

Abstract

Prediction of producible hydrocarbon in unconventional formations, is vital because it governs returns on investments. Kuske *et. al.*, 2019 used a PhaseSnapShot workflow to model target well hydrocarbon phases based on PVT data and nearest slightly less mature well. Gorynski *et. al.*, 2019, showed low-maturity shales can be dominated by heavy (C_{32+}) oils and that the ratios of SARA components in the C_{15+} fraction of produced fluid and core extract can be used to estimate the mobile oil. Pepper *et.al.*, 2019 discriminated fluid saturation from sorbed oil. Prediction of producible hydrocarbon in unconventional formations is complicated by the co-occurrence of sorbed oil with fluid saturation. Our objective was to investigate and identify pyrolysis attributes that can assist in predicting producible hydrocarbon in unconventional formations. Seven core samples spanning the Eagle Ford Formation's early mature, oil window and condensate/wet gas zones were analyzed on the HAWK pyrolysis instrument using both classical bulk-flow pyrolysis and HAWK-PAM the latter of which provides insights into boiling ranges. Hydrocarbons were extracted using DCM, while the extracted rock was analyzed using both pyrolysis methods. The extract was quantified and fingerprinted using both gas chromatography and PAM. The suppression effect of 'S2 shoulders' on maturity was evident on four cores. While the S1 mg HC/g rock values for the seven core samples were 5.3, 2.23, 2.82, 2.19, 8.33, 6.68 and 3.94 for Tmax (°C) maturity values of 436, 442, 458, 465, 443, 434 and 435 respectively, their S1 + (S2_{whole rock} - S2_{extract rock}) values were 20.07, 5.13, 5.18, 3.41, 15.32, 25.6 and 12.54 mg HC/g rock respectively. These two measurements, however, do not enable the discrimination of producible hydrocarbons because of the presence of sorbed oil which is highest in early mature cores. Conversion of mg HC/g rock measurements to their respective organic carbon using the assumption that 85% of hydrocarbons content in petroleum is organic carbon, together with conversion of the quantified extracted organic matter (EOM) from ppm to weight % enabled the identification of a new set of pyrolysis attributes; For the Tmax (°C) maturity values of 436, 442, 458, 465, 443, 434 and 435 respectively, S1 Organic Carbon/EOM was 0.18, 0.27, 0.34, 0.3, 0.42, 0.18, and 0.23; The $(C_4 - C_{19})/EOM$ ratio was 0.05, 0.1, 0.14, 0.14, 0.17, 0.05 and 0.09 while that of $(C_4 - C_{36})/EOM$ was 0.31, 0.36, 0.5, 0.39, 0.55, 0.24 and 0.34 respectively. The ratio of $(C_4 - C_{19})/(C_4 - C_{36})$ yielded values of 0.17, 0.27, 0.28, 0.37, 0.31, 0.22 and 0.25. These four pyrolysis attributes enable ranking of predicted producible hydrocarbons, with the highest to lowest values in each of the attributes, corresponding to highest to lowest producible hydrocarbon contents. Determination of these pyrolysis attributes for a producing interval can provide calibration for predicting similar production.

Introduction

Seven core samples spanning the Eagle Ford Formation's early mature, oil window and condensate/wet gas zones (Figure 1 and Figure 2) were analyzed as whole rock, extracts and extracted rock, with the objective of investigating and identifying pyrolysis attributes that can assist in predicting producible hydrocarbon in unconventional formations. This is a vital need because it governs returns on investments. Kuske *et. al.*, 2019 used a PhaseSnapShot workflow to model target well hydrocarbon phases based on PVT data and nearest slightly less mature well. Gorynski *et. al.*, 2019, showed low-maturity shales can be dominated by heavy (C_{32+}) oils and that the ratios of SARA components in the C_{15+} fraction of produced fluid and core extract can be used to estimate the mobile oil. Pepper *et.al.*, 2019 discriminated fluid saturation from sorbed oil. Prediction of producible hydrocarbon in unconventional formations is complicated by the co-occurrence of sorbed oil with fluid saturation.

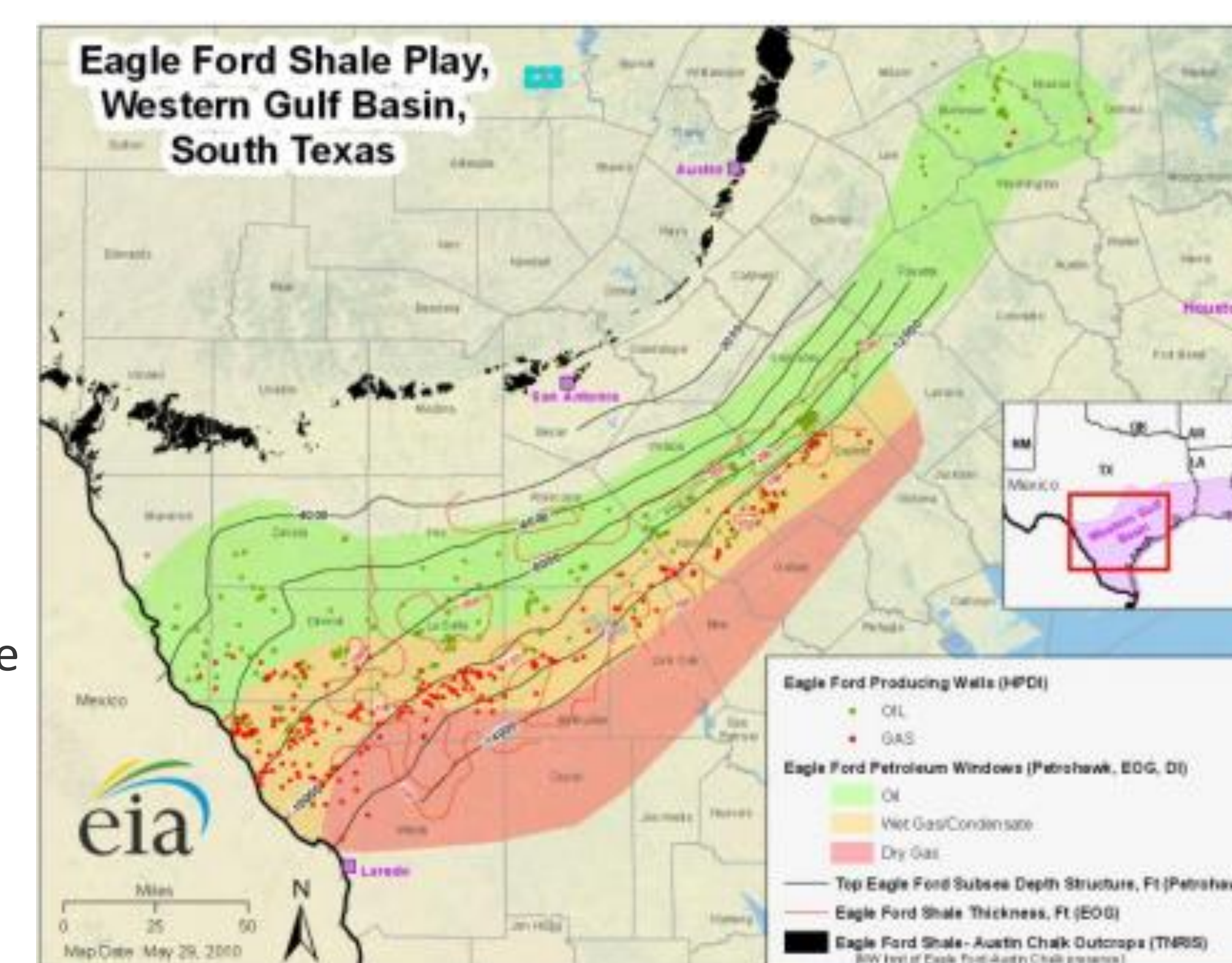


Figure 1. Eagle Ford Shale Play, Western Gulf Basin, South Texas (EIA, 2014)

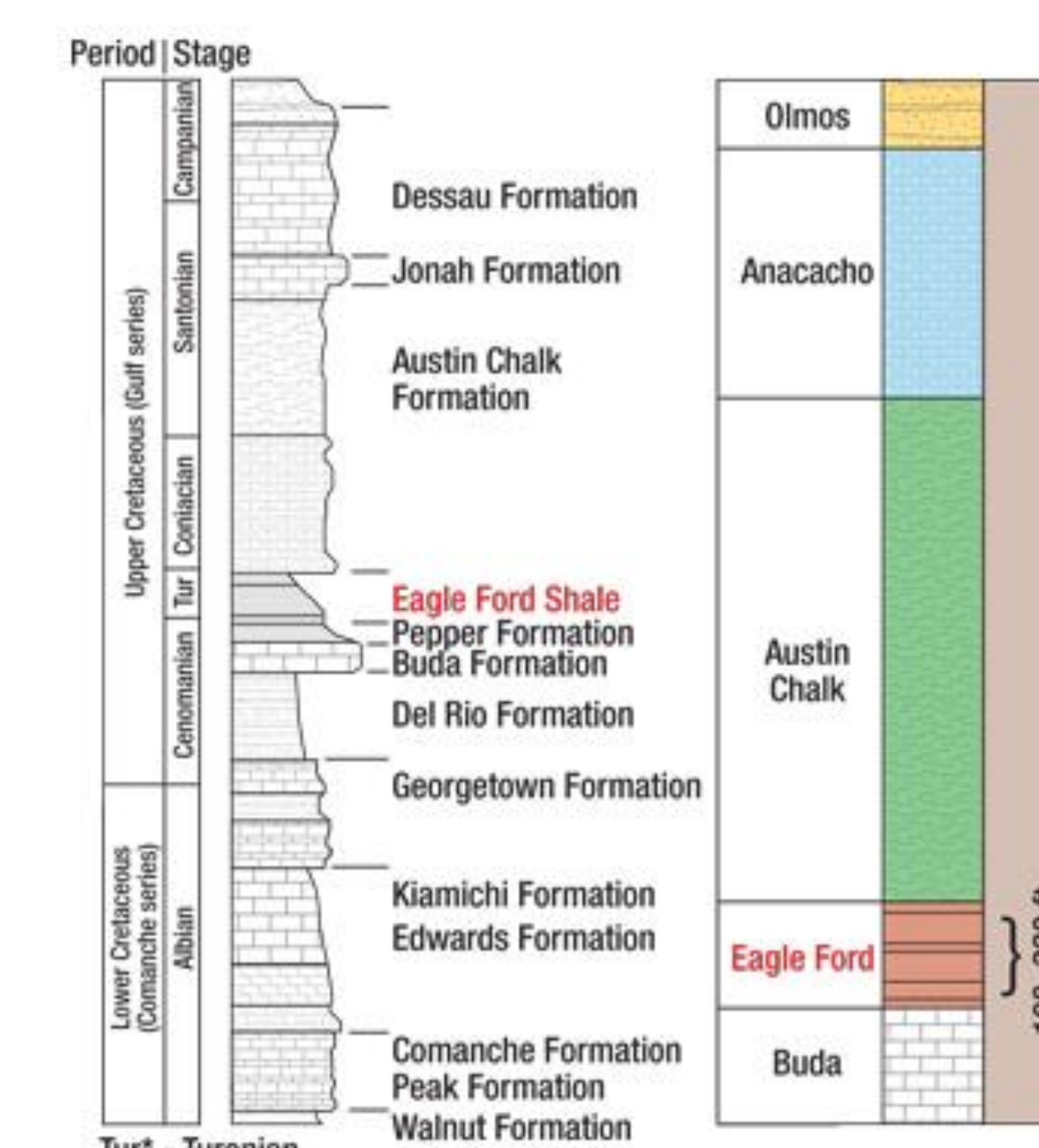


Figure 2. Stratigraphy of Western Gulf Basin, South Texas (Ononogbu, 2012)

As a result of this study, the Shale Prospectivity Tool has been developed. The objective of the Shale Prospectivity Pyrolysis Tool is to utilize Six Pyrolysis Attributes to Predict the Occurrence of Producing Hydrocarbons and in addition, also map Structures. The six pyrolysis attributes are determined through conversion of two Classical Pyrolysis rock measurements and four HAWK-PAM rock measurement's mg HC/g rock (milligram hydrocarbons per gram rock), values to their respective organic carbon using the assumption that 85% of hydrocarbons content in petroleum is organic carbon. These values are then normalized to either their respective TOC (Total Organic Carbon) or Extractable Organic Matter (EOM) measurements.

Analyses

The core samples were analyzed on the HAWK pyrolysis instrument using both classical bulk-flow pyrolysis and HAWK-PAM the latter of which provides insights into boiling ranges. Hydrocarbons were extracted using dichloromethane (DCM), while the extracted rock was analyzed using both pyrolysis methods. The extract was quantified and fingerprinted using both gas chromatography and PAM.

HAWK® Pyrolysis

The seven core and extracted core samples were analyzed on the HAWK Pyrolysis, TOC & Carbonate Carbon instrument using two pyrolysis methods, namely; Classical Pyrolysis and HAWK-PAM.

Classical Pyrolysis was performed; these are analyses to determine thermally released oil (S1 in mg HC/g rock) at 300 °C, hydrocarbons yield from pyrolysis of kerogen (S2 in mg HC/g rock) through heating in an inert environment using a ramp rate of 25 °C from 300 to 650 °C, pyrolysis measurements of both CO and CO₂ (S3CO in mg CO/g rock and S3CO₂ in mg CO₂/g rock) and maturity (Tmax in °C) determined as the temperature at the maximum generation of hydrocarbons on the S2 peak.

HAWK-PAM, analyses were performed whereby, a ramp rate of 25 °C is utilized to generate five petroleum peaks – four on oil fractions and one on kerogen. It is a pyrolysis method through which, determination of the occurrence of carbon number groupings corresponding to C₄ – C₅ (Oil-1) at ~50 – 100 °C, C₆ – C₁₀ (Oil-2) at 100 °C, C₁₁ – C₁₉ (Oil-3) at 100 – 180 °C, C₂₀ – C₃₆ (Oil-4) at 180 – 350 °C and C₃₇₊ (K-1; Kerogen plus any C₃₇₊) at 350 – 650 °C, is done. In addition, maturity (K-1 Tmax in °C) is determined as the temperature at the maximum generation of hydrocarbons on the K-1 peak (Maende *et. al.*, 2017).

Extractable Organic Matter (EOM)

Quantitative extraction of extracts for Gas Chromatography analyses was done using the Dionex ASE 350 model.

For Dionex extraction, the rock sample is ground to 60 mesh size, after which a weight of sample ranging from 5 to 20 grams is placed into the Dionex' steel extraction cell and then using dichloromethane as the solvent, extraction of the oil is done within the 40 °C to 100 °C operating temperature range of the Dionex. The extract is then dried under a fume hood and weighed for quantification.

Gas Chromatography (GC)

Whole Oil Gas Chromatography on the extracted oil was performed using an Agilent GC.

Petroleum extracted from rock samples can be fingerprinted by gas chromatography (GC). A fingerprint of petroleum provides an indication of the distribution and yield of resolvable compounds, i.e., basically a histogram of the individual compounds that can be separated by this analytical technique. An oil or extract with an internal standard(s) is injected into a GC inlet which vaporizes the petroleum in the presence of an inert carrier gas onto a capillary column that may range from 10 to 150 meters in length. The internal surface of the column is coated with a chemical phase utilized for the required analytical need. This chemical phase interacts with the hydrocarbon molecules moving through the length of the column resulting in separation of the alkanes as well as many iso-alkanes, cyclo-alkanes, and some aromatic hydrocarbons. The end of the column passes the effluent into a flame ionization detector (FID). Integration of the fingerprint provides the weight or mole percent of each compound relative to the internal standard(s) and is used to characterize the alkane fraction of the petroleum (Jarvie, 2015).

Investigation and Identification of Pyrolysis Attributes that can Assist in Predicting Producing Hydrocarbon in the Unconventional Eagle Ford Formation

Presented at: AAPG 2020 Annual Convention & Exhibition, Houston, Texas, USA, September 29th – October 1st by Albert Maende¹, Brian Horsfield², Sascha Kuske², Brian Jarvie³, Dan Jarvie¹, and W. David Weldon¹

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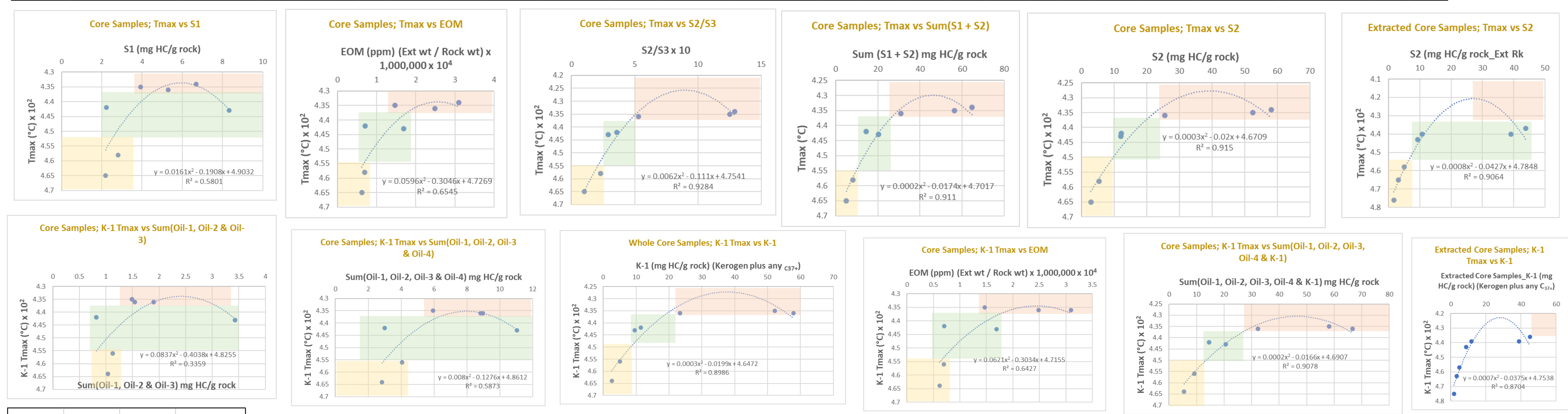
Results and Interpretation

Classical Pyrolysis, HAWK-PAM, Extractable Organic Matter (EOM) and Gas Chromatography (GC)

Table 1. Classical Pyrolysis, HAWK-PAM and Extractable Organic Matter

Sample ID	Method	Sample Type	S1 (mg HC/g rock)	S2 (mg HC/g rock)	S3 (mg CO2/g rock)	Tmax (°C)	Production Index (S1/S1 + S2)	Sum(S1 + S2) mg HC/g rock	Extractable Organic Matter (EOM) (ppm)	S1 _{whrk} - S1 _{extrk} + S2 _{whrk} - S2 _{extrk} (Jarvie, 2012)	Sample ID	Method	Sample Type	Oil-1 (mg HC/g rock) (C ₄ - C ₅)	Oil-2 (mg HC/g rock) (C ₆ - C ₁₀)	Oil-3 (mg HC/g rock) (C ₁₁ - C ₁₉)	Oil-4 (mg HC/g rock) (C ₂₀ - C ₃₆)	K-1 (mg HC/g rock) (Kerogen plus any C ₃₇₊)	K-1 Tmax (°C)	Sum(Oil-1, Oil-2 & Oil-3) mg HC/g rock	Sum(Oil-1, Oil-2, Oil-3 & Oil-4) mg HC/g rock	Whole Core Sum(Oil-1, Oil-2, Oil-3, Oil-4 & K-1) - Ext Core Sum(Oil-1, Oil-2, Oil-3, Oil-4 & K-1) mg HC/g rock	Mobility Index; Sum(Oil-1, Oil-2 & Oil-3)/Sum(Oil-1, Oil-2, Oil-3 & Oil-4) (Sum of C ₄ - C ₃₆)	S2 - K1 (mg HC/g rock)	Sum(Oil-1, Oil-2, Oil-3 & Oil-4) - S1 (mg HC/g rock)	
G014171	Classical Pyrolysis	Core	5.30	25.55	0.48	436	0.17	30.85	24817	19.91	G014171	HAWK-PAM	Core	0	0.07	1.47	7.43	23.32	436	1.54	8.97	32.29	20.33	0.17	2.23	3.67
G014174	Classical Pyrolysis	Core	2.23	12.17	0.34	442	0.15	14.40	7015	4.93	G014174	HAWK-PAM	Core	0	0.04	0.78	2.19	11.47	442	0.82	3.01	14.48	5.42	0.27	0.70	0.78
G014177	Classical Pyrolysis	Core	2.82	5.46	0.24	458	0.34	8.28	6955	4.95	G014177	HAWK-PAM	Core	0	0.07	1.06	2.93	5.11	456	1.13	4.06	9.17	5.49	0.28	0.35	1.24
G014180	Classical Pyrolysis	Core	2.19	2.91	0.29	465	0.43	5.10	6174	3.16	G014180	HAWK-PAM	Core	0	0.11	0.93	1.8	2.6	464	1.04	2.84	5.44	3.35	0.37	0.31	0.65
G014183	Classical Pyrolysis	Core	8.33	11.99	0.41	443	0.41	20.32	16943	15.01	G014183	HAWK-PAM	Core	0.02	0.37	3.04	7.61	9.54	443	3.43	11.04	20.58	15.33	0.31	2.45	2.71
G014185	Classical Pyrolysis	Core	6.68	58.08	0.45	434	0.1	64.76	30933	25.47	G014185	HAWK-PAM	Core	0	0.2	1.7	6.92	57.9	436	1.9	8.82	66.72	27.56	0.22	0.18	2.14
G014188	Classical Pyrolysis	Core	3.94	52.47	0.42	435	0.07	56.41	14700	12.41	G014188	HAWK-PAM	Core	0.01	0.23	1.25	4.44	52.2	435	1.49	5.93	58.13	12.84	0.25	0.27	1.99
G014171	Classical Pyrolysis	Extracted Core	0.16	10.78	0.27	440	0.01	10.94			G014171	HAWK-PAM	Extracted Core	0	0	0.07	0.23	11.66	439	0.07	0.3	11.96				
G014174	Classical Pyrolysis	Extracted Core	0.20	9.27	0.30	443	0.02	9.47			G014174	HAWK-PAM	Extracted Core	0	0	0.07	0.18	8.81	443	0.07	0.25	9.06				
G014177	Classical Pyrolysis	Extracted Core	0.23	3.10	0.31	465	0.07	3.33			G014177	HAWK-PAM	Extracted Core	0	0	0.07	0.27	3.34	463	0.07	0.34	3.68				
G014180	Classical Pyrolysis	Extracted Core	0.25	1.69	0.26	476	0.13	1.94			G014180	HAWK-PAM	Extracted Core	0	0.01	0.12	0.2	1.76	475	0.13	0.33	2.09				
G014183	Classical Pyrolysis	Extracted Core	0.31	5.00	0.42	458	0.06	5.31			G014183	HAWK-PAM	Extracted Core	0	0.01	0.1	0.26	4.88	457	0.11	0.37	5.25				
G014185	Classical Pyrolysis	Extracted Core	0.13	39.16	0.31	440	0.00	39.29			G014185	HAWK-PAM	Extracted Core	0	0	0.05	0.38	38.73	439	0.05	0.43	39.16				
G014188	Classical Pyrolysis	Extracted Core	0.13	43.87	0.25	437	0.00	44.00			G014188	HAWK-PAM	Extracted Core	0	0	0.03	0.27	44.99	436	0.03	0.3	45.29				

The suppression effect of 'S2 shoulders' on maturity was evident on four cores (those of Tmax 436, 458, 465 and 443). The "S2 shoulder" which is an overlap of the heavier oil component from S1 into S2 is quantifiable through the almost equality of the "S2 - K1" value with the "Sum(Oil-1, Oil-2, Oil-3 and Oil-4) - S1" value of the cores of Tmax 442 and 443 which are of mid oil window maturity (Table 1).



Immature
Oil Window
Condensate to Wet Gas

Figure 3. Graphical Plots of Selected Pyrolysis Measurements against Tmax

Table 2. Summary of the Various Ranges of Pyrolysis Parameters that Demarcate the Immature, Oil Window and Condensate to Wet Gas Zones

Maturity	S1 (mg HC/g rock) from Tmax vs S1	EOM (ppm) from Tmax vs EOM	S2/S3 from Tmax vs S2/S3	Sum(S1 + S2) (mg HC/g rock) from Tmax vs Sum(S1 + S2)	S2 (mg HC/g rock) from Tmax vs S2	K-1 Tmax (°C) from K-1 Tmax vs Sum(Oil-1, Oil-2 & Oil-3)	K-1 Tmax (°C) from K-1 Tmax vs Sum(Oil-1, Oil-2, Oil-3 & Oil-4)	K-1 (mg HC/g rock) from K-1 Tmax vs K-1	K-1 (mg HC/g rock) from K-1 Tmax vs EOM	K-1 (mg HC/g rock) from K-1 Tmax vs Sum(Oil-1, Oil-2, Oil-3, Oil-4 & K-1)	S2 (mg HC/g rock) from Tmax vs S2	K-1 (mg HC/g rock) from K-1 Tmax vs K-1
Immature (< 435 °C Tmax)	3.5 - 10	1.3 - 4	5 to 15	25 - 80	23 to 70	1.2 - 3.4	5.5 - 12	21 - 60	1.4 to 3.5	27 - 80	27 to 50	48 - 60
Oil Window (435 °C - 455 °C Tmax)	2 to 10	0.5 - 1.8	2.5 to 5	10 to 25	10 to 23	0.7 - 3.5	1.5 - 12	9 to 21	0.5 - 1.8	11 to 27	7 to 46	5 to 48
Condensate to Wet Gas (455 °C - 475 °C Tmax)	0 - 3.5	0 - 0.8	0 to 2.5	0 to 10	0 to 10	0.7 - 1.2	0 - 4.3	0 to 9	0.5 - 0.8	0 - 11	0 to 8	0 to 5

Graphical plots of selected pyrolysis measurements against Tmax (Figure 3) demonstrate that the immature, oil window and condensate to wet gas zones plot along elliptical arcs that have specified exponential equations with correlation values that range from an R² of 0.59 to 0.93. The highest R² values are in the 0.90 to 0.93 range and are those of Tmax vs S2, Tmax vs S2/S3, and K-1 Tmax vs K-1. Table 2 is a summary of the various ranges of pyrolysis measurements that demarcate the immature, oil window and condensate to wet gas zones.



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Gas Chromatography (GC) and Evaporative Loss

Figure 4 shows the gas chromatography (GC) fingerprints of the extracts of the seven core samples. Samples G014177, G014180 and G014183 whose Tmax values are 458, 465 and 443 respectively, have evaporative losses of 82.6% for nC₁₉, 83.7% for nC₁₉, and 84.2% for nC₂₀, respectively (Table 4).

Sample ID	Sample Type	S1 (mg HC/g rock)	S2 (mg HC/g rock)	S3 (mg CO ₂ /g rock)	Tmax (°C)
G014171	Core / Extracted Core	5.3 / 0.16	25.55 / 10.78	0.48 / 0.27	436 / 440
G014174	Core / Extracted Core	2.23 / 0.20	12.17 / 9.27	0.34 / 0.30	442 / 443
G014177	Core / Extracted Core	2.82 / 0.23	5.46 / 3.10	0.24 / 0.31	458 / 465
G014180	Core / Extracted Core	2.19 / 0.25	2.91 / 1.69	0.29 / 0.26	465 / 476
G014183	Core / Extracted Core	8.33 / 0.31	11.99 / 5.00	0.41 / 0.42	443 / 458
G014185	Core / Extracted Core	6.68 / 0.13	58.08 / 39.16	0.45 / 0.31	434 / 440
G014188	Core / Extracted Core	3.94 / 0.13	52.47 / 43.87	0.42 / 0.25	435 / 437

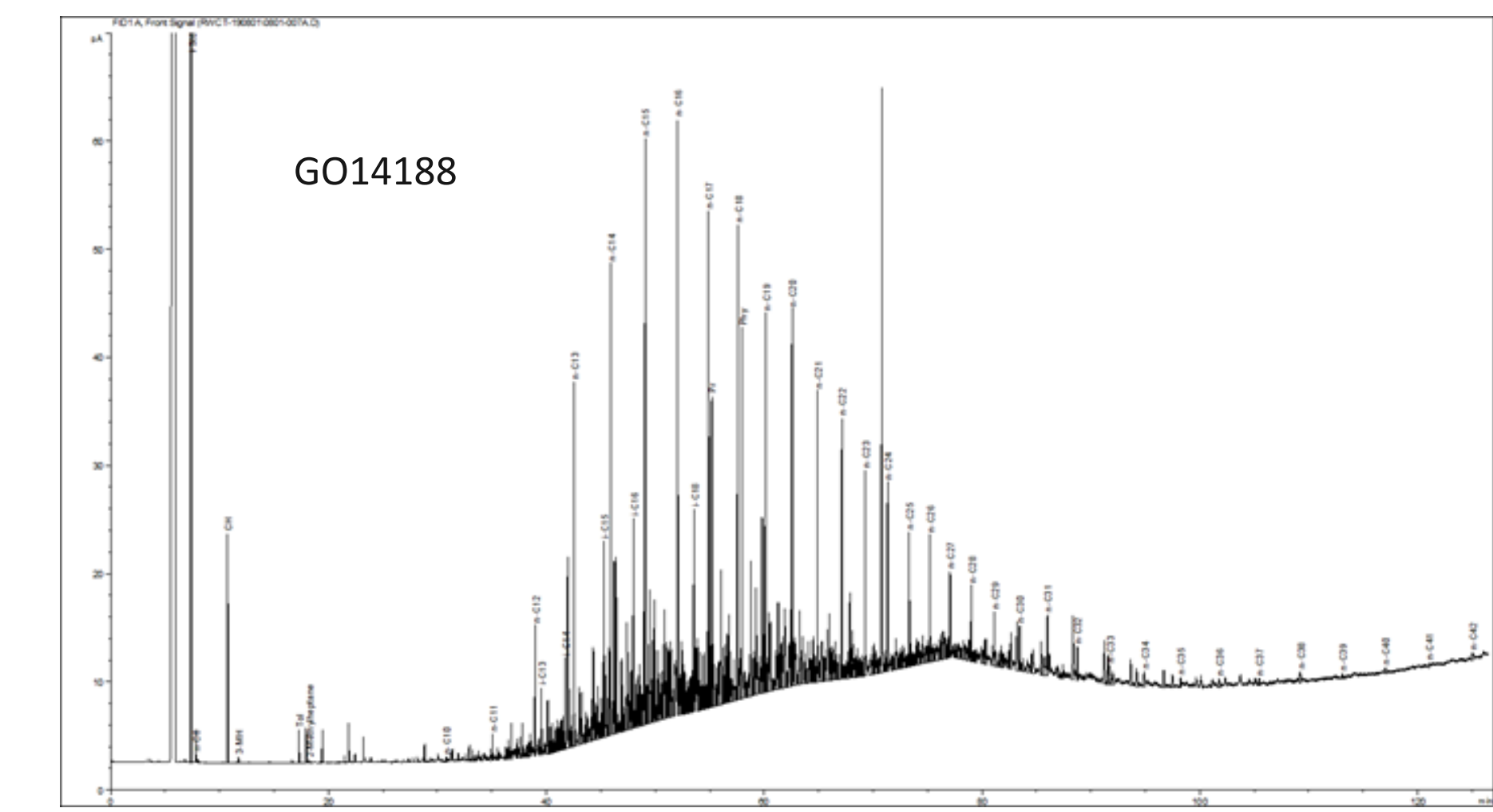
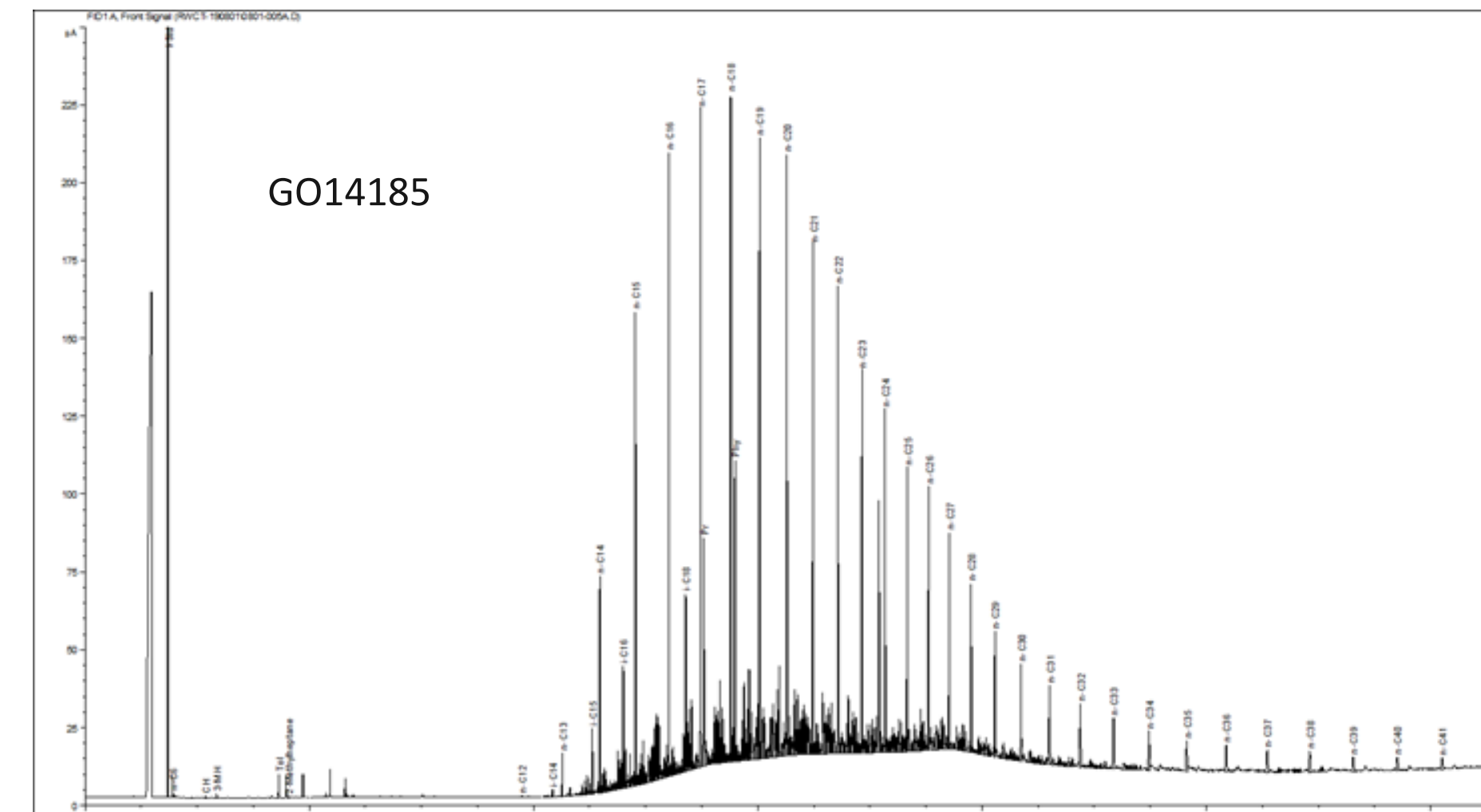
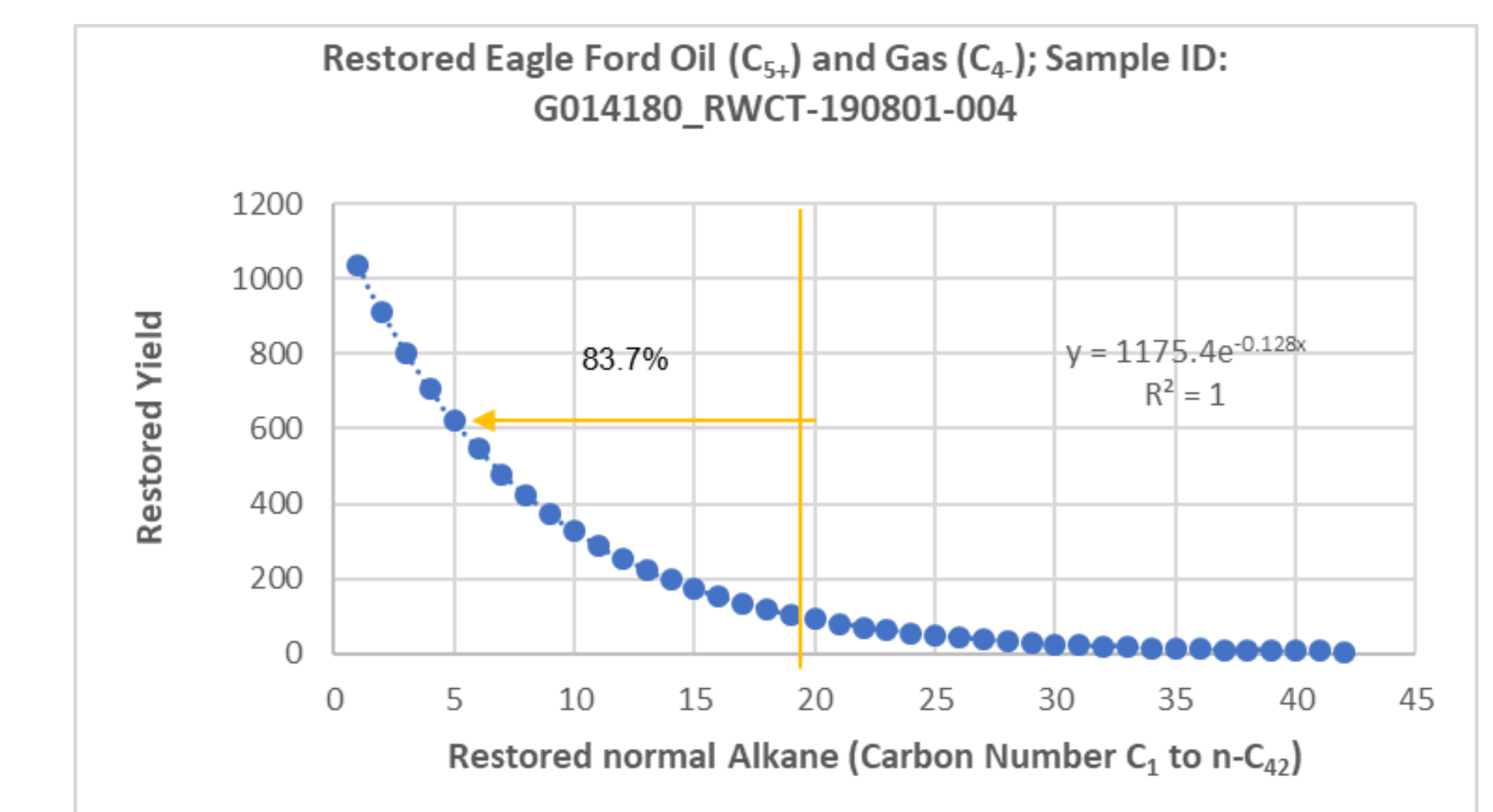
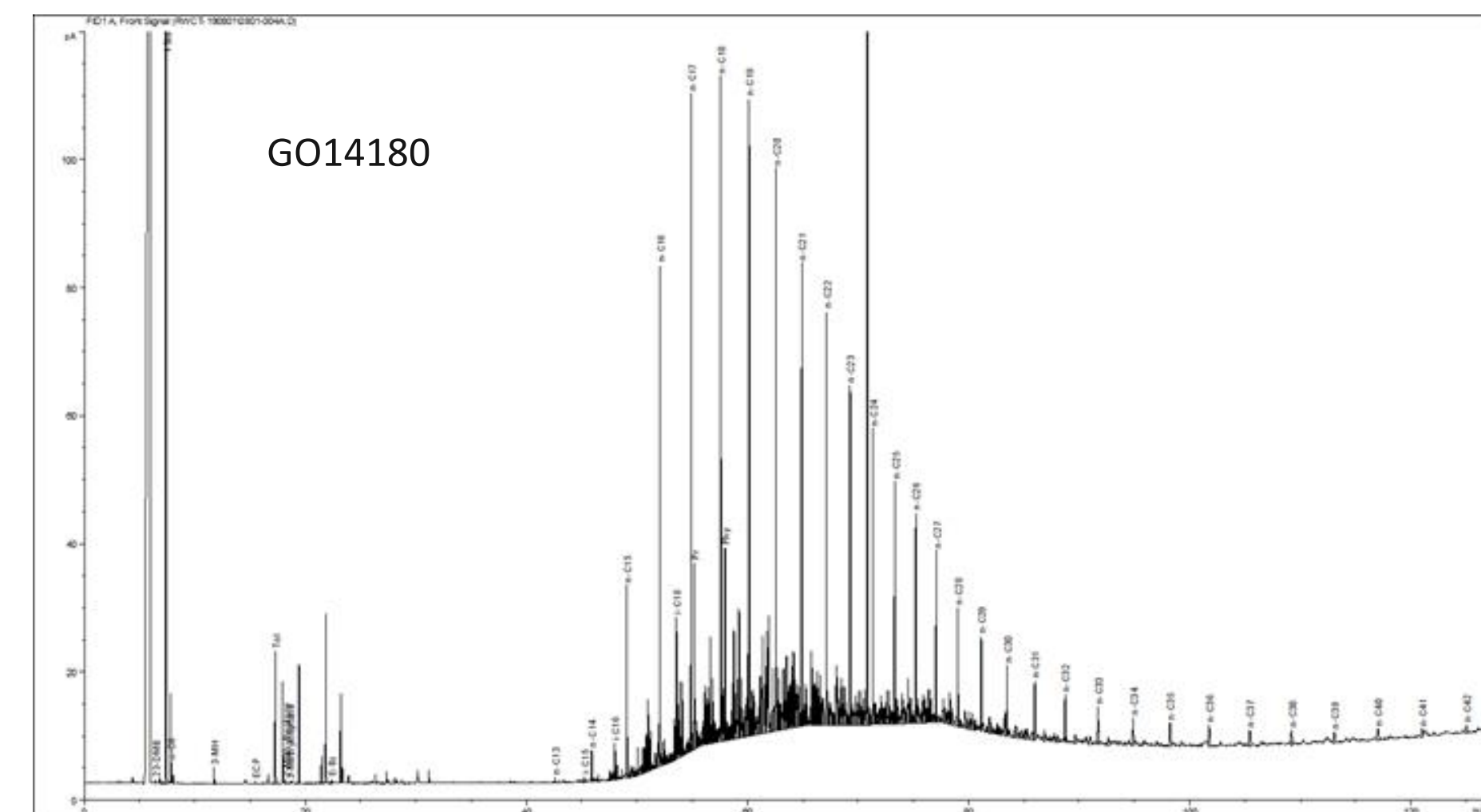
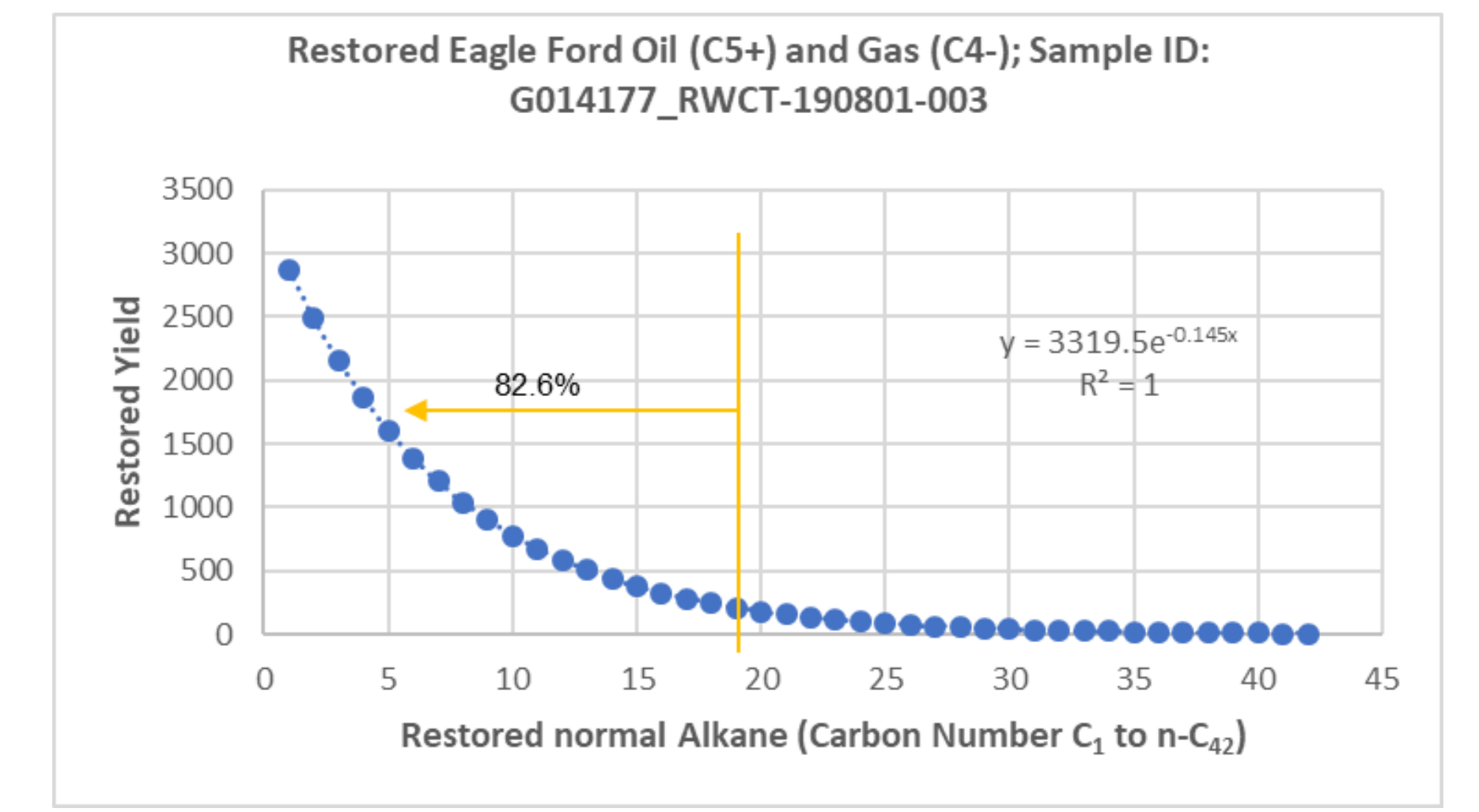
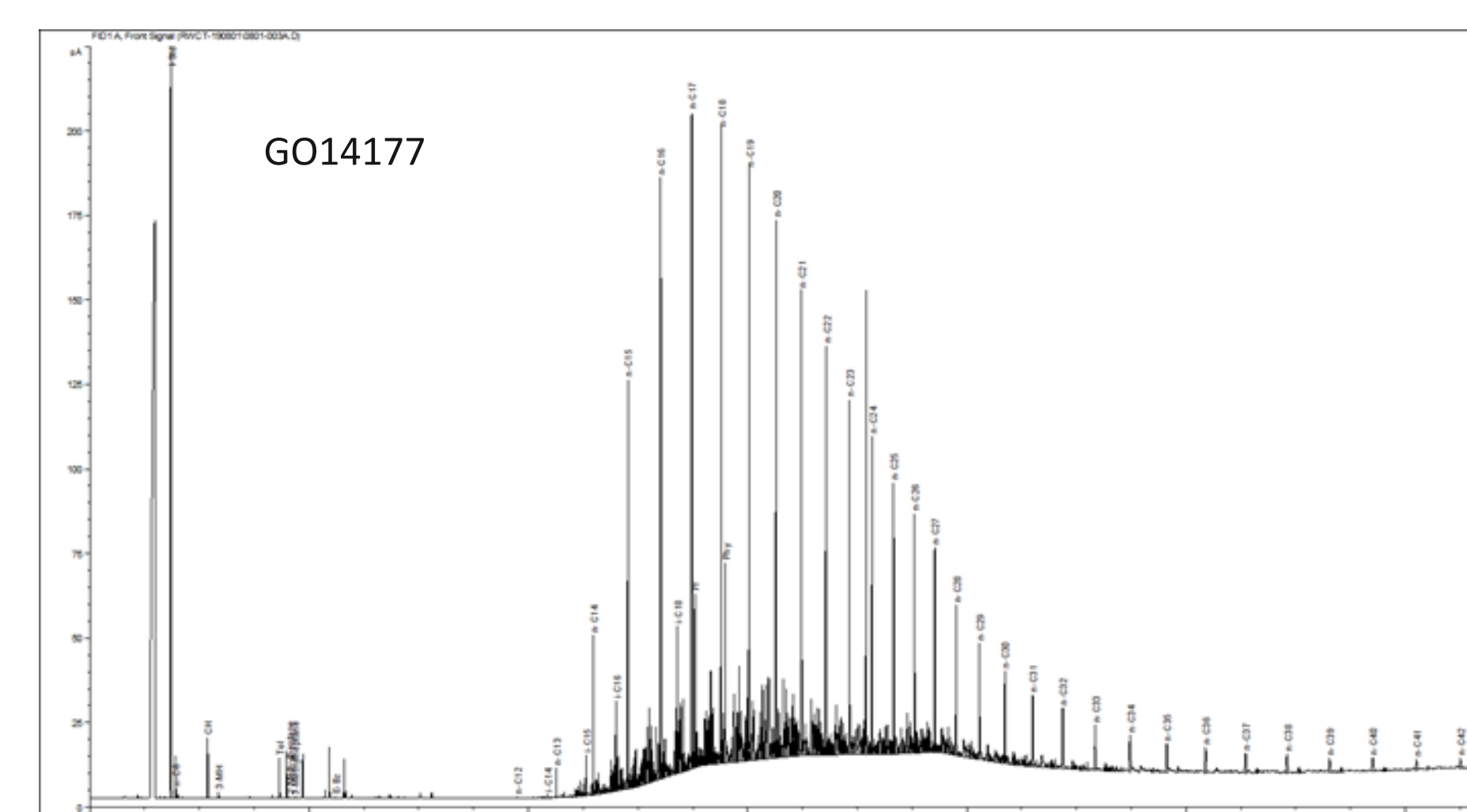
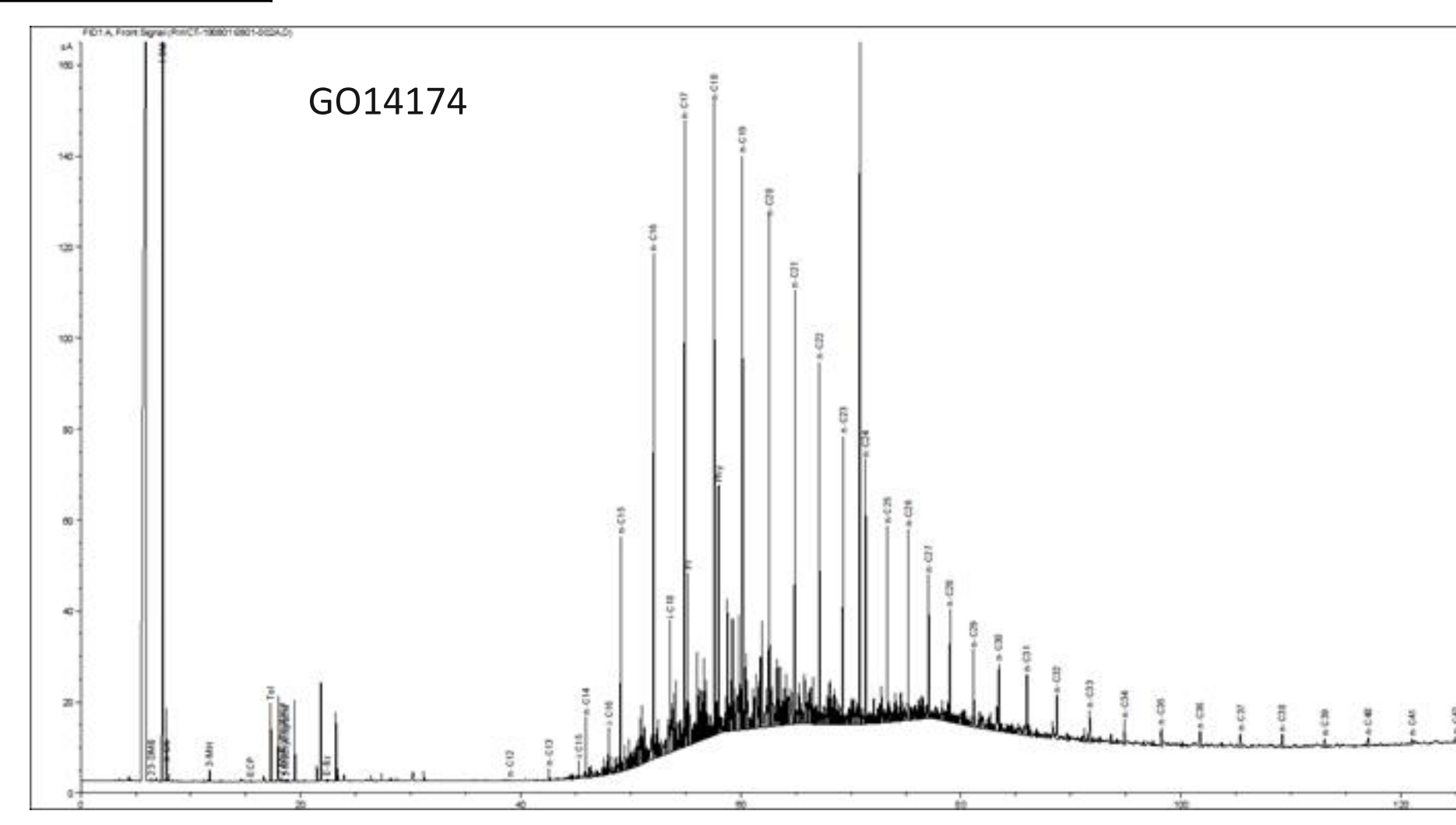
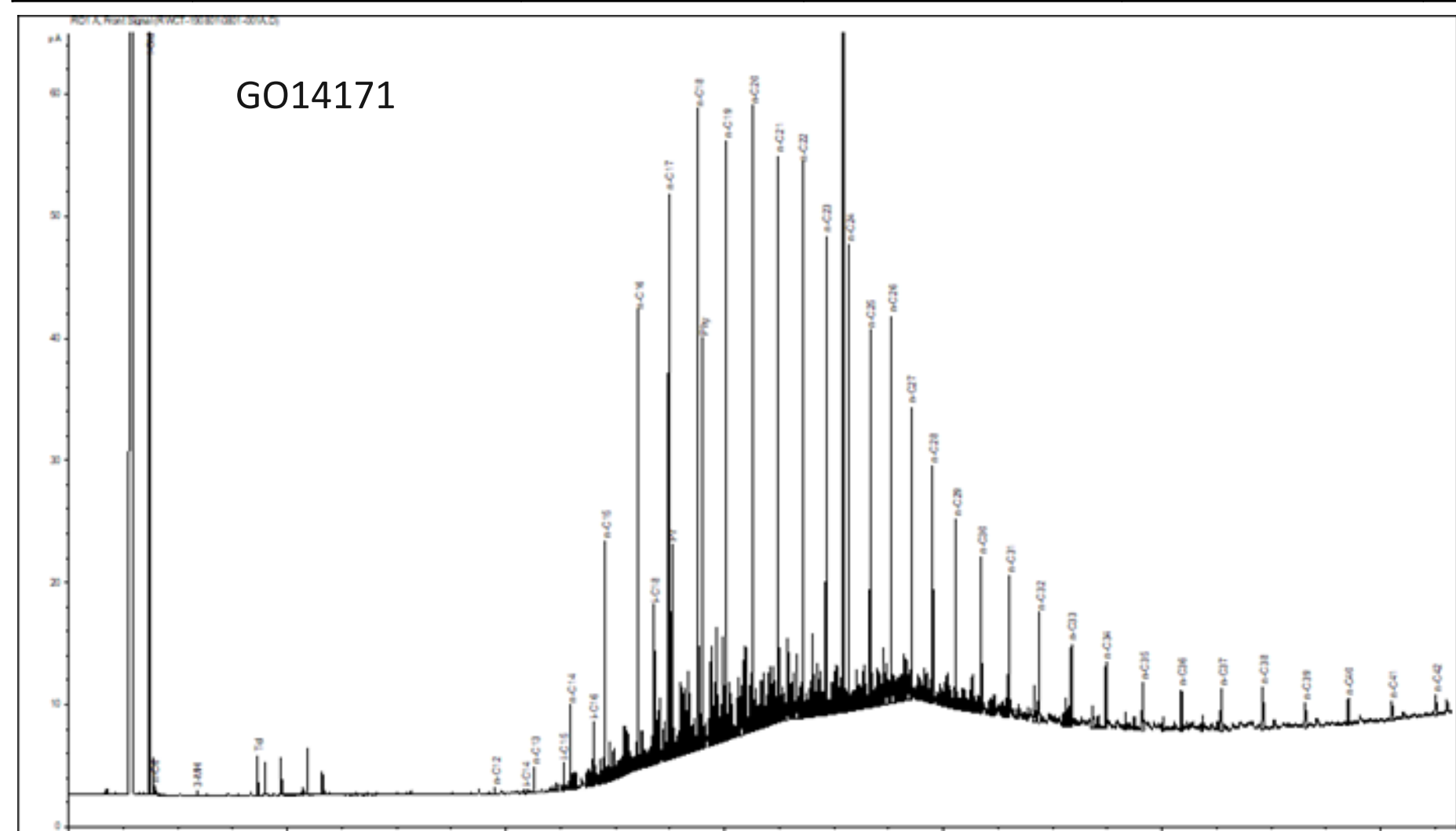


Figure 4. Gas Chromatography (GC) Fingerprints of the Extracts of the Seven Core Samples

Seven core samples spanning the Eagle Ford Formation's early mature, oil window and condensate/wet gas zones were analyzed both as whole rock and extracted rock, whereby, six pyrolysis attributes that can assist in predicting producible hydrocarbon in unconventional formations and also map structures were identified and collectively labelled as "the Shale Prospectivity Tool". The six pyrolysis attributes are determined through conversion of two Classical Pyrolysis rock measurements and four HAWK-PAM rock measurement's mg HC/g rock values to their respective organic carbon with the assumption that 85% of hydrocarbons content in petroleum is organic carbon. These values are then normalized to either their respective TOC or EOM measurements. The suppression effect of 'S2 shoulders' on maturity was evident on four cores (those of Tmax 436, 458, 465 and 443). The "S2 shoulder" which is an overlap of the heavier oil component from S1 into S2 is quantifiable through the almost equality of the "Sum(Oil-1, Oil-2, Oil-3 and Oil-4 - S1)" value of the cores of Tmax 442 and 443 which are of mid oil window maturity. Graphical plots of selected pyrolysis measurements against Tmax (Figure 3) demonstrate that the immature, oil window and condensate to wet gas zones plot along elliptical arcs that have specified exponential equations with correlation values that range from an R² of 0.59 to 0.93. The highest R² values are in the 0.90 to 0.93 range and are those of Tmax vs S2, Tmax vs S2/S3, and K-1 Tmax vs K-1. Samples G014177, G014180 and G014183 whose Tmax values are 458, 465 and 443 respectively, have evaporative losses of 82.6% for nC₁₉, 83.7% for nC₁₉, and 84.2% for nC₂₀, respectively. An analyzed sample that has at least three of the Shale Prospectivity Tool's pyrolysis attributes either equating or exceeding the cut-off value is considered to be indicative of a producible oil zone. All the seven core samples fulfill the Shale Prospectivity Tool's conditions for being identified as being in a producible oil zone. However it is only the G014180 core of Tmax 465 °C (K-1 Tmax 464 °C) that equates or exceeds the Mobility Index pyrolysis attribute cut-off value. A graphical plot of the Shale Prospectivity Tool's Pyrolysis Attribute 1 (S1*°C in HCs/EOM) against Pyrolysis Attribute 6 (S2*°C in HCs/EOM) maps the drilled structure and show the separation between these values to be widest in the immature zone, of intermediate width in the oil window and so close to each other as to be virtually touching in the condensate to wet gas zone.

Conclusions

Shale Prospectivity Tool

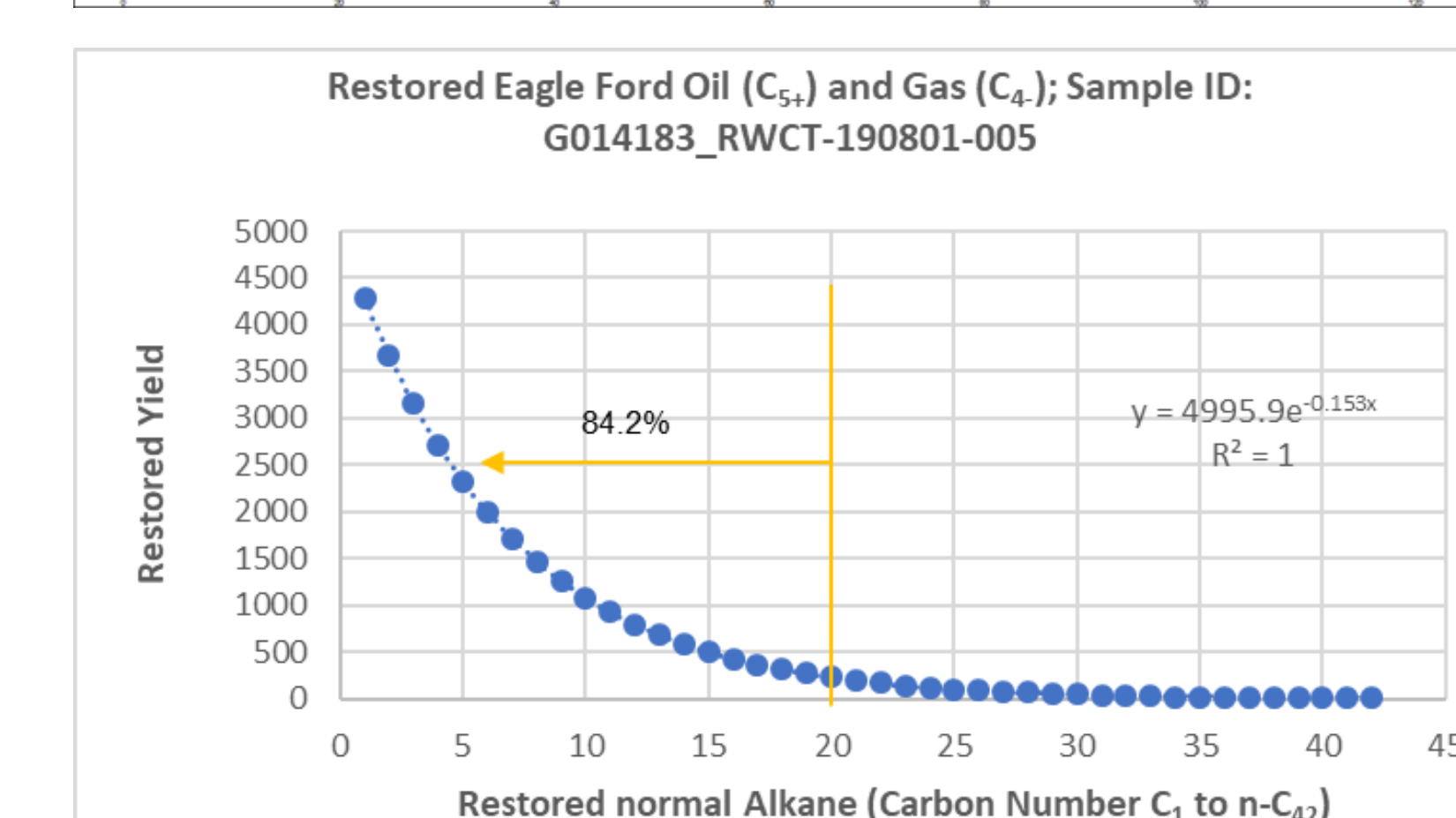
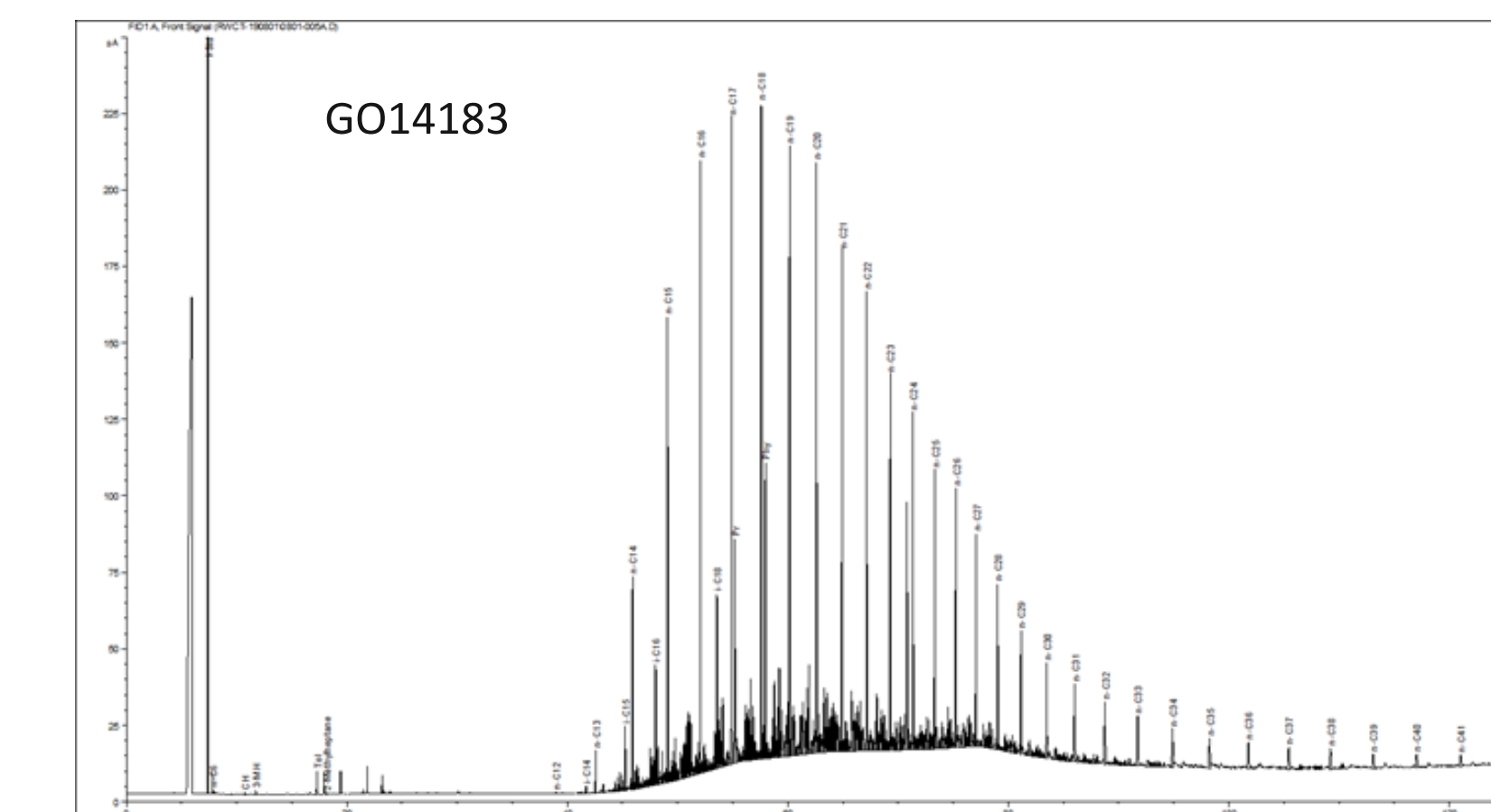
The Six Pyrolysis Attributes of the Shale Prospectivity Tool are defined as shown below:

- Pyrolysis Attribute 1: - Classical Pyrolysis' S1 organic carbon content in hydrocarbons normalized to either EOM or TOC. i.e., S1*°C in HCs/EOM or TOC
- Pyrolysis Attributes 2, 3, 4 and 5 are all derived from HAWK-PAM measurements:
- Pyrolysis Attribute 2: - Oil4 (C₂₀-C₃₆)*°C in HCs/EOM or TOC
- Pyrolysis Attribute 3: - Sum of Oil1, Oil2, & Oil3 (C₄-C₁₉)*°C in HCs/EOM or TOC
- Pyrolysis Attribute 4: - Sum of Oil1, Oil2, Oil3 & Oil4 (C₄-C₃₆)*°C in HCs/EOM or TOC
- Pyrolysis Attribute 5 is the Mobility Index: - Sum(Oil1, Oil2 & Oil3)/Sum(Oil1, Oil2, Oil3 & Oil4) (C₄ - C₁₉/C₄ - C₃₆)
- Pyrolysis Attribute 6: - Classical Pyrolysis' S2 kerogen pyrolyzed hydrocarbons normalized to either EOM or TOC. i.e., S2*°C in HCs/EOM or TOC

Each of these five pyrolysis attributes has been assigned a cut-off value that it needs to either equal or exceed in order for it to be a candidate to be utilized in identifying a producible oil zone. An analyzed sample that has at least three of these pyrolysis attributes either equating or exceeding the cut-off value is considered to be indicative of a producible oil zone. Table 5 and Figure 5 show that all the seven core samples fulfill the Shale Prospectivity Tool's conditions for being identified as being in a producible oil zone. However it is only the G014180 core of Tmax 465 °C (K-1 Tmax 464 °C) that equates or exceeds the Mobility Index cut-off value.

Table 5. Pyrolysis Attributes of the Shale Prospectivity Tool

Sample Type	Sample ID	S1*°C in HCs/EOM; Pyrolysis Attribute 1_0.1 as cut off	Oil4 (C ₂₀ -C ₃₆)*°C in HCs/EOM; Pyrolysis Attribute 2_0.05 as cut off	Sum of Oil1, Oil2, & Oil3 (C ₄ -C ₁₉)*°C in HCs/EOM; Pyrolysis Attribute 3_0.05 as cut off	Sum of Oil1, Oil2, Oil3 & Oil4 (C ₄ -C ₃₆)*°C in HCs/EOM; Pyrolysis Attribute 4_0.1 as cut off	Mobility Index; Sum(Oil1, Oil2 & Oil3)/Sum(Oil1, Oil2, Oil3 & Oil4) (C ₄ - C ₁₉ /C ₄ - C ₃₆); Pyrolysis Attribute 5_0.35 as cut off
Core	G014171	0.18	0.25	0.05	0.31	0.17
Core	G014174	0.27	0.27	0.10	0.36	0.27
Core	G014177	0.34	0.36	0.14	0.50	0.28
Core	G014180	0.30	0.25	0.14	0.39	0.37
Core	G014183	0.42	0.38	0.17	0.55	0.31
Core	G014185	0.18	0.19	0.05	0.24	0.22
Core	G014188	0.23	0.26	0.09	0.34	0.25



Sample ID	Core_Tmax (°C)	Evaporative Loss
G014177	458	82.6%_nC ₁₉
G014180	465	83.7%_nC ₁₉
G014183	443	84.2%_nC ₂₀

Table 4. Evaporative Losses of 3 Core Samples

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Figure 6. Two Pyrolysis Attributes of the Shale Prospectivity Tool used to Delineate Maturity Zones and Map Structure

A graphical plot of the Shale Prospectivity Tool's Pyrolysis Attribute 1 (S1*°C in HCs/EOM) against Pyrolysis Attribute 6 (S2*°C in HCs/EOM) maps the drilled structure and show the separation between these values to be widest in the immature zone, of intermediate width in the oil window and so close to each other as to be virtually touching in the condensate to wet gas zone (Figure 6). The down-dip direction can also be discerned. Kuske et al., 2019 showed that Hydrogen Index values of two of the Eagle Ford suites of samples that they analyzed, systematically varied with structural dip direction.

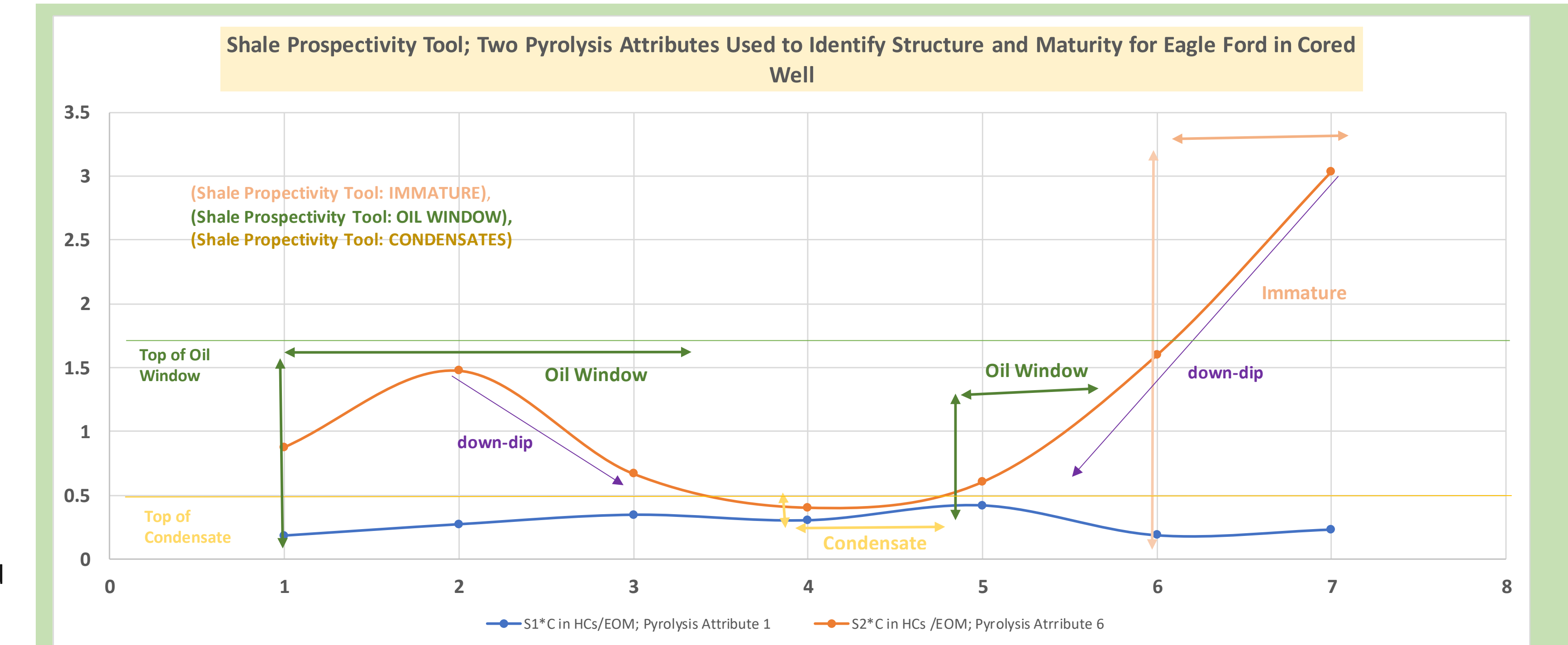
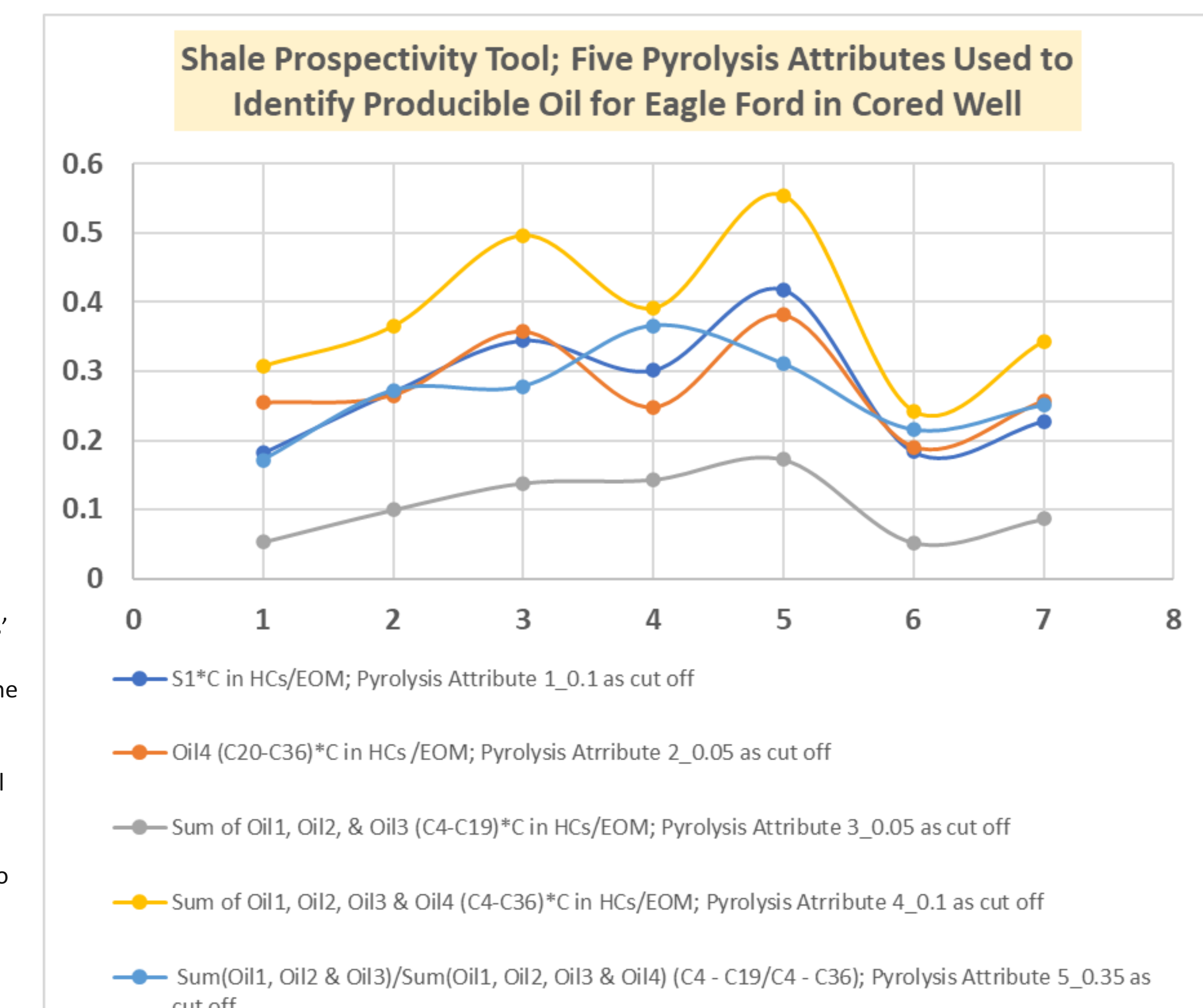


Figure 5. Graphical Plot of Five Pyrolysis Attributes of the Shale Prospectivity Tool



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