GEOLOGICAL SURVEY OF CANADA
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Rock Eval^{6} and Vitrinite Reflectance Data from Baffin Island Shelf and Hudson Strait

S. Zhang
Canada-Nunavut Geoscience Office

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1. INTRODUCTION

During 1970s and 1980s, a program to extend geological knowledge of the Baffin Island shelf was undertaken by the Geological Survey of Canada (GSC). The primary objective of a number of oceanographic cruises was to collect bedrock samples for lithostratigraphic and biostratigraphic analyses in support of geological mapping. The bedrock sampling was undertaken by drilling using an underwater electric drill with 10 m seabed penetration capability. All the short cores and piston cores collected during this program have been stored at the Bedford Institute of Oceanography, Dartmouth.

In the early stage, these shallow drillings revealed that bedrock of the Baffin Shelf in the Baffin Bay and Davis Strait areas includes: 1) Precambrian igneous and metamorphic rocks commonly found immediately adjacent to the coast; 2) Upper Ordovician carbonate rocks underlying much of the southeast Baffin Shelf between Frobisher Bay and Cumberland Sound; and 3) Cretaceous non-marine and marine clastic rocks found in Cumberland Sound and at several other localities on the eastern Baffin Island Shelf (MacLean et al., 1990) (Fig. 1). In the Hudson Strait area, the Precambrian igneous and metamorphic rocks also constitute the bedrock immediately adjacent to the coast, and the carbonate rocks of Ordovician age underlie most of the western part of the strait, but occur together with Silurian and possibly younger rocks in the eastern part (MacLean et al., 1986) (Fig. 1). These shallow drillings are still valuable for the advanced studies in geology, stratigraphy, paleontology, geochemistry, and petroleum potential in the Baffin Island Shelf area, presently being undertaken as part of NRCan's GEM-Energy Program.

From a regional petroleum perspective, the most important findings from the 1970s–1980s cruises that have encouraged this study were: 1) a slick and what were considered to be oily materials were observed erupting at the sea surface off Scott Inlet (Fig. 1) (Loncarevic and Falconer, 1977), with more geological, geophysical, and chemical evidence from natural seepage of petroleum off the northeast coast of Baffin Island (MacLean et al., 1981); 2) in Cumberland Sound area, MacLean and Williams (1983) recovered a dark grey shale of Early Cretaceous age (Barremian-Cenomanian); and 3) finely laminated limestone similar to that of the Upper Ordovician Red Head Rapids Formation on Southampton Island was recovered from Hudson Strait (MacLean and Williams, 1983) (Red Head Rapids Formation on Southampton Island yields three intervals with a total organic carbon (TOC) ranging between 5%–34% (Zhang, 2008)).

In order to better understand the petroleum potential of the Baffin Island Shelf and Hudson Strait areas, the author accessed the short core and piston core collections at 77 stations drilled by Cruises 74026, 75009, 76029, 77027, 78029, 80028, 82034, and 85027 and collected samples from 30 stations from Cruises 75009, 77027, 78029, 82034, and 85027 for both Rock Eval^6 and vitrinite reflectance analyses, as well as palynological analysis (Table 1). The palynological studies have been undertaken by Graham Williams at Bedford Institute of Oceanography, and the preliminary results were presented by MacLean et al. (2012). This report will focus on the Rock Eval^6 and vitrinite reflectance analyses.

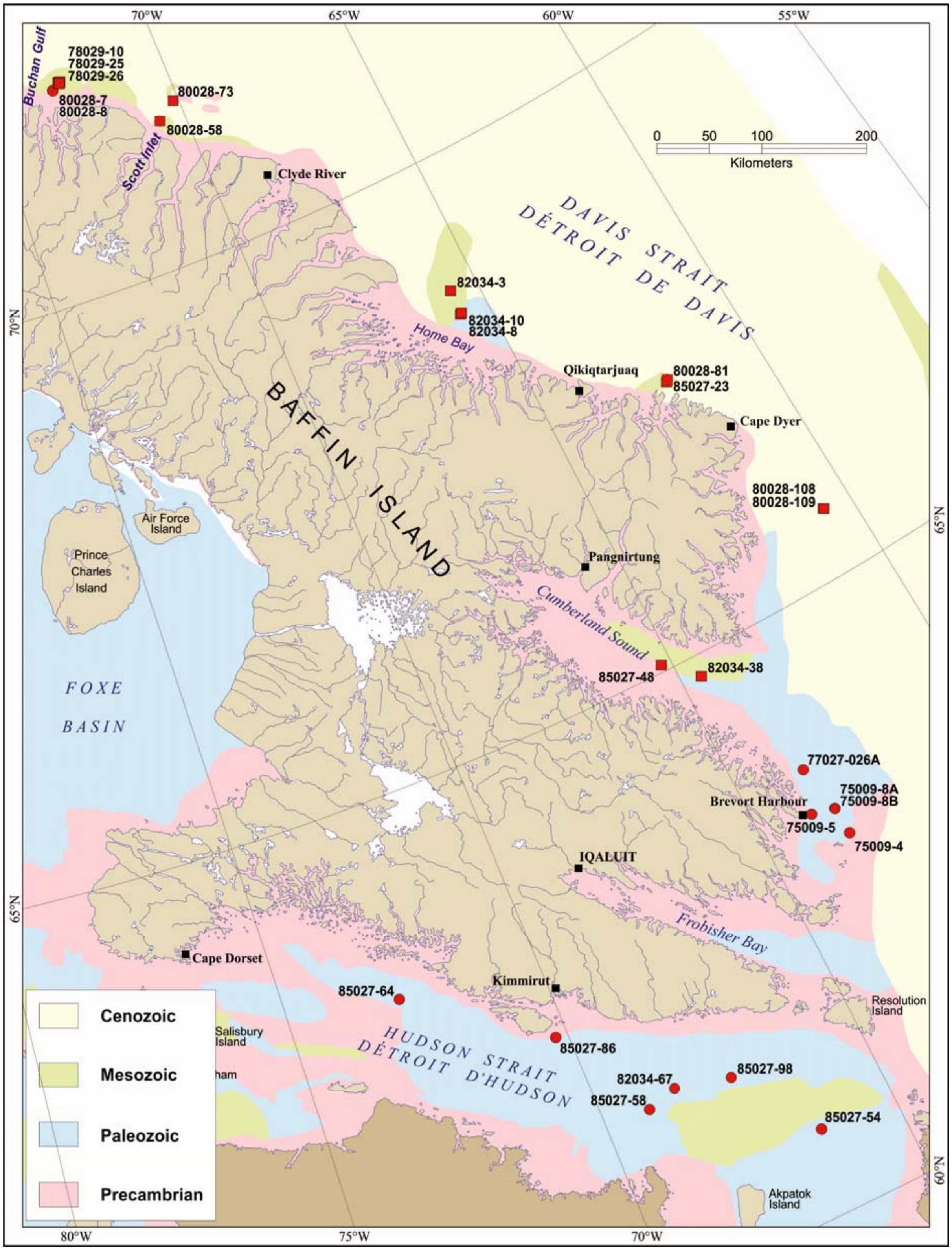


Figure 1. Geological map of Baffin Island Shelf and Hudson Strait (modified from Wheeler et al., 1996) with sample locations. Circles and squares represent the possible Paleozoic and Mesozoic/Cenozoic rocks, respectively. See Table 1 for geographical coordinates.

2. SAMPLES

The details of sampling for Rock-Eval[6] and vitrinite reflectance data collection are summarized in Table 1. A total of 59 samples were collected from short cores and piston cores at 30 stations during six cruises (75009, 77027, 78029, 80028, 82034 and 85027) in Baffin Island Shelf and Hudson Strait areas. These samples were analyzed using the Rock-Eval[6] apparatus and high-quality microscope located at GSC Calgary, and the data are summarized in Table 2.

Samples were collected selectively. Most core samples were taken from the intervals in which shale was visible. Of the 59 samples, 52 were collected from short cores; all 52 samples were analysed for Rock-Eval[6] data, but only 8 were selected for vitrinite reflectance analysis (Table 3). Seven samples of the 59 were collected from a piston core. The piston core is composed of rock fragments, mud and sands; half of the core was consecutively sampled and washed with water. The black shale fragments in the seven samples were preferentially picked for both Rock-Eval[6] and vitrinite reflectance analyses (Tables 2 and 3).

3. EXPERIMENTAL PROCEDURES AND GUIDELINES FOR INTERPRETATION

The Rock-Eval[6] experimental procedures and its application to hydrocarbon exploration are given by Lafargue et al. (1998) and Behar et al. (2001). The guidelines developed by Peters (1986) for Rock-Eval[2] were used in interpreting the data herein. Samples with an $S_2 < 0.2$ mg HC/g rock are considered to produce unreliable T_{max} values. Samples with an $S_2 < 0.2$ mg HC/g rock or with total organic carbon (TOC) < 0.3% produce unreliable HI values. It is considered that the thresholds for the onset of oil generation are $T_{max} = 435$ and production index (PI) = 0.1, and good HC source rock attributes are TOC >2wt% and hydrogen index (HI) > 300 for Type I/II kerogen or 0–150 for Type III kerogen.

Table 2 contains the Rock-Eval[6] data of 59 samples. Among the 59 samples, only two samples (85027-54-R01 and 77027-026A-R01) have S_2 values less than 0.2; and five samples (85027-86-R01, 85027-64-R01, 85027-58-R01, 85027-54-R01 and 77027-026A-R01) exhibit TOC values less than 0.3% (0.1–0.22%). All these samples are from Ordovician limestone. Overall, the data are reliable for the evaluation of the source rock and interpretation of source rock maturity.

In addition to the Rock-Eval[6] analysis, 15 out of 59 samples were selected for vitrinite reflectance analysis in order to get additional data to support the interpretation of source rock maturity. Generally, the onset of oil generation is correlated with a vitrinite reflectance of 0.5-0.6%.

4. RESULTS

This report will divide the data into two parts: Ordovician short cores and Cretaceous/Tertiary short cores and piston cores. The age designation of the samples in the following discussion is based on the stratigraphic units at the stations located on Wheeler et al.'s (1996) geological map (Fig. 1).

Table 1. Samples collected from short cores and piston cores in Baffin Island Shelf and Hudson Strait

Cruise No.	Station No.	Lat	Long	Region	Sample No	Location	Description
85027	98	61.49783	-67.514	H.S.	85027-98-R01	middle of core, from thin film	light grey limestone, argillaceous, two piece of ~5mm core with dark brown-black upper and lower surface (thin film)
	86	62.44483	-70.22933		85027-86-R01	bottom	limestone
					85027-86-M01	1/4 of sec. 11; 1/2of sec. 10 plus chips from top	limestone
	64	63.25317	-72.78617		85027-64-R01	top	limestone
	58	61.5315	-69.13683		85027-58-R01	middle	red breccia limestone
	54	60.74817	-66.42167		85027-54-R01	bottom	light brown limestone
	48	65.06217	-65.21633	C.S.	85027-48-R01	top from a vial	black limestone
					85027-48-R02	right below R01, totally ~4-5cm in a vial	black shale
					85027-48-R03	bottom, in a plastic bag	black shale (R02 and R03 are separated by 1foot of granite)
	23	67.25417	-62.18167	B.S.	85027-23-R00	bottom	thin layer black shale (entire core from station 23 is almost siltstone-sandstone)
					85027-23-R01	12 cm from bottom	black silty shale (sample from 1-2 mm black layer)
					85027-23-M01	1/2 of sec. 2; 1/2 of sec. 1-2	dark grey silt stone
					85027-23-R02	35 cm from bottom	siltstone-shale laminated (sample from 1.5 cm layer)
					85027-23-R03	56 cm from bottom	siltstone-shale laminated (sample from 1.5 cm layer)
					85027-23-R-04	79 cm from bottom	siltstone-shale laminated (sample from 0.5 cm layer)
					85027-23-M02	43-55 cm from bottom; 1/4 of sec. 4A-3; 1/2 of 4A-2	dark grey silt stone
	67	61.61533	-68.55583	H.S.	82034-67-R01	33 cm from bottom	light brown limestone-shale laminated; mostly limestone
					82034-67-R02	40 cm from bottom	light brown limestone-shale laminated
					82034-67-R03	50 cm from bottom	light brown limestone-shale laminated
					82034-67-R04	75 cm from bottom	light brown limestone-shale laminated; more shale
					82034-67-R05	85 cm from bottom	light brown limestone-shale laminated; more limestone
					82034-67-R06	105 cm from bottom	light brown limestone-shale laminated
					82034-67-R07	130 cm from bottom	light brown limestone-shale laminated; more limestone
					82034-67-R08	top 13 cm (no sequence)	mostly shale
					82034-67-R09	top 13 cm (no sequence)	shale (sample is shale fragments peeled off the core)

82034					82034-67-R09	top 13 cm (no sequence)	shale (sample is shale fragments peeled off the core)
					82034-67-R10	top 13 cm (no sequence)	shale (sample is 2 mm thick, half core of pure black shale)
					82034-67-R11	top 13 cm (no sequence)	light brown laminated limestone and shale (more limestone; sample is 4-5 mm, 1/4 core)
					82034-67-M01	1/2 of sec. 1; 1/2 of sec. 4	light brown limestone-shale laminated
					82034-67-M02	3/4 of sec. 27A, 1/4 of sec 27B; 1/4 of sec 28; 1/4 of sec. 30	light brown limestone-shale laminated
	38	64.815	-64.58167	C.S.	82034-38-R01	bottom	black mudstone
					82034-38-R02	top	black mudstone
	10	68.63667	-65.7	B.S.	**82034-10-R01**	middle	grey sandstone
	8	68.64667	-65.67		82034-8-R01	bottom	black mudstone
					82034-8-R02	8 cm from bottom	black mudstone
					82034-8-R03	top	black mudstone
					82034-8-M01	chips from entire core	black mudstone
	3	68.86667	-65.66		82034-3-R01	8 cm from bottom	light brown mudstone
					82034-3-M01	1/2 of sec. 2; 3/4 of sec. 4A; 1/2 of sec. 4B	brown mudstone
80028	109	65.59	-60.61	B.S.	80028-109-R01	bottom	brown limestone
					80028-109-M01	middle; 1/2 of sec. 5 plus chips	brown siltstone
	108	65.58667	-60.60667		80028-108-R01	7 cm from bottom	brown siltstone
	81	67.26517	-62.1525		80028-81-R01	bottom	brown siltstone
	73	71.395	-70.15333		**80028-73PC-01**	208-200 cm	black shale fragments mixed with mud and sands (all samples are from half core)
					80028-73PC-02	200-190 cm	
					80028-73PC-03	190-180 cm	
					80028-73PC-04	175-162 cm	
					80028-73PC-05	162-150 cm	
					80028-73PC-06	145-133 cm	
					80028-73PC-07	133-120 cm	
	58	71.266	-70.68333		80028-58-R01	near top	black shale from 0.5 cm black shale thin layer
					80028-58-M01	all chips from entire core	dark grey limestone (~ 20 g)
	8	71.85333	-73.16333		80028-8-R01	5 cm from bottom	dark grey limestone
	7	71.84833	-73.16333		80028-7-R01	bottom	dark grey-black mudstone
					80028-7-R02	16 cm from bottom	dark grey-black mudstone
					80028-7-R03	top	dark grey-black mudstone

					80028-7-M01	chips from lower part	dark grey-black mudstone
					80028-7-M02	chips from upper part	dark grey-black mudstone
78029	26	71.90333	-72.94333	B.S.	78029-26-R01	bottom	dark grey mudstone
					78029-26-R02	23 cm from bottom	dark grey mudstone
					78029-26-R03	46 cm from bottom	dark grey mudstone
					78029-26-M01	chips from lower part	dark grey mudstone
					78029-26-M01	chips from upper part	dark grey mudstone
	25	71.905	-72.89667		78029-25-R01	6 cm from bottom	dark grey mudstone
					78029-25-M01	1/2 of sec. 2; 1/2 of sec 4 plus chips	dark grey mudstone
	10	71.89333	-72.92167		78029-10-R01	bottom	dark grey mudstone
					78029-10-M01	all chips from entire interval	dark grey mudstone
77027	026A	63.65833	-63.635	B.S.	77027-026A-R01	bottom	grey limestone
	026A				77027-026A-M01	35-40 cm from bottom; 1/2 of sec 11 plus chips	grey limestone
	026A				77027-026A-M02	top 10 cm; 1/2 of sec. 14	grey limestone
	024A	64.81167	-64.31		77027-026A-R01	top	resistant black shale from top
75009	8B	63.22033	-63.45983	B.S.	75009-8B-R01	bottom	brown limestone (sample from scattered fragments)
					75009-8B-R02	39 cm from bottom	brown limestone
					75009-8B-M01	1/2 of sec. 6; 1/2 of sec. 8; 1/4 of sec. 11	brown limestone
	8A	63.21533	-63.45917		75009-8A-R01	9cm from bottom	brown limestone
					75009-8A-R02	10 cm from top	brown limestone
					75009-8A-M01	1/4 of sec. 2; 1/2 of sec. 4	brown limestone
	5	63.27017	-63.91067		75009-5-R01	34 cm from bottom	brown limestone
	4	62.9705	-63.43433		75009-4-R01	60 cm from bottom	dark gray limestone with very few shally layer (sample from shally layer)
					75009-4-M01	1/4 of sec. 3; 1/4 of sec. 4; 1/4 of sec. 6	dark gray limestone

NOTE: All "R" samples are about 100 mg or less, and are for Rock Eval[6] data collection; all "R" samples highlighted by blue font are for both Rock-Eval [6] and vitrinite reflectance analyses; "M" samples highlighted by red font are less than 50 g, and are for microfossil collection; all piston samples (PC) are for both Rock-Eval[6] and vitrinite reflectance analyses, as well as microfossil collection. C.S.: Cumberland Sound; B.S.: Baffin Island Shelf; H.S.: Hudson Strait.

Table 2. Rock-Eval[6] data for the samples from short cores and piston core

Sample	Qty	S_1	S_2	PI	S_3	T_{max}	Tpeak	S_3CO	PC%	TOC	RC%	HI	OICO	OI	MINC%
85027-98-R01	70.5	1.43	1.79	0.44	0.26	338	377	0.05	0.28	0.46	0.18	389	11	57	11.4
85027-86-R01	70.5	0.05	0.36	0.11	0.36	430	469	0.10	0.05	0.20	0.15	180	50	180	12.7
85027-64-R01	70.2	0.03	0.39	0.07	0.32	399	438	0.16	0.05	0.20	0.15	195	80	160	11.8
85027-58-R01	70.5	0.49	0.37	0.57	0.85	400	439	0.34	0.11	0.22	0.11	168	155	386	5.5
85027-54-R01	70.9	0.23	0.15	0.61	0.41	423	462	0.05	0.05	0.14	0.09	107	36	293	12.2
85027-48-R01	70.3	0.03	0.77	0.03	3.28	426	465	0.55	0.21	1.69	1.48	46	33	194	4.2
85027-48-R02	70.8	0.08	2.66	0.03	4.55	431	470	1.49	0.46	6.13	5.67	43	24	74	0.6
85027-48-R03	70.5	0.25	3.27	0.07	3.48	432	471	1.09	0.46	5.24	4.78	62	21	66	0.8
85027-23-R00	70.6	0.25	1.40	0.15	2.42	426	465	0.95	0.27	4.83	4.56	29	20	50	6.2
85027-23-R01	70.4	0.21	0.43	0.33	1.11	415	454	0.52	0.11	1.65	1.54	26	32	67	7.4
85027-23-R02	50.7	0.19	3.64	0.05	6.74	426	465	2.92	0.72	15.82	15.10	23	18	43	8.9
85027-23-R03	71.0	0.12	2.88	0.04	5.42	429	468	2.09	0.54	9.06	8.52	32	23	60	9.2
85027-24-R04	70.2	0.09	1.57	0.05	2.76	428	467	1.05	0.29	6.01	5.72	26	17	46	4.2
82034-67-R01	70.5	0.21	3.13	0.06	0.63	418	457	0.31	0.32	0.90	0.58	348	34	70	10.6
82034-67-R02	70.2	0.08	1.29	0.06	0.46	414	453	0.14	0.14	0.46	0.32	280	30	100	11.3
82034-67-R03	70.2	0.06	0.99	0.06	0.51	412	451	0.08	0.11	0.34	0.23	291	24	150	11.4
82034-67-R04	70.9	0.30	4.11	0.07	0.44	416	455	0.10	0.39	0.87	0.48	472	11	51	11.0
82034-67-R05	70.9	0.05	1.09	0.04	0.39	417	456	0.17	0.12	0.36	0.24	303	47	108	11.4
82034-67-R06	70.7	0.22	2.86	0.07	0.48	412	451	0.09	0.29	0.64	0.35	447	14	75	11.4
82034-67-R07	70.4	0.08	1.52	0.05	0.35	415	454	0.08	0.15	0.40	0.25	380	20	88	11.5
82034-67-R08	70.0	1.34	22.48	0.06	1.02	413	452	0.37	2.04	3.41	1.37	659	11	30	10.7
82034-67-R09	50.7	3.09	52.78	0.06	2.06	411	450	0.82	4.75	7.99	3.24	661	10	26	8.0
82034-67-R10	50.0	4.52	84.93	0.05	2.50	412	451	1.13	7.56	12.78	5.22	665	9	20	4.4
82034-67-R11	70.3	0.89	14.68	0.06	0.73	411	450	0.24	1.33	2.36	1.03	622	10	31	11.3
82034-38-R01	70.2	0.15	4.00	0.04	4.76	431	470	1.47	0.58	6.10	5.52	66	24	78	0.5
82034-38-R02	70.4	0.18	3.75	0.05	4.08	429	468	1.56	0.54	6.78	6.24	55	23	60	0.5
82034-10-R01	70.9	0.10	1.45	0.07	3.11	404	443	2.01	0.34	5.73	5.39	25	35	54	0.4
82034-8-R01	70.2	0.14	1.46	0.09	4.77	402	441	1.88	0.36	3.74	3.38	39	50	128	0.5
82034-8-R02	70.7	0.13	1.48	0.08	5.28	402	441	1.72	0.37	3.63	3.26	41	47	145	0.6
82034-8-R03	70.2	0.19	1.72	0.10	5.00	400	439	1.79	0.38	3.86	3.48	45	46	130	0.6
82034-3-R01	70.8	0.07	2.02	0.03	3.29	429	468	0.65	0.31	2.58	2.27	78	25	128	0.4

80028-109-R01	70.8	0.12	1.15	0.09	2.31	424	463	0.55	0.21	1.38	1.17	83	40	167	0.2
80028-108-R01	70.8	0.12	1.60	0.07	2.50	432	471	0.53	0.25	1.84	1.59	87	29	136	0.2
80028-81-R01	70.8	0.08	1.03	0.08	1.02	434	473	0.48	0.16	2.64	2.48	39	18	39	0.1
80028-73-PC1	70.6	0.13	1.48	0.08	0.25	433	472	0.26	0.16	1.54	1.38	96	17	16	0.1
80028-73-PC2	70.8	0.13	1.49	0.08	0.28	433	472	0.25	0.16	1.58	1.42	94	16	18	0.1
80028-73-PC3	70.2	0.11	1.35	0.08	0.36	434	473	0.21	0.15	1.50	1.35	90	14	24	0.1
80028-73-PC4	70.0	0.13	1.92	0.06	0.19	436	475	0.16	0.19	1.55	1.36	124	10	12	0.1
80028-73-PC5	70.2	0.12	1.73	0.06	0.26	434	473	0.26	0.18	1.71	1.53	101	15	15	0.1
80028-73-PC6	70.4	0.22	2.84	0.07	0.38	436	475	0.24	0.29	1.90	1.61	149	13	20	0.1
80028-73-PC7	70.6	0.14	1.90	0.07	0.38	436	475	0.19	0.19	1.52	1.33	125	12	25	0.1
80028-58-R01	70.6	0.05	0.69	0.07	1.34	424	463	0.51	0.13	0.85	0.72	81	60	158	7.1
80028-8-R01	70.3	0.79	5.01	0.14	0.62	332	371	0.22	0.52	1.66	1.14	302	13	37	0.1
80028-7-R01	71.0	0.09	1.50	0.06	0.71	432	471	0.51	0.18	1.66	1.48	90	31	43	0.1
80028-7-R02	70.1	0.11	1.59	0.07	0.93	431	470	0.46	0.19	1.80	1.61	88	26	52	0.1
80028-7-R03	70.6	0.08	1.19	0.06	0.86	430	469	0.40	0.16	1.66	1.50	72	24	52	0.1
78029-26-R01	70.3	0.09	1.13	0.08	0.64	441	480	0.21	0.14	0.74	0.60	153	28	86	0.1
78029-26-R02	70.7	0.06	0.50	0.10	0.50	425	464	0.22	0.08	0.63	0.55	79	35	79	0.1
78029-26-R03	70.3	0.05	0.47	0.09	0.33	426	465	0.27	0.07	0.51	0.44	92	53	65	0.1
78029-25-R01	70.2	0.05	0.50	0.10	0.43	423	462	0.23	0.07	0.51	0.44	98	45	84	0.1
78029-10-R01	70.3	0.11	0.68	0.13	0.55	424	463	0.23	0.10	0.89	0.79	76	26	62	0.1
77027-026A-R01	70.2	0.01	0.06	0.13	0.28	421	460	0.07	0.02	0.10	0.08	60	70	280	12.1
77027-024A-R01	70.3	0.35	4.51	0.07	0.95	411	450	0.40	0.47	2.20	1.73	205	18	43	0.2
75009-8B-R01	70.2	0.21	4.06	0.05	0.30	431	470	0.04	0.37	0.78	0.41	521	5	38	11.1
75009-8B-R02	70.8	0.32	6.61	0.05	0.43	429	468	0.08	0.60	1.05	0.45	630	8	41	9.4
75009-8A-R01	70.0	0.23	4.03	0.05	0.48	426	465	0.05	0.38	0.85	0.47	474	6	56	11.6
75009-8A-R02	70.6	1.70	28.23	0.06	1.28	427	466	0.52	2.56	4.52	1.96	625	12	28	6.8
75009-5-R01	70.6	0.04	1.30	0.03	0.32	433	472	0.04	0.13	0.38	0.25	342	11	84	12.6
75009-4-R01	70.7	0.11	1.13	0.09	0.89	424	463	0.17	0.15	0.61	0.46	185	28	146	7.9

Note: The samples highlighted by yellow color are from short cores of Ordovician age; other samples are from either short cores or piston cores of Cretaceous or Tertiary age.

Table 3. Data of vitrinite reflectance analysis for the samples from short cores and piston core

C #	SAMPLE #	SAMPLE TYPE	PEL #	ORG_TYPE	$\%Ro_R$	SD	N	COMMENTS
Q-001760	85027-48-R02	short core	**129/11**	2	0.44	0.03	18	Organic rich shaly very fine grain siltstone with mostly reworked coaly vitrinite macerals and inertinite macerals. Minor amount of yellow fluorescing sporinite and reddish brown fluorescing bitumen. Vitrinite measurements are taken from telelinite submacerals.
				4	0.28		1	
				2.2	0.54	0.02	2	
Q-001762	85027-23-R00	short core	**130/11**	2	0.45	0.03	41	Sandstone mudstone matrix with mostly reworked intertinite (fusinite, semifusinite, inertodetrinite) some showing evidence of oxidation some showing high thermal heating from unusual heat source (forest fire, dolomitizing fluid). Minor to rare amount of yellow fluorescing sporinite, cutinite, exudatinite, resinite and and weak fluorescing reddish brown fluorescing bitumen.
				2.2	0.30	0.04	4	
				2.2	0.52	0.00	5	
Q-001764	85027-23-R02	short core	**131/11**	2	0.47	0.03	21	Carbonate limestone matrix with mostly reworked intertinite (fusinite, semifusinite, inertodetrinite) some showing evidence of oxidation some showing insitu hydrothermal dolomitizing fluid filled fracture causing enhance thermal maturity. Rare to trace amount of yellow fluorescing sporinite, cutinite, exudatinite, resinite and and weak fluorescing reddish brown fluorescing bitumen.
				4	0.28		1	
					0.60	0.01	4	
Q-001765	85027-23-R03	short core	**132/11**	2	0.44	0.04	49	Carbonate limestone matrix with mostly reworked intertinite (fusinite, semifusinite, inertodetrinite) some showing evidence of oxidation some showing insitu hydrothermal dolomitizing fluid filled fracture causing enhance thermal maturity. Rare to trace amount of yellow fluorescing sporinite, cutinite, exudatinite, resinite and and weak fluorescing reddish brown fluorescing bitumen.
Q-001795	82034-67-R09	short core	**133/11**	N/D				Organic rich shaly dark matrix consiting of interconnected network of orange to brown fluorescing fluoroamorphinite non fluorescing amophinite macerals derived possibly from filamentous and lamalginite with rare inclusion of orange fluorescing liptodetrinite and leiosphaeridia or tasmanites like alginite. Granular phosphatic nodules and abundant framboidal pyrite, a byproduct of bacterial sulphate reduction (BSR), all suggest marine depositional environment.

Q-001796	82034-67-R10	short core	**134/11**	2	0.43	0.041	7	Similar to above sample. Organic rich shaly dark matrix consiting of interconnected network of orange to brown fluorescing fluoroamorphinite non fluorescing amophinite macerals derived possibly from filamentous and lamalginite with rare inclusion of orange fluorescing liptodetrinite and leiosphaeridia or tasmanites like alginite. Granular phosphatic nodules and abundant framboidal pyrite, a byproduct of bacterial sulphate reduction (BSR), all suggest marine depositional environment.
				4	0.24	0.018	2	Orange fluorescing granular solid hydrocarbon
				4	0.32	0.02	3	Orange luorescing bituminte maceral.
Q-001799	82034-38-R02	short core	**135/11**	2	0.50	0.05	52	Organic rich siltstone matrix with mostly reworked small intertinite (fusinite, semifusinite, inertodetrinite) macerals showing evidence of various stages of oxidation and high thermal heating from unusual heat source (forest fire, valcanic eruption, dolomitizing fluid). Minor amount of yellow fluorescing sporinite, cutinite, exudatinite, resinite and and weak fluorescing reddish brown fluorescing bitumen.
Q-001800	82034-10-R01	short core	**136/11**	2	0.50	0.05	41	Organic rich fine grain silty sandstone and mudstone matrix with mostly reworked intertinite (fusinite, semifusinite, inertodetrinite) macerals showing evidence of various stages of oxidation and high thermal heating from unusual heat source (forest fire, valcanic eruption, dolomitizing fluid). Minor to rare amount of yellow to reddish orange fluorescing sporinite, cutinite (micro and macro), exudatinite, resinite and and weak fluorescing reddish brown fluorescing bitumen.
Q-001805	80028-73-PC01	piston core	**137/11**	2	0.48	0.06	26	Silty shale with minor amount of yellow to reddish orange fluorescing sporinite and rare bright yellow fluorescing prasinophyte alginite and possibly trace amount of dinoflagellate. Trace amount of inertodetrinite macerals. Bimodal vitrinite reflectance, higher reflecting sporinite derived tellinite with %Ro = 0.63, partially oxidized
				2	0.65	0.04	10	
Q-001806	80028-73-PC02	piston core	**138/11**	2	0.52	0.54	32	Similar to above sample. Silty shale with minor amount of yellow to reddish orange fluorescing sporinite and rare bright yellow fluorescing prasinophyte alginite and possibly trace amount of dinoflagellate. Trace amount of inertodetrinite macerals. Bimodal vitrinite reflectance, higher reflecting sporinite derived tellinite with %Ro = 0.63, partially oxidized
				2	0.68	0.06	15	sporinite derived telelinite
Q-001807	80028-73-PC03	piston core	**139/11**	2	0.51	0.04	18	Similar to above sample. Silty shale with minor amount of yellow to reddish orange fluorescing sporinite and rare bright yellow fluorescing prasinophyte alginite and possibly trace amount of dinoflagellate. Trace amount of inertodetrinite macerals. Bimodal vitrinite reflectance, higher reflecting sporinite derived tellinite with %Ro = 0.63, partially oxidized
				2.2	0.65	0.03	5	sporinite derived telelinite
				2.4	0.38		1	

Q-001808	80028-73-PC04	piston core	**140/11**	2	0.51	0.056	17	Similar to above sample. Silty shale with minor amount of yellow to reddish orange fluorescing sporinite and cutinite and rare bright yellow fluorescing prasinophyte alginite and possibly trace amount of dinoflagellate and acritarchs. Trace amount of mostly inertodetrinite macerals.
				2.2	0.67	0.04	3	Bimodal vitrinite reflectance, higher reflecting sporinite derived tellinite with %Ro = 0.63, partially oxidized
				2.2	0.37	0.02	3	
Q-001809	80028-73-PC05	piston core	**141/11**	2	0.50	0.054	21	Similar to above sample but with slightly very fine grain siltstone. Silty shale with minor amount of yellow to reddish orange fluorescing sporinite and cutinite and rare bright yellow fluorescing prasinophyte alginite and possibly trace amount of dinoflagellate and acritarchs. Trace amount of mostly inertodetrinite macerals.
				2.2	0.65	0.04	5	Bimodal vitrinite reflectance, higher reflecting sporinite derived tellinite with %Ro = 0.63, partially oxidized
Q-001810	80028-73-PC06	piston core	**142/11**	2	0.50	0.05	30	Similar to above sample but with slightly very fine grain siltstone. Silty shale with minor amount of yellow to reddish orange fluorescing sporinite and cutinite and rare bright yellow fluorescing prasinophyte alginite and possibly trace amount of dinoflagellate. Trace amount of mostly inertodetrinite macerals.
				4	0.33	0.00	2	
				2.2	0.70	0.04	4	
				2.2	0.95		1	
				2.2	1.24		1	
Q-001811	80028-73-PC07	piston core	**143/11**	2	0.52	0.053	14	Similar to above sample but with slightly very fine grain siltstone. Silty shale with minor amount of yellow to reddish orange fluorescing sporinite and cutinite and rare bright yellow fluorescing prasinophyte alginite and possibly trace amount of dinoflagellate. Trace amount of mostly inertodetrinite macerals.
					0.37	0.00	2	

Note 1: In all cases, most of the shale and coal matrix were observed parallel and perpendicular to the bedding even though it is not mentioned or indicated.

Note 2: KEY FOR ORGANIC TYPE: 2 = Vitrinite (highlighted with yellow); 2.1, 2.2, 2.3 = refers to as reworked populations; 3 = vitrinite equivalent (04) = 0.618 x %Ro(bitumen) + 0.40 values (Jacob, 1989); 4 = bitumen.

Note 3: Allochtonous maceral were not all measured, those measured are for reference only to determine %Ro of the reworked maceral, they are not quantitative. Refer to the comments. Please see data sheet which contain histogram (when possible).

Ordovician short cores

The Ordovician short cores were collected mainly in Hudson Strait and the Brevort Harbour area (Fig. 1). The samples used in this study were from six stations during two cruises (82034-67; 85027-54, 58, 64, 67, 86, 98) in Hudson Strait, and five stations during two cruises (75009-4, 5, 8A, 8B, and 77027-26A) in the area southeast of Brevort Harbour, as well as one station (80028-8) in the Buchan Gulf area. The short core samples from the above-mentioned 13 stations consist of either limestone or limestone laminated with black shale (Fig. 2). The limestone laminated with black shale is similar to those in the Red Head Rapids Formation on Southampton Island (Zhang, 2008).

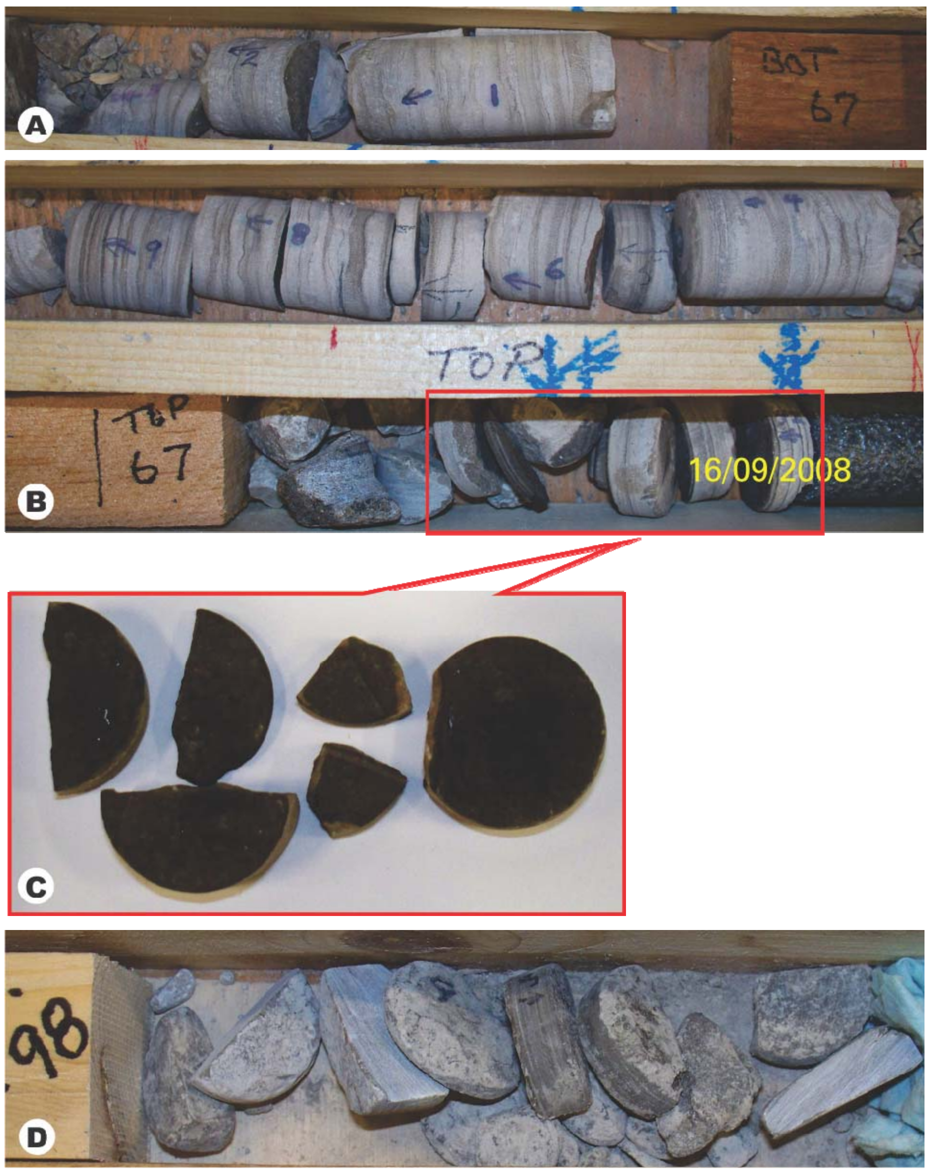


Figure 2. Short core from Station 67, Cruise 82034, and Station 98, Cruise 85027, Hudson Strait. A and B: top, middle and bottom parts of the short core from 82034-67; C: view of cross section from part of top core showing the black shale layers; D: short core from 85027-98.

A total of 25 samples were collected from the above mentioned 13 stations for Rock Eval[6] analysis (Tables 1 and 2), and two of the 25 samples were selected for vitrinite reflectance analysis. Where possible, these samples were carefully and preferentially picked from the black shale layer within the laminated limestone. These 25 samples have TOC values ranging between 0.1% and 12.78%, with an average of 1.76%. Of the 25 samples, eight yield TOC between 1% and 12.78%, which are from those black shale layers preferentially collected from the laminated limestone; and the rest of the samples with TOC<1% are from nearly pure limestone samples (Table 2). The HI of the 25 samples ranges between 60 and 665 with an average of 380 (Table 2). The T_{max} values from these 25 samples are between 332°C and 433°C (Table 2), which indicates that these rocks are immature for petroleum generation. Two samples (82034-67-R09 and 82034-67-R10) out of the 25 were selected for vitrinite reflectance analysis. No vitrinite was found in sample 82034-67-R09 (Table 3); this is simply because the rock was deposited during the Ordovician when the land plants were not yet evolved. However, some organic matter had a kind of texture resembling that of the vitrinite (D. Lavoie, pers. comm. 2013), which probably was why the vitrinite was observed seven times, with an average %Ro of 0.43, in sample 82034-67-R10 (Table 3). Figure 3 shows that these samples probably contain Type II kerogen; some of the samples with HI over 600 (four samples from Hudson Strait and two from southeast of Brevort Harbour, respectively) might be mixed with Type I kerogen. The kerogen type estimated herein is similar to that in the Red Head Rapids Formation on Southampton Island (Zhang, 2008).

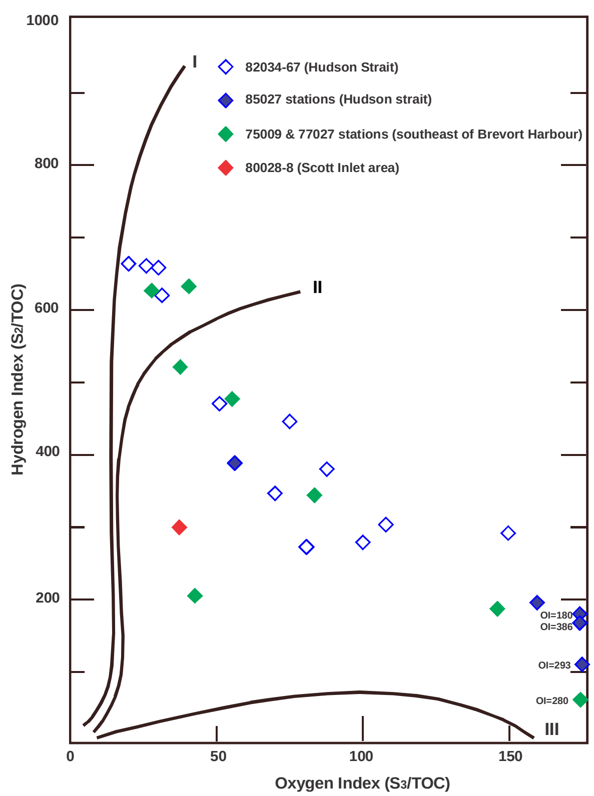


Figure 3. Modified van Krevelen diagram showing relationship between Hydrogen and Oxygen indices (HI and OI) of 25 samples from Hudson Strait, southeast of Brevort Harbour, and Buchan Gulf area.

Cretaceous short cores and piston cores

Short core samples from Cumberland Sound

In the Cumberland Sound area, at Station 48, Cruise 85027, about 4–5 cm black shale core (Fig. 4) and some black shale fragments were obtained, from which three samples were collected for Rock Eval[6] analysis; at Station 38, Cruise 82034, about 8–10 cm black mudstone core (Fig. 4) was obtained, from which two samples were selected for Rock Eval[6] analysis. A total of five samples have TOC ranging between 1.69% and 6.78% with an average of 5.2%, and HI ranging between 43 and 66 with an average of 54.4 (Table 2). The T_{max} values from these five samples are between 426°C and 431°C (Table 2), which indicates that these black shale and mudstone are immature for petroleum generation. Two samples (85027-48-R02 and 82034-38-R02) out of the five were selected for vitrinite reflectance analysis (Fig. 5); the former has an average %Ro of 0.44, and the latter 0.5 (Table 3); the latter might be marginally mature. Fig. 6 shows that these samples contain Type III kerogen.

Figure 4. Black mudstone from station 38, Cruise 82034 and black shale from station 48, Cruise 85027 in Cumberland Sound.

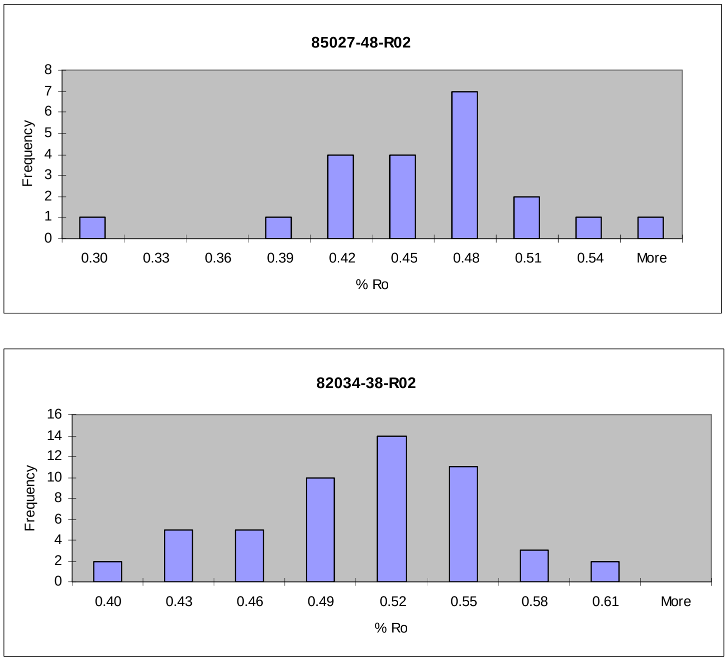


Figure 5. Values of % Ro and their frequency in two samples from Cumberland Sound.

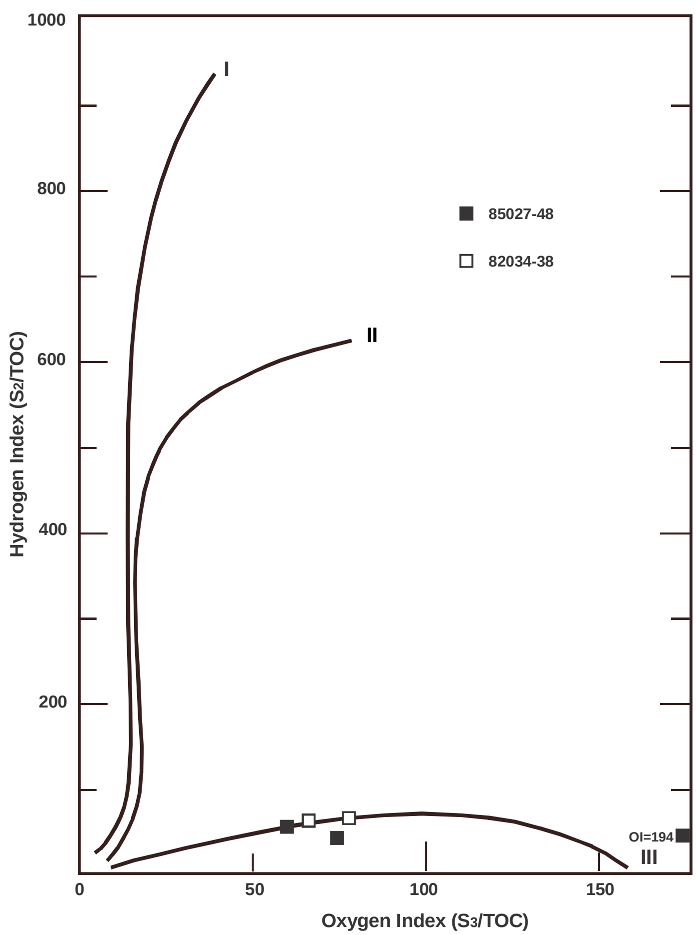


Figure 6. Modified van Krevelen diagram showing relationship between HI and OI of five samples from Cumberland Sound.

Short core samples from eastern Baffin Island Shelf

In the eastern Baffin Island Shelf, the short cores from Cretaceous rocks were collected from three areas (Fig. 1): 1) southeast of Qikiqtarjuaq including three stations during two cruises (85027-23, 24; 80028-81); 2) the Home Bay area including three stations during one cruise (82034-3, 8, and10); and 3) the Scott Inlet area including six stations during two cruises (78029-10, 25, and 26; 80028-7, 58 and 73).

1) ***The area southeast of Qikiqtarjuaq***. A total of six samples were collected from this area, and four of the six samples are from Station 23, Cruise 85027, which are from the very thin black shale layers preferentially picked within the laminated fine sandstone (Fig. 7). The six samples yield TOC ranging between 1.65% and 16.82% with an average of 6.7%, and HI ranging between 23 and 39, with an average of 29 (Table 2). The T_{max} values from these six samples are between 415°C and 434°C (Table 2), which indicates that these rocks are immature for petroleum generation. Three samples (85027-23-R00, 85027-23-R02, 85027-23-R03) of the six were selected for vitrinite reflectance analysis (Fig. 8). These have average %Ro between 0.44 and 0.47 (Table 3). Figure 9 shows that these samples contain Type III kerogen.

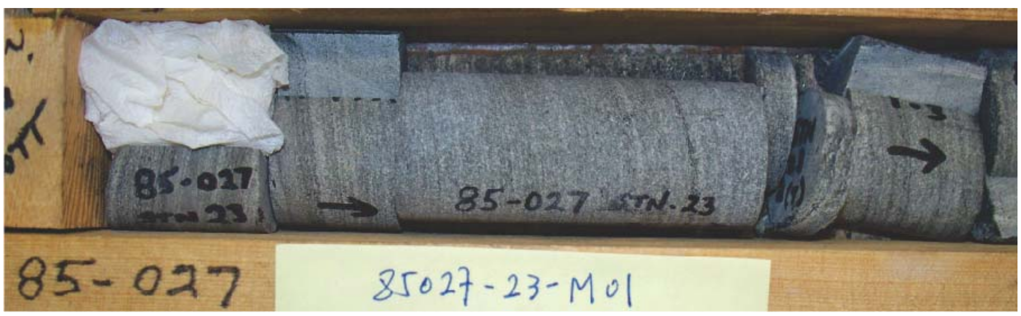


Figure 7. Short core from Stations 23 and 8, Cruise 85027, southeast of Qikiqtarjuaq.

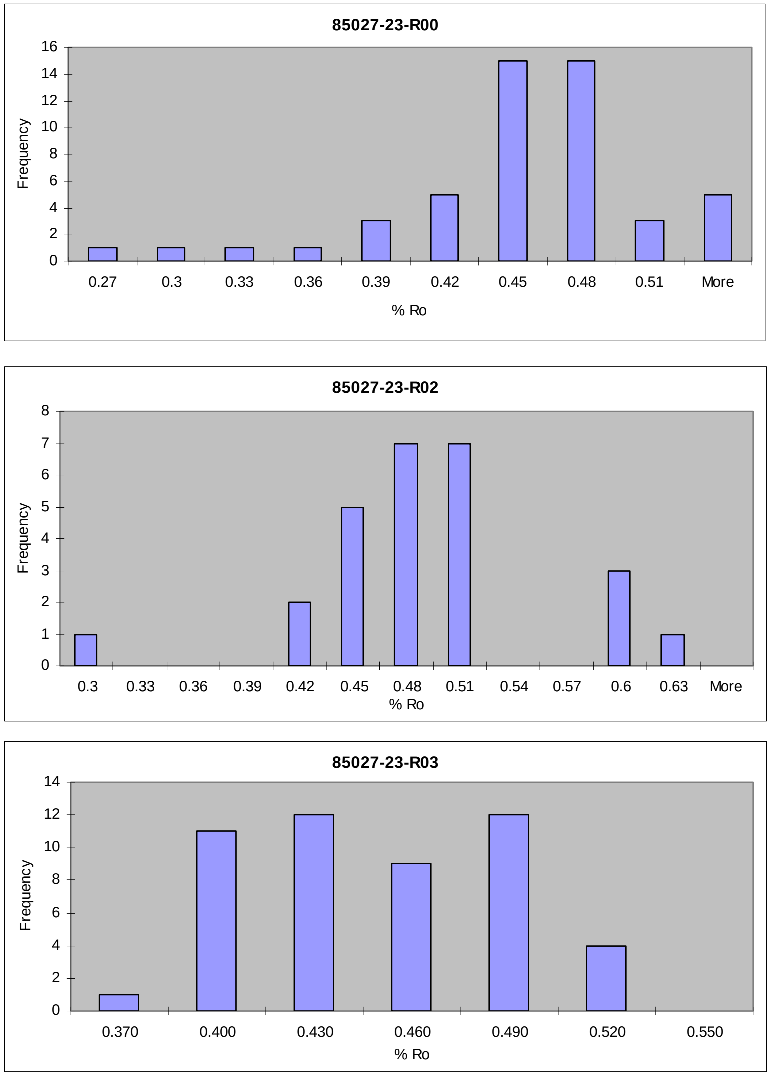


Figure 8. Values of % Ro and their frequency in three samples from the area southeast of Qikiqtarjuaq.

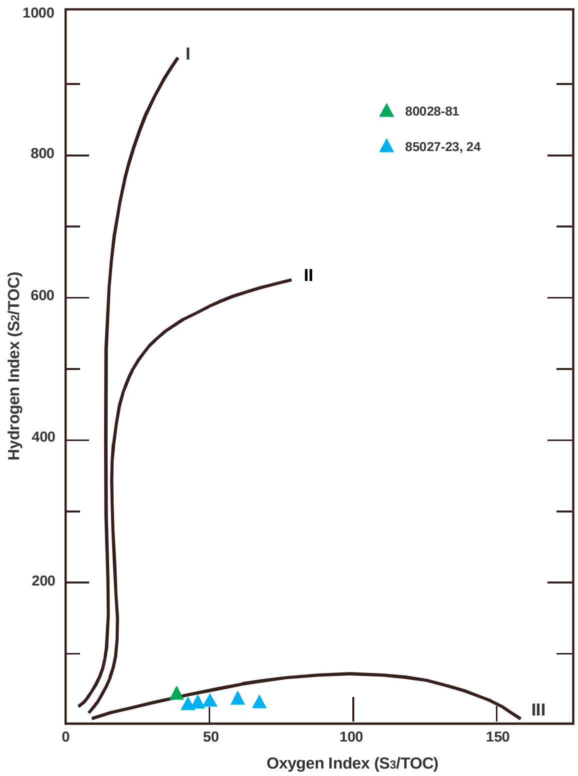


Figure 9. Modified van Krevelen diagram showing relationship between HI and OI of six samples from the area southeast of Qikiqtarjuaq.

2) ***Home Bay*****.** A total of five samples were collected from the short cores at Stations 3, 8, and 10, Cruise 82034. These cores are composed of either black shale or dark brown mudstone (Fig. 10). The five samples contain TOC values ranging between 2.58% and 5.73% with an average of 4%, and HI ranging between 25 and 78 with an average of 46 (Table 2). The T_{max} values from these five samples are between 400°C and 429°C (Table 2), which indicates that these rocks are immature for petroleum generation. One sample (82034-10-R01) out of the five was selected for vitrinite reflectance analysis (Fig. 11), which has an average %Ro of 0.5 (Table 3). Figure 12 shows that these samples contain immature Type III kerogen.

Figure 10. Short cores from Stations 3 and 8, Cruise 82034 in Home Bay area. A: from Station 8; B: from Station 3.

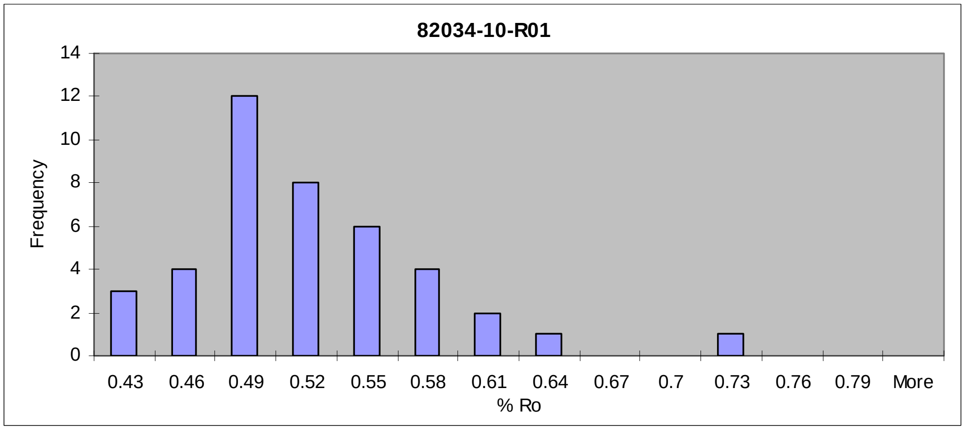


Figure 11. Values of % Ro and their frequency in sample 82034-10-R01 in the Home Bay area.

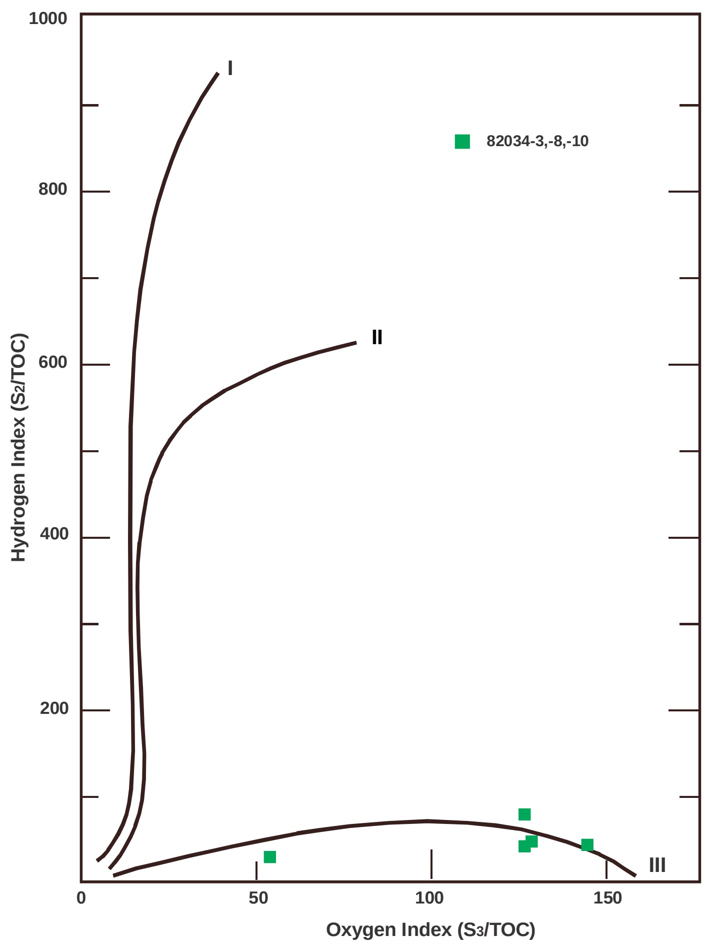


Figure 12. Modified van Krevelen diagram showing relationship between HI and OI of five samples from short cores in the Home Bay area.

3) ***Buchan Gulf.*** A total of eight samples were collected from the short cores at Stations 7 and 58, Cruise 80028, and Stations 10, 25 and 26, Cruise 78029. These cores are composed of dark brown mudstone (Fig. 13). The eight samples yield TOC ranging between 0.51% and 1.8% with an average of 1.02%, and HI ranging between 72 and 153 with an average of 92 (Table 2). The T_{max} values from these nine samples are between 423°C and 432°C, with one exception of 441°C (Table 2), which indicates that the majority of these rocks are immature for petroleum generation. No short core samples were selected for vitrinite reflectance analysis. Figure 14 shows that these samples contain Type III kerogen.

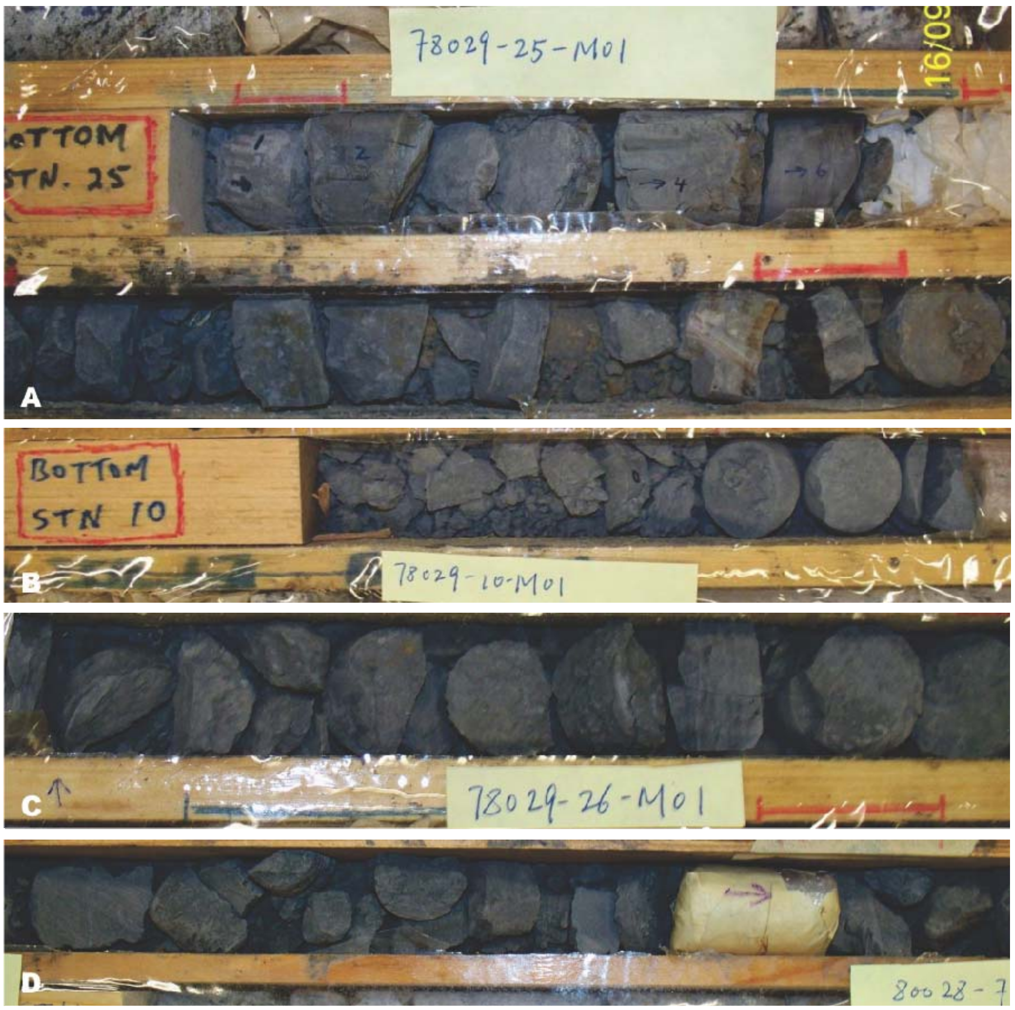


Figure 13. Short cores from Buchan Gulf area. A–C: from Stations 25, 10, and 26, Cruise 78029; D: from Station 7, Cruise 80028.

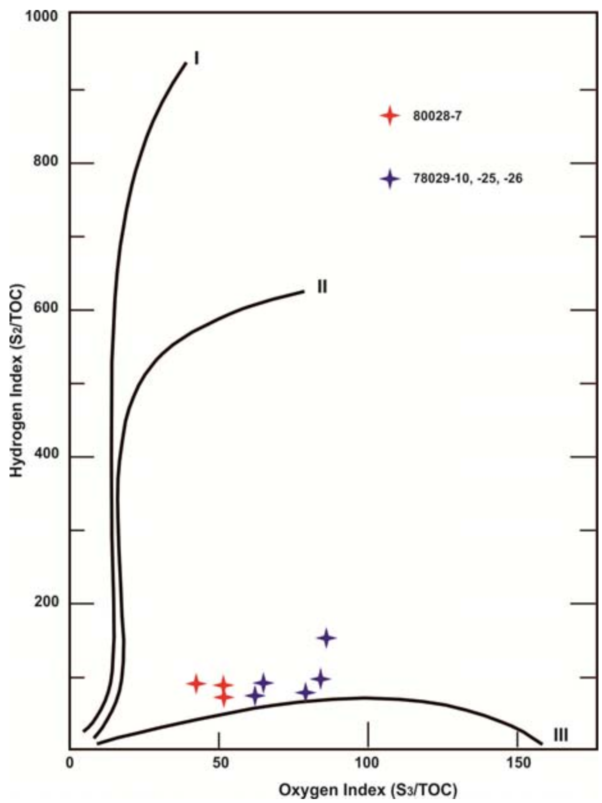


Figure 14. Modified van Krevelen diagram showing relationship between HI and OI of eight samples from short cores in Buchan Gulf area.

Piston core samples from the Scott Inlet area

A piston core was collected from the sea bottom off Scott Inlet beneath where a slick and what were thought to be oily materials were observed erupting at the sea surface (Loncarevic and Falconer, 1977), with more geological, geophysical and chemical evidence from natural seepage of petroleum off the northeast coast of Baffin Island (MacLean et al. 1981).

In the Scott Inlet area, an over 200 cm-long piston core was collected at Station 73 during Cruise 80028, from which seven samples were collected consecutively interval by interval (about 8–13 cm) from half of the core; the samples were then carefully washed with water. After washing, it was obvious that the samples from the lower part of the piston core contain more and larger pieces of black shale fragments than those from the upper part of the core (Fig. 15). The black shale fragments were preferentially picked from the seven washed samples for both Rock Eval[6] and vitrinite reflectance analysis.

A total of seven samples have TOC ranging between 1.5% and 1.9% with an average of 1.6%, and HI ranging between 90 and 149 with an average of 111 (Table 2). The T_{max} values from these seven samples are between 433°C and 436°C, which indicates that these black shales are marginally mature for petroleum generation (Table 2). This is in agreement with the vitrinite reflectance data, with the average % Ro of six samples out of seven between 0.5 and 0.52 (Table 3), although five samples out of the seven have bimodal vitrinite reflectance and higher reflecting sporinite derived tellinite with %Ro = 0.63 (Table 3, Fig. 16).

As for kerogen type and maturation, the diagrams of the relationship between HI and OI (Fig. 17), as well as the relationship between HI and T_{max} (Fig. 18) show a contradictory result; the former displays a Type I/II kerogen with overmature nature, but the latter shows a Type III kerogen with marginally mature nature. The latter is more reasonable when these results are compared to the data from elsewhere in the region.

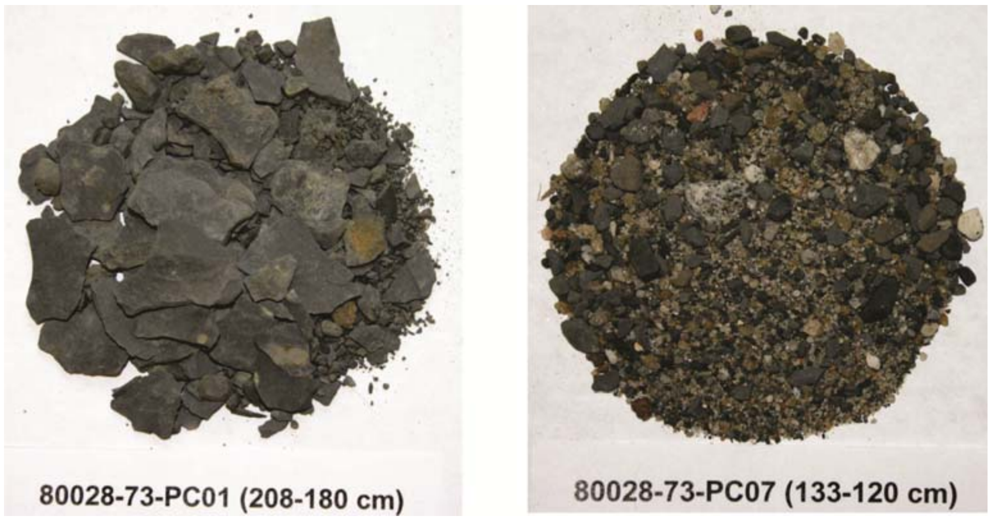
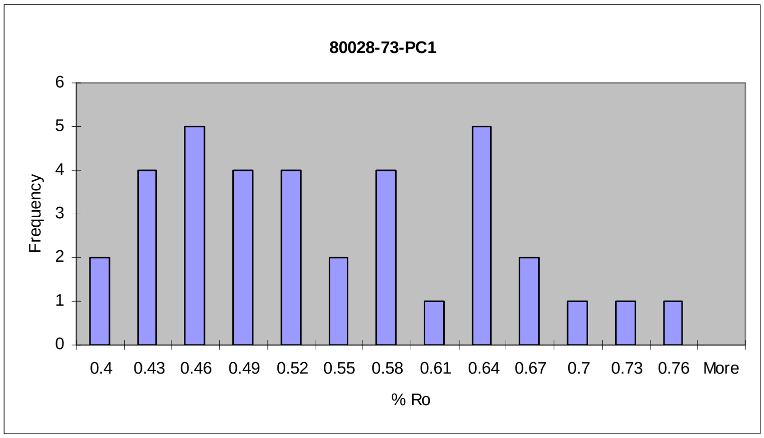
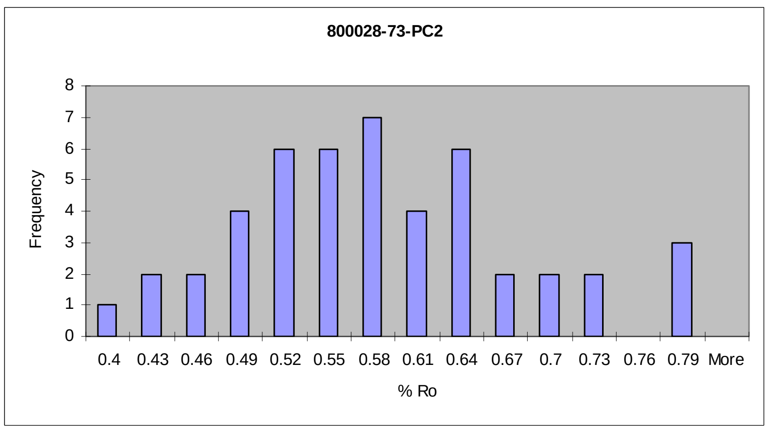


Figure 15. Two samples from the washed piston core at Station 73, Cruise 80028





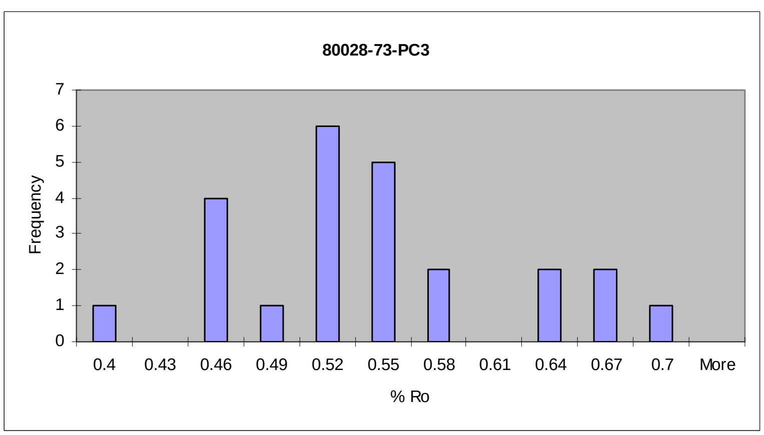


Figure 16. Values of % Ro and their frequency in six piston core samples from the Scott Inlet area (data of sample 80028-73-PC06 are missing) (to be continued in next page).

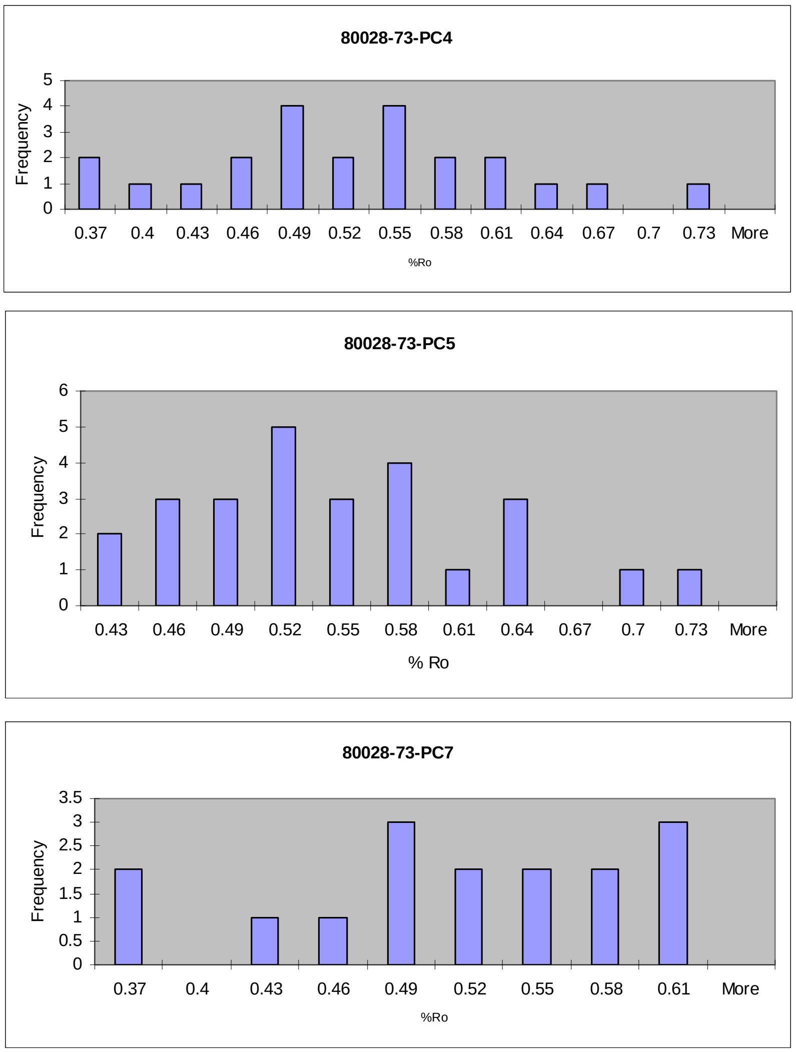


Figure 16. continued.

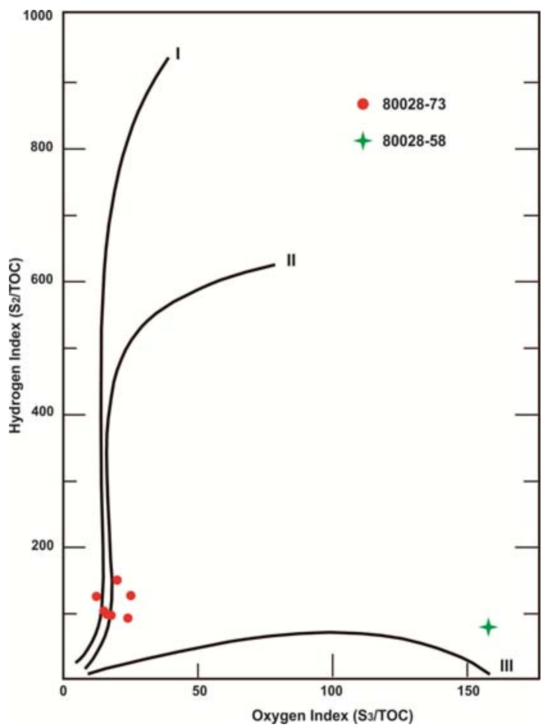


Figure 17. Modified van Krevelen diagram showing relationship between HI and OI of seven piston core samples from the Scott Inlet area (sample 80028-28 from short core).

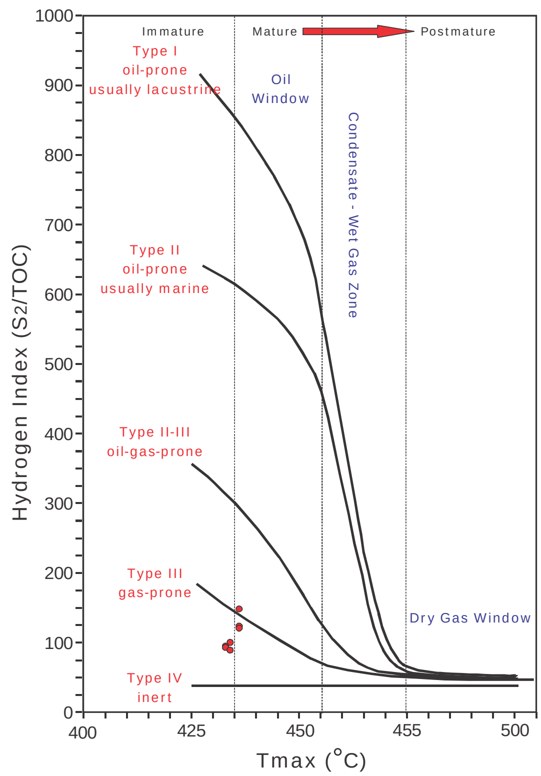


Figure 18. Relationship between HI and T_{max} of seven piston core samples from the Scott Inlet area.

Tertiary short cores

Two possible Tertiary short cores were collected at Stations 108 and 109, Cruise 80028, in the area southeast of Cape Dyer (Fig. 1). These cores consist of dark brown mudstone (Fig. 19). Only two samples were collected from the cores, which contain TOC 1.38% and 1.84% and HI 167 and 136, with T_{max} values 424°C and 432°C (Table 2). No short core samples were selected for vitrinite reflectance analysis. Fig. 20 shows that these samples contain immature Type III kerogen.

Figure 19. Short core from Station 108, Cruise 80028 in the area south of Qikiqtarjuaq

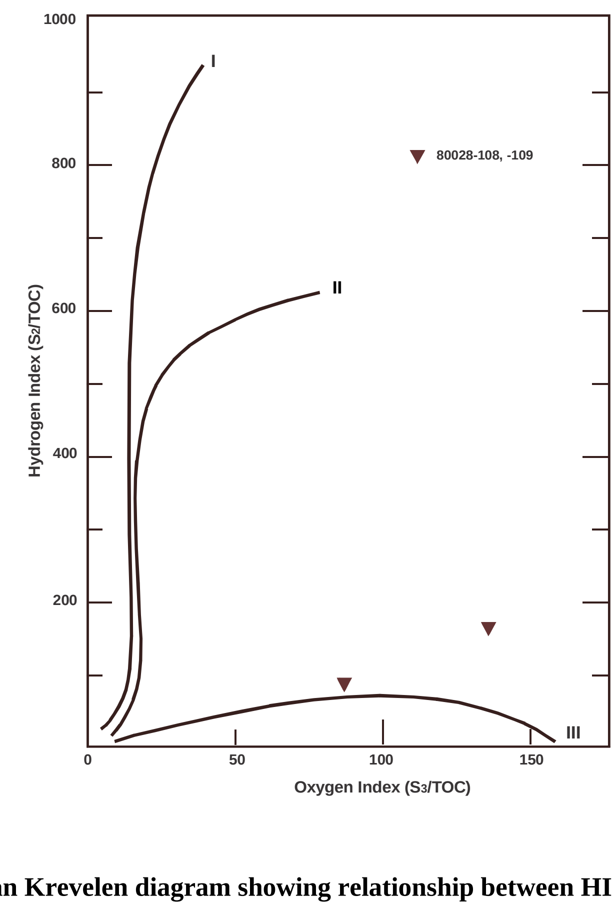


Figure 20. Modified van Krevelen diagram showing relationship between HI and OI of two possible Tertiary core samples from southeast of Cape Dyer.

5. SUMMARY

1) A total of 59 samples were collected from short cores and piston cores at 30 stations during Cruises 75009, 77027, 78029, 82034 and 85027 along the Baffin Island Shelf and Hudson Strait areas (Table 1); Rock-Eval[6] data were collected from all 59 samples (Table 2); and vitrinite reflectance data from 15 samples of the 59 (Table3).

2) Twenty five samples of the 59 were from Ordovician short cores collected from both eastern Baffin Island Shelf and Hudson Strait. Eight samples of the 25 yield TOC values between 1% and 12.78% and HI over 600, which are from the black shale layers preferentially collected from laminated limestone. The HI/OI and the T_{max} values indicate that these Ordovician source rocks contain immature Type I/II kerogen (Table 2; Fig. 3).

3) Thirty four samples of the 59 were from Cretaceous/Tertiary short cores and piston core collected from eastern Baffin Island Shelf area. A majority of these samples contain TOC between 1% and 15.82% and HI between 23 and 153, which can be evaluated as good or very good source rock. The HI/OI and the T_{max} values for all the samples from short cores show that these Cretaceous/Tertiary source rocks contain immature Type III kerogen (Table 2; Fig. 21); however, the samples from the piston core in Scott Inlet may be marginally mature (Fig. 18).

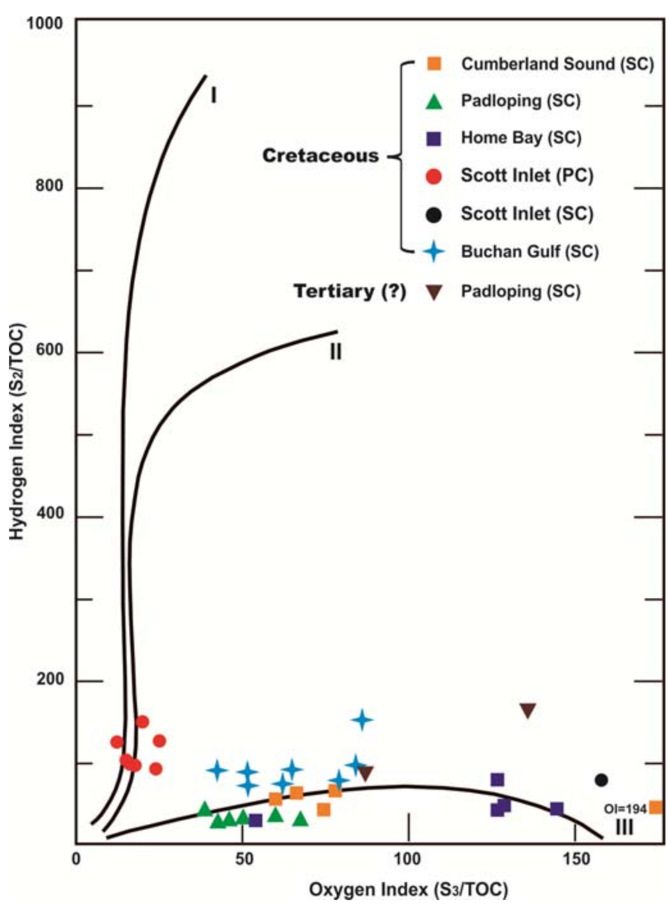


Figure 21. Modified van Krevelen diagram showing relationship between HI and OI of 34 short core and piston core samples from five different areas. SC: short core; PC: piston core.

6. DISCUSSION

The 34 short core and piston core samples from the eastern Baffin Island Shelf area contain Type III kerogen, an indication that the Cretaceous source rocks are gas-prone. The T_{max} values for 27 short core samples from this area suggest that the source rocks are of immature nature, while those of the piston core samples are marginally mature.

An oil slick and what were considered to be oily materials were observed erupting at the sea surface off Scott Inlet (Loncarevic and Falconer, 1977). These oily materials are presumed to have originated from mature oil-prone source rocks that contain Type I or Type II kerogen. Regionally, source rocks containing Type I or Type II kerogen have been discovered previously within Upper Ordovician strata on Southampton Island and southern Baffin Island (Zhang, 2008, 2012). Such rocks are also inferred by this study to be present near the sea floor on the eastern Baffin Island Shelf and Hudson Strait. Unfortunately, they are also immature.

All these evidences suggest that the observed slick and oily materials off Scott Inlet may have originated from the Ordovician source rocks, which were then overlain by Cretaceous strata, creating sufficient load to generate oil. Therefore, a target for source rocks in the eastern Baffin Island Shelf should be the Ordovician source rocks where they have been deeply buried by Cretaceous deposits.

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