CHAPTER 5
COMMON RISK SEGMENT (CRS) MAPS & THE YET TO FIND (YTF)

N

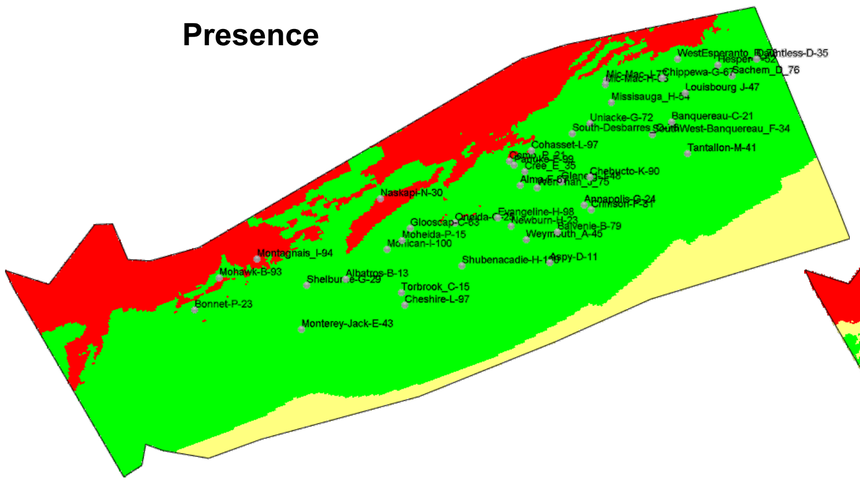
Kilometers
0 100 200

CHS, Esri, GEBCO, DeLorme, NaturalVue

Pliensbachian Source Rock

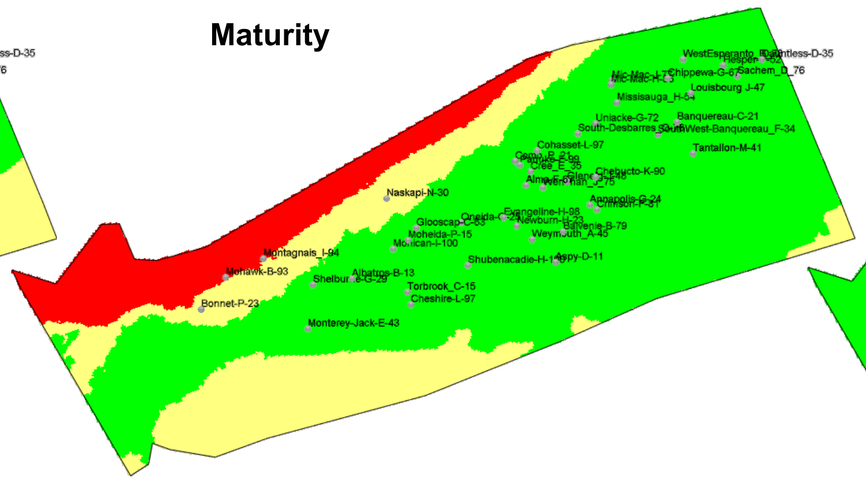
CRS maps Presence/Maturity/Timing

Presence



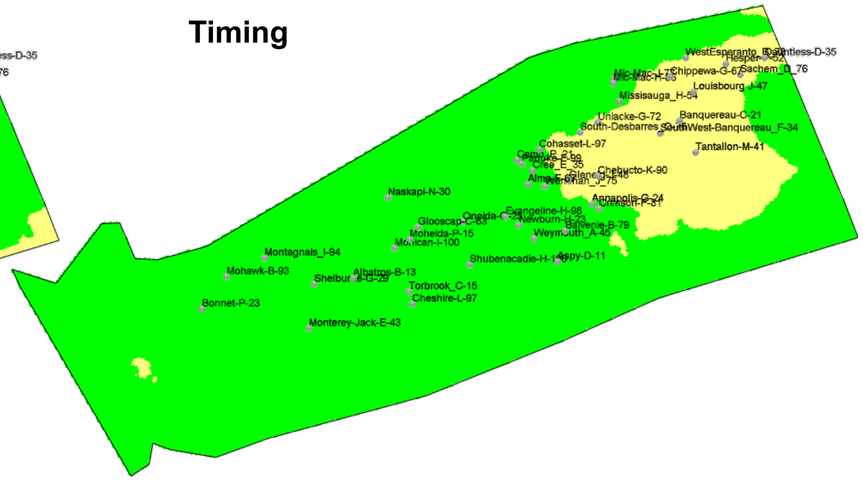
CRS presence map is built from Pliensbachian source rock richness distribution (*Plate 4.4).* High risk in the north corresponds to a continental environment with local by-pass/erosion. Medium risk in the south in ***a*** distal setting corresponds to an uncertain paleogeographic condition. Low risk area present the most favorable condition for source rock deposition and preservation (See Chapter 2)

Maturity



CRS maturity map is based on vitrinite reflectance estimated from the calibrated thermal model (Easy Ro%). High risk corresponds to vitrinite reflectance <0.55% where no expulsion is expected. Medium risk between 0.55% and 0.80% is a range of uncertainties for starting hydrocarbon expulsion taking into account different kerogen kinetics. Low risk is defined where vitrinite values exceed 0.80%, where we can expect expulsion for any kerogen type.

Timing



CRS timing map highlights local risk for hydrocarbon preservation. Here, medium risk area depict an early Generation/Expulsion (late Jurassic) with a possible risk for preservation. Delineation of this area correspond to a source rock transformation ratio >70% at Late Jurassic. 3D migration model confirms also this risk in term of preservation in this specific area.

Combined CRS maps for Pliensbachian source rock

(Presence/Maturity/Timing)

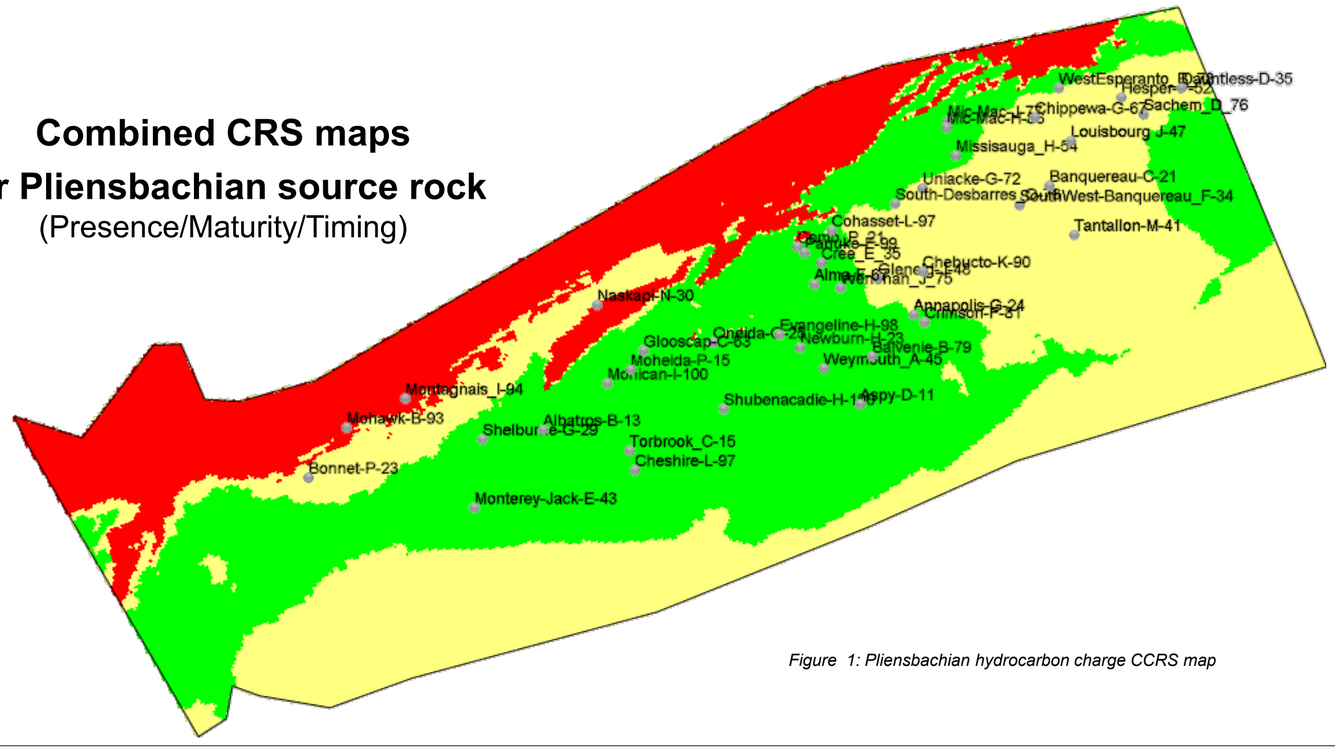


Figure 1: Pliensbachian hydrocarbon charge CCRS map

The combined CRS map takes into account the three previous CRS maps; Presence, Maturity and Timing by combining the three individual CRS maps.

This map summarize the hydrocarbon charge expected from the Pliensbachian source rock assuming vertical migration. Note that it doesn't take into account lateral migration.

Pliensbachian CCRS map gives the potential hydrocarbon charge for reservoir in the Jurassic series (Mohican, Mic Mac and Abenaki formation for example).

Lower Risk

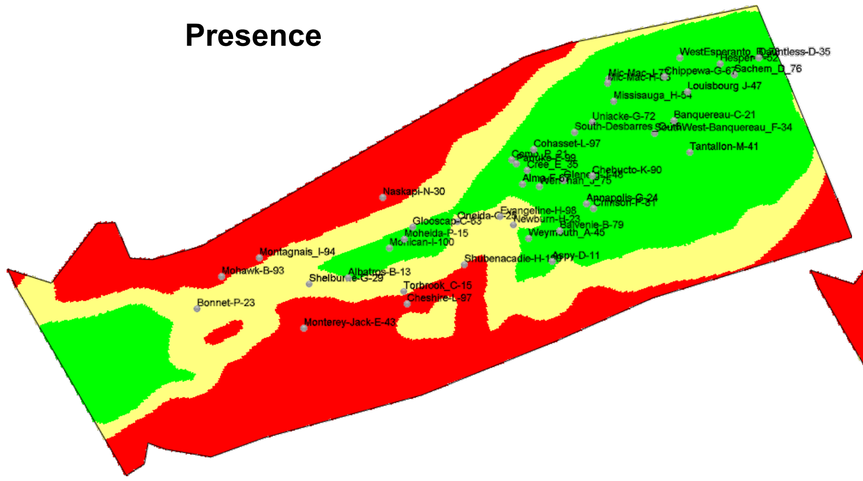
Medium Risk

Higher Risk

Tithonian Source Rock

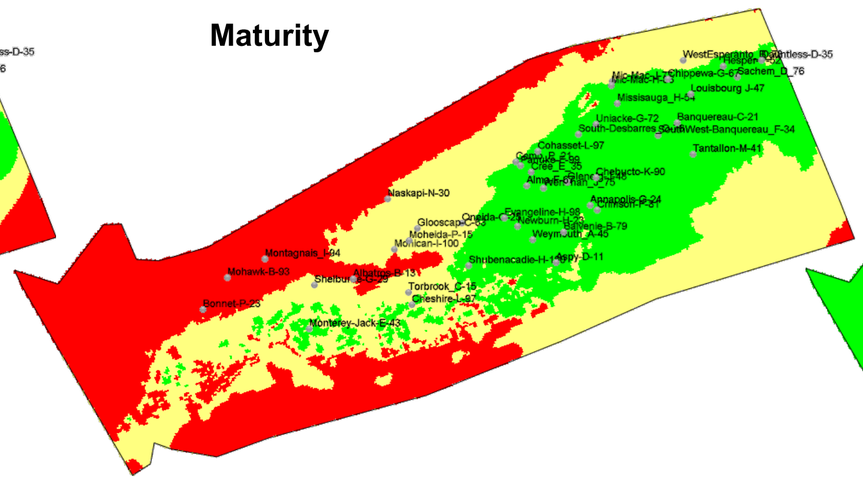
CRS maps Presence/Maturity/Timing

Presence



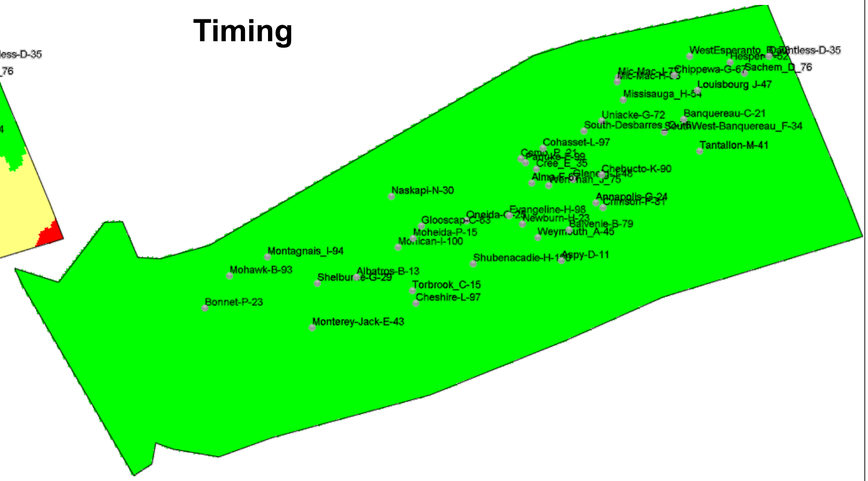
CRS presence map is built from Tithonian source rock richness distribution. High risk in the north corresponds to a continental environment with local by-pass/erosion. High risk in the south-east corresponds to a very limited sedimentation rate leading to a limited organic matter preservation. A possible deep oceanic current can also be expected. Medium risk corresponds to a transitional zone with low the risk area representing the most favorable condition for source rock deposition and preservation.

Maturity



CRS maturity map is built using vitrinite reflectance coming from the calibrated thermal model (Easy Ro%). High risk corresponds to vitrinite reflectance <0.55% where no expulsion is expected. Medium risk between 0.55% and 0.80% is a range of uncertainties for starting hydrocarbon expulsion taking into account different kerogen kinetics. Low risk is defined when vitrinite maturity exceeds 0.80% for what we can expected expulsion for any kerogen type.

Timing



CRS timing map highlights a low risk environment for Tithonian source rock. Indeed, Generation/Expulsion process occurred mainly after main structuration (gravity sliding and diapirism).

Combined CRS maps for Tithonian source rock (Presence/Maturity/Timing)

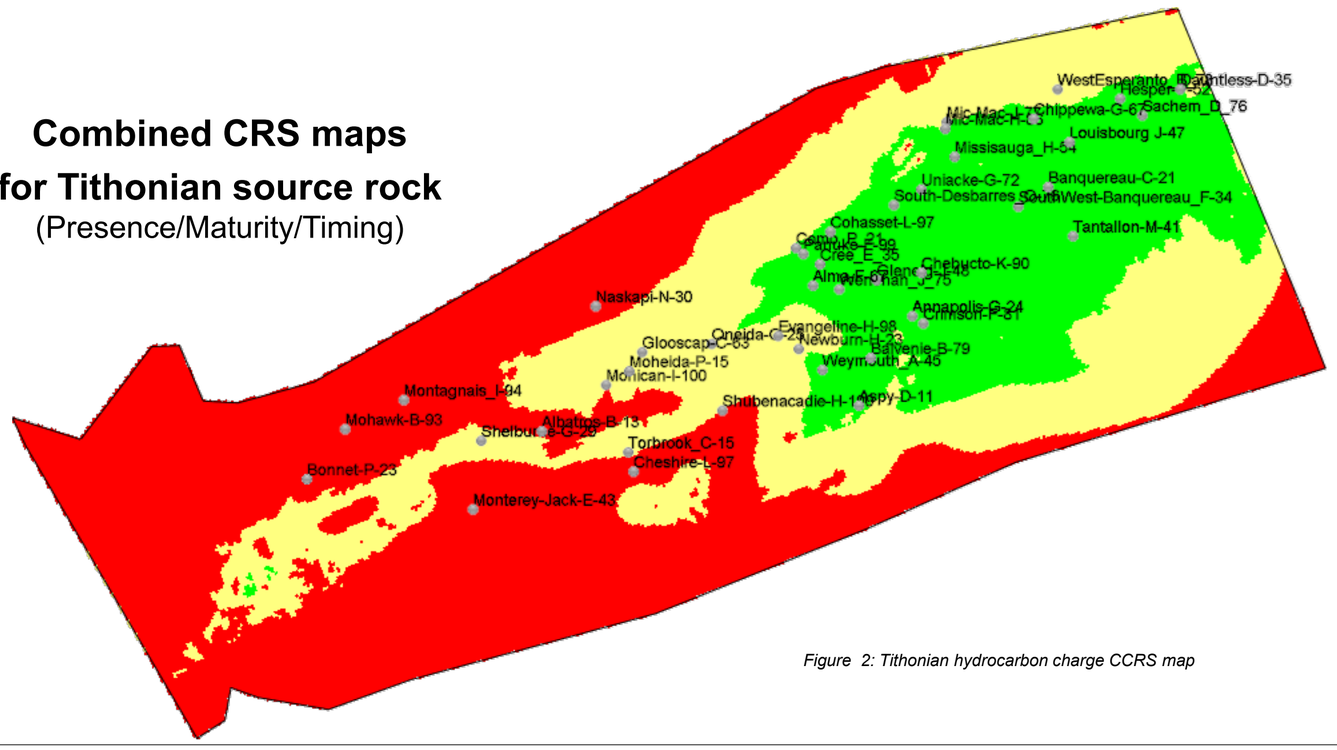


Figure 2: Tithonian hydrocarbon charge CCRS map

The composite CRS map takes into account the three previous CRS maps; Presence, Maturity and Timing by convolving the individual risk maps.

This map reflects the hydrocarbon charge expected from the Tithonian source rock in a pure vertical way. Note that, it doesn't take into account lateral migration.

Tithonian CCRS map is an additional hydrocarbon charge contribution with Pliensbachian source rock for the reservoirs into Cretaceous and tertiary series.

Lower Risk

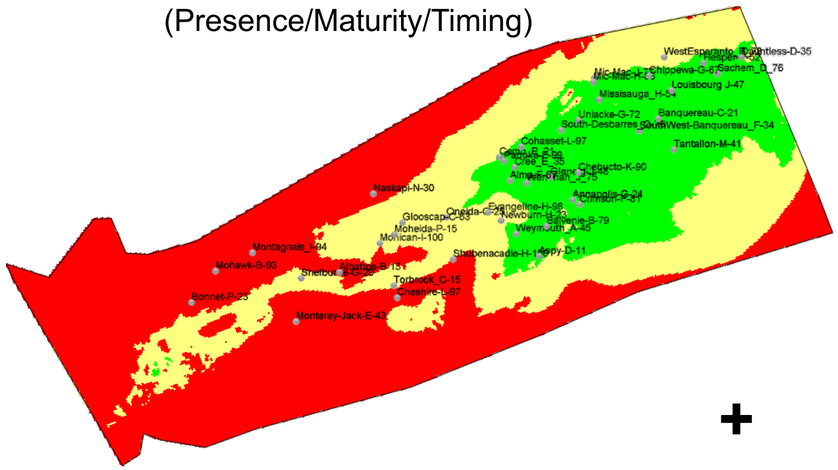
Medium Risk

Higher Risk

Pliensbachian + Tithonian source rocks

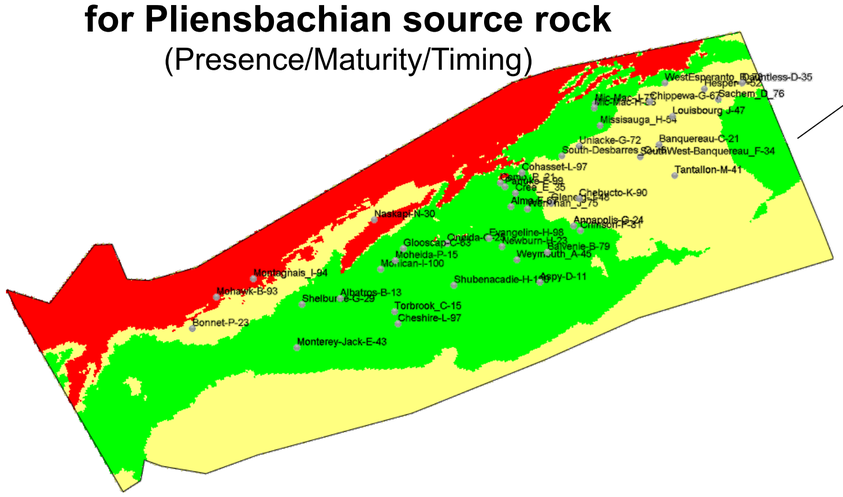
CCRS map

Combined CRS maps for Tithonian source rock
(Presence/Maturity/Timing)



+

Combined CRS maps for Pliensbachian source rock
(Presence/Maturity/Timing)



CCRS maps Tithonian + Pliensbachian

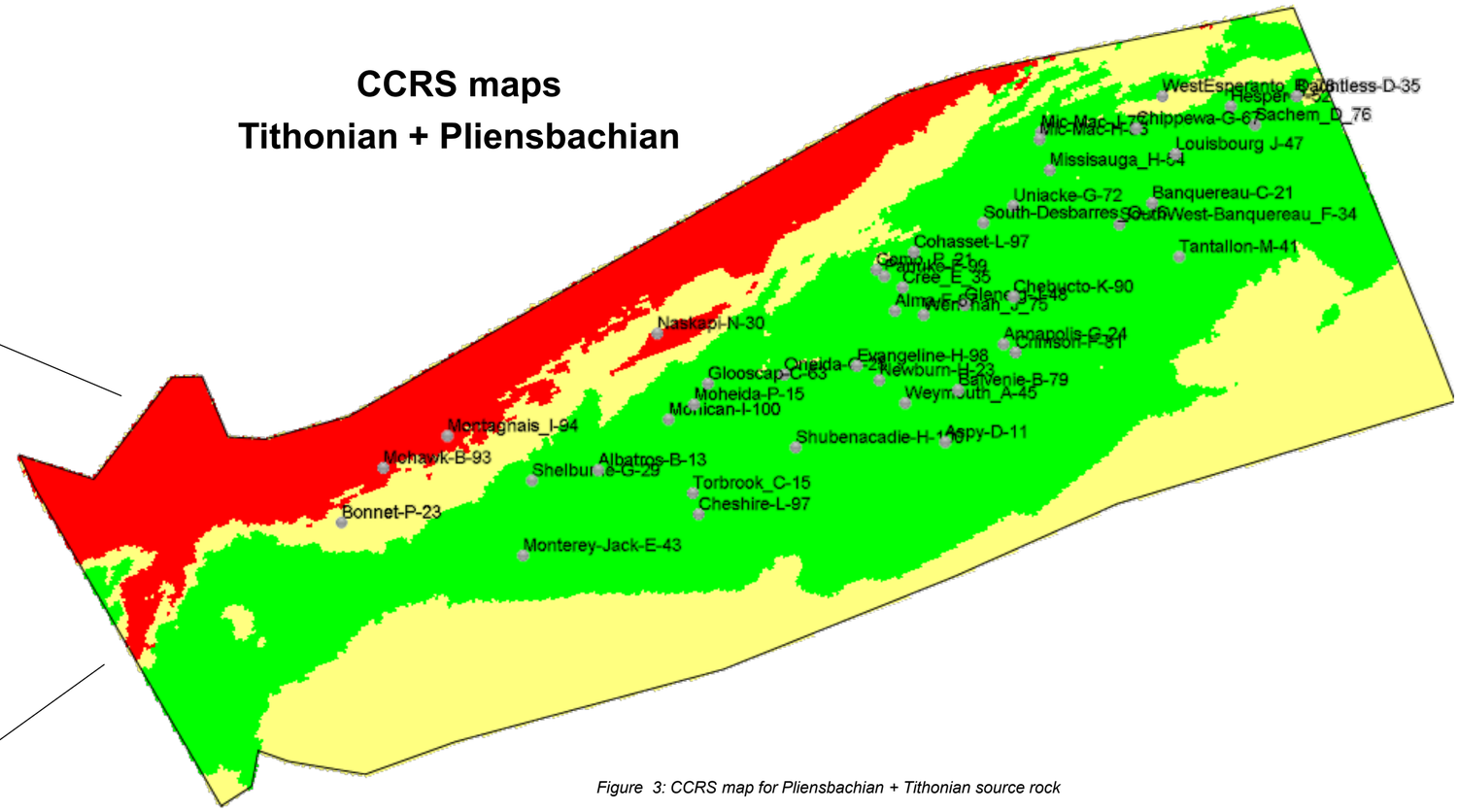


Figure 3: CCRS map for Pliensbachian + Tithonian source rock

This CCRS map sums CCRS map of Pliensbachian source rock and CCRS map of Tithonian source rock to provide the potential hydrocarbon charge for reservoir into the Cretaceous and Tertiary series. Note that, when Pliensbachian charge appears to be medium risk in the east, the Tithonian charge should exist.

Lower Risk
Medium Risk
Higher Risk

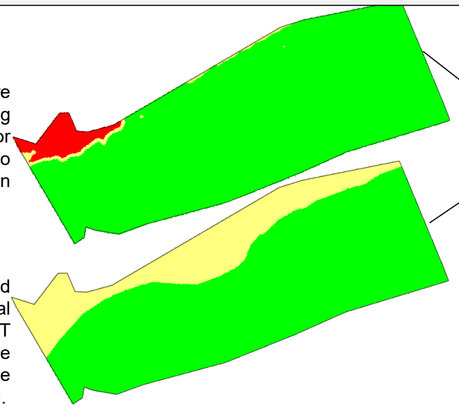
Seal

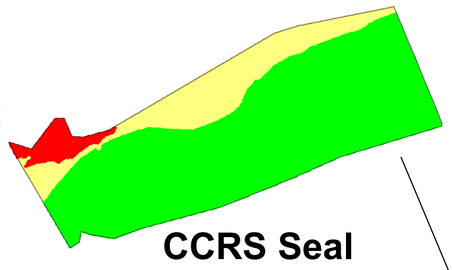
Seal Effectiveness

Based on seal capillary pressure extracted from basin modeling (lithology and compaction). Red color results from a cut-off that highlights no efficient capillary pressure to maintain hydrocarbon column.

Seal Presence

Based on sedimentologic and stratigraphic analysis, the seal presence correspond to the TST lithofacies distribution above the expected reservoir. It highlights the probability to encounter a vertical seal.





CCRS Seal

Combined Seal presence and effectiveness. The map shows low risk in the outer shelf to deep marine environment and medium risk upstream in the continental area.

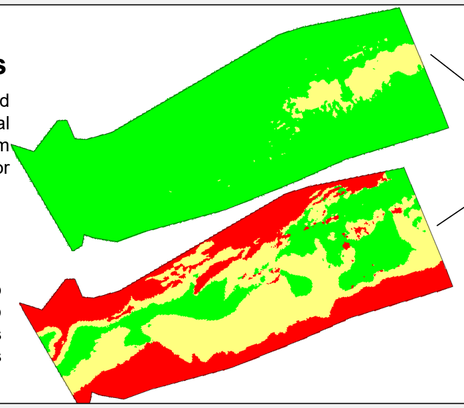
Reservoir

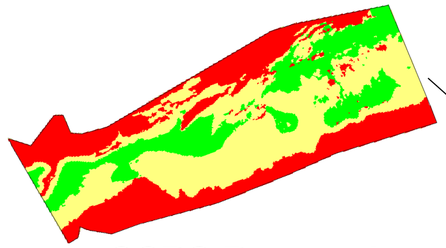
Reservoir Effectiveness

Based on reservoir porosity simulated in the basin modeling through burial and pore-pressure evolution. Medium risk (yellow) highlights porosity inferior to 6%.

Reservoir Presence

Based GDE mapping. This map highlights the probability to encounter a reservoir. Envelop has been drawn in order to catch areas of expected reservoir geobodies.





CCRS Reservoir

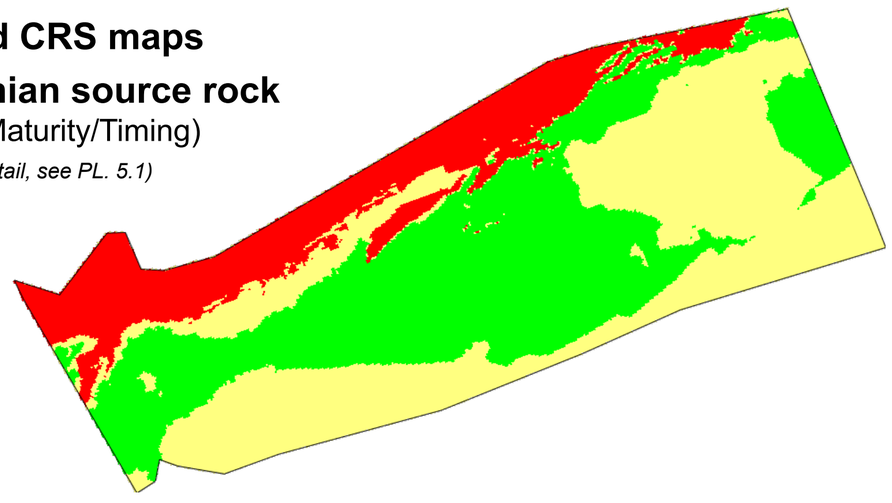
Combined reservoir presence and effectiveness.

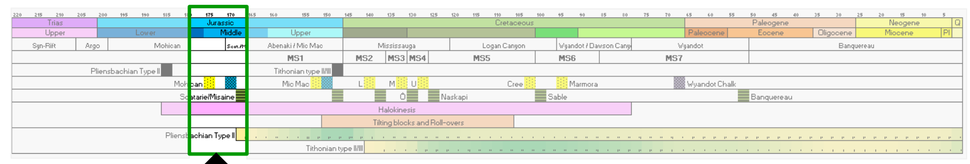
Charge

Combined CRS maps for Pliensbachian source rock

(Presence/Maturity/Timing)

(for more detail, see PL. 5.1)





CCRS map of Middle Jurassic (Mohican Fm)

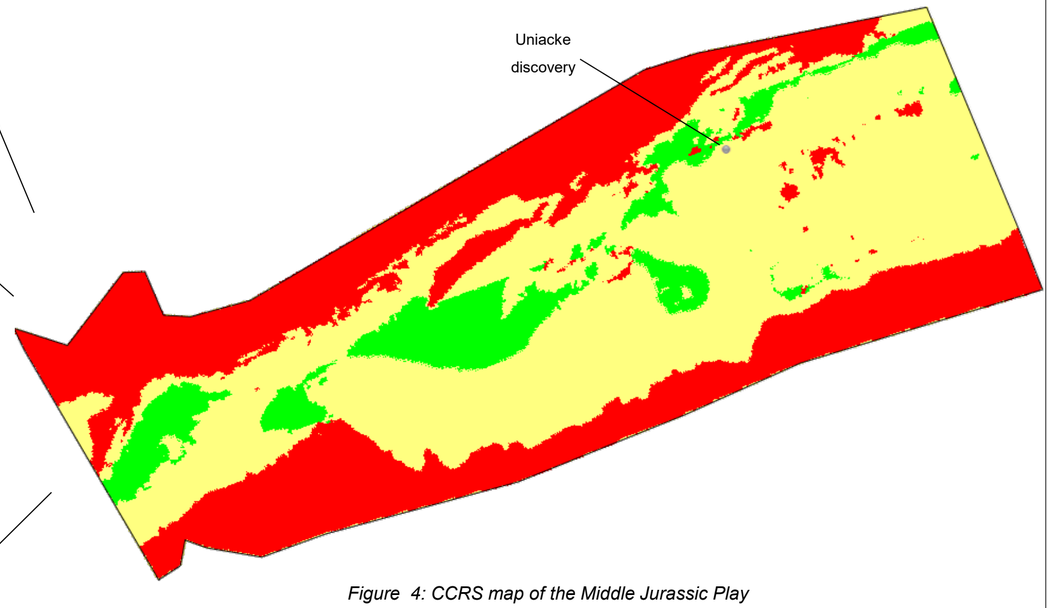


Figure 4: CCRS map of the Middle Jurassic Play

The Combined Common Risk Segment (CCRS) map of the Middle Jurassic play combines the CRS maps for reservoir, seal and charge. The Middle Jurassic play shows some favorable areas for exploration in green (lower risk) especially in the deep water and on shelf boarder in the western part of the province, where hydrocarbon charge is expected to be oil dominated. The eastern part doesn't appear to be favorable due to very thick sedimentary series what is too deep and too cooked.

Discoveries

Lower Risk

Medium Risk

Higher Risk

Common Risk Segment (CRS) Maps and the Yet to Find (YTF)

Nova Scotia Play Fairway Analysis 2023 – CANADA – June 2023

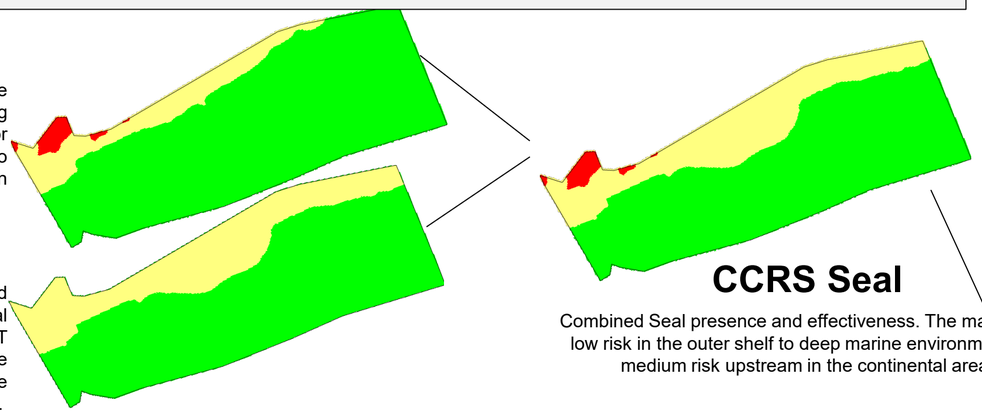
Seal

Seal Effectiveness

Based on seal capillary pressure extracted from basin modeling (lithology and compaction). Red color results from a cut-off that highlights no efficient capillary pressure to maintain hydrocarbon column.

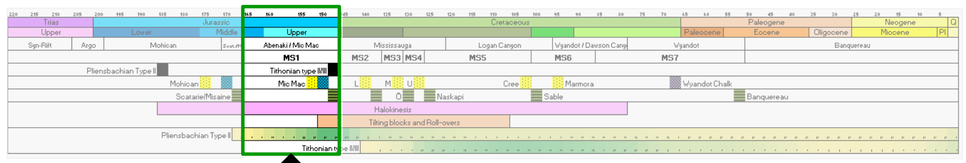
Seal Presence

Based on sedimentologic and stratigraphic analysis, the seal presence correspond to the TST lithofacies distribution above the expected reservoir. It highlights the probability to encounter a vertical seal.



CCRS Seal

Combined Seal presence and effectiveness. The map shows low risk in the outer shelf to deep marine environment and medium risk upstream in the continental area.



CCRS map of MS1

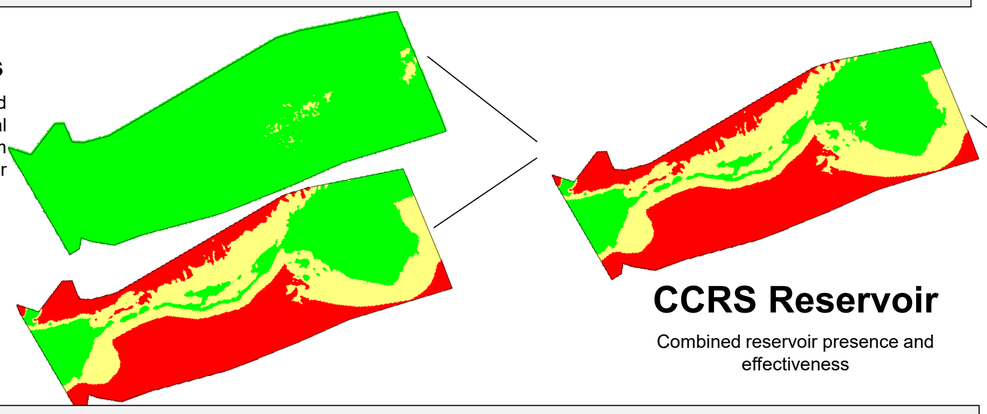
Reservoir

Reservoir Effectiveness

Based on reservoir porosity simulated in the basin modeling through burial and pore-pressure evolution. Medium risk (yellow) highlights porosity inferior to 6%.

Reservoir Presence

Based GDE mapping. This map highlights the probability to encounter a reservoir. Envelop has been drawn in order to catch areas of expected reservoir geobodies.



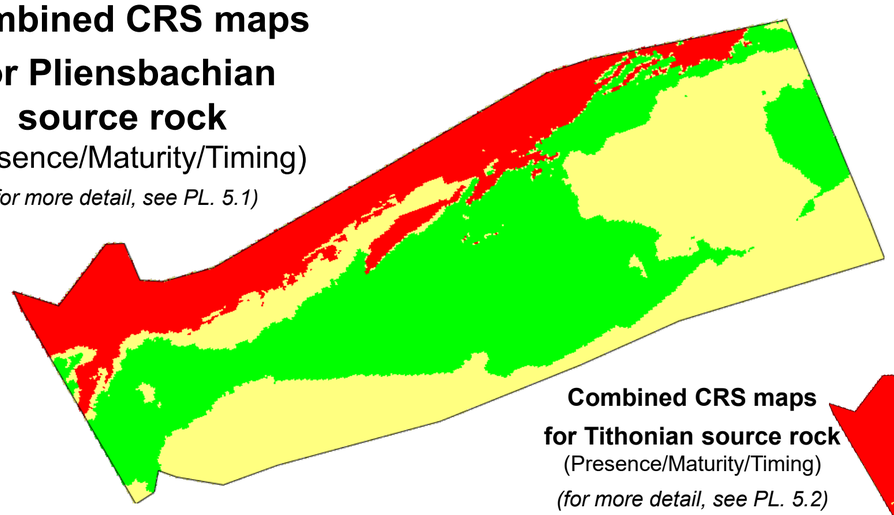
CCRS Reservoir

Combined reservoir presence and effectiveness

Charge

Combined CRS maps for Pliensbachian source rock (Presence/Maturity/Timing)

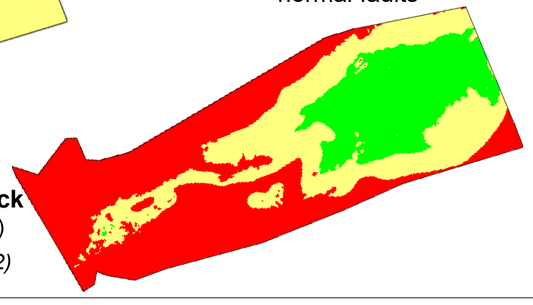
(for more detail, see PL. 5.1)



\+ Probable Tithonian source rock contribution on the shelf through normal faults

Combined CRS maps for Tithonian source rock (Presence/Maturity/Timing)

(for more detail, see PL. 5.2)



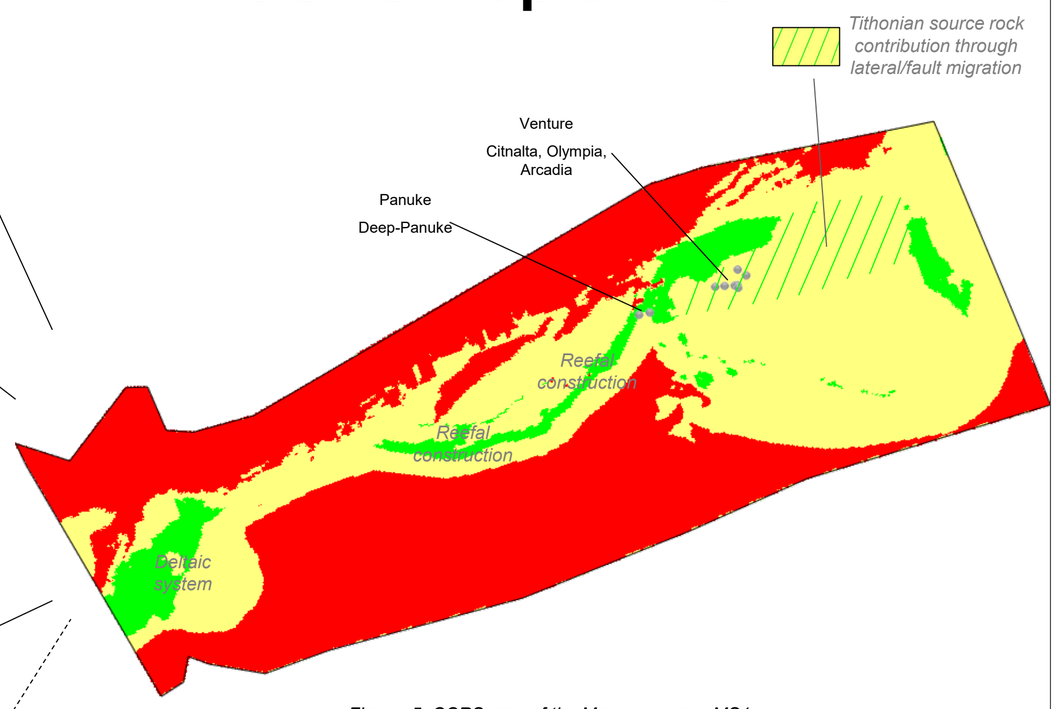


Figure 5: CCRS map of the Megasequence MS1

The Late Jurassic play MS1 shows some favorable areas for exploration in the western side in the deltaic system, along the reefal construction of Abenaki in the center of the study area and also at the eastern side in the large depocenter of Mic Mac Formation. Higher potential can be expected in the shelf of the eastern side thanks to Tithonian source rock contribution by lateral migration through normal faults and through downward migration (dashed green area).

Discoveries

Lower Risk

Medium Risk

Higher Risk

Common Risk Segment (CRS) Maps and the Yet to Find (YTF)

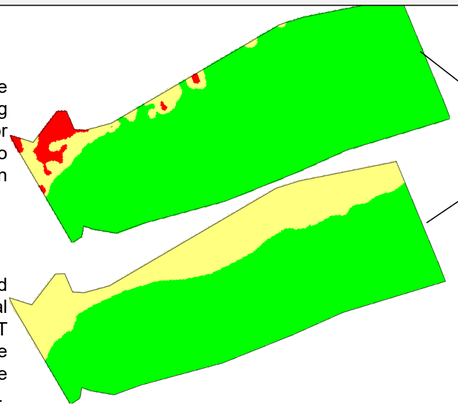
Seal

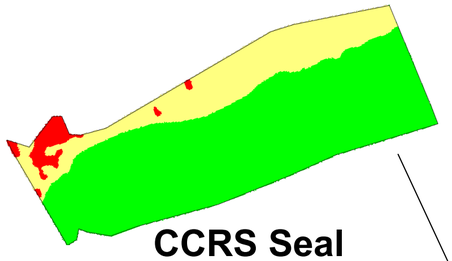
Seal Effectiveness

Based on seal capillary pressure extracted from basin modeling (lithology and compaction). Red color results from a cut-off that highlights no efficient capillary pressure to maintain hydrocarbon column.

Seal Presence

Based on sedimentologic and stratigraphic analysis, the seal presence correspond to the TST lithofacies distribution above the expected reservoir. It highlights the probability to encounter a vertical seal.





CCRS Seal

Combined Seal presence and effectiveness. The map shows low risk in the outer shelf to deep marine environment and medium risk upstream in the continental area.

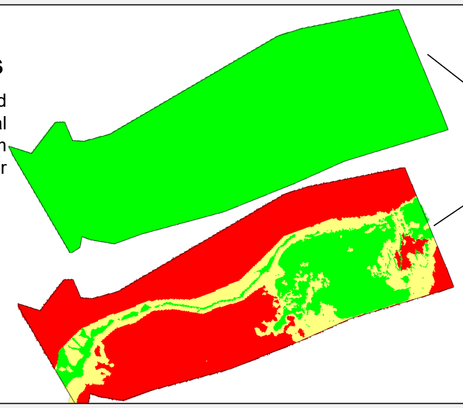
Reservoir

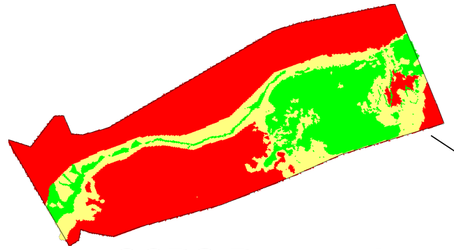
Reservoir Effectiveness

Based on reservoir porosity simulated in the basin modeling through burial and pore-pressure evolution. Medium risk (yellow) highlights porosity inferior to 6%.

Reservoir Presence

Based GDE mapping. This map highlights the probability to encounter a reservoir. Envelop has been drawn in order to catch areas of expected reservoir geobodies.





CCRS Reservoir

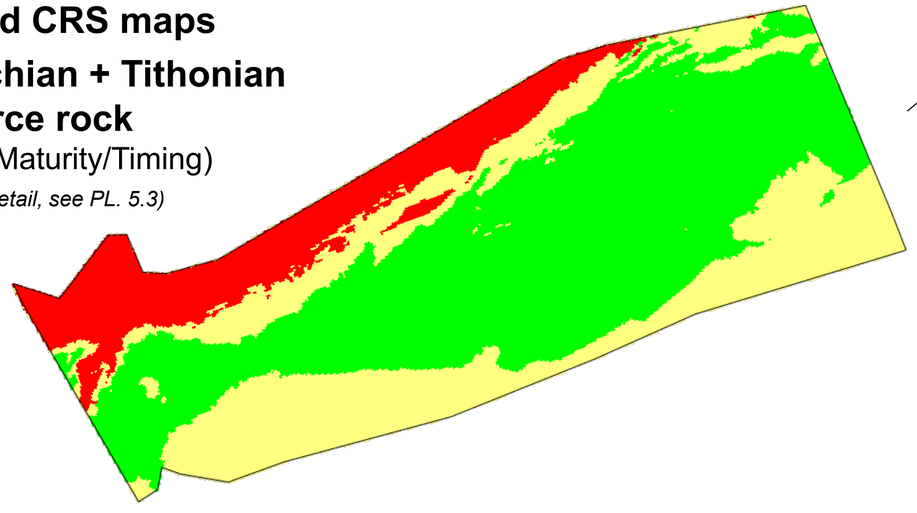
Combined reservoir presence and effectiveness

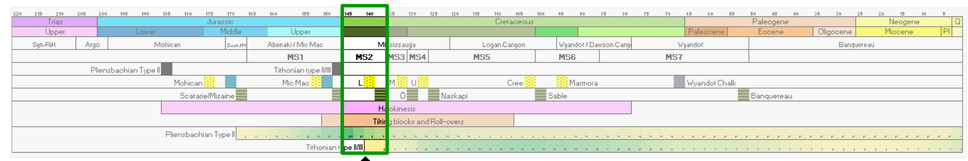
Charge

Combined CRS maps for Pliensbachian + Tithonian source rock

(Presence/Maturity/Timing)

(for more detail, see PL. 5.3)





CCRS map of MS2

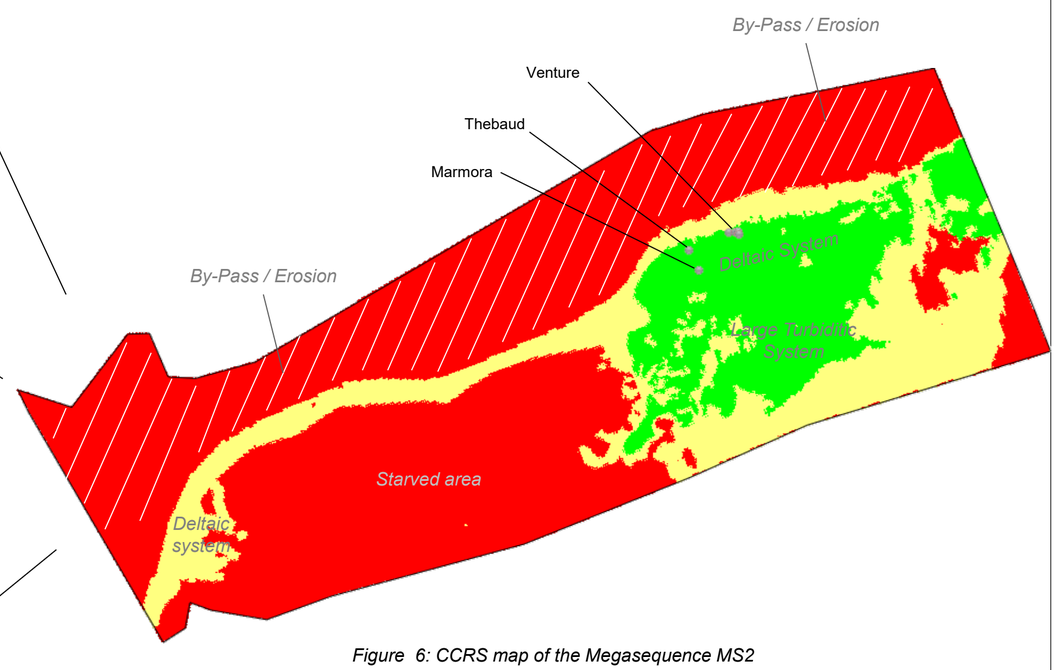


Figure 6: CCRS map of the Megasequence MS2

The very early Lower Cretaceous MS2 play shows large favorable areas for exploration in the eastern side. MS2 has two source rock contributions (Tithonian and Pliensbachian) moreover it is deposited just above the Tithonian source rock what limit the migration risk. In the east, reservoir presence is associated to a strong forced regression transferring a large volume of clastic sediments from shelf to deep water area through deltaic and turbiditic system (Lower Mississauga Formation). Large part of the shelf is in by-pass or erosion what limit the reservoir extension to the north. Border of the carbonate platform in the center such as western side can present some potential but with limited extension.

Discoveries

Lower Risk

Medium Risk

Higher Risk

Common Risk Segment (CRS) Maps and the Yet to Find (YTF)

Nova Scotia Play Fairway Analysis 2023 – CANADA – June 2023

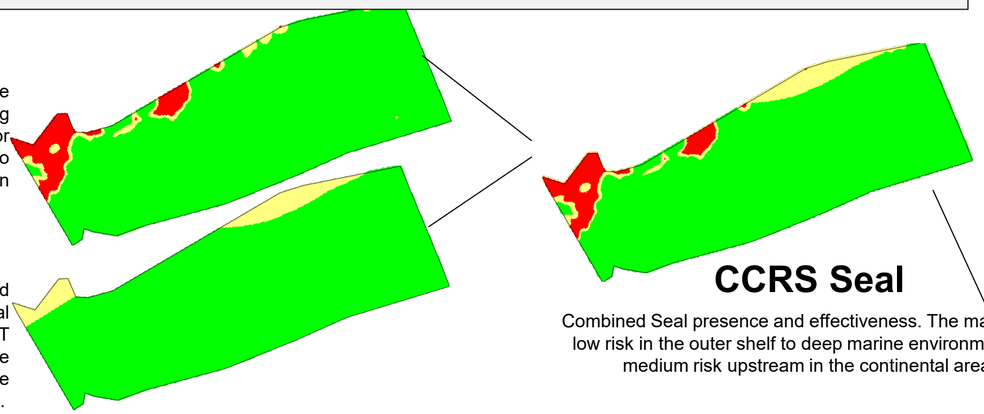
Seal

Seal Effectiveness

Based on seal capillary pressure extracted from basin modeling (lithology and compaction). Red color results from a cut-off that highlights no efficient capillary pressure to maintain hydrocarbon column.

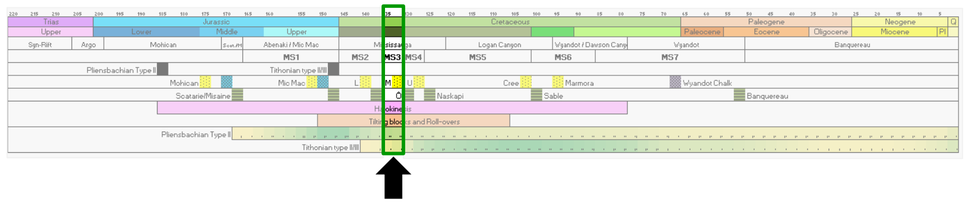
Seal Presence

Based on sedimentologic and stratigraphic analysis, the seal presence correspond to the TST lithofacies distribution above the expected reservoir. It highlights the probability to encounter a vertical seal.



CCRS Seal

Combined Seal presence and effectiveness. The map shows low risk in the outer shelf to deep marine environment and medium risk upstream in the continental area.



CCRS map of MS3

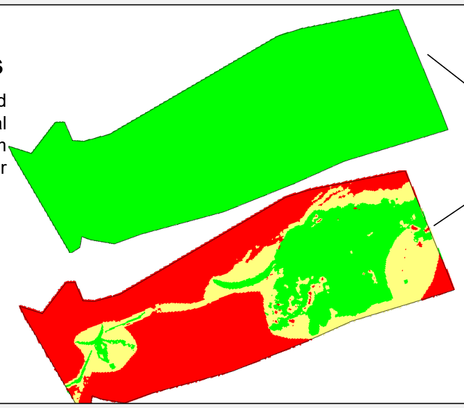
Reservoir

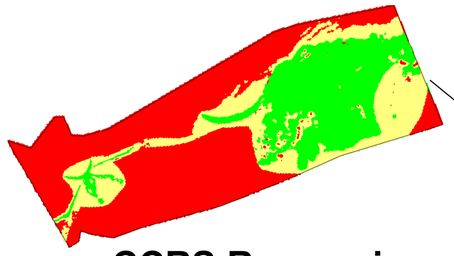
Reservoir Effectiveness

Based on reservoir porosity simulated in the basin modeling through burial and pore-pressure evolution. Medium risk (yellow) highlights porosity inferior to 6%.

Reservoir Presence

Based GDE mapping. This map highlights the probability to encounter a reservoir. Envelop has been drawn in order to catch areas of expected reservoir geobodies.





CCRS Reservoir

Combined reservoir presence and effectiveness

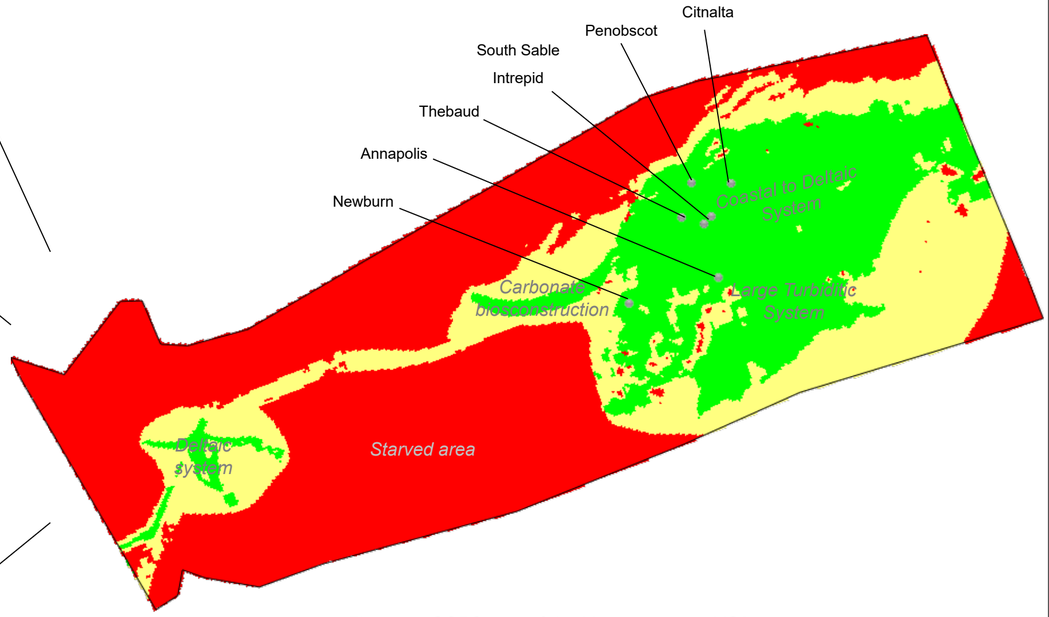


Figure 7: CCRS map of the Megasequence MS3

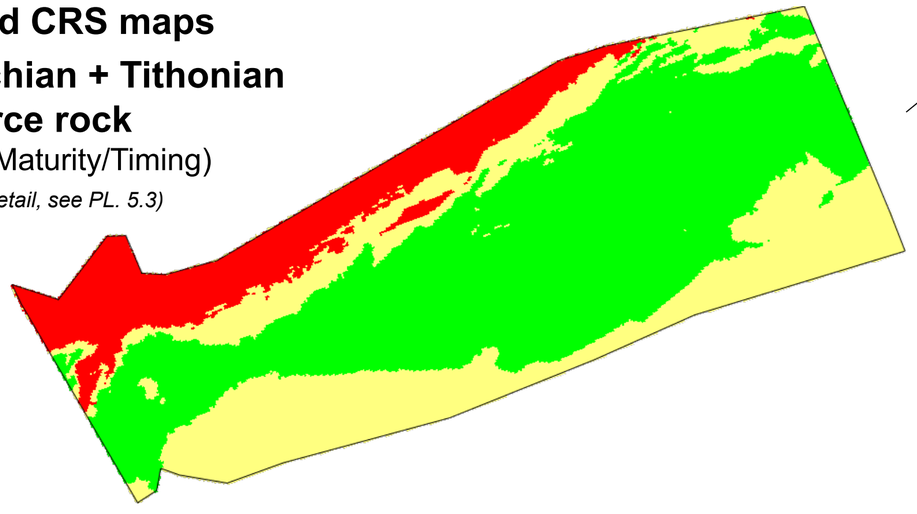
The early Lower Cretaceous MS3 play shows a large exploratory potential especially in the east (Middle Mississauga Formation). The two source rocks, Tithonian and Pliensbachian, provide a efficient hydrocarbon charge. Seal is efficient. It is constituted by a large transgressive system tract named “O” marker thick and continuous visible in seismic and validated pore-pressure analysis. This megasequence is a large highstand system tract ending with forced regression what provides a large deltaic and turbiditic system. The highstand system tract developed extensive clastic reservoir in the shelf and there is reservoir potential of carbonate construction locally.

Charge

Combined CRS maps for Pliensbachian + Tithonian source rock

(Presence/Maturity/Timing)

(for more detail, see PL. 5.3)



Discoveries

Lower Risk

Medium Risk

Higher Risk

Common Risk Segment (CRS) Maps and the Yet to Find (YTF)

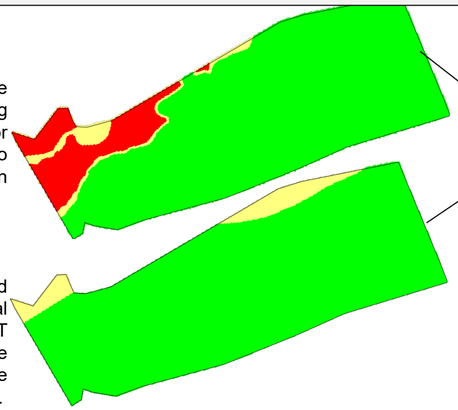
Seal

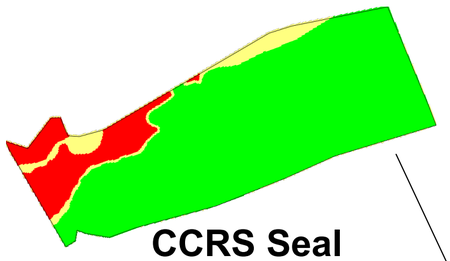
Seal Effectiveness

Based on seal capillary pressure extracted from basin modeling (lithology and compaction). Red color results from a cut-off that highlights no efficient capillary pressure to maintain hydrocarbon column.

Seal Presence

Based on sedimentologic and stratigraphic analysis, the seal presence correspond to the TST lithofacies distribution above the expected reservoir. It highlights the probability to encounter a vertical seal.





CCRS Seal

Combined Seal presence and effectiveness. The map shows low risk in the outer shelf to deep marine environment and medium risk upstream in the continental area.

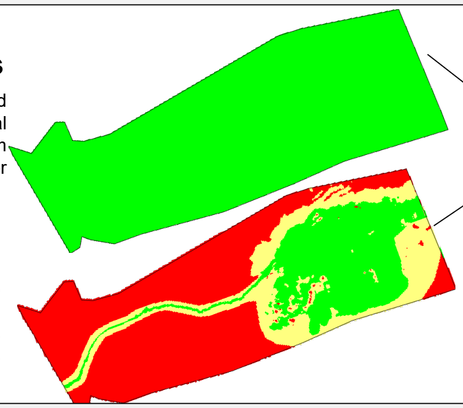
Reservoir

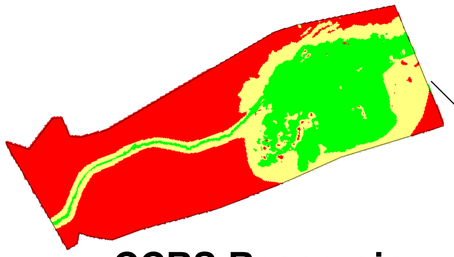
Reservoir Effectiveness

Based on reservoir porosity simulated in the basin modeling through burial and pore-pressure evolution. Medium risk (yellow) highlights porosity inferior to 6%.

Reservoir Presence

Based GDE mapping. This map highlights the probability to encounter a reservoir. Envelop has been drawn in order to catch areas of expected reservoir geobodies.





CCRS Reservoir

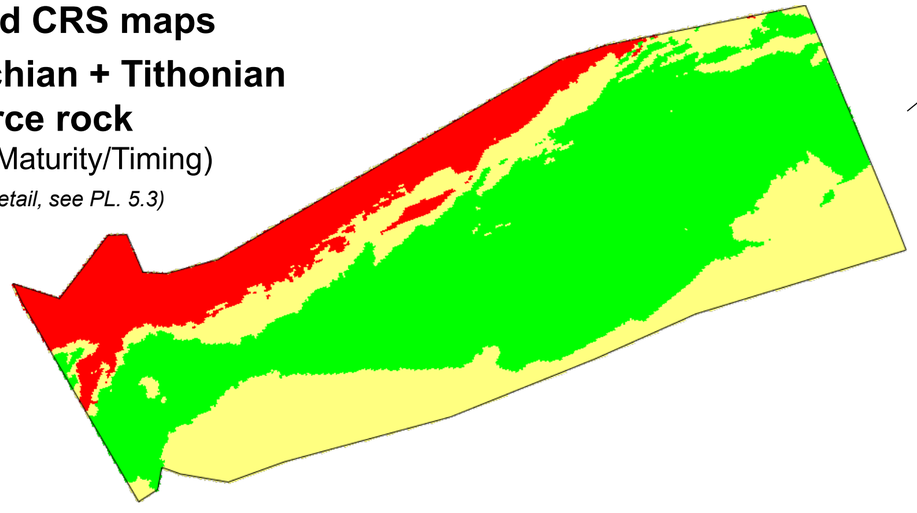
Combined reservoir presence and effectiveness

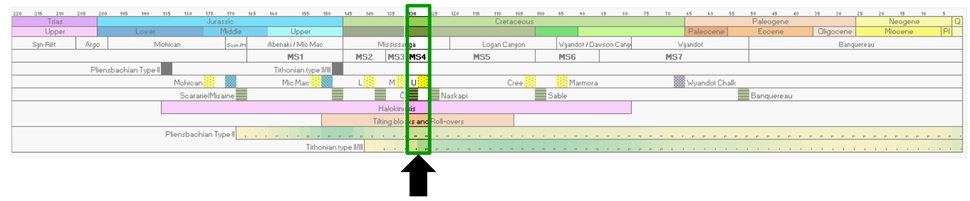
Charge

Combined CRS maps for Pliensbachian + Tithonian source rock

(Presence/Maturity/Timing)

(for more detail, see PL. 5.3)





CCRS map of MS4

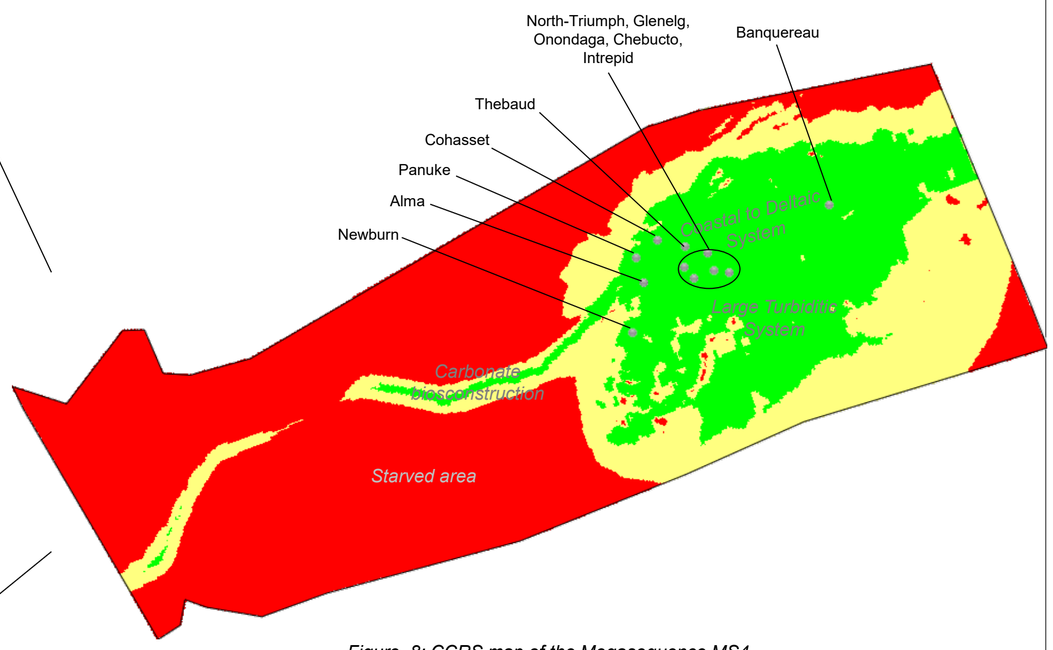


Figure 8: CCRS map of the Megasequence MS4

The Lower Cretaceous MS4 play shows a large exploratory potential especially in the east (Upper Mississauga Formation). The two source rocks, Tithonian and Pliensbachian, provide a hydrocarbon charge. Seal is constituted by the efficient Naskapi Fm. regional seal. This megasequence is a large highstand system tract ending with forced regression that provides a large deltaic and turbiditic system. The highstand system tract developed extensive clastic reservoir in the shelf and there is also reservoir potential in the carbonate reef.

Discoveries

Lower Risk

Medium Risk

Higher Risk

Common Risk Segment (CRS) Maps and the Yet to Find (YTF)

Nova Scotia Play Fairway Analysis 2023 – CANADA – June 2023

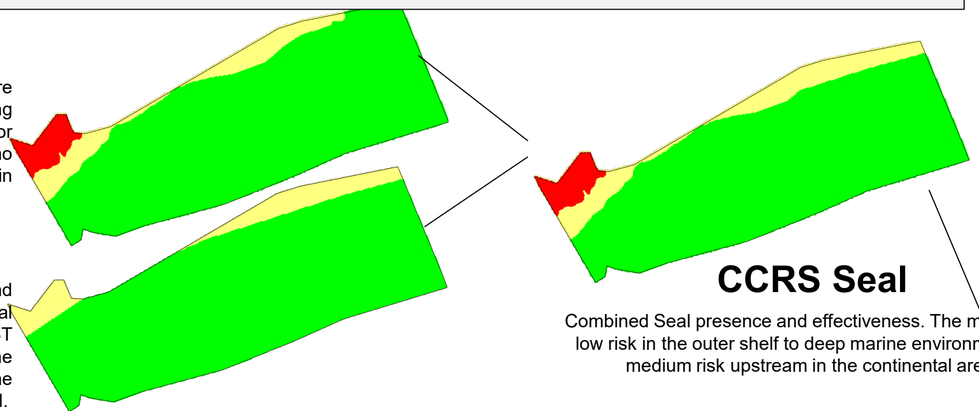
Seal

Seal Effectiveness

Based on seal capillary pressure extracted from basin modeling (lithology and compaction). Red color results from a cut-off that highlights no efficient capillary pressure to maintain hydrocarbon column.

Seal Presence

Based on sedimentologic and stratigraphic analysis, the seal presence correspond to the TST lithofacies distribution above the expected reservoir. It highlights the probability to encounter a vertical seal.



CCRS Seal

Combined Seal presence and effectiveness. The map shows low risk in the outer shelf to deep marine environment and medium risk upstream in the continental area.

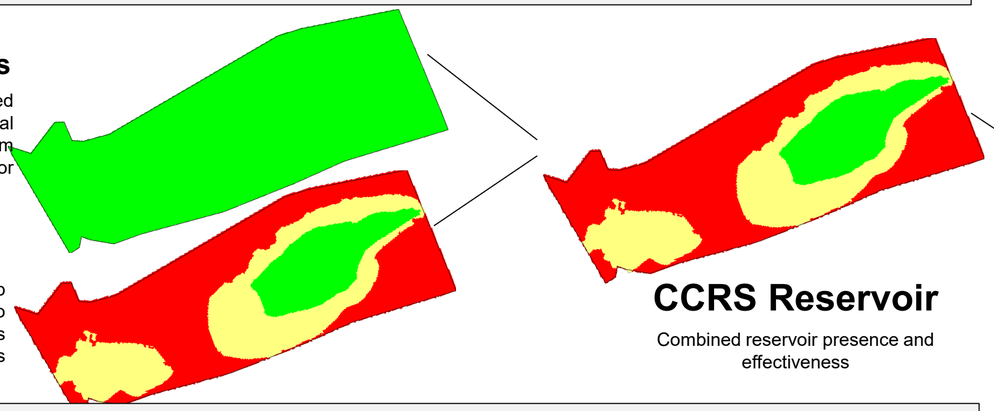
Reservoir

Reservoir Effectiveness

Based on reservoir porosity simulated in the basin modeling through burial and pore-pressure evolution. Medium risk (yellow) highlights porosity inferior to 6%.

Reservoir Presence

Based GDE mapping. This map highlights the probability to encounter a reservoir. Envelop has been drawn in order to catch areas of expected reservoir geobodies.



CCRS Reservoir

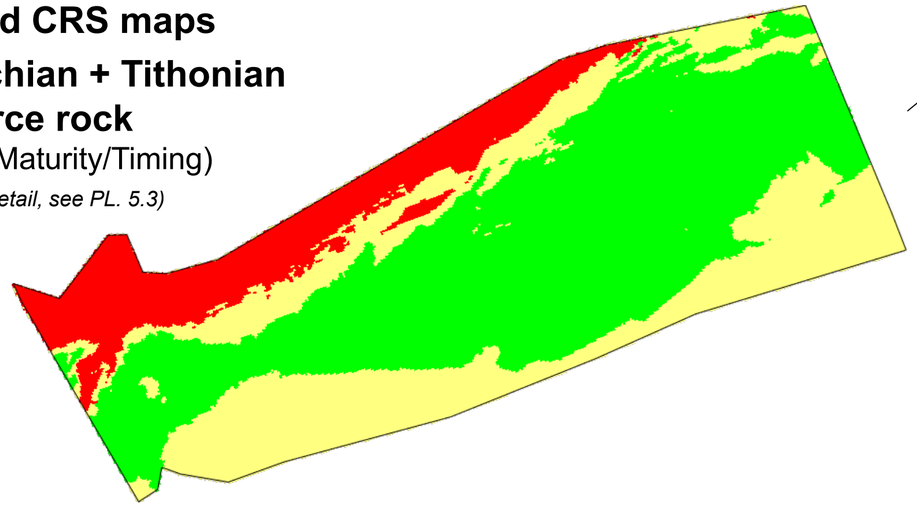
Combined reservoir presence and effectiveness

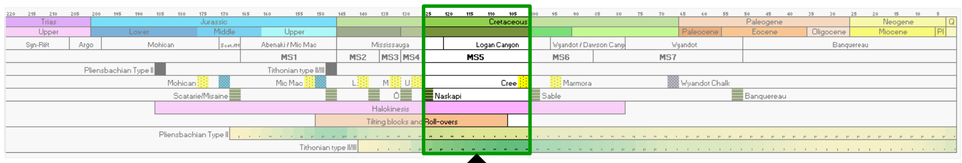
Charge

Combined CRS maps for Pliensbachian + Tithonian source rock

(Presence/Maturity/Timing)

(for more detail, see PL. 5.3)





CCRS map of MS5

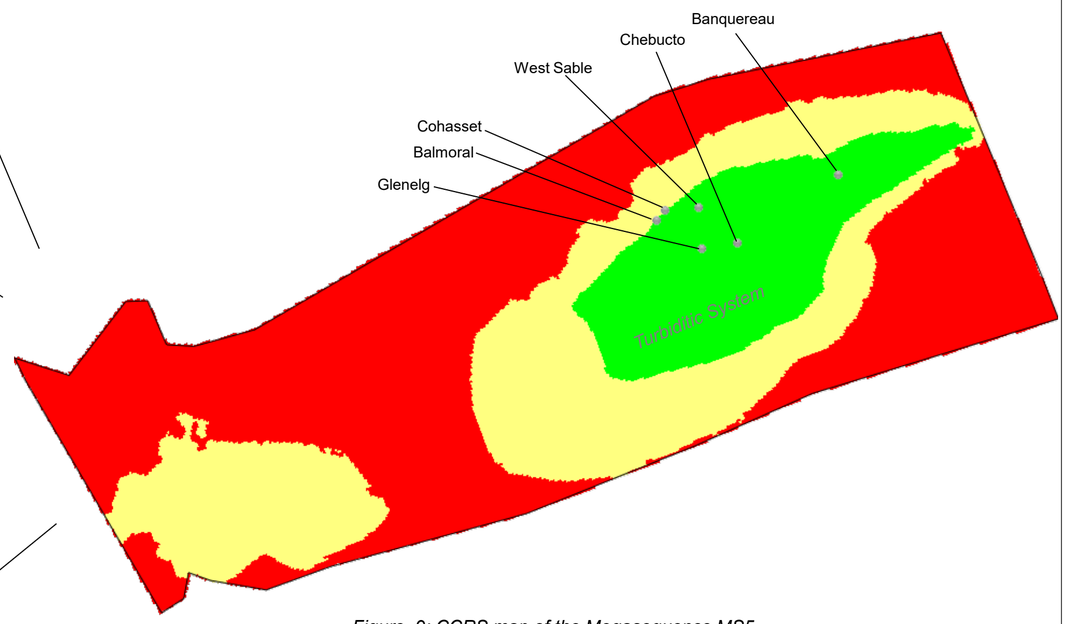


Figure 9: CCRS map of the Megasequence MS5

The Lower Cretaceous MS5 play shows a large exploratory potential especially in the east (Logan Canyon Formation - Cree Member). The two source rocks, Tithonian and Pliensbachian, provide a hydrocarbon charge. This megasequence is a large highstand system tract with a depo-center migrated slightly to the west. Seal is constituted by internal transgressive sequences and by salt in some places.

Discoveries

Lower Risk

Medium Risk

Higher Risk

Common Risk Segment (CRS) Maps and the Yet to Find (YTF)

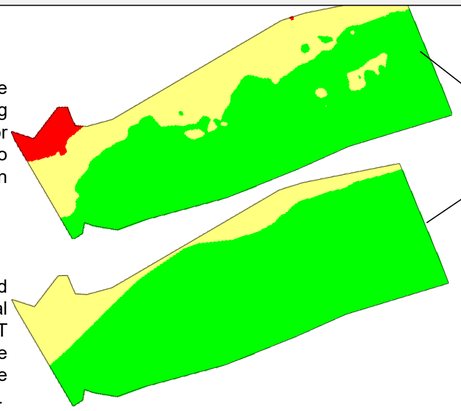
Seal

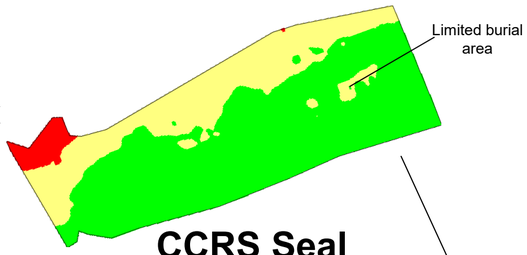
Seal Effectiveness

Based on seal capillary pressure extracted from basin modeling (lithology and compaction). Red color results from a cut-off that highlights no efficient capillary pressure to maintain hydrocarbon column.

Seal Presence

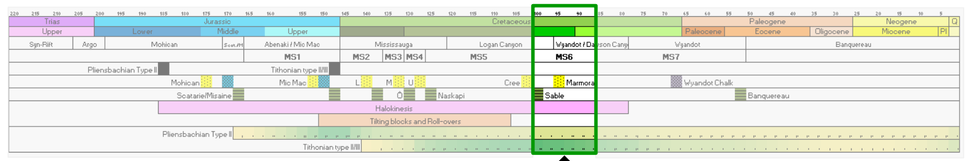
Based on sedimentologic and stratigraphic analysis, the seal presence correspond to the TST lithofacies distribution above the expected reservoir. It highlights the probability to encounter a vertical seal.





CCRS Seal

Combined Seal presence and effectiveness. The map shows mainly low risk in the outer shelf to deep marine environment, and medium risk upstream in the continental to fluvial plain environment with limited burial.



CCRS map of MS6

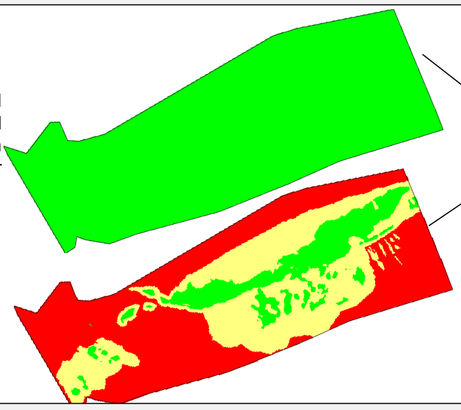
Reservoir

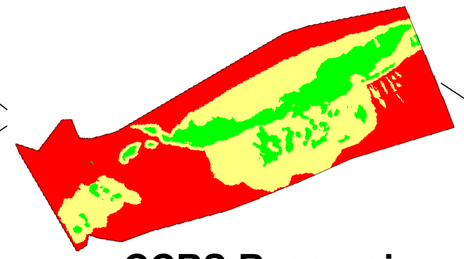
Reservoir Effectiveness

Based on reservoir porosity simulated in the basin modeling through burial and pore-pressure evolution. Medium risk (yellow) highlights porosity inferior to 6%.

Reservoir Presence

Based GDE mapping. This map highlights the probability to encounter a reservoir. Envelop has been drawn in order to catch areas of expected reservoir geobodies.





CCRS Reservoir

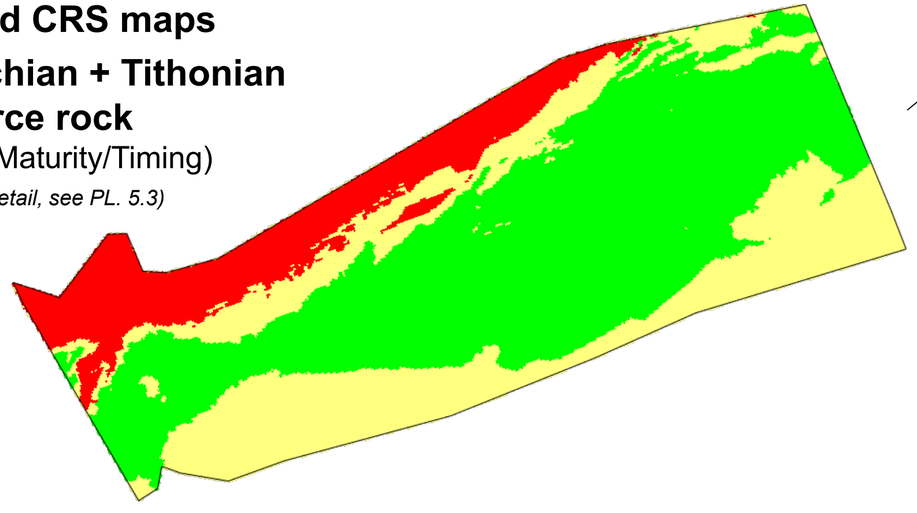
Combined reservoir presence and effectiveness

Charge

Combined CRS maps for Pliensbachian + Tithonian source rock

(Presence/Maturity/Timing)

(for more detail, see PL. 5.3)



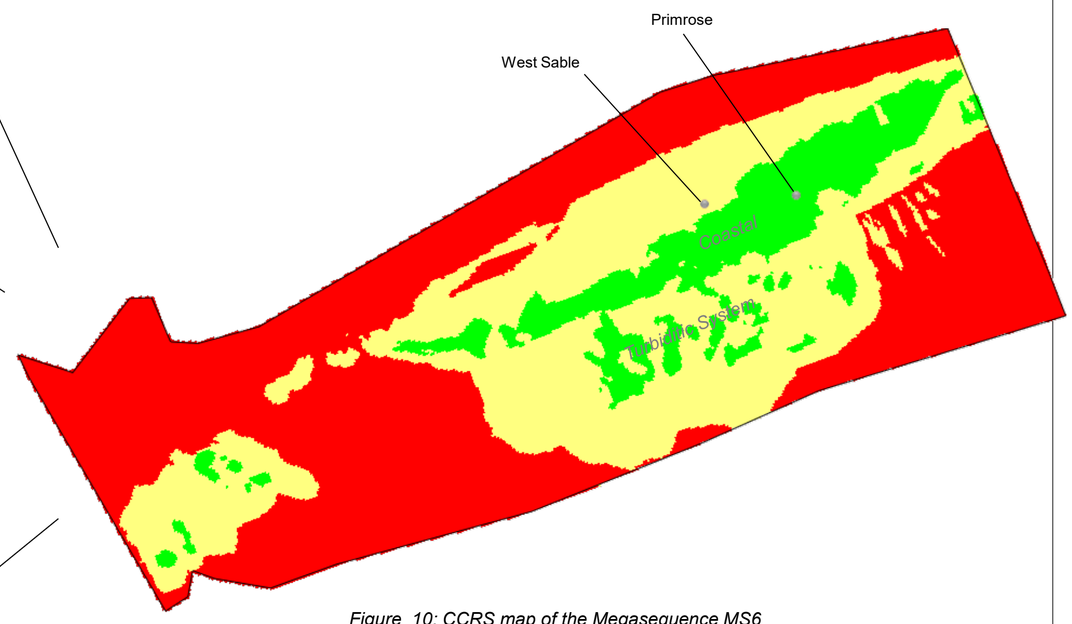


Figure 10: CCRS map of the Megasequence MS6

The Middle Cretaceous MS6 play shows a quite large exploratory potential especially in the east (Logan Canyon Formation - Marmora Member). The two source rocks, Tithonian and Pliensbachian, provide a hydrocarbon charge. Seal is constituted by Wyandot transgressive system which acts as a regional seal. Salt can also constitute lateral and top seal. This megasequence is a large highstand system tract ending with forced regression that provides deltaic and turbiditic systems. Depocenter has migrated to the center of the study area.

Discoveries

Lower Risk

Medium Risk

Higher Risk

Common Risk Segment (CRS) Maps and the Yet to Find (YTF)

Nova Scotia Play Fairway Analysis 2023 – CANADA – June 2023

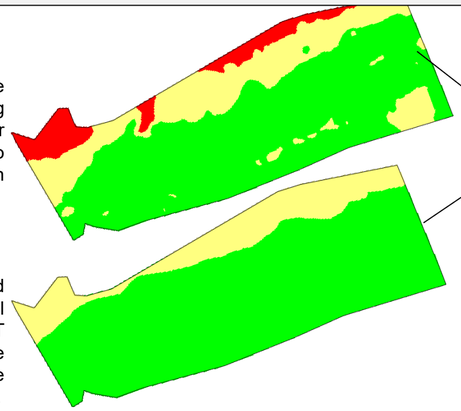
Seal

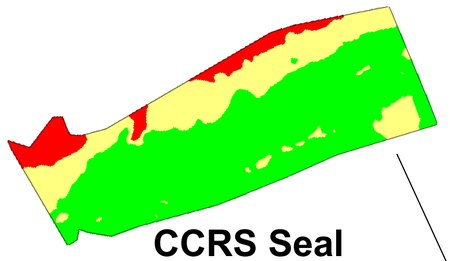
Seal Effectiveness

Based on seal capillary pressure extracted from basin modeling (lithology and compaction). Red color results from a cut-off that highlights no efficient capillary pressure to maintain hydrocarbon column.

Seal Presence

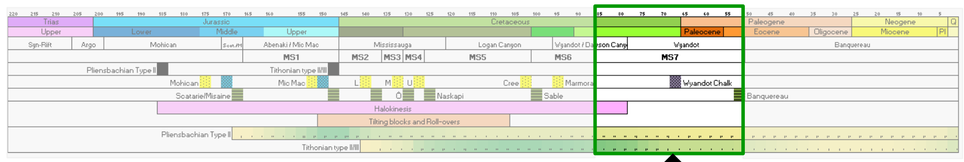
Based on sedimentologic and stratigraphic analysis, the seal presence correspond to the TST lithofacies distribution above the expected reservoir. It highlights the probability to encounter a vertical seal.





CCRS Seal

Combined Seal presence and effectiveness



CCRS map of MS7

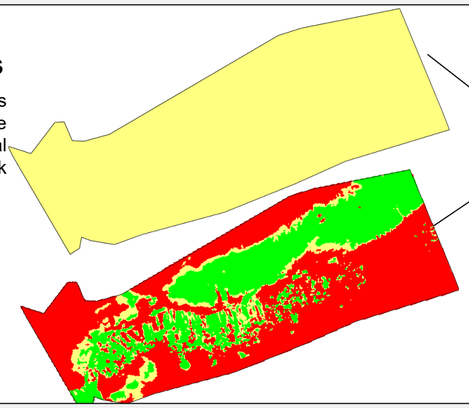
Reservoir

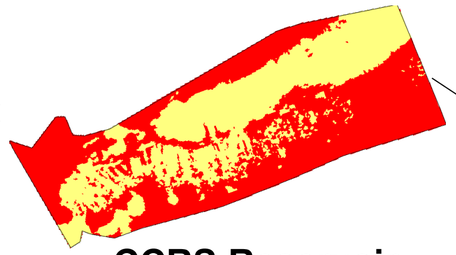
Reservoir Effectiveness

The map has been considered as medium risk everywhere due to the high variability of the petrophysical parameters of the carbonate chalk observed on wells.

Reservoir Presence

Based GDE mapping. This map highlights the probability to encounter a reservoir. Envelop has been drawn in order to catch areas of expected reservoir geobodies.





CCRS Reservoir

Combined reservoir presence and effectiveness. Even if chalk unit exist the high variability of the petrophysical parameter class this interval as a medium risk to high risk

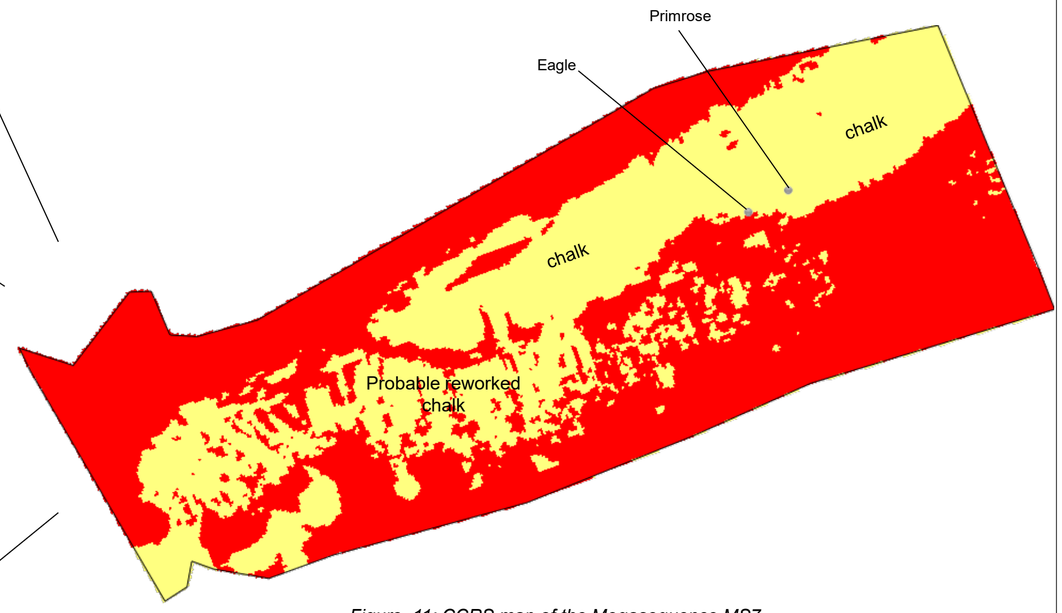


Figure 11: CCRS map of the Megasequence MS7

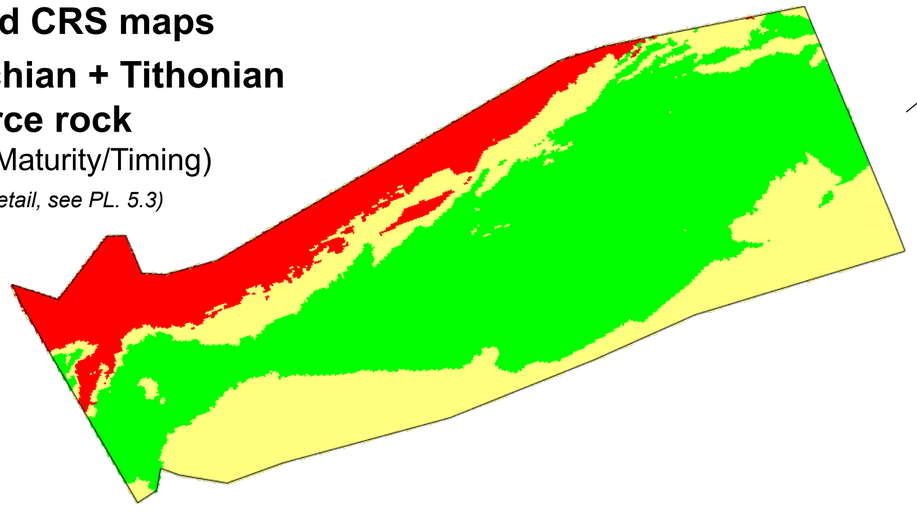
The Upper Cretaceous MS7 play shows low risk for the seal constituted by transgressive system tract of Banquereau Formation, and low risk for hydrocarbon charge constituted by Tithonian and Pliensbachian source rocks. This chalk unit (Wyandot Chalk) has quite good continuity over the study area but petrophysical properties are variables. In the shelf, permeability is fair at Primrose well discovery but very limited at Eagle well discovery. On the slope, reworked chalks are expected to present higher reservoir potential (*Steven J. Ings 2005, Diagenesis and porosity reduction in the Late Cretaceous Wyandot Formation, Offshore Nova Scotia: a comparison with Norwegian North Sea chalks*)

Charge

Combined CRS maps for Pliensbachian + Tithonian source rock

(Presence/Maturity/Timing)

(for more detail, see PL. 5.3)



Discoveries

Lower Risk

Medium Risk

Higher Risk

Yet to Find

HC Volumes

in reservoir condition (Graph Mm^3) and in standard condition (Bbl, Tcf)
most likely scenario

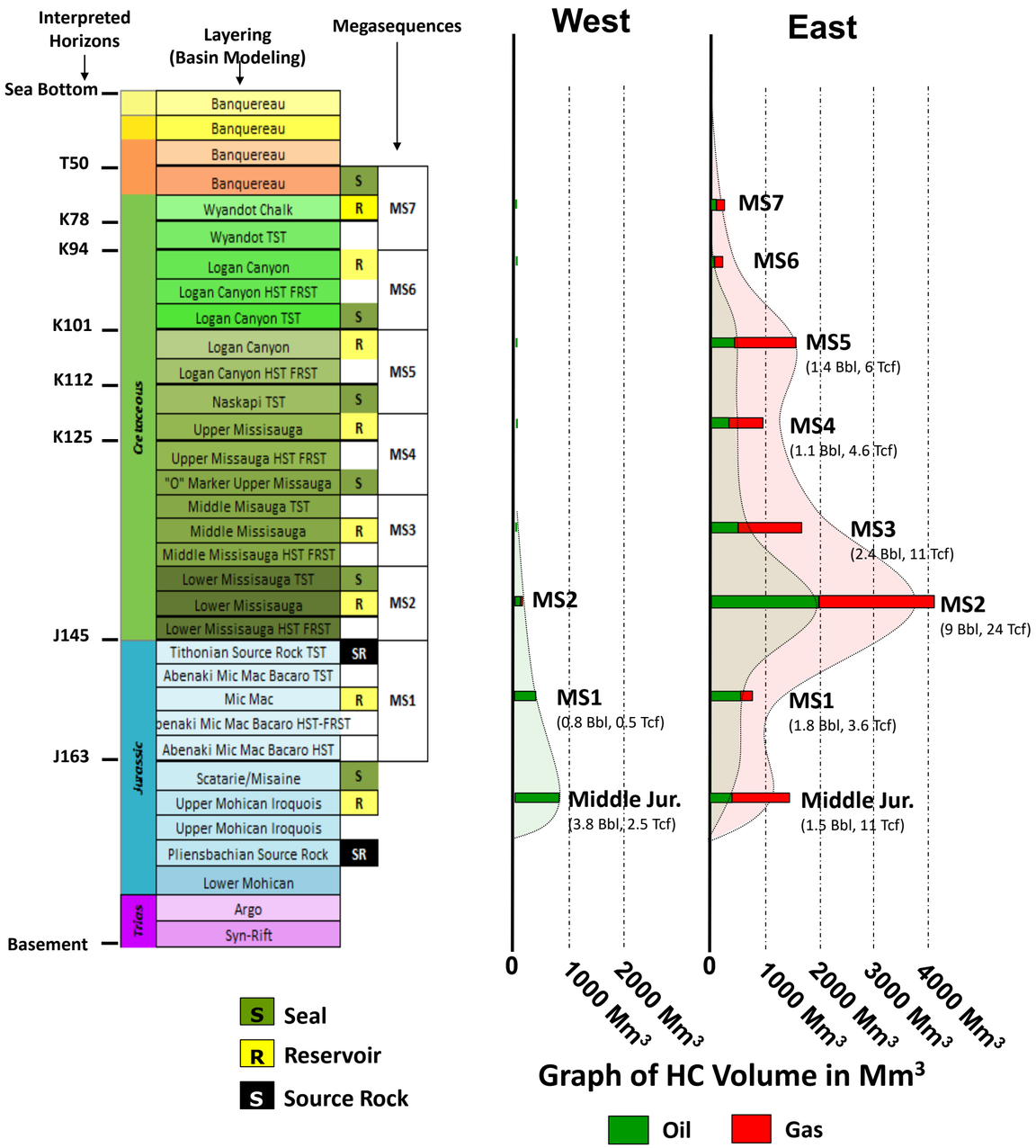
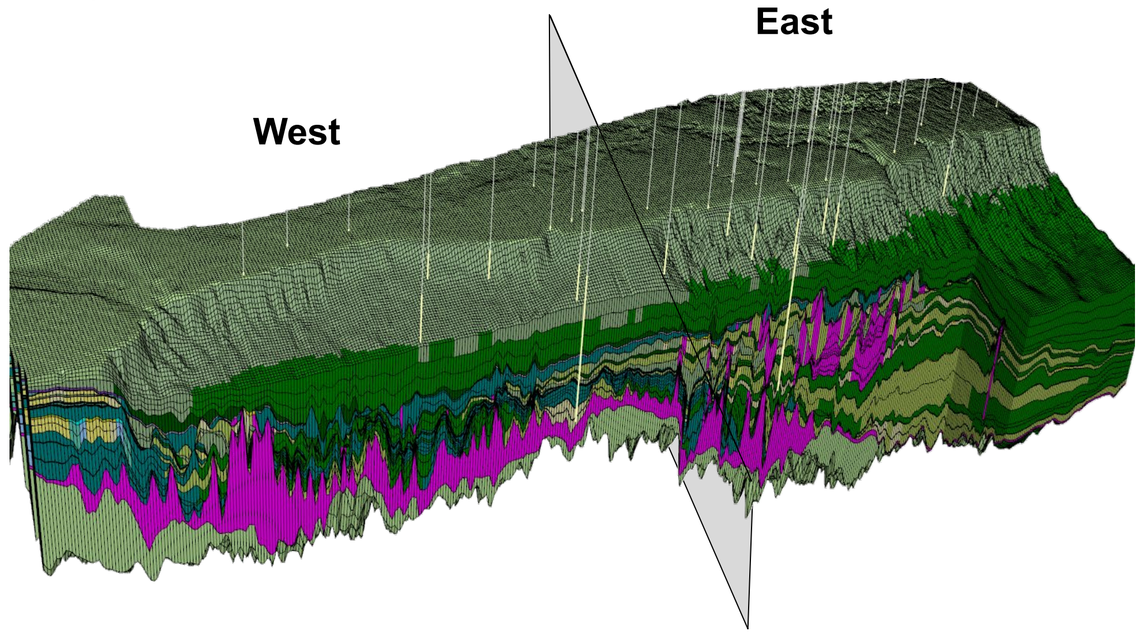


Figure 12: Yet to Find graph showing hydrocarbon volumes per plays



In the eastern area, a large turbiditic system (Mississauga Formation) exists just above the mature Tithonian source rock. The Pliensbachian source rock is an additional contributor. Gas and condensate dominates in this depocenter with a transition from condensate to oil such as at Panuke on the shelf (proven) and Tangier blocks on the slope. Megasequences MS2 and MS3 appear to be the main target for exploration at play level with respectively 9 Bbl and 24 Tcf for MS2 and 2.4 Bbl and 11 Tcf for MS3 in place. Main reason is the source rock proximity and an efficient cap rock (“O” marker) above MS3. Faults, fractures and diapirism provide some efficient vertical conduits to feed hydrocarbon to the megasequence above.

The western area is an oil province. Timing of the Pliensbachian source rock generation is favorable (late Tertiary). Pliensbachian charge can migrate directly to reservoirs, which limits loss of trapped hydrocarbons because it avoids the critical moment (no tectonic events expected after the generation). Due to generation timing, and also to the efficient top seal capacity, vertical migration seems to be limited to the margins of diapirs. In this context, Middle Jurassic (Mohican Formation) appears to be the main target of the western area.

The table below, gives the Yet To Find in place for the entire study area with the total oil (Bbl), total gas (Tcf) and total Oil and Gas (Bbloe). The result combines various 3D petroleum system models playing with uncertainties on net reservoir thickness, source rock richness, hydrocarbon saturation cut-off and hydrocarbon mass cut-off in reservoir cells. Probabilistic assessment comes from Monte carlo simulations derived from the petroleum system models to provide the P10 (High Case), P50 (Most Likely) and P90 (Low Case).

Total	Total Oil (Bbl)	Total Gas (Tcf)	Total Oil & Gas (Bbloe)
P90 Low Case	19.3	47.4	25.8
P50 Most Likely	22.6	64.6	31.5
P10 High Case	49.2	148.4	69.6

Figure 13: Yet to Find table; hydrocarbon volumes in place in Standard Condition for the entire study area P10, P50 and P90