

**Origins and characteristics of the basin-centered continuous-reservoir
unconventional oil-resource base of the Bakken Source System, Williston Basin**
Manuscript by Leigh C. Price (1999/2000)

Table of Contents to Manuscript [*not PDF*] pages

Cover		
Table of Contents	.....	1
Abstract/Executive Summary	.....	8
1.0	Introduction	..... 25
2.0	The Williston Basin	..... 26
	2.01 Synopsis	..... 26
	2.02 Background	..... 27
	2.03 Stratigraphy	..... 28
	2.04 The Bakken Source System	..... 30
	2.05 The Uniqueness of the Williston Basin Sample Base	..... 31
3.0	Classic Petroleum Geologic and Geochemical Williston Basin Studies	..... 33
	3.01 Synopsis	..... 33
	3.02 Williams-Dow	..... 34
	3.03 Meissner	..... 37
	3.04 Accepted Model of Oil Expulsion and Accumulation	..... 38
	3.05 ROCK-EVAL	..... 39
	3.06 ROCK-EVAL Data Supporting the Accepted Model of Oil Expulsion and Accumulation	..... 41
4.0	Present-Day Williston Basin Petroleum-Geochemical Research	..... 43
	4.01 Synopsis	..... 43
	4.02 Introduction	..... 45
	4.03 Bakken Oil to Mid Madison Oil Comparison	..... 45
	4.04 Western Canadian Basin	..... 48
	4.05 Alternate Oil Expulsion and Accumulation Model	..... 48
	4.06 Basin Richness versus Structural Intensity	..... 49
	4.07 Implications of the Alternate Expulsion and Accumulation Model	..... 50
5.0	Unconventional Energy Deposits	..... 52
	5.01 Synopsis	..... 52
	5.02 Introduction	..... 53
	5.03 Antrim Shale Gas	..... 54
	5.04 San Juan Basin Coal Gas	..... 57
	5.05 Discontinuous (Conventional) versus Continuous (Unconventional) HC Deposits	..... 61
6.0	Characteristics, and Causes Thereof, of Bakken Source System Reservoir Rocks	..... 63
	6.01 Synopsis	..... 63
	6.02 Introduction	..... 66
	6.03 Stratigraphy	..... 67
	6.04 The Lowermost Lodgepole Shale	..... 68
	6.05 Traditional Core Analyses	..... 70

6.051	Introduction.....	70
6.052	NDGS #8177 Immature Shales (Pre-HC Generation)	70
6.053	NDGS #8637 Less Mature Shales (Pre-HC Generation).....	71
6.054	NDGS #7851 Immature Shales Just Having Commenced HC Generation	73
6.055	NDGS #8709 Thick Moderately-Mature Shales.....	75
6.056	NDGS #12494 Thin Mature Shales	78
6.057	NDGS #11617 Thick Mature Shales	80
6.058	Discussion of Conventional Core Analyses.....	82
6.06	ROCK-EVAL Analysis of Immature Core Samples	84
6.06 1	Introduction.....	84
6.062	NDGS #8177	85
6.063	Early Movement of Oil	86
6.064	NDGS #2618	87
6.065	NDGS #9001	89
6.066	NDGS #8368	90
6.067	NDGS #2010	91
6.07	ROCK-EVAL Analysis of Mature Core Samples	94
6.071	NDGS #8474	94
6.072	Oil Loss to the Drilling Mud during Drilling.....	95
6.073	NDGS #5088	96
6.074	Significance of Increased S ₂ Values	98
6.075	NDGS #1405	100
6.076	Evidence of Oil Loss to the Drilling Mud and Evaporation during Storage.....	101
6.08	Evidence and Causes of Super-Lithostatic Fracturing.....	108
	Leigh C. Price and Kathy Stolper	
6.081	NDGS #4958 Immature Bakken Shales	108
6.082	NDGS #8824 Slightly Increased Bakken Shale Maturity.....	110
6.083	NDGS #13098 Mature Shales-Bakken HC Kitchen.....	112
6.084	NDGS #12160 Thin Moderately-Mature Shale.....	116
6.085	NDGS #11689	118
6.086	Causes of Super-Lithostatic Fracturing	121
6.087	Consequences of Super-Lithostatic Fracturing	126
6.088	IFP 's Position on Hydraulic Fracturing.....	128
6.089	Bakken Source System Oil to Water Ratios	129
6.09	Implication to Source Rock Expulsion	130
6.10	Discussion and Conclusions: Bakken Reservoir Rocks.....	133
7.0	Williston Basin Maturity and Heat Flow	136
7.01	Synopsis	136
7.02	Introduction	138
7.03	Vitrinite Reflectance (R _o)	139
7.04	Williston Basin R _o Profiles	140
7.041	NDGS #6464	140
7.042	NDGS #607	141
7.043	NDGS #527	143
7.044	All Analyzed Wells.....	144
7.05	Corroborating Evidence	145
7.06	Discussion	145
7.07	Basin Cooling	148
7.08	Maturity versus Rank.....	150

7.09	Suppression of Organic Metamorphism in Hydrogen-Rich OM	152
7.091	Introduction.....	152
7.092	Examples/Consequences of Suppression of Organic Metamorphism	152
7.10	Causes of Suppressed Organic Metamorphism in Hydrogen-Rich OM	157
7.101	Controlling Parameters of Organic Metamorphism.....	157
7.102	Hydrolytic Disproportionation of OM.....	159
7.103	Water Availability versus OM Type.....	161
7.11	Conclusions and Implications	166
8.0	Recent Publications	167
8.01	Synopsis	167
8.02	Burrus et al. (1996).....	171
8.03	Reasons for the Burrus et al. (1996) Model.....	176
8.04	Schmoker (1996).....	177
8.05	Carlisle et al. (1992).....	183
8.06	LeFever et al. (1991).....	187
9.0	The Lower Lodgepole Waulsortian Mound Play	196
9.01	Synopsis	196
9.02	Introduction	197
9.03	The Source Rock.....	198
9.04	Oil Source-Rock Maturity.....	200
9.05	Reservoir Porosity and Permeability	201
9.06	Fracturing	204
9.07	Salt Collapse	205
10.0	Mass Balance Estimates of Bakken-Generated Oil	208
10.01	Synopsis	208
10.02	Introduction	210
10.03	Inputs and Assumptions.....	211
10.04	Schmoker and Hester (1993), Webster (1984).....	214
10.05	Starting TOC Contents.....	216
10.06	Estimated Amounts of Generated Oil	217
10.061	ROCK-EVAL	217
10.062	Closed System Measurements	219
10.063	HC Generation Models	224
10.064	Hydrolytic Disproportionation of OM.....	225
10.065	The Present Estimate of Bakken-Generated Oil	233
10.066	Small-Scale Estimates.....	235
10.067	Comparisons to Other Source Systems.....	237
11.0	Other Considerations	239
11.01	Synopsis	239
11.02	Introduction	240
11.03	The Uniqueness of the Bakken Source System	241
11.031	Williston Basin Paleo-Heat Flow	241
11.032	The Unparalleled Williston Basin Sample Base	242
11.033	The Source-Reservoir Relationship.....	242
11.04	Additional Positive Aspects of the Bakken Source System.....	244
11.05	Oil Recovery	244
12.0	Conclusions	247

13.0 Bibliography	.....	263
List of Figures	.....	282
Tables		
Figures		