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Publications in this series have not been edited; they are released as submitted by the author.

Supplementary materials:

Appendix A. ED-XRF and TOC data
Appendix B. Data-integrating Striplogs
Appendix C. Table of formation tops for the Lower Devonian clastic wedge and underlying strata

ABSTRACT

This collection of data comprises new XRF data, TOC data, and a new table of formation tops for the lower portion of the Devonian clastic wedge (Weatherall, Cape de Bray and Blackley formations *sensu* Embry and Klovan, 1976) and the underlying basinal and carbonate-platform strata of variable Ordovician to Lower-Middle Devonian age. Main results include ED-XRF data for 15 well sections within the N.W.T. jurisdiction of the SW Arctic Archipelago. These XRF data were obtained in 2018-2020 through non-destructive measurements of drillhole cutting samples using a Bruker Tracer IV instrument. Testing of these samples has been restricted to preserve them for future study as they are irreplaceable. The goal of using the non destructives XFR has given us a methodology that does not harm these samples. We find this to be a reasonable method when data is required but no destructive testing is permitted, such as in these legacy wells. Reading acquisition procedure and instrument calibrations are discussed herein. These XRF logs cover cumulatively 12,538 m of well sections, which is the best attainable physical coverage for these strata in the absence of representative cores. For each section surveyed with XRF, we provide graphical striplogs with geophysical logs, descriptive lithology, XRF elemental logs, biostratigraphic data, and, selectively, synthetic seismograms and TOC data. Scientific discussion based on these results is a subject of a separate paper-in-preparation, (Kabanov, P. 2020.)

INTRODUCTION

The stratigraphic understanding of the Devonian Clastic Wedge (further DCW) and underlying strata, particularly in the western Canadian Arctic, has seen little evolution over the past four decades, although subdivisions established in milestone works (Tozer and Thorsteinsson 1964; Embry and Klovan, 1976) conceal unresolved discrepancies. Our study offers a solution to these identified issues. Scientific results of this study are discussed in Kabanov et al. (in prep.), whereas this report provides supplementary data, including new ED-XRF surveys, compilation of TOC data, and a new table of formation tops. Our study focuses on the stratigraphy of the lower DCW and the underlying organic-rich mudrocks bundled in the Lower-Middle Devonian Kitson Formation (Embry and Klovan, 1976). The lower DCW includes the Weatherall, Cape de Bray, and Blackley formations *sensu* Embry and Klovan (1976). It is important to note that the original Weatherall Formation included the Cape de Bray and Blackley units in member rank (Tozer and Thorsteinsson, 1964). Older units of the upper Ordovician-Silurian age were surveyed in a few wells to help clarify the nature and traceability of the Kitson Formation base. Our analysis also involved reinterpretation of legacy reflection seismic, which is reported in the main paper.

The DCW is a name that encompasses the Lower to Upper Devonian siliciclastic sequences in the Canadian Arctic Archipelago (Tozer and Thorsteinsson, 1964; Trettin, 1991) and its southwestern tail in the N.W.T. mainland and Yukon (Lane, 2007). The thick (up to 4 km) DCW clastics were shed from the

Ellesmerian Orogen uplifted as a result of a continent-scale collision. The name Ellesmerian Orogeny, introduced by Thorsteinsson and Tozer (1970), applies to the foldbelt developed along the Arctic (Franklinian) continental margin of Laurentia. The colliding continent, variously referred to as Arctida or Crockerland (Embry, 1988; Anfinson et al., 2012), has been mostly removed from Arctic Canada by subsequent plate motions. In the study area (Fig. 1), the base of the DCW is within the Middle Devonian as suggested by available biostratigraphic data. The Ellesmerian foreland clastics were shed southwestward across Laurentia, as far south as Alberta (Patchett et al., 1999). The study area (Fig. 1) spans regions of undisturbed to moderately disturbed sedimentary cover as well as regions heavily impacted by Ellesmerian deformation.

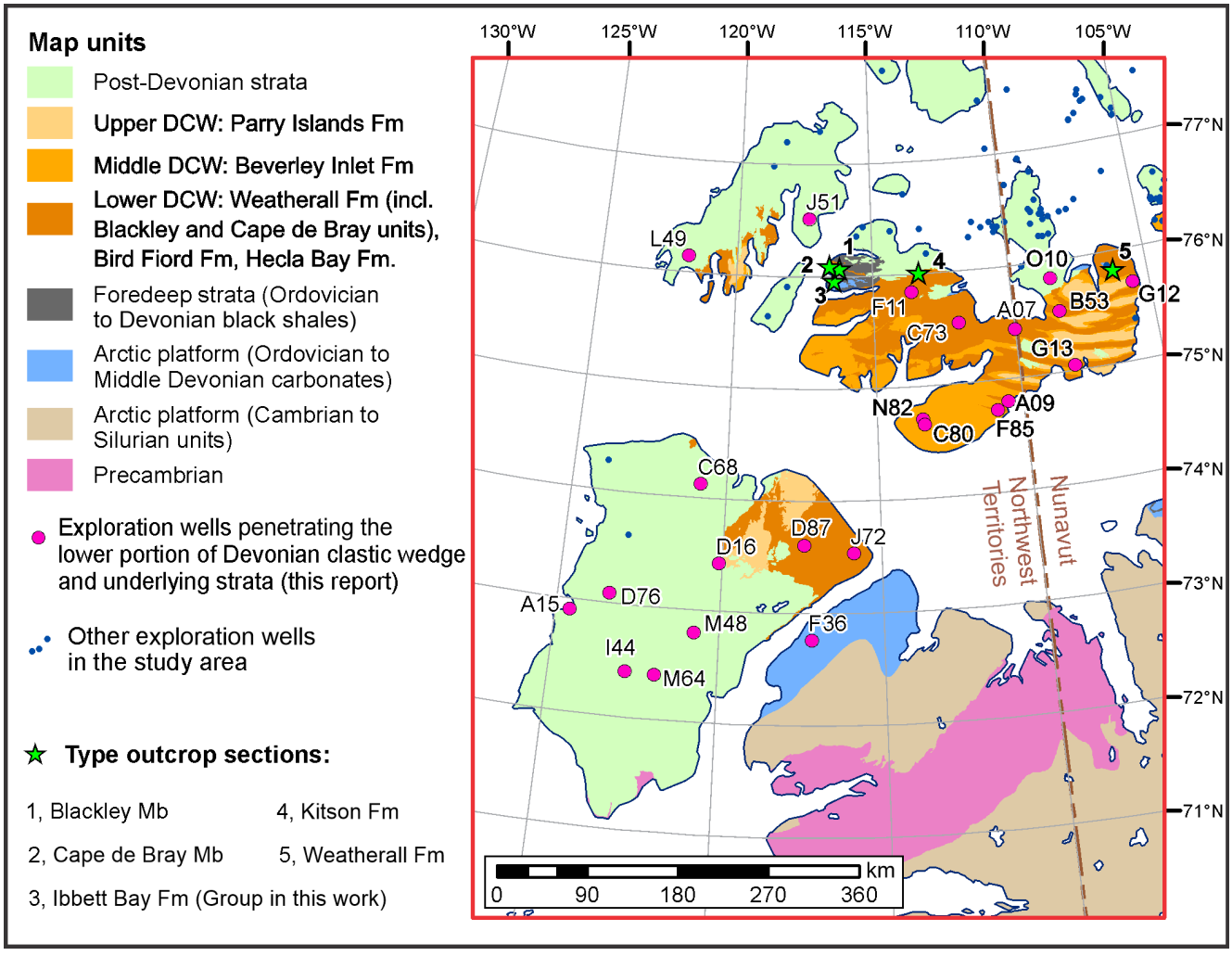

Figure 1. Simplified bedrock geology map of the study area (based on Harrison et al., 2016). Wells are labelled with units (letter) and section (two digits) from the FPS unique well identifier. Wells in N.W.T.: Orksut I-44, Ikkariktok M-64, Storkerson Bay A-15, Tiritchik M-48, Victoria Island F-36, Nanuk D-76, Kurshaak D-16, Muskox D-87, Parker River J-72, Castel Bay C-68, Dundas C-80, North Dundas N-82, Hearne F-85, Winter Harbor # 1 (A-09), Zeus F-11, Apollo C-73, Sabine Bay A-07, Dyer Bay L-49, and Wilkie Point J-51. Wells in Nunavut: Weatherall O-10, King Point West B-53, and Richardson Point G-12. Abbreviations: Fm – Formation; incl. – including.

ED-XRF DATA COLLECTION

Energy-dispersive X-ray fluorescence (ED-XRF) surveys of drillhole cutting samples from exploration wells cover 12,538 m of the lower part of the Middle-Upper Devonian (Ellesmerian) clastic wedge (DCW) and underlying strata. These data are reported in Appendix A. This is the best attainable physical coverage for well sections, since there are only a few short cores (82.6 m in cumulative thickness) in the surveyed intervals. Some of these short cores in Banks Island wells were documented by Kabanov (2018). The cutting samples were collected every 10 ft before 1979 and every 3 m once drilling migrated to metric units in 1979. The fifteen wells surveyed with XRF are the main inventory of subsurface sections penetrating the basal part of DCW, into underlying strata within the western Arctic Islands in N.W.T. jurisdiction. Due to access, timing and budgetary constraints four wells were not included in XRF survey: Winter Harbor # 1 A-09, Hearne F-85, North Dundas N-82 and Richardson Point G-12. Also, none of the wells drilled on Melville Island in Nunavut jurisdiction were surveyed with XRF. All of these wells could be considered for future study. Graphical striplogs for each surveyed section with borehole logs, descriptive lithology, XRF elemental logs, biostratigraphic data, and, selectively, synthetic seismograms and TOC (total organic carbon) data, are given in Appendix A B and C. Data points on these logs are mid-points of sampled intervals.

X-Ray Fluorescence (XRF) occurs when an x-ray is emitted from a sample that is being excited by a primary x-ray source. Because this fluorescence is unique to the elemental composition of the sample, XRF is an excellent technology for qualitative and quantitative analyses of the material's composition. Each element present in a sample produces a set of characteristic fluorescent x-rays unique to that element. This is why XRF spectroscopy is useful for elemental analysis. This elemental "fingerprint" is best illustrated by examining the x-ray energy spectrum and its "scattering peaks". Most atoms have several electron orbitals (K shell, L shell) and when x-ray energy causes electrons to transfer in and out of these shell levels, XRF peaks with varying intensities are created and will be present in the spectrum. The peak energy identifies the element, and the peak intensity indicates its concentration.

The rock drillhole cuttings and powdered samples were measured with a Bruker Tracer IV™ ED-XRF instrument. For quick turnaround, samples were left in their original vials and the vial caps were replaced with Prolene® 4 µm film. This film has one of the highest photon transmittances relative to uncovered pressed pellets of rock reference materials: 67-71% for Mg, 80-86% for Al, and 87-92% for Si (Hall et al., 2014). Differences in photon transmittance between prolene-covered and uncovered samples decreases with increasing atomic number (*ibid.*). The film-covered vials were gently shaken upside down to ensure concentration of fines on the film-covered aperture. The vials were then placed film-down on the instrument aperture, which is 10 mm in the long axis, so that the 17 mm wide vial openings covered it completely (Kabanov et al., 2020). X-rays were generated for 60 seconds, and two standards were run at regular intervals to insure credible results.

The GeoQuant Majors factory calibration of the Bruker Tracer IV™ was designed to detect the major element composition of shales and other clay material in pressed pellet form, and our earlier tests proved it is the most adequate detector available when applied to cutting samples of sedimentary strata (Kabanov et al., 2020). This calibration involves a single 15 kV excitation and reports elements from Mg to Zn. The manufacturer's limits of detection for major elements (in oxide notation except S) are 5% for MgO, 0.5 wt % for Al_2O_3, 1 wt % for SiO_2, and progressively smaller for elements with higher atomic numbers. Note that non-quantifiable reduction in accuracy comes from rough surfaces of rock chips and their random piling in a vial, making the density of the rock material very uneven. The chemostratigraphic signals can also be distorted by the uncontrollable presence of borehole cave-ins and particulate drilling-mud additives. Four trace metals reported in GeoQuant Majors (Cr, Ni, Cu, and Zn) appear at highest

concentrations well below 1 wt % and show only random spikes with no tangible stratigraphic signals. We disregard these noise-like readings and limit our analysis to the ten elements listed in Table 1.

Table 1. Approximate limit of detection in GeoQuant Majors customized calibration of a Bruker Tracer IV instrument measured on pressed pellets of CRM (Kabanov et al., 2020).

Element analysed	Characteristic X-ray line	Approximate LOD (PPM)	Possible interferences
MgO	Kα	50,000	
Al_2O_3	Kα	5000	
SiO2	Kα	10,000	
P_2O_5	Kα	500	
S	Kα	500	
K_2O	Kα	150	
CaO	Kα	100	
TiO_2	Kα	50	Ba
MnO	Kα	30	Cr
Fe_2O_3	Kα	80	Mn

TOTAL ORGANIC CARBON (TOC) DATA

LECO analyses

Total organic carbon content for this study comes from two sources: LECO analysis and Rock-Eval pyrolysis. The first type of data was obtained during cutting gas analyses (Dewing et al., 2007). Cuttings were collected from Arctic Island petroleum exploration boreholes while drilling. Wet cutting samples were collected at the well site and shipped to Calgary for LECO analysis. TOC in this method was determined by combusting the organic carbon and measuring the resulting carbon dioxide produced (see Snowdon and McCrossan, 1973). In the LECO method, samples are powdered, weighed, and chemically treated prior to analysis to remove the inorganic carbon (carbonate) from the rock. The sample is then combusted in the presence of excess oxygen, allowing carbon dioxide to form from the free (organic) carbon in the rock. The amount of carbon dioxide is directly proportional to the amount of organic carbon (or the TOC) of the rock. The TOC measured by the LECO method does not include a measurement of the free hydrocarbons present in the sample. The free hydrocarbons are volatized when the samples are dried after the acid treatment is performed to remove the inorganic carbonate minerals. Thus, if a sample has a high free hydrocarbon content, the LECO TOC value will be smaller than a Rock-Eval / Hawk TOC value, which includes free hydrocarbons (S1) in the TOC calculation (Law, 1999).

TOC - total organic carbon (weight percent)

Total Gas – (C1+C2+C3+iC4+C4)

% Wet – (C1)/(C2+C3+iC4+C4)

Rock-Eval analyses

The Rock-Eval analyses were performed at the Geological Survey of Canada (Obermajer et al., 2007). A typical Rock-Eval experiment heats a powdered rock sample at 300 ºC for 3 min in a helium atmosphere, then the oven temperature is steadily increased to 600ºC. The final stage involves oxidation and combustion of the residual organic matter up to 600ºC. Present day tests would continue with pyrolysation until 650^{O}C and oxidation until 850ºC. The amount of hydrocarbons volatilized at 300ºC and evolved from kerogen at 300ºC to 600ºC is quantitatively determined by a flame ionization detector (FID). The percentage of carbon in CO_2 formed during oxidation at 600ºC and in the hydrocarbon peaks is used to calculate TOC, expressed as a weight percent.

During Rock-Eval pyrolysis (also known as the bulk rock or basic pyrolysis method) a rock sample is heated in the absence of oxygen to 300°C and kept at this temperature for three minutes. Any free hydrocarbons within the sample become volatized during this initial heat and are and are recorded as the S1 peak (free hydrocarbons) in HC/g. The temperature is then raised from 300°C to 650°C, at a rate of 25°C per minute, to pyrolyze the kerogen present in the rock. The hydrocarbons generated during this phase are measured with the FID (HC/g) and recorded as the S2 peak (hydrocarbon potential). CO_2 released from the thermal cracking of kerogen during this stage is also measured (using a thermal conductivity detector) and reported as the S3 peaks. The S3 peaks represent Organic Carbon yield form the rock. The temperature at which the maximum generation of S2 yield occurs is designated as Tmax and it is a measure of the maturity of the rock sample in °C. Generally, the higher the Tmax, the more mature the sample. After attaining a maximum pyrolysis temperature of 600°C the oven is cooled to 300°C and the oxidation cycle is performed whereby a ramp rate of 25°C/minute is utilized as the sample is heated from 300C to a maximum temperature of 800°C in the presence of oxygen. Here the S4 peaks are determined. These represent Organic Carbon in the rock liberated with Oxygen from 300^{O}C until 600^{O}C. After 600^{O}C and up to 800^{O}C in the Oxidation cycle liberated CO2 and CO come from the Inorganic Carbon and therefore are not part of the Total Organic Carbon, TOC. The pyrolysis / oxidation cycle then yields hydrocarbons, kerogen, TOC and mineral carbonate and indicates maturity.

TOC is a measure of organic carbon content calculated from S peaks a follows:

TOC (wt.%) = (0.085 x (S1 + S2)) + (0.10 x S4)

Or more correctly

TOC (wt%) = {(S1+S2)*0.085} + (S3CO2*12/144) + (S3CO+S3'CO*12/280) + S4CO2*12/440) +(S4CO*12/280)}

Table 2. Intervals in exploration wells (measured depth) surveyed with ED-XRF.

Wells	Interval[1]	Interval (m)
Apollo C-73	3390 – 8490 ft	1033 – 2587.75 m
Castel Bay C-68	8420 – 9500 ft	2566.4 – 2895.6 m
Dundas C-80	6120 – 9570 ft	1865.4 – 2917 m
Dyer Bay L-49	3490 – 8930 ft	1063.75 – 2721.9 m
Ikkariktok M-64	1870 – 3020 ft	570 – 920.5 m
Kusrhaak D-16	6800 – 12000 ft	2072.6 – 3657.6 m
Muskox D-87	999 – 2052 m	999 – 2052 m
Nanuk D-76	3430 – 4530 ft	1045.45 – 1380.75 m
Orksut I-44	5750 – 7570 ft	1752.6 – 2307.33 m
Parker River J-72	396 – 924 m	396 – 924 m
Storkerson Bay A-15	5040 – 6510 ft	1536.2 – 1984.25 m
Sabine Bay A-07	4580 ft – 7560 ft	1396 – 2304.3 m
Tiritchik M-48	3100 – 4710 ft	945 – 1435.6 m
Wilkie Point J-51	2600 – 5100 ft	792.48 – 1554.5 m
Zeus F-11	1310 – 2160 ft	399.3 – 658.37 m

[1]Interval depths are shown in the units of the original samples.

UPDATES IN LITHOSTRATIGRAPHY

While not proposing new lithostratigraphic names, we argue for changes in the usage and ranks of several units, as reflected in the table of formation tops (Appendix C). These updates, summarised hereafter, are discussed in full by Kabanov et al. (in prep.).

The long-living (Ordovician-Devonian), thick basinal succession of Melville Island is unified under the name Ibbett Bay Group within N.W.T. jurisdiction. We elevate the Ibbett Bay succession from its long-standing formation status (Tozer, 1956) to a formal group based on gamma-log traceability of the Kitson Formation it is upper part. The Cape Phillips Formation, previously recognized in N.W.T. in Apollo C-73 and Sabine Bay A-07 wells, is considered the Ibbett Bay equivalent east of the N.W.T.-Nunavut border (Fig. 1). Our seismic interpretation is consistent with a tongue of the Ibbett Bay Group extending southward to northern Banks Island ("Banks embayment"), although it is not intersected by wells there and seismic character could be explained simply by poor data quality where this package is more deeply buried.

Six high-gamma horizons (nicknamed "hot shales") are traced in the Ibbett Bay – Cape Phillips succession. Three upper horizons (4a, 4b and 5) are traced as the geophysical markers of the Kitson Formation. In the subsurface of Melville Island, where Kitson is part of the Ibbett Bay Group, the hot shale 4a defines the Kitson base. Hot shales 4a, 4b, and 5 are traced across the entire study area through a significant facies changes between the Kitson mudrocks and the Blue Fiord ramp carbonates. From NE to SW, the base of Kitson is migrating from hot shale 4a, which approximates the Silurian/Devonian boundary, to the hot shale 5, which is lower or mid-Eifelian. Our seismic interpretation traces clinoforms in the lower DCW, leading to the interpretation that the upper Kitson are basinal toes of these clinoforms, and therefore, once the age control is improved, the top of the Kitson Formation is expected to switch to younger ages in the progradation direction. We concur with Embry and Klovan (1976) who considered the Orksut Formation a redundant equivalent of Kitson. The Eids Formation is no longer recognized in N.W.T. part of Western Arctic Islands.

The scrutiny of available materials on the lower DCW indicates that the Blackley and Cape de Bray formations of Embry and Klovan (1976) are not traceable enough to warrant their formation rank. We therefore revert to the original stratigraphic layout of Tozer and Thorsteinsson (1964) where Blackley and Cape de Bray are two lower members within the Weatherall Formation.

Tracing of clinoforms under Melville and Banks islands corroborates the earlier suggestion of Harrison and Brent (2005) that, generally, the Cape de Bray Member is a time-migrating, fine-grained facies developed along the distal offshore foresets of Weatherall clinoforms. It is practical to trace the Cape de Bray as a formal Member from its type area in the Canrobert Hills in western Melville Island across much of Melville Island at surface and into the subsurface on industry seismic from these outcrops (Harrison, 1995). The reason that a consistent package can be defined on Melville Island is that for a period of time, progradation dominated the DCW system, whilst aggradation was limited. Thus, the Cape de Bray Member on Melville Island can be defined to represent a relatively synchronous fine grained marine slope facies of the foresets, with the mappable top of the Member defined at the top-lap surface where clinoforms are apparently truncated by topsets or at the first topset reflector (Harrison, 1995). The Member has clinoform geometries at its top in outcrop and distinct clinoform reflectors at the top of the Member on seismic (Harrison, 1995). This study confirmed the mapping of this Cape de Bray Member (formal sense). Whilst the area where the Cape de Bray Member is defined is significant, the definition does not work away from Melville Island, in other portions of the DCW. Where the system is both prograding and aggrading, the top of foresets can not be mapped consistently, and are distinctly different

ages from the Cape de Bray type area. This condition exists both to the NE in the older parts of the DCW and to the SW on Banks Island. We therefore revert to the Weatherall Formation of Tozer and Thorsteinsson (1964) for the complete package, and the Cape de Bray member is a sub-set of the Weatherall Formation. We use the Cape de Bray (formal) Member definition only on Melville Island, and in those wells where the thick (≥100 m) basal part of the Weatherall Formation is dominated by shales, the Cape de Bray is treated as an informal member.

Similarly, the Blackey unit can be treated as a formal member in the local Canrobert Hills area (~2000 km^2) within western Melville Island, where it is mapped on surface (Fig. 1; Harrison et al., 2016), and we no longer recognize Blackley in wells as a formal unit.

On eastern Melville Island in Nunavut jurisdiction, the lower DCW reveals essentially the same character as in N.W.T (Appendix C). Three out of four wells there show presence of the basal finer-grained parts within the Weatherall Formation (shale and siltstone, practically no sandstone) assignable to the Cape de Bray member. Only in the Weatherall O-10 well sandstones intervene down to the Weatherall base, making recognition of the Cape de Bray unit impractical. Seismic surfaces, in particular traces of "Cape de Bray" clinoforms, highlight that lithostratigraphic tops are discordant just like to the west of N.W.T.-Nunavut border. Furthermore, the lithostratigraphic Cape de Bray unit seems to become younger in the SW direction, reflecting the position of this basal fine-grained facies within the prograding Weatherall Formation. The sub-DCW strata in the Nunavut part of Melville Island show significant change in lithostratigraphy comparing to N.W.T. There is no Kitson Formation, and the basal shale-dominated strata of the Weatherall Formation directly onlap the Blue Fiord carbonate platform. The thick stratal succession below the Blue Fiord platform carbonate is dominated by organic-rich mudrocks. Names in use to describe this basinal succession are Eids Formation, Devon Island Formation, and Cape Phillips Formation. Revision of the sub-DCW lithostratigraphic nomenclature in Nunavut is a call for future study.

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