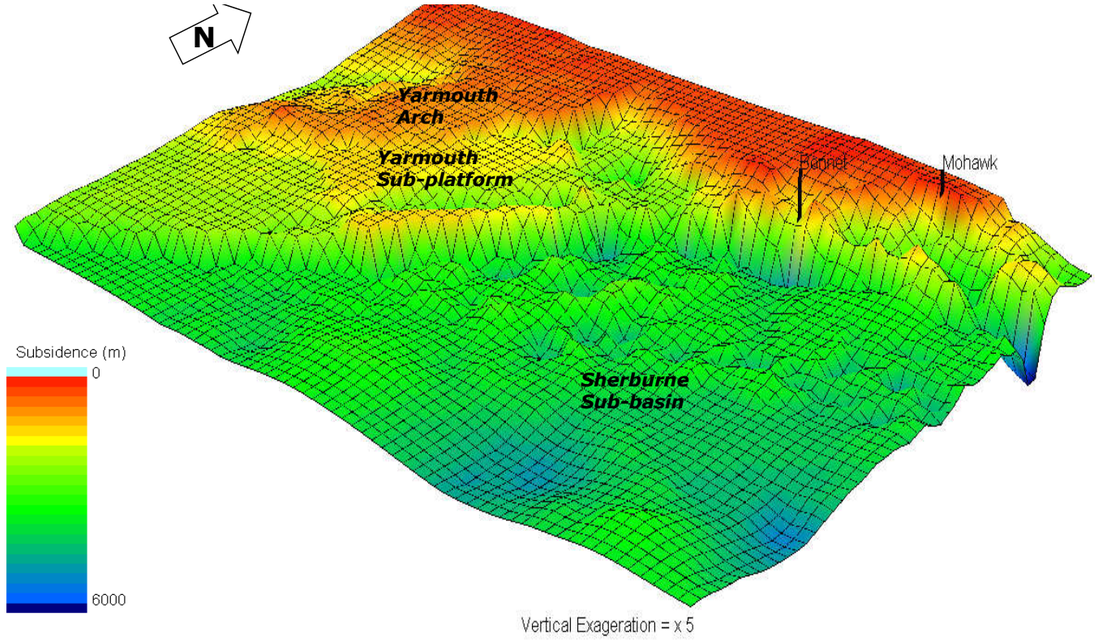


Figure 43. The total subsidence at this age was estimated following this formula: $Total\ Subsidence = Subidence\ (t-1) + SedThick(t) + Bathy\ (t) - Bathy\ (t-1)$; t=150 Ma; (t-1)=163

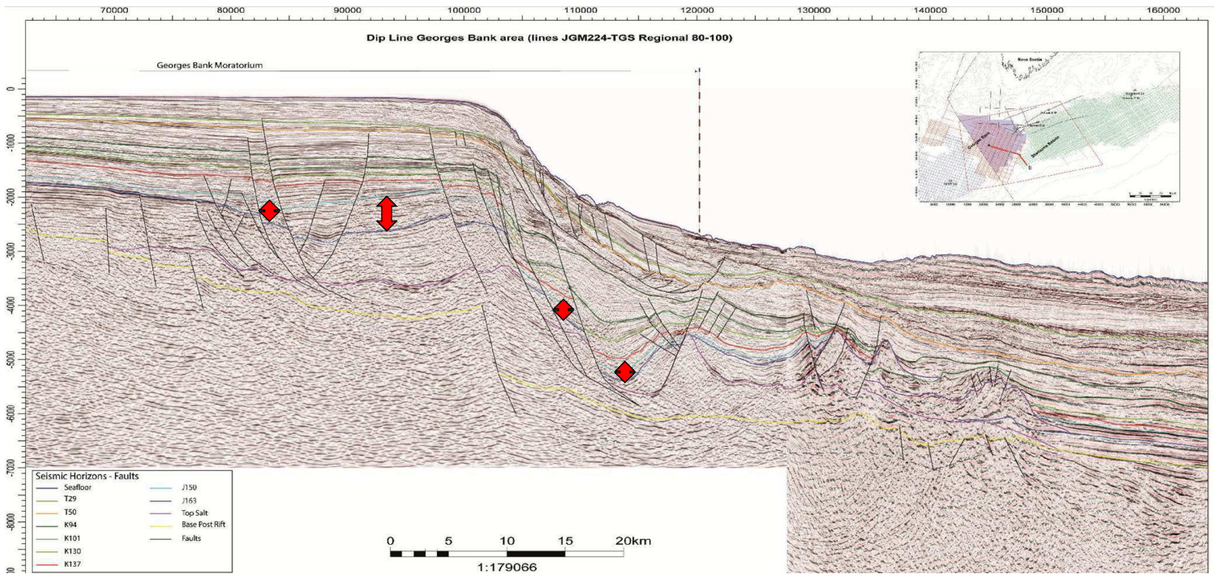


Figure 44. Seismic section (lines JGM 224 – TGS regional 80-100) across the Yarmouth Sub-platform and the Shelburne Sub-basin showing the interval 163 – 150 Ma.

STRATIGRAPHIC MODELLING- OXFORDIAN-TITHONIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

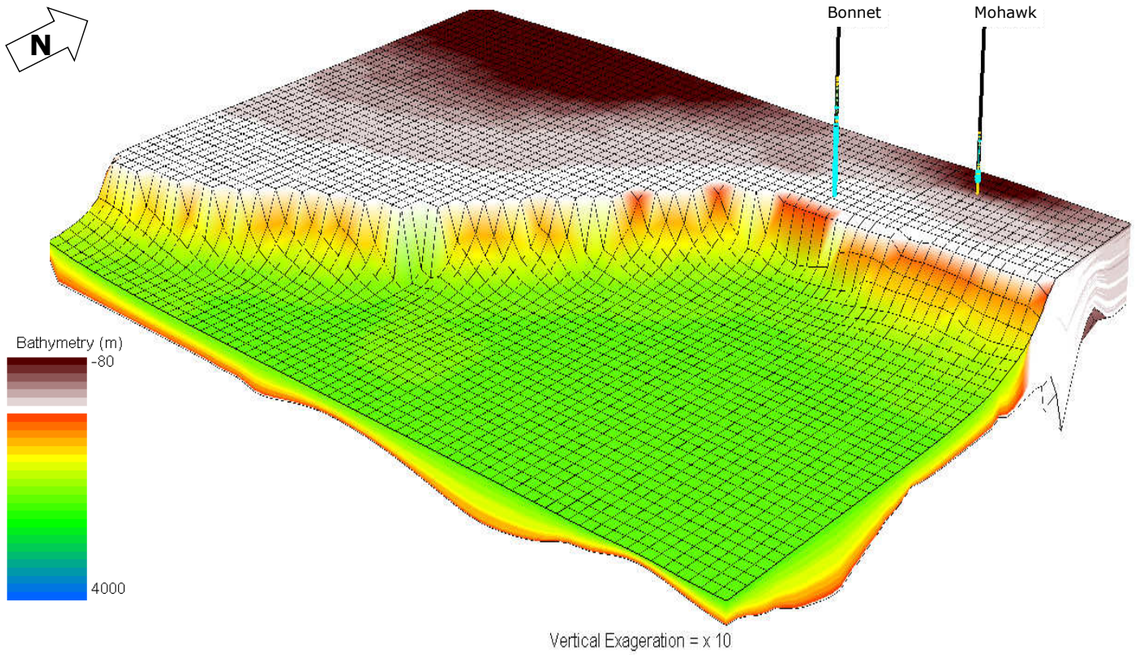


Figure 45. Bathymetry map at 163 Ma

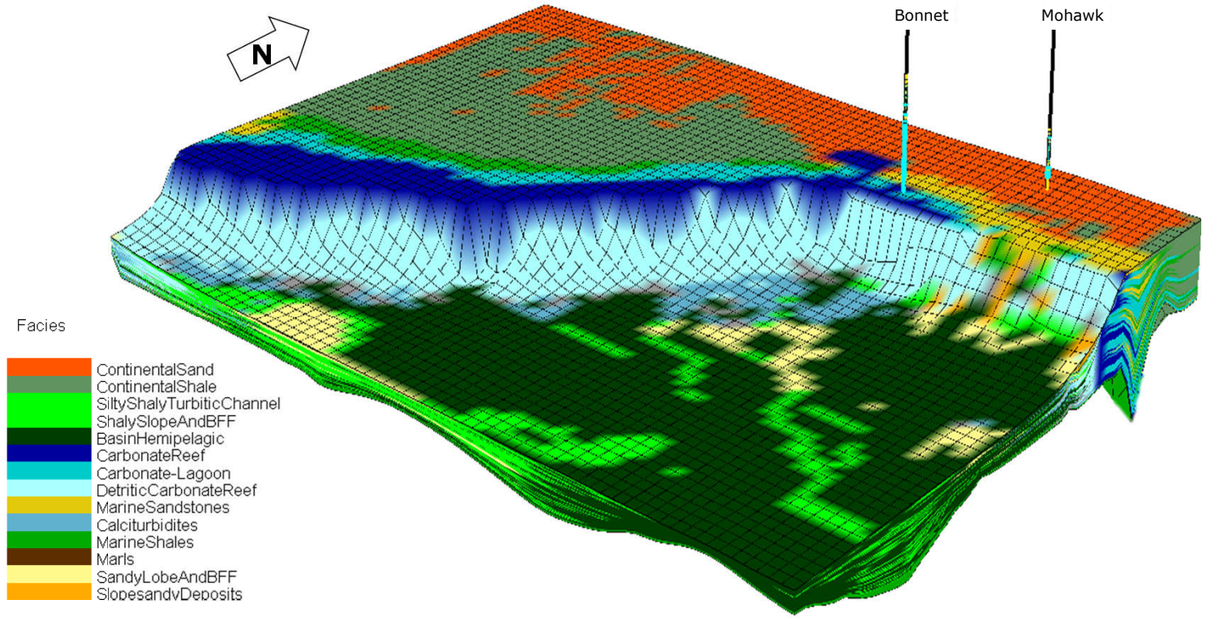


Figure 46. Facies distribution at 163 Ma

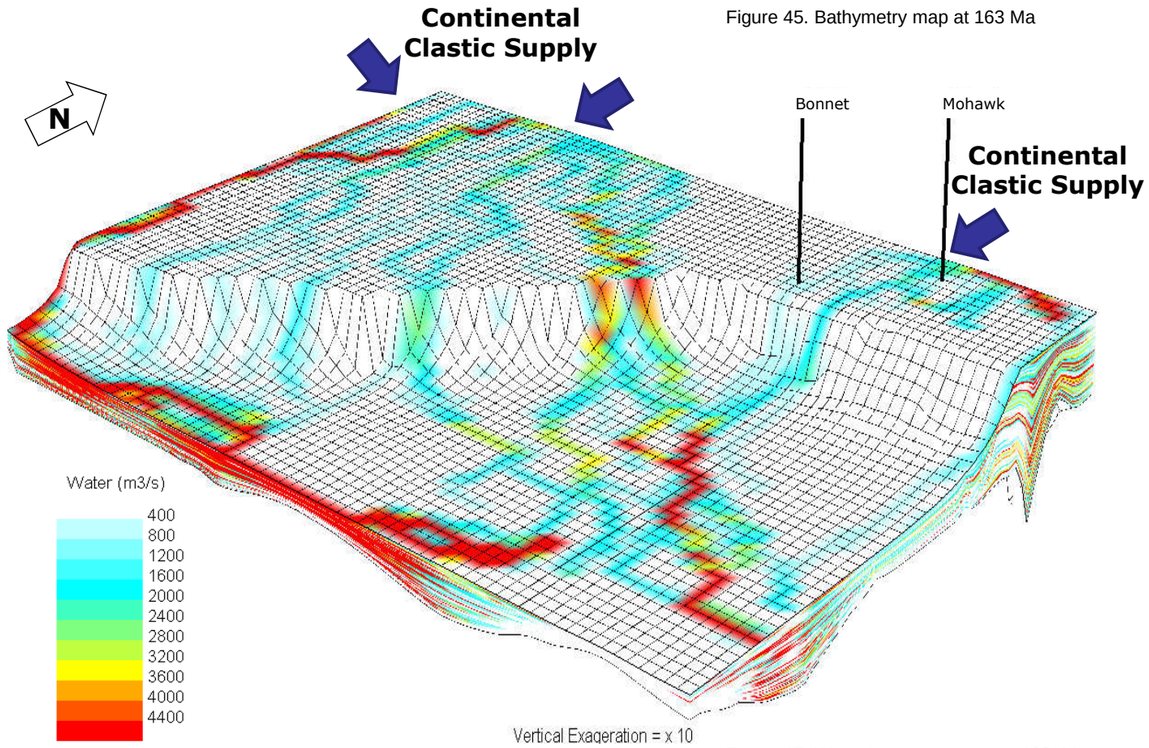


Figure 47. Water flow distribution at 163 Ma

✓ Sequence simulated: Hettangian - Tithonian

✓Age represented: Oxfordian.

✓Stratigraphic event: Carbonate shelf aggradation and turbidites supply to the Shelburne Sub-basin.

✓ During this period carbonates and siliciclastic deposits are dominant on the shelf, carbonate debris flow deposits are mostly present at the slope toe (probably breccia deposits as those identified to the west of the Yucatan platform in the Cretaceous interval of the Cantarell Field). Basinward, sedimentary deposits are dominated by calciturbidites and clastic turbidites more common to the top of the sequence (associated to the 163 Ma surface).

✓The sediment supplies at this time correspond to fluvial systems located to the north of the simulation area being preferentially concentrate to the northwest border of the model and close to the Mohawk Well position (Figure 47).

The average sand content of the sediment sources ranged from 20% to 35% in average.

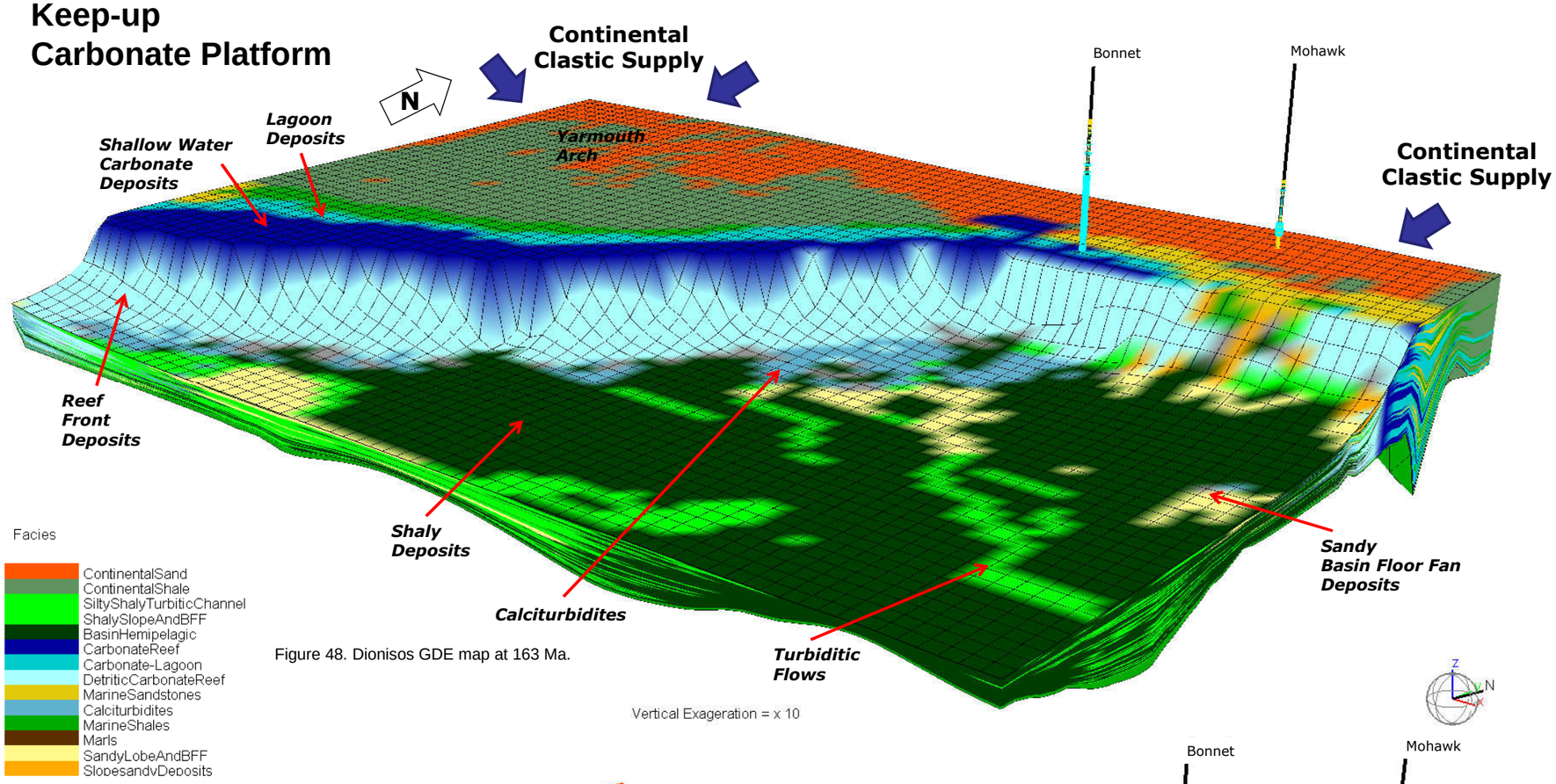
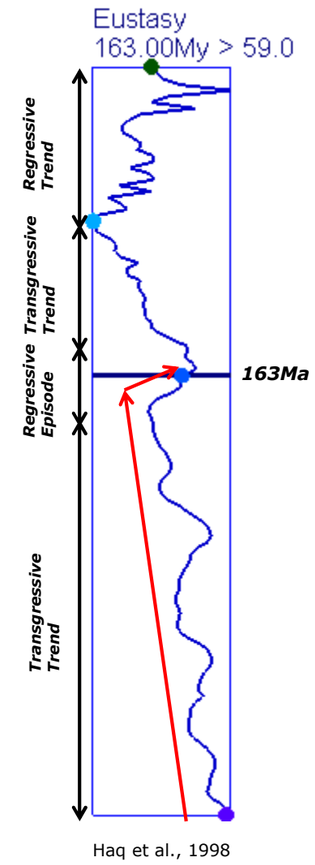


Figure 48. Dionisos GDE map at 163 Ma.



Haq et al., 1998

Figure 49. Eustatic curve at 163 Ma.

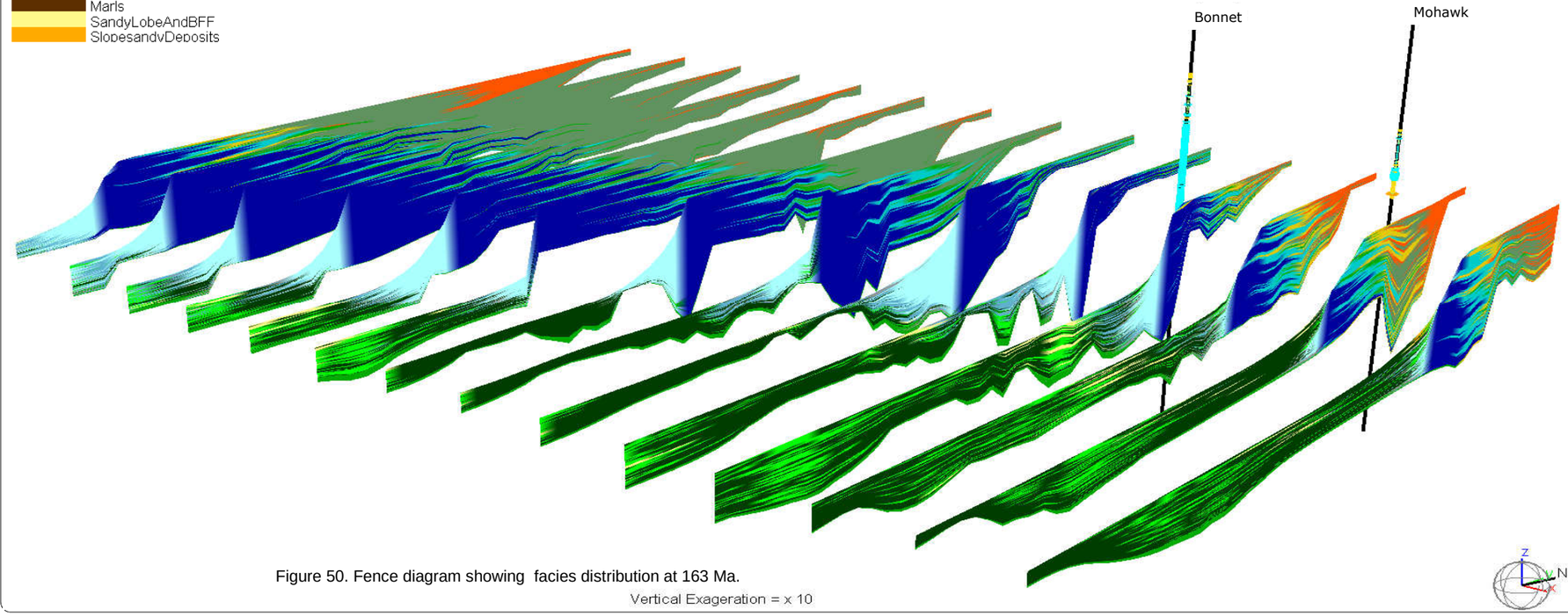


Figure 50. Fence diagram showing facies distribution at 163 Ma.

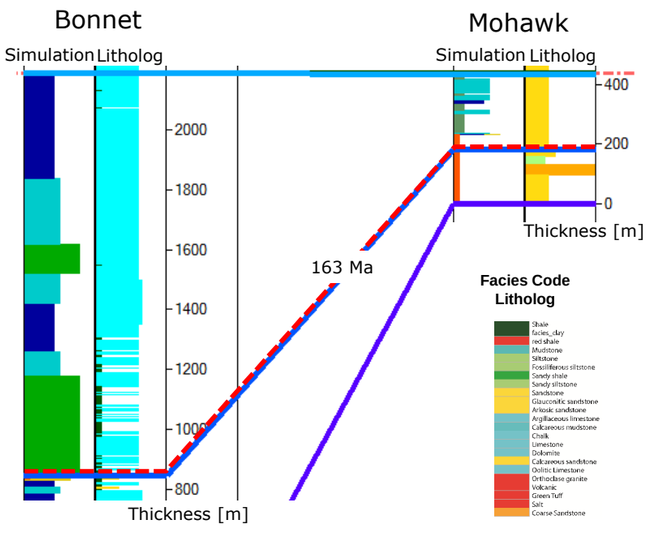


Figure 51. Well correlation between wells Bonnet and Mohawk at 163 Ma.

STRATIGRAPHIC MODELLING- OXFORDIAN-TITHONIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

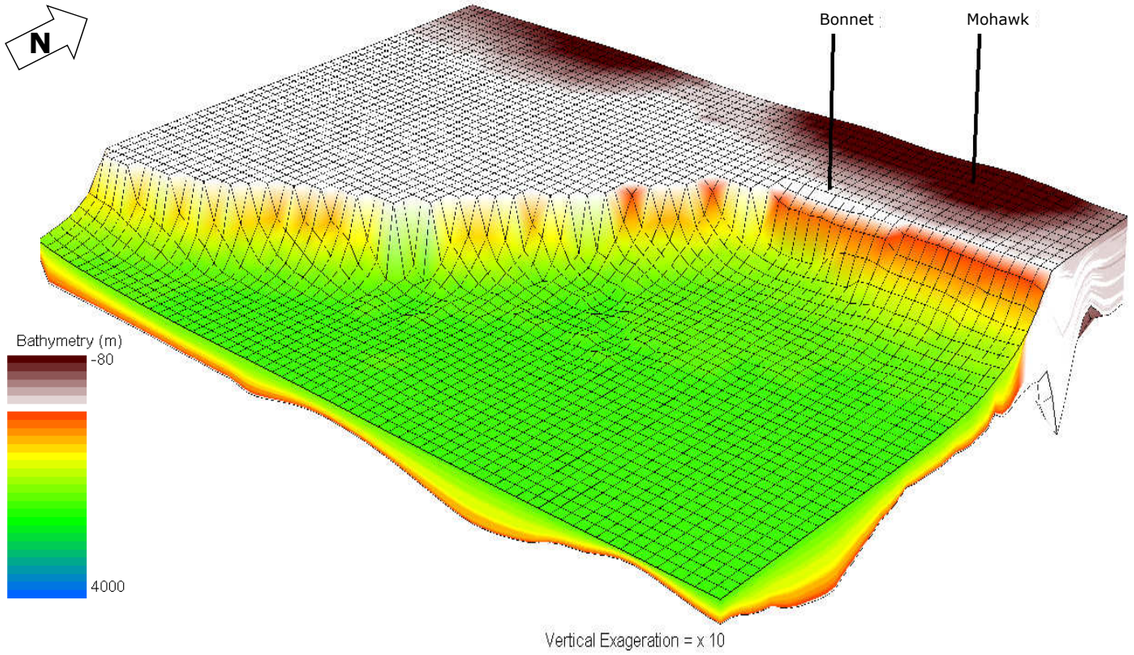


Figure 52. Bathymetry map at 161 Ma

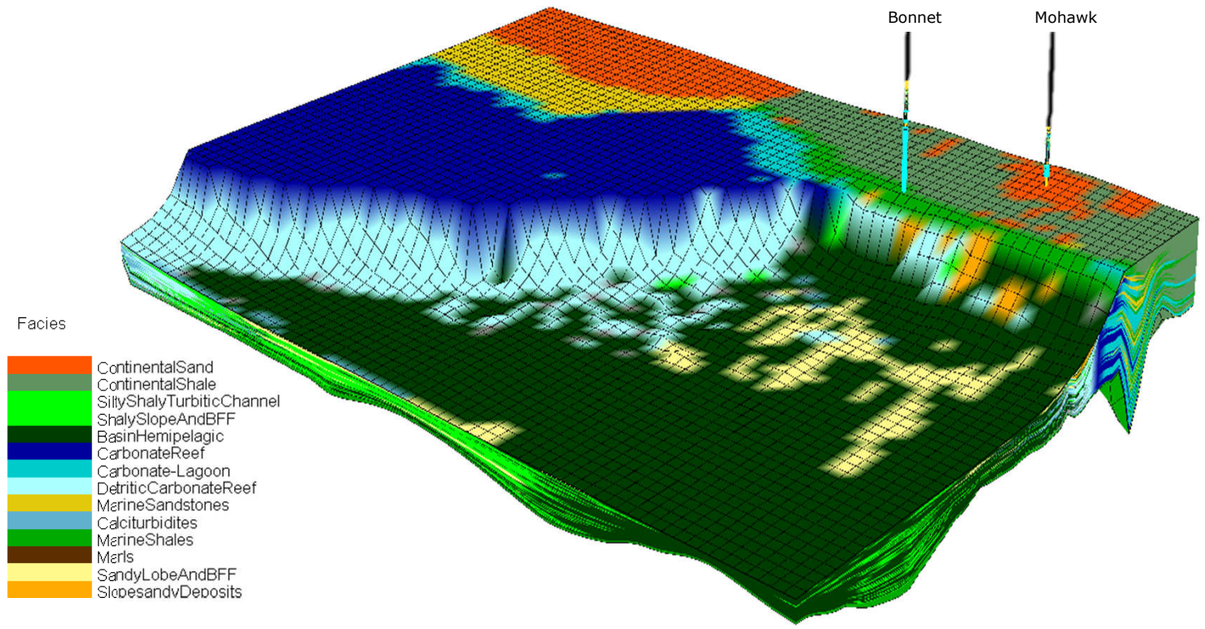


Figure 53. Facies distribution at 161 Ma

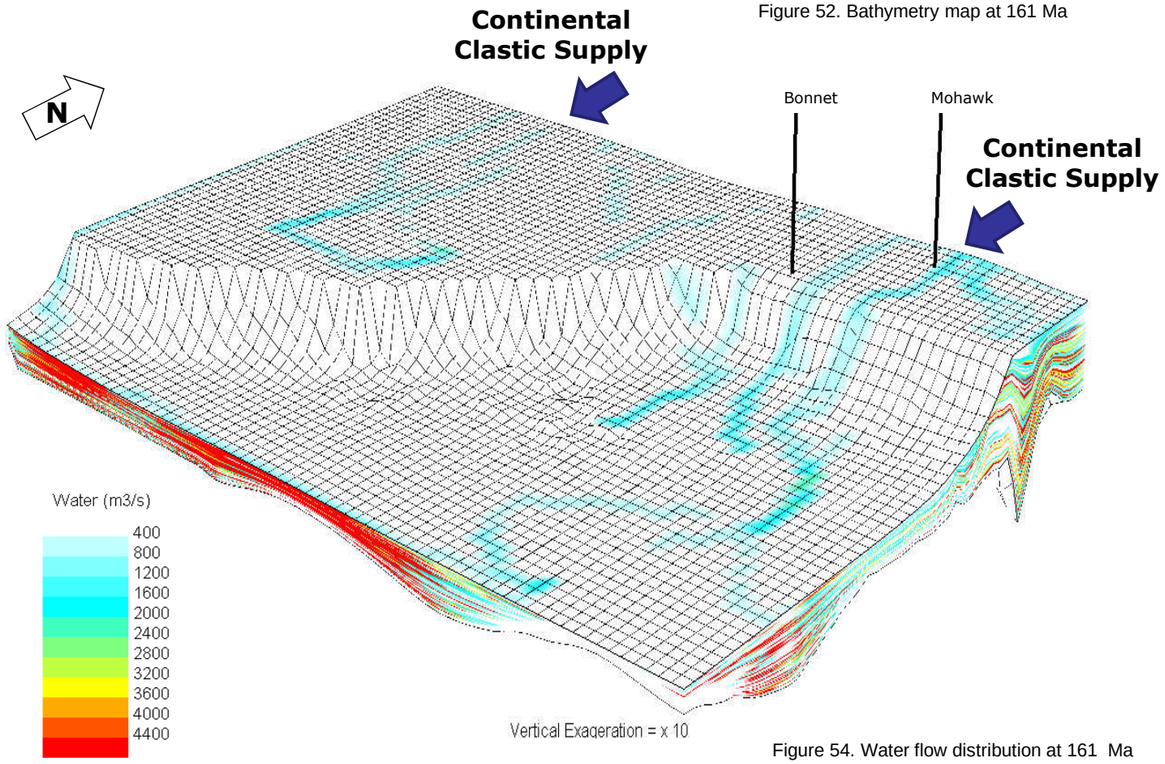


Figure 54. Water flow distribution at 161 Ma

✓ Sequence simulated: Hettangian - Tithonian

✓Age represented: Oxfordian.

✓Stratigraphic event: Transgressive episode at 161 Ma.

✓ This time step corresponds to a decrease on continental supply during the onset of a rapid sea level increase. However some sediment pulses continue reaching the basin from the Bonnet Mohawk area. The rapid sea level increase that follows this time step will provide the necessary bathymetry conditions for generating clinoform geometries during a later increasing of the siliciclastic input during the Cretaceous Shelburne Delta Episode.

✓The sediment supplies at this time correspond to fluvial systems located to the north of the simulation area being preferentially concentrate to the northwest border of the model and close to the Mohawk Well position (Figure 54).

The average sand content of the sediment sources ranged from 20% to 35% in average.

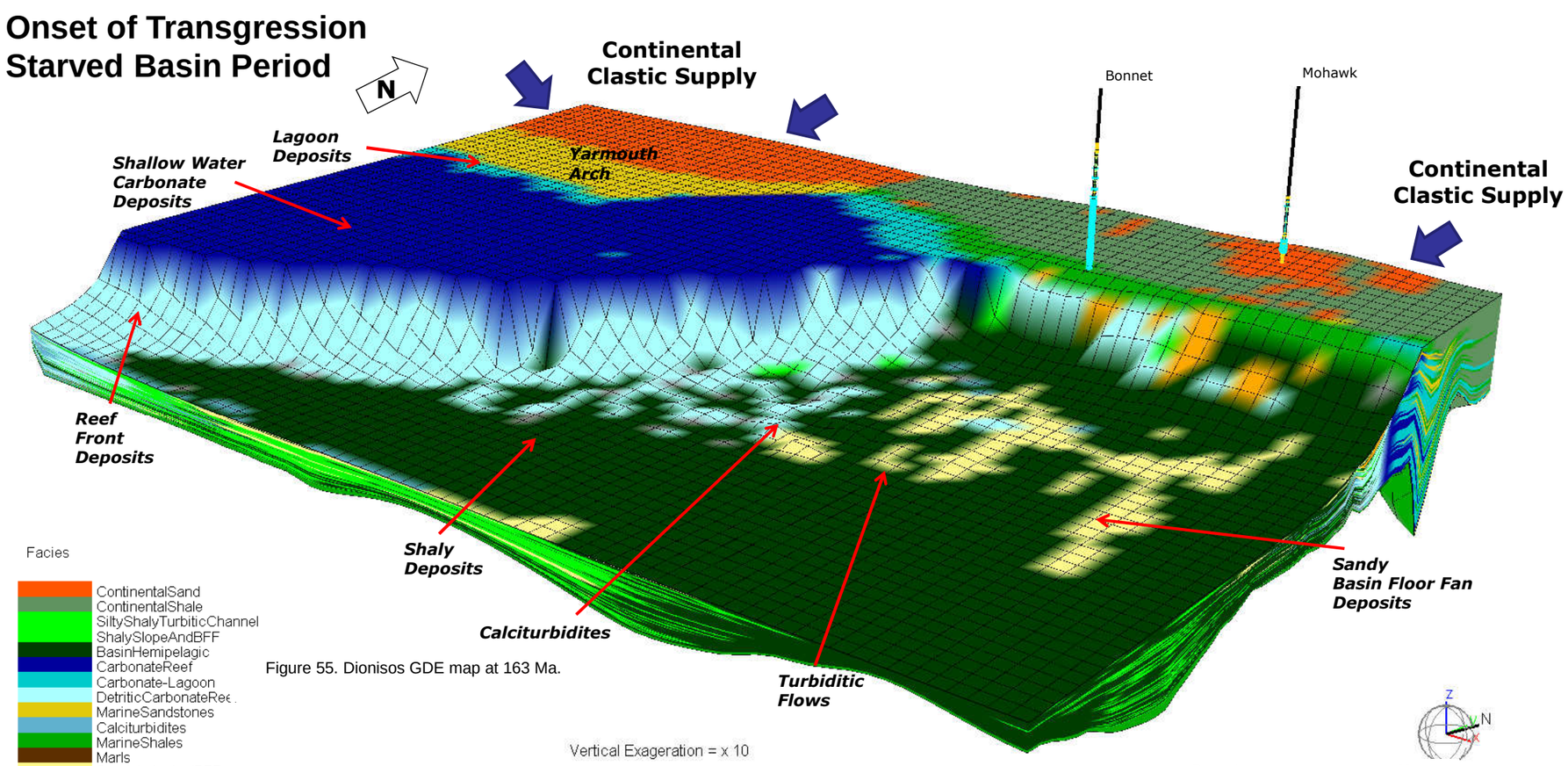


Figure 55. Dionisos GDE map at 163 Ma.

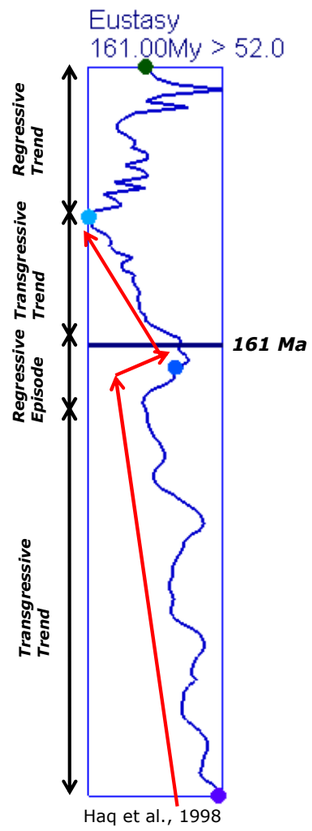


Figure 56. Eustatic curve at 163 Ma.

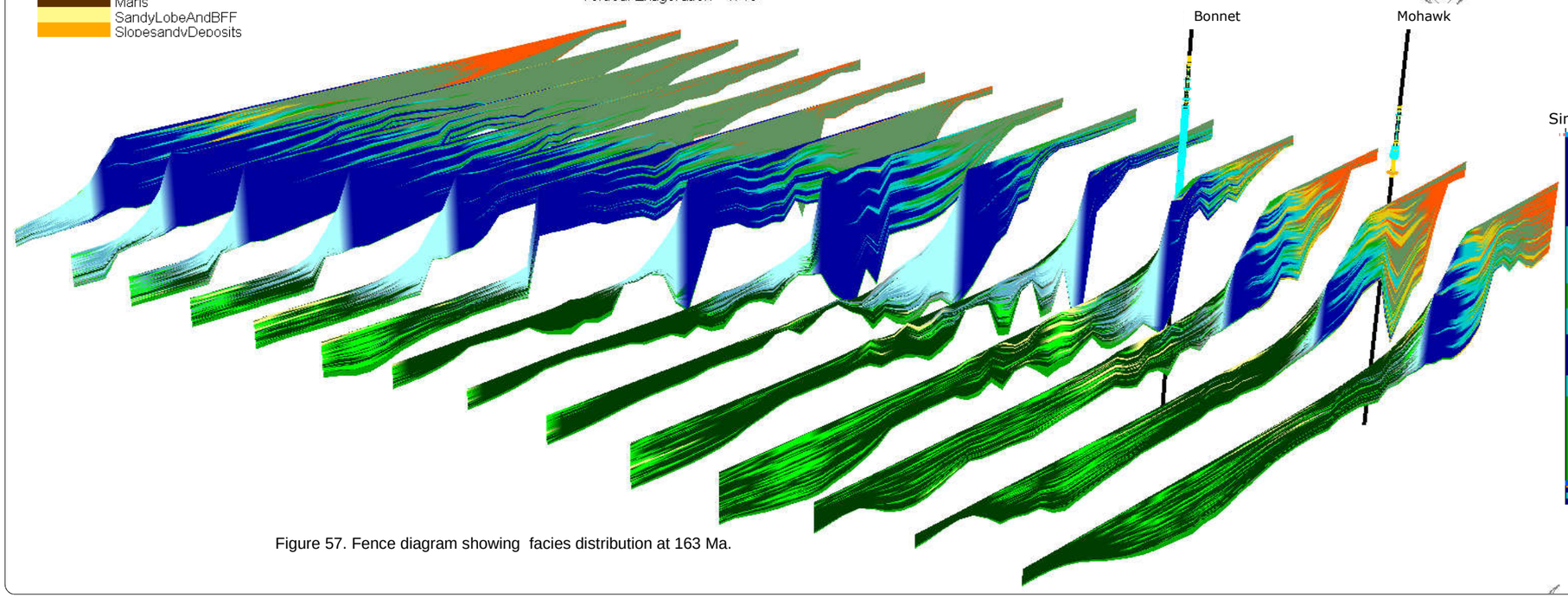


Figure 57. Fence diagram showing facies distribution at 163 Ma.

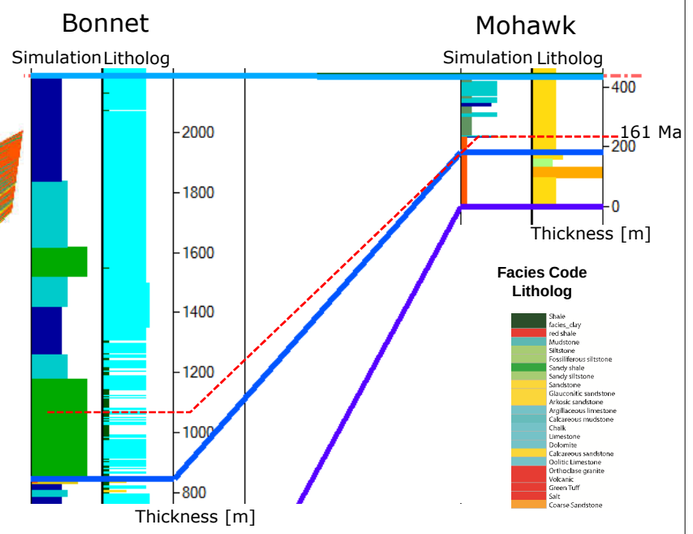


Figure 58. Well correlation between wells Bonnet and Mohawk at 163 Ma.

STRATIGRAPHIC MODELLING- OXFORDIAN-TITHONIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

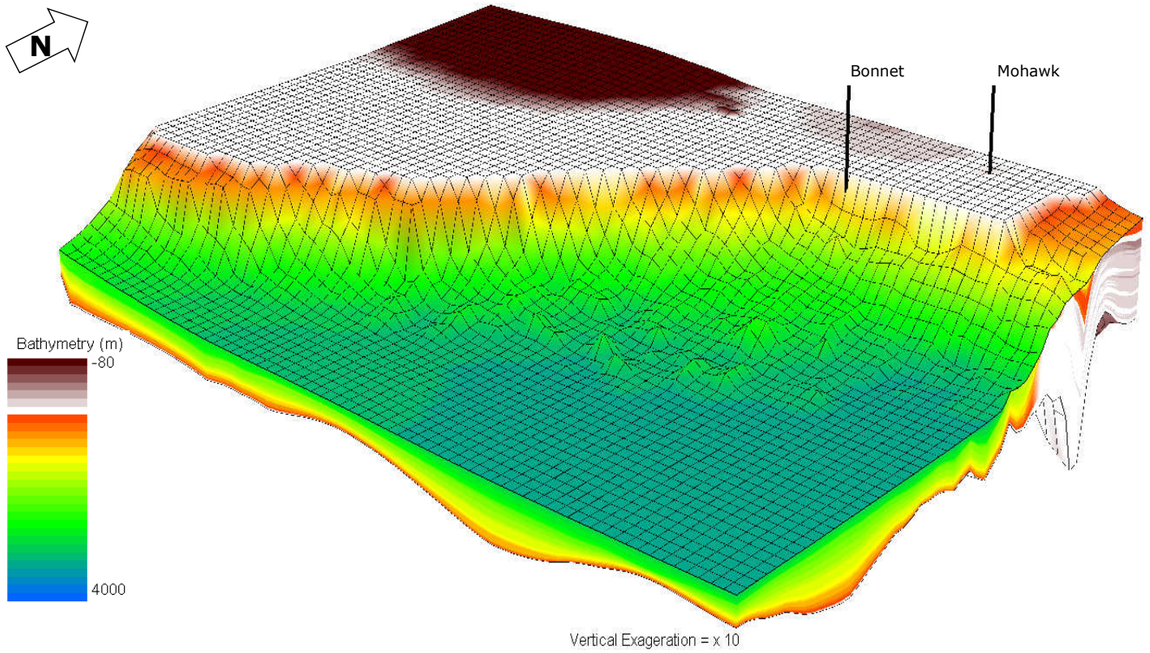


Figure 59. Bathymetry map at 150 Ma

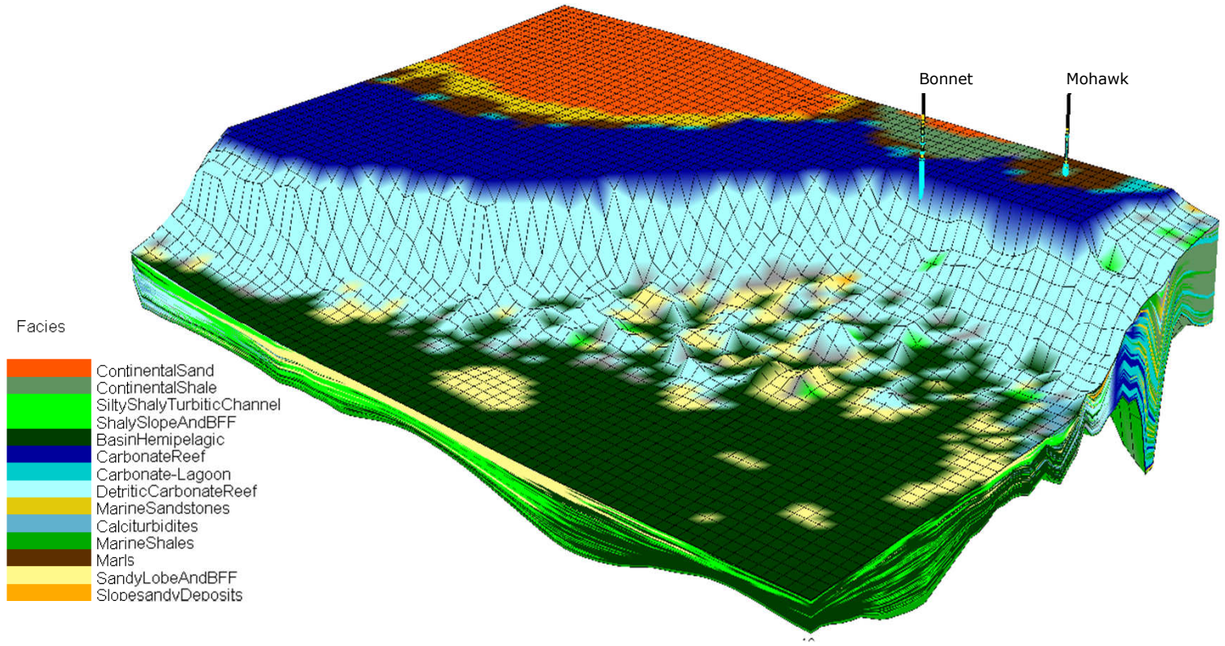


Figure 60. Facies distribution at 150 Ma

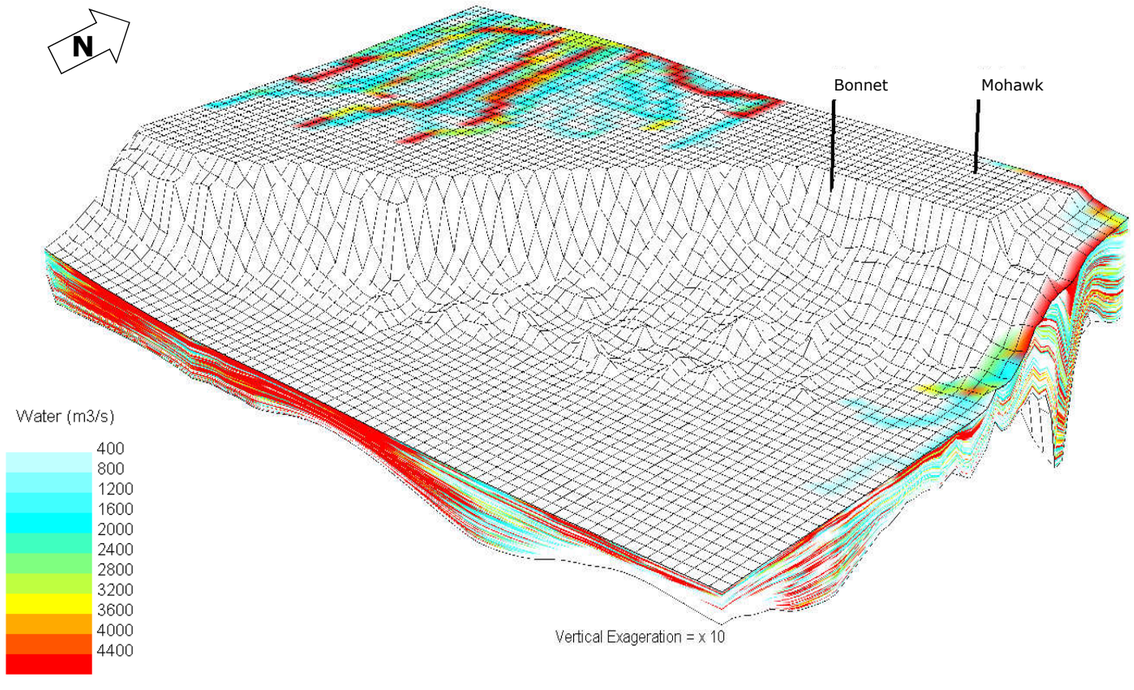


Figure 61. Water flow distribution at 150 Ma

✓ Sequence simulated: Hettangian – Tithonian

✓Age represented: Tithonian.

✓Stratigraphic event: End of the “Cretaceous Shelburne Delta”.

✓ This time step shows the end of the progradation of deltaic facies all along the shelf with well developed clinoform geometries. During the progradation of the deltaic facies a localized subsidence episode in the Yarmouth sub-platform normal faulting with a consequent in this area. An important volume of sandstones were transported to the basin during this time as a consequence of the bypass of deltaic sandstones from the shelf edge to the basin.

✓The sediment supplies at this time correspond to fluvial systems located to the north of the simulation area being preferentially concentrate to the northwest border of the model (Figure 61).

The average sand content of the sediment sources ranged from 20% to 35% in average.

PL. 6.3.6 **GDE Maps and Dionisos Results : 3D View – Age 150 Ma**

STRATIGRAPHIC MODELLING- CALLOVIAN-TITHONIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

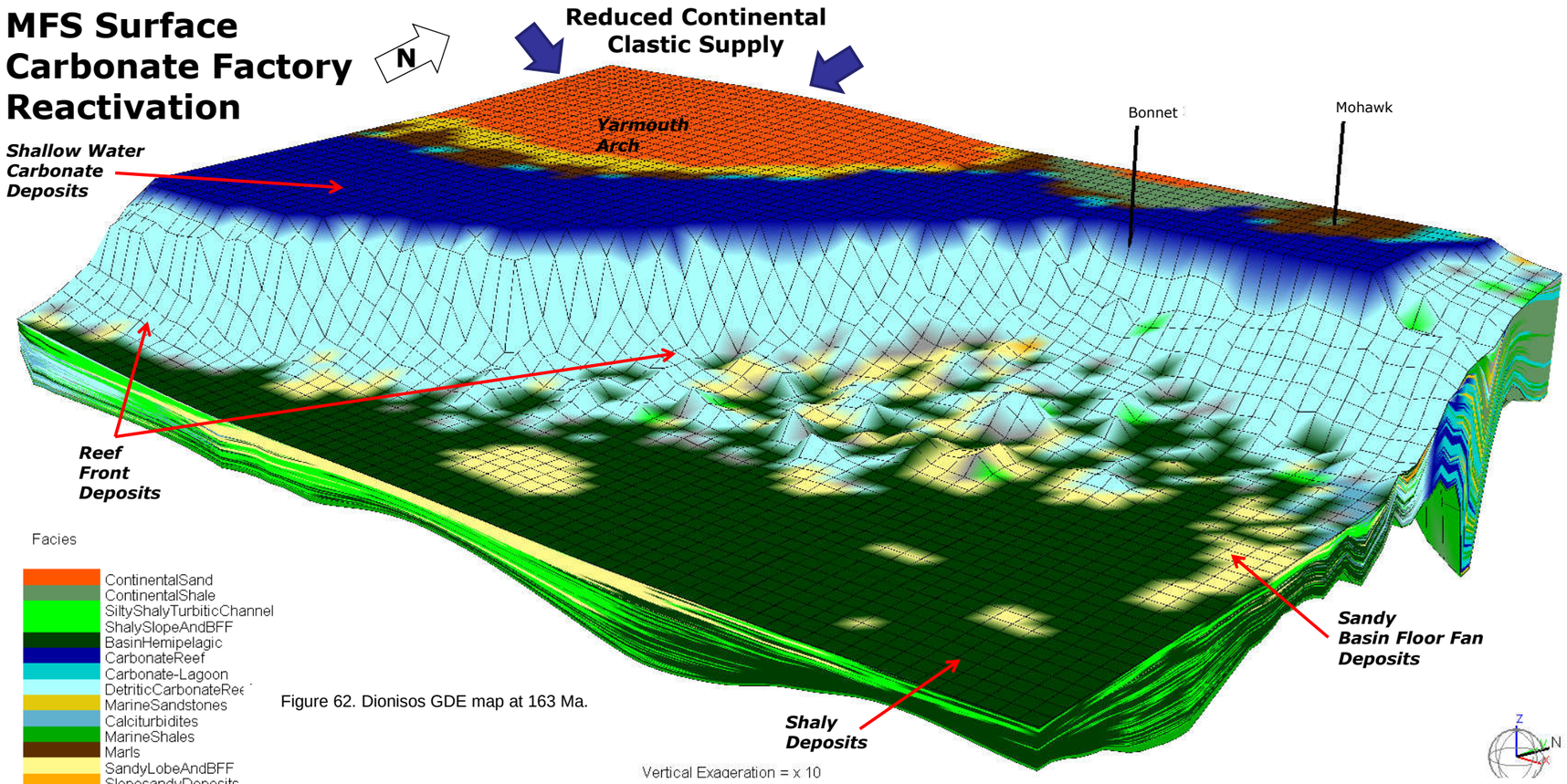
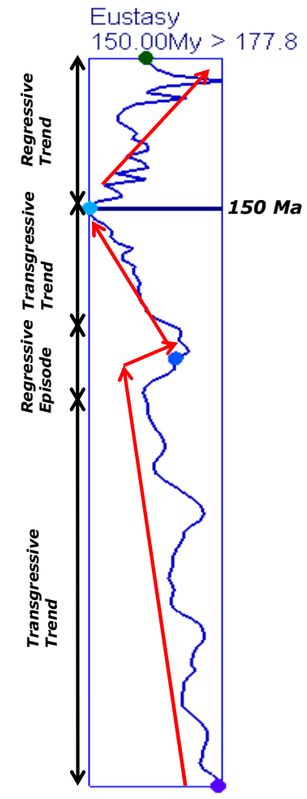


Figure 62. Dionisos GDE map at 163 Ma.



Haq et al., 1998

Figure 63. Eustatic curve at 150 Ma.

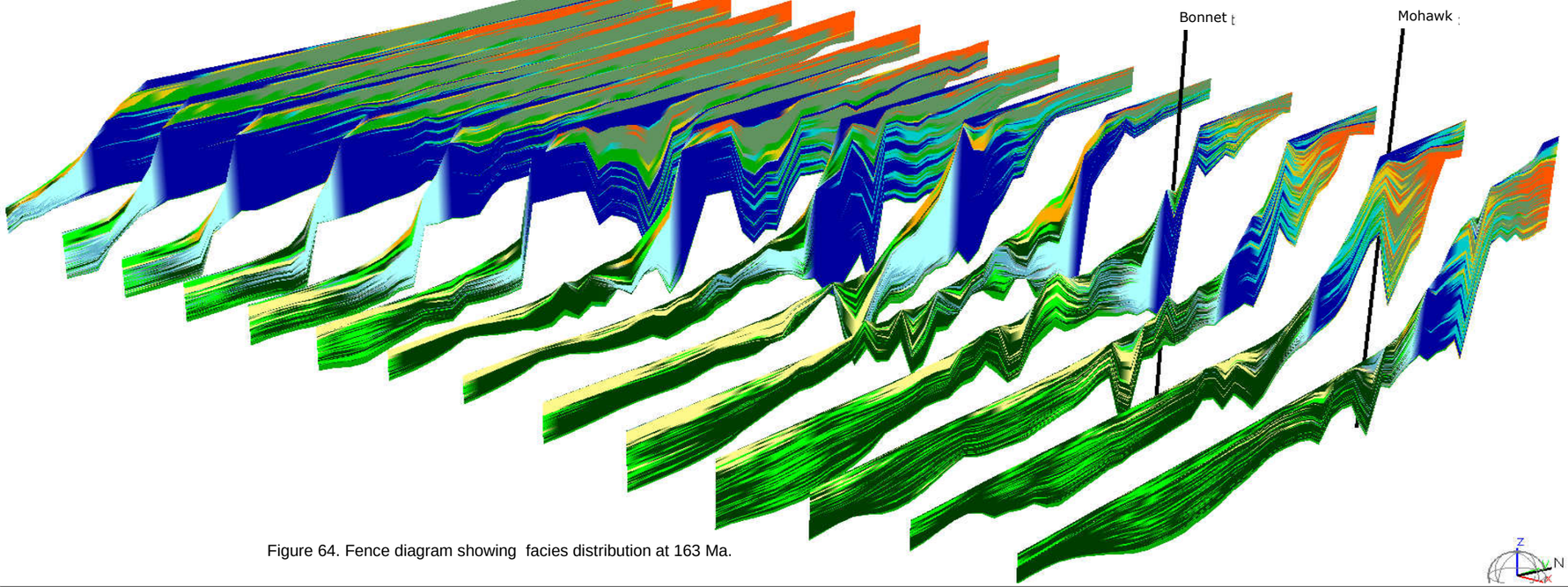


Figure 64. Fence diagram showing facies distribution at 163 Ma.

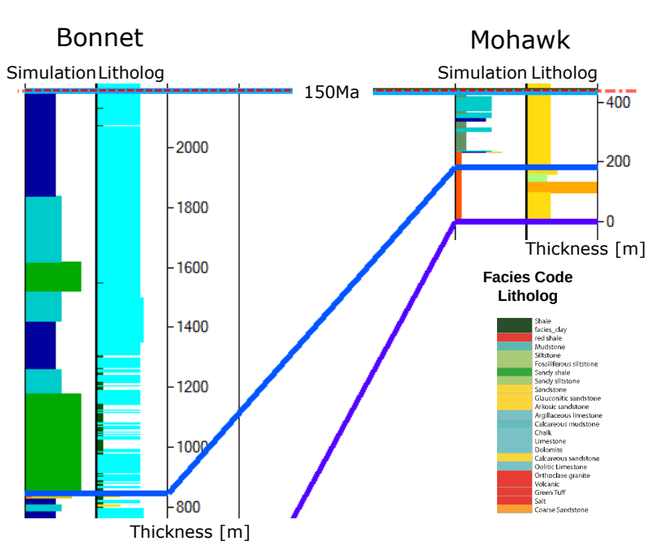


Figure 65. Well correlation between wells Bonnet and Mohawk at 150 Ma.

GDE Maps and Dionisos Results : Fence Diagram and 3D View – Age 150 Ma

PL 6.3.7

CHAPTER 6.4

STRATIGRAPHIC MODELLING
TITHONIAN-BARREMIAN SEQUENCE

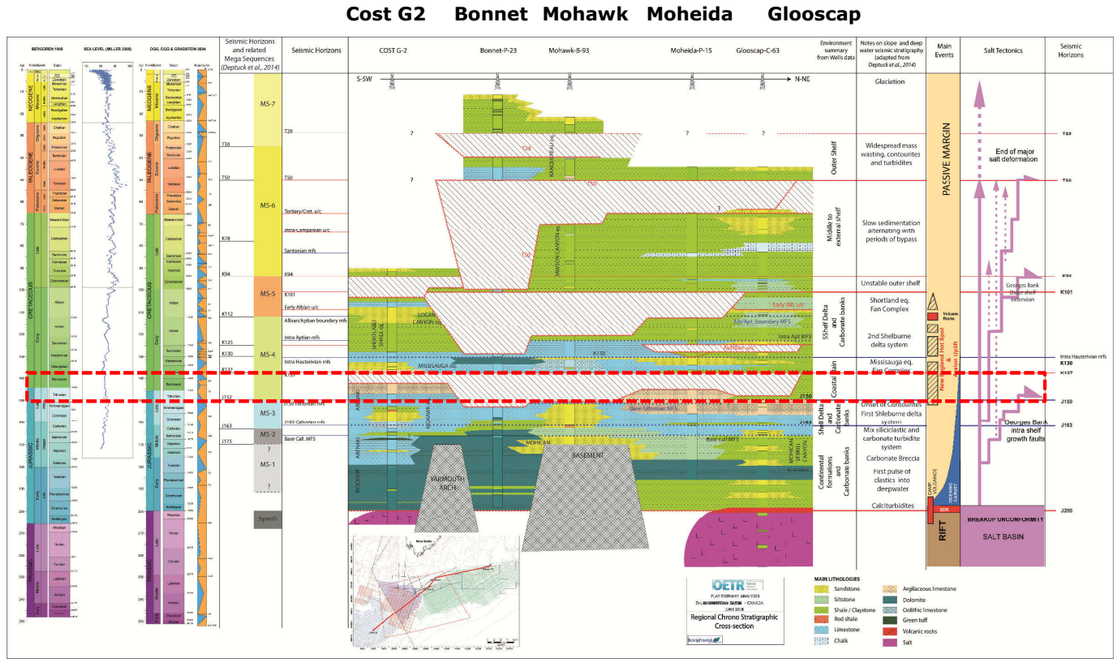


Figure 66. Stratigraphic Cross-Section across the study area. Dotted red line represents the period of time showed in this section.

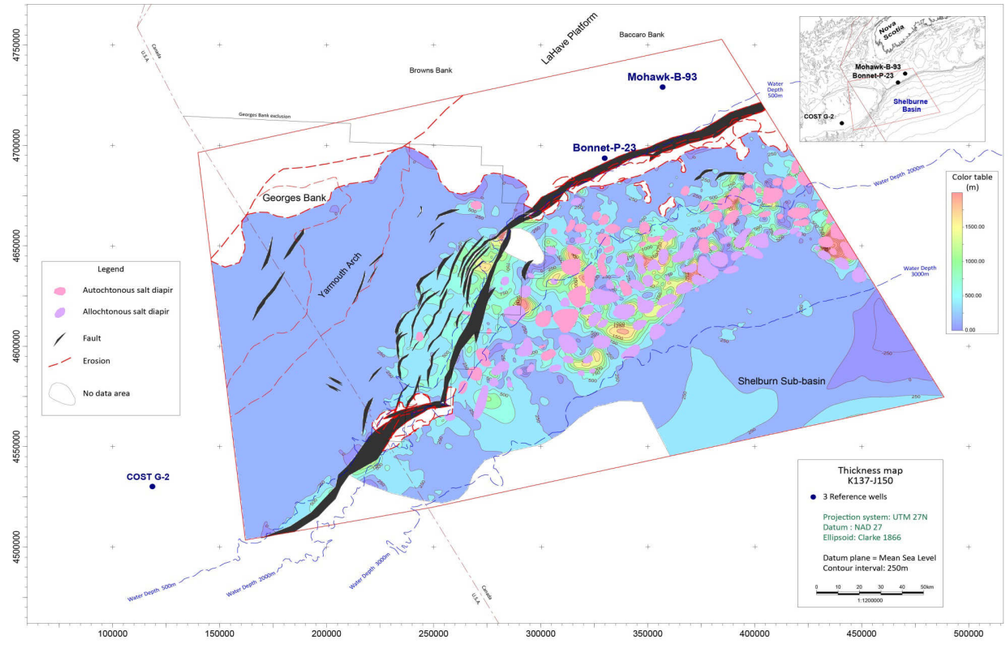


Figure 67. Isopach map J150 – K137.

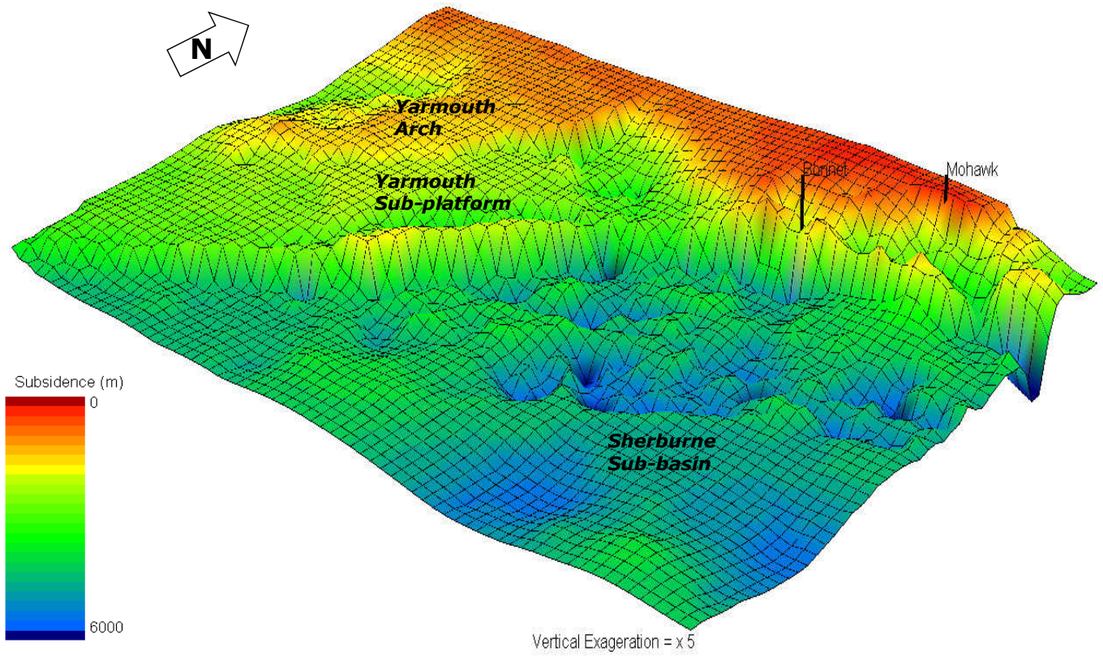


Figure 68. The total subsidence at this age was estimated following this formula: $Total\ Subsidence = Subidence\ (t-1) + SedThick(t) + Bathy\ (t) - Bathy\ (t-1)$; t=137 Ma; (t-1)=150

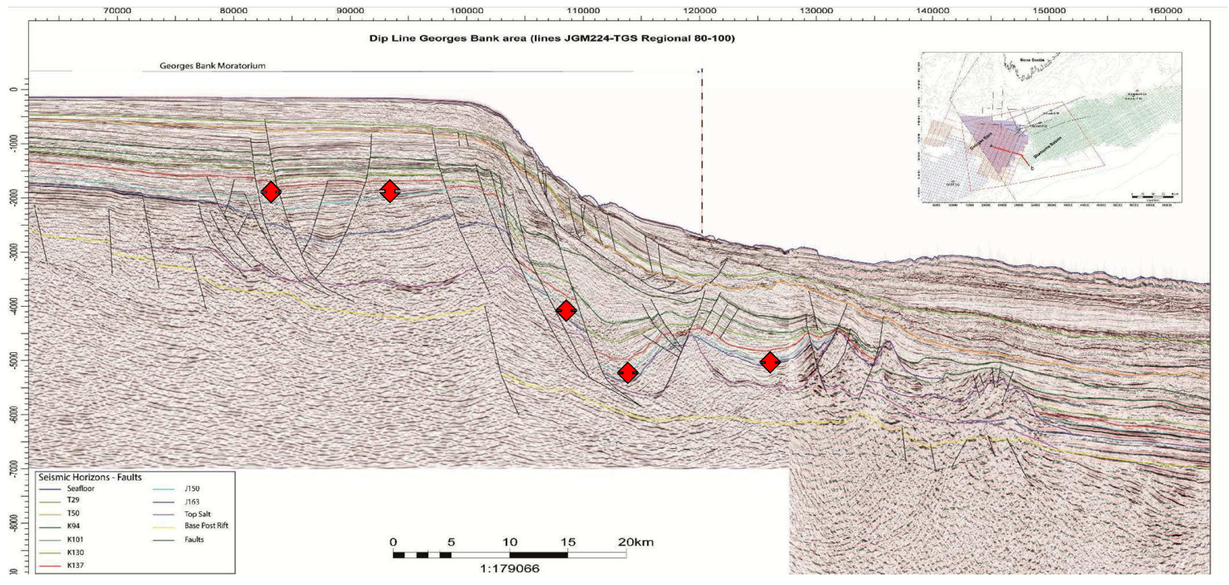


Figure 69. Seismic section (lines JGM 224 – TGS regional 80-100) across the Yarmouth Sub-platform and the Shelburne Sub-basin showing the interval J150 – K137.

STRATIGRAPHIC MODELLING- TITHONIAN-VALANGINIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

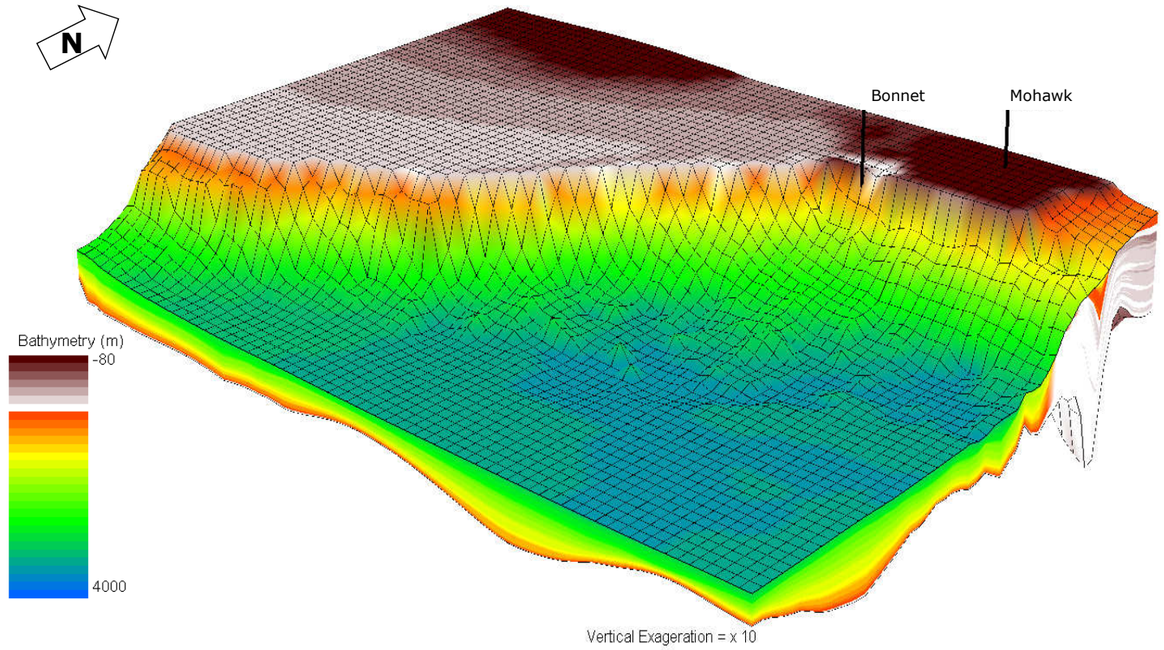


Figure 70. Bathymetry map at 145 Ma

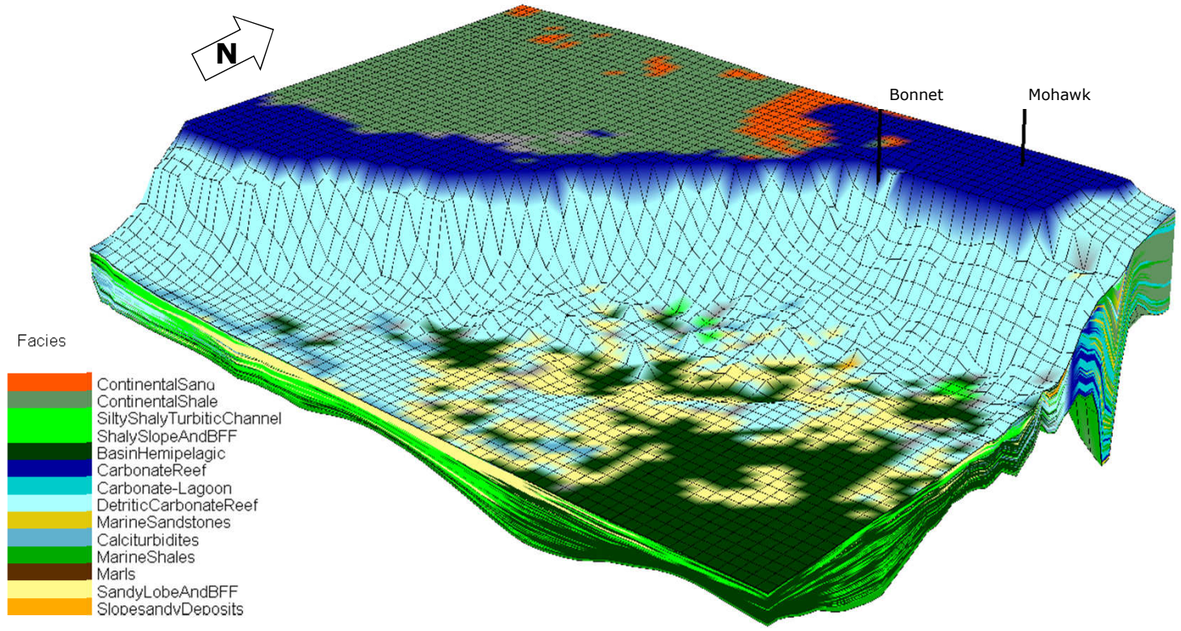


Figure 71. Facies distribution at 145 Ma

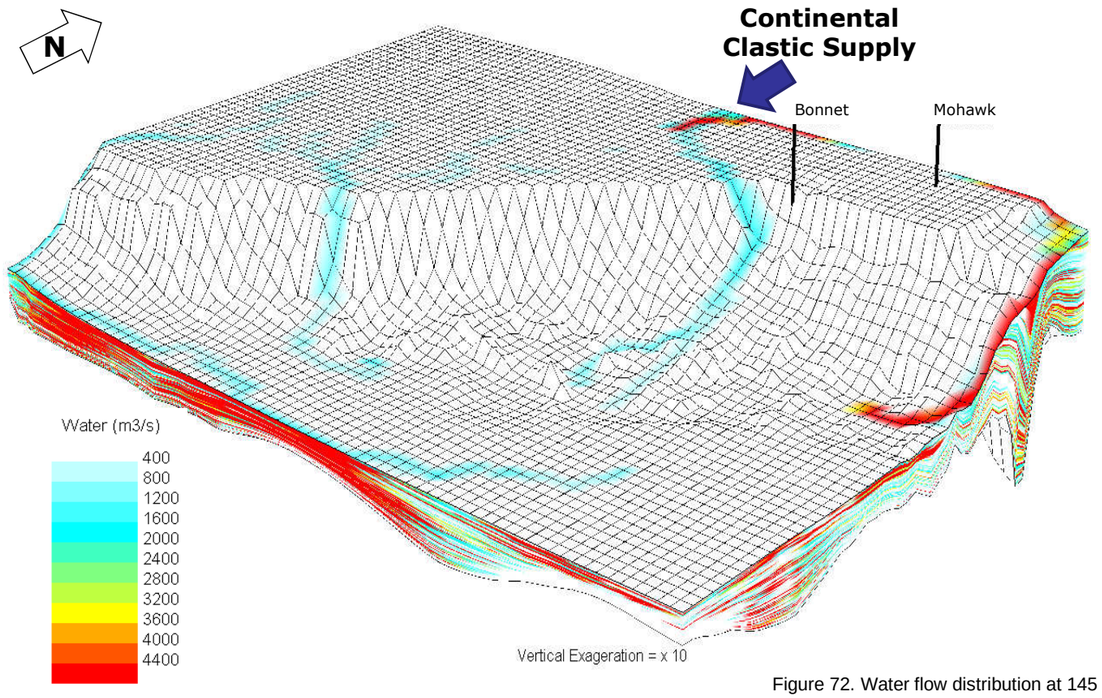


Figure 72. Water flow distribution at 145 Ma

✓ Sequence simulated: Hettangian- Valanginian

✓Age represented: Berriasian.

✓Stratigraphic event: Regressive Episode with erosion on shelf carbonates .

✓This time step shows the erosion of post Tithonian carbonate facies accumulated in the shelf. Most of the sediment that will be transported to the basin during this period correspond to carbonatic flows transported from the platform – slope.

✓The sediment supplies at this time correspond to fluvial systems located to the north of the simulation area being preferentially concentrate close to the Mohawk Well position (Figure 72).

The average sand content of the sediment sources ranged from 20% to 35% in average.

PL. 6.4.2 **GDE Maps and Dionisos Results : 3D View – Age 145 Ma**

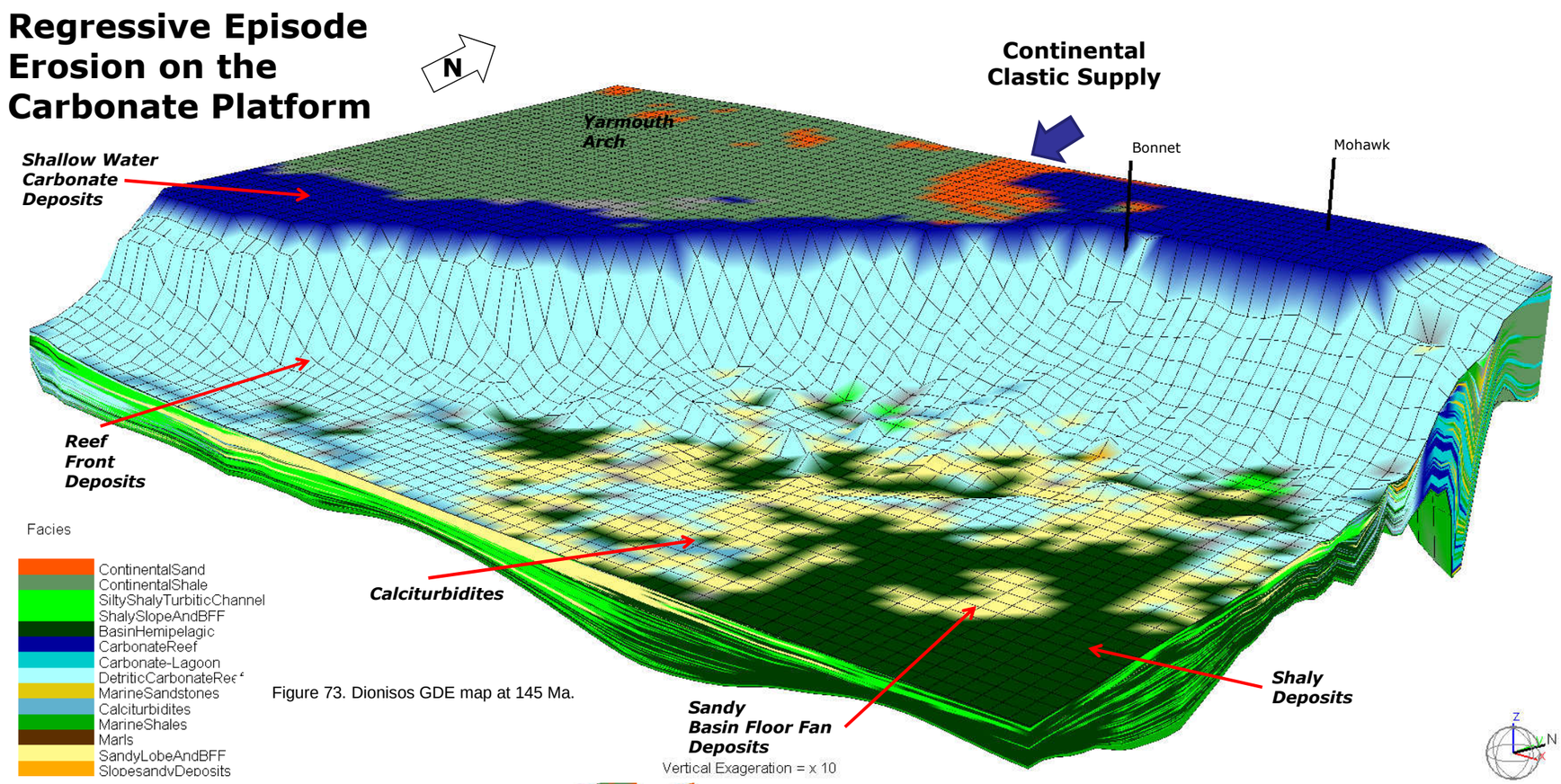
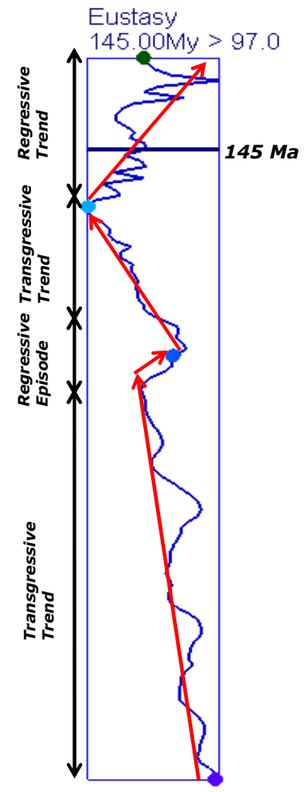


Figure 73. Dionisos GDE map at 145 Ma.



Haq et al., 1998

Figure 74. Eustatic curve at 145 Ma.

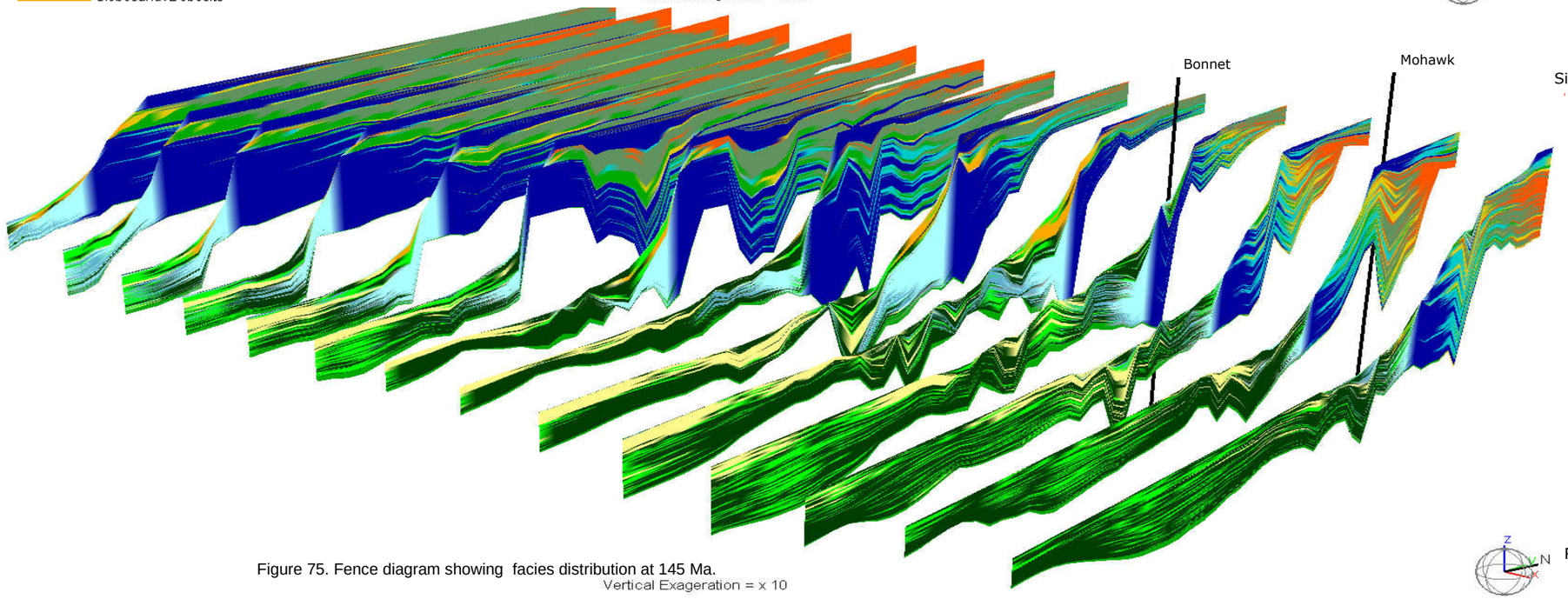


Figure 75. Fence diagram showing facies distribution at 145 Ma.

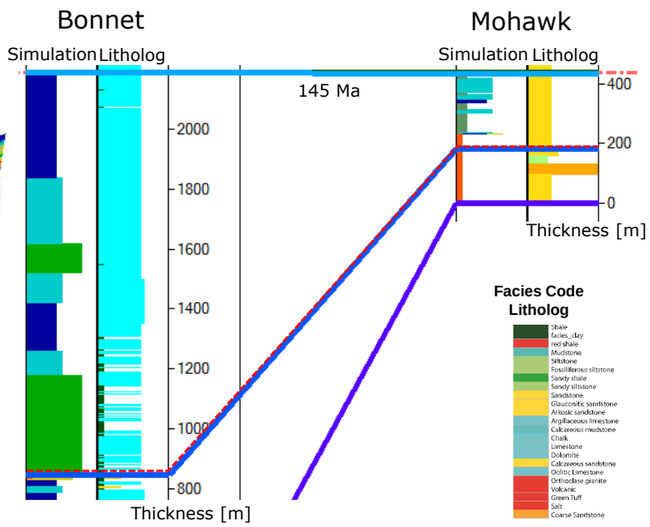


Figure 76. Well correlation between wells Bonnet and Mohawk at 145 Ma.

GDE Maps and Dionisos Results : Fence Diagram and 3D View – Age 145 Ma

PL. 6.4.3

STRATIGRAPHIC MODELLING- TITHONIAN-VALANGINIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

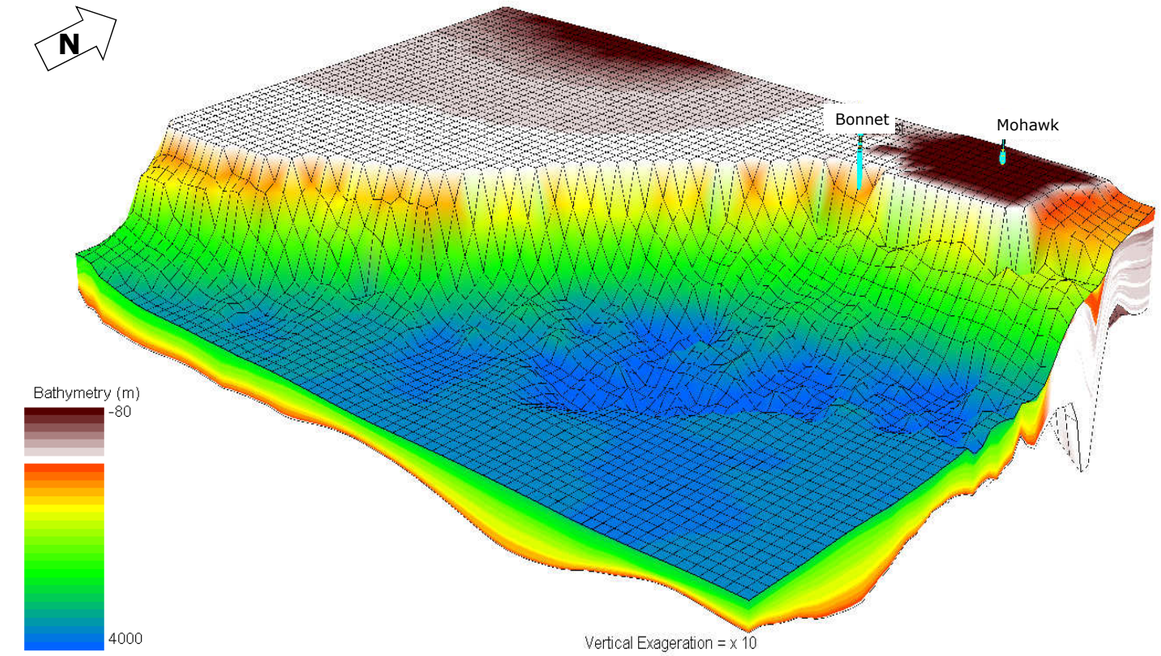


Figure 77. Bathymetry map at 137 Ma

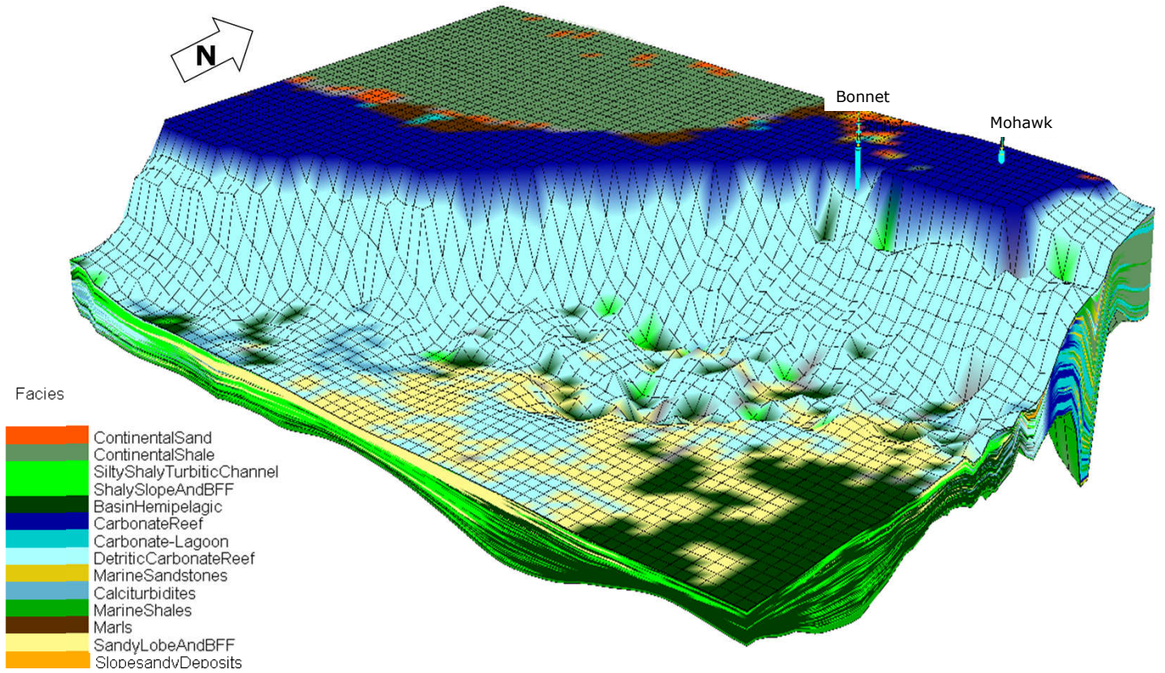


Figure 78. Facies distribution at 137 Ma

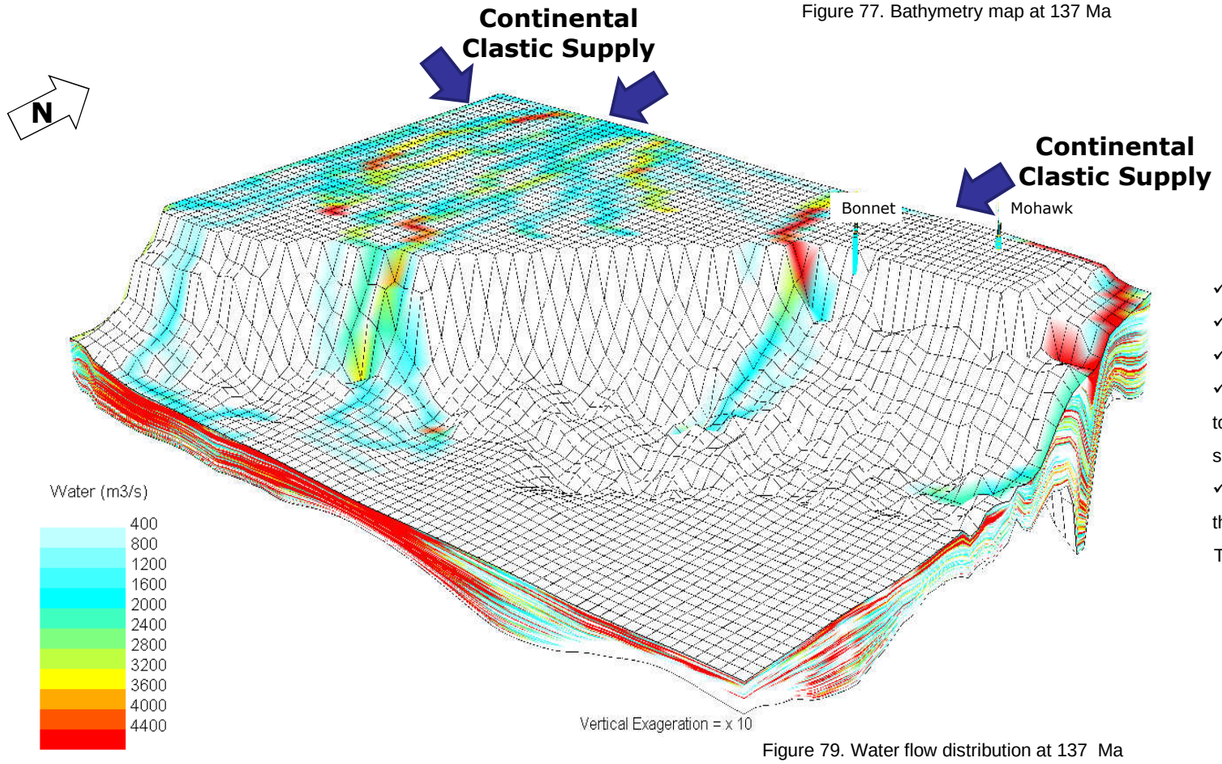


Figure 79. Water flow distribution at 137 Ma

✓ Sequence simulated: Hettangian – Valanginian

✓Age represented: Valanginian.

✓Stratigraphic event: Regressive Episode with erosion on shelf carbonates .

✓ This time step shows the erosion of post Tithonian carbonate facies accumulated in the shelf. Most of the sediments that will be transported to the basin during this period correspond to carbonatic flows transported from the shelf – slope. Due to a sensible decrease on sediment supply from the continent, a sediment starvation episode start to be present in the active deformation areas in the basin (mini-basins).

✓The sediment supplies at this time correspond to fluvial systems located to the north of the simulation area being preferentially concentrate to the northwest border of the model and close to the Mohawk Well position (Figure 79).

The average sand content of the sediment sources ranged from 20% to 35% in average.

STRATIGRAPHIC MODELLING- TITHONIAN-VALANGINIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

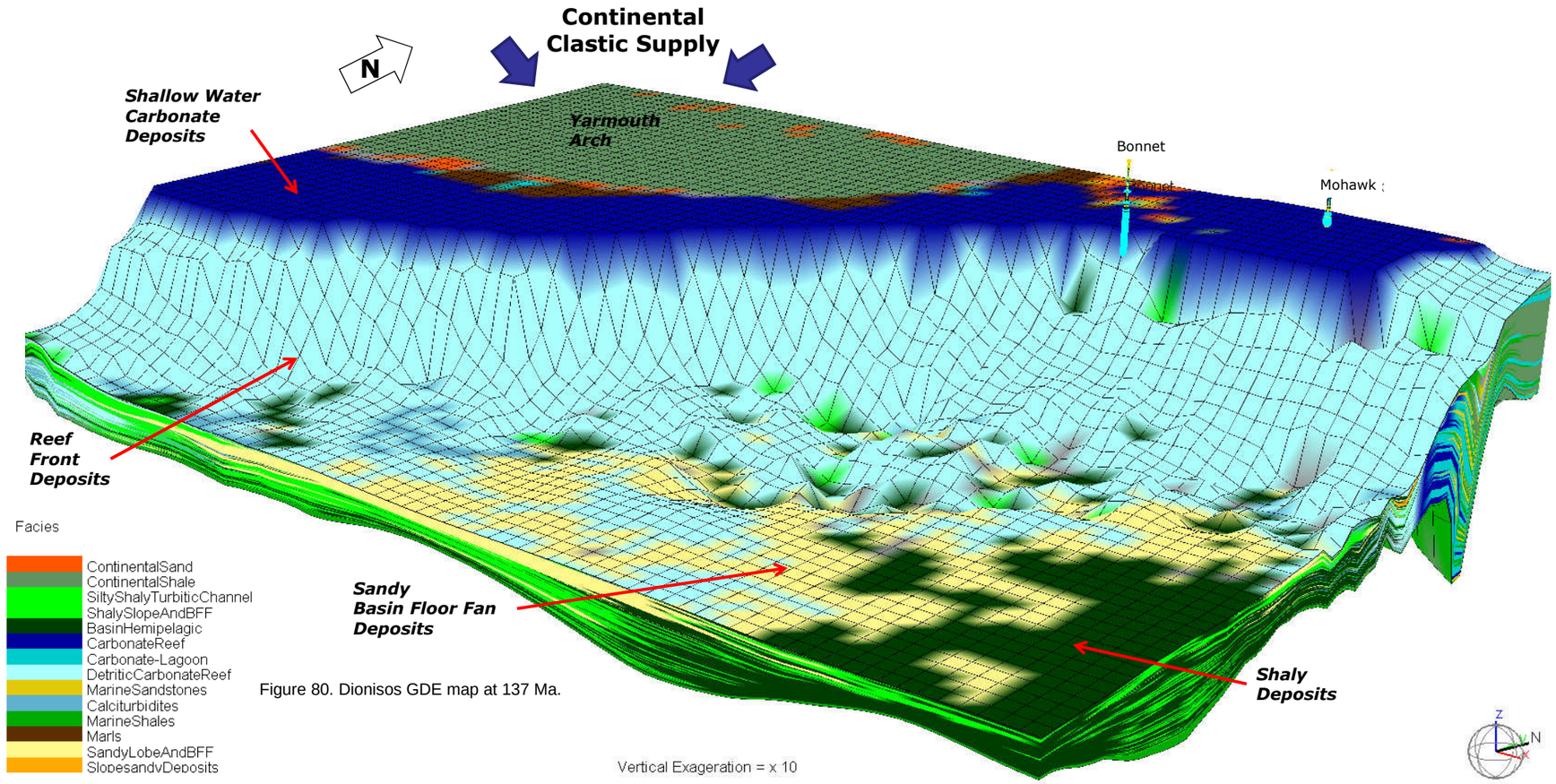
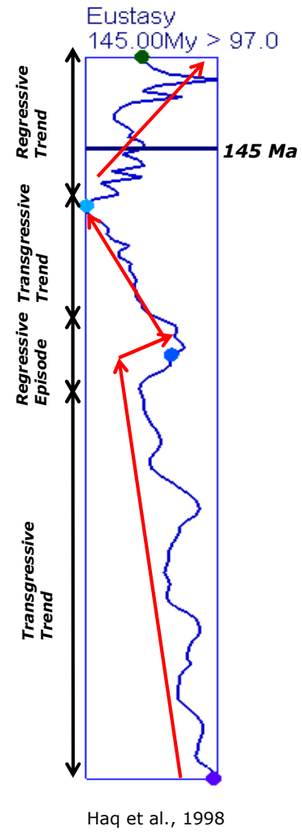


Figure 80. Dionisos GDE map at 137 Ma.



Haq et al., 1998

Figure 81. Eustatic curve at 137 Ma.

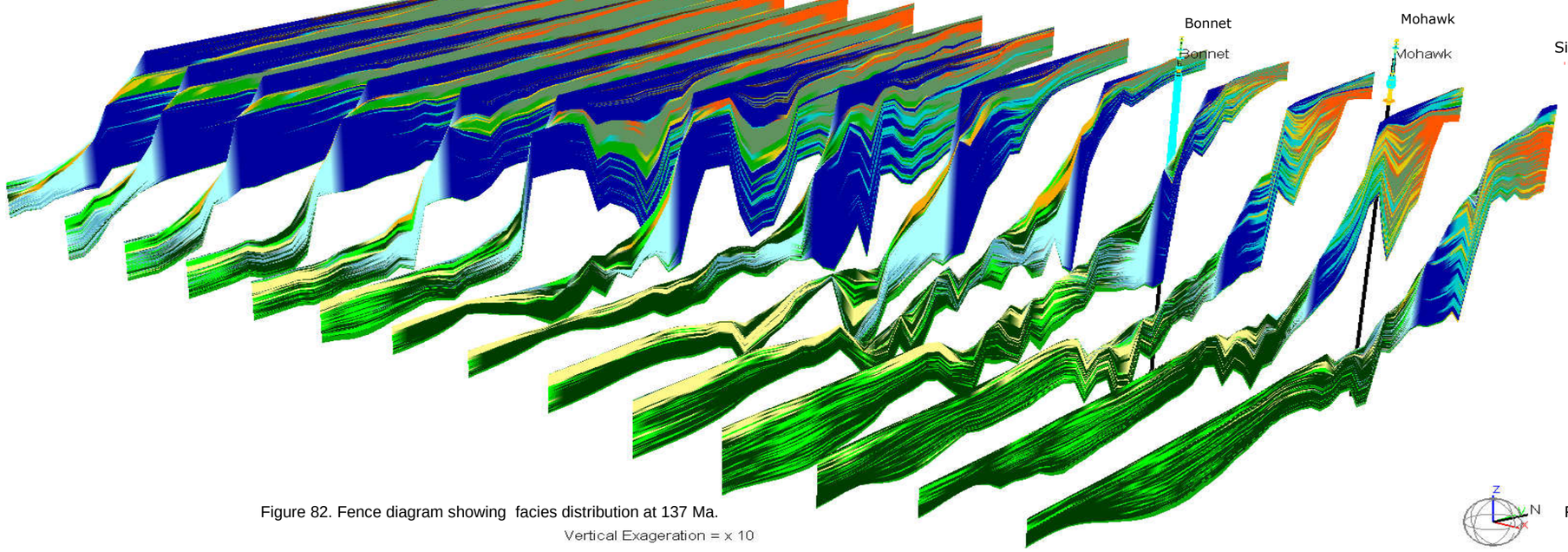


Figure 82. Fence diagram showing facies distribution at 137 Ma.

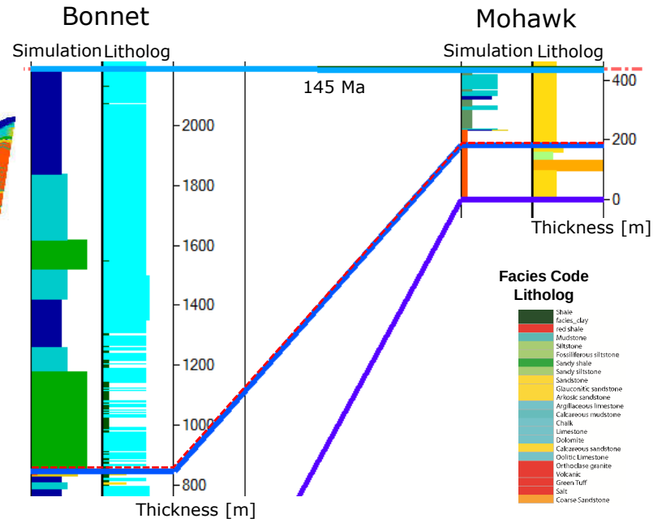


Figure 83. Well correlation between wells Bonnet and Mohawk at 137 Ma.

GDE Maps and Dionisos Results : Fence Diagram and 3D View – Age 137 Ma **PL. 6.4.5**

STRATIGRAPHIC MODELLING VALANGINIAN - BARREMIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

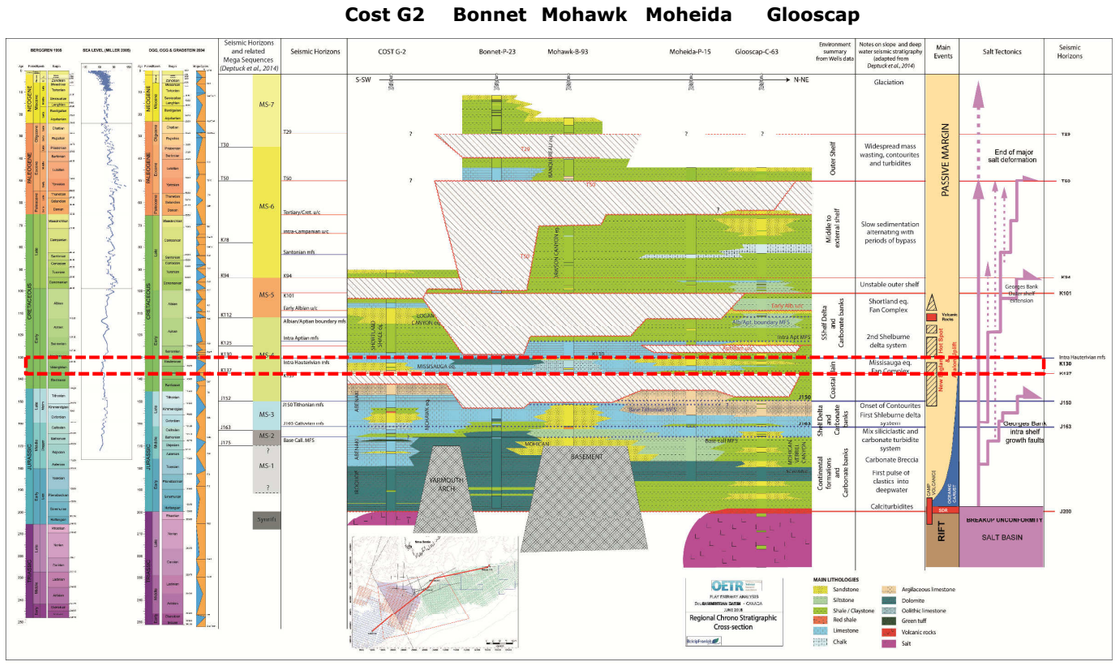


Figure 84. Stratigraphic Cross-Section across the study area. Dotted red line represents the period of time showed in this section.

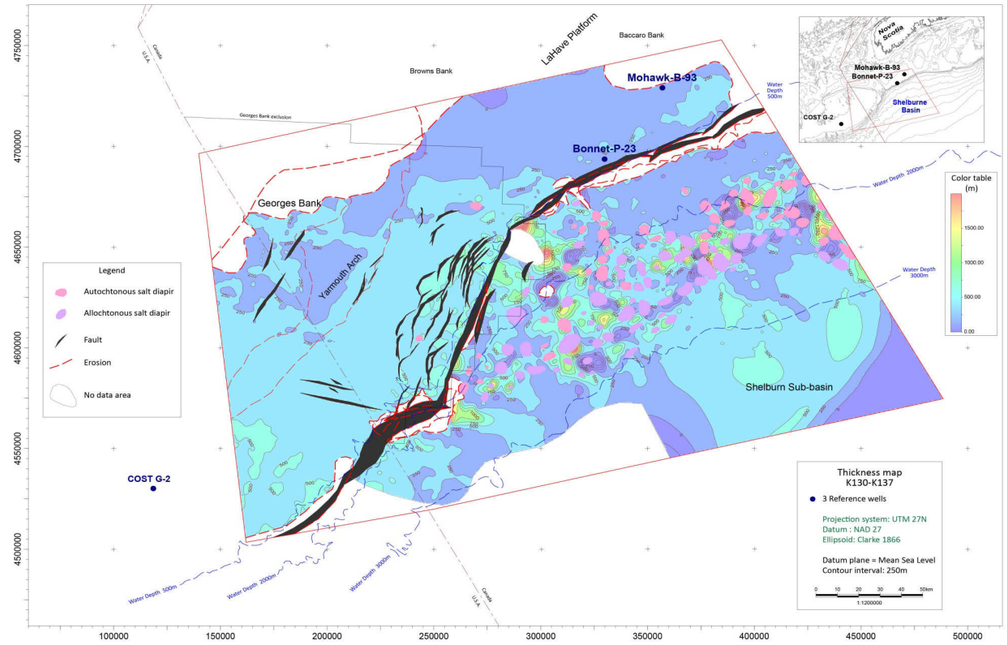


Figure 85. Isopach map K137 – K130.

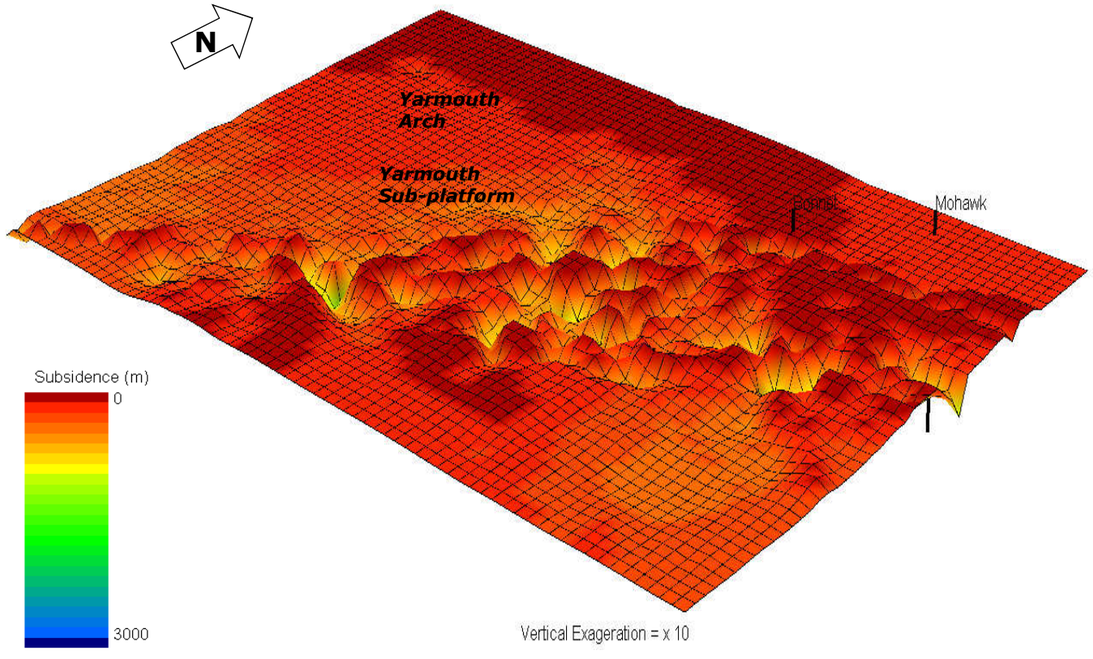


Figure 86. The total subsidence at this age was estimated following this formula: $Total\ Subsidence = Subidence\ (t-1) + SedThick(t) + Bathy\ (t) - Bathy\ (t-1)$; t=130 Ma; (t-1)=137

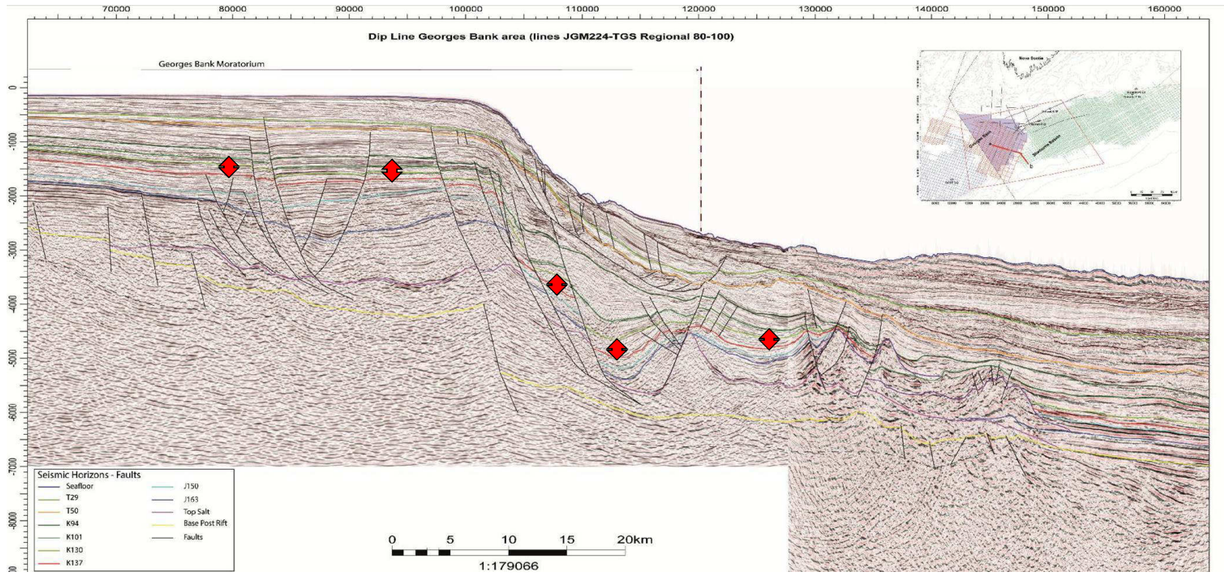


Figure 87. Seismic section (lines JGM 224 – TGS regional 80-100) across the Yarmouth Sub-platform and the Shelburne Sub-basin showing the interval K137 – K130.

PL. 6.4.6 **K137 – K130 Interval**

STRATIGRAPHIC MODELLING- VALANGINIAN - BARREMIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

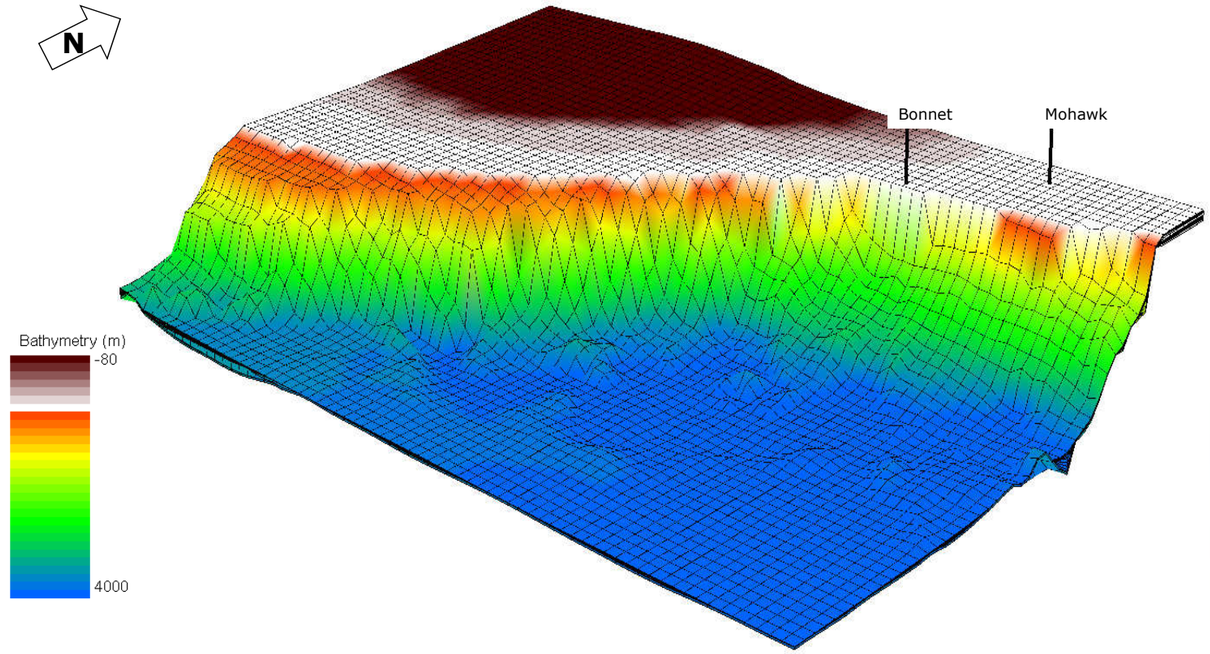


Figure 88. Bathymetry map at 130 Ma

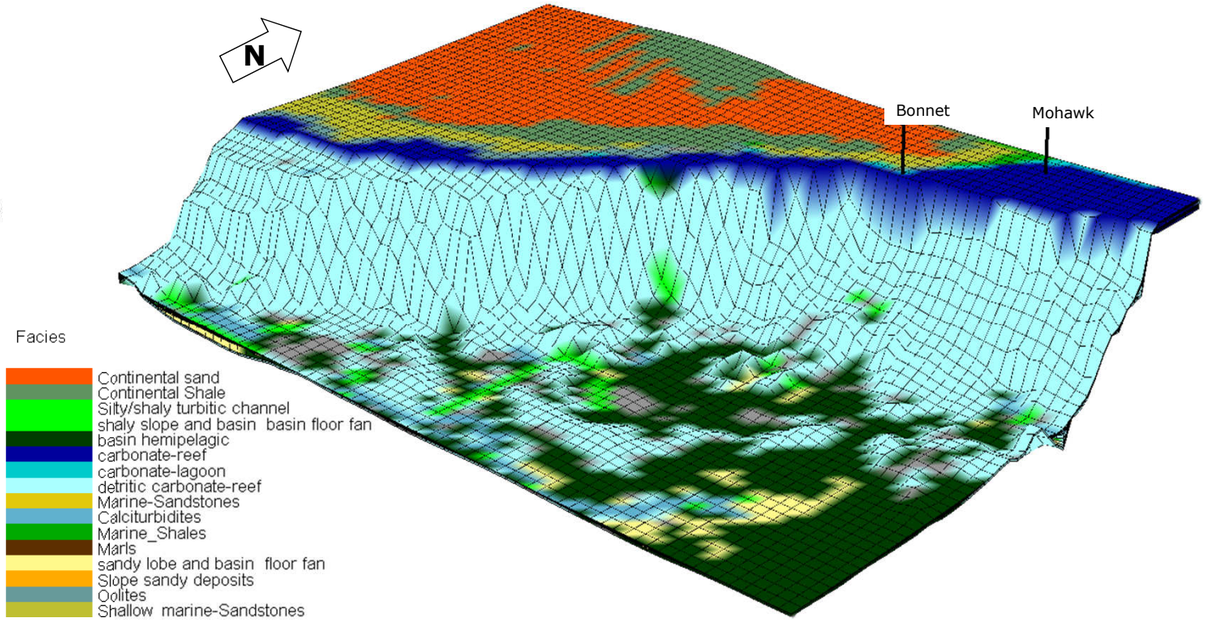


Figure 89. Facies distribution at 130 Ma

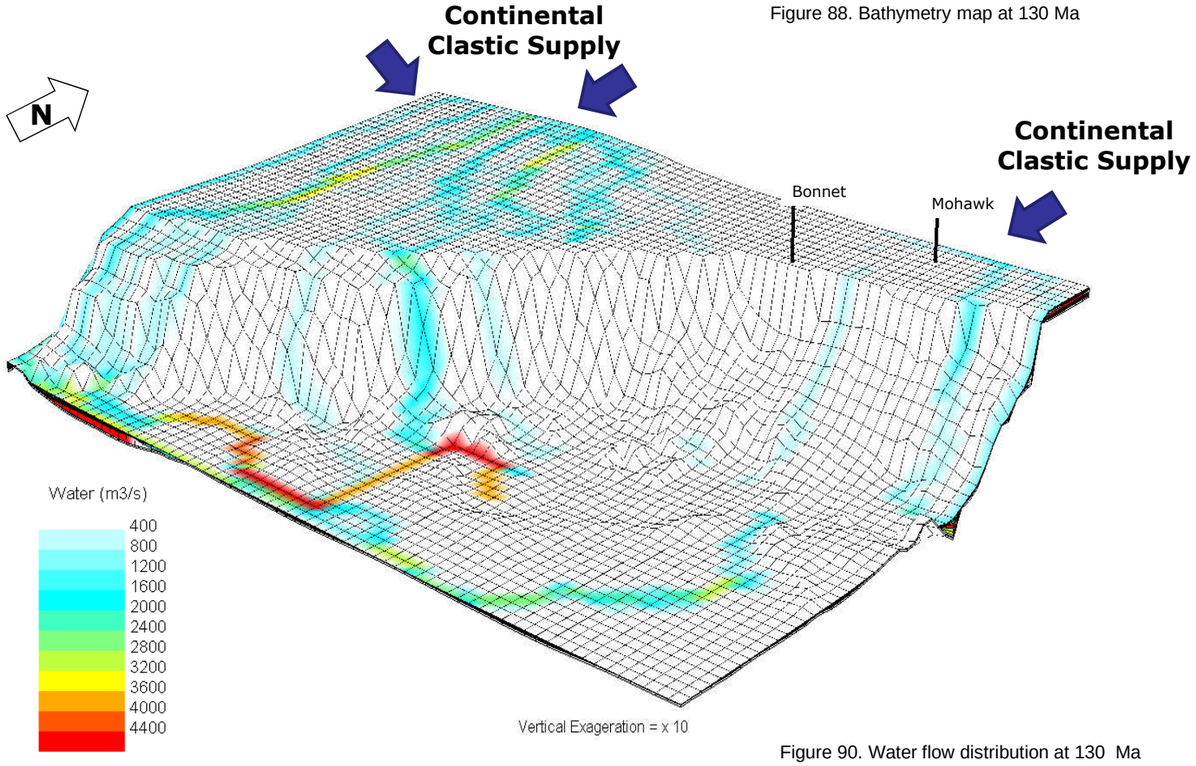


Figure 90. Water flow distribution at 130 Ma

✓ Sequence simulated: Post rift to Barremian

✓Age represented: Barremian.

✓Stratigraphic event: Transgressive Episode and onset of the “Cretaceous Shelburne Delta” .

✓After the erosive period during the lower cretaceous a new deltaic progradation episode reached the shelf. This was a response to a combination of the Avalon uplift and the effect of the hotspot related to the New England Sea Mounts; A previous step to this deltaic progradation was the drowning of carbonates in the shelf by a rapid sea level rise providing suitable bathymetric condition for clinoforms progradation.

✓The sediment supplies at this time correspond to fluvial systems located to the north of the simulation area being preferentially concentrate to the northwest border of the model and close to the Mohawk Well position (Figure 90).

The average sand content of the sediment sources ranged from 20% to 35% in average.

STRATIGRAPHIC MODELLING VALANGINIAN - BARREMIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

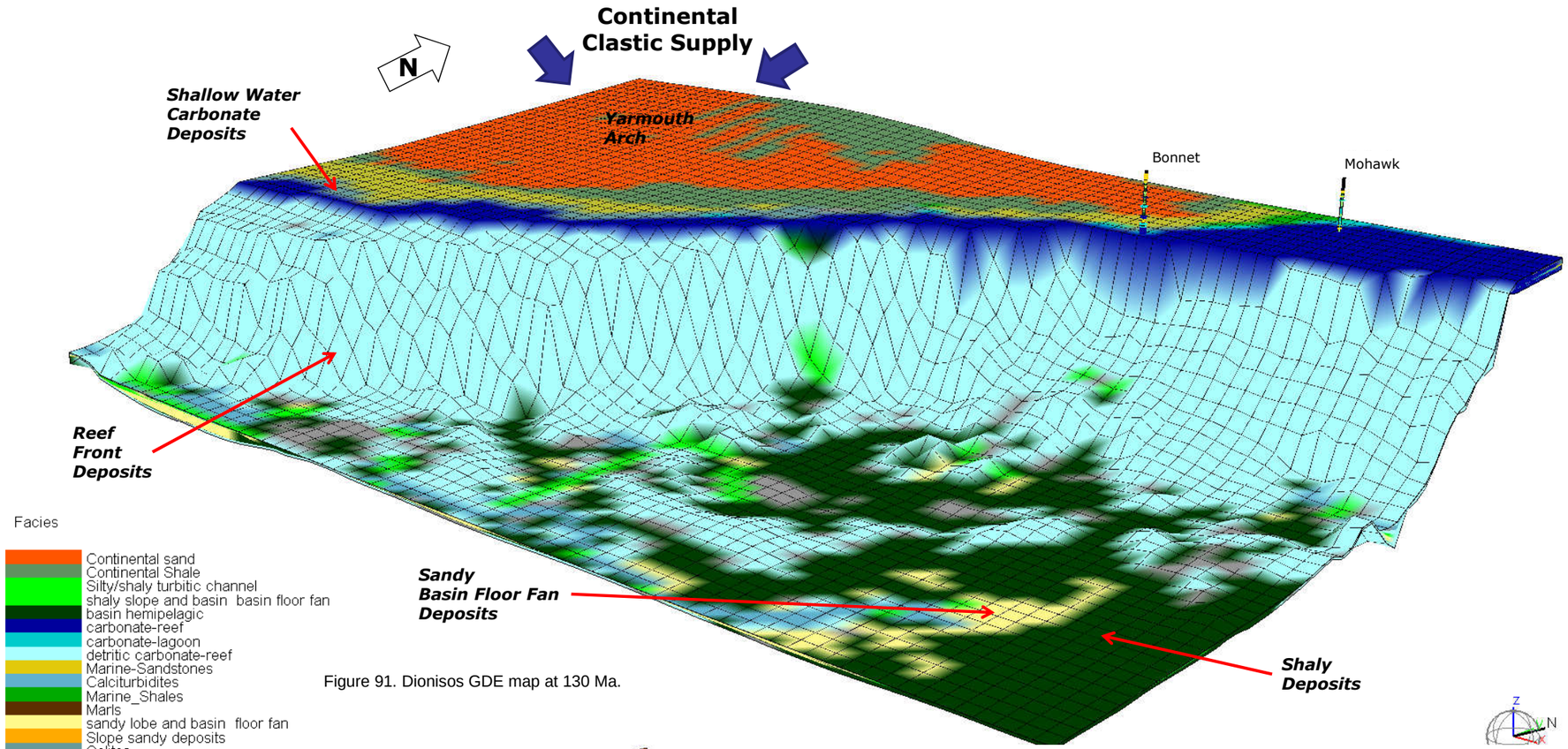
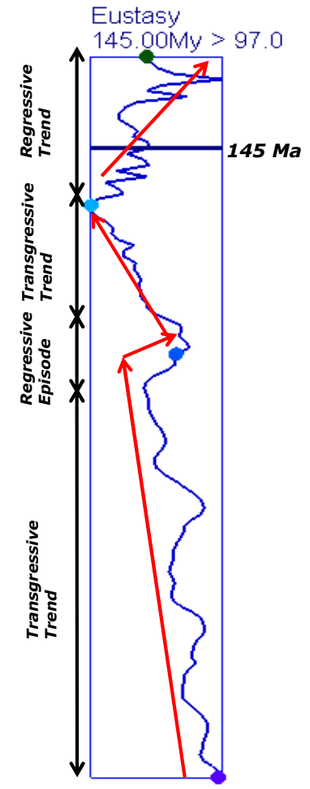


Figure 91. Dionisos GDE map at 130 Ma.



Haq et al., 1998

Figure 92. Eustatic curve at 130 Ma.

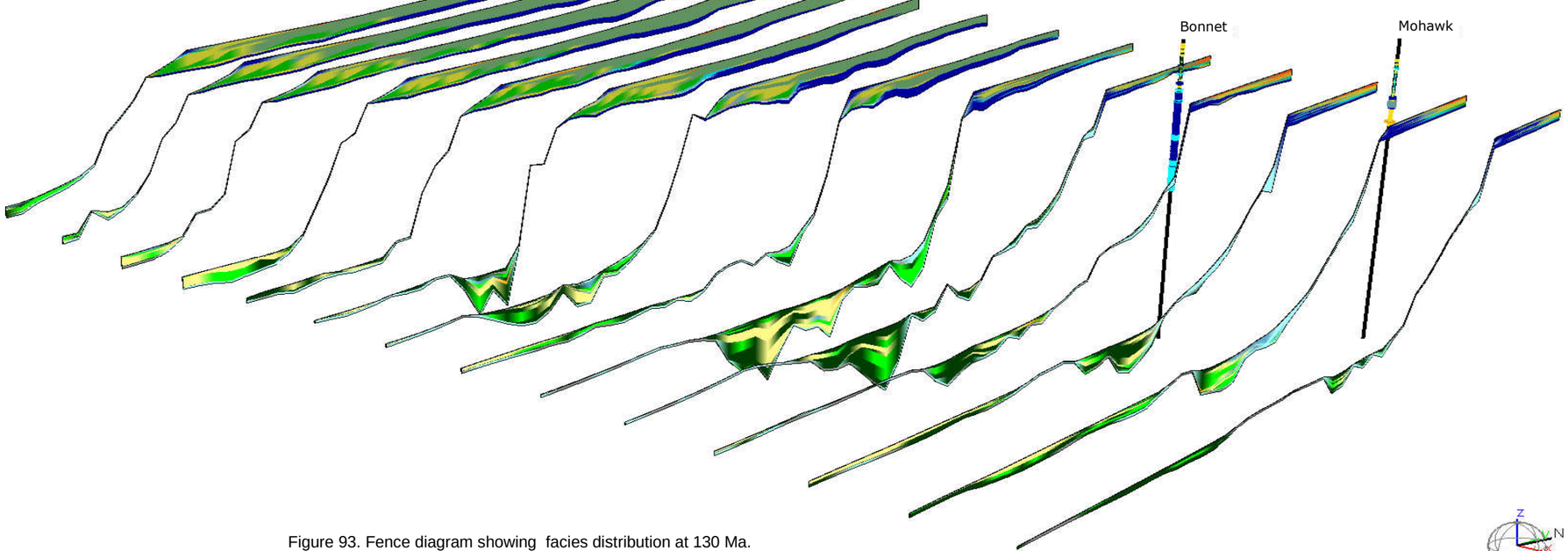


Figure 93. Fence diagram showing facies distribution at 130 Ma.
Vertical Exageration = x 10

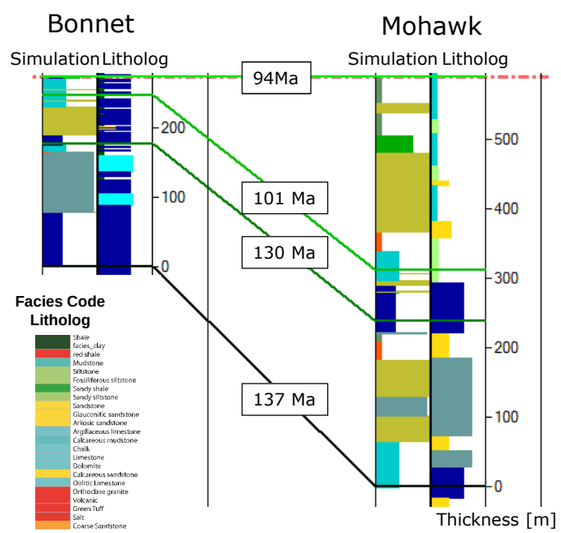


Figure 94. Well correlation between wells Bonnet and Mohawk at 150 Ma.

PL. 6.4.8 **GDE Maps and Dionisos Results : Fence Diagram and 3D View – Age 130 Ma**

CHAPTER 6.5

STRATIGRAPHIC MODELLING
BARREMIAN - CENOMANIAN SEQUENCE

STRATIGRAPHIC MODELLING - BARREMIAN-CENOMANIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

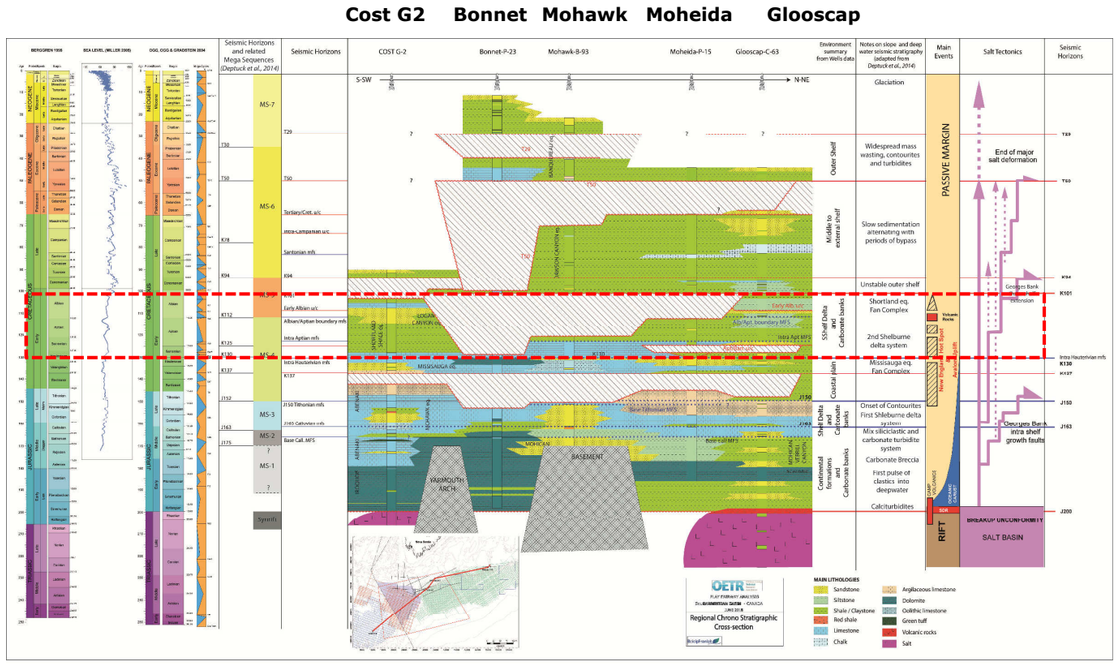


Figure 95. Stratigraphic Cross-Section across the study area. Dotted red line represents the period of time showed in this section.

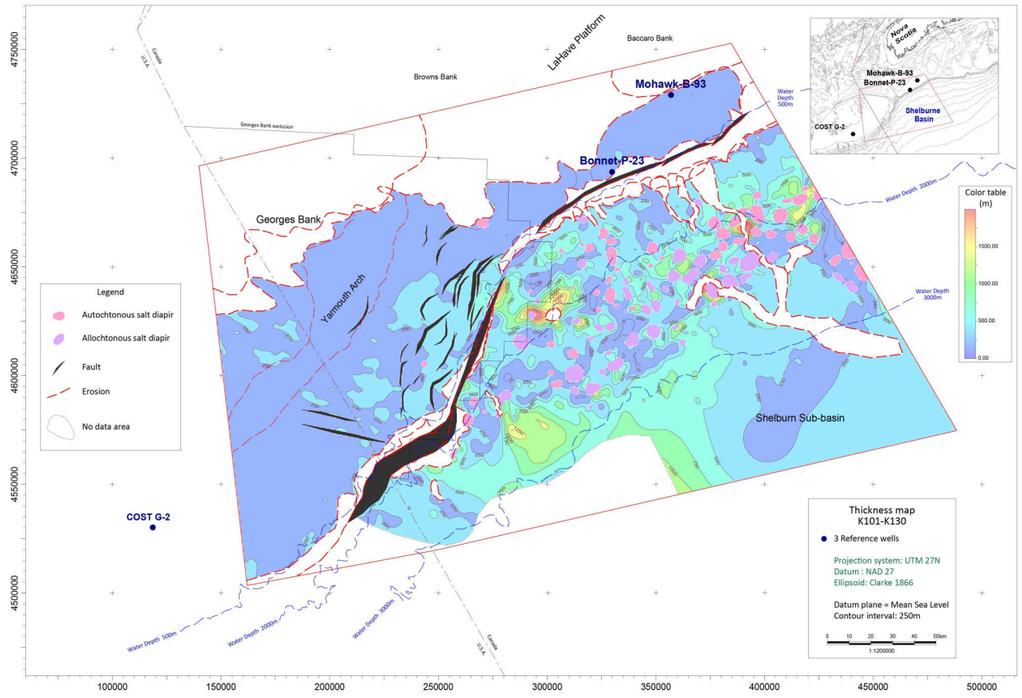


Figure 96. Isopach map K130 – K101.

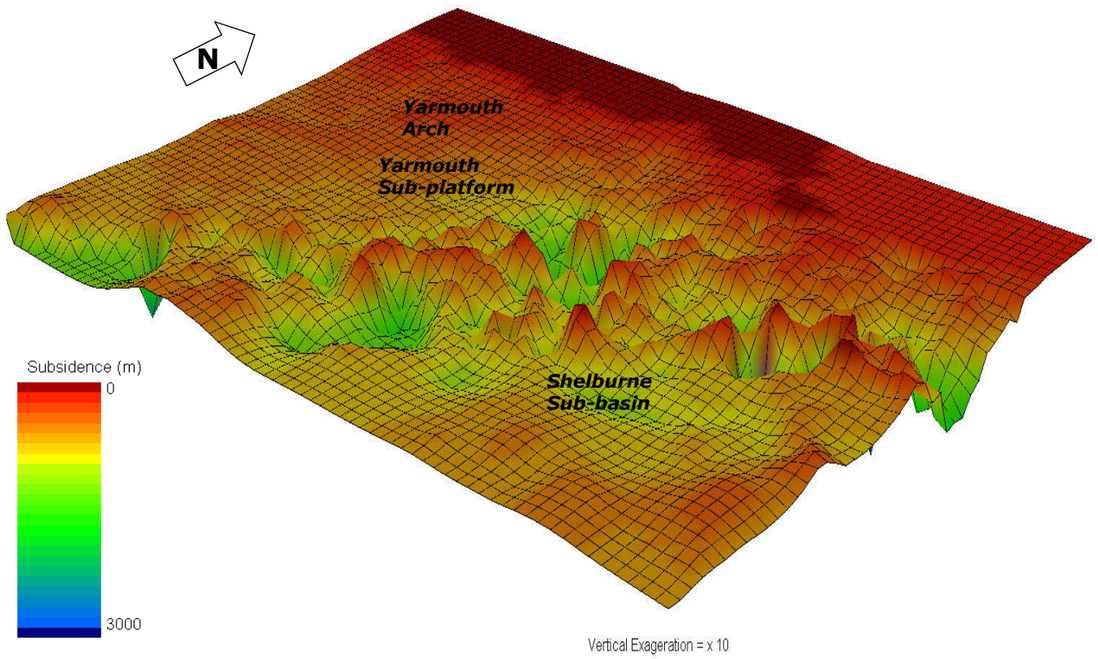


Figure 97. The total subsidence at this age was estimated following this formula: $Total\ Subsidence = Subidence\ (t-1) + SedThick(t) + Bathy\ (t) - Bathy\ (t-1)$; t=101 Ma; (t-1)=137

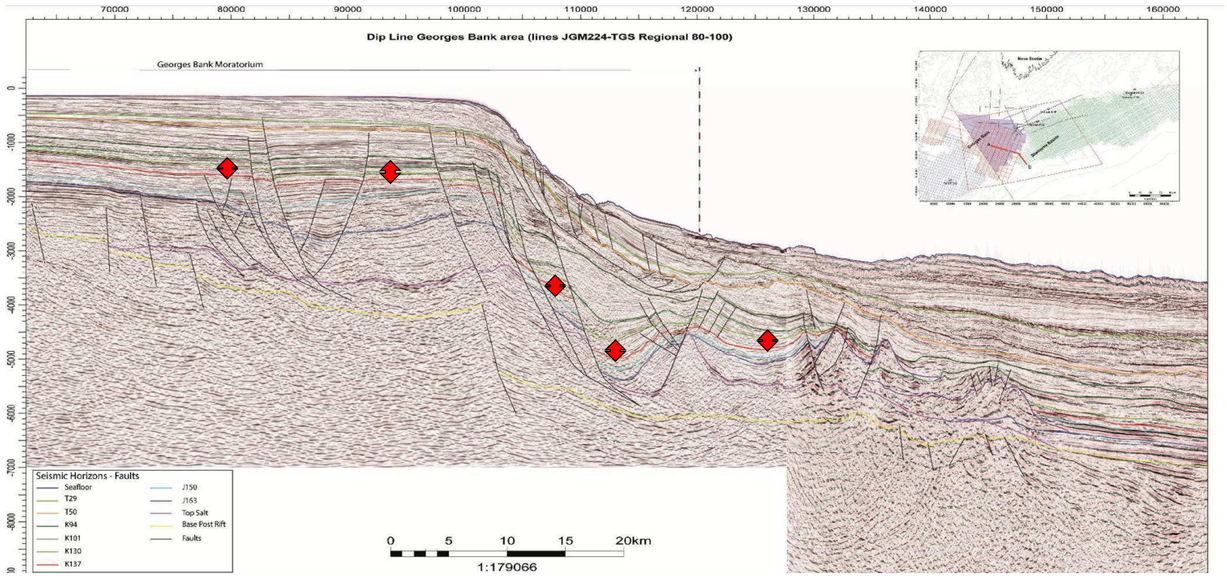


Figure 98. Seismic section (lines JGM 224 – TGS regional 80-100) across the Yarmouth Sub-platform and the Shelburne Sub-basin showing the interval K130 – K101.

STRATIGRAPHIC MODELLING - BARREMIAN-CENOMANIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

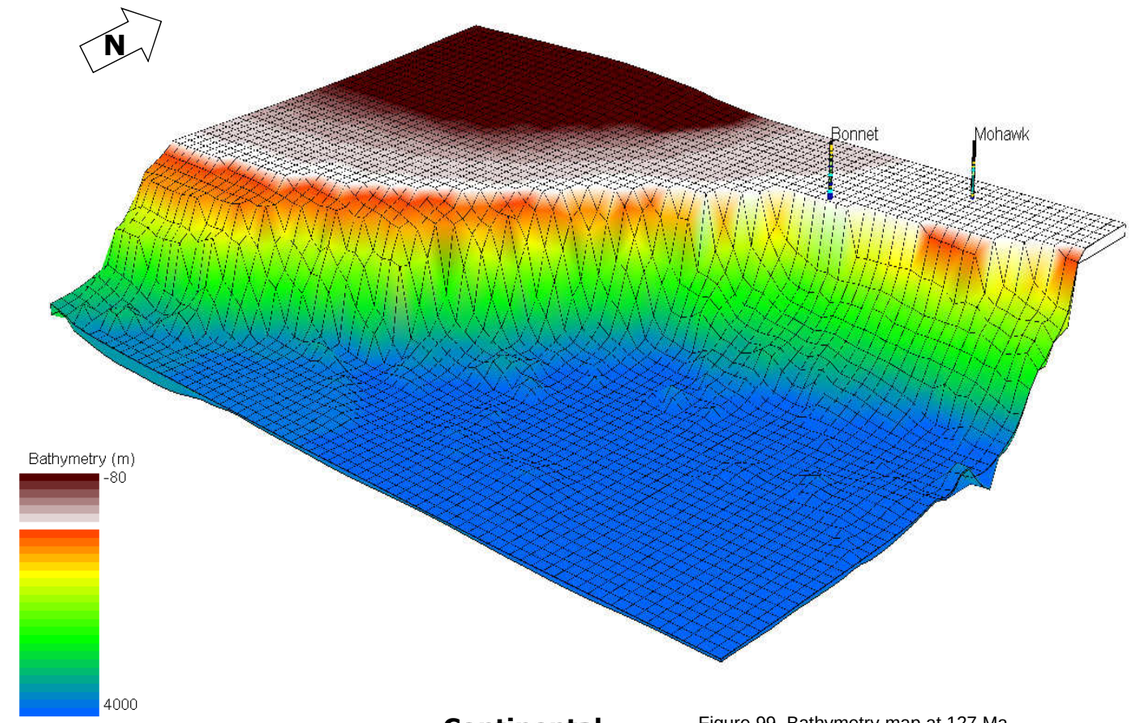


Figure 99. Bathymetry map at 127 Ma

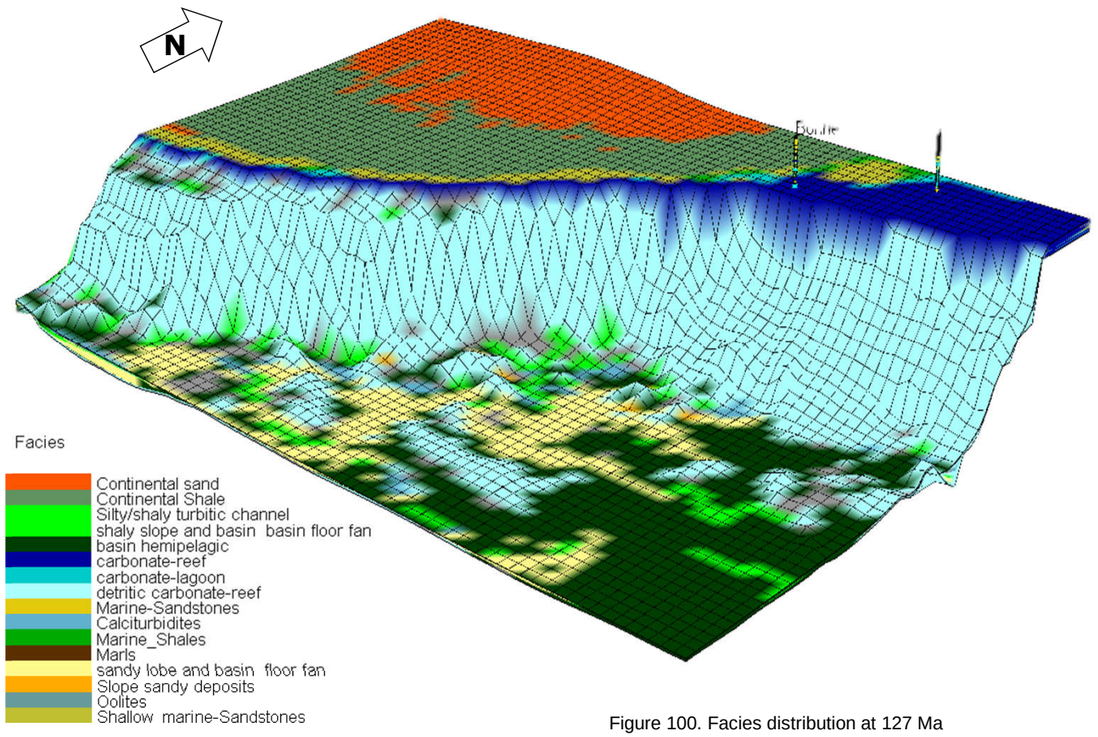


Figure 100. Facies distribution at 127 Ma

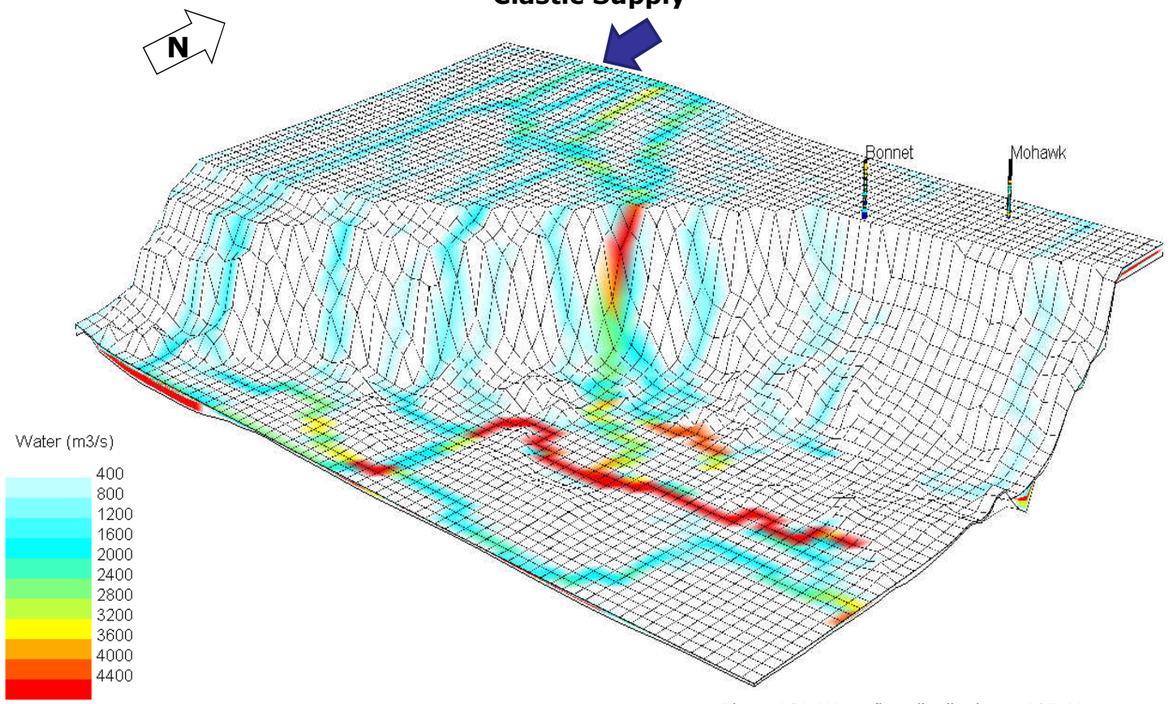


Figure 101. Water flow distribution at 127 Ma

✓ Sequence simulated: Barremian - Albian

✓Age represented: Barremian.

✓Stratigraphic event: High-Stand Episode, onset of the Cretaceous Shelburne Delta.

✓This time step shows the accumulation of the first deltaic facies after the Lower Cretaceous erosive period. During this new deltaic progradation episode known as the Cretaceous “Shelburne Delta” the turbiditic system in the Shelburne Sub-basin was reactivated allowing the accumulation of sand rich deposits in ponded areas (mini-basins) surrounding anticline structures generated by salt flow.

✓The sediment supplies at this time correspond to fluvial systems located to the north of the simulation area being preferentially concentrate to the north western border of the model (Figure 101).

The average sand content of the sediment sources ranged from 20% to 35% in average.

STRATIGRAPHIC MODELLING - BARREMIAN-CENOMANIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

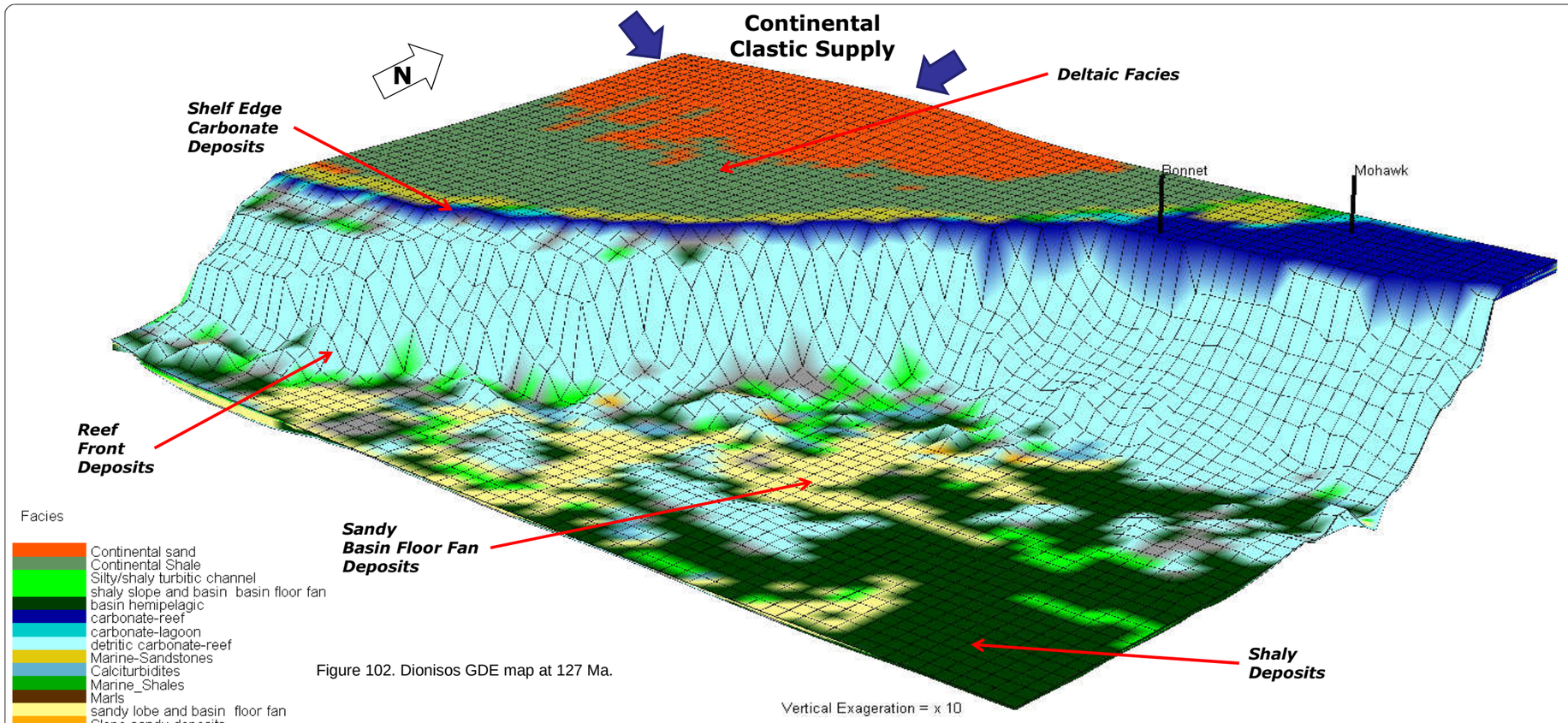
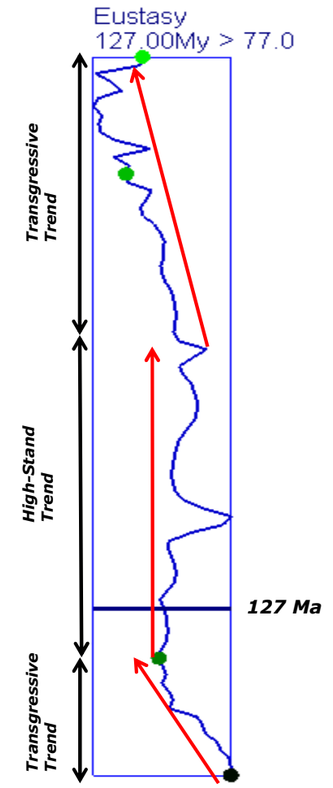


Figure 102. Dionisos GDE map at 127 Ma.



Haq et al., 1998

Figure 103. Eustatic curve at 127 Ma.

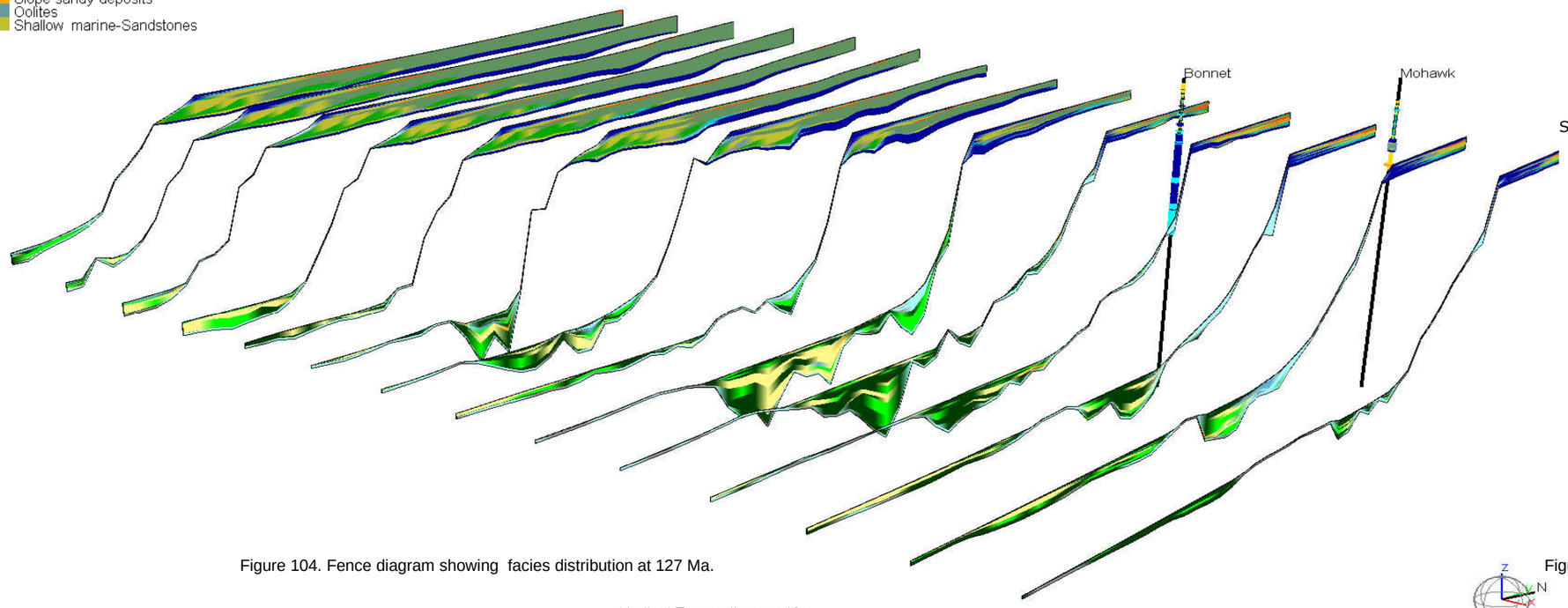


Figure 104. Fence diagram showing facies distribution at 127 Ma.

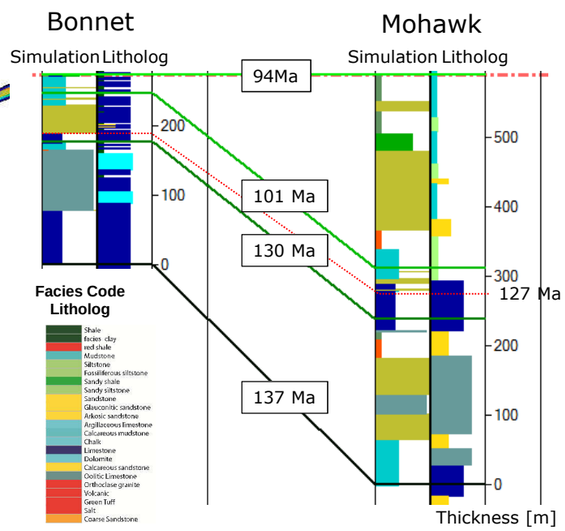


Figure 105. Well correlation between wells Bonnet and Mohawk at 127 Ma.

GDE Maps and Dionisos Results : Fence Diagram and 3D View – Age 127 Ma **PL. 6.5.3**

STRATIGRAPHIC MODELLING - BARREMIAN-CENOMANIAN SEQUENCE

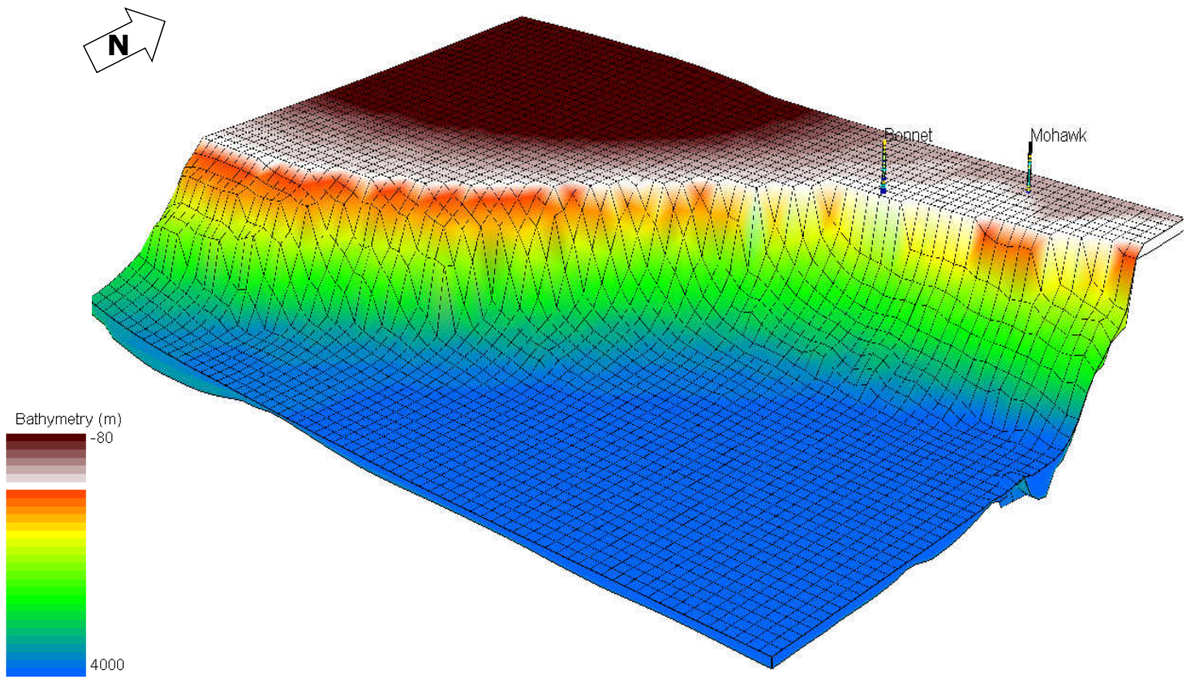


Figure 106. Bathymetry map at 117.5 Ma

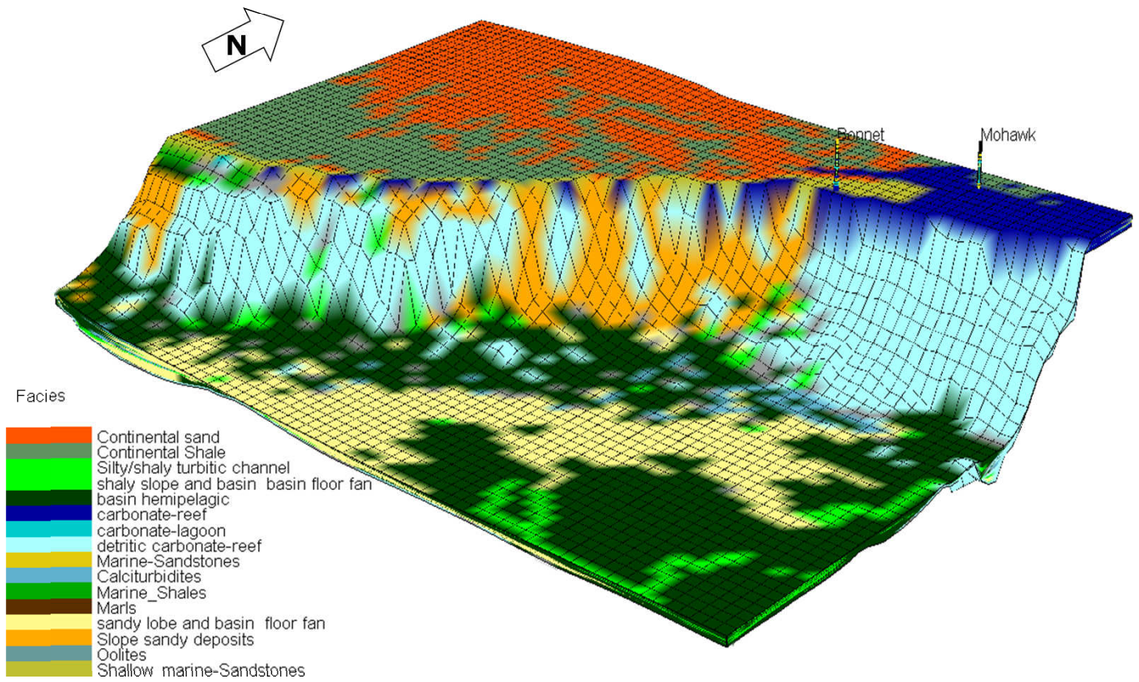


Figure 107. Facies distribution at 117.5 Ma

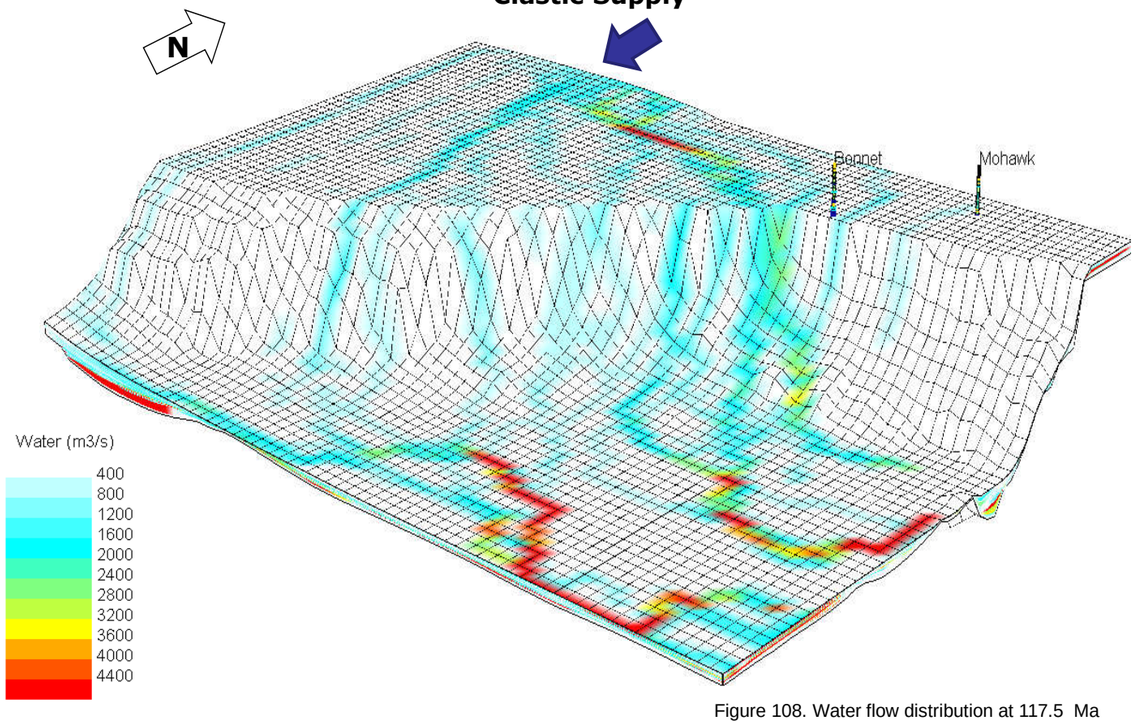


Figure 108. Water flow distribution at 117.5 Ma

✓ Sequence simulated: Barremian - Albian

✓Age represented: Aptian.

✓Stratigraphic event: High-Stand Episode, onset of the Cretaceous Shelburne Delta.

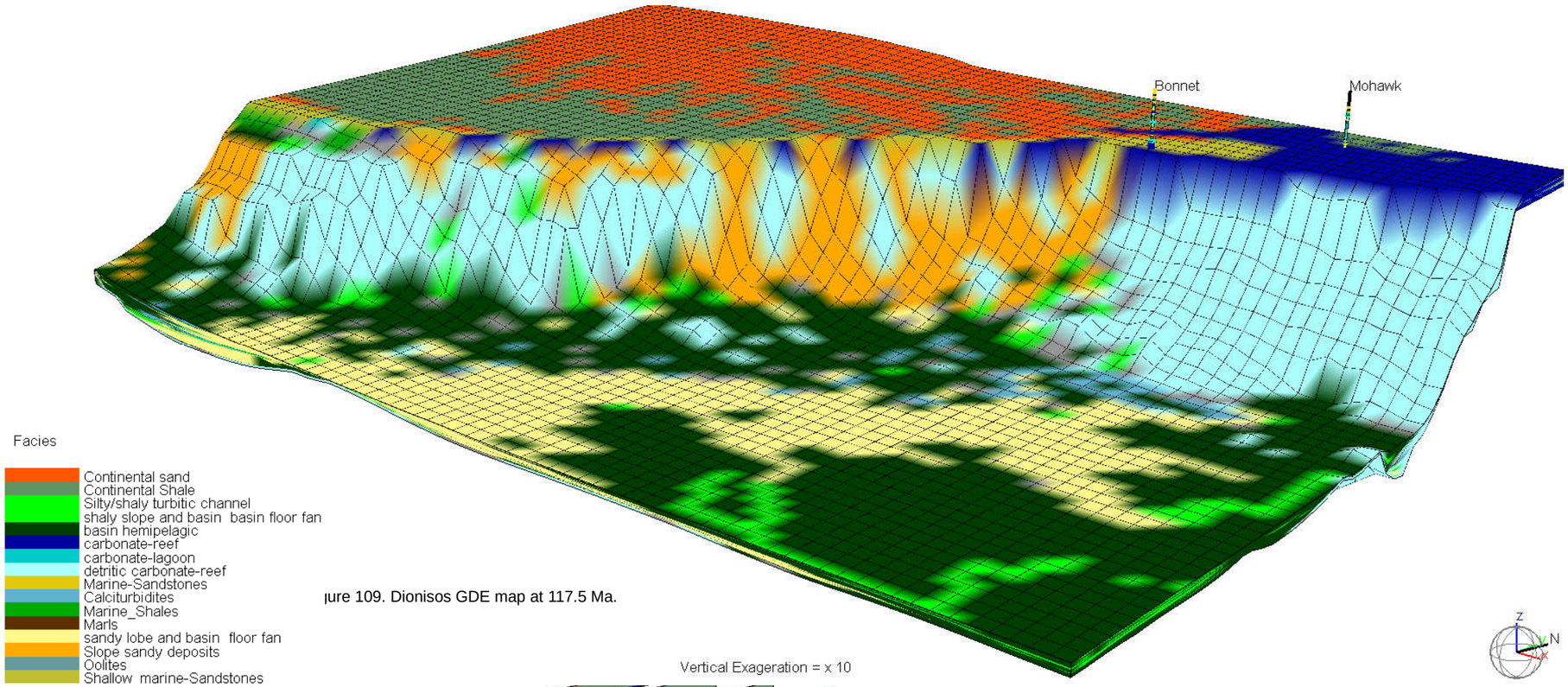
✓At this time step deltaic facies progradation continues to the south and due to a restricted accommodation space in the shelf, most of the sediments are bypassed to the slope and basin floor. An active turbiditic system is present in the basin area being supplied by the Cretaceous "Shelburne Delta" providing suitable conditions for sand rich deposits accumulations in ponded areas (mini-basins) surrounding anticline structures generated by salt flow.

✓The sediment supplies at this time correspond to a fluvial systems located to the north of the simulation area being preferentially concentrate to the north western border of the model (Figure 108).

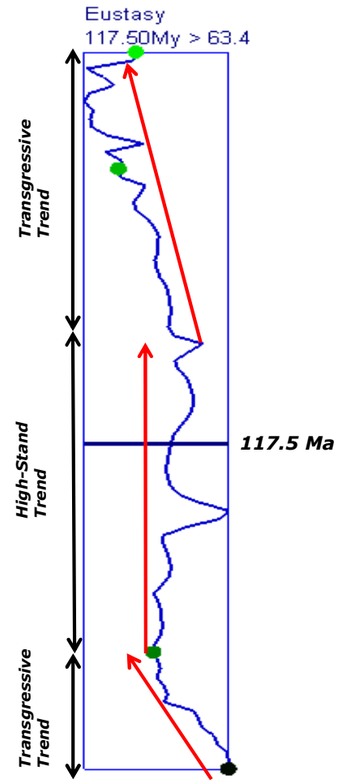
The average sand content of the sources ranged from 20% to 35% in average.

STRATIGRAPHIC MODELLING - BARREMIAN-CENOMANIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015



ıure 109. Dionisos GDE map at 117.5 Ma.



Haq et al., 1998

Figure 110. Eustatic curve at 117.5 Ma.

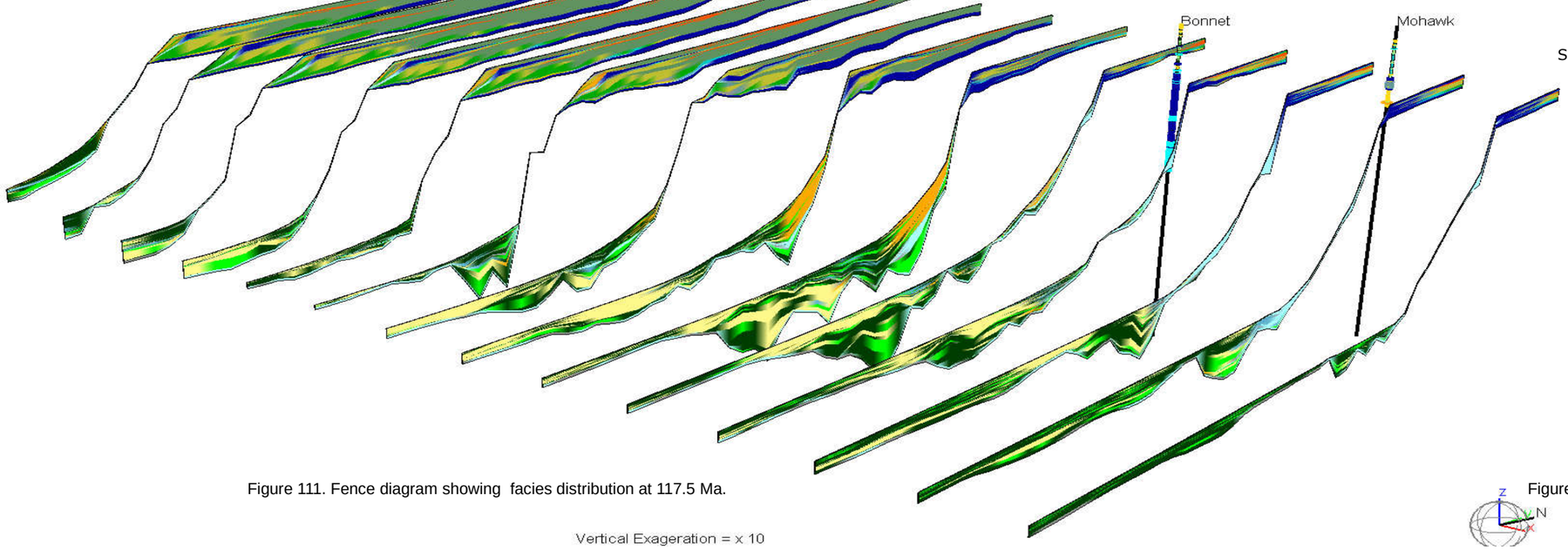


Figure 111. Fence diagram showing facies distribution at 117.5 Ma.

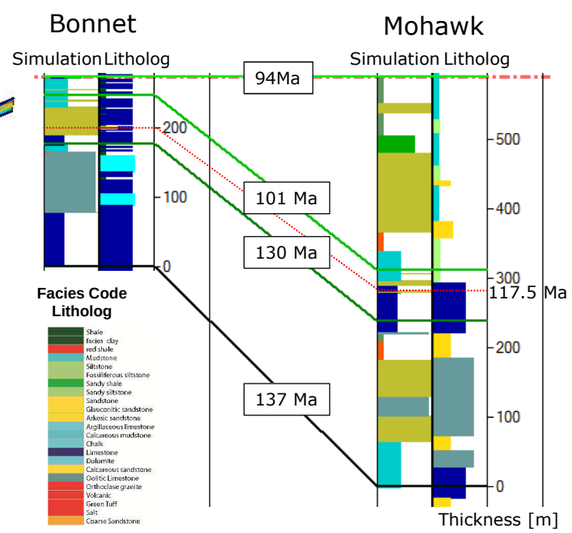


Figure 112. Well correlation between wells Bonnet and Mohawk at 117.5 Ma.

GDE Maps and Dionisos Results : Fence Diagram and 3D View – Age 117.5 Ma

PL. 6.5.5

STRATIGRAPHIC MODELLING - BARREMIAN-CENOMANIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

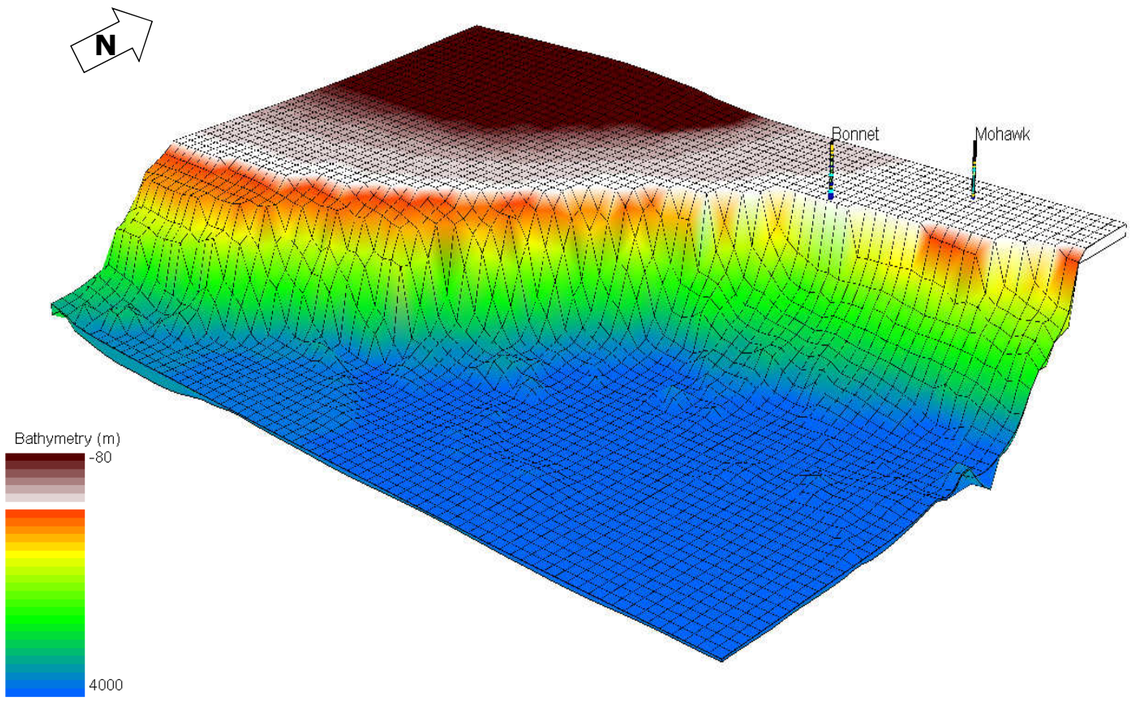


Figure 113. Bathymetry map at 110 Ma

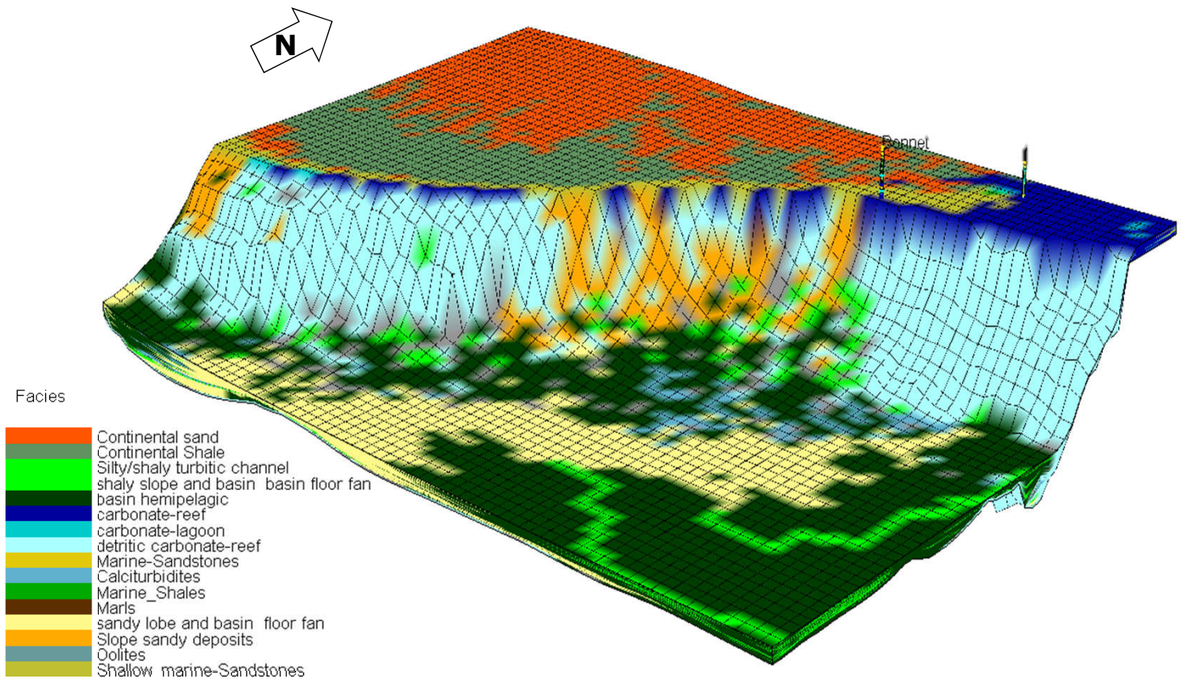


Figure 114. Facies distribution at 110 Ma

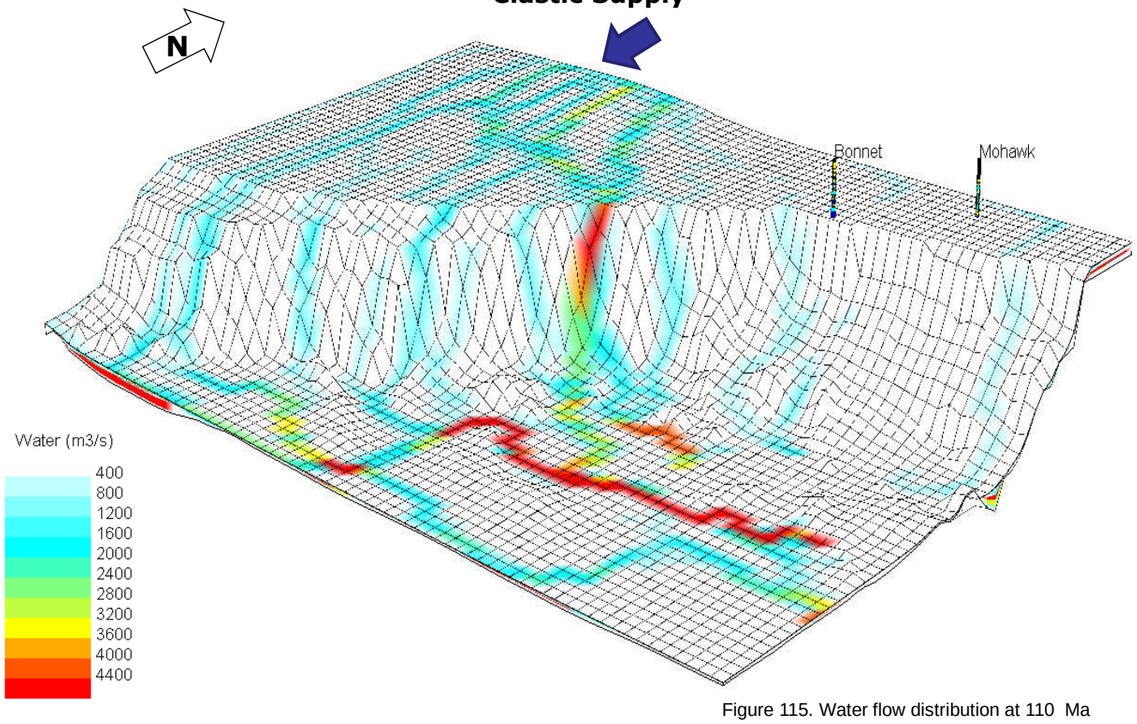


Figure 115. Water flow distribution at 110 Ma

✓ Sequence simulated: Barremian - Albian

✓Age represented: Albian.

✓Stratigraphic event: Transgressive Episode, Cretaceous Shelburne Delta.

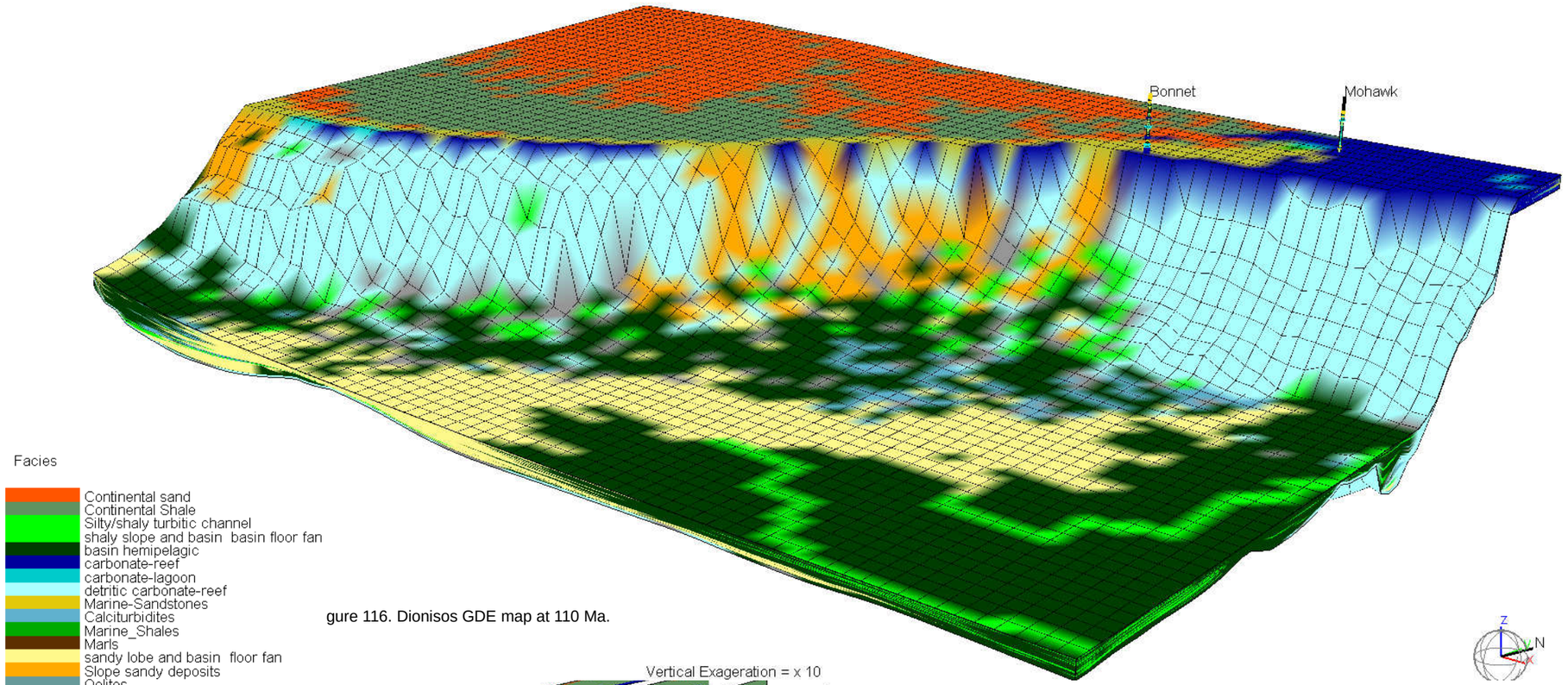
✓At this time step deltaic sedimentation continues on the shelf but due to a restricted accommodation space most of the sediments are then bypassed to the slope and basin. The Turbiditic system continues being active in the basin area.

✓The sediment supplies at this time correspond to a deltaicl systems located to the north of the simulation area being preferentially concentrate to the north western border of the model (Figure 115).

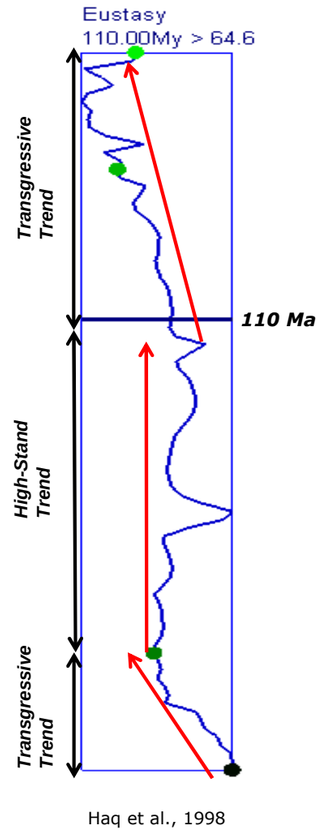
The average sand content of the sources ranged from 20% to 35% in average.

STRATIGRAPHIC MODELLING - BARREMIAN-CENOMANIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015



gure 116. Dionisos GDE map at 110 Ma.



Haq et al., 1998

Figure 117. Eustatic curve at 110 Ma.

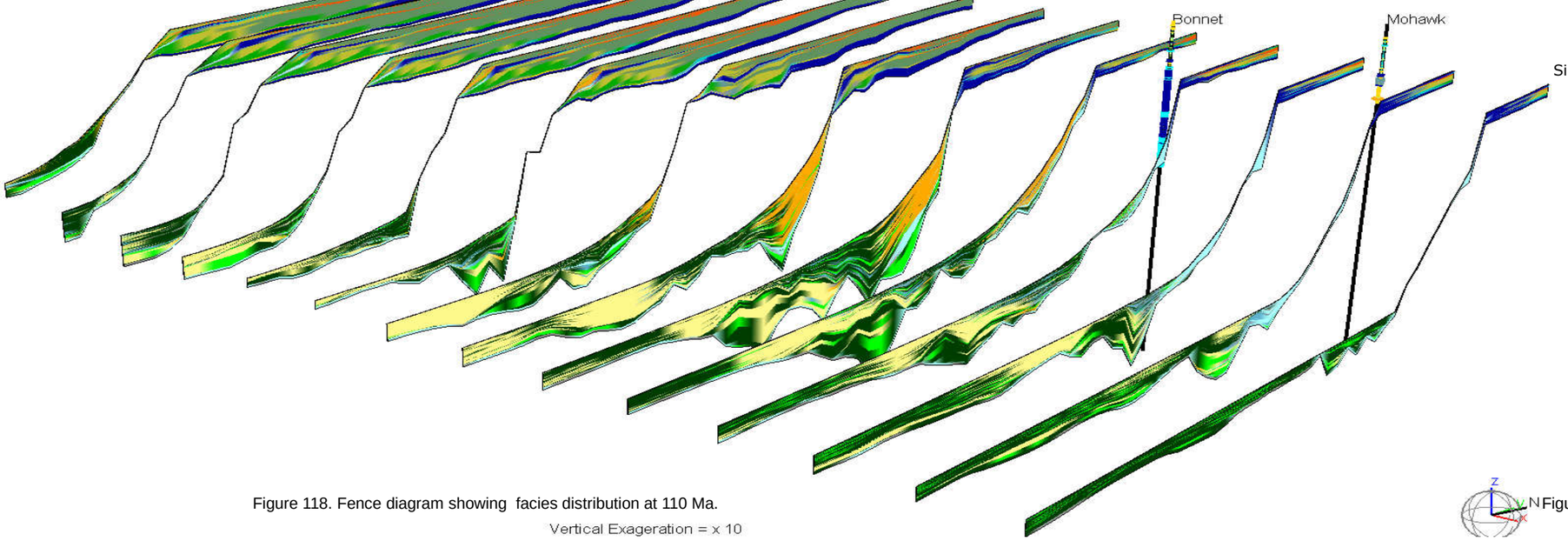


Figure 118. Fence diagram showing facies distribution at 110 Ma.

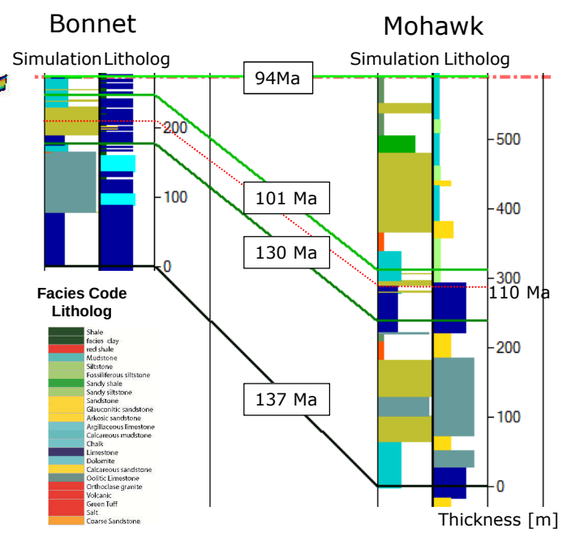


Figure 119. Well correlation between wells Bonnet and Mohawk at 110 Ma.

STRATIGRAPHIC MODELLING - BARREMIAN-CENOMANIAN SEQUENCE

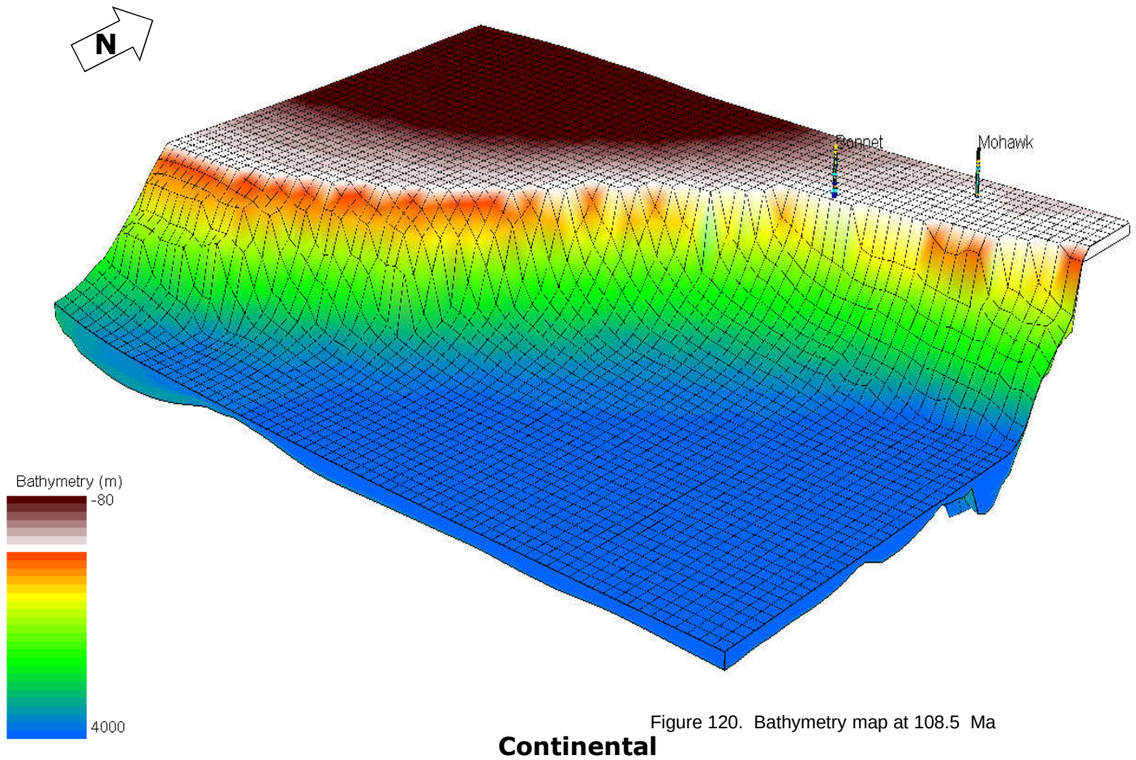


Figure 120. Bathymetry map at 108.5 Ma

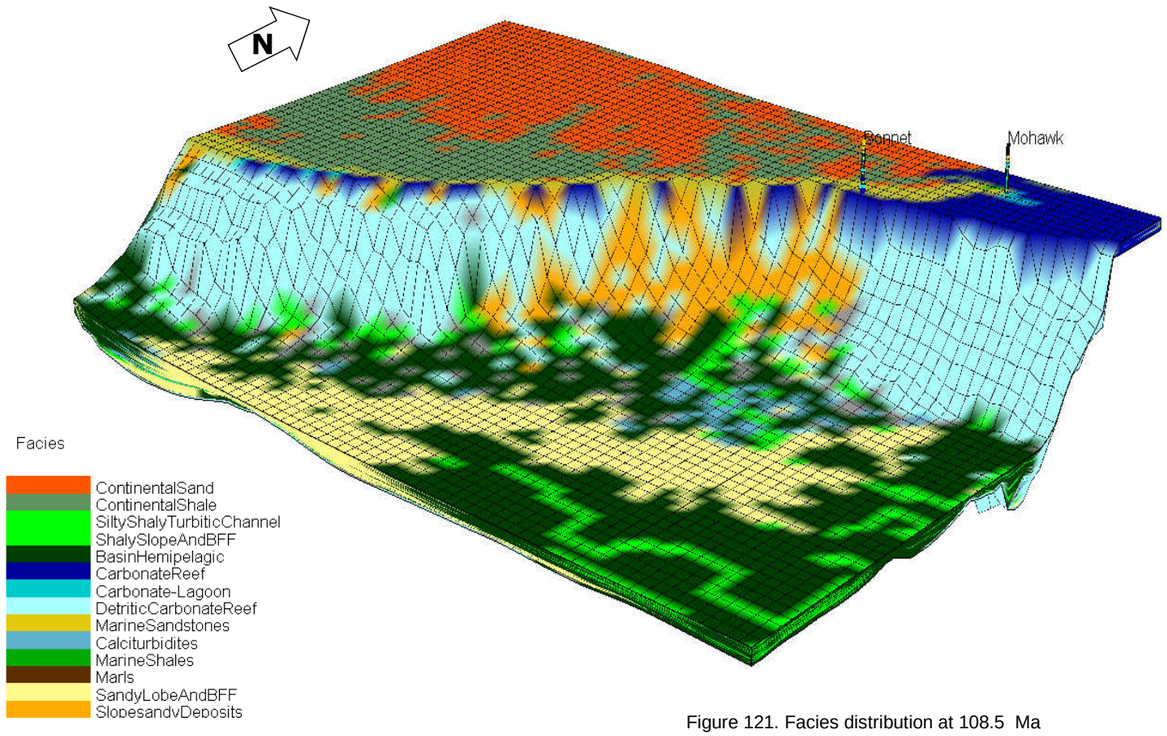


Figure 121. Facies distribution at 108.5 Ma

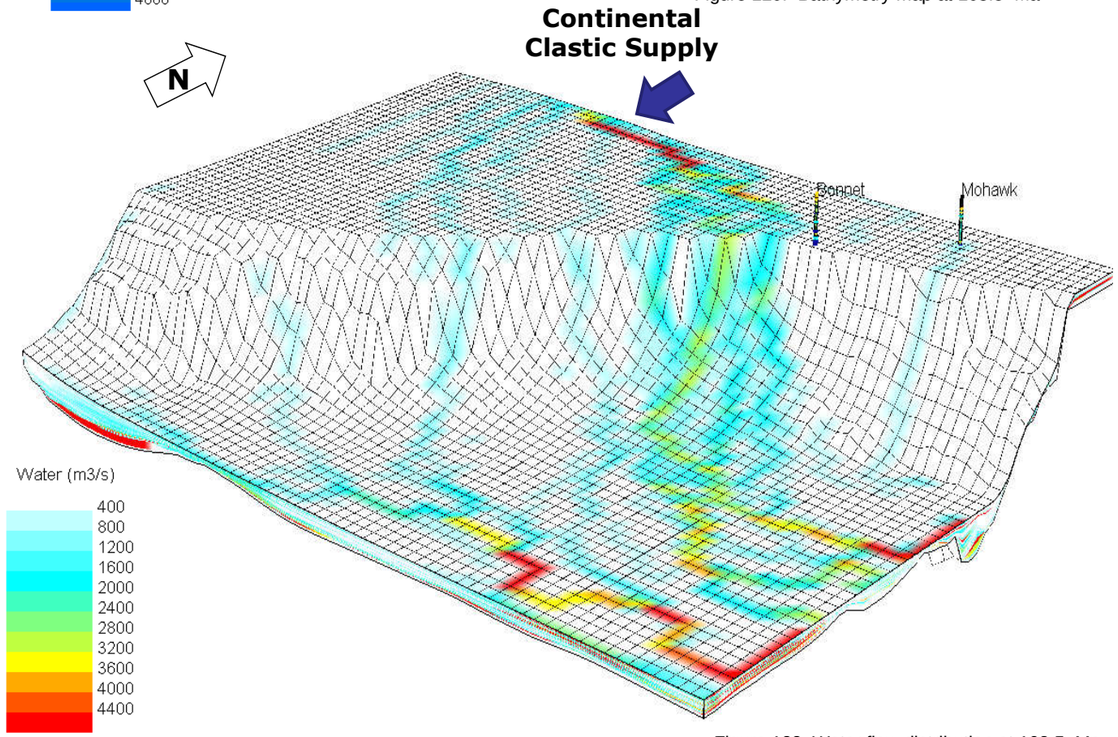


Figure 122. Water flow distribution at 108.5 Ma

✓ Sequence simulated: Barremian - Albian

✓Age represented: Albian.

✓Stratigraphic event: Transgressive Episode, Cretaceous Shelburne Delta.

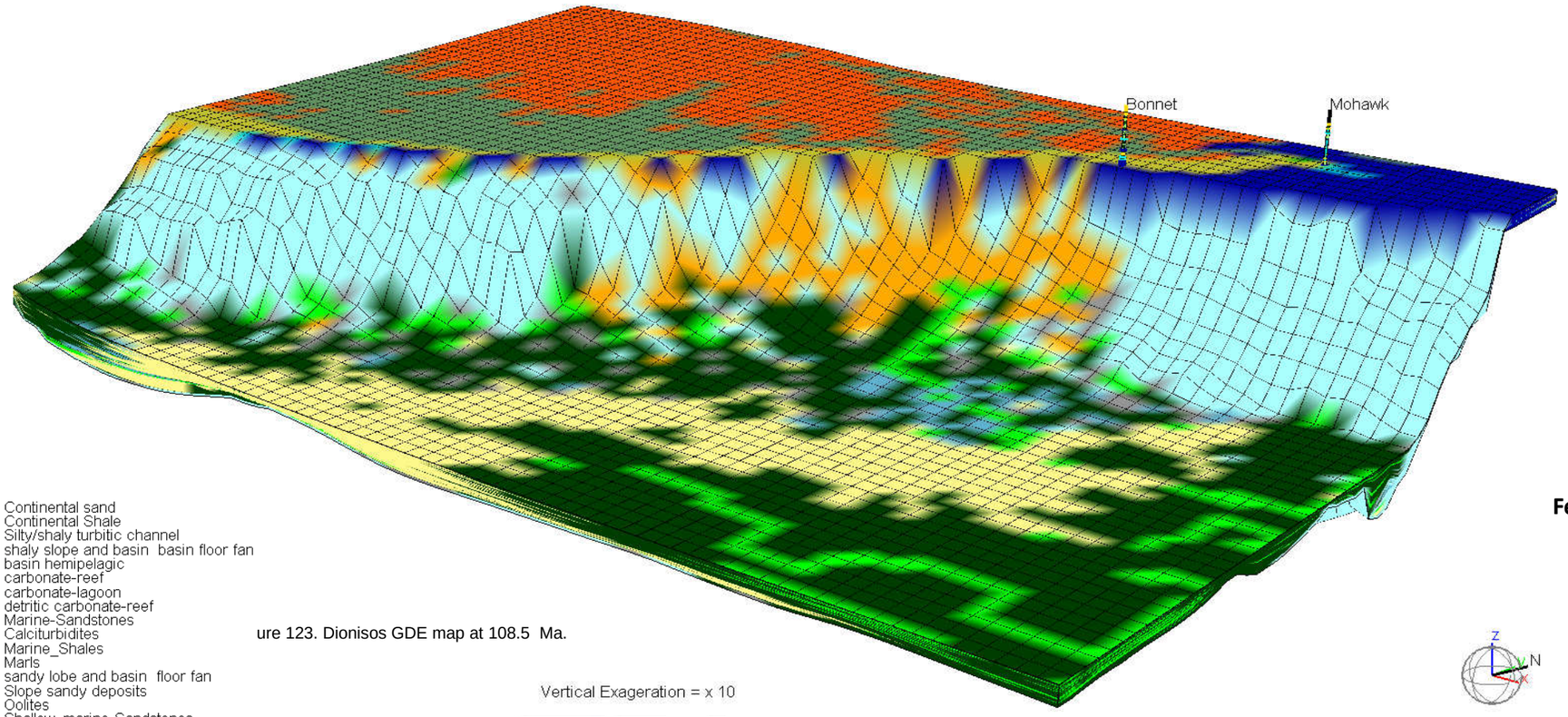
✓At this time step deltaic sedimentation continues on the shelf but due to a restricted accommodation space most of the sediments are then bypassed to the slope and basin. Lateral restricted carbonates built-ups are present along the shelf edge. The Turbiditic system is not only transporting deltaic sediments to the basin area but also eroding Jurassic carbonates from the slope.

✓The sediment supplies at this time correspond to a deltaic systems located to the north of the simulation area being preferentially concentrate to the north western border of the model (Figure 122).

The average sand content of the sources ranged from 20% to 35% in average.

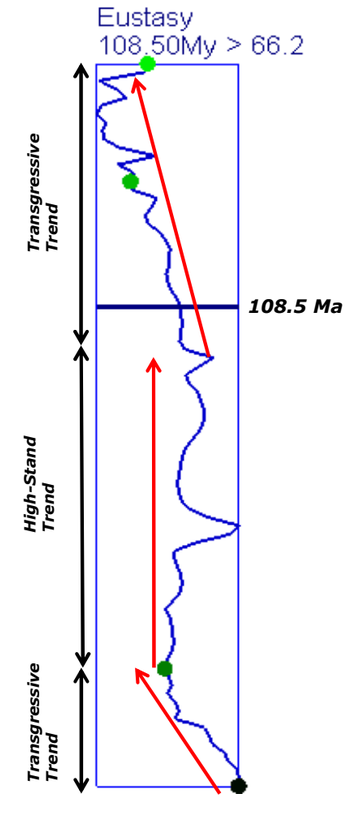
STRATIGRAPHIC MODELLING - BARREMIAN-CENOMANIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015



ure 123. Dionisos GDE map at 108.5 Ma.

Fence Diagram



Haq et al., 1998

Figure 124. Eustatic curve at 108.5 Ma.

Figure 125. Fence diagram showing facies distribution at 108.5 Ma.

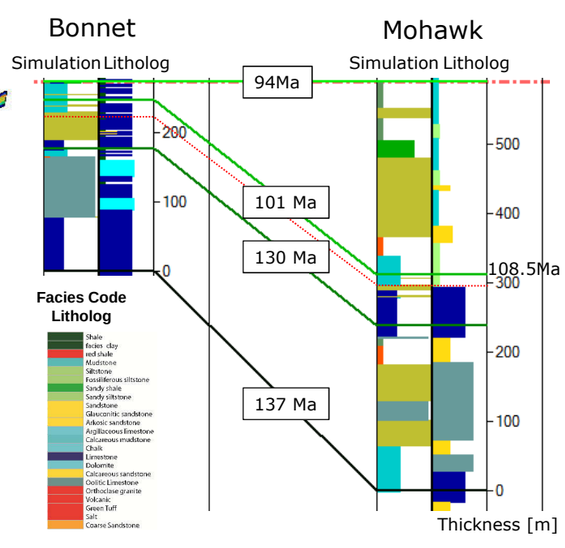


Figure 126. Well correlation between wells Bonnet and Mohawk at 108.5 Ma.

GDE Maps and Dionisos Results : Fence Diagram and 3D View – Age 108.5 Ma **PL. 6.5.9**

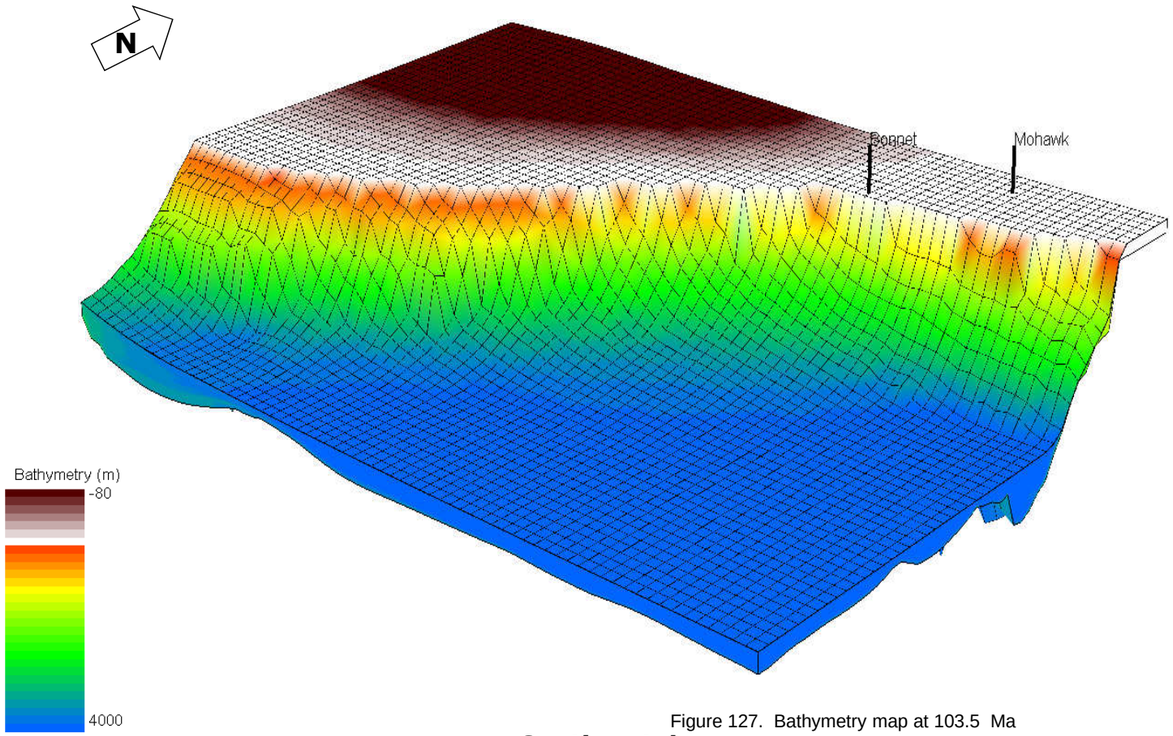


Figure 127. Bathymetry map at 103.5 Ma

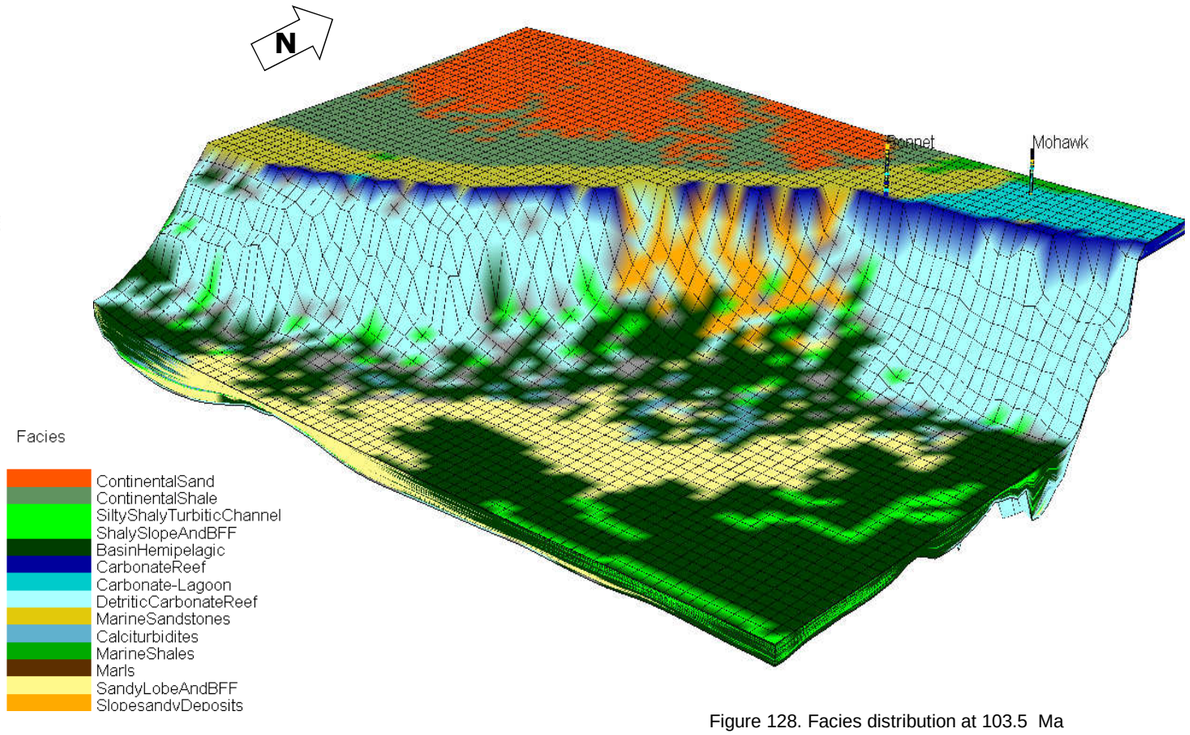


Figure 128. Facies distribution at 103.5 Ma

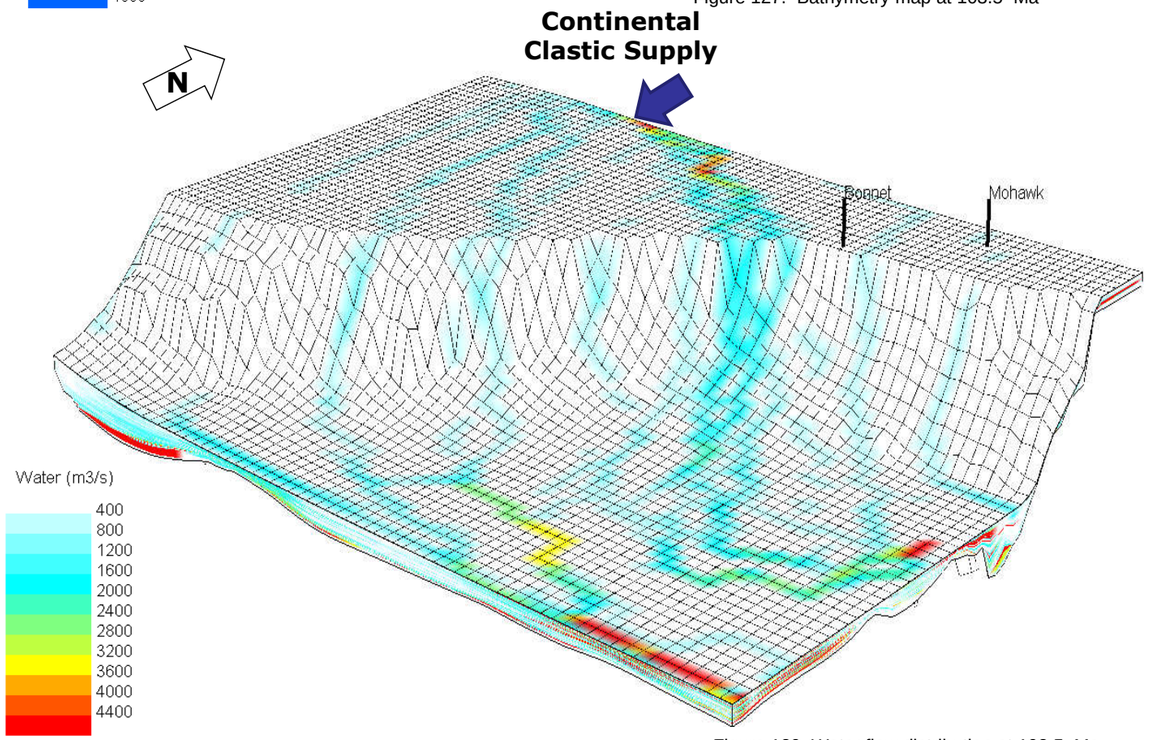


Figure 129. Water flow distribution at 103.5 Ma

✓ Sequence simulated: Barremian - Albian

✓Age represented: Albian.

✓Stratigraphic event: Transgressive Episode, Cretaceous Shelburne Delta.

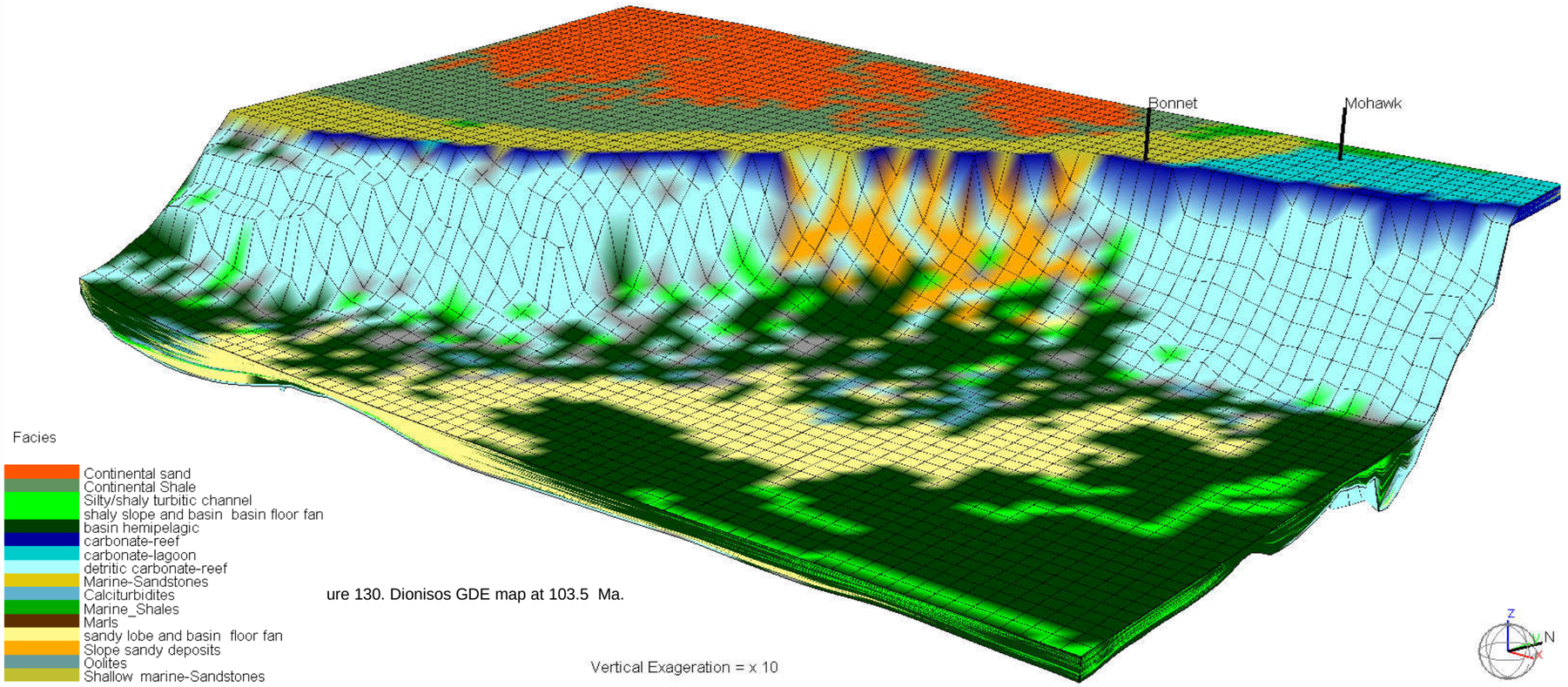
✓At this time step deltaic sedimentation continues on the shelf but due to a restricted accommodation space most of the sediments are then bypassed to the slope and basin. Sandy turbidites deposits become more abundant in the Shelburne Sub-basin area prograding from the base of the slope and basinward.

✓The sediment supplies at this time correspond to a fluvial systems located to the north of the simulation area being preferentially concentrate to the north western border of the model (Figure 129).

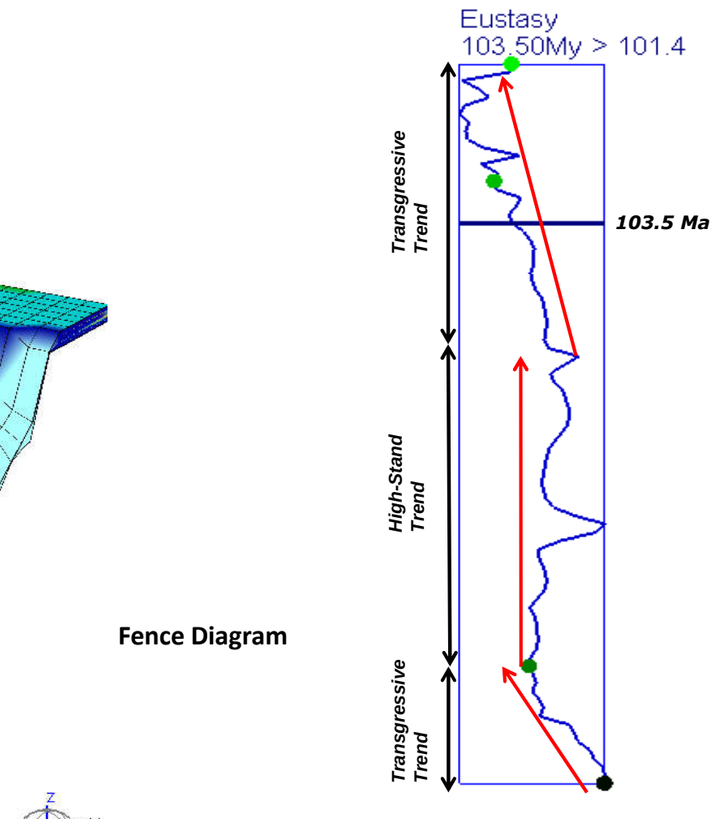
The average sand content of the sources ranged from 20% to 35% in average.

STRATIGRAPHIC MODELLING - BARREMIAN-CENOMANIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015



ure 130. Dionisos GDE map at 103.5 Ma.



Haq et al., 1998

Figure 131. Eustatic curve at 103.5 Ma.

Fence Diagram

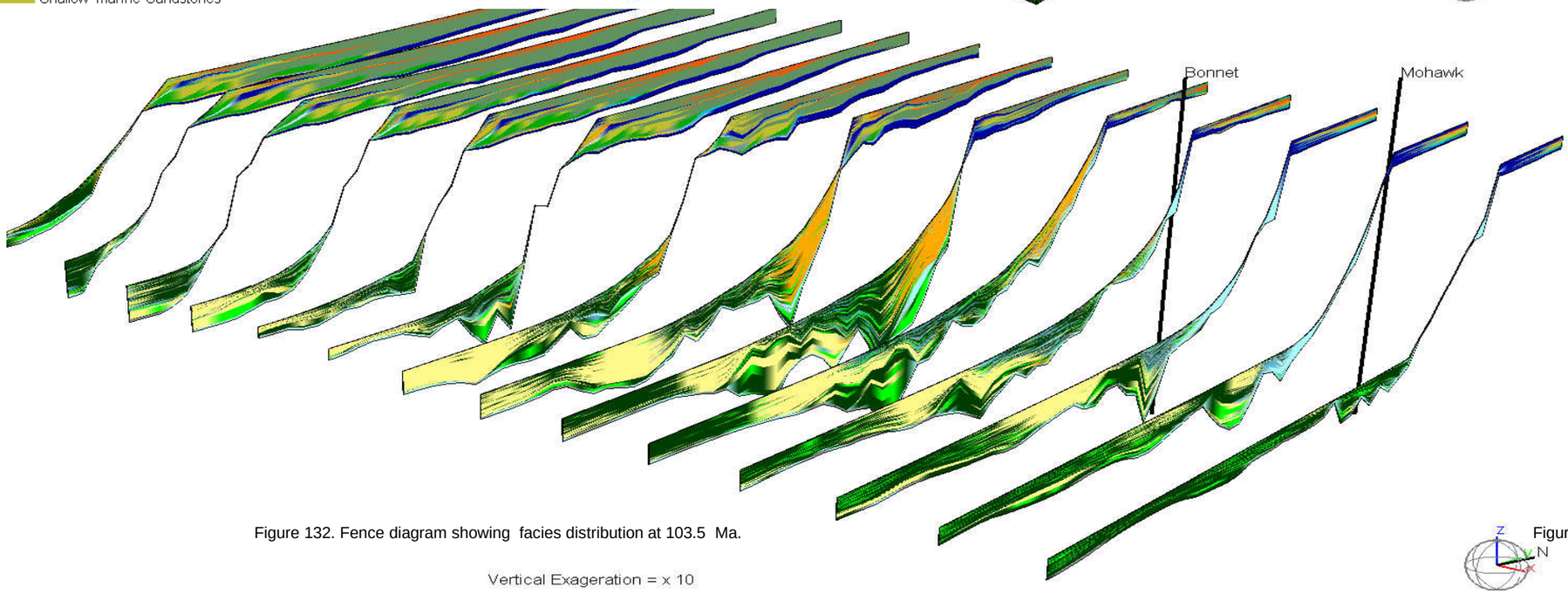


Figure 132. Fence diagram showing facies distribution at 103.5 Ma.

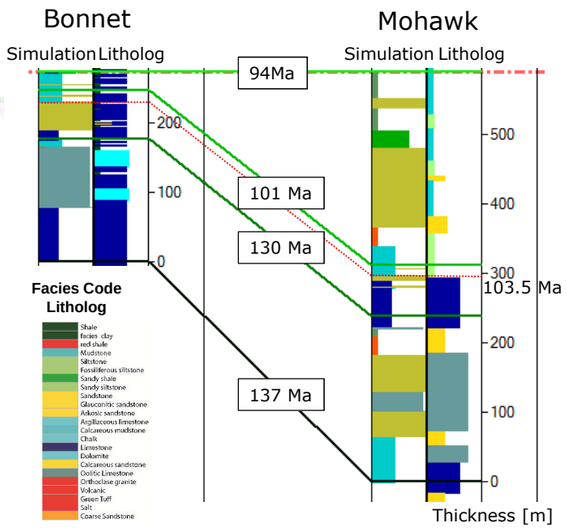


Figure 133. Well correlation between wells Bonnet and Mohawk at 103.5 Ma.

GDE Maps and Dionisos Results : Fence Diagram and 3D View – Age 103.5 Ma

PL. 6.5.11

STRATIGRAPHIC MODELLING - BARREMIAN-CENOMANIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

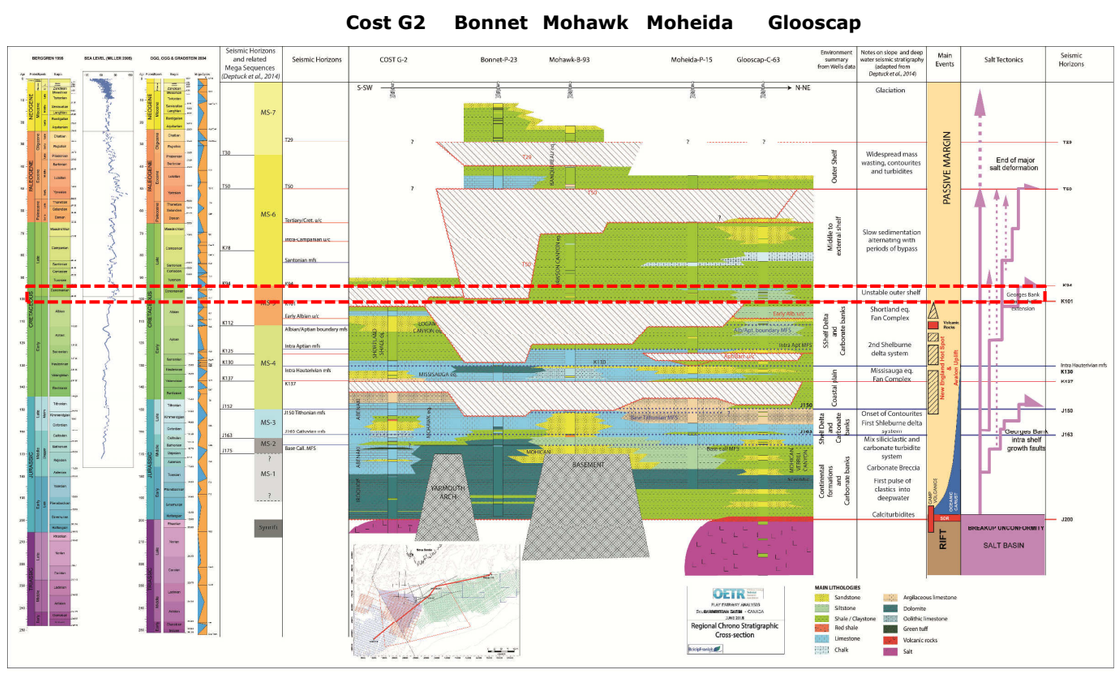


Figure 134. Stratigraphic Cross-Section across the study area. Dotted red line represents the period of time showed in this section.

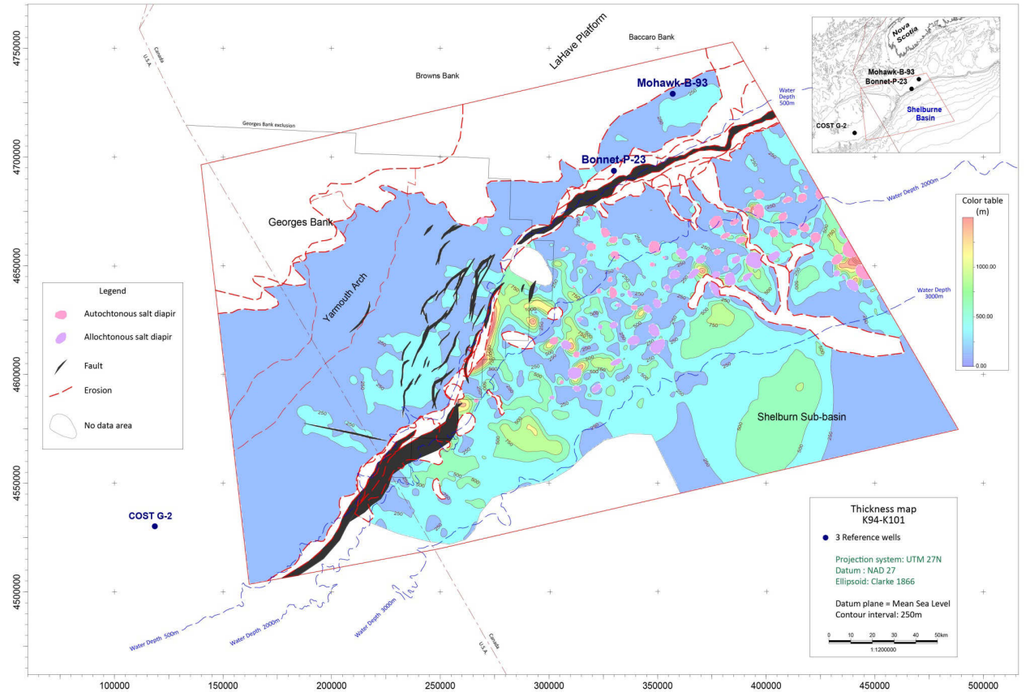


Figure 135. Isopach map K101– K94.

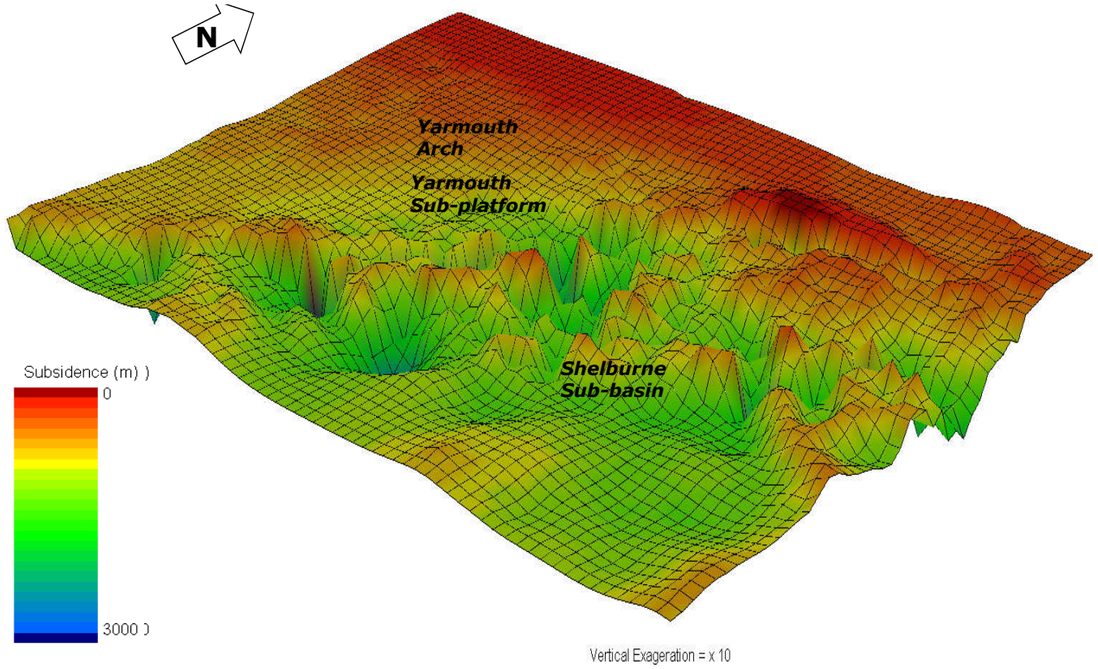


Figure 136. The total subsidence at this age was estimated following this formula: $Total\ Subsidence = Subidence\ (t-1) + SedThick(t) + Bathy\ (t) - Bathy\ (t-1)$; t=94Ma; (t-1)=137

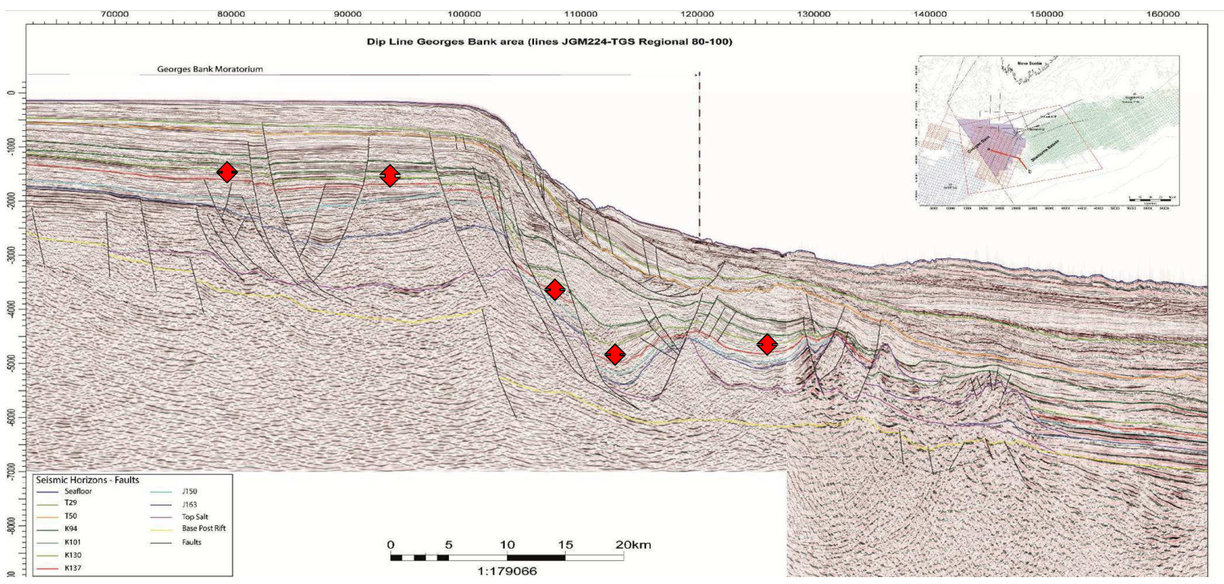


Figure 137. Seismic section (lines JGM 224 – TGS regional 80-100) across the Yarmouth Sub-platform and the Shelburne Sub-basin showing the interval K101 – K94.

STRATIGRAPHIC MODELLING - BARREMIAN-CENOMANIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

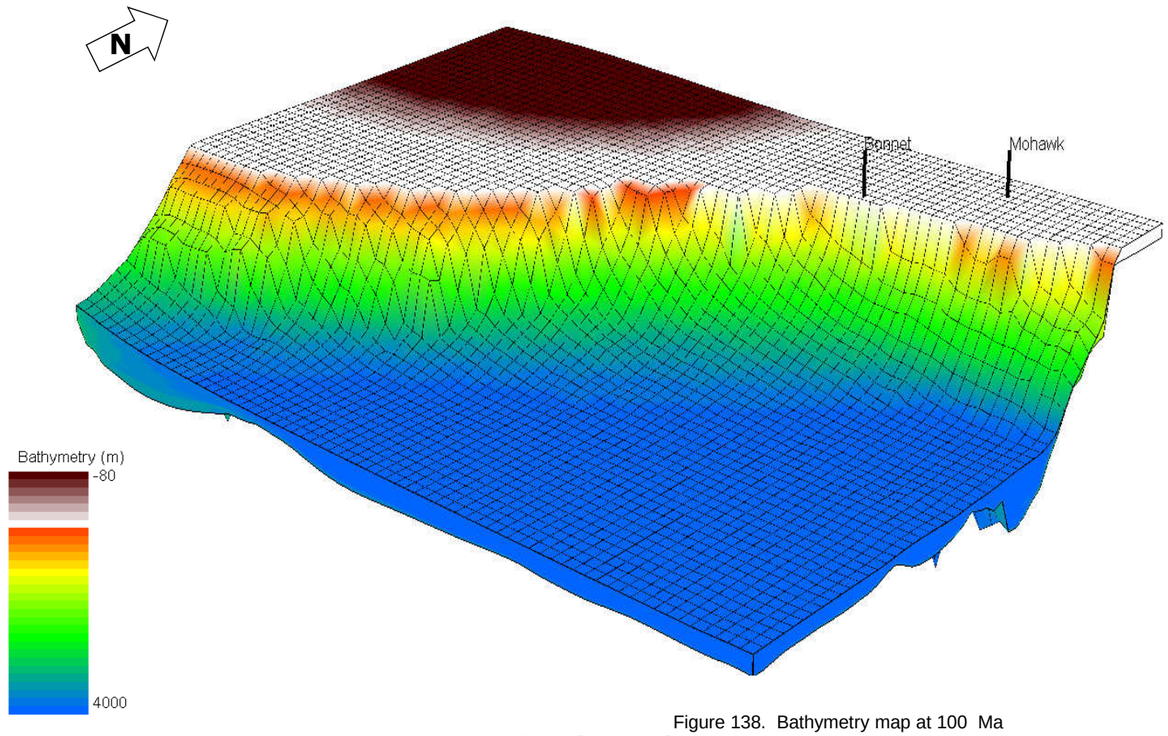


Figure 138. Bathymetry map at 100 Ma

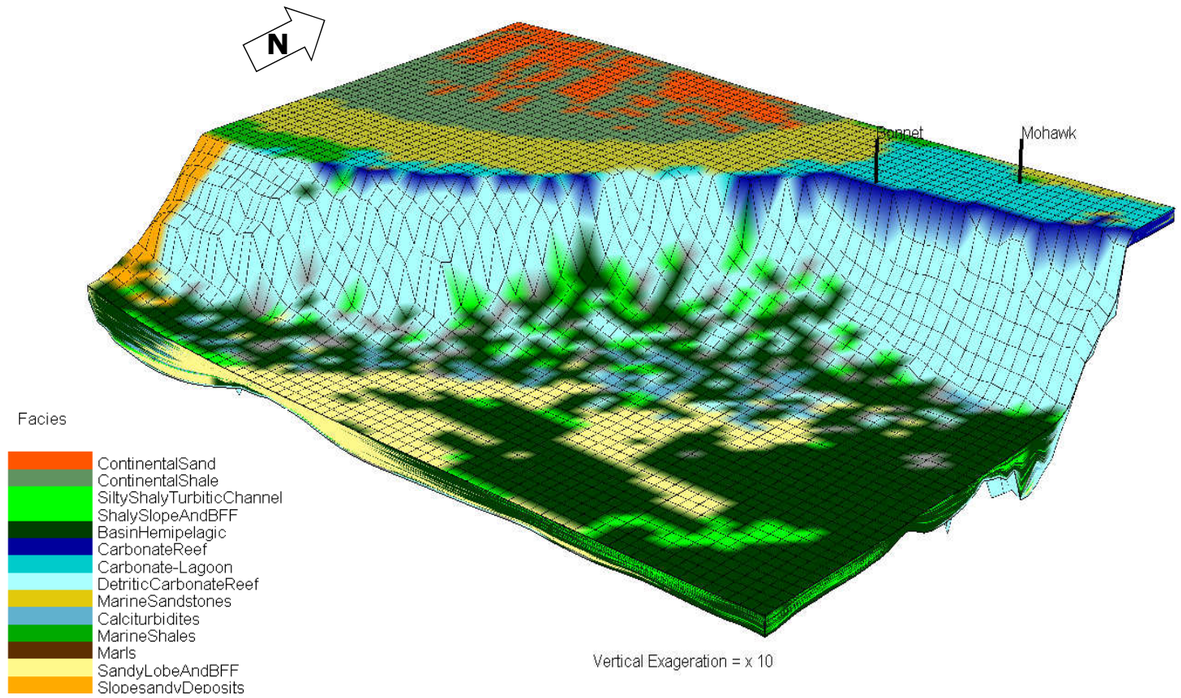


Figure 139. Facies distribution at 100 Ma

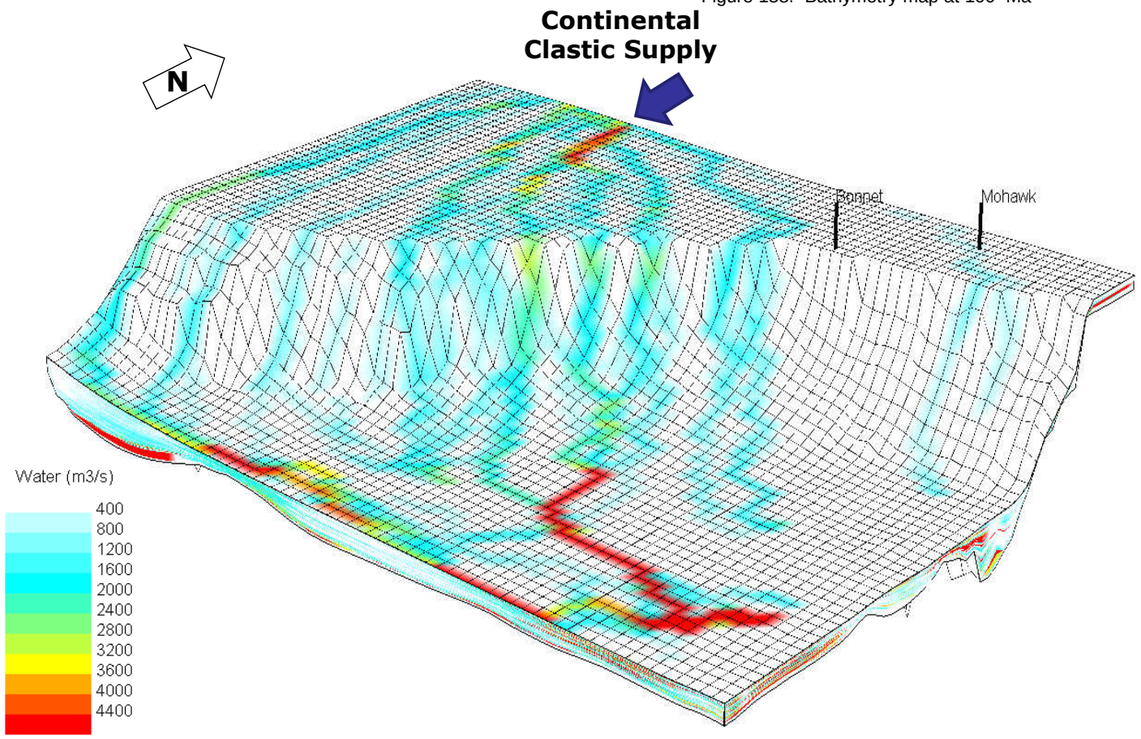


Figure 140. Water flow distribution at 100 Ma

✓ Sequence simulated: Barremian - Cenomanian

✓Age represented: Albian.

✓Stratigraphic event: Transgressive Episode, Cretaceous Shelburne Delta.

✓At this time step deltaic sedimentation concentrates mostly in the shelf area with mostly retrograding patterns due to the continuous rise of the sea level. Basin sedimentation start to be restricted to carbonatic flow from the slope and deltaic shales.

✓The sediment supplies at this time correspond to a fluvial systems located to the north of the simulation area being preferentially concentrate to the north western border of the model (Figure 140).

The average sand content of the sources ranged from 20% to 35% in average.

STRATIGRAPHIC MODELLING - BARREMIAN-CENOMANIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

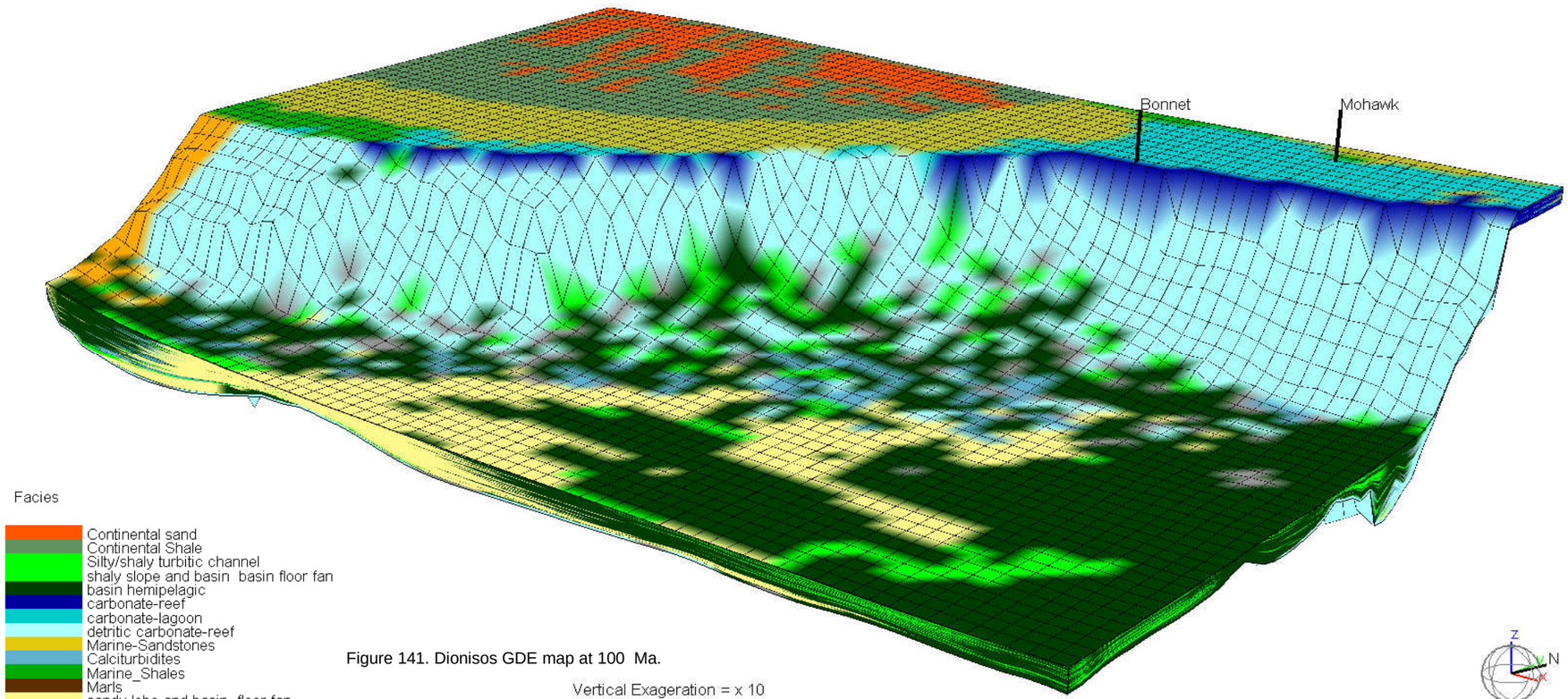
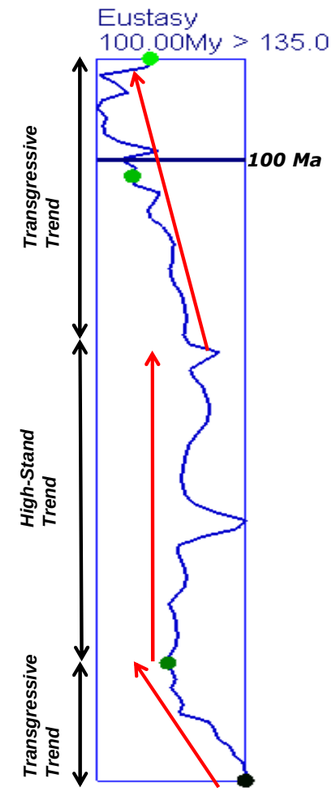


Figure 141. Dionisos GDE map at 100 Ma.



Haq et al., 1998

Figure 142. Eustatic curve at 100 Ma.

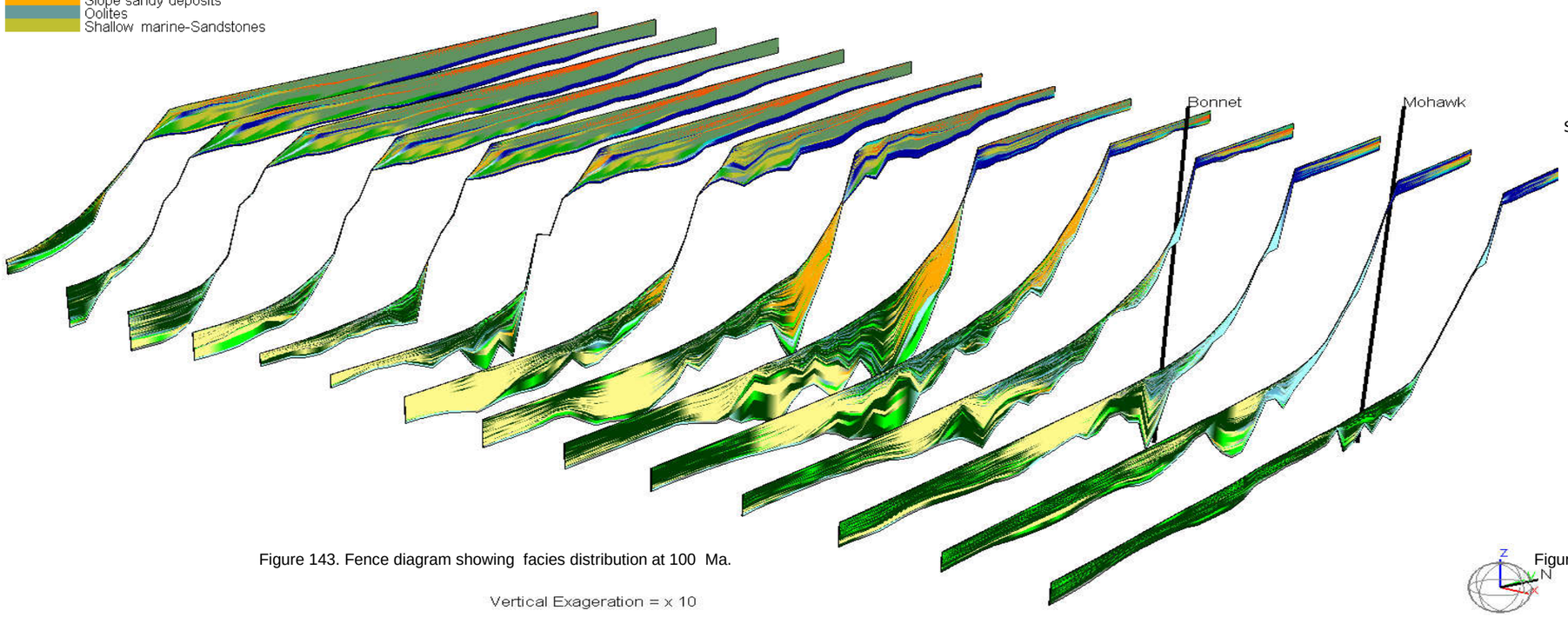


Figure 143. Fence diagram showing facies distribution at 100 Ma.

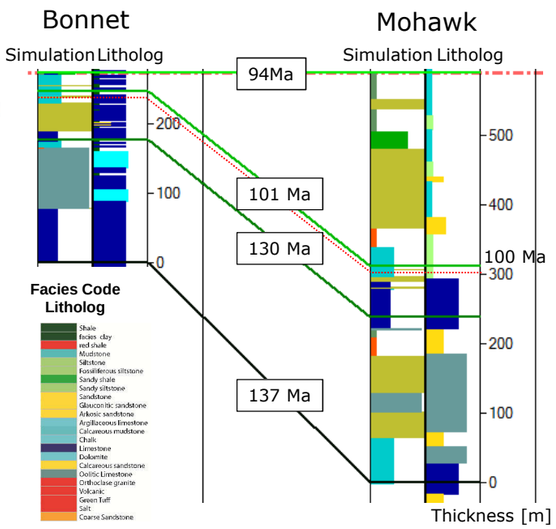


Figure 144. Well correlation between wells Bonnet and Mohawk at 100 Ma.

PL. 6.5.14 **GDE Maps and Dionisos Results : Fence Diagram and 3D View – Age 100 Ma**

STRATIGRAPHIC MODELLING - BARREMIAN-CENOMANIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

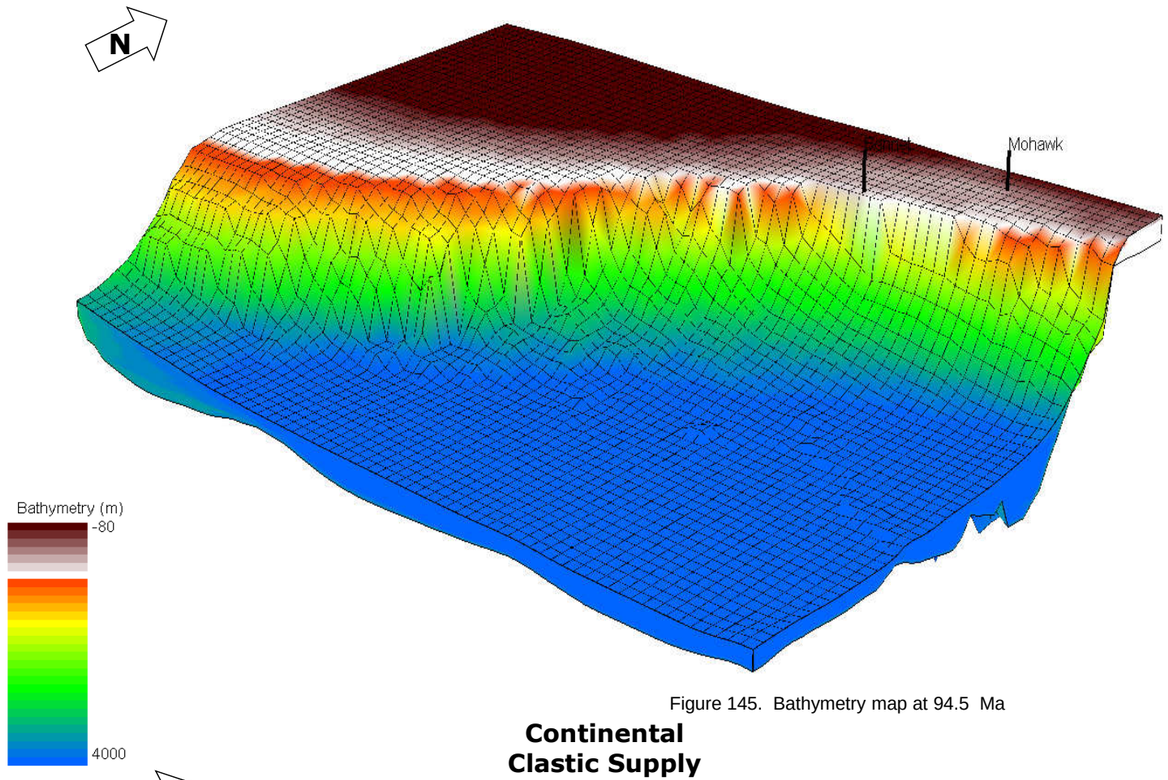


Figure 145. Bathymetry map at 94.5 Ma

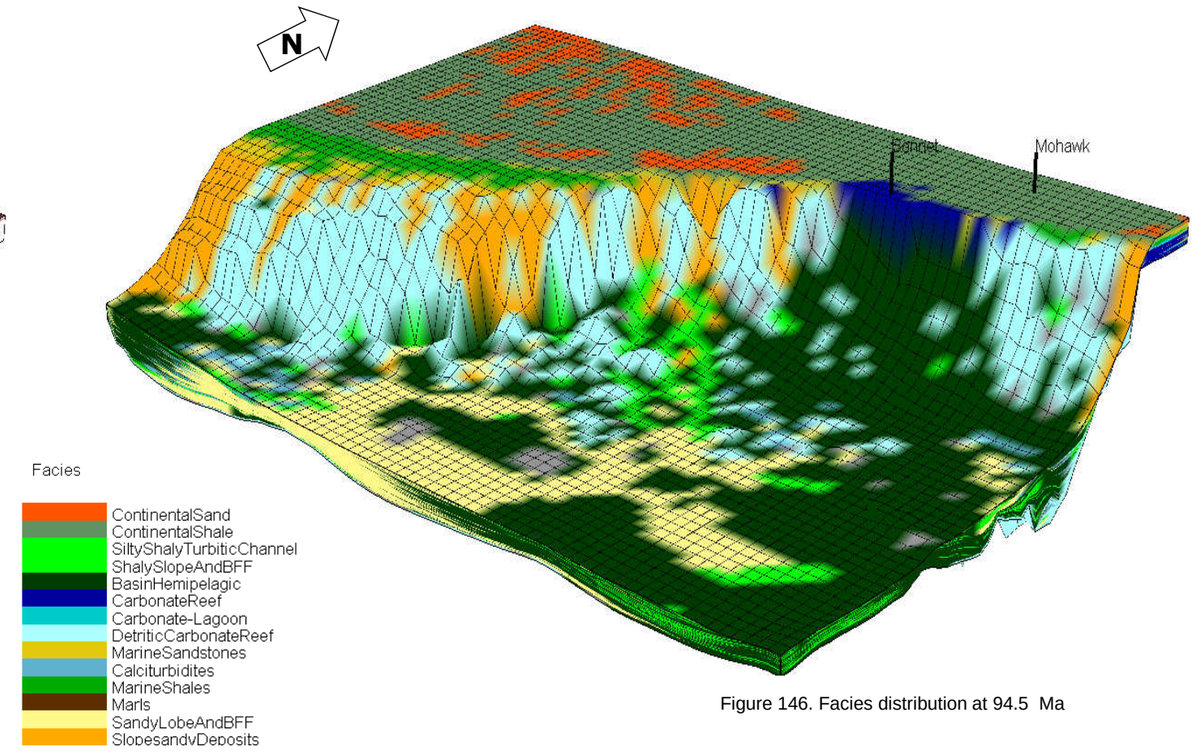


Figure 146. Facies distribution at 94.5 Ma

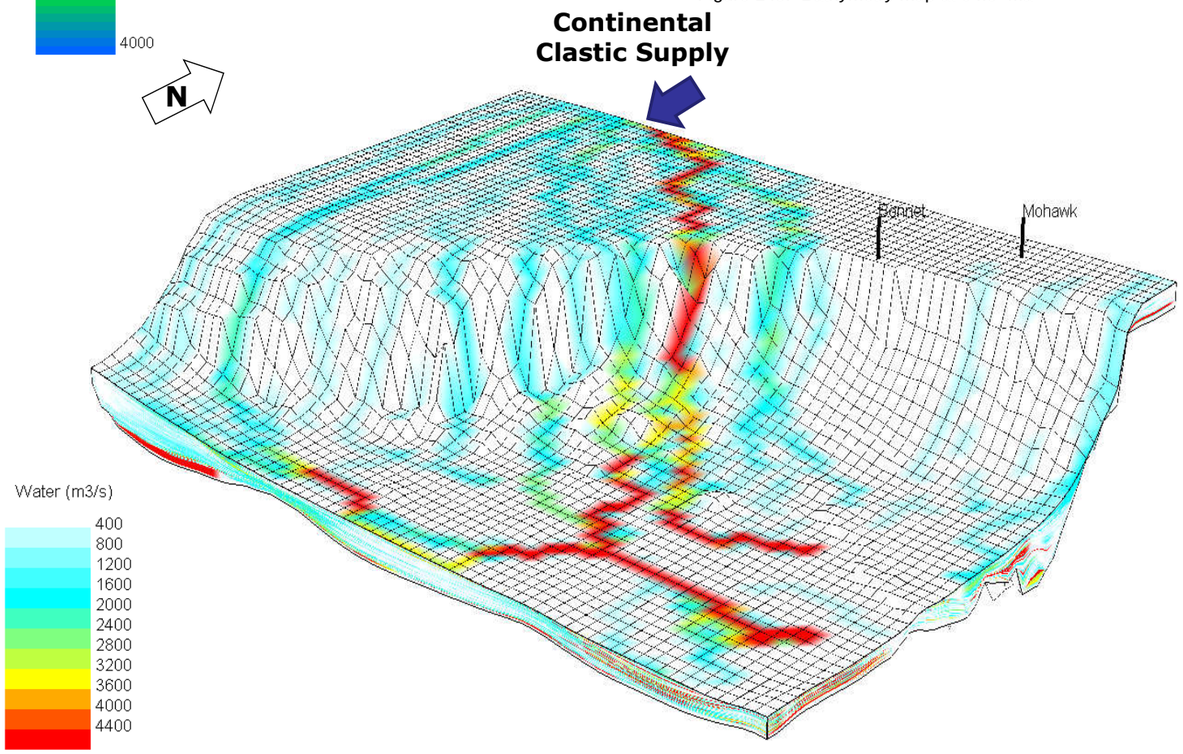


Figure 147. Water flow distribution at 94.5 Ma

✓ Sequence simulated: Barremian - Cenomanian

✓Age represented: Cenomanian.

✓Stratigraphic event: Onset of a regressive Episode, Cretaceous Shelburne Delta.

✓At this time step a new prograding episode of deltaic facies is present in the shelf area reactivating the sediment supply to the basin. It is important to mention the presence of potential reservoir intervals inside the slope sandy deposits and sandy turbidites in the basin area.

✓The sediment supplies at this time correspond to a fluvial systems located to the north of the simulation area being preferentially concentrate to the north western border of the model (Figure 147).

The average sand content of the sources ranged from 20% to 35% in average.

STRATIGRAPHIC MODELLING - BARREMIAN-CENOMANIAN SEQUENCE

SOUTH WEST NOVA SCOTIA EXTENSION - CANADA - June 2015

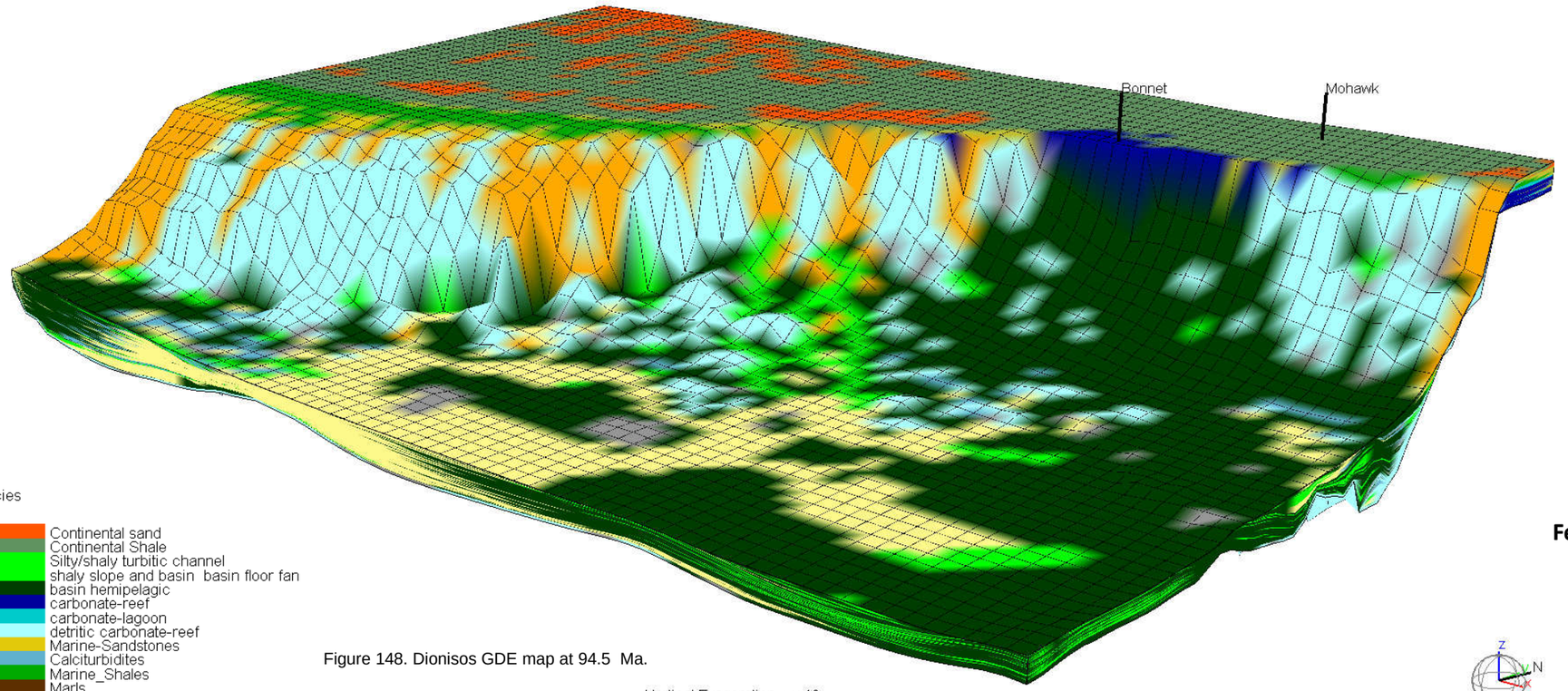
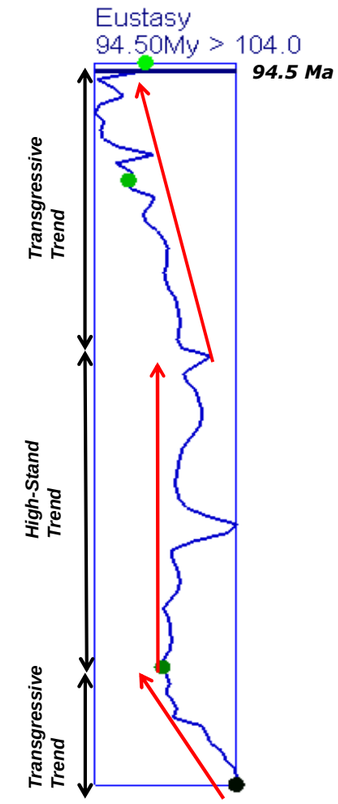


Figure 148. Dionisos GDE map at 94.5 Ma.

Fence Diagram



Haq et al., 1998

Figure 149. Eustatic curve at 94.5 Ma.

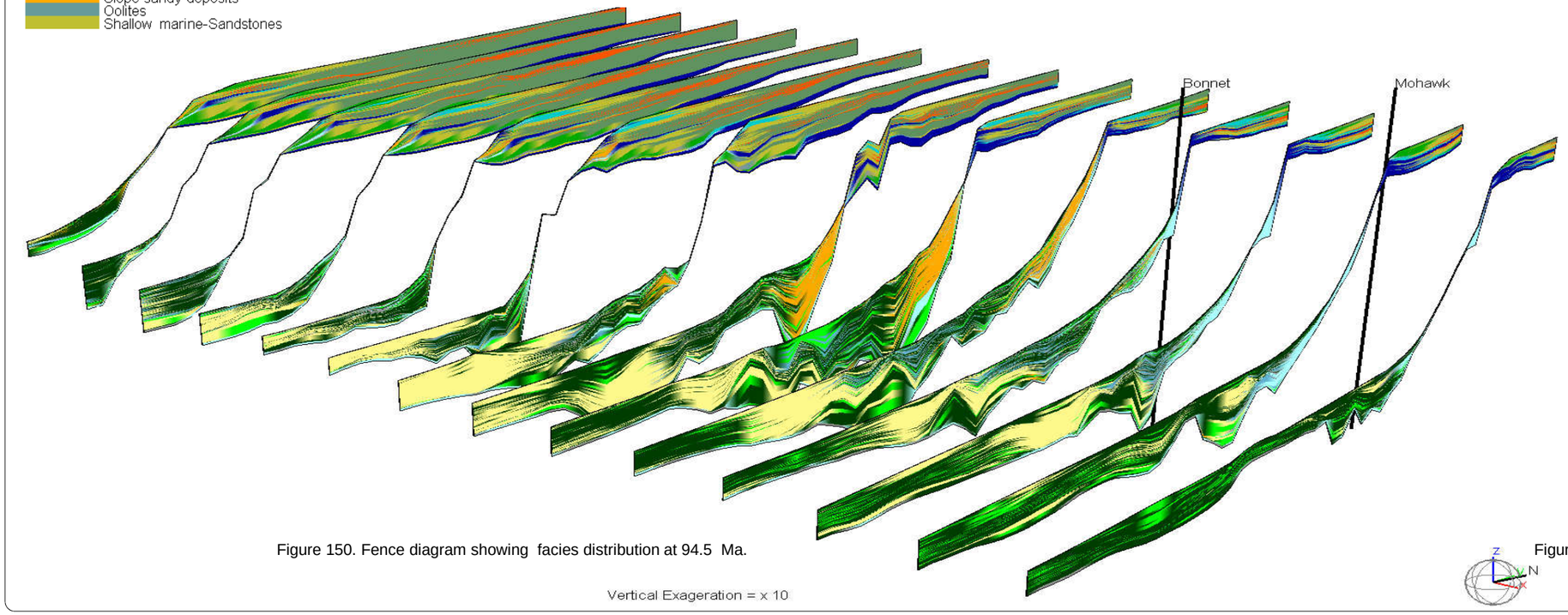


Figure 150. Fence diagram showing facies distribution at 94.5 Ma.

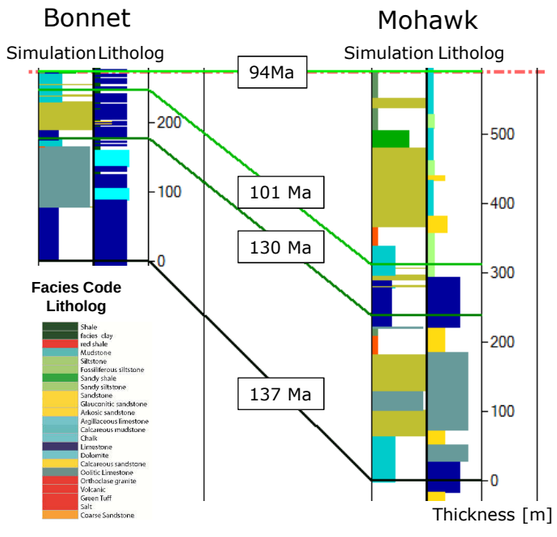


Figure 151. Well correlation between wells Bonnet and Mohawk at 94.5 Ma.

PL. 6.5.16 **GDE Maps and Dionisos Results : Fence Diagram and 3D View – Age 94.5 Ma**