APPENDIX 2
SCOTIAN MARGIN BIOSTRATIGRAPHY

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CHS, Esri, GEBCO, DeLorme, NaturalVue

SYNTHESIS OF POST-PFA BIOSTRATIGRAPHIC STUDIES

A biostratigraphic study of 24 wells across the Scotian Margin produced a well-log sequence stratigraphic framework to calibrate regionally-mappable seismic horizons. This study was published in Weston *et al.* (2012); see white dots in Figure 1 below for well locations. Subsequently, the same biostratigraphy team have reviewed pre-existing biostratigraphic data held within the internal GSC(A) BASIN database and within publications and industry reports, and undertaken new biostratigraphic analyses, from 15 additional wells (see red dots in Figure 1 for well locations). These wells have been chosen to extend the study area to the northeast into the Laurentian Subbasin on the southern Grand Banks of Newfoundland (Weston *et al.*, 2023), to the southwest onto Georges Bank (USA), to the south into the deeper water slope area and targeted specific areas on the Scotian Shelf.

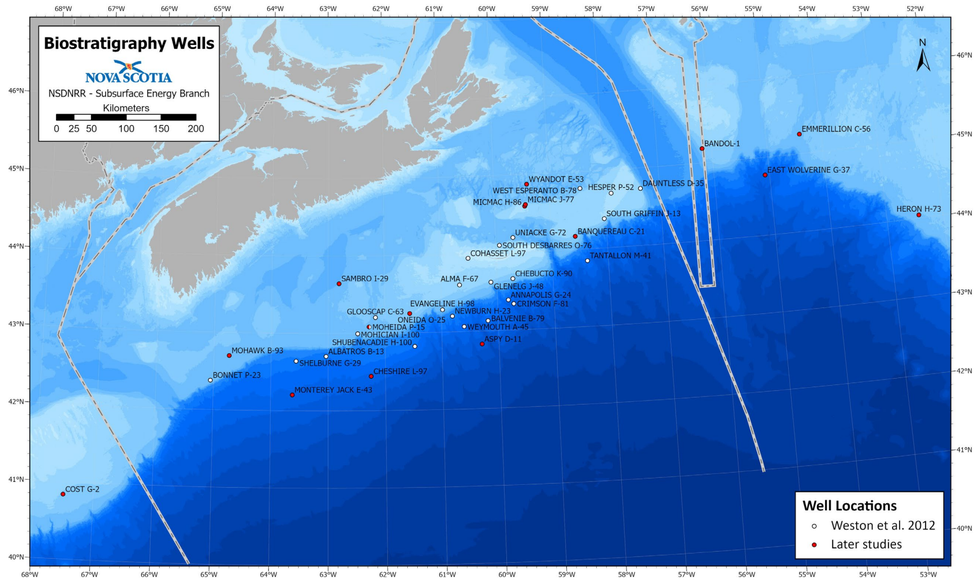


Figure 1: Location of wells studied biostratigraphically. Those from the original PFA published in Weston et al. (2012) are shown as white dots; those studied subsequently are shown as red dots.

Laurentian Subbasin (OERA, 2014)

The wells analyzed from the Laurentian Subbasin are located at the northeastern extremity of the Scotian Basin, where it transitions to the southern Grand Banks of Newfoundland across the Newfoundland Transform Zone. Four wells have been studied from this area: **Bandol-1, East Wolverine G-37, Emerillon C-56** and **Heron H-73**.

The well-log sequence stratigraphic framework established by Weston *et al.* (2012) for the Scotian Margin has been successfully extended into this area and four new regional biostratigraphically-constrained seismically-mappable horizons have been recognized and one surface from Weston *et al.* (2012) has been redefined (Figure 2, column D). These include new surfaces within the early Middle and Early Jurassic (shown preceded by * in Figure 2 and in bold in Figure 3). Weston *et al.* (2012) noted great difficulty in recognizing pre-Bajocian marine biotic indicators on the Scotian Margin and considered that either Lower Jurassic strata in the wells they examined were absent due to erosion, or that marine incursions did not reach far enough landward to influence the well locations studied at that time. On the southern Grand Banks, age diagnostic marine microfossils allow confident identification of Lower Jurassic marine strata in **Emerillon C-56** and **Heron H-73**. The depths of the well-log sequence stratigraphic surfaces recognized in the four wells from the Laurentian Subbasin are given in Figure 3 (in measured depth, MDBRT). The Bathonian/Bajocian MFS of Weston *et al.* (2012) recognized in Cohasset L-97 at 4774m is renamed the Late Bajocian MFS.

A comparison of the lithostratigraphy of the Scotian Margin, as discussed in Weston *et al.* (2012), and of the Laurentian Subbasin on the southern Grand Banks is shown in the Wheeler Diagram in Figure 2 (Weston *et al.*, 2023). This highlights the similarities, but also the differences between the two areas that is due to their differing Mesozoic tectonic histories, particularly the amalgamation of unconformities within the Mesozoic (e.g. the Avalon Unconformity, which at its maximum can extend from the Early Jurassic to the Late Cretaceous).

Five samples from the Lower Jurassic section in **Deep Sea Drilling Project Site 547B** (cores 15-22) on the conjugate Moroccan Margin were also analyzed as a part of this study, as this area would have been adjacent to the Laurentian Subbasin during the rifting and earliest spreading phases of the Central Atlantic Ocean (Weston *et al.*, 2023). The aim was to determine if Lower Jurassic source horizons comparable in age and depositional setting to those from the Moroccan Margin are present on the eastern North American Margin. Possible source rocks provided ages of early Pliensbachian to late Sinemurian at **DSDP Site 547B**, which is older than the lower Toarcian shales and Pliensbachian limestones and shales in **Heron H-73**. The conclusion was that both **DSDP Site 547B** and **Heron H-73** lay in perched basins that may have developed potential hydrocarbon source rocks at different times, due to local structural and tectonic controls (OERA, 2014).

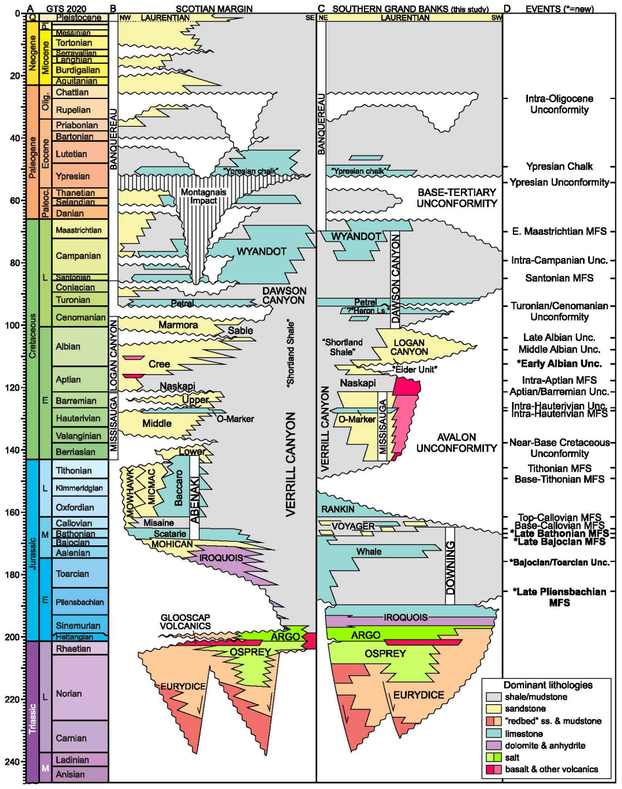


Figure 2: Wheeler Diagram showing lithostratigraphy (B and C) and biostratigraphic events (D) on the Scotian Margin (B) in comparison to the southern Grand Banks area (C) (Weston et al., 2023). Scotian Margin chart is modified from Weston et al. (2012) and Deptuck and Altheim (2018); it does not show post-depositional salt tectonic movement. Grand Banks chart is modified from Sinclair (1988), McAlpine (1990) and MacLean and Wade (1992). Age of volcanic rocks is based on Pe-Piper and Jansa (1987) and Bowman et al. (2012). Timescale (A) is from Gradstein et al. (2020). Two colour shades for 'redbeds' refer to sandstone- and mudstone-dominated lithologies, respectively, and the two shades for volcanic rocks refer to basalts and other types of volcanic rocks, respectively. Formation labels are in upper case, members are lower case. Informal units are in quotation marks. Abbreviations: ls. = limestone; ss. = sandstone; Unc. = unconformity; MFS = maximum flooding surface; Pl. = Pliocene; Olig. = Oligocene; Paleoc. = Paleocene; E. = Early; M. = Middle; L. = Late.

OERA (2014) mapped the top of the dolostones of the Iroquois Formation across the area as the J188 seismic horizon. An age of 188Ma is approximately consistent with an Early Pliensbachian age at the top of the dolostones, as dated by nannofossils in **Heron H-73**. However, the top of the Iroquois Formation as placed by Maclean and Wade (1993) in **Emerillon C-56** is younger, likely Toarcian. We therefore envisage this lithostratigraphic formation top and seismic horizon J188 to be diachronous within the Early Jurassic in the Laurentian Subbasin. On the Scotian Margin, core samples analyzed palynologically from the Iroquois Formation in the **Mohican I-100** well are of Middle Jurassic age, again suggesting the diachroneity of this lithostratigraphic unit.

Event (bold = new)	Bandol-1 (m)	East Wolverine G-37 (m)	Emerillon C-56		Heron H-73	
			(ft)	(m)	(ft)	(m)
Intra-Oligocene Unc. (T29)	1388	3674	2566?	782?	4928?	1502?
Ypresian Chalk	Truncated beneath Unc.	4184	-		5710	1740.4
Ypresian Unc. (T50)	Truncated beneath Unc.	4193	3634?	1107.6?	5792	1765.4
Base-Tertiary Unc. (BTU)	1636	4205	3746	1141.8	-	
Intra-Campanian Unc.	1644	-	4147	1264	6195?	1888.2?
Santonian MFS	1654?	-	4686?	1428.3?	6420?	1956.8?
Turonian/Cenomanian Unc. (K94)	1890	4224	5400	1645.9	7598	2315.9
Late Albian Unc. (K101)	1952	4248	5582?	1701.4?	7778?	2370.7?
Early Albian Unc.	2058?	4359	5858?	1785.5?	-	
Albian/Aptian boundary MFS	2082?	-	-		-	
Intra-Aptian MFS	2287	4484	6438	1962.3	-	
Aptian/Barremian Unc.	2328	4578	6482	1975.7	-	
Intra-Hauterivian MFS (K130)	2516	Truncated beneath Unc.	-		-	
Near-Base Cretaceous Unc./NBCU (K137)	2642	4867?	6847	2087	-	
Avalon Unconformity	-	5149	-		8072	2460.4
Top-Callovian MFS	2669	?Truncated beneath Unc.	?Truncated beneath Unc.		?Truncated beneath Unc.	
Base-Callovian MFS (J163)	2797	5556	7048	2148.2	9070?	2764.5?
Late Bathonian MFS (J166)	-	6611	7762	2365.86	-	
Bajocian/Toarcian Unc. (J170)	-	-	10214?	3113.2?	9998	3047.4
JPl8 SB Haq (2018)	-	-	-		10176?	3101.6?
Late Pliensbachian MFS (J186)	-	-	-		10830	3301
Top Salt	-	-	-		11478	3498.5

Figure 3: Table showing the depths of well-log sequence stratigraphic surfaces of Weston et al. (2012, 2023) within the four wells studied from the Laurentian Subbasin. Surfaces of Weston et al. (2023) defined in wells from the Laurentian Subbasin are shown in bold. Surfaces that have corresponding seismic horizons in the Laurentian PFA (OERA, 2014) show the corresponding seismic horizon in parentheses. Abbreviations: Unc. = unconformity; MFS = maximum flooding surface; JPl8 SB = Jurassic Pliensbachian sequence boundary 8 of Haq (2018).

Biostratigraphic Update

SW Scotian Margin (OERA, 2015)

Following on from the biostratigraphic study published in Weston *et al.* (2012), additional calibration of Mesozoic seismic horizons in the Shelburne Basin in the southwest of the Scotian Shelf was required. A new biostratigraphic study of the **Mohawk B-93** well was undertaken, together with some new biostratigraphic analyses from the Jurassic strata of the **Moheida P-15** well (to update the interpretation in Weston *et al.*, 2012) (see Figure 1 for new well locations; red dots). The resulting biostratigraphically-constrained well-log sequence stratigraphic surfaces were correlated seismically with other wells in the original PFA study (Weston *et al.*, 2012): Bonnet P-23, Glooscap C-63 and Mohican I-100 (see well locations on Figure 1; white dots). A review of pre-existing biostratigraphic data from the **COST G-2** well in the Georges Bank Basin, offshore USA was also carried out to determine if the regional biostratigraphically-calibrated well-log sequence stratigraphic surfaces of Weston *et al.* (2012) could be extended further south along the North American margin. The interpreted positions of the Mesozoic well-log sequence stratigraphic surfaces recognized in these three wells are shown in Figure 4.

Event (Weston *et al.*, 2012; 2023)	Mohawk B-93 (m)	Moheida P-15 (m)	COST G-2 (m)
Turonian/Cenomanian Unc. (K94)	1040	-	?677
Late Albian Unc. (K101)	1324	2047	-
Middle Albian Unc.	-	?2244	-
Albian/Aptian boundary MFS	-	-	-
Intra-Aptian MFS	1335	2348	-
Aptian/Barremian Unc.	1340	2382	-
Intra-Hauterivian MFS (K130)	1404	2437.5	?1267
Near-Base Cretaceous Unc./NBCU (K137)	1635	2629	?1678
Tithonian MFS (J150)	-	2688	1784
Base-Tithonian MFS	1670.5	?2852	-
Top-Callovian MFS	1925	3437	?3104
Base-Callovian MFS (~J163)	?1932	?3584	-
Late Bathonian MFS (J166)	2056.5	-	?3602

Figure 4: Table showing the depths of well-log sequence stratigraphic surfaces of Weston et al. (2012, 2023) within the three additional wells studied from the southwestern Scotian Shelf and Georges Bank (OERA, 2015). Corresponding seismic horizons are shown in parentheses. Abbreviations: Unc. = unconformity; MFS = maximum flooding surface.

This study of **Mohawk B-93** showed that there was major truncation of the Cretaceous section beneath the Late Albian Unconformity (seismic horizon K101) at this location, and that the oldest strata overlying basement in this well are Late Bathonian in age.

Palynological analysis of samples collected from core 3 (top Iroquois Formation) in **Moheida P-15** proved that samples were deposited in a marine environment and were Middle Jurassic in age, no older than Late Bajocian. This supported an interpretation that the top Iroquois Formation is diachronous across the Scotian Margin, as the Iroquois Formation at its type locality in the Iroquois J-17 well is Early Jurassic in age (Barss *et al.*, 1979).

Published biostratigraphic data from the **COST G-2** well showed significant disagreements between the various disciplines and authors. This has led to the recognition of relatively few of the regional well-log sequence stratigraphic surfaces within the Cretaceous part of **COST G-2**. New analyses were undertaken on samples collected from the nine cored intervals within the lower part of this well, which had previously been dated as Late to Middle Jurassic (cores 1-4) and variably Middle to Early Jurassic or Triassic (cores 5-9) (e.g. Amato & Simonis, 1980; Cousminer & Steinkraus, 1988). The new analyses indicate:

- Core 1 (2670-2673m) is Late Jurassic (Tithonian to Kimmeridgian)
- Core 2 (3350.5-3355m) is Middle Jurassic (Callovian to Late Bathonian)
- Core 3 (3607.6-3614.5m) is Middle Jurassic (Late Bathonian to Bathonian)
- Core 4 (4034-4042m) is Middle Jurassic (Bajocian to Middle Aalenian)
- Core 5 (4437-4441.5m) is Middle Jurassic (no older than Middle Aalenian)
- Core 6 (5707m) is Middle to Early Jurassic (no older than late Early Jurassic, Toarcian)
- Cores 7-8 (6264-6488m) are Middle to Early Jurassic, and possibly Hettangian

Figure 5: Dinocyst Pareodinia ceratophora from Core 4 at 4034m

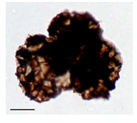


Figure 6: Spherical pollen tetrad from Core 5 (4437m)

A sharp change in palynological assemblage composition and preservation between samples from cores 4 and 5 from **COST G-2** implies an *intra*-Middle Jurassic stratigraphic break between 4042m and 4441.5m, possibly corresponding to the sharp lithofacies change downhole around 4150m at the top of the evaporitic section. A further change in palynofloral composition between cores 6 and 7 (5707m and 6264m) suggests the position of another significant *intra*-Jurassic stratigraphic break, possibly around 6095m.

A single composite core sample from the **Corsair Canyon 975-1** well from the Georges Bank Basin to the northwest of the COST G-2 well was analysed palynologically, from core 1 (at 4311-4314m). This core sample lies beneath halite beds in an interval that had previously been dated as Late Triassic. The halite in Corsair Canyon 975-1 appears from the seismic data to lie within much younger strata than the halites penetrated at the base of the COST G-2 well (below 6655m). Although palynological recovery was poor from core 1 in the Corsair Canyon 975-1 well, marker taxa indicate an age no older than late Early Jurassic (Toarcian), and the palynoflora is similar to those derived from core 6 at around 5700m in COST G-2. This implies that the halite above core 1 in Corsair Canyon 975-1 is probably Middle to late Early Jurassic in age and correlative to a part of the section characterized by dolomitic/anhydritic strata in COST G-2.

Scotian Shelf

New biostratigraphic analyses and re-interpretation studies of pre-existing data from wells on the central and northeastern Scotian Shelf have been undertaken between 2018 and 2022 to provide better stratigraphic calibration for seismic mapping across the Scotian Margin, particularly within the Cretaceous and Middle Jurassic. The wells studied are marked by red dots on Figure 1 and are:

- **Sambro I-29** – 116 new biostratigraphic analyses (Coniacian/Turonian to ?Late Triassic/Indeterminate)
- **Wyandot E-53** – 264 new biostratigraphic analyses and a review of pre-existing data (Campanian to earliest Callovian/Late Bathonian)
- **Banquereau C-21** – review of pre-existing data (Miocene to Early Valanginian/Berriasian)
- **Mic Mac H-86** – review of pre-existing data (Eocene to Callovian/?Middle Jurassic)
- **Mic Mac J-77** – review of pre-existing data (Miocene to Early Callovian)
- **Oneida O-25** – review of pre-existing data (Oligo-Miocene to earliest Callovian/Bathonian)

The regional biostratigraphically-calibrated well-log sequence stratigraphic surfaces recognized within these wells are summarized in Figure 7.

Event (Weston *et al.*, 2012; 2023)	Banquereau C-21 (m)	Mic Mac H-86		Mic Mac J-77		Oneida O-25		Sambro I-29		Wyandot E-53	
		(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)
Intra-Oligocene Unc. (T29)	?734	-	-	?995	?303	?1628	?496	-	-	-	-
Ypresian Unc. (T50)	?1070	?1136	?346	?1484	?452	?2170	?661.5	-	-	-	-
Base-Tertiary Unc. (BTU)	1583	2120	646	2033	620	2415	736	-	-	-	-
Early Maastrichtian MFS	1641.5	-	-	-	-			-	-	-	-
Intra-Campanian Unc.	-	-	-	?2160	?658	?3043	?927.5	-	-	?1110	?338
Santonian MFS	1791.5	-	-	-	-			-	-	-	-
Turonian/Cenomanian Unc. (K94)	1910	3192	973	3100	945	4606	1404	2382	726	2332	711
Late Albian Unc. (K101)	?2458	?4630	?1411	?4837.5	?1474.5	?6675	?2034.5	3180	969	?2920	?890
Middle Albian Unc.	-	-	-	-	-	7205	2196	-	-	?4692	?1430
Albian/Aptian boundary MFS	-	-	-	-	-	7599	2316	-	-	-	-
Intra-Aptian MFS	?3315	?6263	?1909	6319	1926	?8006	?2440	3520	1073	5105	1556
Aptian/Barremian Unc.	?3452.5	?6564.5	?2001	6510	1984	?8100	?2469	3625	1105	5150	1570
Intra-Hauterivian Unc.	?3730	-	-	-	-	?8835	?2693			-	-
Intra-Hauterivian MFS (K130)	?3885	?7256	?2211.5	7104	2165	?8873	?2704.5			?5797	?1767
Near-Base Cretaceous Unc./NBCU (K137)		9650	2941	9525	2903	9467.5	2886			6870	2094
Tithonian MFS (J150)		?Truncated beneath Unc		?Truncated beneath Unc		?9595	?2954.5			?Truncated beneath Unc	
Base-Tithonian MFS		?Truncated beneath Unc		?Truncated beneath Unc		?10506	?3202			?Truncated beneath Unc	
Top-Callovian MFS		-	-			?12135	?3699			7730	2356
Base-Callovian MFS (J163)		14367	4379			12243	3731.5			8139	2481
Late Bathonian MFS (J166)										?8750	?2667

Figure 7: Table showing the depths of well-log sequence stratigraphic surfaces of Weston et al. (2012, 2023) within the six additional wells studied from the central and northeastern Scotian Shelf. Corresponding seismic horizons are shown in parentheses. Abbreviations: Unc. = unconformity; MFS = maximum flooding surface.

Wells from the northeastern Scotian Shelf (**Mic Mac H-86, Mic Mac J-77 and Wyandot E-53**) all show significant erosion of Jurassic strata beneath the Near-Base Cretaceous Unconformity (NBCU), with no Tithonian sediments preserved at the well locations.

As at Mohawk B-93 on the southwestern part of the Scotian Shelf, the oldest marine strata overlying basement at **Wyandot E-53** are Late Bathonian in age.

At **Sambro I-29**, Early Cretaceous (possibly Barremian) strata of the Missisauga Formation unconformably overlie syn-rift red beds of the Eurydice Formation at 4886ft/1489m. No accurately age diagnostic biostratigraphic data are recorded from samples taken in the Eurydice Formation, although rare palynomorphs recovered at 5570-6000ft/1698-1829m suggest a very tentative Early Jurassic to Late Triassic (Early Sinemurian to Late Norian) age.

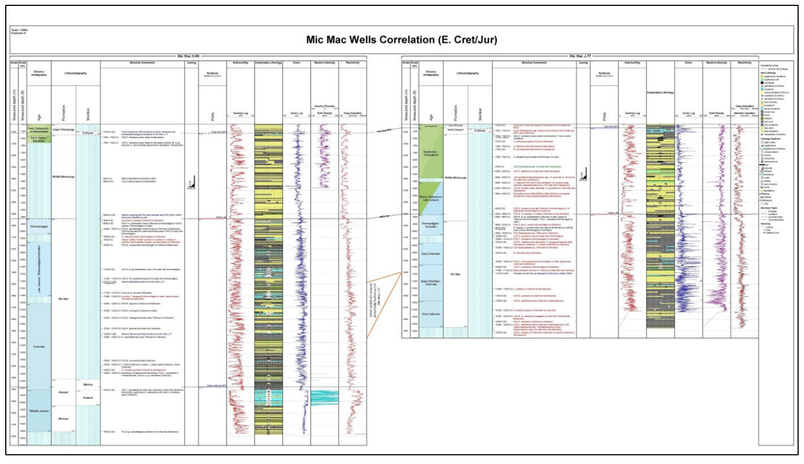


Figure 8: Correlation panel showing Jurassic intervals in Mic Mac H-86 (left) and Mic Mac J-77 (right). Correlation produced in StrataBugs™.

Correlation of the Jurassic intervals in the Mic Mac H-86 and Mic Mac J-77 wells is shown in Figure 8. The **Mic Mac H-86** well reaches TD in Middle Jurassic sediments of the Mohican Formation, probably no older than Bathonian. The overlying Scatarie Member of the Abenaki Formation is capped by earliest Callovian strata containing the Base-Callovian MFS of Weston *et al.* (2012). A thick sequence of Callovian to Kimmeridgian strata is present above this, truncated beneath the Near-Base Cretaceous Unconformity (NBCU).

The **Mic Mac J-77** well penetrates an uplifted, faulted, anticlinal structure above a halite diapir (MacLean and Wade, 1993). It reaches TD within Early Callovian sediments above the level of the Base-Callovian MFS and appears to be cut by a normal fault at 11165ft/3403m within the Early Oxfordian to Late Callovian (see Figure 8).

Biostratigraphic Update

DEEP-WATER WELLS FROM THE SCOTIAN SLOPE (SEE FIGURE 1)

Aspy D-11/D-11A

New biostratigraphic analyses have been undertaken from Aspy D-11/D-11A in 2022 in order to define the age of the strata overlying the salt canopy and to better define the age of the section beneath the salt canopy, allowing recognition of the regional well-log sequence stratigraphic surfaces in the central part of the Scotian Slope.

The post-salt canopy section of Aspy D-11 comprises Miocene to Middle Eocene strata (3695-4120m). Beneath the salt canopy in Aspy D-11A is a thin raft of sediments of possible Tithonian age, potentially transported beneath the salt canopy (6285-6294m). This is underlain by Aptian to Late Hauterivian strata deposited in a bathyal marine setting (6310-7390m), which comprise mainly claystones. Thin, interbedded very fine grade sandstones and siltstones are notable in the Late Aptian, and there are fine to medium grade sandstones around 7110-7130m in the Barremian. Regional biostratigraphically-calibrated well-log sequence stratigraphic surfaces of Weston *et al.* (2012) recognized in Aspy D-11/D-11A are shown in Figure 9.

Event (Weston *et al.*, 2012; 2023)	Aspy D-11/D-11A (m)	Cheshire L-97/L97A	Monterey Jack E-43 /E-43A
Intra-Oligocene Unc. (T29)	?3845	4090.5	4055
Ypresian Unc. (T50)	?4125	4437	4367
Base-Tertiary Unc. (BTU)	Salt Canopy	-	4436/?4435
Early Maastrichtian MFS		-	-
Intra-Campanian Unc.		-	?4587/4558
Santonian MFS		-	-
Turonian/Cenomanian Unc. (K94)		4792	4893/4891
Late Albian Unc. (K101)		5182	5230
Middle Albian Unc.		?5399	-
Albian/Aptian boundary MFS	-	-	-
Intra-Aptian MFS	6921	5540	5548
Aptian/Barremian Unc.	?6982	5567	5646
Intra-Hauterivian Unc.	-	-	-
Intra-Hauterivian MFS (K130)	?7297	?5690	?5765
Near-Base Cretaceous Unc./NBCU (K137)		5815	6191
Tithonian MFS (J150)		?5875	?6271
Base-Tithonian MFS		-	?6352
Top-Callovian MFS		6424	6657
Base-Callovian MFS (J163)		6456	
Late Bathonian MFS (J166)		?6548	
Late Bajocian MFS		6954	

Figure 9: Table showing the depths of well-log sequence stratigraphic surfaces of Weston et al. (2012, 2023) within the deep-water wells studied from Scotian Slope. Surfaces in Monterey Jack E-43 are shown in black, while those in the sidetrack (Monterey Jack E-43A) are shown in red. Corresponding seismic horizons are shown in parentheses. Abbreviations: Unc. = unconformity; MFS = maximum flooding surface.

Cheshire L-97/L-97A

This well lies on the Scotian Slope in the Shelburne Basin, southwest Nova Scotia. A wellsite biostratigraphic study of Cheshire L/97 and the sidetrack well L-97A were undertaken for the operator (Shell Canada Energy) in 2017 by RPS Energy Ltd. Additional biostratigraphic analyses were undertaken for OERA in 2018 from two parts of the Cheshire L-97/L-97A section to better define the age of the Cretaceous strata and the age at TD (7060m); between 5350m and 5690m in Cheshire L-97 and between 6400m and 7060m in Cheshire L-97A. These new analyses enabled definition of Bajocian-aged strata in the lowermost part of Cheshire L-97A and recognition of some of the regional biostratigraphically-constrained well-log sequence stratigraphic surfaces of Weston *et al.* (2012; 2023) (see Figure 9). The micropalaeontological data suggest deposition of the Middle Jurassic section in Cheshire L-97A under open marine, bathyal conditions.

Monterey Jack E-43/E-43A

Monterey Jack E-43/E-43A in the Shelburne Basin lies furthest to the southwest of any of the wells drilled on the Scotian Margin (see Figure 1). A biostratigraphic study of the Monterey Jack E-43 well and the sidetrack well E-43A was undertaken for the operator (Shell Canada Energy) in 2017 by RPS Energy Ltd. Some of the regional biostratigraphically-constrained well-log sequence stratigraphic surfaces were recognized within this original study (as shown in Figure 9). Micropalaeontological assemblages from the Jurassic of Monterey Jack E-43A suggest deposition under predominantly open marine, neritic conditions, with deeper water (probably bathyal) conditions related to major marine transgressions (such as around the Tithonian MFS/J150 seismic horizon and the Base-Tithonian MFS).

CONJUGATE MARGIN OF MOROCCO

A study of pre-existing biostratigraphic data from seven wells along the Moroccan Margin was undertaken in 2018/2019: Amber-1, Cap Juby-1, Cap Sim-1X, FA-1, FD-1, MZ-1 and Tan Tan-1. This was supplemented by new biostratigraphic analyses from the Cap Juby-1 and Tan Tan-1 wells, plus the license of a biostratigraphic data review study of DSDP sites 415A, 416A, 545 and 547B from a part of the SRC Eastern Atlantic Ocean Crust Project (see Figure 10 for well and DSDP Site locations).

The aims of this biostratigraphic study of wells from the Moroccan Margin were:

- Delivery of a consistent and coherent set of biostratigraphically-constrained well-log sequence stratigraphic surfaces correlative to those of Weston *et al.* (2012, 2023) for seismic calibration (see Figure 11)
- Confirmation of the age of the oldest sediments penetrated at each well location (see Figure 11)
- New biostratigraphic analysis of potential source rocks to determine their age and depositional setting
- Analysis of sections of Early Jurassic age, and their comparison with strata from the Laurentian Subbasin.

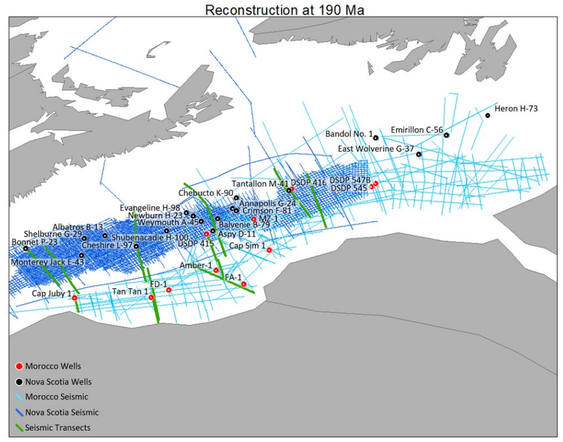
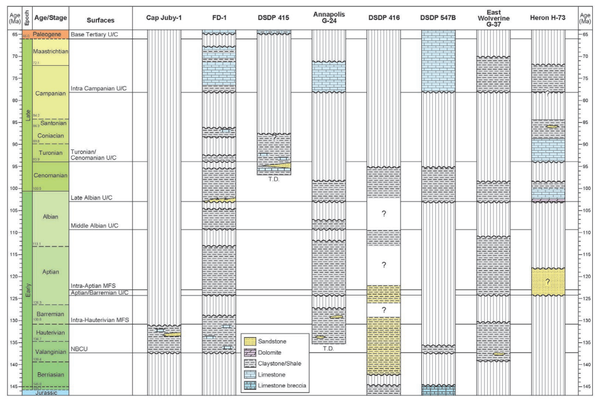
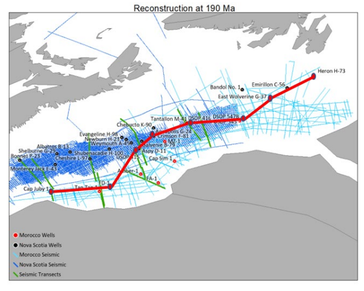


Figure 10: Reconstruction of the Scotian and the conjugate Moroccan margins at 190 Ma (Pliensbachian) showing wells studied from the Scotian Margin (black dots) and from the Moroccan Margin (red dots). Reconstructed seismic transects from the Beicip-Franlab Atlas (2019) are shown in green.

Event (Weston *et al.*, 2012; 2023)	Amber-1	Cap Juby-1	Cap Sim-1X (ft)	Cap Sim-1X (m)	FA-1 (m)	FD-1 (m)	MZ-1 (m)	Tan Tan-1 (ft)	Tan Tan-1 (m)
Intra-Oligocene Unc. (T29)	3644	-	-	-	1776	?2526	-	-	-
Ypresian Unc. (T50)	?4515.5	Amalgamated at 1522	-	-	1865	3023.5	?3012	-	-
Base-Tertiary Unc. (BTU)	?4761		-	-	2002	?3064.5	3108	-	-
Early Maastrichtian MFS	4888	Truncated below Unc.	-	-	-	-	Truncated below Unc.	-	-
Intra-Campanian Unc.	5048		?3820	?1164	2032	3172		-	-
Santonian MFS	-		-	-	-	-		-	-
Turonian/Cenomanian Unc. (K94)	5230		?4899	?1493	?2077	3195		-	-
Late Albian Unc. (K101)			?9890	?3014.5	2861	3328	3620	-	-
Middle Albian Unc.					-	?3464.5	3766.5	?2073	?632
Intra-Aptian MFS					3211.5	3637.5	3961	?2254	?687
Aptian/Barremian Unc.					3284	?3690	4002	?2299	?700.5
Intra-Hauterivian Unc.						-	-	3393	1034
Intra-Hauterivian MFS (K130)						3798	4015	3433	1046.5
Near-Base Cretaceous Unc./NBCU (K137)		2067.5				4644	4862	6000	1828.8
Tithonian MFS (J150)		?2078				4771.5	Truncated below Unc.	?Truncated below Unc.	
Base-Tithonian MFS		-				5066	4718.5	7350	2240.5
Top-Callovian MFS		-					?5051.5	9128	2782
Base-Callovian MFS (J163)		3536					5194	9694	2954.5
Late Bathonian MFS (J166)		?3610					-	?10655	?3247.5
Late Bajocian MFS		-					5321	-	-
Bajocian/Toarcian Unc. (J170)		?3874					?5400	?14850	?4526
Pl8 SB of Haq (2018)							?5584.5		
Late Pliensbachian MFS (J186)		-					5595	-	-
Age at TD	Cenomanian to latest Albian, ?Cenomanian	?Sinemurian	latest Albian overlying Late Triassic (salt diapir)		?Early Barremian overlying salt diapir	?Kimmeridgian	?Sinemurian	?Pliensbachian/Sinemurian	

Figure 11: Table showing the depths of well-log sequence stratigraphic surfaces of Weston et al. (2012, 2023) within the wells studied from the Moroccan Margin. Corresponding seismic horizons are shown in parentheses. The table also shows the age of the oldest sediments penetrated at each well location. Abbreviations: Unc. = unconformity; MFS = maximum flooding surface.





A Cretaceous chronostratigraphic chart from Scotian and Moroccan wells along a transect through the reconstructed margin shows correlation of major unconformity surfaces on both margins (Figure 12).

Figure 12: Chronostratigraphic Chart of Cretaceous strata in wells studied across the Scotian-Moroccan conjugate margins. Well locations shown above, with red line indicating locations on the reconstruction of the margins at 190 Ma (Pliensbachian). Timescale of Chronostratigraphic Chart: Ogg, Ogg & Gradstein (2016).

JURASSIC OF THE CONJUGATE MARGIN

EARLY JURASSIC

Strata at the TD of both MZ-1 and Cap Juby-1 ST4 had previously been dated as earliest Jurassic/latest Triassic and Triassic, respectively. The TD of MZ-1 is now shown to be Early Sinemurian and that of Cap Juby-1 ST4 to be no older than Late Hettangian and probably Sinemurian. Above TD, there are dark grey/black shales/marls of Sinemurian age (possible source facies) in both wells.

MZ-1

The TD of MZ-1 is within dolomitic facies that yield nannofossils suggestive of an Early Sinemurian age (Figure 13). These are overlain by thin dark grey/back marls of definite Early Sinemurian age that yield a pungent smell when placed in HCL and may represent possible source rocks (although TOC values recovered were relatively low) (Beicip-Franlab, 2019). The depositional setting of these dark grey/black claystones is low energy sublittoral marine shelf.

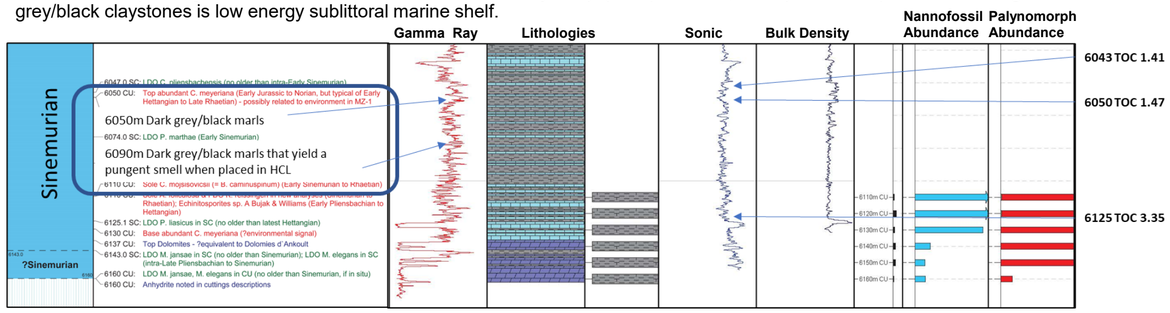


Figure 13: Snapshot of the MZ-1 Stratigraphic Summary Log showing the deepest part of the well above TD at 6160m. Note the thin dark/grey/black marls (?source facies) at 6050m and 6090m in strata dated as Early Sinemurian.

Cap Juby-1 ST4

The TD of Cap Juby-1 ST4 is within halite that was not analyzed for biostratigraphy. However, greyish red to reddish siltstones overlying the halite yield palynofloras suggestive of a Sinemurian age (see Figure 14), while there are black siltstones within the Pliensbachian to Sinemurian interval at 4350-4360m. The depositional setting of the Sinemurian strata is marginal marine, ?coastal plain.

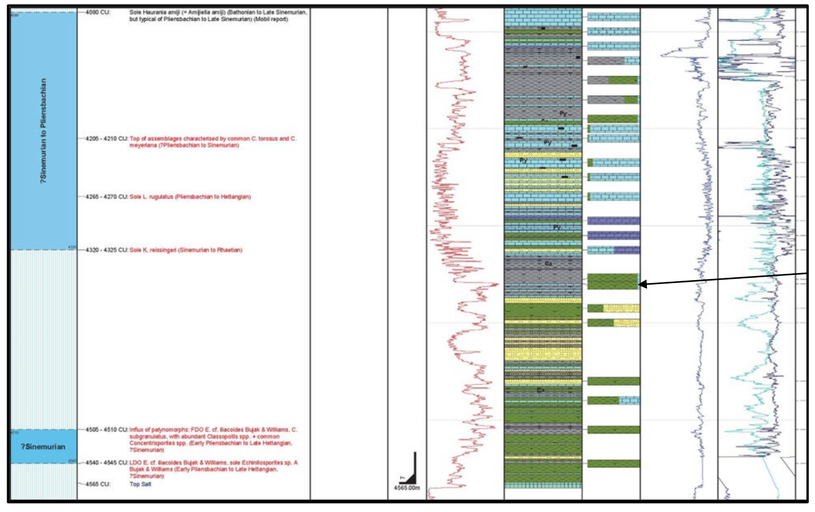


Figure 14: Snapshot of the Cap Juby-1 ST4 Stratigraphic Summary Log showing age determinations and the position of black siltstones (?source facies).

A significant well-constrained unconformity between Bajocian and Early Toarcian strata was defined in Heron H-73 from the southern Grand Banks of Newfoundland in the Laurentian Subbasin Study. Another potential hiatus/unconformity was recognized at the Toarcian/ Pliensbachian boundary in this well, which is attributed to the Pl8 SB of Haq (2018), while a maximum flooding surface was also defined within the Late Pliensbachian (the Late Pliensbachian MFS) (Weston *et al.*, 2023; see Figure 15). These surfaces are tentatively correlated into the MZ-1 and Cap Juby-1 ST4 wells from the Moroccan Margin in Figure 15, and the main unconformities recognised in the Jurassic in wells from the Scotian and Moroccan margins are highlighted on the Jurassic Chronostratigraphic Chart (Figure 16). The Pl8 SB may also define the sharp change in depositional conditions between cores 14 and 15 of DSDP Site 547B (see Figure 16; Pl8 SB of Haq is labelled ?Toarcian/Pliens. U/C).

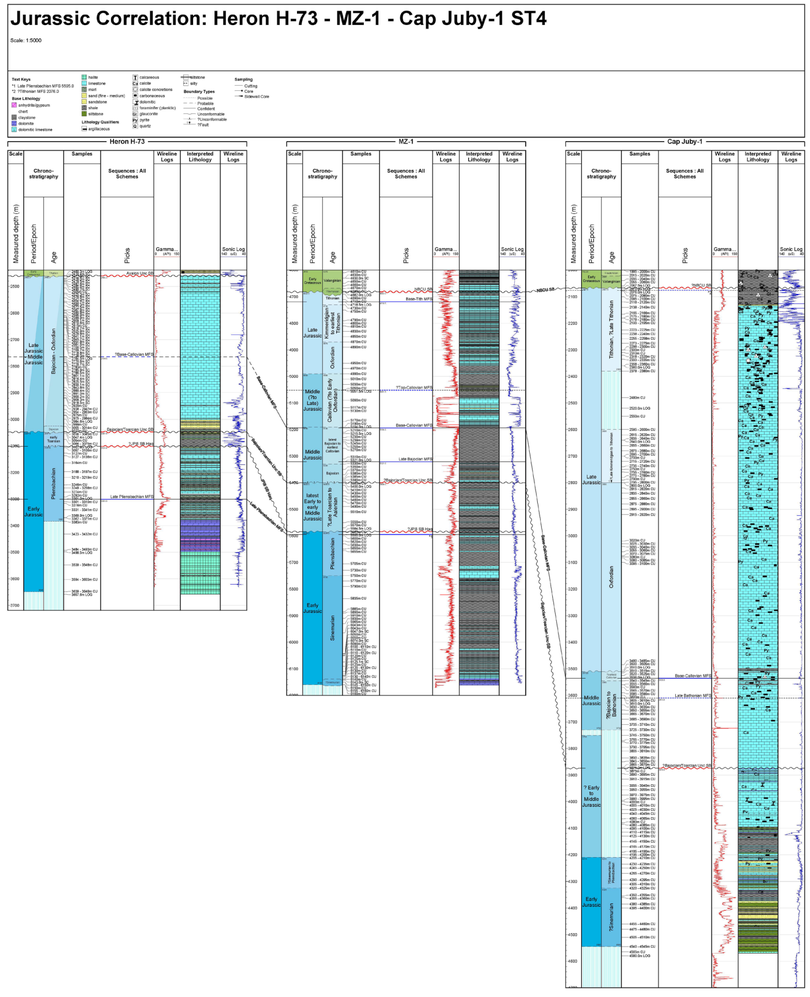
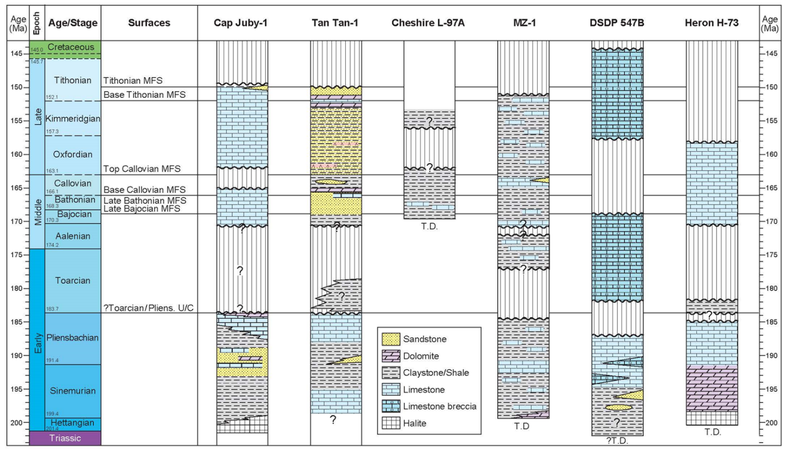


Figure 15: Correlation of Jurassic strata in Heron H-73 from the southern Grand Banks of Newfoundland with the MZ-1 and Cap Juby-1 ST4 wells from the Moroccan Margin. Correlation lines are well-log sequence stratigraphic surfaces as defined in Weston et al. (2012, 2023). Correlation produced in StrataBugs™.



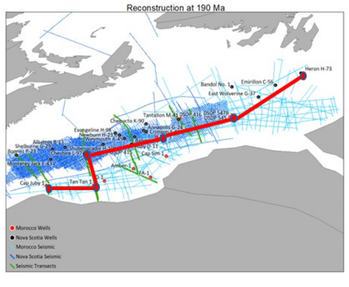


Figure 16: Chronostratigraphic Chart of Jurassic strata in wells studied across the Scotian-Moroccan conjugate margins. Well locations shown above, with red line indicating locations on the reconstruction of the margins at 190 Ma (Pliensbachian). Timescale of Chronostratigraphic Chart: Ogg, Ogg & Gradstein (2016).

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