Petroleum System Modeling of the Shelburne Sub-Basin: An Insight on the Petroleum Potential of Southwest Nova Scotia*

E. A. Marfisi[1], A. Arbeaumont[1], F. Saint-Ange[1], A. MacDonald[2], M. Luheshi[3], and L. Cuilhe[1]

Search and Discovery Article #10885 (2016)**
Posted November 21, 2016

*Adapted from oral presentation given at AAPG/SEG International Conference & Exhibition, Cancun, Mexico, September 6-9, 2016

[1]BeicipFranlab, Rueil Malmaison, France (emerson.marfisi@beicip.com)
[2]Department of Energy, OERA, Halifax, Nova Scotia, Canada
[3]Leptis E&P Ltd, Watford, United Kingdom

Abstract

The Department of Energy and the Offshore Energy Research Association (OERA) published in 2015 an integrated hydrocarbon (HC) exploration study concerning the offshore of Southwest Nova Scotia. It extends the 2011 Play Fairway Analysis (PFA) to the western limit of the Canadian Atlantic Shelf, covering the Shelburne Sub-Basin area. The HC resources assessment is based on a 3D model TemisFlow (TF) with a Full Darcy migration of fluids. The Shelburne Sub-Basin (SS) contains as much as 15 km of sedimentary column composed of basal Triassic deposits overlain by a thick salt cover and Jurassic to present-day sediments. No well has been ever drilled on the basin's slope and deepwater areas. Two wells were drilled in the shelf area: Bonnet P23 and Mohawk B93, showing only HC stained intervals.

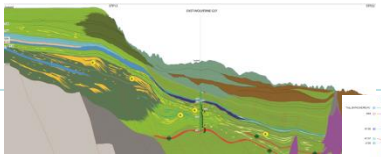
The TF model consist of a 36 layer grid with 351×199 cells of 1 km side representing the post-salt to present-day interval including reservoirs, carrier, salt bodies and five source rocks (SR). The SR intervals considered in the model represent a Lower Jurassic Complex grouping potential Hettangian to Toarcian type II source rocks; two type II – III source rocks placed at the Callovian and Tithonian position, and finally two type III source rocks placed at the Valanginian-Aptian levels. Potential Jurassic – Cretaceous reservoirs consist of shelf carbonates, deltaic sandstones, slope toe carbonate breccia and clastic to carbonate turbidites. The spatial distribution of these facies was estimated using a forward stratigraphic model. The TF results showed suitable conditions for oil generation in the Jurassic interval, however Cretaceous SR's are immature or at their earlier stage of maturity with no sensible expulsion. The best maturity conditions are present in the Hettangian to Toarcian interval with only local maturity windows in the Callovian and Tithonian SRs. HC accumulations correspond mainly to flank traps on salt cored anticlines, roll-over structures, traps under salt canopy and basin floor turbidites. HC phase is oil at reservoir conditions with API ranging from 25° to 40°. HC resources in the Lower Jurassic interval were estimated at around 6 to 1 BBL OOIP mainly related with slope toe carbonate breccia reservoirs. The Upper Jurassic accumulations correspond to clastic and carbonatic turbidites in the SS with HC resources estimated at around 5 to 3.7 BBL OOIP. The Tithonian to Albian interval contains estimated resources of around 1.5 to 0.8 BBL OOIP, mainly in deepwater clastic and carbonate turbidites.

Petroleum System Modeling of the Shelburne Sub-basin: An insight on the petroleum potential of the SW Nova Scotia.

E. Marfisi [1], A. Arbeaumont [1], F. Saint-Ange [1], A. MacDonald [2], M. Luheshi [3], L. Cuilhe [1]

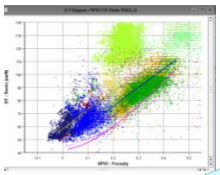
1: BeicipFranlab, 232 Avenue Napoleon Bonaparte, BP 213, 92502 Rueil- Malmaison, France
2: Department of Energy, Halifax, Province of Nova Scotia, B3J 3P7, Canada
3: Leptis E&P Ltd., Watford, WD17 4QX, UK

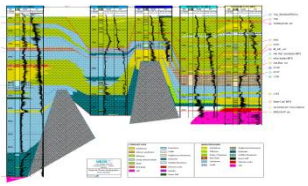
AAPG ICE, Cancun, September 6 to 9, 2016



Sedimentologic &
Stratigraphic framework

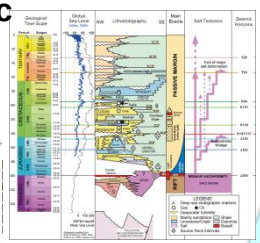
Petrophysical interpretation

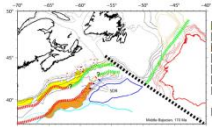


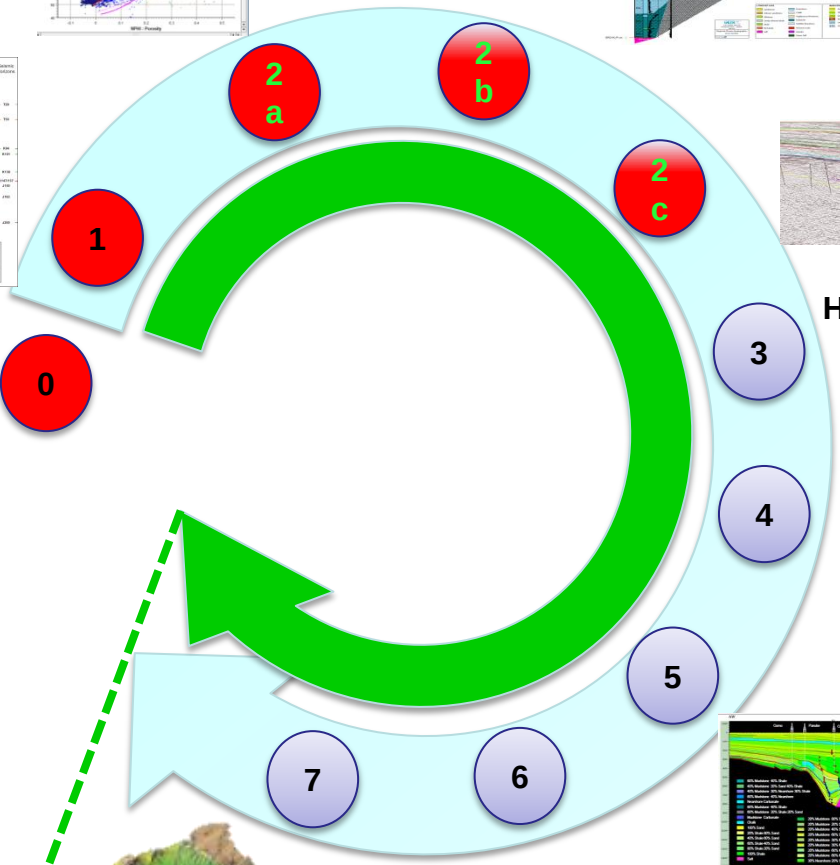


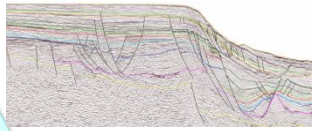
Structural framework / seismic interpretation

Regional tectono-stratigraphic settings

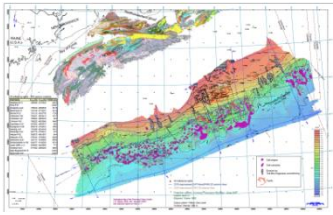






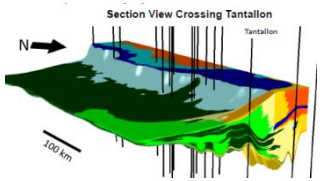


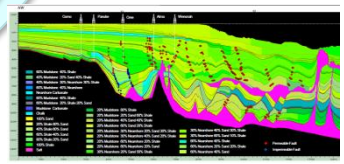
Horizon/Structural Maps
Time depth conversion



Data Base construction

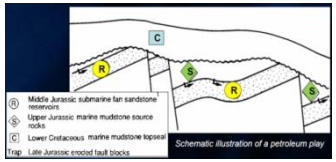
GDE Maps / Stratigraphic Modeling





Petroleum Geochemistry/ Petroleum System Modeling

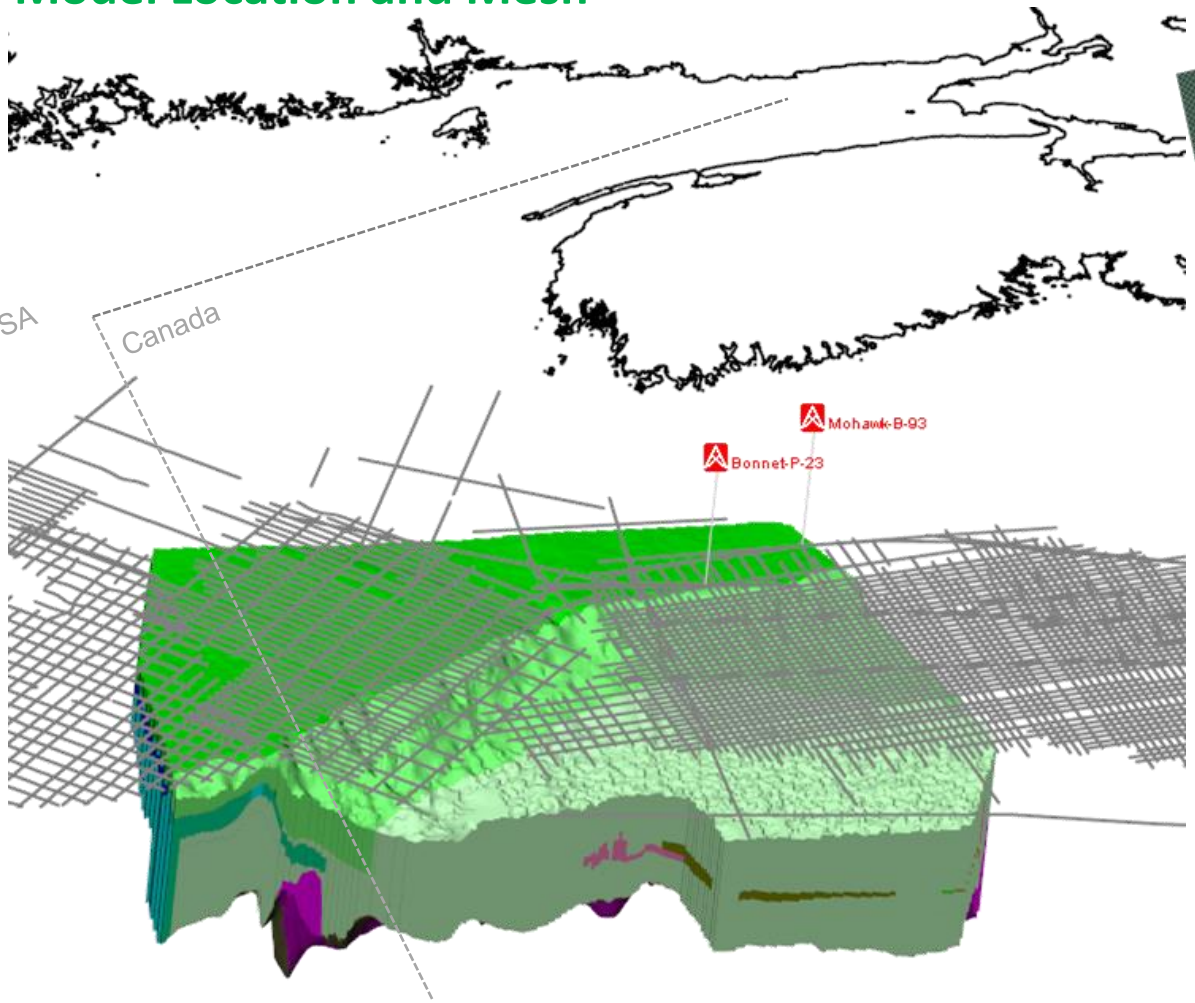
HC Accumulations

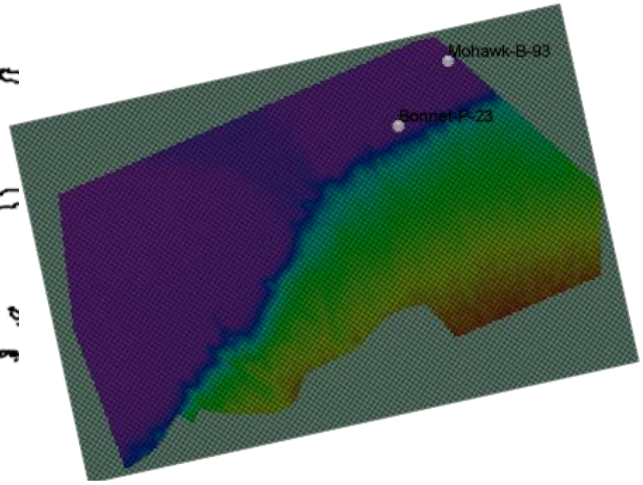


Play concepts & identification

Petroleum System Modeling

Model Location and Mesh





Dimension: 306km x 199km
Cells number: nX=198, nY=99 nZ=36
Cells size: 2km x 2km

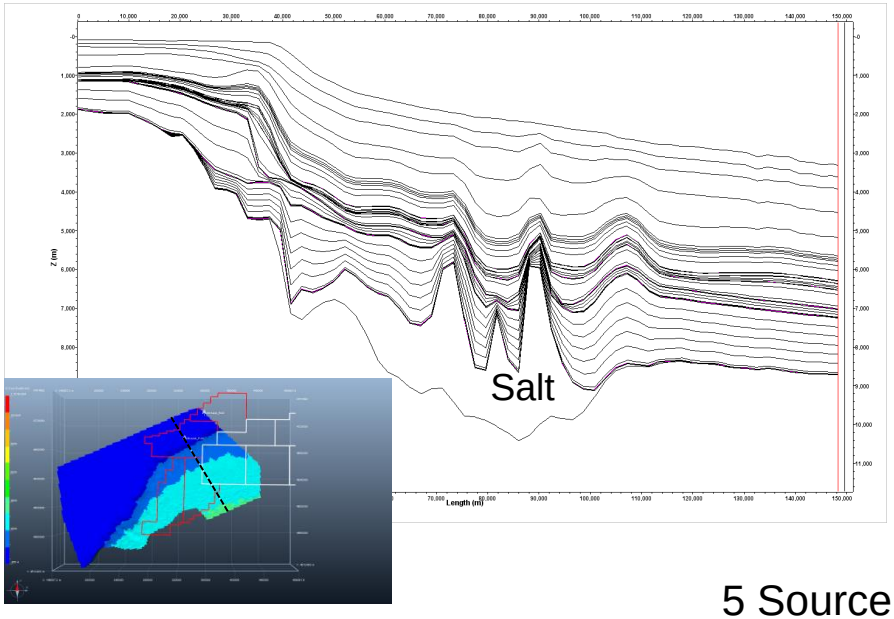
SW Nova Scotia

BeicipFranlab

TemisFlow Block Construction

5 STRATIGRAPHIC INTERVAL and 5 SOURCE ROCKS are studied:

STRATIGRAPHIC INTERVAL	*SOURCE ROCKS*
Cenomanian-Albiann(K101-K94)	APTIAN SR (~K124)
Albian-Barremian (K130-K101)	VALANGINIAN SR (~K136)
Barremian-Tithonian (J150-K130)	TITHONIAN SR (~J150)
Tithonian-Callovian (J163-J150)	CALLOVIAN SR (~J163)
Early-Middle-Jurassic (J200-J163)	LOW JURASSIC COMPLEX SR (~J196)



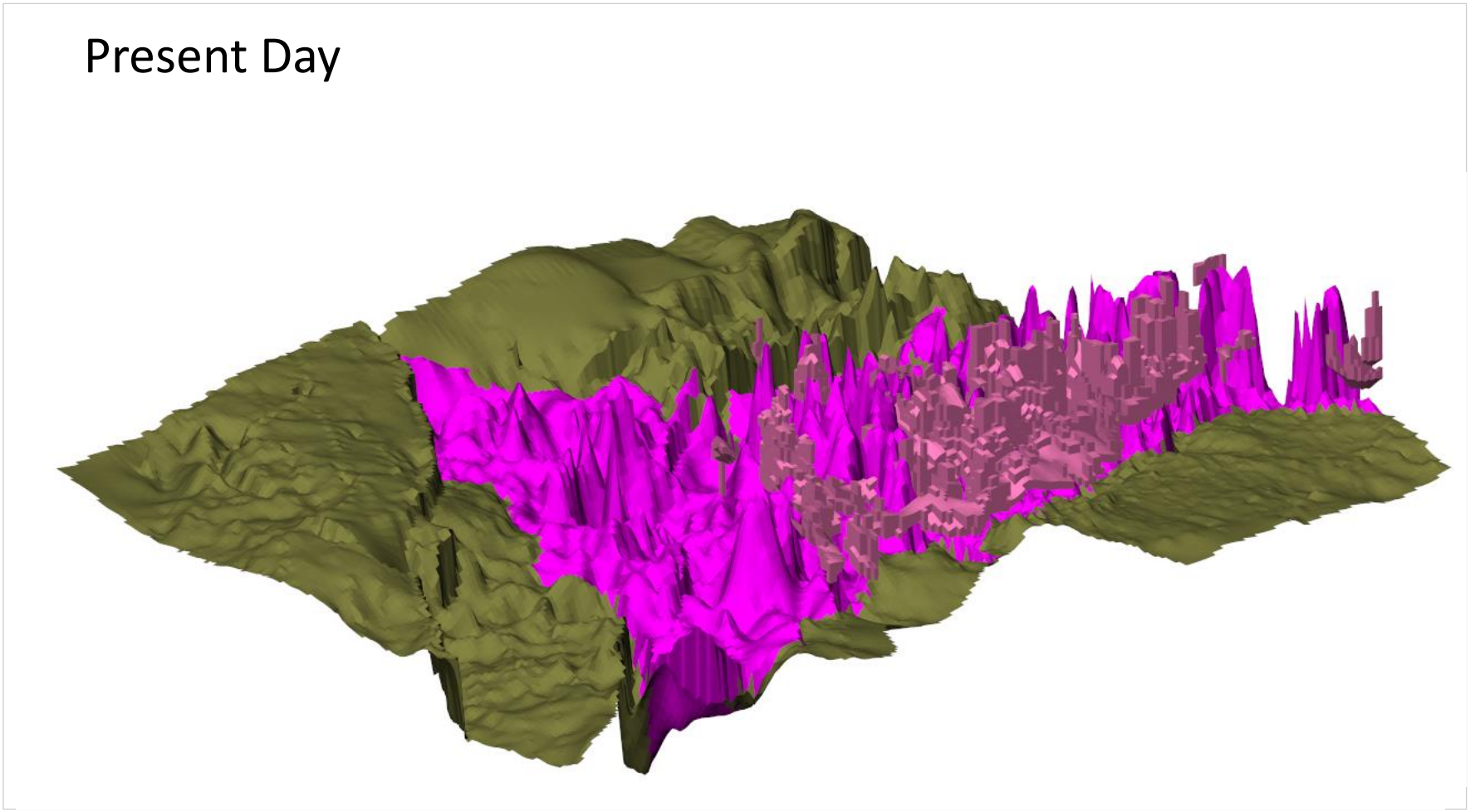
37 layers

Age (horizon)	Horizon	Top Source Rocks	Seismic Horizons	Horizon Color
0	Sea bottom		Yes	
14,5	Miocene		Subdivision	
29	Oligocene Unconformity		Yes	
50	Eocene		Yes	
70	Upper Cretaceous		Subdivision	
94	Cenomanian Unconformity		Yes	
97	Cenomanian		Subdivision	
99	Cenomanian		Subdivision	
101	Albian-Logan Unconformity		Yes	
106	Albian		Subdivision	
112	Aptian Logan-Cree		Subdivision	
124	Top Aptian SR		10m Thickness	
125	Barremian		Subdivision	
130	Barremian		Yes	
131,5	Barremian		Subdivision	
133,5	Hauterivian		Subdivision	
134,5	Hauterivian		Subdivision	
136	Top Valanginian SR		10m Thickness	
137	Top BCU		Yes	
140	Valanginian		Subdivision	
148	Berriasian		Subdivision	
150	Top SR Tithonian		Yes	
151	Top Tithonian		Subdivision	
154	Upper Jurassic Ind.		Subdivision	
157	Kimmeridgian		Subdivision	
160,5	Callovian		Subdivision	
163	Top SR Callovian		Yes	
165	Scatarie		Subdivision	
170	Bajocian		Subdivision	
175	Aalenian		Subdivision	
180	Toarcian		Subdivision	
185	Toarcian		Subdivision	
190	Pleisbachian		Subdivision	
195	Sinemurian		Subdivision	
196	Top Low Jurassic Complex SR		20m Thickness	
197	Top Autochtonous Salt		Yes	
220	Top Basement		Yes	

5 Source Rocks

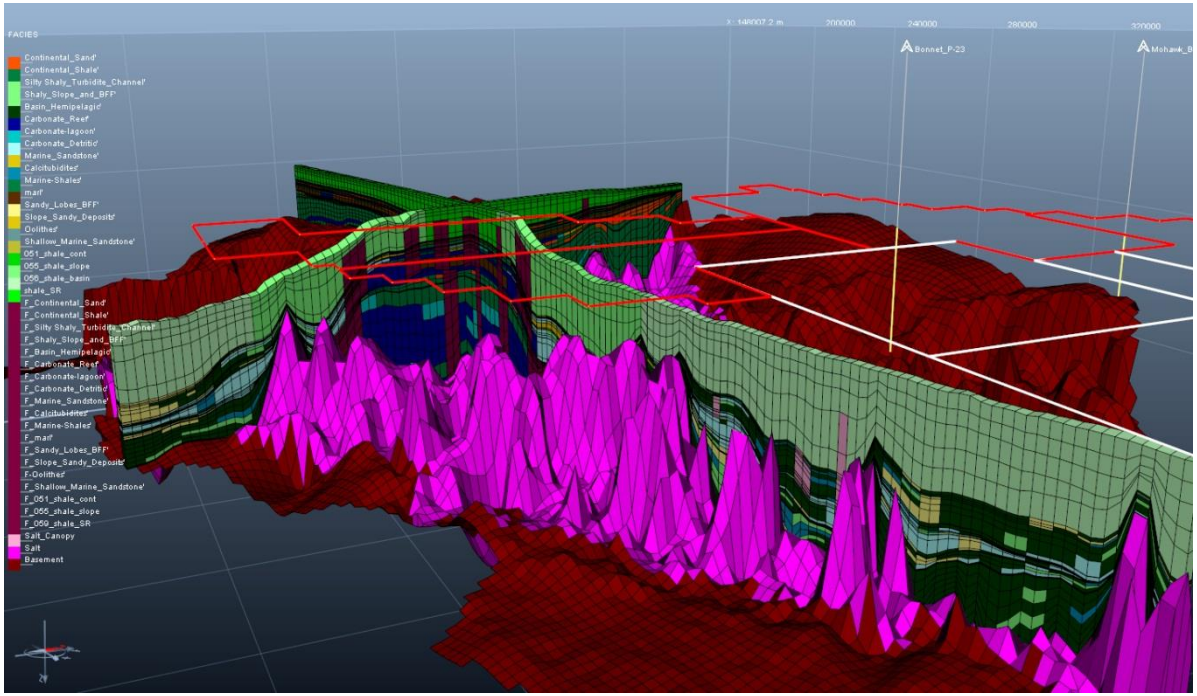
Source Rock	Approx. Age	Initial TOC	Kerogen type Initial HI	Description
Aptian	124 Ma	2 % (constant)	III (continental) HI = 235 mgHC/gTOC (Dogger. North Sea) - Open system kinetics - Vandenbrouke et al. 1999	Potential source rock in the Naskapi shale (and equivalent), identified in some wells. Variable effective thickness between 0 – 10 m.
Valanginian	136 Ma	1 % (constant)	III (continental) HI = 235 mgHC/gTOC (Dogger. North Sea) - Open system kinetics - Vandenbrouke et al. 1999	Very poor and scattered source rock (coal fragments in deltaic environment, through the Mississauga formation) Variable effective thickness between 0 – 10 m.
Tithonian	150 Ma	3 % (constant)	II-III mix HI = 424 mgHC/gTOC	Best defined SR, widely proven. Variable effective thickness between 0 – 20 m.
Callovian	163 Ma	2 % (constant)	II-III mix HI = 424 mgHC/gTOC	Potential source rock in the Misaine shale (and equivalent), uncertain extend and richness due to the lack of data. Variable effective thickness between 0 – 20 m.
Lower Jurassic Complex	196 Ma	5 % (constant)	II (marine) HI = 600 mgHC/gTOC (Toarcian. France) - Open system kinetics - Behar et al. 1997	Suspected, not proven (Pleisbachian/Toarcian SR). Potentially present above salt basins only. Assumed average thickness 20 m.

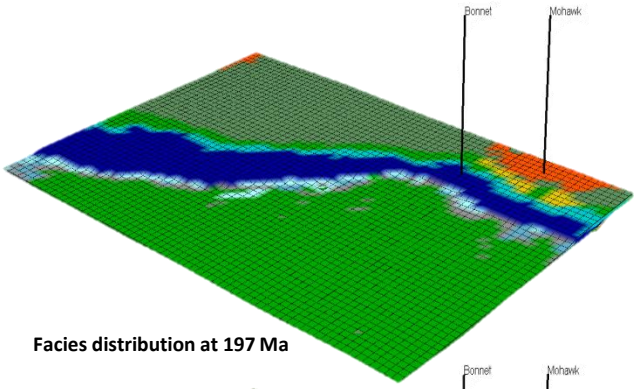
Salt Geometry Reconstruction Trough Time



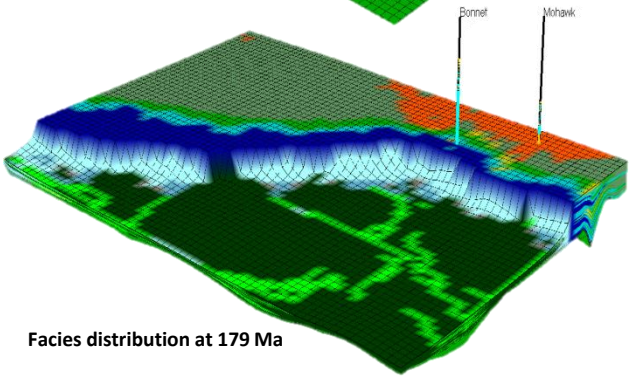
BeicipFranlab

TemisFlow Block Construction

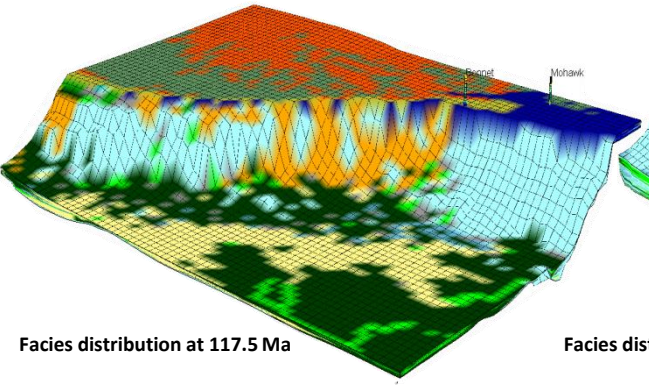




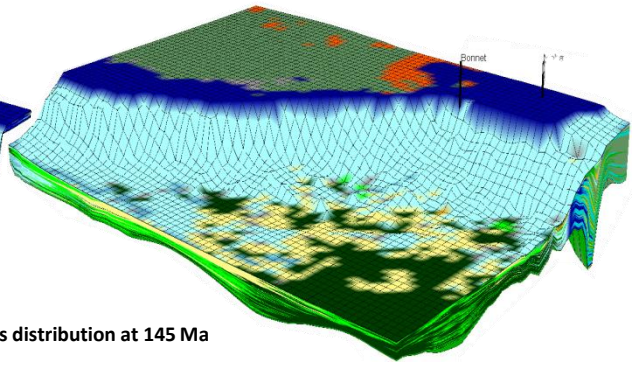
Facies distribution at 197 Ma



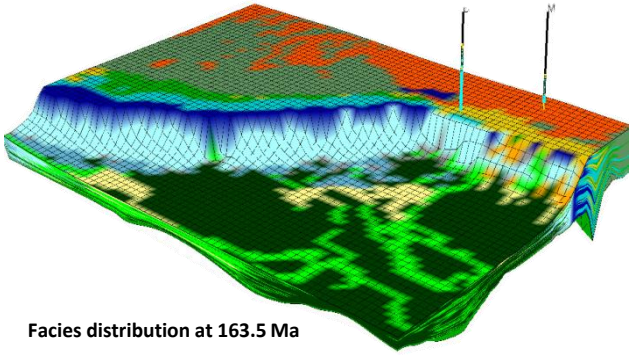
Facies distribution at 179 Ma



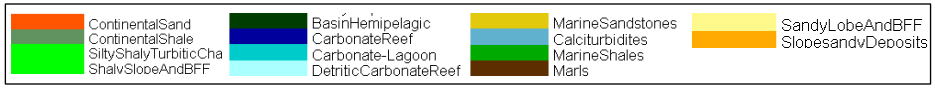
Facies distribution at 117.5 Ma



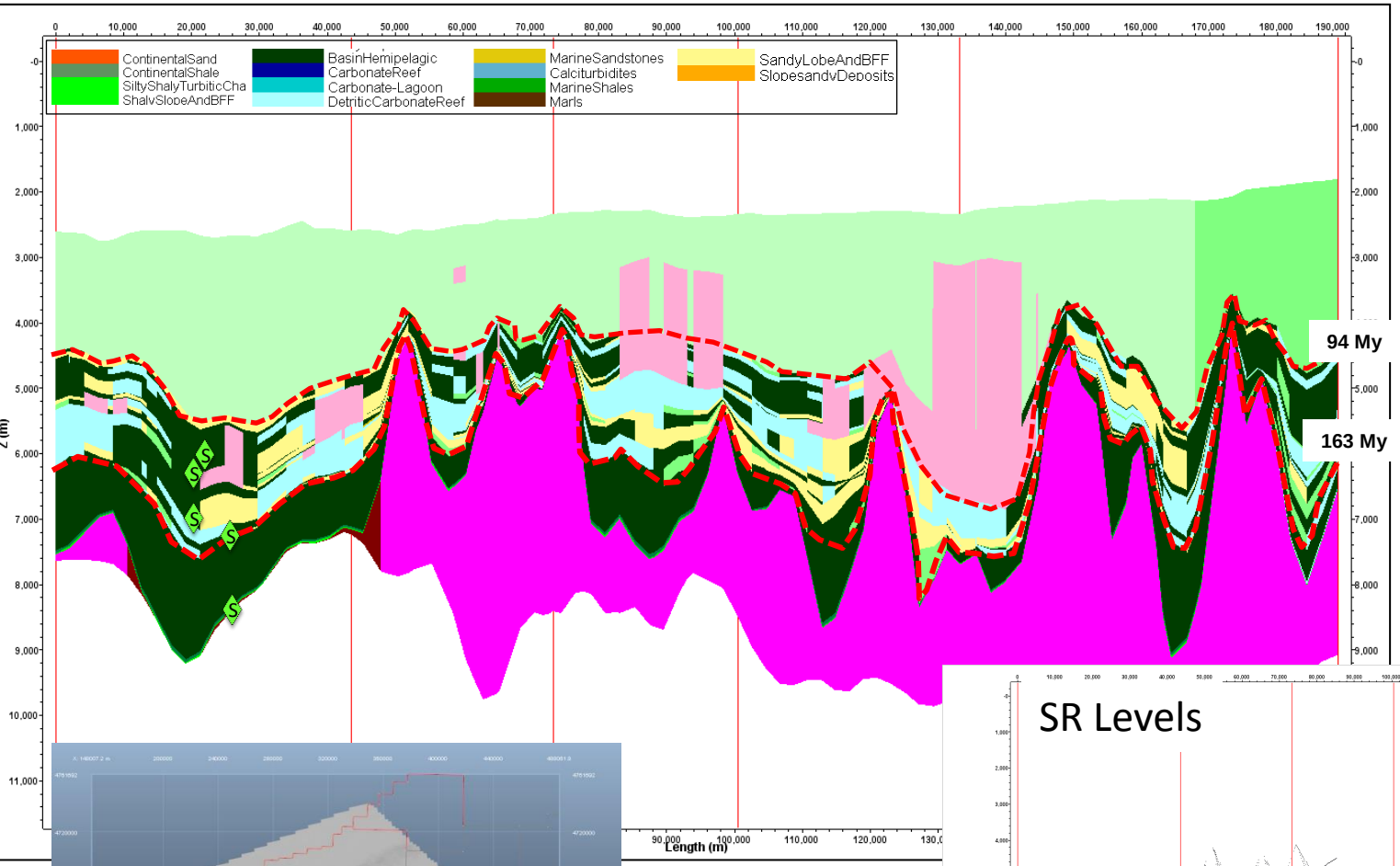
Facies distribution at 145 Ma



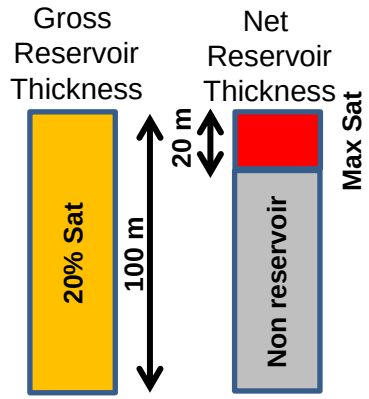
Facies distribution at 163.5 Ma

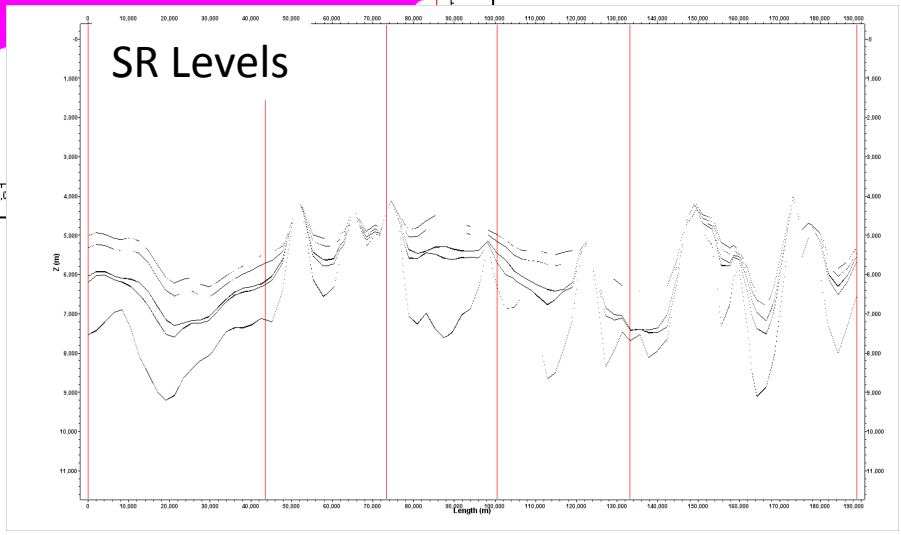


Petroleum System Definition



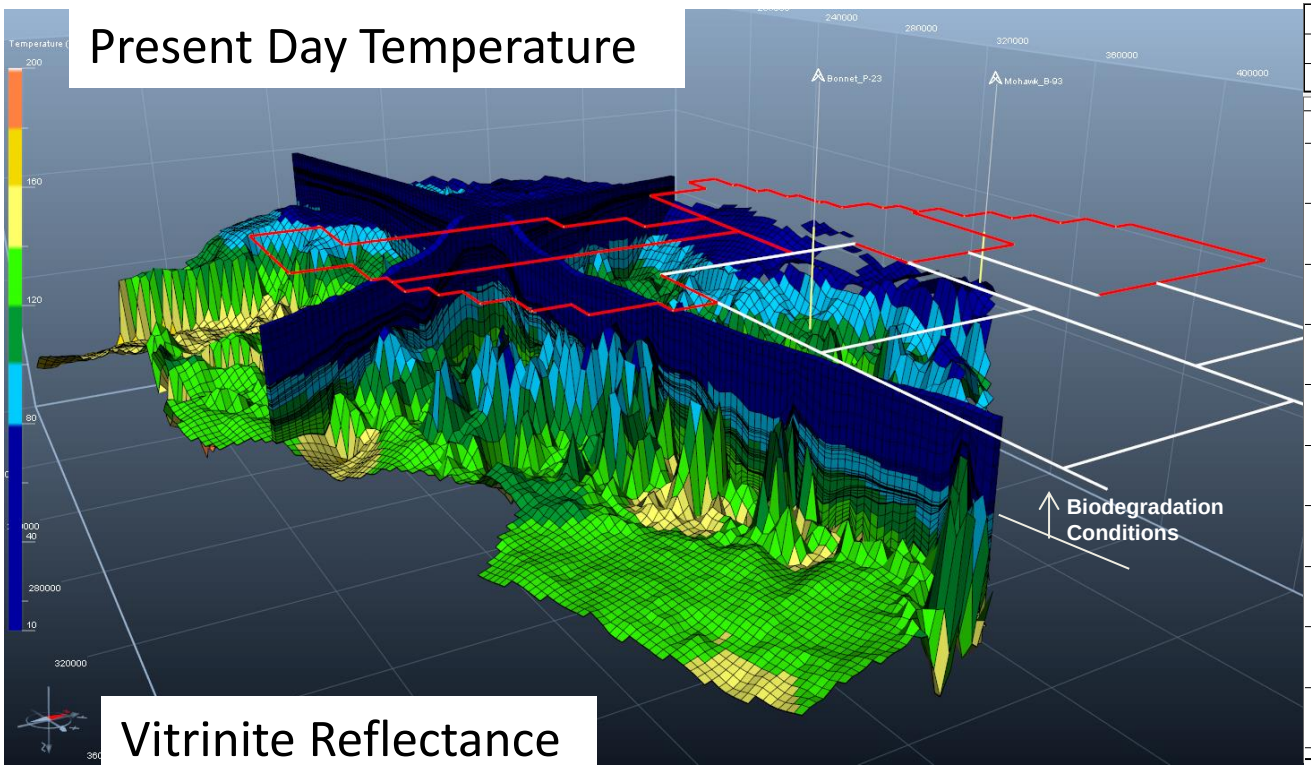
Reservoir Definition

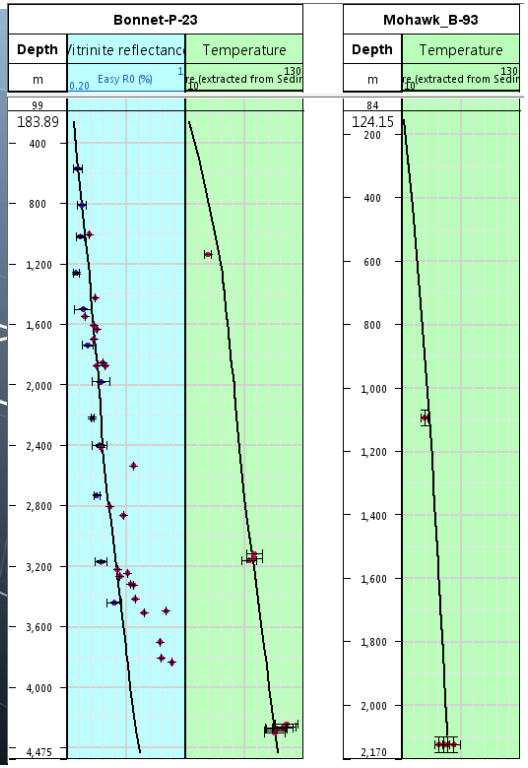




Thermal Calibration

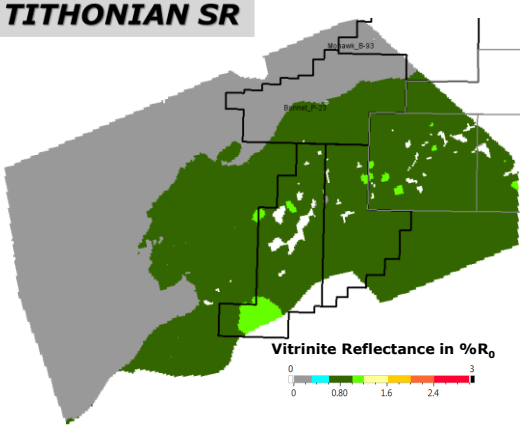
Present Day Temperature



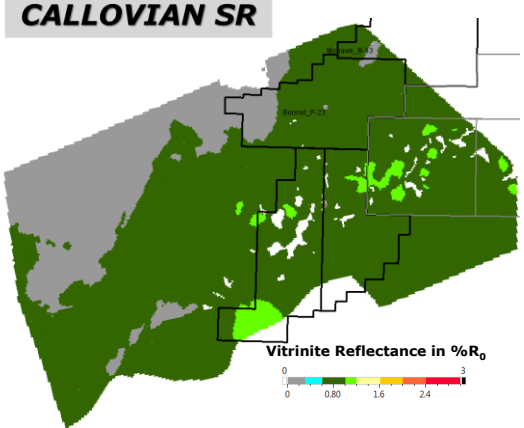


Vitrinite Reflectance

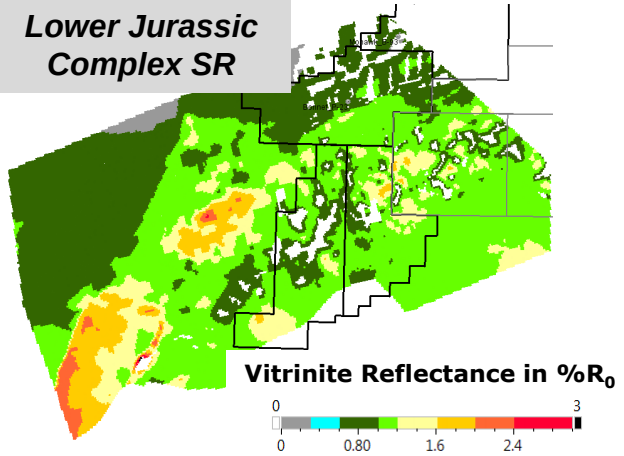
TITHONIAN SR



CALLOVIAN SR



Lower Jurassic Complex SR

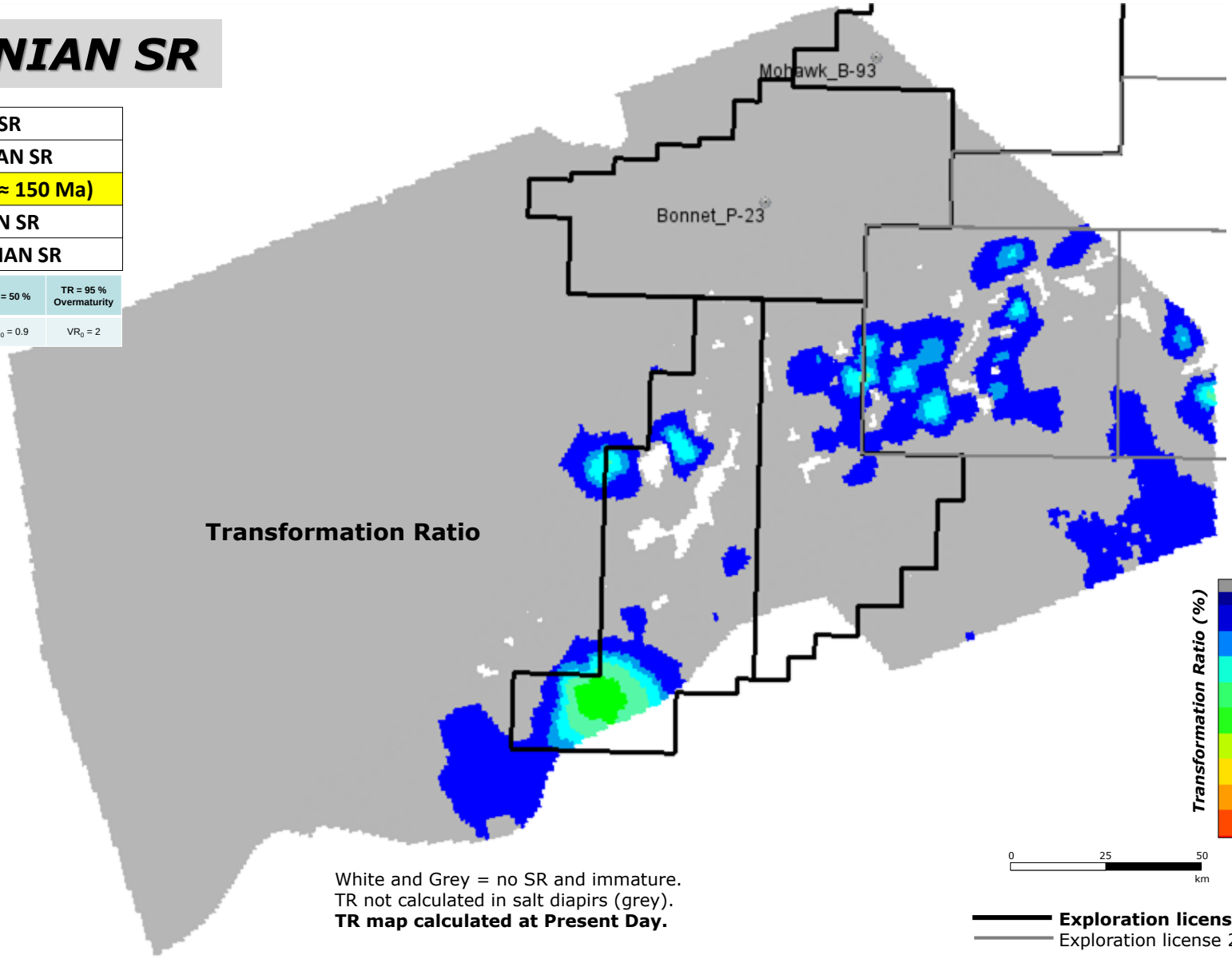


Transformation Ratio Tithonian SR

TITHONIAN SR

APTIAN SR
VALANGINIAN SR
TITHONIAN SR (≈ 150 Ma)
CALLOVIAN SR
PLIENSBACHIAN SR

Relationship TR / Vitrinite	TR = 5% Maturity (oil window)	TR = 50 %	TR = 95 % Overmaturity
Kerogen Type II	VR_0 = 0.7	VR_0 = 0.9	VR_0 = 2



White and Grey = no SR and immature.
TR not calculated in salt diapirs (grey).
TR map calculated at Present Day.

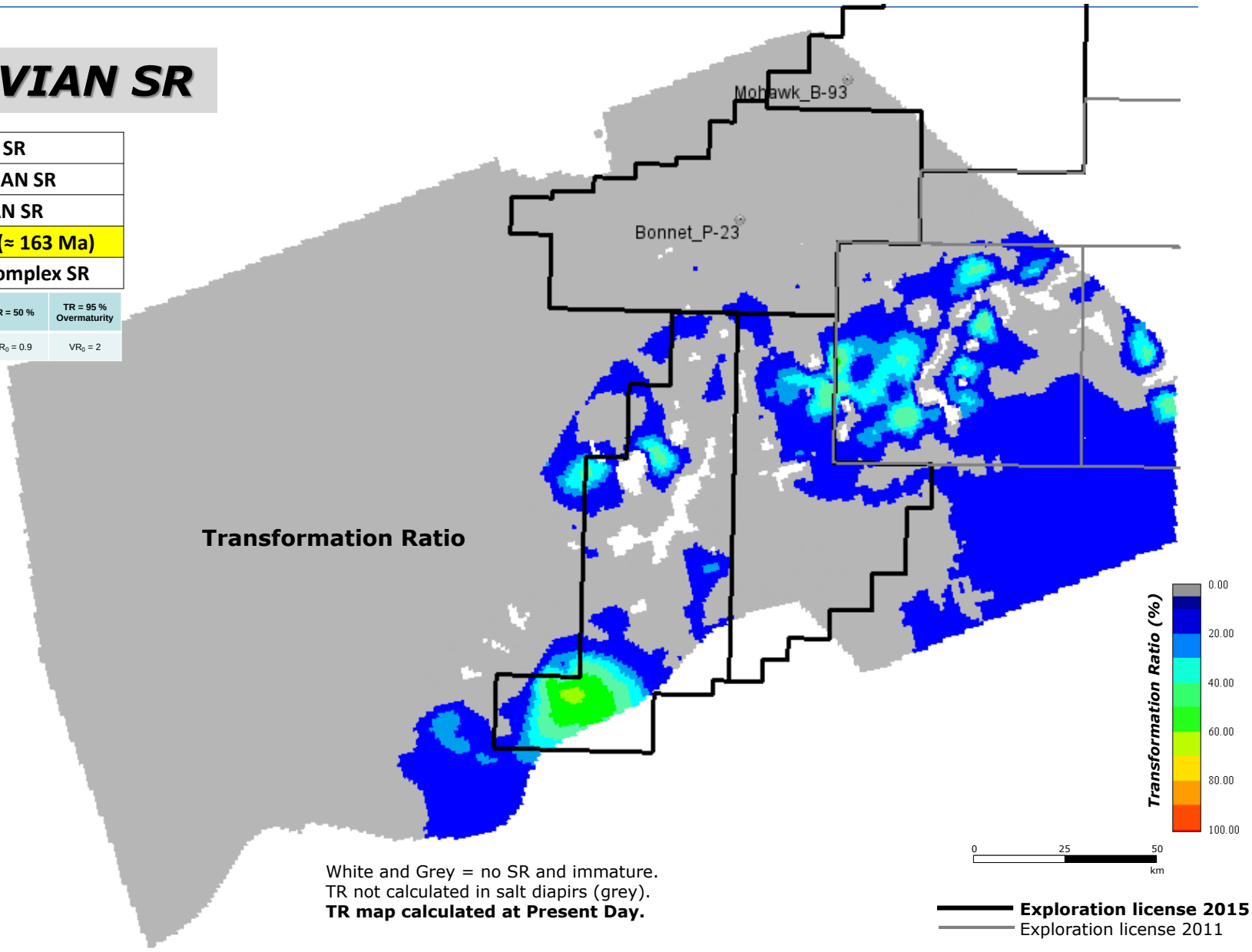
Exploration license 2015
Exploration license 2011

Transformation Ratio Callovian SR

CALLOVIAN SR

APTIAN SR
VALANGINIAN SR
TITHONIAN SR
CALLOVIAN SR (≈ 163 Ma)
Low Jurassic Complex SR

Relationship TR / Vitrinite	TR = 5% Maturity (oil window)	TR = 50 %	TR = 95 % Overmaturity
Kerogen Type II	VR_0 = 0.7	VR_0 = 0.9	VR_0 = 2



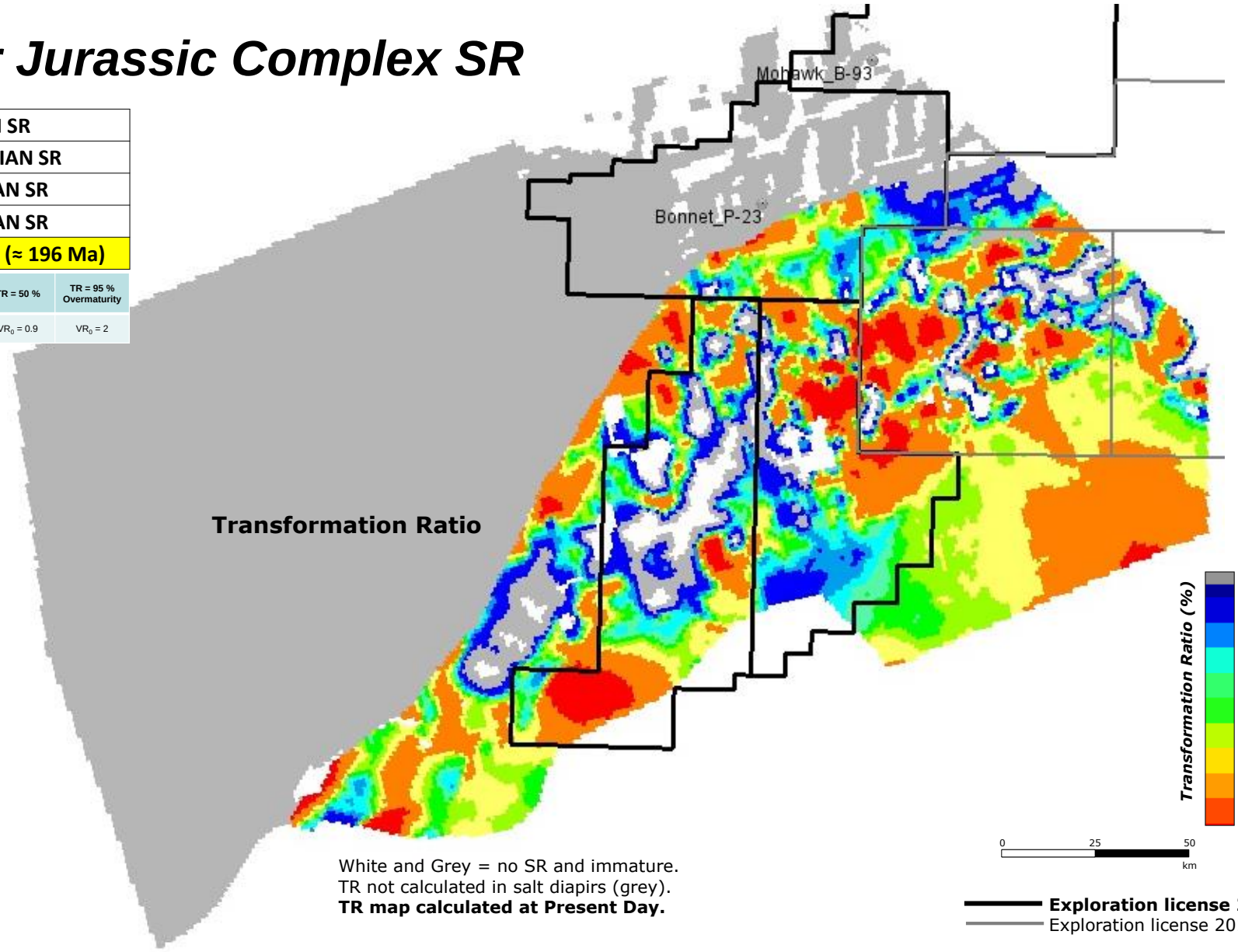
White and Grey = no SR and immature.
TR not calculated in salt diapirs (grey).
TR map calculated at Present Day.

Transformation Ratio Lower Jurassic SR

Lower Jurassic Complex SR

APTIAN SR
VALANGINIAN SR
TITHONIAN SR
CALLOVIAN SR
Low Jurassic SR (≈ 196 Ma)

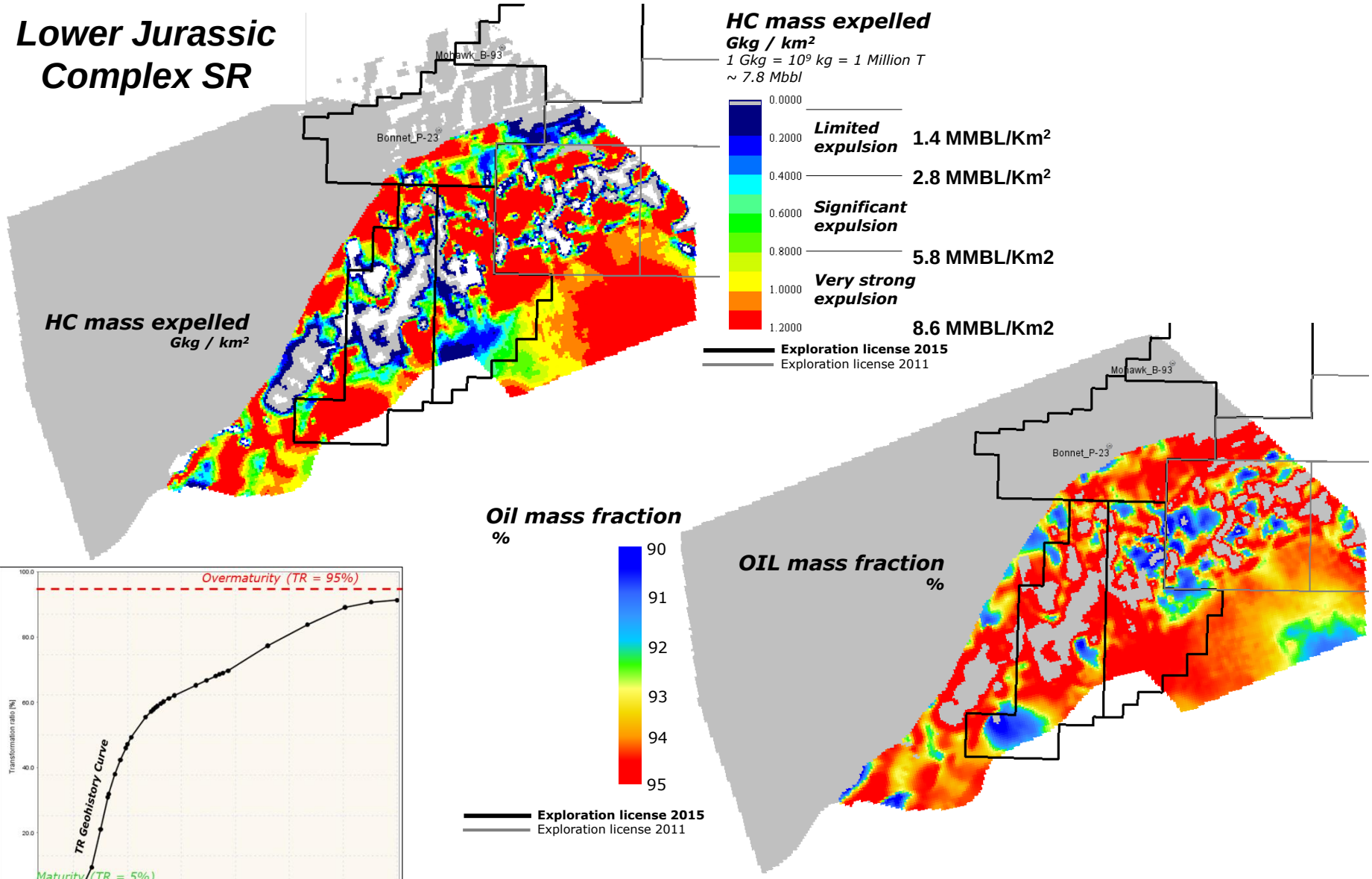
Relationship TR / Vitrinite	TR = 5% Maturity (oil window)	TR = 50 %	TR = 95 % Overmaturity
Kerogen Type II	VR_0 = 0.7	VR_0 = 0.9	VR_0 = 2



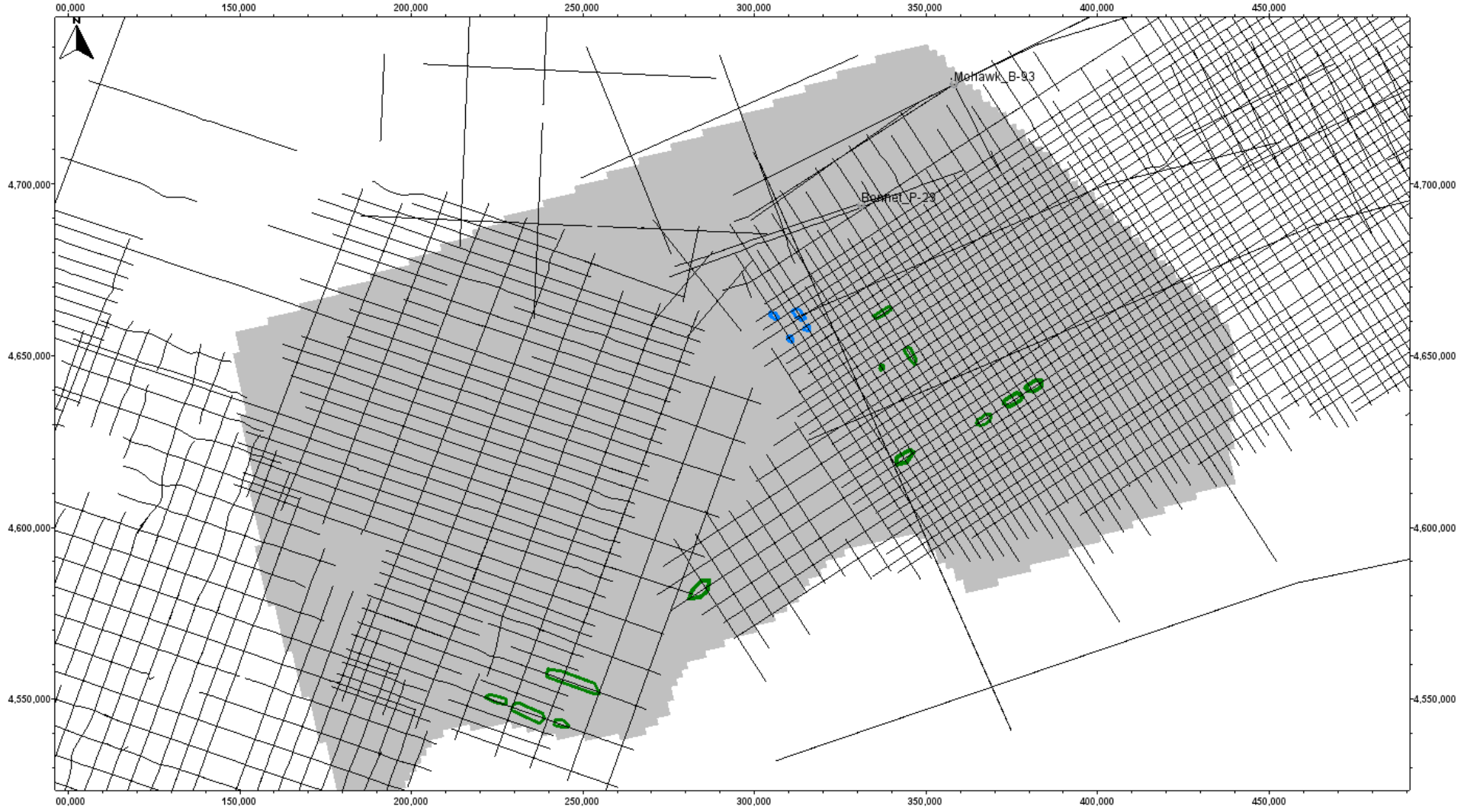
White and Grey = no SR and immature.
TR not calculated in salt diapirs (grey).
TR map calculated at Present Day.

Exploration license 2015
Exploration license 2011

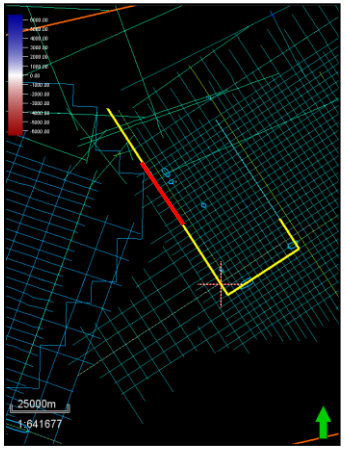
HC Mass Expelled Lower Jurassic SR

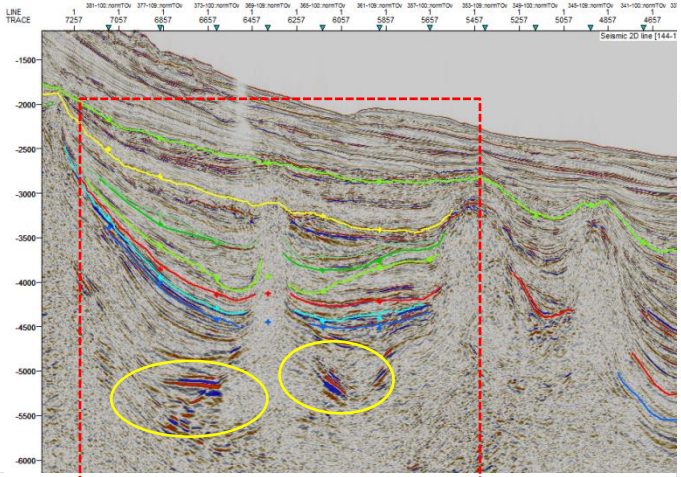


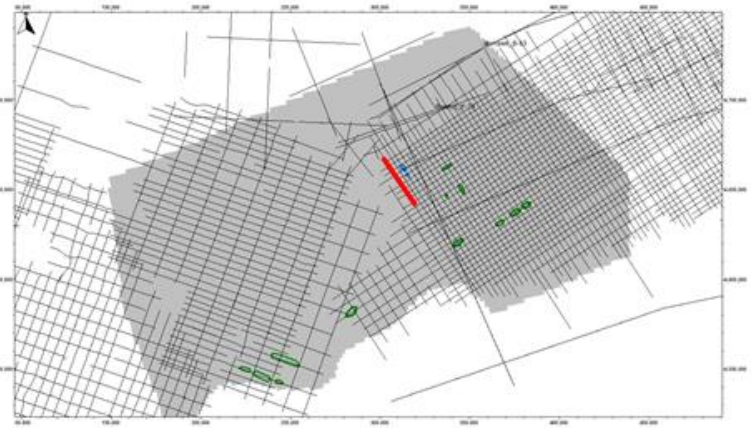
DHI Distribution

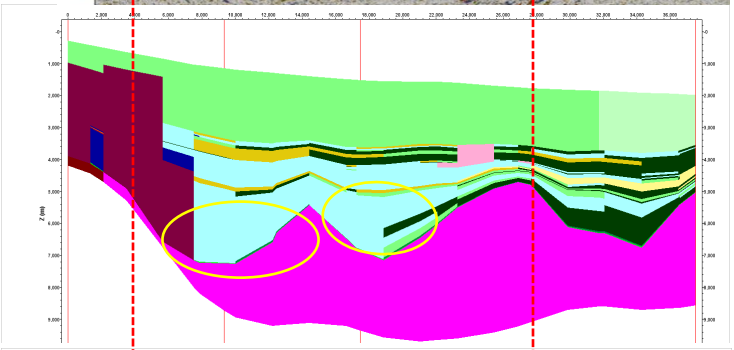


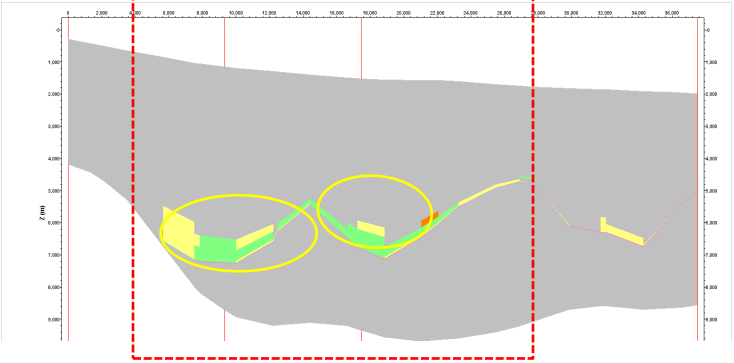
Model Calibration : Lower Jurassic











Facies

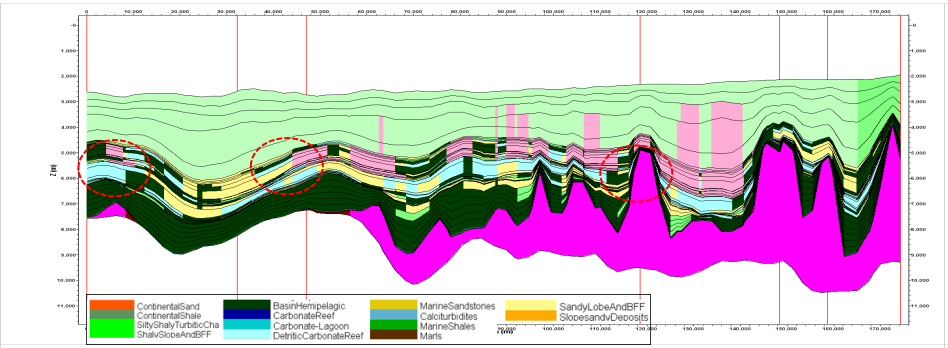
- ContinentalSand
- ContinentalShale
- SiltyShalyTurbiticChannel
- ShalySlopeAndBFF
- BasinHemipelagic
- CarbonateReef
- Carbonate-Lagoon
- DetriticCarbonateReef
- MarineSandstones
- Calciturbidites
- MarineShales
- Marls
- SandyLobeAndBFF
- SlopesandyDeposits

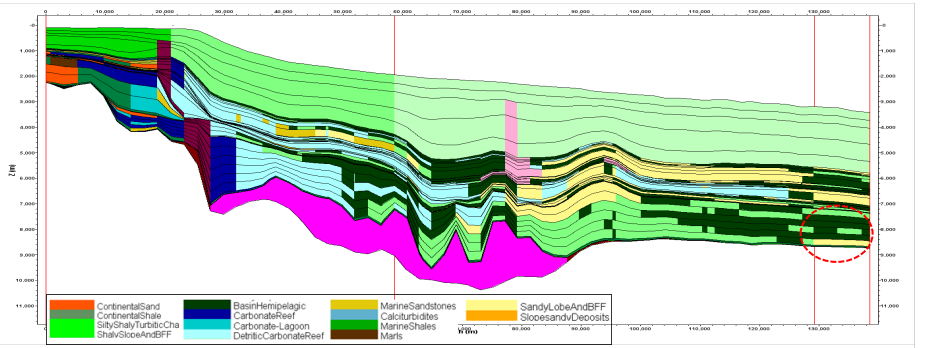
HC Sat [%]

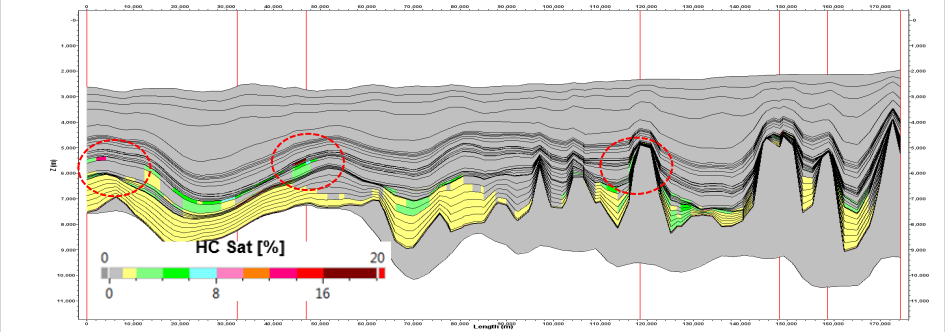
0 20

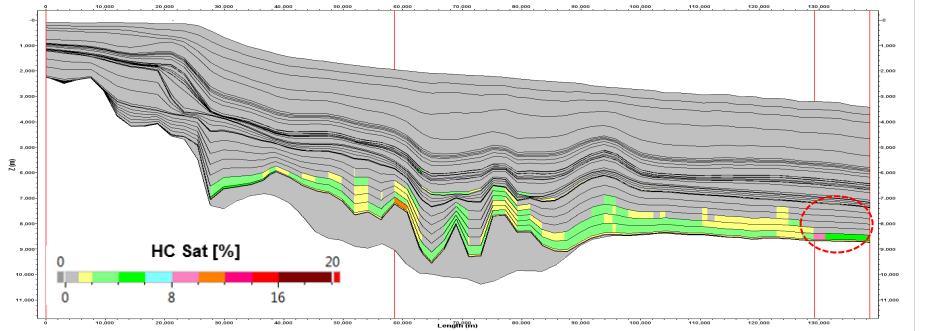
0 8 16

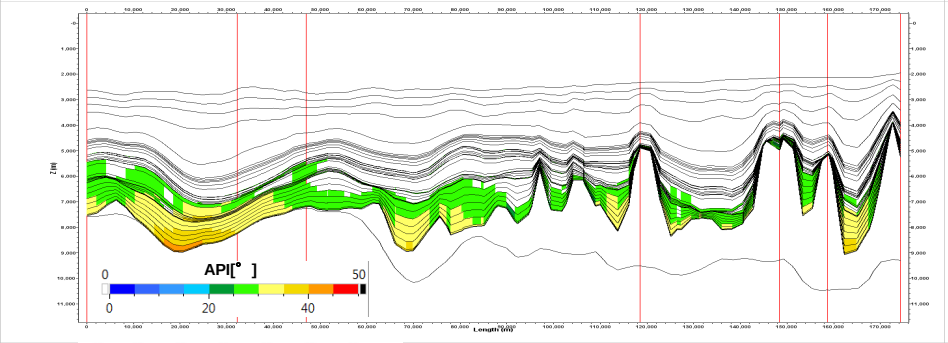
HC Migration Results

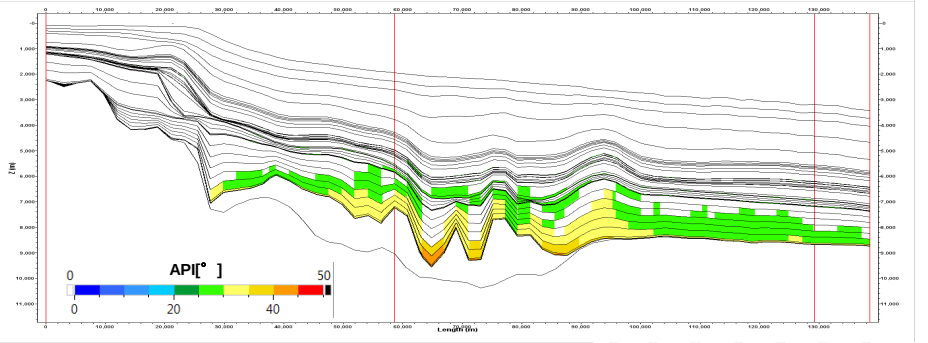


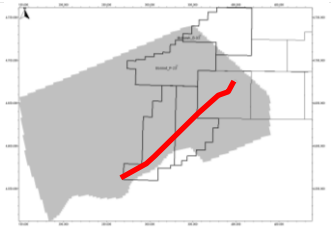




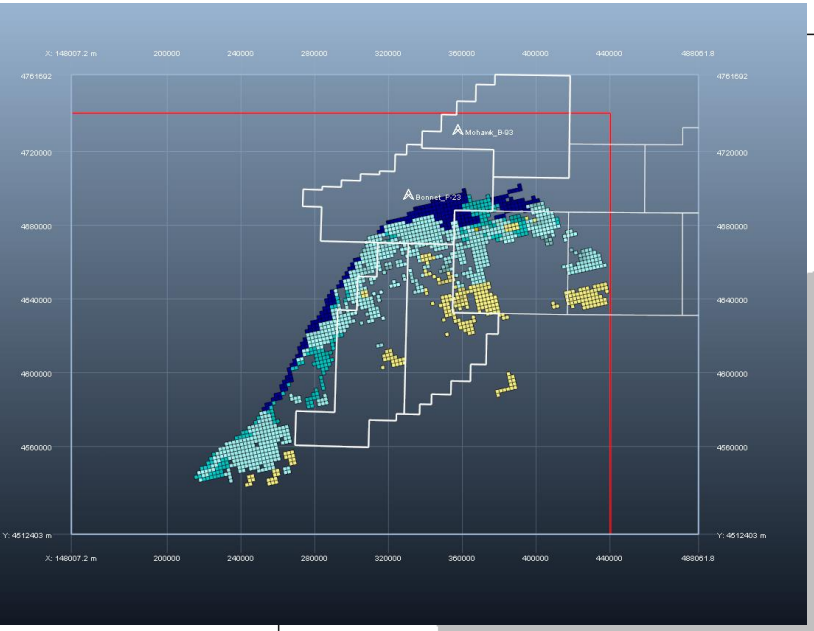








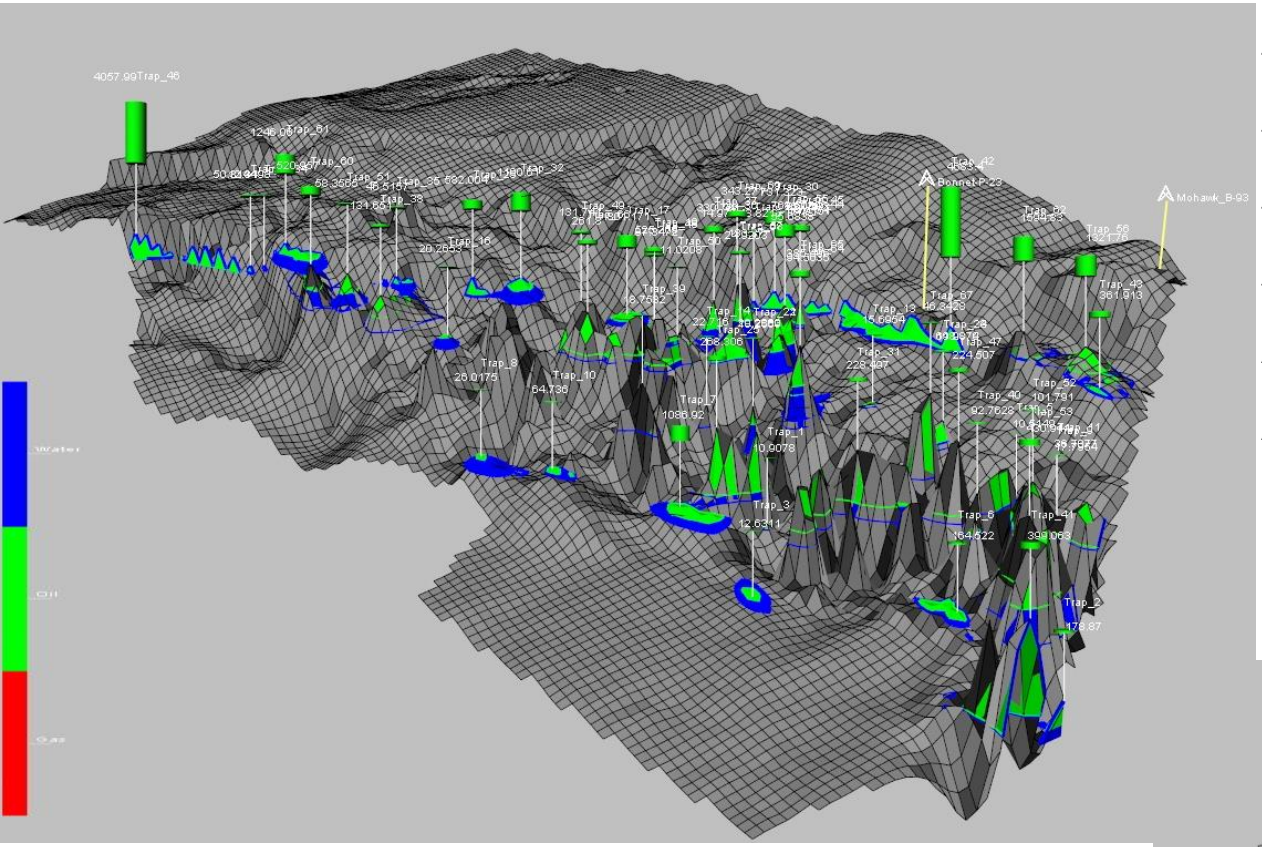
HC Total Volume Lower Jurassic [200 – 163 Ma]

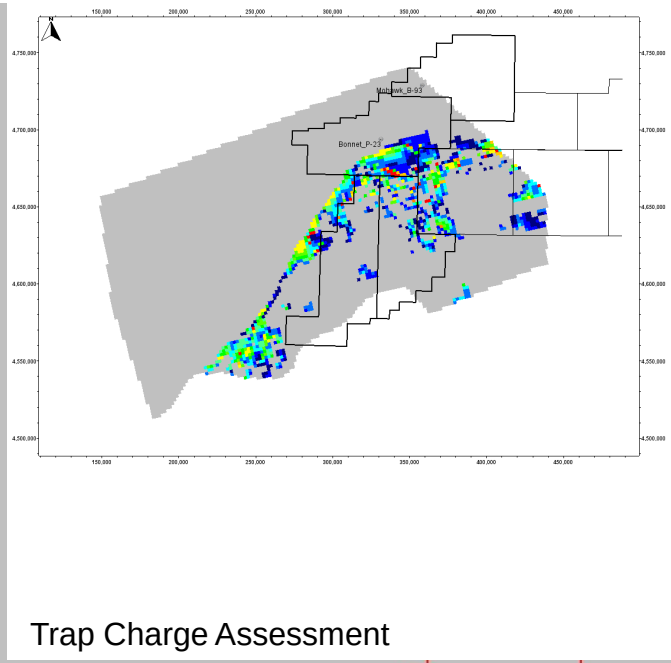


Lower Jurassic Play:
Location: Base of the slope and depth basin
Reservoir: Carbonate Breccia, Reef facies, Detritic carbonate deposits and Sandy turbidites basinward.
HC Source: Lower Jurassic SR
Trap Style: Tilted block, lateral pinch-out against the slope or salt diapirs

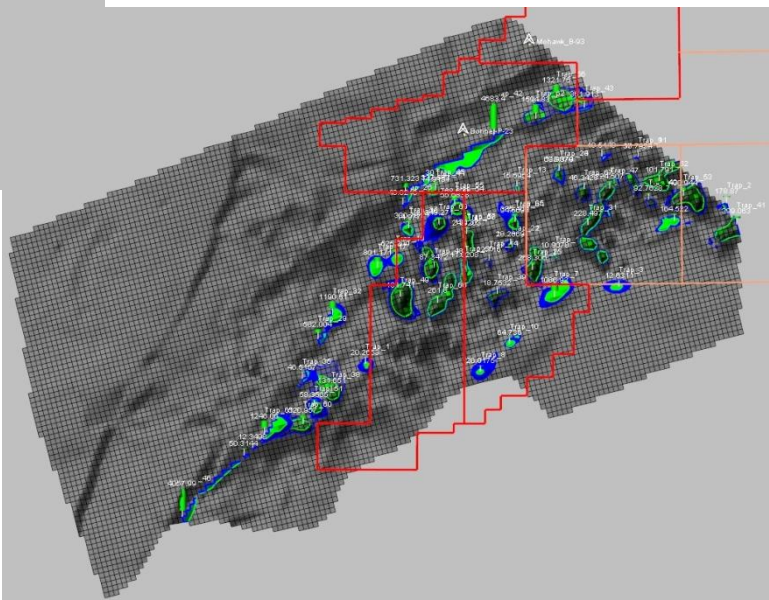
HC Sat Cutoff	Total Volume of Liquid (in place)
>1 %	23 BBL
>5 % ~P10	5.9 BBL
>10 % ~P50	1.3 BBL
>12 % ~P90	0.97

HC Total Volume Lower Jurassic [200 – 163 Ma]





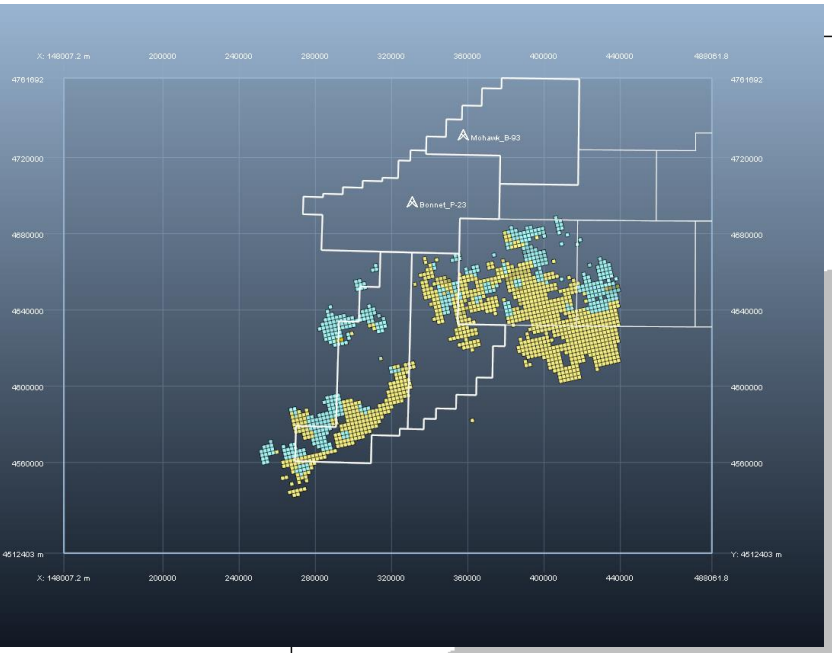
Trap Charge Assessment



HC Accumulations > 10 MMBL

The total volume of HC retained in the interval is projected to the top of the structures.

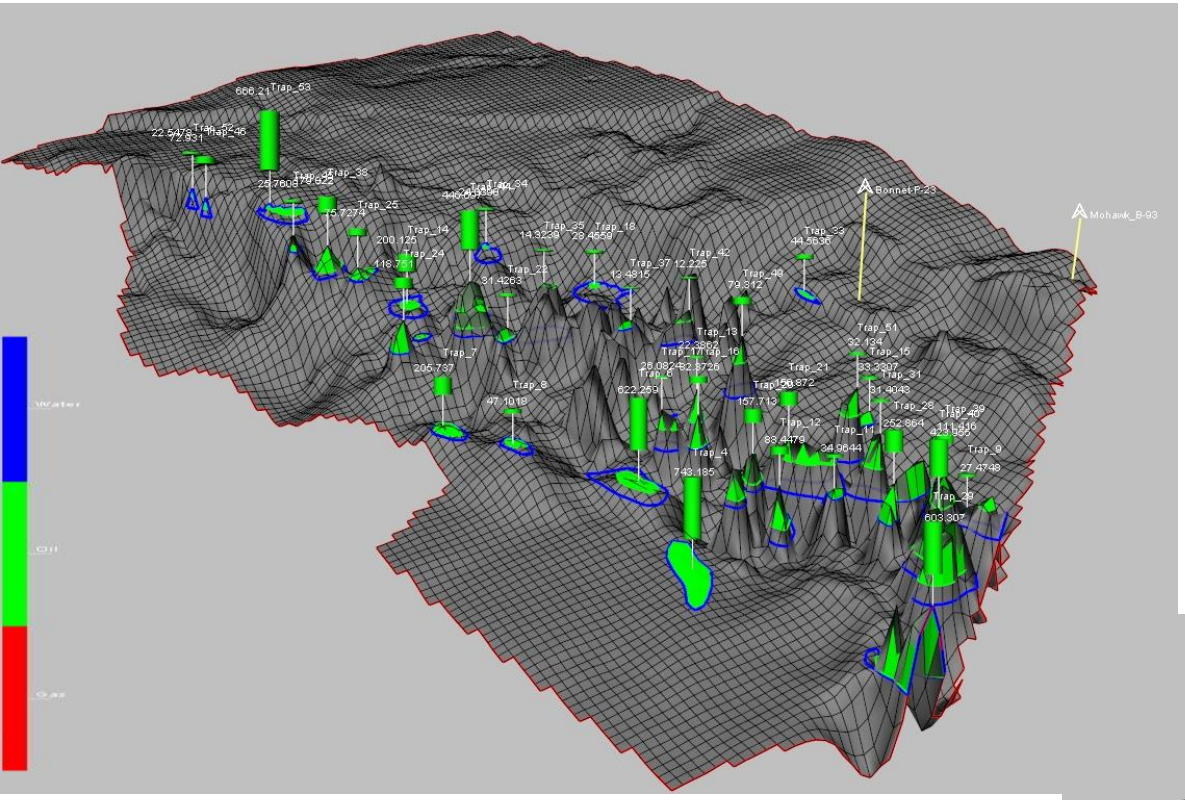
HC Total Volume Upper Jurassic [163 – 150 Ma]

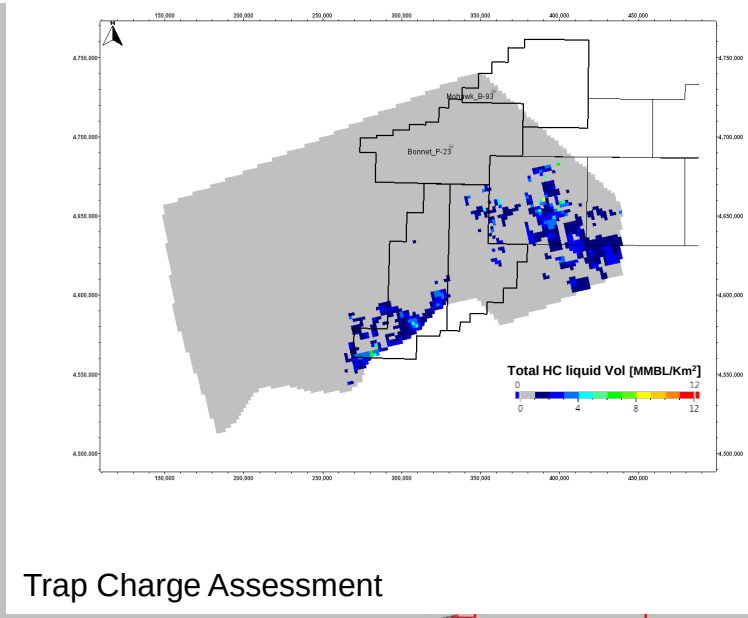


Upper Jurassic Play:
Location: basin
Reservoir: Calciturbidites, detritic carbonates and Sandy turbidites.
HC Source: Lower Jurassic SR; Callovian SR Locally
Trap Style: lateral pinch-out, stratigraphic traps, pinch-out againts salt diapir flanks; doming structures linked to salt deformation.

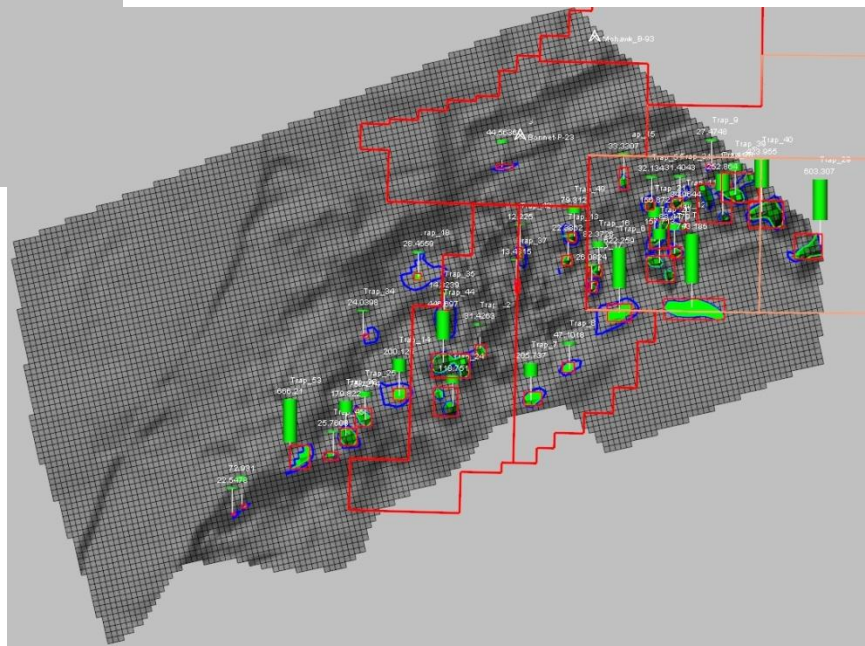
HC Sat Cutoff	Total Volume of Liquid (in place)
>1 %	8.2 BBL
>5 % ~P10	5.2 BBL
>10 % ~P50	4 BBL
>12 % ~P90	3.7 BBL

HC In Traps Upper Jurassic [163 – 150 Ma]





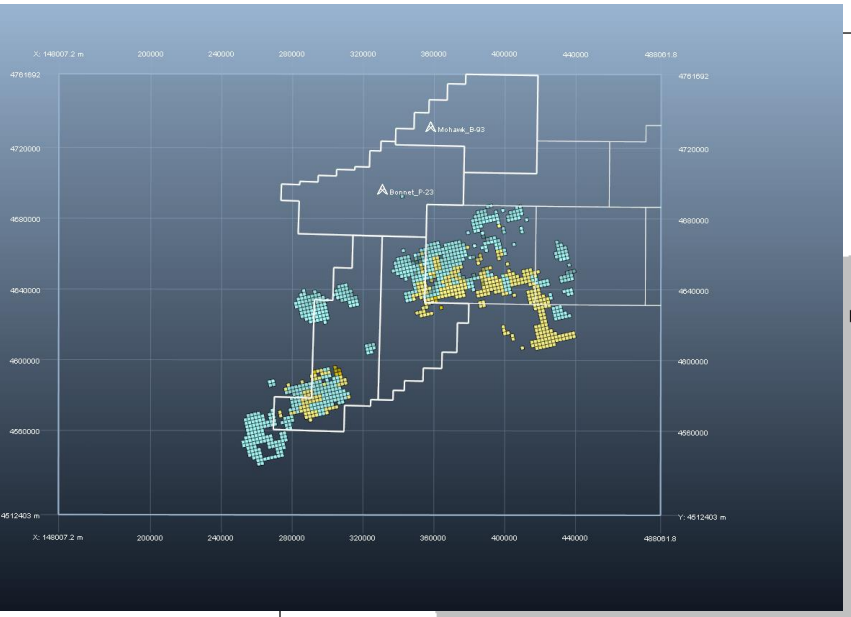
Trap Charge Assessment



HC Accumulations > 10 MMBL

The total volume of HC retained in the interval is projected to the top of the structures.

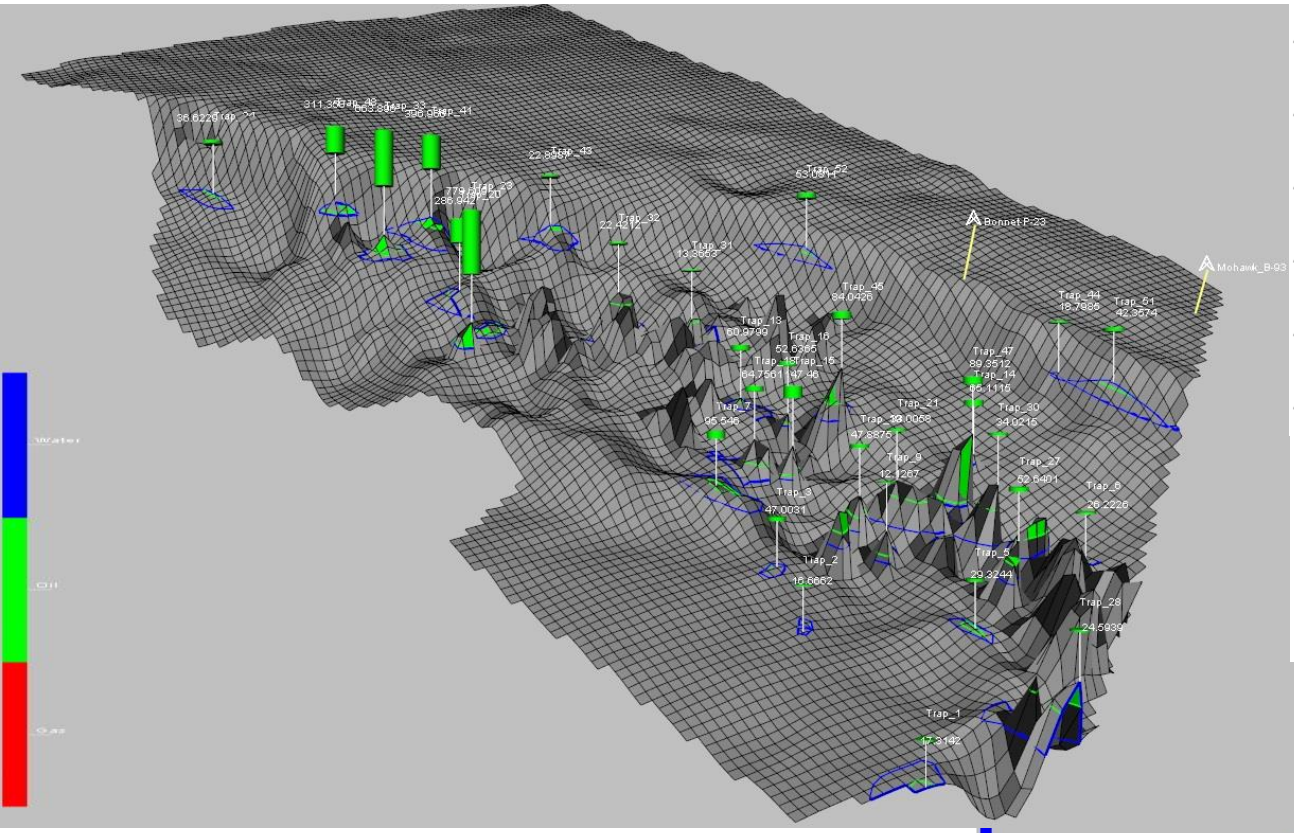
HC Total Volume U.Jurassic / L.Cret [150 – 130 Ma]

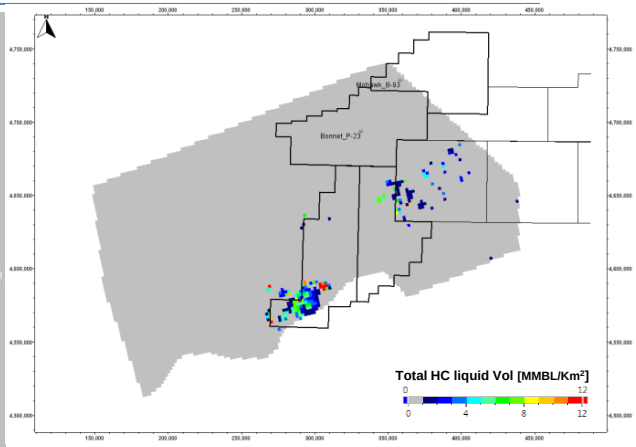


Upper Jurassic / Lower cretaceous Play:
Location: basin
Reservoir: Calciturbidites, detritic carbonates and Sandy turbidites.
HC Source: Lower Jurassic SR; Callovan and Tithonian SR locally
Trap Style: lateral pinch-out against salt diapir flanks; stratigraphic traps, Top of salt diapirs.

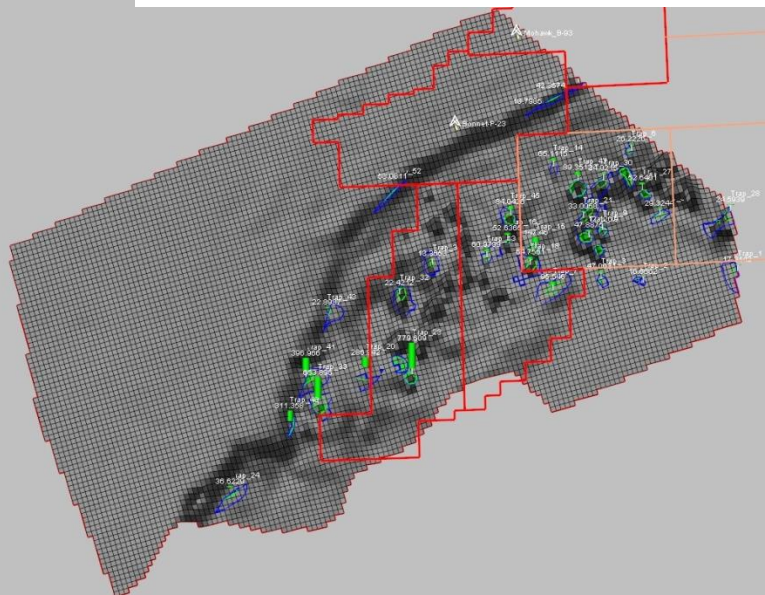
HC Sat Cutoff	Total Volume of Liquid (in place)
>1 %	5 BBL
>5 % ~P10	1.4 BBL
>10 % ~P50	0.9 BBL
>12 % ~P90	0.7 BBL

HC Total Volume U.Jurassic / L.Cret [150 – 130 Ma]





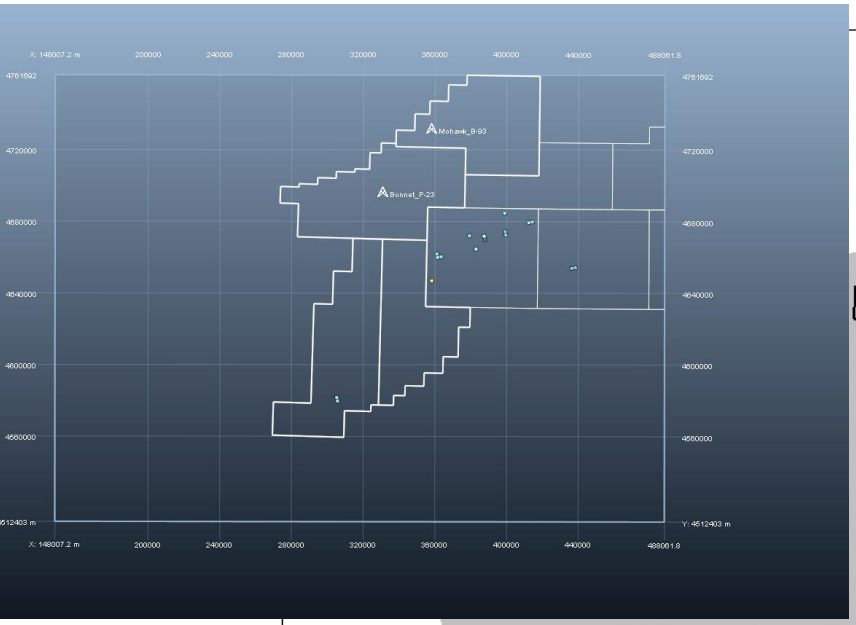
Trap Charge Assessment



HC Accumulations > 10 MMBL

The total volume of HC retained in the interval is projected to the top of the structures.

HC Total Volume Lower Cretaceous [130 – 101 Ma]



Lower cretaceous Play:
Location: basin
Reservoir: Calciturbidites, and Sandy turbidites.
HC Source: Lower Jurassic SR; Callovan and Tithonian SR locally
Trap Style: Top of salt diapirs.

HC Sat Cutoff	Total Volume of Liquid (in place)
>1 %	0.2 BBL
>5 % ~P10	0.15 BBL
>10 % ~P50	0.10 BBL
>12 % ~P90	0.1 BBL

Conclusions

- The SW Nova Scotia Basin exhibit suitable conditions for hydrocarbon generation and preservation at different stratigraphic levels.
- Hydrocarbons generation is almost restricted to a Lower Jurassic source rock (Plienbachian to Toarcian). Younger SR levels will have only a local influence in the HC charge of the Upper Jurassic / Lower Cretaceous intervals.
- Generated hydrocarbons correspond to Oil with a API gravity ranging from 25 to 40 degrees.
- The most prospective area for the **lower Jurassic interval** extends East to West close to the base of the slope. Reservoirs correspond to carbonatic deposits and sandy turbidites basinward.
- The **Upper Jurassic**, **Upper Jurassic / Lower Cretaceous** and **Lower Cretaceous** plays correspond to stratigraphic traps, pinch-out against salt diapirs flanks and doming deformation at the top of salt diapirs. Reservoirs for these plays mainly correspond to calciturbidites and turbidites.
- **Main Risks**: The presence and quality of a lower Jurassic source rock is a major risk in the area as well the quality of reservoirs.

Q & A

Thank you for your attention!