

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. Software such as the StraTerra's LogManager (www.straterrainc.com) greatly simplifies core logging. 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 biological 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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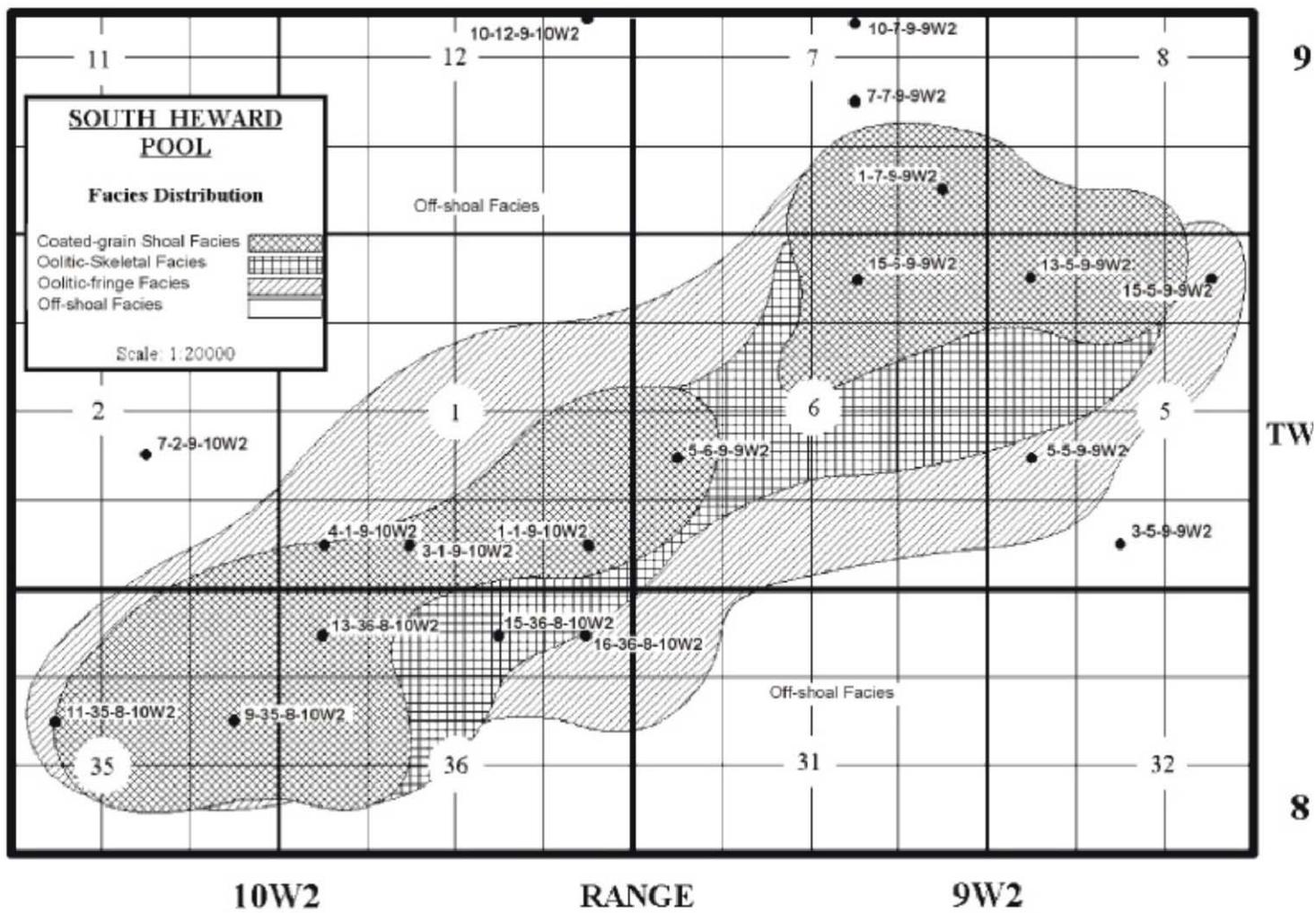


Figure 4 - Map showing facies distribution in the lower Frobisher Beds of the South Heward Pool.

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

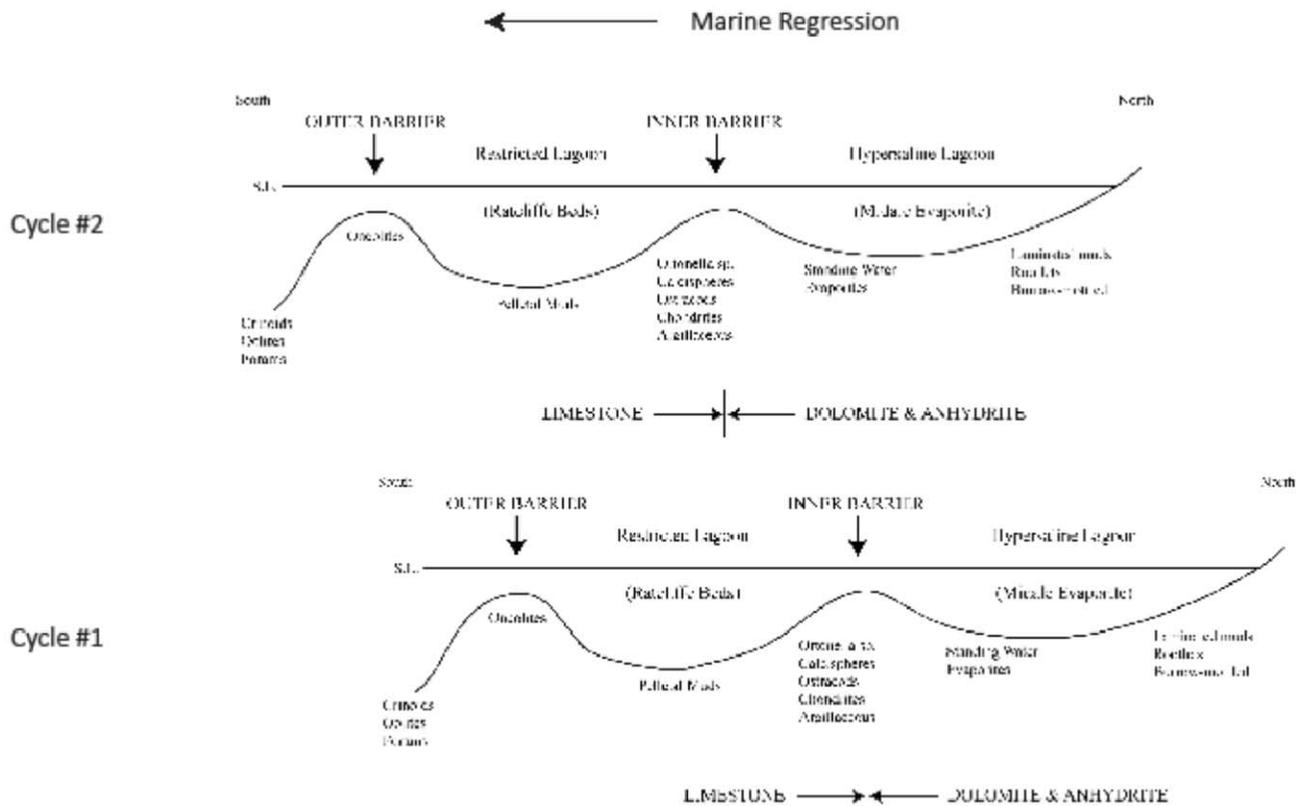


Diagram to illustrate the relationship of facies changes in a vertical sense in a marine regression. "Dissecting" the vertical succession in any core will give you the lateral facies picture. Note how easy it is to make the mistake of joining similar lithologies (lithostratigraphy).

Modified after Lake, 2007.

Well
 Well Location: I-33-14-12W2H
 Well Name: Wascana Nflex 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	Mud Wack Pack Grain Bound Cryst	Lithology	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, mudst. thin bdd, bdd, lt, ft stn, vert fract.	Outer Tidal Flat
	2089.750					Ms								
	2090.000					Ms								
	2090.250					Ms								
	2090.500					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								
4	2092.000					Ms								
	2092.250					Ms								
	2092.500					Ms								
	2092.750					Ms								
5	2093.000					Ms								
	2093.250					Ms								
	2093.500					Ms								
	2093.750					Ms								
6	2094.000					Ms							Dolomite: lt brn, lam, mudst, calc algae wackest, lt stn, tt.	Tidal flat/Restricted Lagoon
	2094.250					Ms								
	2094.500					Vvs							Dolomite: gry, mudst, silty, lam, tt.	Land
	2094.750					Ms							Dolomite: lt brn, mudstone, lam, calc algae wackest, bdd, v ft stn, tt.	Tidal flat/Very Restricted Lagoon
7	2095.000					Ms								
	2095.250					Ms								
	2095.500					Ms								
	2095.750					Ms								
8	2096.000					Ms							Dolomite: lt brn, mudst, microlam, mud cracks, calc algae wkst, lt stn, fair intpart por.	Tidal flat/Restricted & Anoxic Lagoon
	2096.250					Vvs					12%			
	2096.500					Ms					6%			
	2096.750					Vvs								
9	2097.000					Ms							Dolomite: lt brn, mudst, rr ostracods, calc algae, crin, ripups, even stn, poor intxn por, vert fract.	Very restricted/Restricted Lagoon
	2097.250					Ms								
	2097.500					Ms								
	2097.750					Ms								
10	2098.000					Ms								
	2098.250					Ms								
	2098.500					Ms								
	2098.750					Ms								
11	2099.000					Vvs							Limestone: brn, calc algae wackest, biv, even stn, poor por, open vert fract.	Restricted lagoon
	2099.250					Vvs								
	2099.500					Vvs								
	2099.750					Ms							Limestone: lt brn, thallasanoides mudst, stn in burrows, tt.	Restricted lagoon
12	2100.000					Ms								
	2100.250					Ms								
	2100.500					Ms								
	2100.750					Ms								
13	2101.000					Ms								
	2101.250					Ms								
	2101.500					Ms								
	2101.750					Vvs							Limestone: lt brn, biv, crin wackest, planolites, encrusting algae, good intxn por, grades to mudst,	Restricted lagoon
14	2102.000					Vvs								
	2102.250					Ms								
	2102.500					Ms								
	2102.750					Ms								
15	2103.000					Ms							Limestone: lt brn, mudst, argil, tt, no stn, rr crin;	Land/Restricted Lagoon
	2103.250					Vvs								
	2103.500					Vvs								
	2103.750					Vvs								
16	2104.000					Ms							Dolomite: dk brn, crin wackest, coarsely xln, xln, good vuggy por, hvy stn, grades to mudst, xln, excel intxn por	
	2104.250					Ms								
	2104.500					Ms								
	2104.750					Ms								
17	2105.000					Ms							Limestone: lt brn, mudstone, muddy, bdd, tripolitic chert, stn, tt, hi organics.	Anoxic Outer Tidal Flat/Lagoon
	2105.250					Ms								
	2105.500					Ms								
	2105.750					Ms								
18	2106.000													
	2106.250													
	2106.500													
	2106.750													
19	2107.000													
	2107.250													
	2107.500													
	2107.750													

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

Logged with the StraTerra LogManager (www.straterrainc.com).



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 Location: 7-7-7-11W2M
 Well Name: Midale et al Weyburn
 Well Field: Weyburn
 Well Latitude:
 Well Longitude:
 KB Elevation:
 Ground Elevation:
 Core Set #: 1
 Num of Boxes: 13
 Recovery: 18
 Core Top: 1372.0
 Core Bottom: 1390.0
 Core On Depth: 0.0
 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	Dunhams	Dunhams Image	Energy	Fauna	Sedimentary Structures	Porosity	Oil Stains	Description	Facies						
1	1372.000	Midale Evapor.		Mud	Ms							Dolomite: yel, gry, mudst, rootlets, lam, tt	Tidal flat						
	1372.250											Ms					Dolomite: yel, grn, mudst, rootlets, lam, tt	Tidal flat	
	1372.500											Ms					Dolomite: yel, grn, mudstone, rootlets, bdd, tt, no stn, organic lenses		
	1373.000											Ms					Dolomite: lt gry, argil. mudstone, muddy, grades to calc. algae mudst, tt, no stn.	Land/Very Restricted Lagoon	
	1373.250											Ms							
2	1373.500	Midale		Mud	Ms														
	1373.750											Ms							
	1374.000											Ms							
	1374.250											Ms							
	1374.500											Ms							
3	1374.750	Midale		Mud	Ms														
	1375.000											Ms							
	1375.250											Ms							
	1375.500											Ms							
	1375.750											Ms							
4	1376.000	Midale		Mud	Ms							Dol: lt gry, mudst, calc. algae tt, anhy-filled fract	Restricted lagoon						
	1376.250											Ms							
	1376.500											Vs					4%	Dol: gry-brn, calc algae wkst.	Restricted lagoon
	1376.750											Gs					22%	Limestone: brn, crin wackest, stn, poor por;	Shoal/Restricted Lagoon/Land
	1377.000											Gs					22%	Limestone: brn, calc algae grainst, even stn, good intgran por, grades to wackest, stn, poor por & mudst, tt, no stn, vert fract, stylolite.	
5	1377.250	Midale		Mud	Ps														
	1377.500											Ps					18%		
	1377.750											Ps					18%		
	1378.000											Ps					4%		
	1378.250											Ps					4%		
6	1378.500	Midale		Mud	Ps														
	1378.750											Ps					4%		
	1379.000											Vs					4%		
	1379.250											Vs							
	1379.500											Ms							
7	1379.750	Midale		Mud	Ms														
	1380.000											Vs							
	1380.250											Vs							
	1380.500											Vs							
	1380.750											Ms							
8	1381.000	Midale		Mud	Vs							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							
9	1382.250	Midale		Mud	Ms														
	1382.500											Ms							
	1382.750											Ms							
	1383.000											Ms							
	1383.250											Ms							
10	1383.500	Midale		Mud	Vs														
	1383.750											Vs					4%	Limestone: lt brn, calc algae wackest, lt stn, poor por;	Restricted lagoon/Shoal.
	1384.000											Gs					4%	Calc algae grainst, packst, even stn, good intergran por.	
	1384.250											Gs					18%		
	1384.500											Gs					14%		
11	1384.750	Midale		Mud	Ps														
	1385.000											Ps					8%		
	1385.250											Ps					8%		
	1385.500											Ps					8%		
	1385.750											Vs							
12	1386.000	Frob. Evap.		Mud	Ms							Limestone: lt brn, calc algae wackest, v ft stn, tt, argil mudst, ripups	Restricted lagoon/Land						
	1386.250											Ms							
	1386.500											Ms							
	1386.750											Ms							
	1387.000											Ms							
13	1387.250	Frob. Evap.		Mud	Ms							Dolomite: lt brn, pink, mudst, argil, mottled, tt, no stn.	Soil						
	1387.500											Ms							
	1387.750											Ms							
	1388.000											Ms							
	1388.250											Ms							
14	1388.500	Frob. Evap.		Mud	Ms							Anhydrite: lt gry, pur, bdd.	Standing water evaporite						
	1388.750											Ms							
	1389.000											Ms							
	1389.250											Ms							
	1389.500											Ms							
15	1389.750	Frob. Evap.		Mud	Ms							Anhydrite: pur, nodular, chicken-wire.	Salina Margin						
	1390.000											Ms							
	1390.250											Ms							
	1390.500											Ms							
	1390.750											Ms							

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

Logged with the StraTerra LogManager (www.straterrainc.com).



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.