How to Log Core (With Examples from the Williston Basin of Southeast Saskatchewan)

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In the past couple of decades, geologists have become increasingly inclined to depend on geophysical well logs for their subsurface information, consequently core examination techniques are becoming a lost art. In fact, many geologists become uncomfortable when confronted with the possibility of having to look at cores, and core studies are being assigned more and more to a rapidly diminishing group of core-orientated consulting geologists.

This presentation is intended to demonstrate the importance of the information obtained from cores as well as outlining a systematic procedure to follow in core examination. Some of the points made will be specific to carbonate rocks, but others are more general. Core examination can be systematically divided into three phases, preparation, description and interpretation. An important aspect of preparation is becoming familiar with the pitfalls of core layout, for example misplaced cored intervals or improper order of core box layout. In the matter of description, emphasis will be on getting the most important information from cores in order to make acceptable interpretations of facies, facies controls on reservoir characteristics and diagenesis. To make acceptable interpretations of the information from carbonate cores the examiner should have a working understanding of the origins of carbonate rock components. These will be discussed and demonstrated through the cores laid out for this presentation. Three dimensional facies relationships determined from core studies can resolve lithostratigraphic problems created using merely geophysical log correlations.

Lithostratigraphy (the concept of correlating similar lithologies or “log tops”) is now obsolete. The major shortfall of Lithostratigraphy is that we cross time lines in correlation. Most stratigraphic traps involve a shoreline or barrier to stop the migration of hydrocarbons. Seismic appears to reflect off identical facies rather than time.

Using a simple modeling technique involving Walther’s Law, we can arrive at a first approximation of facies relationships in three dimensions. Walther’s Law states that facies are stacked vertically in the same manner that they are arranged laterally. If we “dissect” the vertical succession in the core boxes, we can predict what is occurring laterally. Computer modeling makes this idea of facies modeling easier to accomplish because of the cross-section and fence diagram capabilities for the third dimension. We must correlate the section to see the changes in facies in multiple well studies. The correlations must be accomplished during the description of each core rather than trying to correlate afterwards. The Red River core shows marine regression with salina evaporate overstepping the inner barrier facies. Moving the successive packages in a basinward direction explains the vertical stratigraphy that we see in one dimension (core). The salinas become progressively more Mg-rich with precipitation of anhydrite. The regression liberates these fluids to dolomitize everything in their way (inner barrier and very restricted lagoon). The volume of Mg-rich fluid is related to the volume of the salina. Papers by Harvey, Kent and Qing (2004) and Jones and Xiao, (2005) further detail how this mechanism works (not to be confused with reflux dolomitization, since the fluids only dolomitize their contemporaneously stratigraphic equivalents.

The Midale Beds core shows shoaling cycles in which wave energy on the shelf has winnowed the fines to create a calcareous algal grainstone with excellent reservoir properties. This shoaling reservoir should be exploited using horizontal wells along the linear shoal features.

The three examples of facies modelling based on cores from the Ordovician Red River (1-33-14-12W2M Chapleau Lake), Mississippian Midale Beds (7-7-7-11W2M Weyburn).of southeast Saskatchewan as well as two cores from the South Heward Pool. Despite their age difference, the first two cores show similar responses to sea level in terms of facies relationships. Both are created in response to marine regressions in which the Williston Basin was shrinking with time.

The key concepts include the extremely shallow nature of the carbonate platform and development of multiple barriers (Lake, 2007) (hence the tendency to exposure of inner and outer barrier and resulting tendency to karsting of these features during sea level drops). James and Bourque (1992) outline the principal bioligical components of the outer barrier/reef environment through time. The end of Devonian mass extinction of colonial corals makes it difficult to recognize the outer barrier during Mississippian sedimentation.

It is critical to realize that the individual facies in the sedimentary record do not span the entire basin, but were deposited contemporaneously with all the other facies present. You will have great difficulty in discovering new strat traps if you ignore this concept. High resolution satellite imagery of the modern Exuma Platform (Harris, 2010) shows that water depth is critical for winnowing and wave movement of sediment as well as facies distribution of the shoaling events. There must be a critical depth for wave activity to winnow the shoals which cross the platform. An ancient example of shoaling is observed in the 7-7-7-11W2M Midale core. The core contains both in situ calcareous algae facies wackestone non-reservoir which grades to algal grainstone reservoir. Mapping the trend of the shoaling features makes it easier to horizontally exploit the hydrocarbon potential of this high perm rock. The rock record indicates that oolites, calcareous algae and crinoids were all capable of winnowing and transport as shoal facies.

References

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James, N.P., and Bourque, P.A., 1992, Reefs and Mounds; in Facies Models: Response to Sea Level Change in R.G.Walker and N.P James (eds) Geol. Assoc. Canada, pp323-347.

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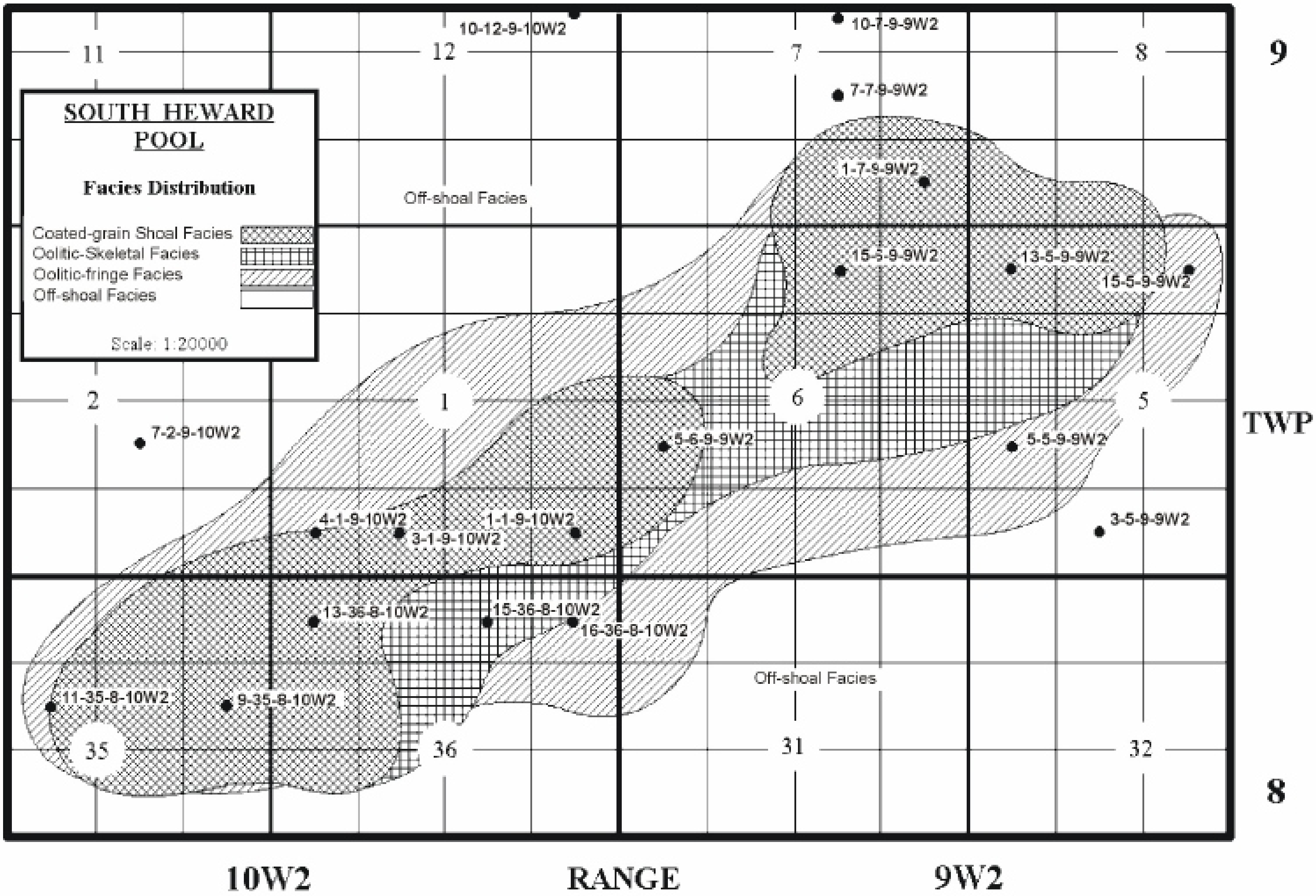


Figure 4 - Map showing facies distribution in the lower Frobisher Beds of the South Heward Pool.

Facies Map of lower Frobisher Beds of South Heward Pool (Kent and Curry, 2002).

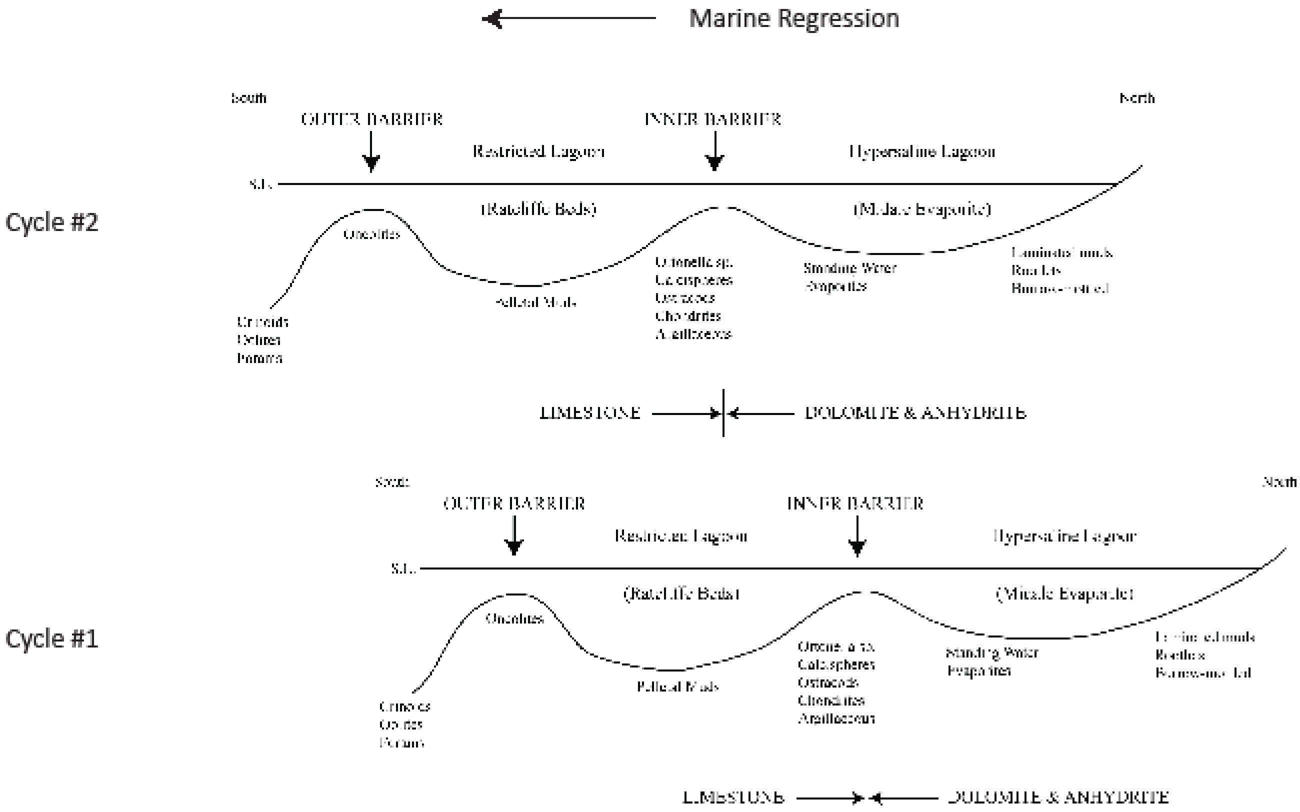
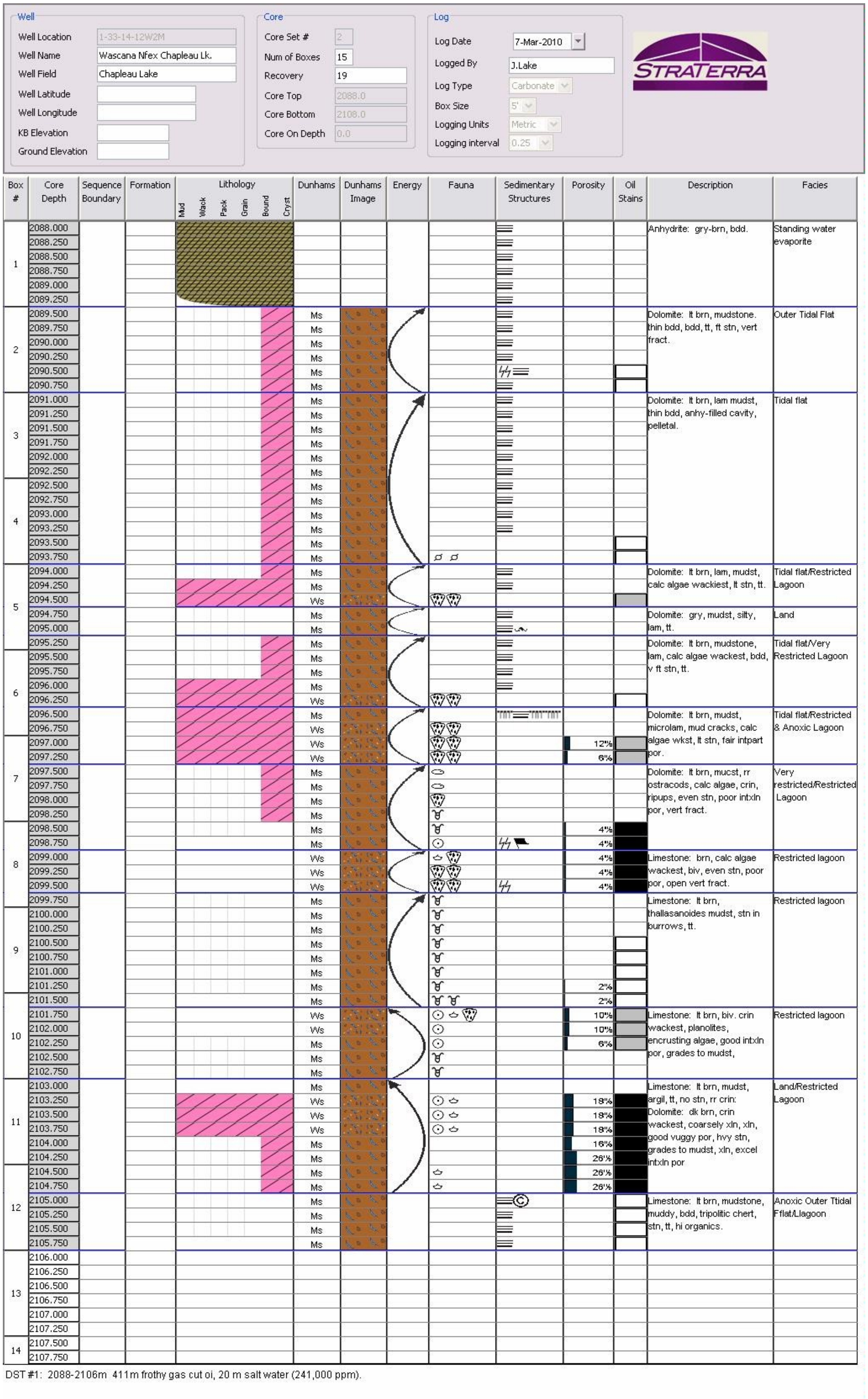


Diagram to illustrate the relationship of facies changes in a vertical sense in a marine regression. "Dissecting" the vertical succession in any core will give you the lateral facies picture. Note how easy it is to make the mistake of joining similar lithologies (lithostratigraphy).

Modified after Lake, 2007.



Well
Well Location: 1-33-14-12W2M
Well Name: Wascana Nfex Chapleau Lk.
Well Field: Chapleau Lake
Well Latitude:
Well Longitude:
KB Elevation:
Ground Elevation:

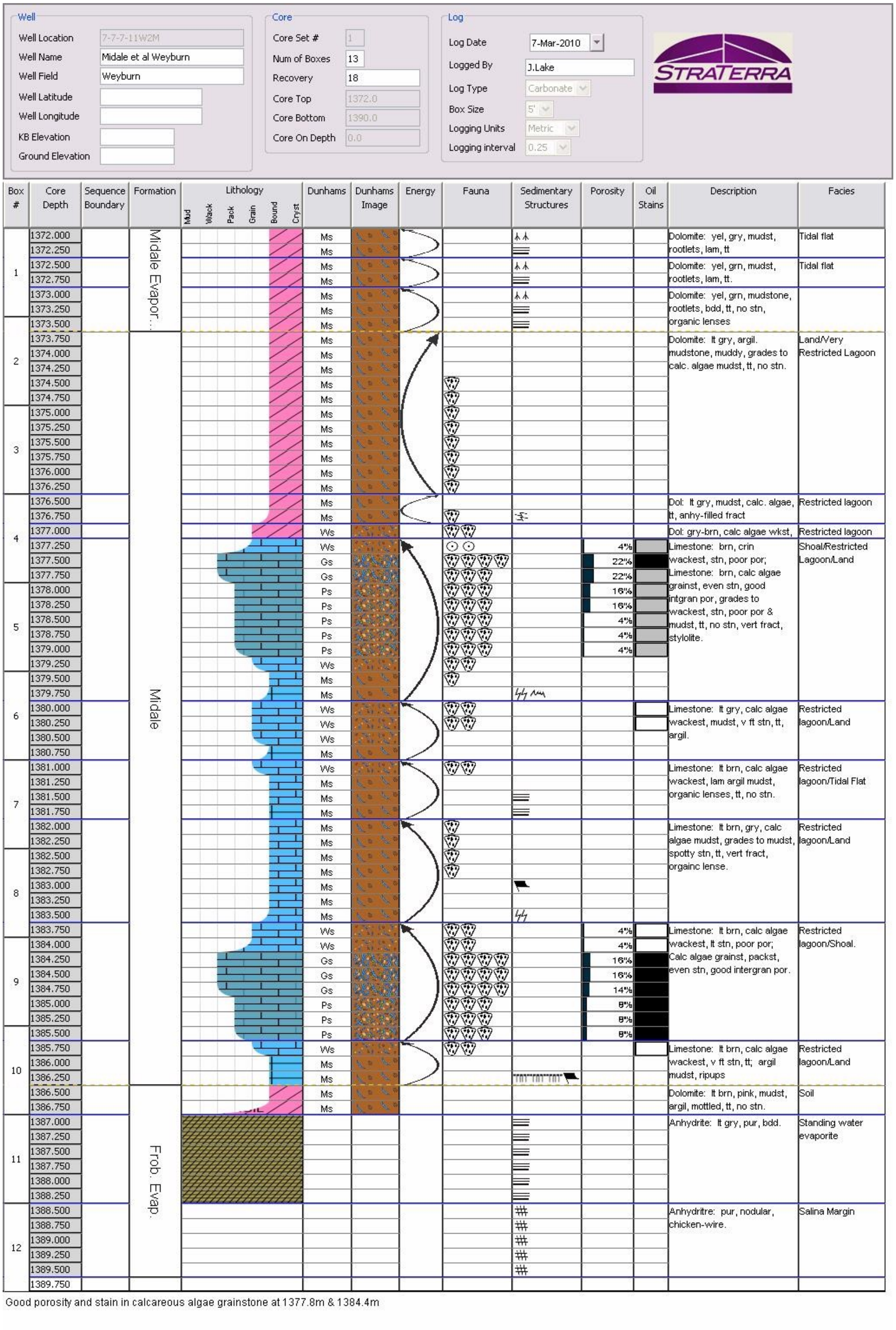
Core
Core Set #: 2
Num of Boxes: 15
Recovery: 19
Core Top: 2088.0
Core Bottom: 2108.0
Core On Depth: 0.0

Log
Log Date: 7-Mar-2010
Logged By: J.Lake
Log Type: Carbonate
Box Size: 5'
Logging Units: Metric
Logging interval: 0.25

Box #	Core Depth	Sequence Boundary	Formation	Lithology Mud Wack Pack Grain Bound Cryst	Dunhams	Dunhams Image	Energy	Fauna	Sedimentary Structures	Porosity	Oil Stains	Description	Facies
1	2088.000											Anhydrite: gry-brn, bdd.	Standing water evaporite
	2088.250												
	2088.500												
	2088.750												
	2089.000												
	2089.250												
2	2089.500				Ms							Dolomite: lt brn, mudstone. thin bdd, bdd, tt, ft stn, vert fract.	Outer Tidal Flat
	2089.750				Ms								
	2090.000				Ms								
	2090.250				Ms								
	2090.500				Ms								
	2090.750				Ms								
3	2091.000				Ms							Dolomite: lt brn, lam mudst, thin bdd, anhy-filled cavity, pelletal.	Tidal flat
	2091.250				Ms								
	2091.500				Ms								
	2091.750				Ms								
	2092.000				Ms								
	2092.250				Ms								
4	2092.500				Ms								
	2092.750				Ms								
	2093.000				Ms								
	2093.250				Ms								
	2093.500				Ms								
	2093.750				Ms								
5	2094.000				Ms							Dolomite: lt brn, lam, mudst, calc algae wackiest, lt stn, tt.	Tidal flat/Restricted Lagoon
	2094.250				Ms								
	2094.500				Ws								
	2094.750				Ms							Dolomite: gry, mudst, silty, lam, tt.	Land
	2095.000				Ms								
6	2095.250				Ms							Dolomite: lt brn, mudstone, lam, calc algae wackest, bdd, v ft stn, tt.	Tidal flat/Very Restricted Lagoon
	2095.500				Ms								
	2095.750				Ms								
	2096.000				Ms								
	2096.250				Ws								
	2096.500				Ms							Dolomite: lt brn, mudst, microlam, mud cracks, calc algae wkst, lt stn, fair intpart por.	Tidal flat/Restricted & Anoxic Lagoon
	2096.750				Ws								
7	2097.000				Ws					12%			
	2097.250				Ws					6%			
	2097.500				Ms							Dolomite: lt brn, mucst, rr ostracods, calc algae, crin, ripups, even stn, poor intxln por, vert fract.	Very restricted/Restricted Lagoon
	2097.750				Ms								
	2098.000				Ms								
	2098.250				Ms								
8	2098.500				Ms					4%			
	2098.750				Ms					4%			
	2099.000				Ws					4%		Limestone: brn, calc algae wackest, biv, even stn, poor por, open vert fract.	Restricted lagoon
	2099.250				Ws					4%			
	2099.500				Ws					4%			
	2099.750				Ms							Limestone: lt brn, thallasanoides mudst, stn in burrows, tt.	Restricted lagoon
9	2100.000				Ms								
	2100.250				Ms								
	2100.500				Ms								
	2100.750				Ms								
	2101.000				Ms								
	2101.250				Ms					2%			
10	2101.500				Ms					2%			
	2101.750				Ws					10%		Limestone: lt brn, biv. crin wackest, planolites, encrusting algae, good intxln por, grades to mudst,	Restricted lagoon
	2102.000				Ws					10%			
	2102.250				Ms					6%			
	2102.500				Ms								
	2102.750				Ms								
11	2103.000				Ms							Limestone: lt brn, mudst, argil, tt, no stn, rr crin: Dolomite: dk brn, crin wackest, coarsely xln, xln, good vuggy por, hvy stn, grades to mudst, xln, excel intxln por	Land/Restricted Lagoon
	2103.250				Ws					18%			
	2103.500				Ws					18%			
	2103.750				Ws					18%			
	2104.000				Ms					16%			
	2104.250				Ms					26%			
12	2104.500				Ms					26%			
	2104.750				Ms					26%			
	2105.000				Ms							Limestone: lt brn, mudstone, muddy, bdd, tripolitic chert, stn, tt, hi organics.	Anoxic Outer Ttidal Fflat/Llagoon
	2105.250				Ms								
	2105.500				Ms								
	2105.750				Ms								
13	2106.000												
	2106.250												
	2106.500												
	2106.750												
	2107.000												
	2107.250												
14	2107.500												
	2107.750												

DST #1: 2088-2106m 411m frothy gas cut oi, 20 m salt water (241,000 ppm).

Core Description and photos for the 1-33-14-12W2M Chapleau Lake (Red River Formation). The sequence represents a marine regression which can be "dissected" to apply Walther's Law and interpret facies in a two dimensional model.



Well

Well Location	7-7-7-11W2M
Well Name	Midale et al Weyburn
Well Field	Weyburn
Well Latitude	
Well Longitude	
KB Elevation	
Ground Elevation	

Core

Core Set #	1
Num of Boxes	13
Recovery	18
Core Top	1372.0
Core Bottom	1390.0
Core On Depth	0.0

Log

Log Date	7-Mar-2010
Logged By	J.Lake
Log Type	Carbonate
Box Size	5'
Logging Units	Metric
Logging interval	0.25

Box #	Core Depth	Sequence Boundary	Formation	Lithology (Mud Wack Pack Grain Bound Cryst)	Dunhams	Dunhams Image	Energy	Fauna	Sedimentary Structures	Porosity	Oil Stains	Description	Facies
1	1372.000		Midale Evapor...		Ms							Dolomite: yel, gry, mudst, rootlets, lam, tt	Tidal flat
	1372.250				Ms								
	1372.500				Ms							Dolomite: yel, grn, mudst, rootlets, lam, tt.	Tidal flat
	1372.750				Ms								
	1373.000				Ms							Dolomite: yel, grn, mudstone, rootlets, bdd, tt, no stn, organic lenses	
	1373.250				Ms								
2	1373.500				Ms								
	1373.750		Midale		Ms							Dolomite: lt gry, argil. mudstone, muddy, grades to calc. algae mudst, tt, no stn.	Land/Very Restricted Lagoon
	1374.000				Ms								
	1374.250				Ms								
	1374.500				Ms								
	1374.750				Ms								
3	1375.000				Ms								
	1375.250				Ms								
	1375.500				Ms								
	1375.750				Ms								
	1376.000				Ms								
	1376.250				Ms								
4	1376.500				Ms							Dol: lt gry, mudst, calc. algae, tt, anhy-filled fract	Restricted lagoon
	1376.750				Ms								
	1377.000				Ws							Dol: gry-brn, calc algae wkst,	Restricted lagoon
	1377.250				Ws					4%	▒	Limestone: brn, crin wackest, stn, poor por; Limestone: brn, calc algae grainst, even stn, good intgran por, grades to wackest, stn, poor por & mudst, tt, no stn, vert fract, stylolite.	Shoal/Restricted Lagoon/Land
	1377.500				Gs					22%	■		
	1377.750				Gs					22%	▒		
5	1378.000				Ps					16%	▒		
	1378.250				Ps					16%	▒		
	1378.500				Ps					4%	▒		
	1378.750				Ps					4%	▒		
	1379.000				Ps					4%	▒		
	1379.250				Ws								
6	1379.500				Ms								
	1379.750				Ms								
	1380.000				Ws						□	Limestone: lt gry, calc algae wackest, mudst, v ft stn, tt, argil.	Restricted lagoon/Land
	1380.250				Ws						□		
	1380.500				Ws								
	1380.750				Ms								
7	1381.000				Ws							Limestone: lt brn, calc algae wackest, lam argil mudst, organic lenses, tt, no stn.	Restricted lagoon/Tidal Flat
	1381.250				Ms								
	1381.500				Ms								
	1381.750				Ms								
	1382.000				Ms							Limestone: lt brn, gry, calc algae mudst, grades to mudst, spotty stn, tt, vert fract, orgainc lense.	Restricted lagoon/Land
	1382.250				Ms								
8	1382.500				Ms								
	1382.750				Ms								
	1383.000				Ms								
	1383.250				Ms								
	1383.500				Ms								
	1383.750				Ws					4%	□	Limestone: lt brn, calc algae wackest, lt stn, poor por; Calc algae grainst, packst, even stn, good intergran por.	Restricted lagoon/Shoal.
9	1384.000				Ws					4%	□		
	1384.250				Gs					16%	■		
	1384.500				Gs					16%	■		
	1384.750				Gs					14%	■		
	1385.000				Ps					8%	■		
	1385.250				Ps					8%	■		
10	1385.500				Ps					8%	■		
	1385.750				Ws						□	Limestone: lt brn, calc algae wackest, v ft stn, tt; argil mudst, ripups	Restricted lagoon/Land
	1386.000				Ms								
	1386.250				Ms								
	1386.500		Frob. Evap.		Ms							Dolomite: lt brn, pink, mudst, argil, mottled, tt, no stn.	Soil
	1386.750				Ms								
11	1387.000											Anhydrite: lt gry, pur, bdd.	Standing water evaporite
	1387.250												
	1387.500												
	1387.750												
	1388.000												
	1388.250												
12	1388.500											Anhydritre: pur, nodular, chicken-wire.	Salina Margin
	1388.750												
	1389.000												
	1389.250												
	1389.500												
	1389.750												

Good porosity and stain in calcareous algae grainstone at 1377.8m & 1384.4m

Core Description and Photos of the 7-7-7-11W2M Midale (Midale Beds) showing shoaling calcareous algae facies (heavily oil-stained) immediately above the Frobisher Evaporite. The Midale Beds represent a marine regressive sequence.