PRELIMINARY CHARACTERIZATION OF TWO COALS FROM THE UPPER PRINCE CREEK FORMATION, SAGWON BLUFFS, NORTH SLOPE, ALASKA

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PRELIMINARY CHARACTERIZATION OF TWO COALS FROM THE UPPER PRINCE CREEK FORMATION, SAGWON BLUFFS, NORTH SLOPE, ALASKA

Nina Harun[1] and Marwan Wartes[1]

INTRODUCTION

In July of 2018 the Alaska Division of Geological & Geophysical Surveys (DGGS) studied and sampled the coal beds within the upper section of the Prince Creek Formation at Sagwon Bluffs (fig. 1). Sagwon Bluffs lies 55 miles south of Deadhorse (Prudhoe Bay), Alaska, and approximately one mile east of the Dalton Highway, on the west side of the Sagavanirktok River. At Sagwon Bluffs, Upper Cretaceous to Paleocene rocks of the Prince Creek and Sagavanirktok Formations are exposed.

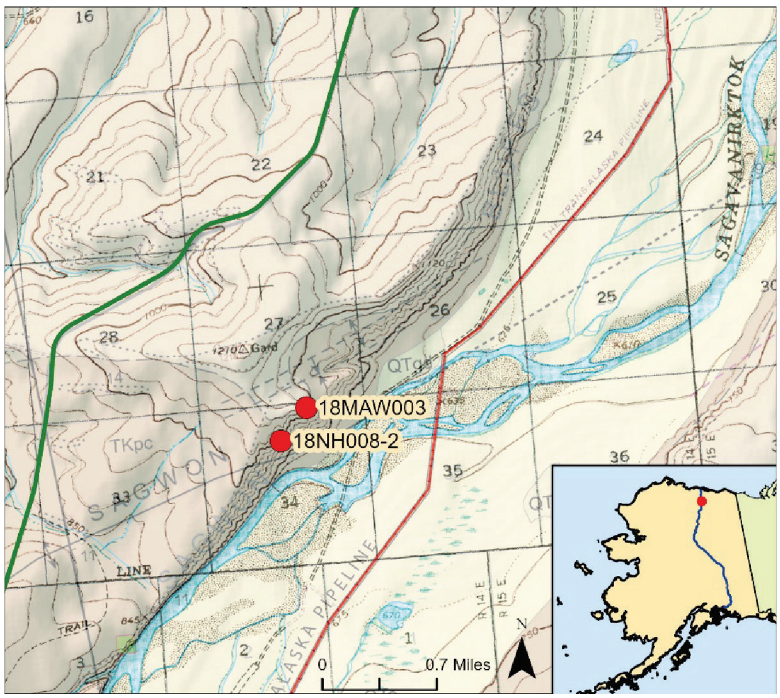

Figure 1. Sample locations at Sagwon Bluffs. Dalton Highway in green to west. Trans-Alaskan pipeline in red to east.

PREVIOUS WORK

The Campanian to Paleocene Prince Creek Formation consists of nonmarine sandstones with interbedded carbonaceous mudstone, coal, and bentonite (Mull, 2003). Gryc and others (1951) first defined the Prince Creek Formation as consisting of the lower Tuluvak Tongue and the upper Kogosukruk Tongue divided by the Schrader Bluff Formation. Mull and others (2003) revised the Cretaceous stratigraphic nomenclature of the Colville basin and restricted the Prince Creek Formation to include only the interbedded conglomerates, sandstones, mudstones, and coals originally assigned to the Kogosukruk Tongue and the lower part of the Sagwon Member of the Sagavanirktok Formation.The Tuluvak Tongue, lying below the lowest part of the Schrader Bluff Formation,

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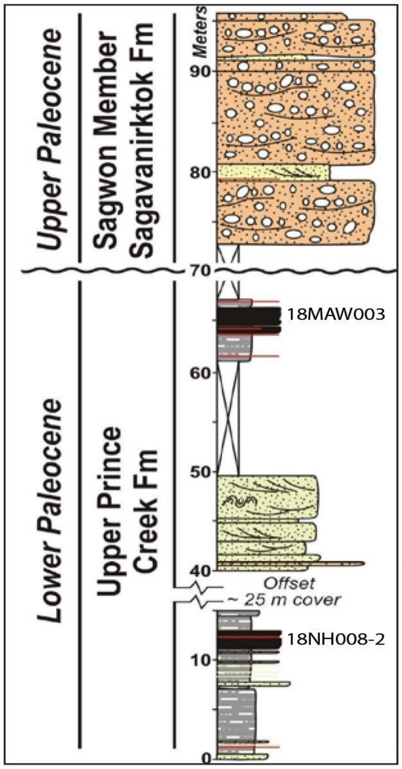

Figure 2. Stratigraphic position in the upper Prince Creek Formation of coal samples used in the study. Figure from Wartes and others (2011).

was elevated to formation rank (Tuluvak Formation) and the name "Kogosukruk Tongue" was abandoned. The non-marine Prince Creek Formation and the marine Schrader Bluff Formation comprise eastwardly to northeastwardly prograding topset strata (Gillis and others, 2014; Mull and others, 2003).

This report focuses on the upper Prince Creek Formation. The lower Prince Creek Formation, not addressed in this report, is best exposed on the Colville River downstream from Umiat, at Shivugak Bluff, and downstream from the mouth of the Anaktuvuk River (Mull and others, 2003; Flores and others, 2007; van der Kolk and others, 2015). The best exposures of the upper Prince Creek Formation crop out along the Sagavanirktok River at Sagwon Bluffs, where it is separated from the overlying Sagavanirktok Formation by a sharp erosional contact (Mull and others, 2003). Wartes and others (2011) recognized the Prince Creek/Sagavanirktok contact as a Paleocene sequence boundary based on changes in fluvial style, sandstone and clast composition, and an abrupt increase in grain size across the contact (fig. 2). Daly and others (2011) palynological study at Sagwon Bluffs characterized the Prince Creek as flood plain deposits consisting of fluvial overbank sediments. The upper Prince Creek Formation at this location contains several distinct coal seams interbedded with fine-grained fluvial sandstone (fig. 2; Wartes and others, 2015). A lower coal seam (18NH008-2) and an upper seam (18MAW003) were sampled for this study (fig. 2).

METHODS

Two coal seams were sampled in the upper Prince Creek Formation at Sagwon Bluffs (figs. 1 and 2). The lower coal (18NH008-2) is a one-meter-thick seam consisting of black vitreous coal layers and thin splits of carbonaceous mudstone (figs. 3 and 4). The upper coal (18MAW003) seam is approximately 50 m up-section from the lower seam, where it is exposed along several spines below the gravel cliff of the Sagavanirktok Formation. The upper coal seam forms a conspicuous black band above an olive-green weathering granule-bearing sandstone in the upper Prince Creek Formation (fig. 5). This 1.5 m-thick seam has a relatively high ash content, but includes locally developed vitreous laminae of pure coal. Channel samples were collected from each seam for coal quality (proximate and ultimate analysis), Rock-Eval pyrolysis, hydrous pyrolysis, vitrinite reflectance, and kerogen microscopy analyses. Geochemical Testing (2005 N. Center Avenue, Somerset, PA) conducted proximate and ultimate analyses following the American Society for Testing and Materials standards for coal analyses (ASTM, 2002) (tables 1 and 2). Weatherford Laboratories (Houston, Texas) analyzed samples for Rock-Eval pyrolysis (table 3). Weatherford analyzed a total of 96 subsamples for vitrinite reflectance (Ro) values as well as visual identification and reflection of specific maceral types in these coals; 48 subsamples were taken from 18NH008-2 and 48 subsamples from 18MAW003. The hydrous pyrolysis samples from each seam have not been submitted for analysis.

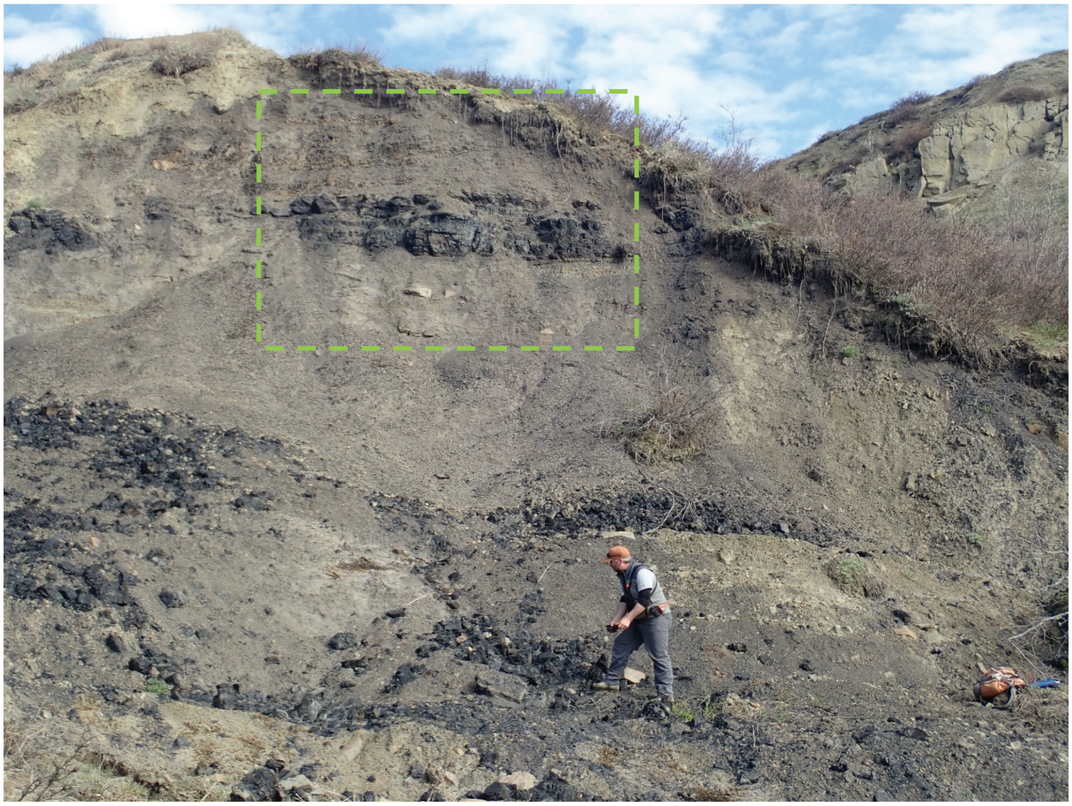

Figure 3. Photograph showing the lower coal seam from which channel sample 18NH008-2 was collected. Green dashed box indicates view in figure 4.

Figure 4. Lower coal interval sampled (18NH008-2). Coal bed is one meter thick.

Figure 5. Upper coal seam (18MAW003) in upper Prince Creek Formation directly below the base of the Sagavanirktok Formation. Photo by Marwan Wartes.

Table 1. Proximate coal quality analyses of Prince Creek Formation samples.

Sample Number	Collector	Date	Analysis date	Unit	Location	Latitude NAD83	Longitude NAD83	Lithology	Description	Proximate Moisture (%)	Proximate Ash (%)	Proximate Volatile Matter (%)	Proximate Fixed Carbon (%)
18NH008-2A	Nina Harun	7/10/2018	8/2/2018	Prince Creek Formation	Sagwon Bluffs	69.40250	-148.66775	Coal	lower Coal	18.98	6.04	42.22	32.76
18MAW003A	Marwan Wartes	7/10/2018	8/2/2018	Prince Creek Formation	Sagwon Bluffs	69.40527	-148.66076	Coal	upper coal with car-bonaceous mudstone	18.14	4.77	40.95	36.14
18NH008-2A (dry-ash-free)	Nina Harun	7/10/2018	8/2/2018	Prince Creek Formation	Sagwon Bluffs	69.40250	-148.66775	Coal	lower Coal			56.00	43.69
18MAW003A (dry-ash-free)	Marwan Wartes	7/10/2018	8/2/2018	Prince Creek Formation	Sagwon Bluffs	69.40527	-148.66076	Coal	upper coal with car-bonaceous mudstone			53.12	46.88

Table 2. Ultimate coal quality analyses, heating value and coal rank of the Prince Creek Formation samples.

Sample Number	Ultimate Hydrogen	Ultimate Carbon	Ultimate Nitrogen	Ultimate Sulfur	Ultimate Oxygen	Ultimate Ash	Pyritic Sulfur	Organic Sulfur	Equilibrium Moisture	Heating Value (BTU/lb.)	Coal Rank
18NH008-2A	5.44	53.79	1.42	0.22	33.09	6.04	0.02	0.2	23.34	11785	bituminous C
18MAW003A	5.48	55.78	1.17	0.13	32.67	4.77	0.05	0.08	23 .61	9522	subbituminous A

Table 3. Rock-Eval pyrolysis analyses, upper Prince Creek Formation

Sample Number	Unit	Type	TOC (wt.%)	S1 (mg/g)	S2 (mg/g)	S3 (mg/g)	Tmax(°C)	Ro, 0%	HI (mg HC/g TOC)	OI (mg CO_2/g TOC)	S2/S3	S1/ TOC*100	PI
18NH008-2C	Prince Creek Formation	Coal	52.8	1.22	104	9.6	409	0.33	197	787	10.84	2.31	0.0116
18MAW003C	Prince Creek Formation	Coal	63.1	1.74	84	18.77	414	0.34	133	1079	4.46	2.76	0.0204

RESULTS AND CONCLUSIONS

Coal Quality Analyses

Coal quality data for the two Prince Creek coal samples are summarized in tables 1 and 2. The sampled coals are ranked as bituminous C for the lower coal interval (18NH008-2A) and subbituminous A for the upper coal interval (18MAW003A), as calculated from coal quality data (tables 1 and 2). Heat content of the lower coal interval (18NH008A-2A) and the upper coal interval (18MAW003A), based on dry ash-free samples, are 11785 and 9522 BTU/lb respectively. Ash content is not high at 4.77 and 6.04, indicating only modest clastic dilution. This is consistent with high latitude Cenozoic coals (Sable and Stricker, 1987). Sulfur content is low (0.13 to 0.22) and consists predominately of organic sulfur (tables 1 and 2).

Organic Macerals and Vitrinite Reflectance

Weatherford Labs identified maceral types in these samples through fluorescence and reflected light microscopy (appendix 1). They reported a substantial amount of inert macerals; predominately fusinite with lesser amounts of semi fusinite and funginite. Maceral also include various types of vitrinite and huminite at low levels of maturity. Minor amounts of cutinite, sporinite, resinite, and a few rare instances of suberinite are also present. Pyrite in a finely disseminated form is rare. Weatherford reported an average %Ro of 0.33 and 0.34 on 96 polished huminite samples with sparse overall fluorescence. Fluorescence is blue-green to greenish-yellow with some vivid-yellow and rare- to dark-orange. Weatherford labs reported that the blue-green to green-yellow fluorescing macerals are sporinite and possibly degraded alginate (appendix 1).

Rock-Eval Pyrolysis

The quality, quantity, and thermal maturity of the organic components are characterized by Rock-Eval pyrolysis, total organic carbon (TOC), and vitrinite reflectance analyses (Peters and Cassa, 1994). The TOC in weight percent as a measure of the quantity of the organic component varies from 52.8 to 63.1 (table 3). The S1 peak measures the amount of hydrocarbons (mg/g) that can be thermally distilled from the sample (essentially hydrocarbons already in the rock at the time of sampling); the S2 peak indicates the amount of hydrocarbons (mg/g) generated by pyrolytic degradation of the kerogen in the sample and is an indicator of hydrocarbon generation potential; the S3 peak records the amount of CO_2 generated during pyrolysis (Peters, 1986). Tmax(°C) records the temperature at which the maximum amount of S2 hydrocarbons are generated (Peters, 1986).

Rock-Eval pyrolysis and vitrinite reflectance data indicate that all of the samples are immature in relation to the onset of oil generation (table 3). As discussed in the previous section, mean vitrinite reflectance values are low and range from 0.33 and 0.34 (%Ro) (table 3; appendix 1). Tmax values—409°C and 414°C for these samples—indicate immature organic matter (table 3; fig. 6). Production index (PI), hydrogen index (HI), and oxygen index (OI) were calculated from the Rock-Eval data. The production index (PI) is the ratio of the S1 and S2 peaks (PI= (S1)/(S1+S2)) and is an important measure of the thermal maturity of the sample, with values less than 0.1 indicating immature organic matter (Peter, 1986). The PI for the Prince Creek coal samples is 0.0116 and 0.0204, indicating immature organic matter (figs. 6 and 7). The HI (HI = S2*100/TOC) suggests the nature of the organic matter, specifically lipid- and protein-rich vs. carbohydrate-rich, and therefore the type of products (gas or oil) the rock would be likely to generate The HI vs. Tmax plot reveals both the maturity and the type of organic matter in the samples (oil-or gas-prone). These samples plot in the thermally immature Type III gas-prone field (fig. 8). Likewise, coal samples plot

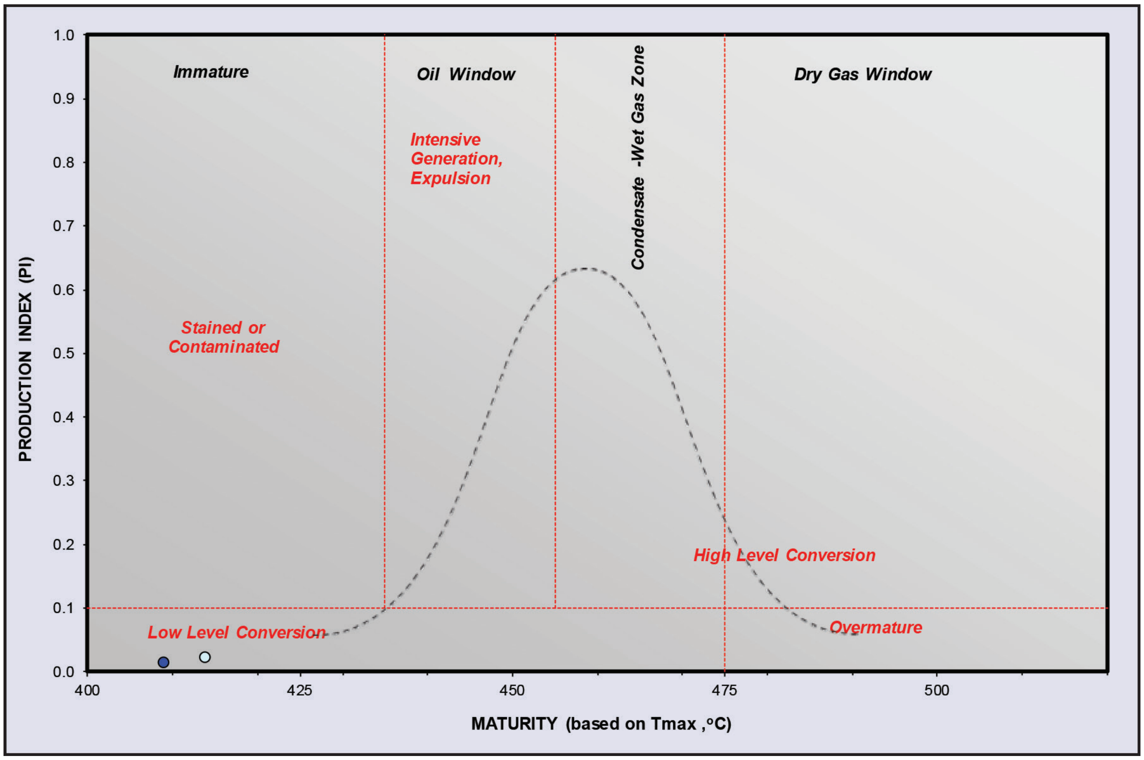

Figure 6. Production index vs. maturity (Tmax°C). Samples fall into the immature field.

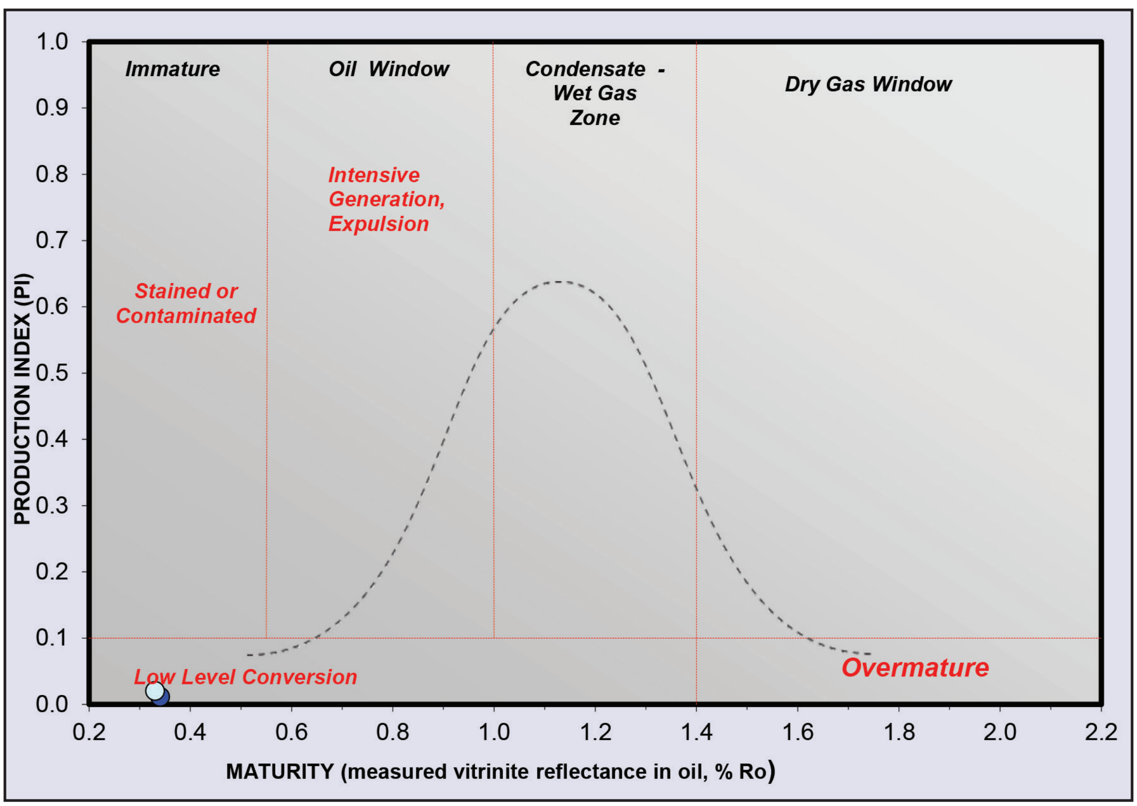

Figure 7. Production index vs. maturity (%Ro). Samples fall into the immature field.

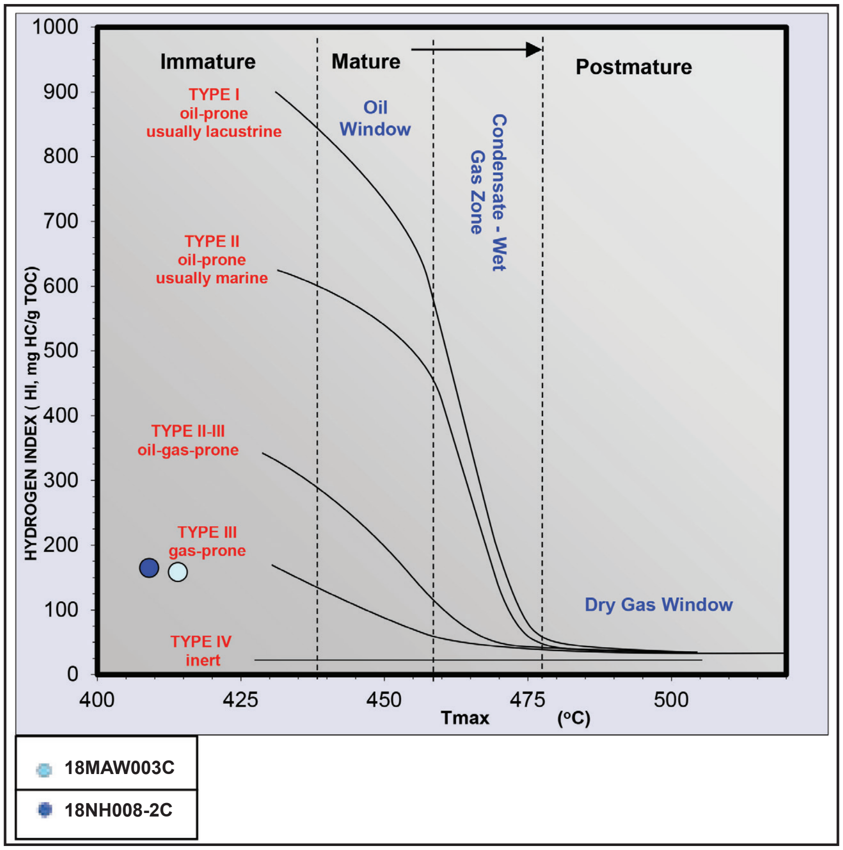

Figure 8. Hydrogen index vs. Tmax indicate these samples fall into the immature gas-prone field.

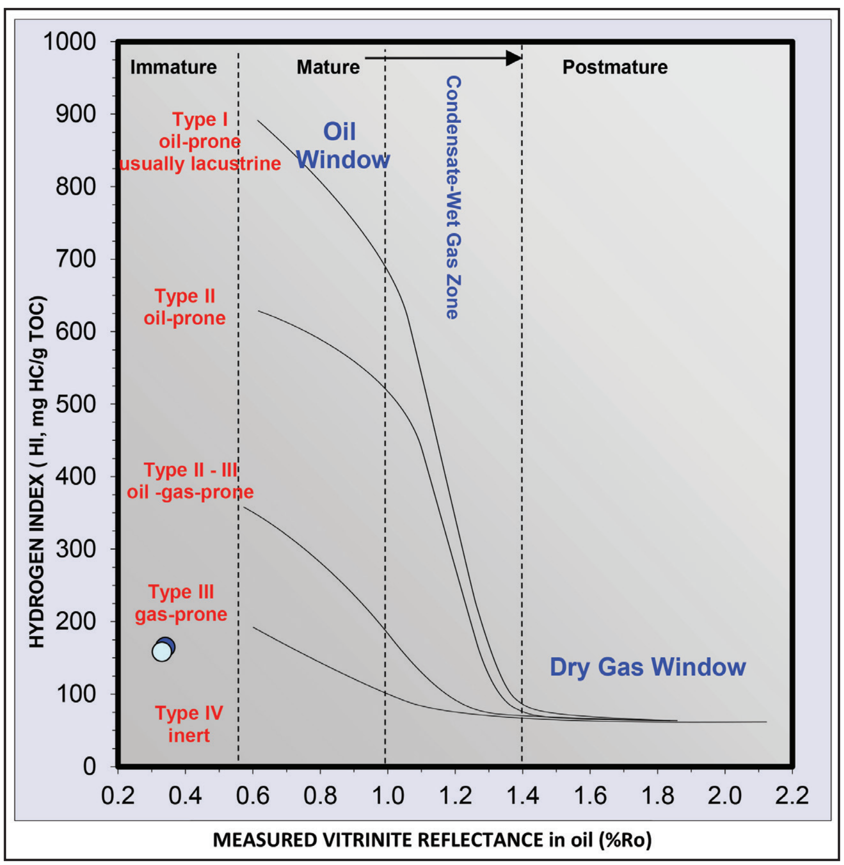

Figure 9. Hydrogen index vs. vitrinite reflectance.

close to the Type III kerogen curve in a hydrogen index (HI) vs. vitrinite reflectance plot (fig. 9). Type III kerogen indicates the source is prone to generate gas when thermally mature. The onset of oil generation corresponds to a vitrinite reflectance of at least 0.55 %Ro (Peters, 1986). Vitrinite reflectance values of 0.33 and 0.34 Ro% indicate the coals are submature. The HI vs. OI plot indicates these samples fall in the oil/gas and gas fields (fig. 10). Rock-Eval pyrolysis analysis and vitrinite reflectance data indicate an immature, predominately gas-prone source.

ACKNOWLEDGMENTS

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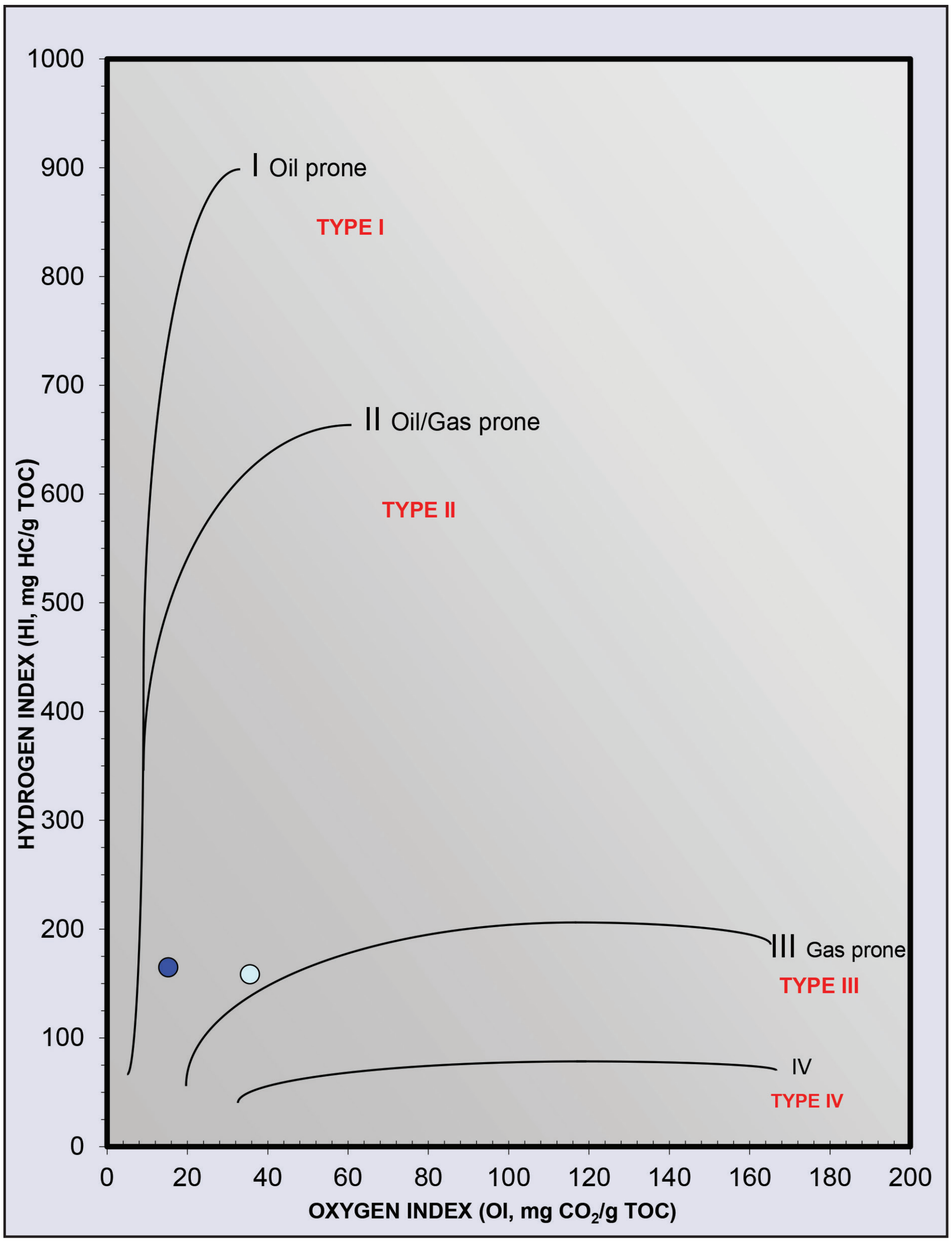

Figure 10. Hydrogen index vs. oxygen index from Rock Eval pyrolysis data. Van Krevelen diagram modified from Emeis and Kvenvolden (1986).

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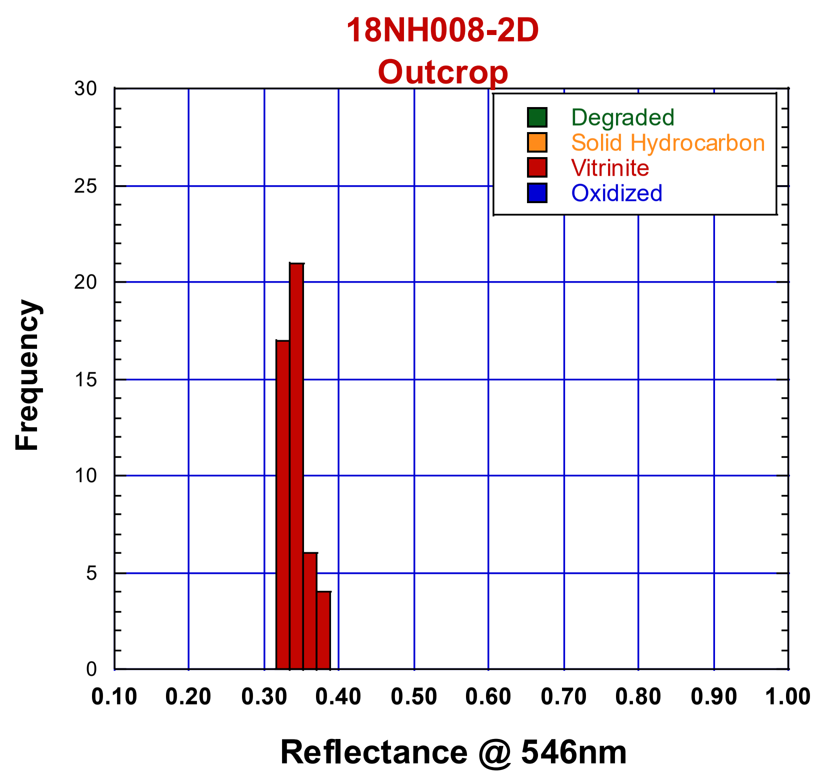
APPENDIX

Appendix included on the following pages.



Comments: Sample preparation consists of crushed outcrop mounted in epoxy and polished. There is no transmitted light slide, thus no TAI estimate. Polish on the reflected light preparation and on the humic particles is generally good however some particles are at least slightly nonplanar. Pyrite is extremely rare and typically in the form of very finely disseminated pyrite. Organic matter appears somewhat degraded in a few places in this sample. Macerals present are dominated by various types of vitrinite (may also be referred to as “huminite” at this low level of maturity). There are also lesser amounts of what appears to be faintly fluorescing suberinite, resinite, and sporinite. Spores are somewhat degraded and typically not intact. Cutinite is present but relatively uncommon. Inert content is fairly low overall predominately in the form of funginite with lesser amounts of semi-fusinite and fusinite. Based on 48 measurements of the better preserved and well polished huminite material the average Ro is 0.34%. Fluorescence is rare to sparse in places and blue-green to greenish-yellow in color with rare instances of yellow as well as a few rare instances of orange to dark orange. Fluorescence photomicrographs show the blue-green to green-yellow fluorescence color of fluorescing sporinite (left and right). Reflected light photomicrograph shows suberinite (right).

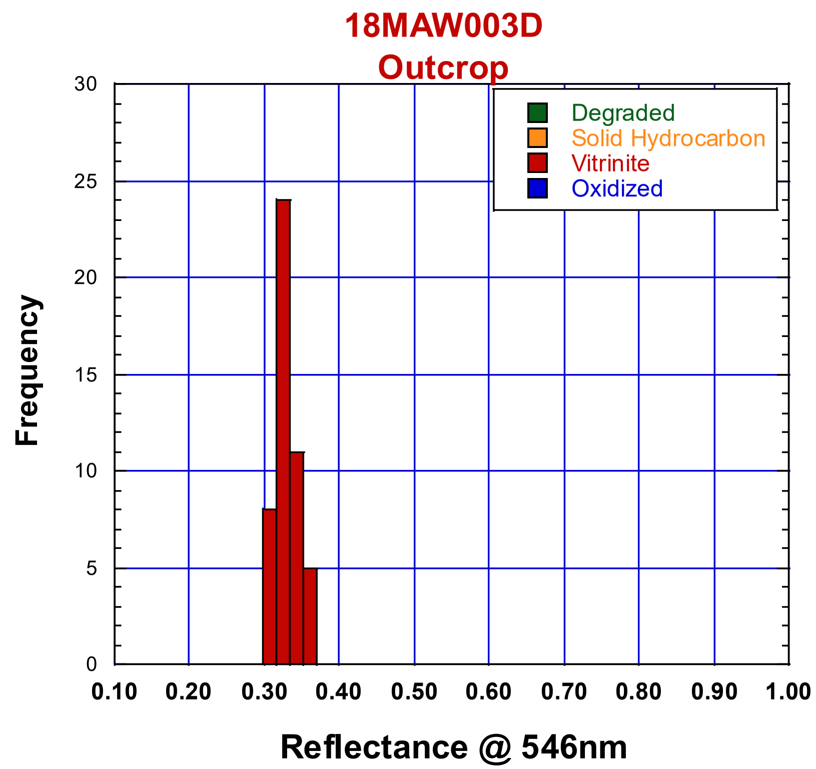
Ordered Ro Values

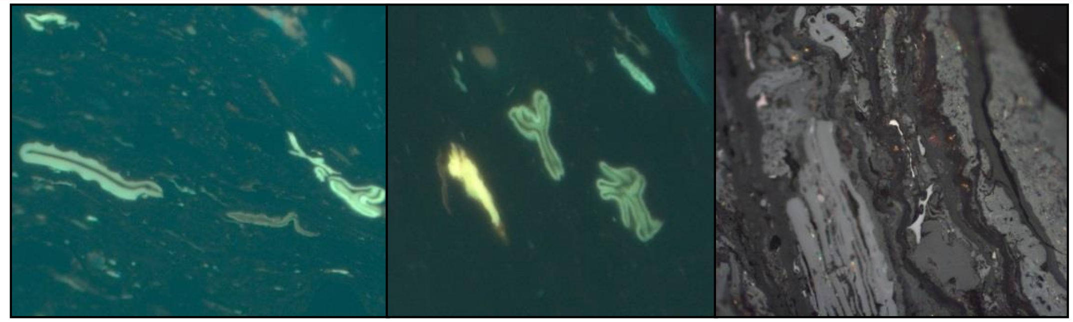
0.32	0.32	0.32	0.32	0.32	0.32	0.33	0.33	0.33	0.33	0.33	0.33
0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.34
0.34	0.34	0.34	0.34	0.34	0.35	0.35	0.35	0.35	0.35	0.35	0.35
0.35	0.35	0.36	0.36	0.36	0.36	0.36	0.36	0.37	0.37	0.37	0.37

Vitrinite	
18NH008-2D	**Outcrop**
Minimum	0.32
Maximum	0.37
Points	48
Std Deviation	0.02
Mean	**0.34**

Visual Kerogen Analysis

Sample ID	Depth	Type 1 (% Alg.)	Type 2 (% Fluorescent Lipt.)	Type 3 (% Vit.)	Type 4 (% Inert.)	Liptinite Fluores Color	% Oil Prone	% Gas Prone	TAI	Spore Color
18NH008-2D	Outcrop	1	11	85	3	Blue-green to green-yellow	12	85	NA	NA





Comments: Sample preparation consists of crushed outcrop mounted in epoxy and polished. There is no transmitted light slide, thus no TAI estimate. Polish on the reflected light preparation and on the humic particles is good. Pyrite is extremely rare and typically in the form of very finely disseminated pyrite. There is a substantial amount of inert macerals in this sample. Additional macerals present are various types of vitrinite (may also be referred to as “huminite” at this low level of maturity) and lesser amounts of cutinite, sporinite, resinite and a few rare instances of suberinite. Inert content is predominately in the form of fusinite, with slightly lesser amounts of semi-fusinite, and sparse instances of funginite. Based on 48 measurements of the better preserved and well polished huminite material the average Ro is 0.33%. Fluorescence is sparse overall and blue-green to greenish-yellow in color with instances of vivid yellow as well as a few rare instances of orange to dark orange. Fluorescence photomicrographs (left and center) show the blue-green to green-yellow fluorescence color of fluorescing sporinite and what appears to be possibly vivid yellow but degraded alginite? fragment (center photo). Reflected light photomicrograph (right) shows the complexity of this sample with a variety of macerals present.

Ordered Ro Values

0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.32	0.32	0.32	0.32
0.32	0.32	0.32	0.32	0.32	0.32	0.33	0.33	0.33	0.33	0.33	0.33
0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34
0.34	0.35	0.35	0.35	0.35	0.35	0.35	0.36	0.36	0.36	0.36	0.36

Vitrinite	
18MAW003D	**Outcrop**
Minimum	0.31
Maximum	0.36
Points	48
Std Deviation	0.02
Mean	**0.33**

Visual Kerogen Analysis

Sample ID	Depth	Type 1 (% Alg.)	Type 2 (% Fluorescent Lipt.)	Type 3 (% Vit.)	Type 4 (% Inert.)	Liptinite Fluores Color	% Oil Prone	% Gas Prone	TAI	Spore Color
18MAW003D	Outcrop	1	16	42	41	Blue-green to green-yellow	17	42	NA	NA