North Dakota Geological Survey
Geologic Investigations No. 132

North to South Cross-Section of the Tyler Formation (Pennsylvanian) With RockEval Data, North Dakota

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2011

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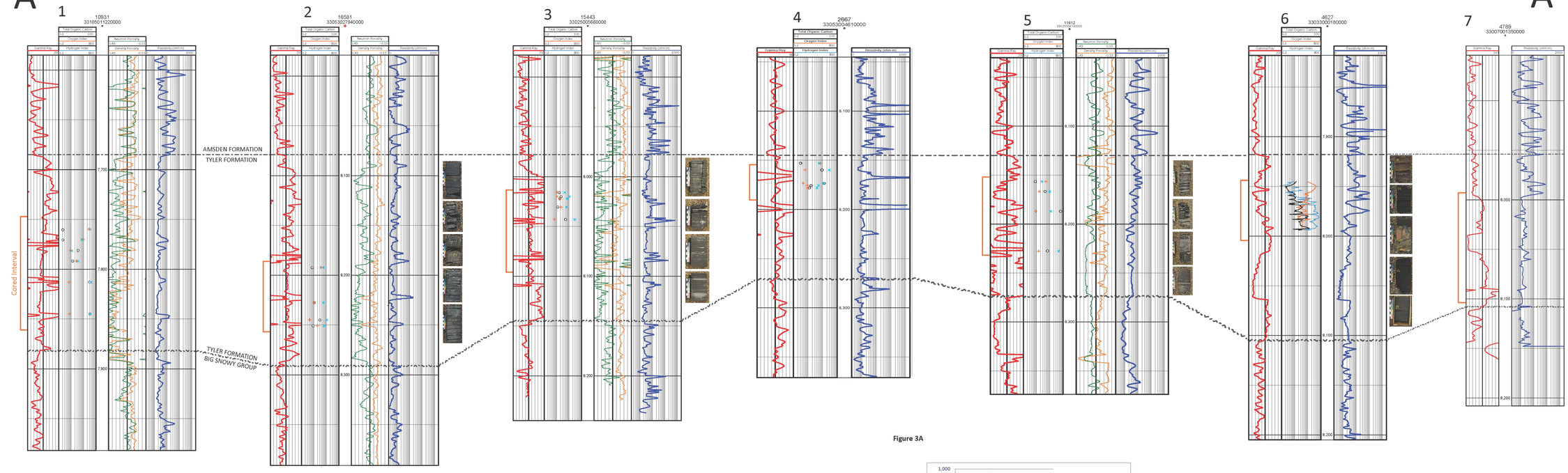

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State 41X-36, Tyler Fm. RockEval
*No Depth Correlation

SAMPLE NUMBER	HYDROGEN INDEX	OXYGEN INDEX	TMAX (°C)	TOC (%)
141020 A	267	43	446	1.78
B	282	42	443	3.07
C	181	64	438	1.63
D	249	37	439	1.98
E	239	150	426	0.82
F	425	28	439	4.08
G	451	71	438	1.2
H	322	121	432	0.93
I	371	33	444	3.05
J	282	37	443	2.99
K	143	29	445	3.39
L	180	38	447	3.38
M	140	60	447	2.78
N	150	72	448	2.66
O	244	63	439	2.88
P	157	55	446	3.28
Q	164	67	445	4
R	152	36	448	4.06
141031 A	136	90	445	2.86
B	140	62	442	3.94
C	209	31	445	3.81
D	56	21	438	0.94
E	85	218	443	0.91
F	149	67	446	2.58
G	133	60	448	2.48
H	149	113	447	1.53
I	168	18	448	1.64
J	139	17	449	1.74
K	173	18	449	1.83
L	257	28	445	2.28
M	271	32	442	2.59
N	246	13	449	2.79
O	255	16	448	3.02
P	126	40	444	1.55
Q	147	27	445	2.36
R	151	16	447	3.67
S	76	5	443	3.12
T	28	85	504	0.21
141042 A	28	9	440	1.11
B	25	48	402	0.31
C	20	37	420	0.29
D	28	30	440	0.52
E	0	0	0	
F	0	0	0	
G	0	0	0	
H	0	0	0	
I	59	10	442	1.19
J	198	114	444	0.61

Cross-Section Notes: Core photos for wells 2, 3, 5, and 6 represent the approximate core intervals sampled for rock analysis. The orange brackets to the left of each gamma ray log depict the approximate cored interval of the Tyler Formation for that well. The Total Organic Carbon (TOC) is plotted on a log scale of 0.2% to 100%. The Hydrogen Index and Oxygen Index values are plotted on a log scale of 0.2 to 800. The resistivity log for wells 4, 6, and 7 were calculated from the conductivity logs within the laterlogs for those wells. Rock analyzes for wells 1-5 were completed at the Weatherford Lab. Rock analyzes for wells 6 and 7 are from previously produced data sets. The CND logs for wells 1, 2, and 5 used a limestone matrix. The CND log for well 3 (NDIC: #15443) used a sandstone matrix.

Figure 1

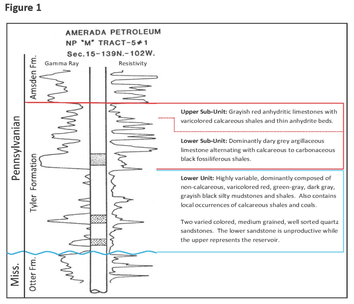


Figure 1: Resistivity and gamma ray logs with lithological descriptions from Amerada Petroleum Corp's N.P. "M" TR-5 #1 (NDIC: 3939, API: 33-007-00089-00-00, Sec. 15-T139N-R102W). Figure 1 is modified from Sturm (1982), who described this well as the type log for the Tyler Formation in southwestern North Dakota.

Figure 2

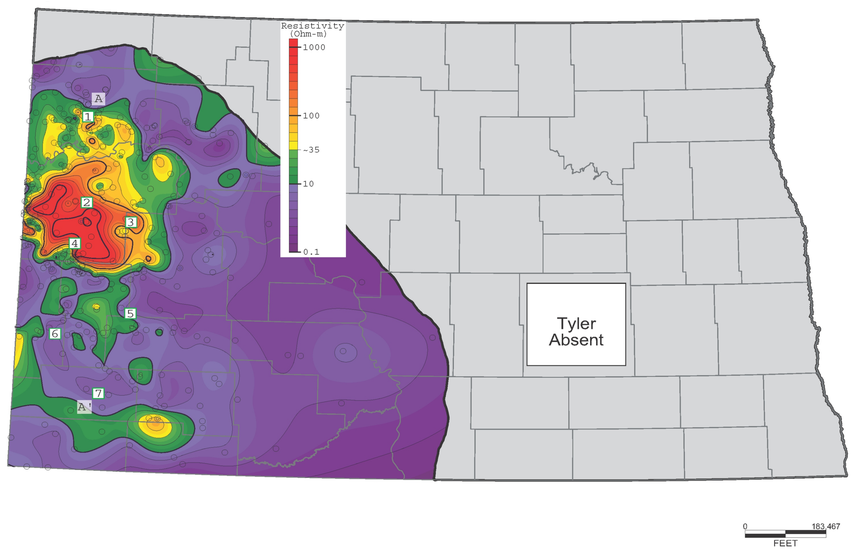


Figure 2: Resistivity map of shale within the Tyler Formation for western North Dakota. This is a map of the logarithm of the maximum resistivity value of shale. Resistivity values are from dual laterlogs of over 300 wells. Purple shaded areas have <35 ohm-m resistivity. Orange-red shaded areas have >35 ohm-m resistivity, which is the parameter Meissner (1978) used to determine where the Bakken Formation is thermally mature. The numbered squares show the location of wells depicted in the cross-section.

Figure 3A

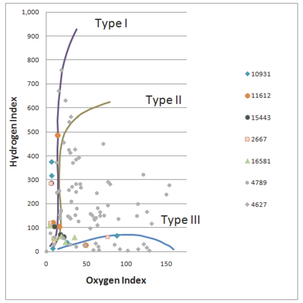
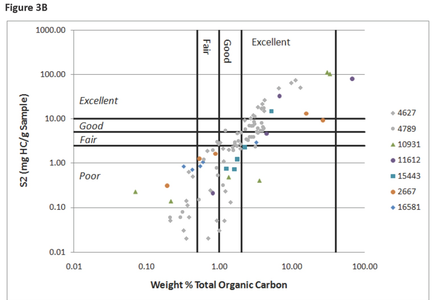


Figure 3: Diagrams depicting the Tyler kerogen type and quality based on RockEval pyrolysis data. A) A modified van Krevelen diagram that plots the Hydrogen Index (HI) versus Oxygen Index (OI) of analyzed samples in order to classify the kerogen type. Type I and Type II kerogen are prone to generating oil. Type III kerogen is gas prone. Two sets of previously analyzed samples from the Tyler showed a lot of scatter between the three types of kerogen (data from wells #4789 and #4627). The preliminary RockEval data set from this study shows Tyler samples plotting along either the Type I or Type III trends (the larger symbol sets). B) Kerogen quality diagram (Dembicki, 2009) that plots the Total Organic Carbon (TOC) versus to total hydrocarbon mass (existing, S1, and potential, S2) contained within Tyler Formation samples. Note that most of the samples plot in the good to excellent range.

Figure 3B



Discussion

The Tyler Formation is an early Pennsylvanian aged sedimentary deposit (Ziebarth, 1962) that has been productive primarily in southwestern North Dakota. In southwestern North Dakota, the Tyler Formation is thought to represent a deltaic deposit with highly variable lithologies, which include; limestone, anhydrite, dolomite, coal, paleosols, shale, and sandstone (Zierbarth, 1962; Sturm, 1982; Maughan, 1983). Lenticular sand intervals, thought to represent delta front bar-type deposits (Harris, 1958; Sturm, 1982), have been productive in southwestern North Dakota. Production from the Tyler sands began in 1954 within the Fryburg Field of southern Billings County (Nordeng, 2011). A total of 284 wells have produced over 83 million barrels of oil from the Tyler sands (total from Oil & Gas website 2009 statistics). Figure 1 shows a type log of the Tyler in southwestern North Dakota. The Tyler Formation is believed to be a self-sourced unit (Dow, 1974; Williams, 1974), i.e., oil generated from its shale has migrated into the producing sand intervals.

The purpose of this publication is to examine RockEval data along a north-south cross-section of the Tyler Formation in western North Dakota. A preliminary suite of 25 samples from 5 Tyler cores (4-6 samples per core) were collected by the North Dakota Geological Survey and analyzed by the Weatherford lab, using the RockEval data method and LECO TOC analysis. The RockEval data set includes: Hydrogen Index (HI), Oxygen Index (OI), and T_{max}. Total Organic Carbon (TOC) was obtained using the LECO method. In general, a good source rock for generating oil and gas has ≥ 1 weight percent TOC (Dembicki, 2009). Source rocks with a high Hydrogen Index and low Oxygen Index are thought to be of marine origin and are prone to generating oil. The RockEval results from this study, as well as two sets of previously generated RockEval data from the Tyler Formation, are plotted versus depth alongside wirelogs on the cross section.

Based on RockEval data, Tyler shale from northwestern North Dakota appears to be a good to excellent source rock for oil and gas generation. Three high gamma ray intervals, which correlate with black shale in core sample, extend through the lower portion of the Tyler Formation in the northern four logs of the above cross-section. Samples taken from the lower two shales of the northern most well (Well #1; NDIC #10931) have TOC of ~30% and Hydrogen Index values of >300. The upper most shale, sampled from well #4 (NDIC #2667), has TOC of ~10% and a maximum Hydrogen Index of 284. The high Hydrogen Index versus generally low Oxygen Index, the high gamma ray values and overall high TOC values indicate these shale intervals are organic-rich marine deposits that might be excellent source rocks (Dembicki, 2009).

Together with the RockEval data, this study also examined the resistivity of shale within the Tyler Formation throughout western North Dakota (Fig. 2). A low resistivity value for a shale indicates that it is water saturated and is therefore not considered thermally mature (formation water typically has high electrical conductivity). A high resistivity value suggests that the shale is thermally mature because generated oil has expelled the water from the shale (oil is highly resistive to electrical current). Shale within the Tyler Formation in western North Dakota is observed to have maximum resistivity values ranging from 3 ohm-m to over 2000 ohm-m. Most of the high resistivity values are found in and around McKenzie County (Fig. 2), the deepest part of the Williston Basin, suggesting that organic-rich shale within the Tyler Formation in that area is thermally mature and oil-saturated.

Several key factors indicate that the Tyler Formation has generated oil in western North Dakota. Extending throughout most of western North Dakota, shale within the Tyler Formation has high TOC values (1-30%) along with an overall high Hydrogen Index and low Oxygen Index indicating the shale is a good to excellent Type I to Tyler II source rock (Figure 3A and B). A preliminary resistivity map of the shale within the Tyler Formation (Fig. 2) shows high resistivity values throughout the deeper parts of the Williston basin, suggesting these rocks are mature and oil saturated. Abnormally-high fluid pressures indicate the Tyler Formation is sealed from communication with surrounding formations (Nordeng and Nesheim, 2010) and minimal migration has likely occurred for any oil generated within. Overall, the preliminary results from this study indicate that the Tyler Formation is a promising future target for oil and gas exploration in western North Dakota.

References

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