ABSTRACT

Paleoceanographic Evolution of the Late Devonian Duvernay Formation:
Insights from the Geochemistry of the Western Canada Sedimentary Basin

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The Late Devonian Duvernay Formation is characterized by organic-rich mudrocks, argillaceous carbonates, and calcareous shales and is located in the Western Canada Sedimentary Basin (WCSB). The Duvernay is partitioned into the West and East Basins by the Leduc Formation carbonate platform along the Rimbey-Meadowbrook trend. This study identifies intervals of organic matter accumulation associated with elevated productivity in a high resolution geochemical analysis of four cored wells in the Duvernay. These geochemical analyses demonstrate the paleoceanographic history of the Duvernay through utilization of major and trace elements, isotopic composition of organic matter, and organic matter abundance. As a result, five chemostratigraphic units are present representing intervals of anoxia punctuated by oxic intervals. Low nitrogen isotopic composition across the WCSB indicates that nitrogen fixation was the dominant nutrient pathway, suggesting that an open marine hydrographic setting with coastal upwelling controlled organic matter supply during deposition of the Duvernay Formation.

Paleoceanographic Evolution of the Late Devonian Duvernay Formation:
Insights from the Geochemistry of the Western Canada Sedimentary Basin

by

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A Thesis

Approved by the Department of Geosciences

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Steven G. Driese, Ph.D., Chairperson

Submitted to the Graduate Faculty of
Baylor University in Partial Fulfillment of the
Requirements for the Degree
of

Master of Science

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December 2019

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ACKNOWLEDGMENTS

I would like to thank my advisor, Dr. Steve Dworkin, and committee members, Dr. Stacy Atchley and Dr. Thad Scott, for their guidance on this project and support throughout my time in graduate school. I would also like to thank my fellow colleagues, Bart Yeates, Anna Thorson, and Elisabeth Rau, for their help with sample collection in Calgary, Alberta and personal support. You all helped me overcome obstacles to become a better geologist and person. Thank you, Hayden Johnson, for your assistance with sample preparation. Lastly, I would like to thank Dr. Ren Zhang for his assistance in laboratory analyses.

DEDICATION

To my parents, Del and Cathi Wisler, for their endless support and encouragement. My father introduced me to the field of geology and inspired my pursuit of a career in the energy industry. I also dedicate my thesis to my sister, Jennifer, who is my very best friend and motivator. Finally, I dedicate this to Nick, Caroline, and puppy Waylon for their positive reinforcement throughout my graduate school experience.

CHAPTER ONE

Introduction

Overview and Objectives

The Late Devonian Duvernay Formation in the Western Canada Sedimentary Basin (WCSB) is a major source rock for conventional hydrocarbon reservoirs such as the Grosmont and Leduc carbonates and has recently been targeted as an unconventional reservoir in Alberta, Canada (Stoakes, 1980; Stoakes and Creaney, 1985; Chow et al., 1995; Rokosh et al., 2012). The Duvernay is composed of organic-rich mudrocks, argillaceous carbonates, and calcareous shales and was deposited in two sub-basins, i.e. the East and West Basins, which are separated by the Leduc Formation along the Rimbey-Meadowbrook reef trend. The West Basin is mostly composed of basinal, siliceous and argillaceous-rich facies whereas the East Basin contains more carbonate-rich facies. The paleoceanographic and hydrographic evolution of the WCSB is unconstrained and it is unclear if the two basins evolved differently as might be indicated by their differences in lithology and net thickness. As a result, most unconventional drilling activity has been conducted in the West Basin, and only recently this activity has expanded rapidly into the East Basin.

This study will further clarify the paleoceanographic evolution of the WCSB and will document chemostratigraphic units within the Duvernay Formation. These chemostratigraphic units have distinct trace element concentrations, organic matter abundance, and isotopic ratios that reflect deposition under a wide range of paleoceanographic conditions. Chemostratigraphic units can be associated with sedimentologic, stratigraphic, and petrophysical characteristics of mudrocks, aiding in subsurface correlations that results in effective predictive potential for hydrocarbon exploration. In turn, this chemostratigraphic framework will aid in the comparison between the East and West Basins and will help to constrain the depositional history of the WCSB.

To identify the chemostratigraphic units that characterize the Duvernay, a high-resolution geochemical study of four Duvernay cores spread across the WCSB was completed (Figure 1.1). The analyses completed in this study include major and trace element concentrations of bulk rock, organic matter abundance, and the carbon and nitrogen isotopic composition of organic matter. These analyses are used to: (1) identify chemostratigraphic units, (2) determine paleoredox conditions, (3) characterize the nutrient dynamics of nitrogen that likely controlled productivity during deposition, and (4) enhance our understanding of the hydrographic setting of the East and West Basins related to the nutrient dynamics of the formation.

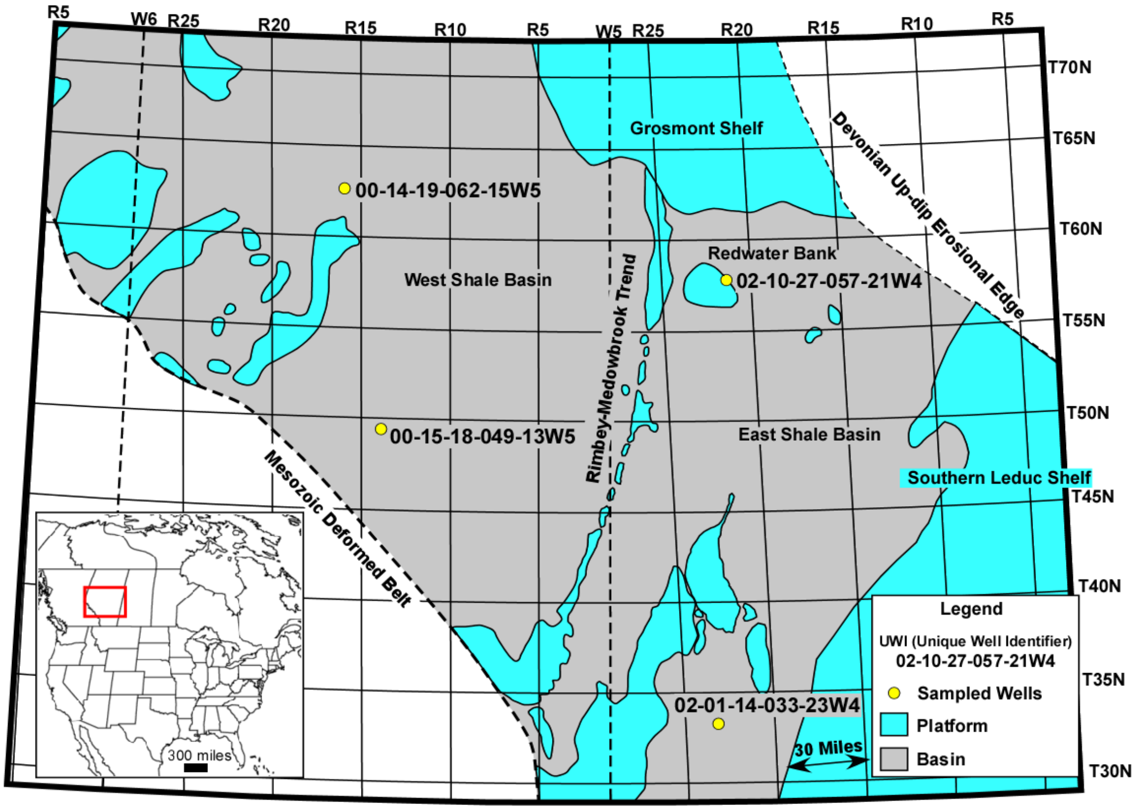


Figure 1.1. Basemap of the Duvernay Formation (gray) surrounded by platform carbonates (light blue). The wells described and sampled are denoted by their UWI and yellow circle. 00-14-19-062-15W5 and 00-15-18-049-13W5 are located in the West Basin and 02-10-27-057-21W4 and 02-01-14-033-23W4 are located in the East Basin. Modified from Rokosh et al., 2012, Switzer et al., 1994, Preston et al., 2016, and Wong et al., 2016a.

Geochemistry of Organic-Rich Mudrocks

Organic-rich mudrocks are critical components to hydrocarbon exploration and production. Mudrocks enriched in organic matter are known as source rocks for conventional hydrocarbon reservoir plays and serve as the target reservoir in unconventional plays. One way to explore and better understand the character of source rocks is by studying their geochemical attributes. The attribute of organic-rich mudrocks that has been most commonly used for the reconstruction of paleoceanographic conditions is the abundance of organic carbon because it indicates water column conditions that favored organic matter production and preservation. However, there are many other geochemical attributes that lend insight into paleo-basin water chemistry.

Chemostratigraphic units are identified using many variables including high resolution analyses of total organic carbon (TOC), the isotopic composition of organic matter, and trace metal concentrations. These data reveal the geochemical evolution of marine depositional environments which in turn leads to a better understanding of controls on organic matter preservation and productivity. Geochemical data are powerful tools for the evaluation of depositional conditions that were responsible for the distinctive chemical conditions that lead to the formation of organic-rich mudrocks. These conditions include low Eh and an abundant nutrient source. The presence or absence of these conditions are revealed through the proxies of TOC, isotopic composition of organic matter, and trace metal concentrations.

Paleoredox Conditions and Elemental Concentrations

Basin redox conditions are one of the major controls on the preservation of organic matter. Bacteria and other aerobic organisms utilize oxygen as the terminal electron acceptor during the decomposition of organic matter. However, as concentrations of oxygen in the water column decline, anaerobic bacteria use a variety of other reduction agents to metabolize organic matter. These mechanisms include denitrification, manganese reduction, iron reduction, sulfate reduction, and methanogenesis (Froelich et al., 1979). In particular, sulfate reduction plays an important role in organic matter depositional conditions because it is abundant in seawater and promotes the presence of free hydrogen sulfide (H_2S), resulting in the precipitation of pyrite (Berner, 1982). Therefore, the presence of depositional pyrite is a stratigraphic indicator suggesting highly reducing conditions that will likely be accompanied by significant organic matter preservation.

Terminology used to convey the abundance of dissolved oxygen in the water column include oxic, suboxic, anoxic, and euxinic (Tyson and Pearson, 1991). Under oxic conditions, aerobic organisms utilize dissolved O_2 for their metabolic processes (Tribovillard et al., 2006). Suboxic conditions refer to low amounts of oxygen which can be reflected in slightly enriched trace metal concentrations. Anoxia is defined by the absence of dissolved oxygen and may occur when waters are restricted or stratified. Anoxia may occur in environments when the demand for oxygen in organic matter decomposition exceeds the rate of supply (Tribovillard et al., 2006). Euxinic conditions refers to conditions where free hydrogen sulfide is present in the water column.

Another geochemical indicator that reveals paleoredox conditions and dissolved oxygen levels is the presence of trace elements. The trace metals primarily used in this study to interpret paleoredox conditions are U and Mo. During deposition, U adsorbs onto clay particles (Tribovillard, 2006). U is used as an indicator of reducing conditions because reduced uranium is sequestered into muddy sediments along with organic matter. Under euxinic conditions, Mo is mineralized by undergoing a ‘geochemical switch’ where thiomolybdates form which adhere to organic particles (Erickson and Helz, 2000; Helz et al., 1996). Because Mo is typically associated with elevated TOC, Mo/TOC ratios can be used to identify the hydrographic setting of a basin (Algeo and Lyons, 2006). The restriction of a basin can be identified because low Mo/TOC ratios are oftentimes caused by the draw-down effect. In contrast, upwelling zones in non-restricted environments experience a constant resupply of trace metal-bearing waters and nutrients, resulting in higher Mo/TOC ratios.

Enrichment factors were calculated for the redox-sensitive trace elements. This process normalizes the trace elements to Al and then to the North American shale standard (Wedepohl, 1971, 1991). The formula for the enrichment factor is; EF = $(\text{trace element/Al})_{\text{sample}}/(\text{trace element/Al})_{\text{average shale}}$ (Tribovillard, 2006). EF values greater than 1 are enriched whereas values less than 1 are depleted.

Organic Matter Accumulation and TOC

Organic matter accumulates in marine sediments due to increased biomass production and conditions that preserve the organics. Because Cu is a micronutrient used by algae during photosynthesis, its abundance can be used as a proxy for productivity (Algeo and Maynard, 2004; Calvert and Pederson, 1993).

The three factors that control organic matter preservation in sediments are net primary productivity, organic matter decomposition, and sedimentation rate or dilution (Sageman et al., 2003). However, some research indicates that sedimentation rates play a much less important role that the other two controlling factors (Tyson, R.V., 2001). Net primary productivity is dependent on nutrient availability including N, P, and/or Fe which are often limiting nutrients (Pedersen and Calvert, 1990). Nutrients may also be delivered to a system by rivers draining the continents or from discharging groundwater. Each of these mechanisms can lead to the accumulation of organic matter.

Isotopic Composition of Organic Matter

The isotopic characterization of organic matter plays a critical role in this study as the $\delta^{13}C_{org}$ reveals perturbations to the carbon cycle as well as serving as a stratigraphic correlation tool. It has been reported that positive excursions in $\delta^{13}C_{org}$ can indicate increased productivity that results in increased storage of ^{12}C within the sediments which in turn increases the abundance of ^{13}C (Sephton et al., 2002).

The nitrogen isotopic composition of the preserved organic matter can be used as an indicator of dominant nutrient pathways. In modern marine ecosystems, values around 0‰ indicate that nitrogen fixation is the dominant process, values between 4-6‰ may indicate a combination of nitrification and denitrification, and values exceeding 6 suggest that denitrification is occurring (Mariotti, 1983; Wada, 1980). Positive $\delta^{15}N$ excursions occur when nitrate is a limiting nutrient and negative excursions occur when aerobic organisms utilize the available nitrogen through fixation. The $\delta^{15}N$ values may also help to discriminate between allochthonous and autochthonous sources of organic matter.

Geologic Setting and Background

During the Late Devonian (Frasnian) stage, approximately 375 Ma, the Duvernay Formation was deposited within 20 degrees of the paleo-equator in North America (Figure 1.2). The Duvernay correlates with the Muskwa Formation in northern Alberta and the Canol and Horn River Formations in the Northwest Territories (Liu et al., 2018). The Cooking Lake Formation, a platform carbonate, underlies the Duvernay and the WCSB is partitioned into the East and West Shale Basins by the contemporaneous platform top Leduc Formation (Figure 1.3). The Duvernay contains primarily type II organic matter with average TOC concentrations of about 5 wt%, although values as high as 17 wt% have been reported (Fowler et al., 2001; Stoakes and Creaney, 1984; Chow et al., 1995; Higley et al., 2009; Dunn et al., 2012).

Figure 1.2. Late Devonian (375 Ma) paleogeographic and plate tectonic map (modified from Ron Blakey, 2013).

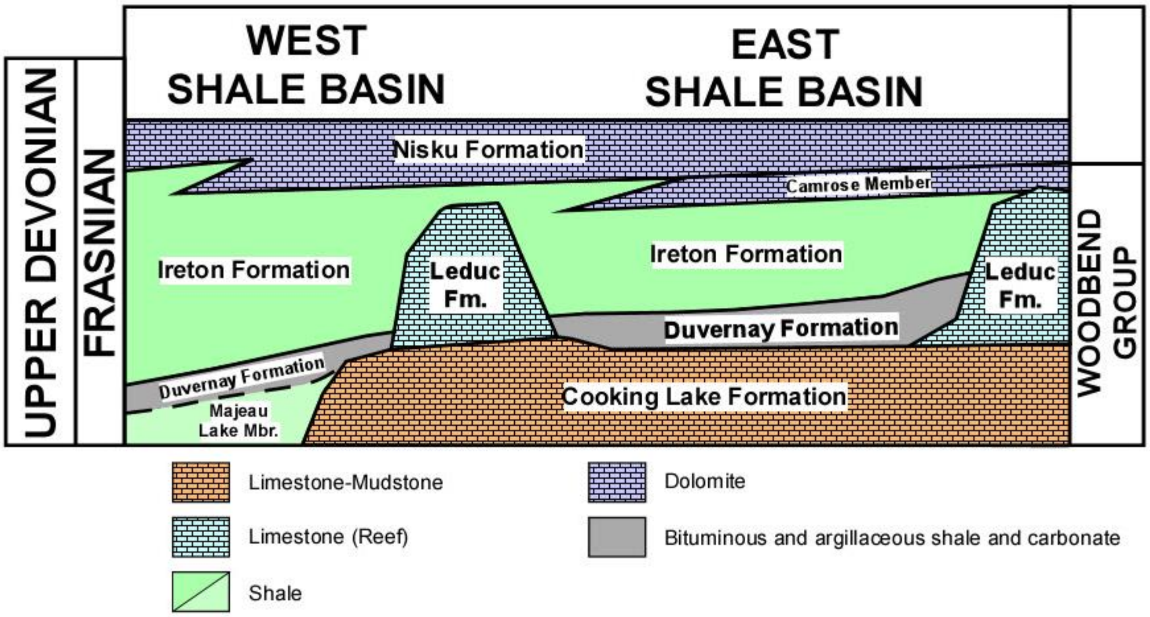


Figure 1.3. Stratigraphic relationships for the Duvernay Formation in the Western Canada Sedimentary Basin. The Duvernay overlies the Cooking Lake Formation and Majeau Lake Member and extends throughout the West and East Basins. Modified from Stoakes (1980).

The Duvernay in the West Basin is primarily composed of basinal mudrocks whereas the East Basin lithologies contain more carbonate-rich facies. During the Late Devonian, areas near the WCSB had an equatorial location favorable for coastal upwelling and humid conditions (Golonka et al. (1994). Andrichuk (1961) concluded that bioclastic limestones in the lower Duvernay are derived from Leduc reef debris with paleocurrents indicating southwestward transport. This flow direction can be compared to the northeast-southwest trend of the reef complexes in the WCSB (Figure 1.1). These studies illustrate contrasting depositional styles; coastal upwelling from the southwest and sediment transport from the northeast. Furthermore, it has been reported that the West Basin became enriched in organic matter from bio-productivity due to upwelling during times of high sea level whereas the East Basin became enriched in organic matter from changes in sedimentation rates during transgressions that restricted carbonate deposition; TOC was high when carbonate deposition was low (Harris et al., 2018).

CHAPTER TWO

Methods

Sample Collection

Duvernay sample collection took place at the Alberta Energy Regulator (AER) Core Research Centre in Calgary, Alberta. Continuous core from four Duvernay wells were selected for this study for geochemical analyses. The Unique Well Identifier (UWI) for the wells are 02-10-27-057-21W4, 00-15-18-049-13W5, 00-14-19-062-15W5, and 02-01-14-033-23W4 and their locations are shown in Figure 2.1. The cores were selected because of their distribution across the East and West Basins, drilling date and associated well log quality, and predicted TOC as determined from petrophysical attributes. Each core was described for its sedimentologic and stratigraphic attributes, with hand samples taken approximately every 1 meter for geochemical analysis. A total of 284 samples were collected and brought back to Baylor University for geochemical analysis. Core descriptions made at the Core Research Centre include characterization of facies, carbonate texture and grains (Dunham, 1962), ichnofabric index (Reineck, 1963), and distribution of pyrite and trace fossils.

Sample Preparation and Analyses

All samples were prepared and processed at Baylor University. Samples were crushed in a shatter-box for two minutes to produce a fine powder. Each crushed sample was stored in a plastic centrifuge tube. Sample preparation for elemental analysis included weighing 6.00g of crushed rock mixed with 1.00g of cellulose binder. The mixed samples were then placed in aluminum cups and pressed into a pellet using a hydraulic press. A Rigaku wavelength dispersive x-ray fluorescence spectrometer analyzed elemental concentrations for 10 major elements and 7 minor trace elements. The major elements include SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, and P_2O_5. The trace elements include V, Cu, Zn, U, Zr, Ni, Mo, and S.

Organic carbon and nitrogen abundances were analyzed on a Thermo Finnigan Flash Elemental Analyzer. The samples were weighed out into silver capsules, treated with 10% HCl to destroy calcite, and then dried in an oven. After drying, the samples were packed in tin capsules before combustion. The analytical precision for these analyses based on duplicate analyses is +/- 0.05 wt% for C and +/- 0.02 wt% for N.

Sample preparation for isotopic analysis included placing approximately 1g of sample into a glass tube with the subsequent addition of 10% HCl until the samples ceased to react. Samples were centrifuged, and the supernatant was poured off. Samples were then washed three times with distilled water to remove all CaCl which interferes with mass spectrometry. After samples were dried, they were analyzed on a ThermoFisher DeltaV stable isotope mass spectrometer. The precision of analyses for $\delta^{13}C_{org}$ is 0.2 per mil, and 0.13 per mil for $\delta^{15}N$.

CHAPTER THREE

Results

Facies Descriptions

Core description resulted in the identification of nine lithofacies (Figure 3.1) (Appendix A). Seven of these facies are associated with basinal depositional settings and are identified as shale facies by previous studies (Wendte and Stoakes, 1982; Klovan, 1964; Weissenberger, 1994; Wendte, 1994; Whalen et al., 2000a, 2000b; Wong et al., 2016a, 2016b, 2016c; Thorson, 2019). The other two lithofacies are Green Shale and Talus and are recognized in the work completed by Thorson (2019). Green shale and Talus occur within the contemporaneous Leduc and Grosmont Formation foreslope, margin, and platform interior carbonates. These deposits are consistent with ideas proposed by Andrichuk (1961) which concluded that bioclastic limestones in the Duvernay were sourced from growing Leduc reefs.

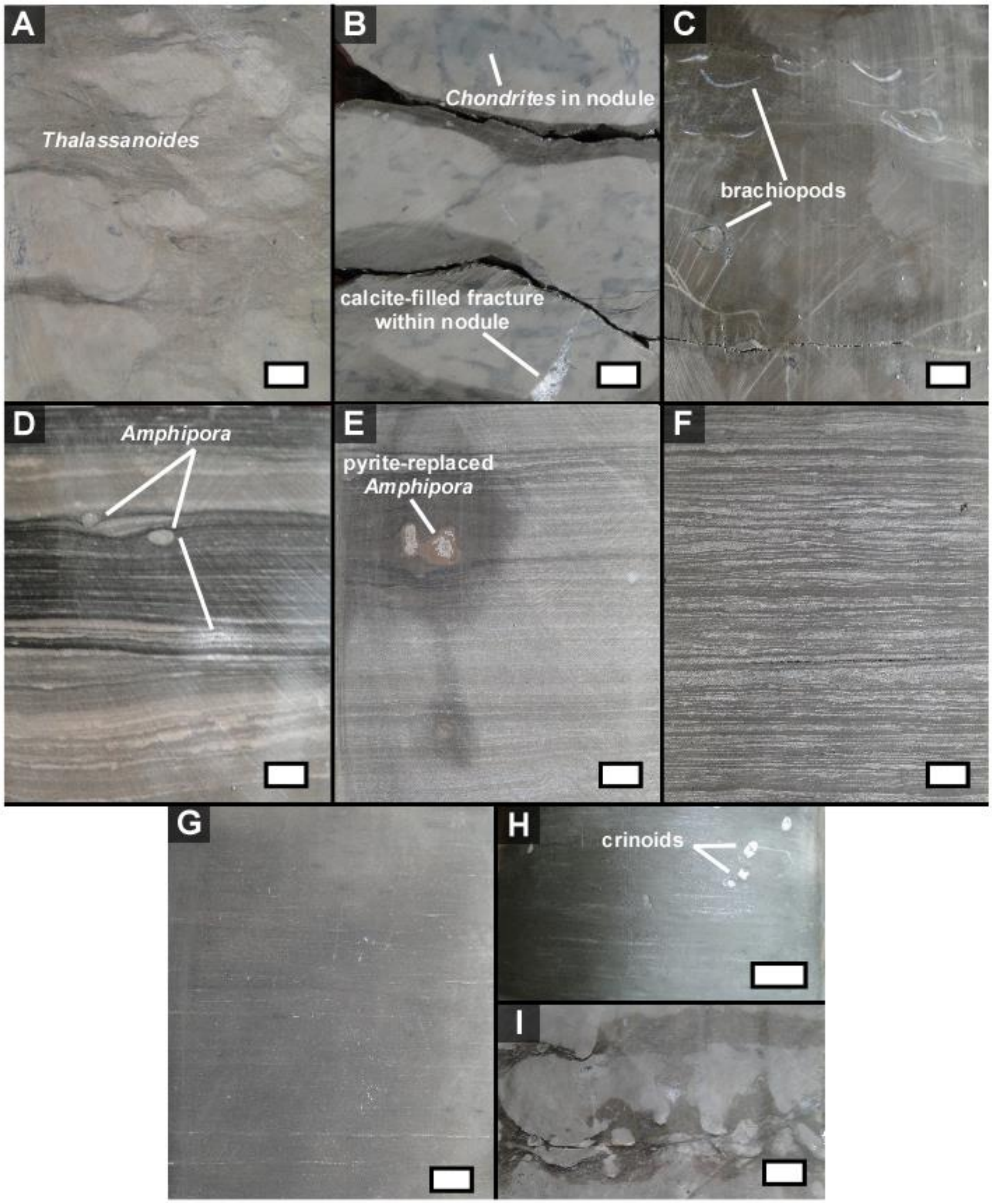


Figure 3.1. Core photographs of seven observed Duvernay Formation basinal facies (A-G), and contemporaneous Leduc/Grosmont facies (H and I) (Thorson, 2019). White scale bar in each photo measures 1 cm (0.39 in). (**A**) Facies BN – Burrowed Nodular within 02-10-27-057-21W4, depth 1204 m (3950.1 ft). (**B**) Facies LN – Laminated Nodular within 02-01-14-033-23W4, depth 2099 m (6886.5 ft). (**C**) Facies BM – Burrowed Mudstone within 02-01-14-033-23W4, depth 2106 m (6909.4 ft). (**D**) Facies B(r)LAM – Burrowed Laminated *Amphipora* Mudstone within 02-10-27-057-21W4, depth 1211 m (3973.1 ft). (**E**) Facies BLAM – Black Laminated *Amphipora* Mudstone within 02-10-27-057-21W4, depth 1206 m (3956.7 ft). (**F**) Facies BMLM – Black Mechanically Laminated Mudstone within 00-14-19-062-15W5, depth 2895 m (9498 ft). (**G**) Facies BLM – Black Laminated Mudstone within 02-10-27-057-21W4, depth 1155 m (3789.4 ft). (**H**) Facies GS – Green Shale within 00-10-08-046-22W4, depth 5675 ft (Thorson, 2019). (**I**) Facies Talus within 02-01-14-033-21W4, depth 2066 (6778.2 ft).

The seven basinal facies are grouped into three Duvernay facies associations based upon inferred paleoredox conditions of oxic (open basin), suboxic (transitional), and anoxic (restricted) environments based on their associated sedimentologic attributes (Table 3.1). Open basin facies include Burrowed Nodular (BN) and Laminated Nodular (LN) and were identified by various mudstone nodules, lamina, carbonate grains, and high ichnofabric index (Thorson, 2019). Transitional basin facies include Burrowed Mudstone (BM), which is distinguished by occurrence of brachiopods and crinoids, some laminations, and high ichnofabric index. Restricted basin facies include Burrowed Laminated *Amphipora* Mudstone (BrLAM), Black Laminated *Amphipora* Mudstone (BLAM), Black Mechanically Laminated Mudstone (BMLM), and Black Laminated Mudstone (BLM). All are characterized by millimeter to centimeter-scale lamina, few carbonate grains, and low ichnofabric index. Ichnofabric index (ii) values were assigned based on the bioturbation index grade rated from 0-6 was established by Reineck (1963): 0 has no bioturbated sediment, 1-3 describes sparse to moderate bioturbation, 4 is high bioturbation with dense trace fossils, 5 characterizes intense bioturbation with disturbed bedding, and 6 is complete bioturbation with reworked sediment (Figure 3.2).

The West Basin wells, 00-14-19-062-15W5 and 00-15-18-049-13W5, contain open, transitional, and restricted facies associations. In contrast, the East Basin wells 02-01-14-033-23W4 and 02-10-27-057-21W4 include Talus and Green Shale along with Duvernay basinal deposits. The West Basin wells consist predominately of restricted basin facies whereas East Basin wells are predominately composed of open basin facies (Figure 3.3). All geochemical data may be found in Appendix B.

Table 3.1: Duvernay facies summary table (modified after Thorson, 2019).

Facies Association	Open Basin		Transitional Basin	Restricted Basin			
Facies Name	Burrowed Nodular (BN)	Laminated Nodular (LN)	Burrowed Mudstone (BM)	Burrowed Laminated *Amphipora* Mudstone [B(r)LAM]	Black Laminated *Amphipora* Mudstone (BLAM)	Black Mechanically Laminated Mudstone (BMLM)	Black Laminated Mudstone (BLM)
Environment	peri-platformal	basinal	basinal	peri-platformal	peri-platformal	basinal (restricted)	basinal (restricted)
Texture	mudstone (wackestone)	mudstone	mudstone (local packstone)	wackestone	mudstone	mudstone	mudstone
Diagnostic Grains	-	-	-	*Amphipora*	oncoids (*Amphipora* = nuclei)	-	-
Other Grains	brachiopods, crinoids, SK, intraclasts, peloids	brachiopods, crinoids, intraclasts, SK, peloids, gastropods	brachs., crinoids, SK, few mudstone-textured intraclasts and lithoclasts, peloids	intraclasts	SK	few: *Amphipora*, crinoids, brachiopods, SK	few: brachiopods, crinoids, SK (<0.5mm), intraclasts
Sedimentary Features	TH, PL, AST, GLOSSI, hardground /firmground, irregular mudstone nodules	elongate horiz. mudstone nodules, cm-lamina, (few) mm-lamina between mudstone nodules & burrows, CH, TH, PL	TH, PL, GLOSSI, CH, mm-lamina, few cm-lamina, firmground/ hardground	mm-lamina, TH	cryptalgal mm-lamina	mm to cm-lamina: alternating silt-sized carbonate grains and mud, TH, PL, Z, calcite concretions	mm-lamina, few TH, GLOSSI, PL, event beds (silt-sized CO_3 grains), firmg./hardg. East Basin: dark grey, blocky recovery West Basin: dark grey to black, poker-chip recovery
Representative Core Photos	Figure 3.1 (A)	Figure 3.1 (B)	Figure 3.1 (C)	Figure 3.1 (D)	Figure 3.1 (E)	Figure 3.1 (F)	Figure 3.1 (G)

Abbreviations: SK = undifferentiated skeletal fragments; mech. strx = mechanical structures; sed. = sediment; strom. frags. = stromatoporoid fragments; horiz. = horizontal; frac. = fractures; TH = *Thalassinoides; PL = Planolites;* AST = *Asterosoma;* GLOSSI = *Glossifungites;* CH = *Chondrites;* Z = *Zoophycos;* firmg. /hardg. = firmground/hardground; brachs. = brachiopods; CO_3 = carbonate.

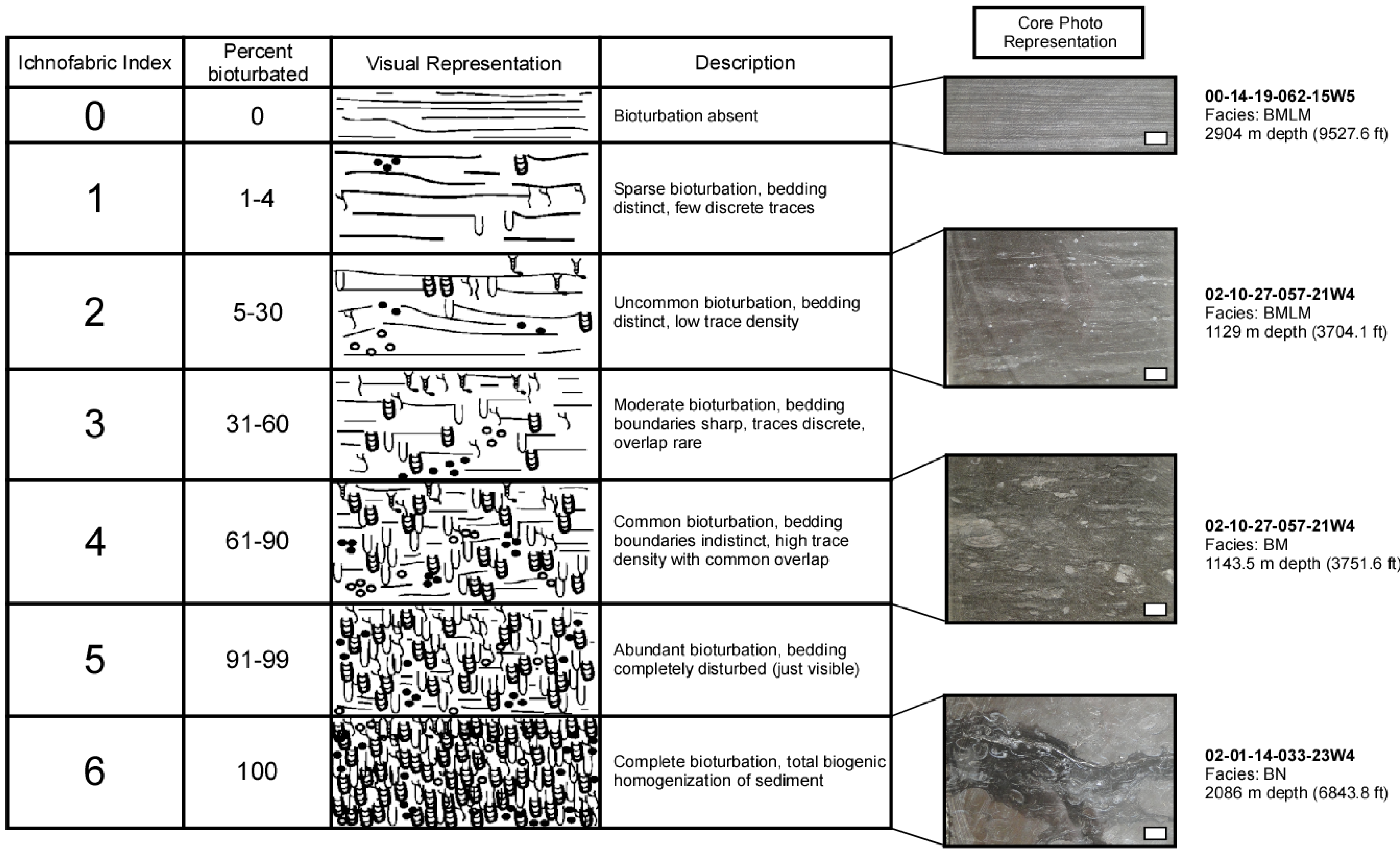


Figure 3.2. Explanation of ichnofabric index (ii) with corresponding examples from the Duvernay Formation wells 00-14-19-062-15W5, 02-10-27-057-21W4, and 02-01-14-033-23W4 (photos via Thorson, 2019). Core photo scale bar represents 1 cm. Oxic conditions, typically open basin facies, correspond with high ii whereas anoxic conditions, typically restricted basin facies, correspond with low ii. Modified from Reineck, 1963, and Bann et al., 200

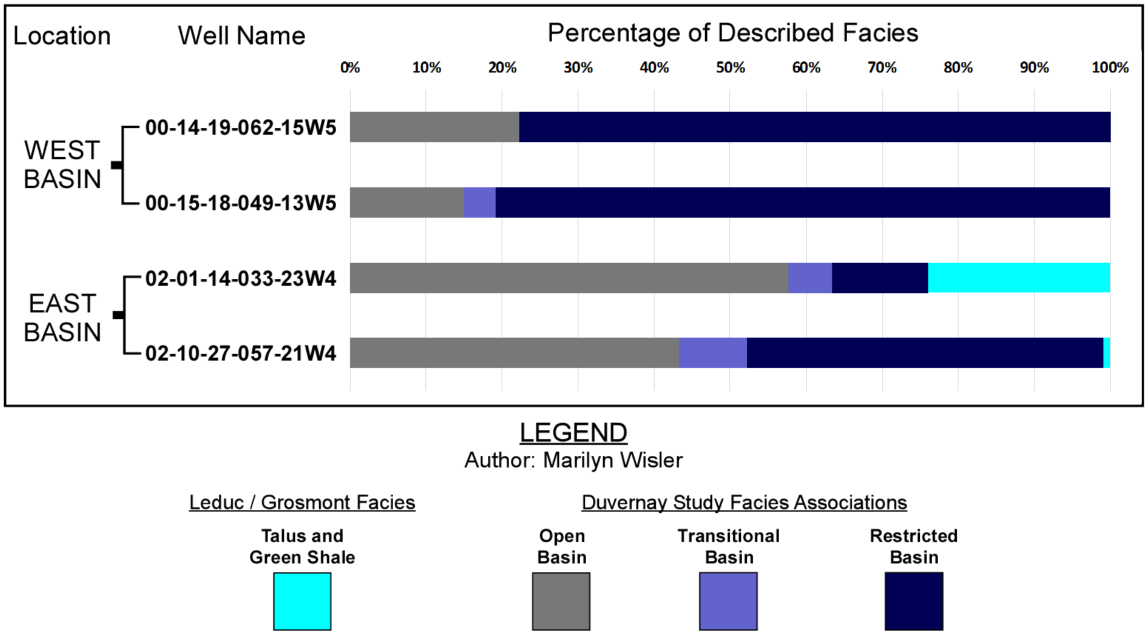


Figure 3.3. Percentage of described facies associations per well from the East and West Basins. Light blue represents Talus and Green shale. Open basin (gray) includes Burrowed Nodular and Laminated Nodular. Transitional basin (purple) includes Burrowed Mudstone. Restricted basin (navy) includes Burrowed Laminated *Amphipora* Mudstone, Black Laminated *Amphipora* Mudstone, Black Mechanically Laminated Mudstone, and Black Laminated Mudstone.

WCSB Geochemistry

A geochemical comparison between Duvernay cores from the West and East Basins reveals differences in major element concentrations that are related to lithology. Si is the most abundant major element in the West Basin and reflects the abundance of biogenic silica, quartz, and clay minerals. The Duvernay in the West Basin is significantly enriched in Si compared to the East Basin (Figure 3.4). This is consistent with the dominance of restricted basin lithofacies and is also reflected in the abundance of Al (Figure 3.5). K is also higher in the West Basin and reflects the abundance of illite which is the dominant clay mineral. The abundance of clays minerals is indicated by both Al and K concentrations and their concentrations reveal higher amounts of clay minerals in the West Basin. Ca is the most abundant major element in the East Basin and indicates the high concentrations of calcite in these wells (Figure 3.6). This is consistent with the dominance of open basin lithofacies in the East Basin where there were more appropriate conditions for carbonate formation.

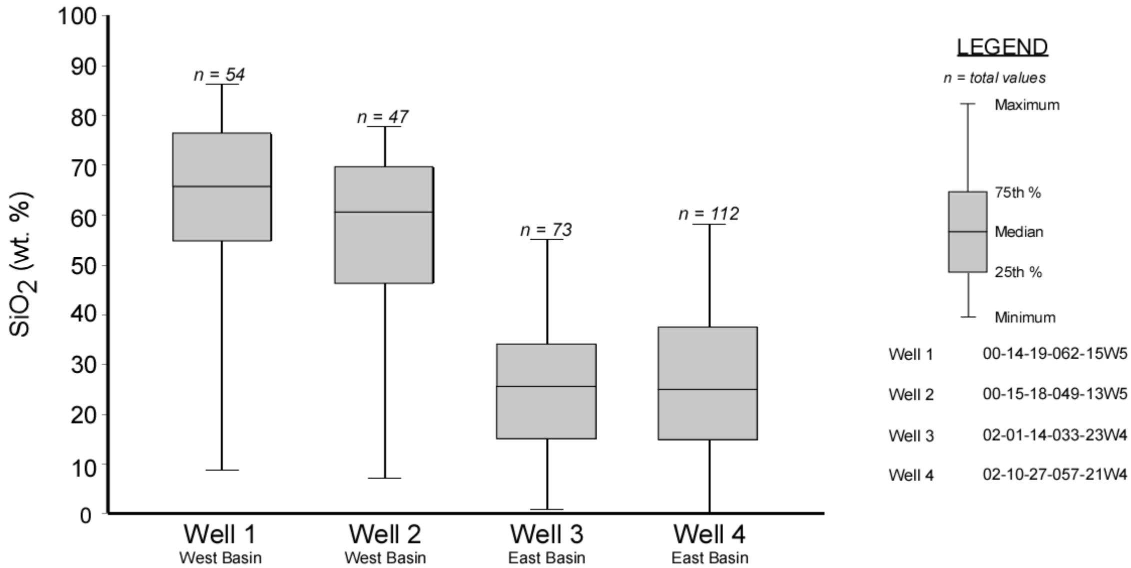


Figure 3.4. Box and whisker plot for Si for the four Duvernay cores. Si is more abundant in the West Basin than the East Basin. This reflects the presence of biogenic silica and clay minerals that are common in restricted basin facies.

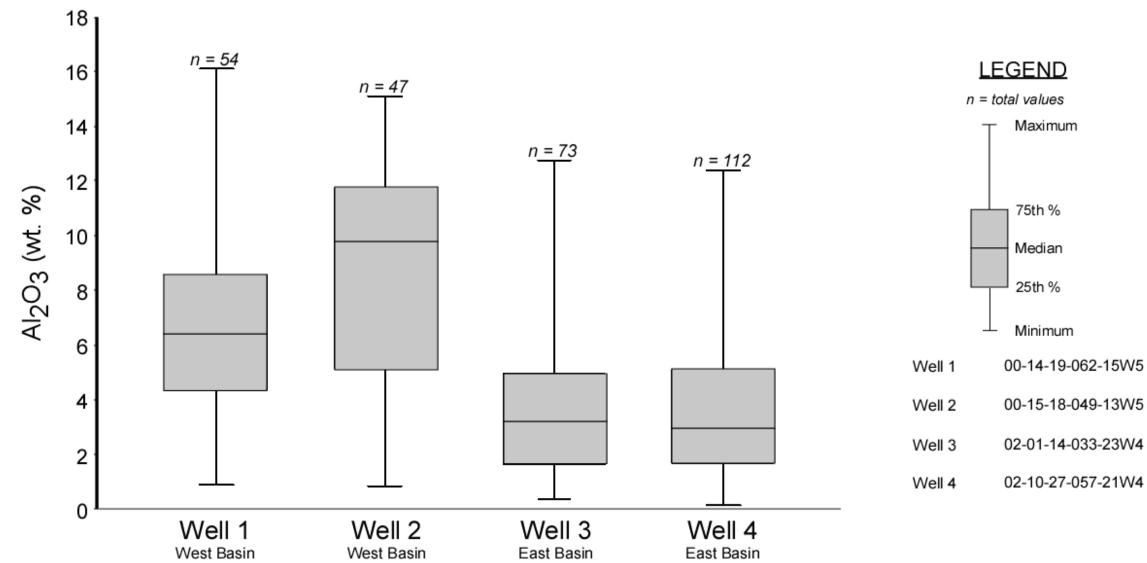


Figure 3.5. Box and whisker plot for Al for the four Duvernay cores. Al is more abundant in the West Basin than the East Basin and reflects the abundance of clay minerals.

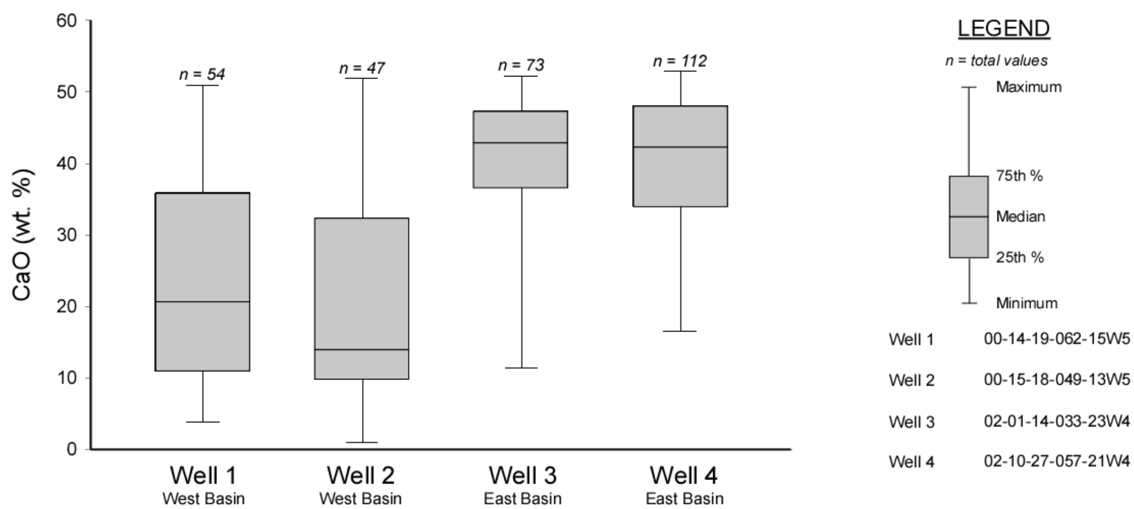


Figure 3.6. Box and whisker plot for Ca for the four Duvernay cores. Ca concentration is higher in the East Basin than the West Basin. This reflects the abundance of calcite which is common in open basin facies.

The range of TOC values for the four cores reveals variability between the West and East Basins (Figure 3.7). The maximum TOC value in the West Basin is 7.0 wt% and in the East Basin is 12.5 wt%. However, the median values are approximately 2 wt% higher in the West Basin than the East Basin (Figure 3.7). The average $\delta^{13}C_{org}$ in both basins is about -28.7 per mil and this uniform isotopic composition for both basins reflects the atmospheric source of the carbon. The average $\delta^{15}N$ of organic matter in the cores averages near +2 per mil and the similarity in nitrogen isotopic composition between the basins suggests similar nutrient pathways (Figure 3.8).

Redox sensitive trace elements U and Mo are enriched throughout the WCSB although Mo has higher EFs than U (Figure 3.9). Well 00-14-19-062-15W5 in the West Basin exhibits the highest enrichment factors for Mo which is consistent with this wells' elevated median organic matter concentrations. Cu concentrations are commonly used an indicator of productivity, although Duvernay median enrichment factors for Cu of about 1 do not suggest elevated productivity for the WSCB during Duvernay deposition.

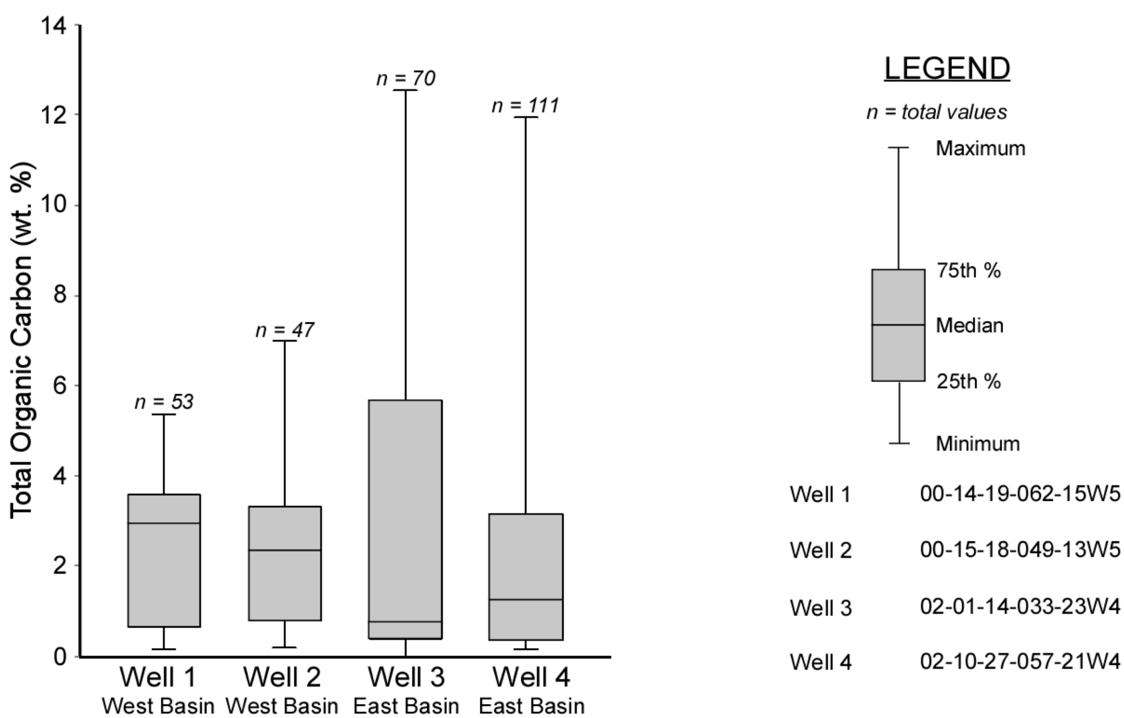


Figure 3.7. Box and whisker plot for TOC for each well. The maximum TOC values are higher in the East Basin, but median values are higher in the West Basin.

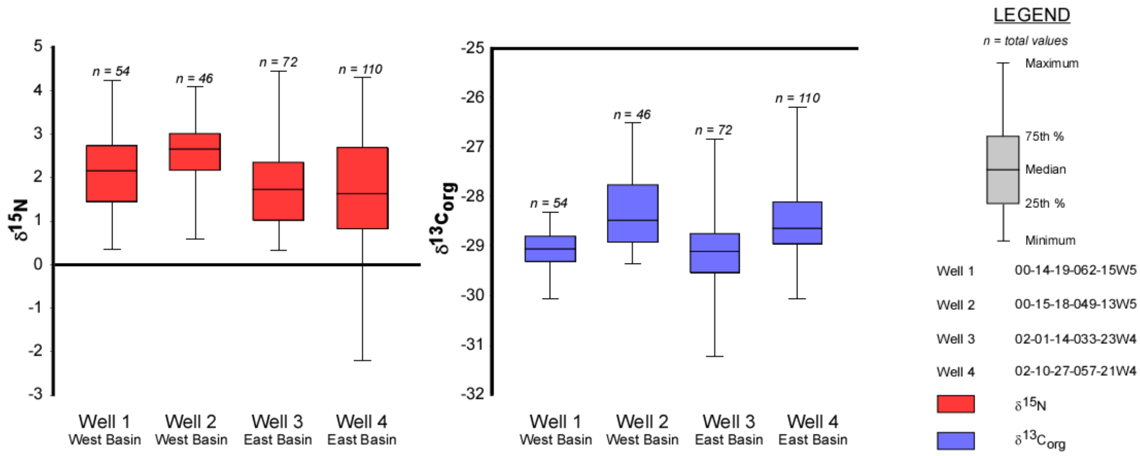


Figure 3.8. Box and whisker plot for $\delta^{15}N$ and $\delta^{13}C_{org}$ for each well. The isotopic composition of $\delta^{15}N$ is higher in the West Basin than the East Basin. The isotopic composition of $\delta^{13}C_{org}$ is similar throughout the WCSB, but has the lowest range in Well 1 and greatest range in Well 3.

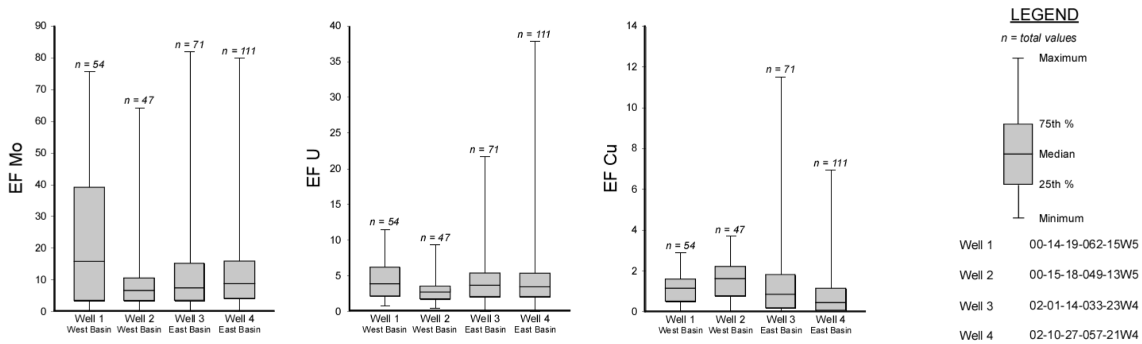


Figure 3.9. Box and whisker plot of the enrichment factor of trace elements Mo, U, and Cu in each well.

Chemostratigraphic Units

Five chemostratigraphic units designated A through E were identified based on their geochemistry and reveal trends in paleoceanographic conditions in the WSCB during Duvernay deposition. The most useful geochemical variables for identifying chemostratigraphic units in the WCSB are TOC, EF Mo, and $\delta^{15}N$. Chemostratigraphic units A, C, and E have higher concentrations of organic matter and Mo than the intervening units B and D, which have higher $\delta^{15}N$ values (Figures 3.10, 3.11, 3.12).

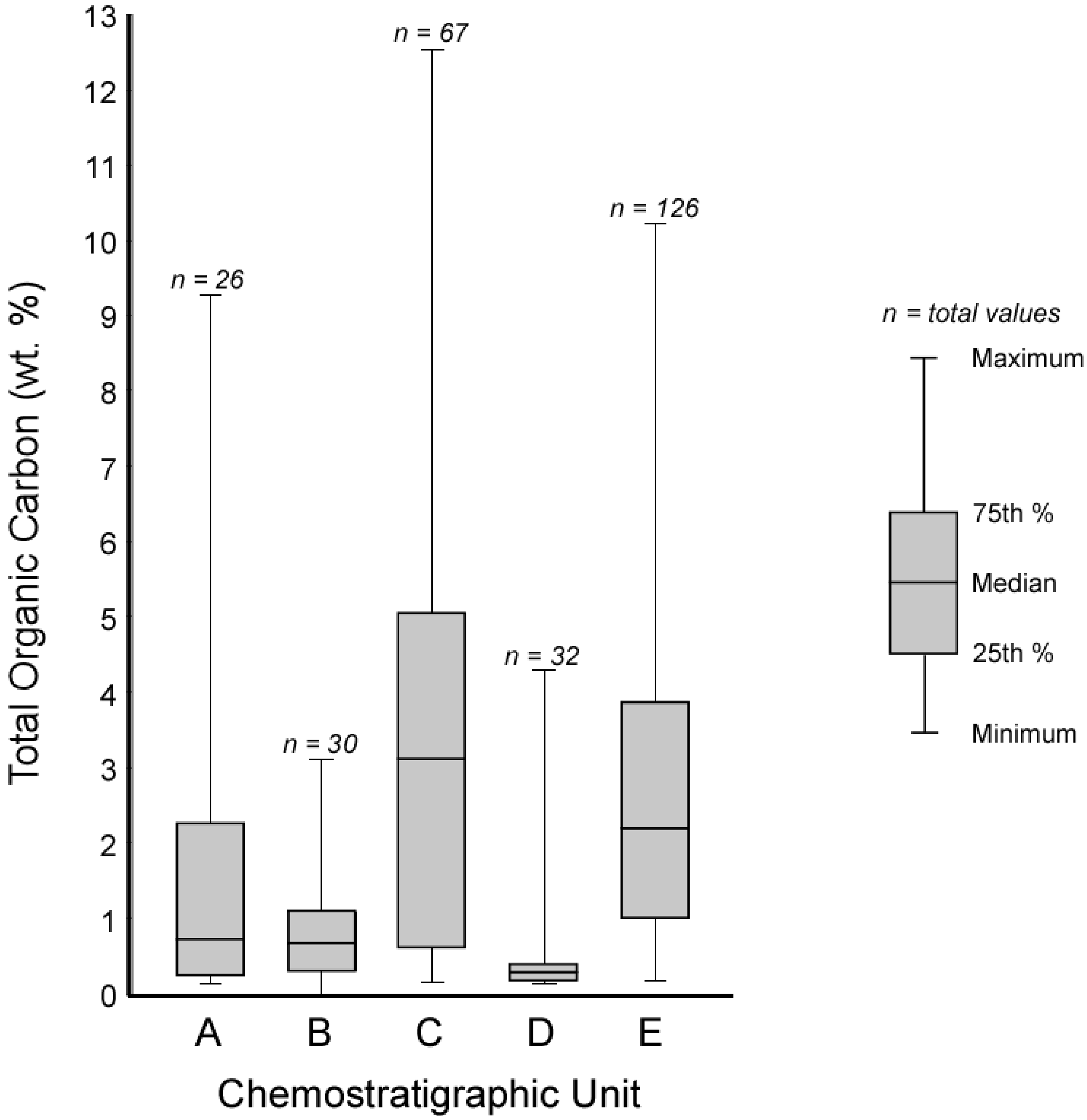


Figure 3.10. Box and whisker plot for TOC vs. chemostratigraphic unit for all four wells. Units A, C, and E have a greater range of TOC than units B and D.

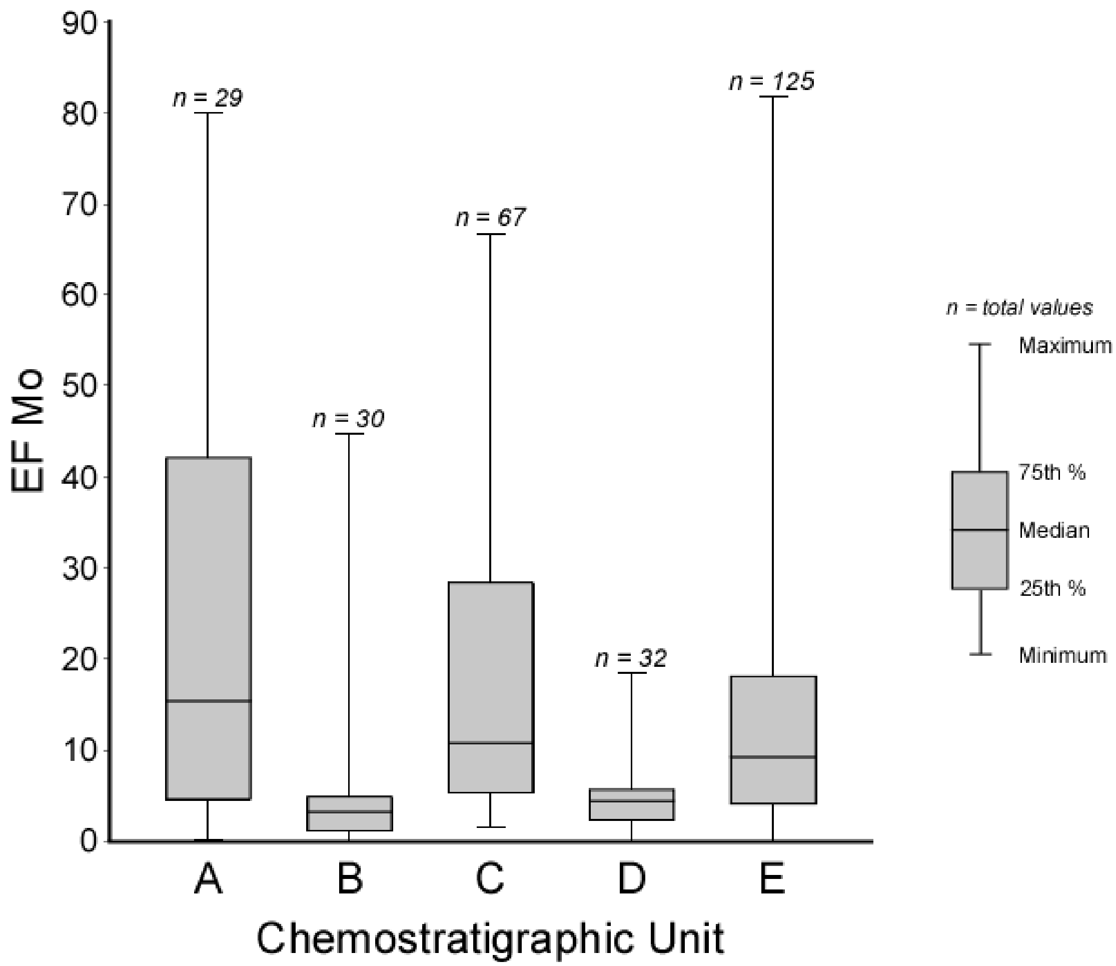


Figure 3.11. Box and whisker plot for the enrichment factor of Mo vs. chemostratigraphic unit for all wells. Units A, C, and E have greater abundance in Mo than units B and D.

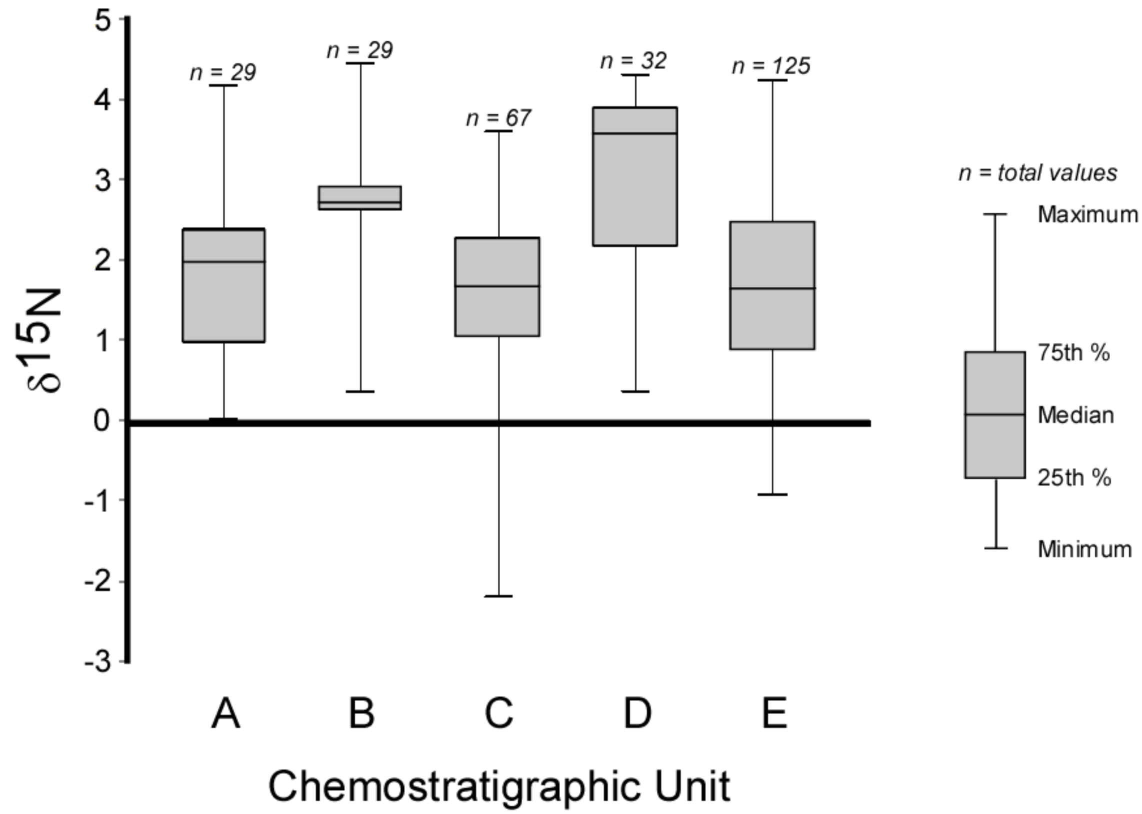


Figure 3.12. Box and whisker plot for $\delta^{15}N$ vs. chemostratigraphic unit for all four wells. Units B and D have higher median values than units A, C, and E.

Chemostratigraphic unit A is identified by elevated concentrations of Mo and TOC, and low $\delta^{15}N$ values (Figures 3.10, 3.11, 3.12). In the West Basin, EF Mo approaches 46 and TOC ranges from 0-3.8 wt% (Figures 3.13, 3.14). In the East Basin, EF Mo approaches 80.0 and the highest EF for U is 37.9 (Figures 3.15, 3.16). In Unit A, $\delta^{15}N$ averages 2.2 in the West Basin and 1.8 in the East Basin. Perhaps the most distinguishing characteristic about unit A is how different it is from the units above it (Figure 3.14, 3.15, and 3.16).

The overlying Unit B is characterized by low TOC, Ca concentrations of about 60 wt% (except in 00-15-18-049-13W5), and higher $\delta^{15}N$ values with average values of 2.7 across the basin. EF Mo decreases significantly in this interval, and never exceeds 7.4.

Unit C represents a return towards higher TOC and EF Mo, but most importantly, unit C is characterized by a positive carbon isotope excursion near its base (Figures 3.13, 3.14, 3.15, 3.16). In the East Basin, EF Mo ranges from 0.5-64.5 and TOC ranges from 0.2-12.5 wt%. In the West Basin, EF Mo ranges from 1.6-66.7 and TOC ranges from 0.3-7.0 wt%.

Unit D is similar to unit B but is characterized by average $\delta^{15}N$ values of 2.9 in the West Basin and 3.4 in the East Basin. EF of Cu, Mo, and U all decrease in Unit D. Ca is the most abundant major element in this interval.

Chemostratigraphic unit E is characterized by an increase in redox sensitive trace metals and displays variable TOC concentrations. Unit E in the East Basin averages 2.9 wt% TOC and the West Basin averages 2.5 wt% TOC. K and Al increase in unit E reflecting an increase in clay minerals.

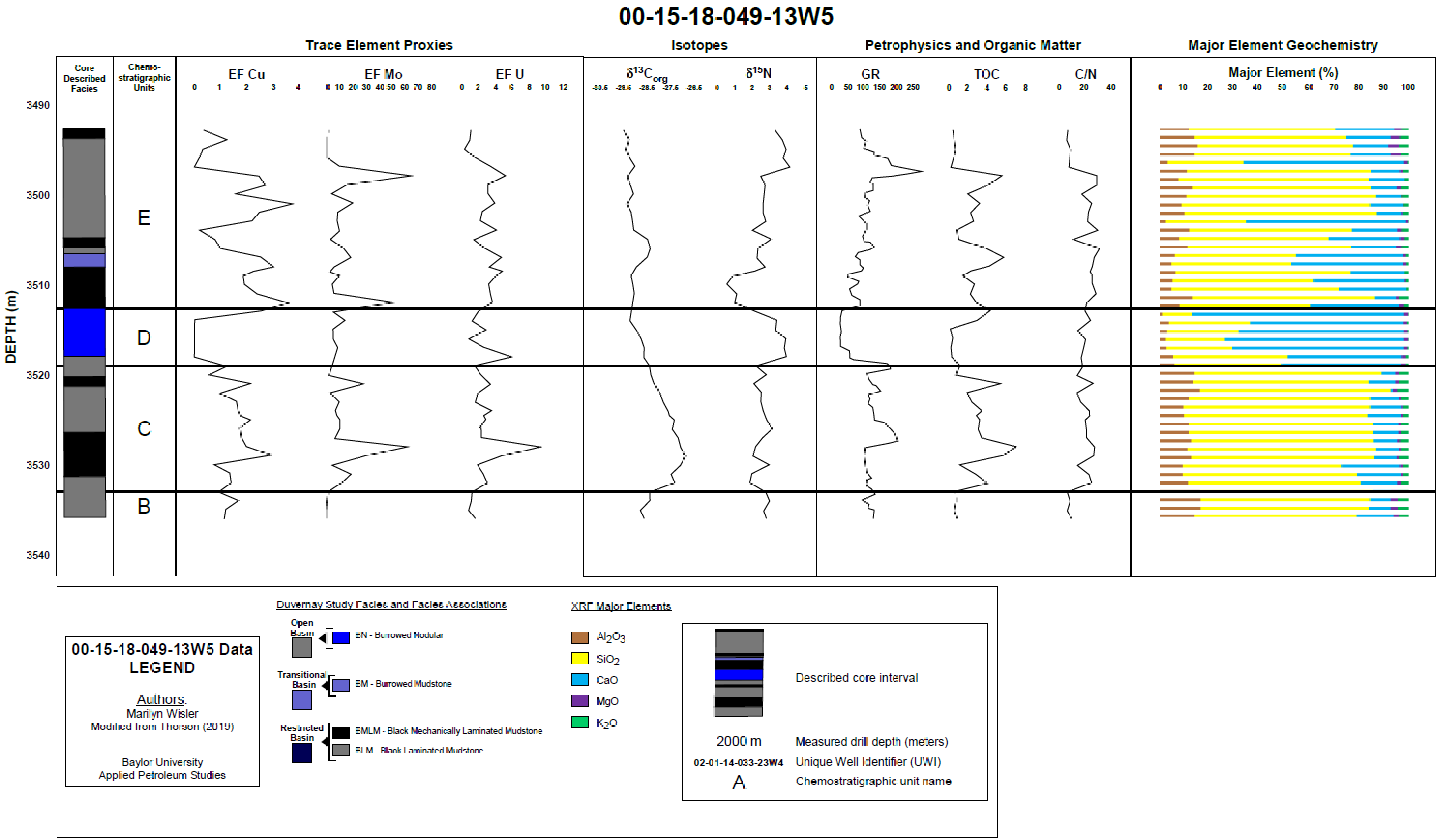


Figure 3.13. Well 00-15-18-049-13W5 data versus depth (m) for the core described facies, chemostratigraphic units, EF Cu, EF Mo, EF U, $\delta^{13}C_{org}$, $\delta^{15}N$, gamma ray from well log, measured TOC, C/N ratio, and proportion of major elements as a percentage.

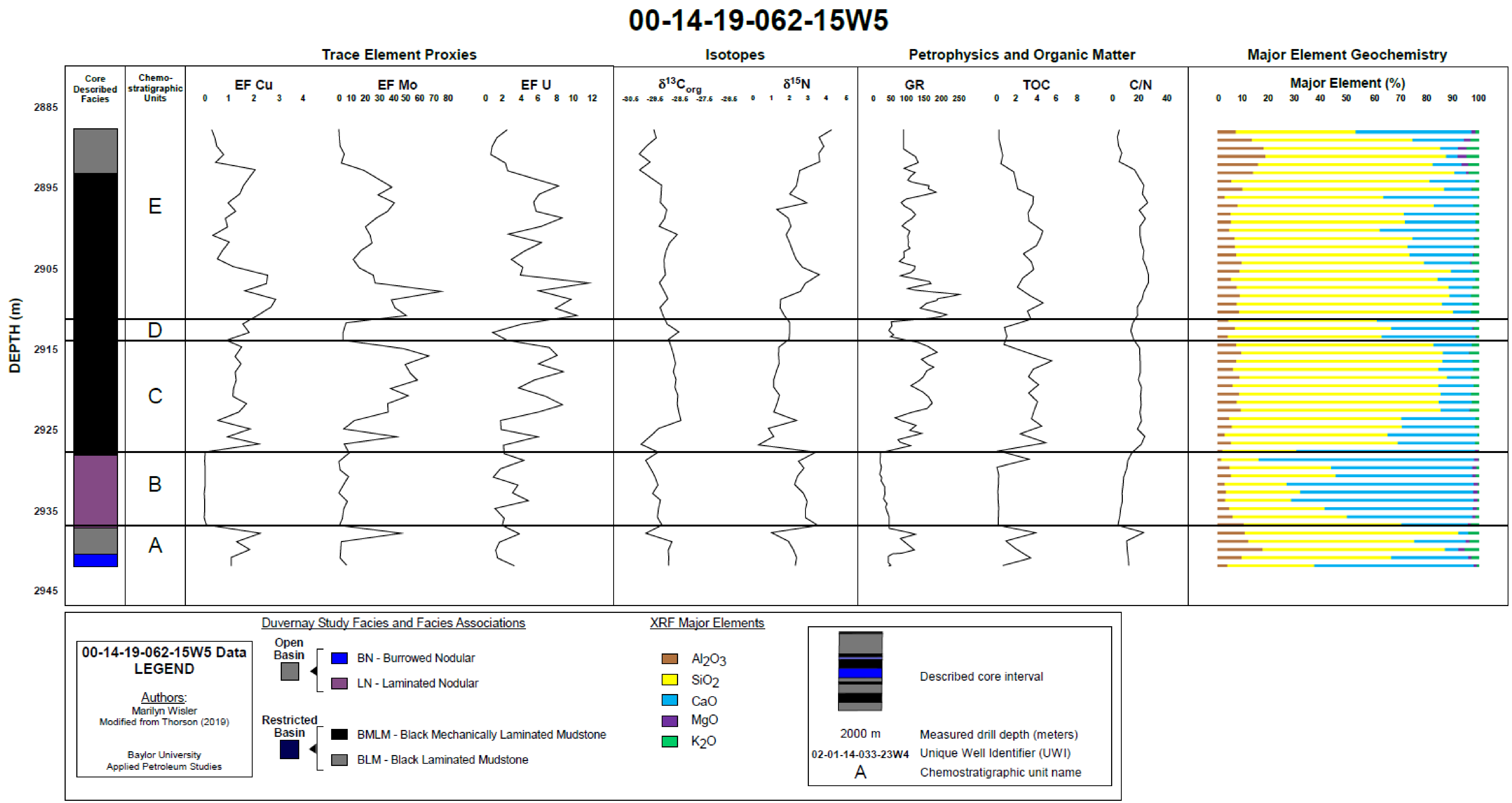


Figure 3.14. Well 00-14-19-062-15W5 data versus depth (m) for the core described facies, chemostratigraphic units, EF Cu, EF Mo, EF U, $\delta^{13}C_{org}$, $\delta^{15}N$, gamma ray from well log, measured TOC, C/N ratio, and proportion of major elements as a percentage.

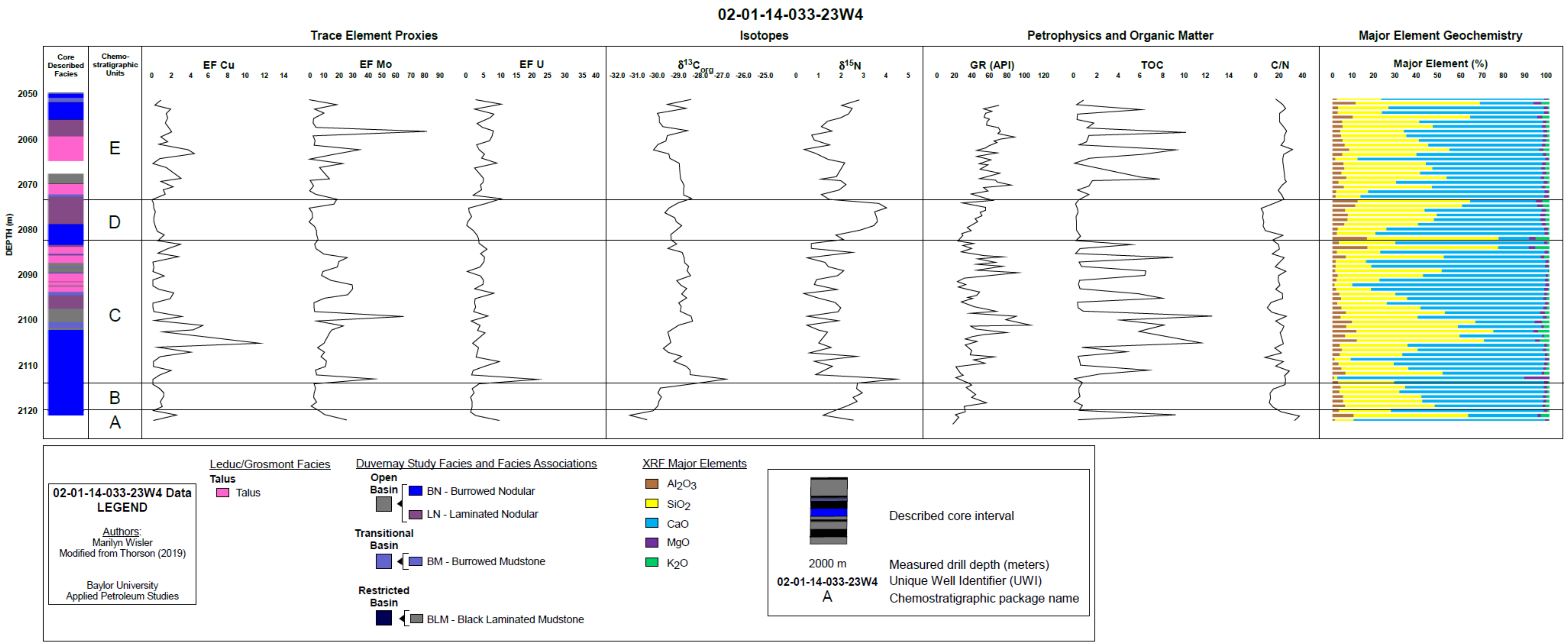


Figure 3.15. Well 02-01-14-033-23W4 data versus depth (m) for the core described facies, chemostratigraphic units, EF Cu, EF Mo, EF U, $\delta^{13}C_{org}$, $\delta^{15}N$, gamma ray from well log, measured TOC, C/N ratio, and proportion of major elements as a percentage.

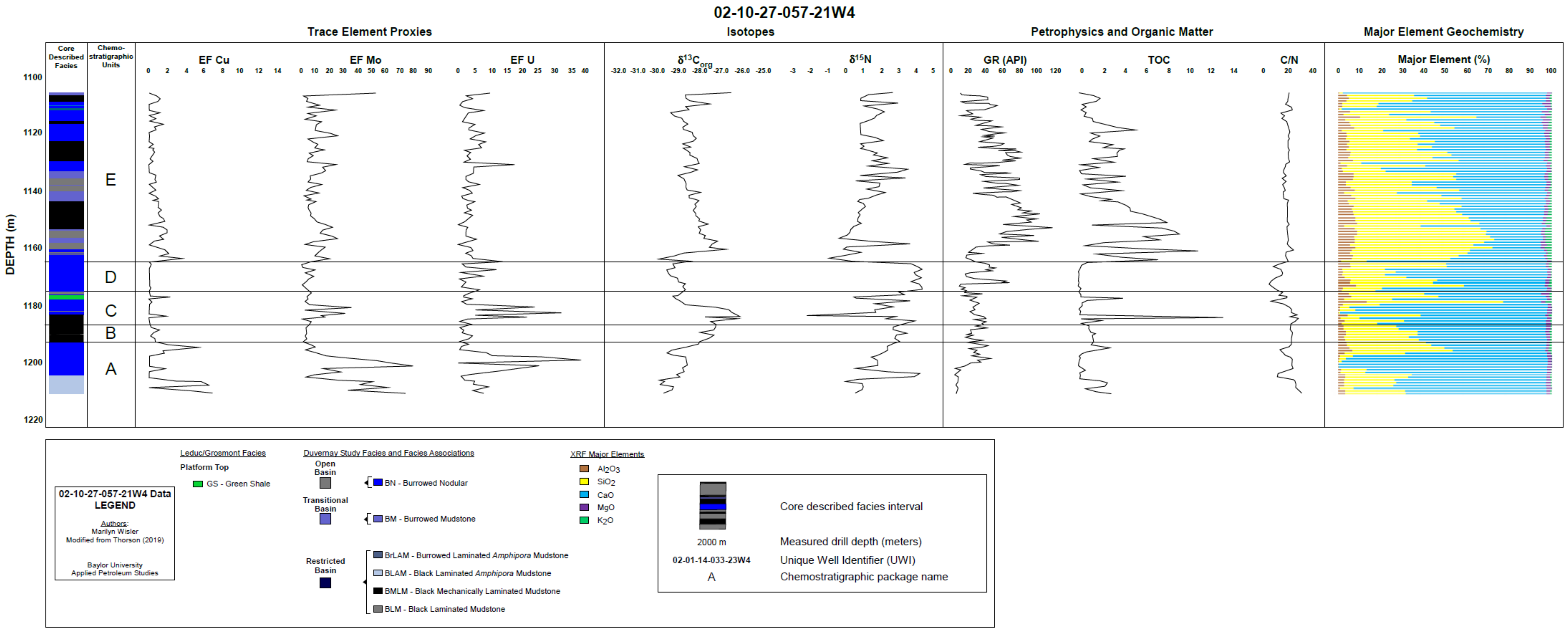


Figure 3.16. Well 02-10-27-057-21W4 data versus depth (m) for the core described facies, chemostratigraphic units, EF Cu, EF Mo, EF U, $\delta^{13}C_{org}$, $\delta^{15}N$, gamma ray from well log, measured TOC, C/N ratio, and proportion of major elements as a percentage.

WCSB Sedimentology

Sedimentological attributes from core descriptions can help describe the relationship between chemostratigraphic units and lithofacies of the WCSB. Notable sedimentological attributes include variations of pyrite in wells 00-15-18-049-13W5 and 02-01-14-033-23W4 and ichnofabric index. The ichnofabric index is scaled from 0-6 with six being complete heterogeneity of sediment from bioturbation, and places geochemically determined redox conditions back into a stratigraphic context. All core description forms can be

The West Basin well 00-15-18-049-13W5 has an ichnofabric index of 6 at depths 3514-3520m corresponding to chemostratigraphic unit D (Figure 3.17). Pyritized grains are present at depths 3503m, 3508m, 3512m, 3521m, and 3531m. Well 00-14-19-062-15W5 has a varied ichnofabric index (Figure 3.18). Notable bioturbated intervals include 2894-2915m within restricted basin facies (BMLM) where there is *Planolites*.

The sedimentologic attributes in the East Basin for well 02-01-14-033-23W4 include angular mudstone intraclasts and elongate/horizontal mudstone nodules throughout the core which is dominated by Talus. The ichnofabric index is 6 throughout the entire cored section, except at depths 2098-2101m where it is 0, and corresponds to restricted basin facies (Figure 3.19). Well 02-10-27-057-21W4 has a variable ichnofabric index (Figure 3.20). Notable intervals include 1189-1194m and 1206-1210m where it is 0 within restricted basin facies.

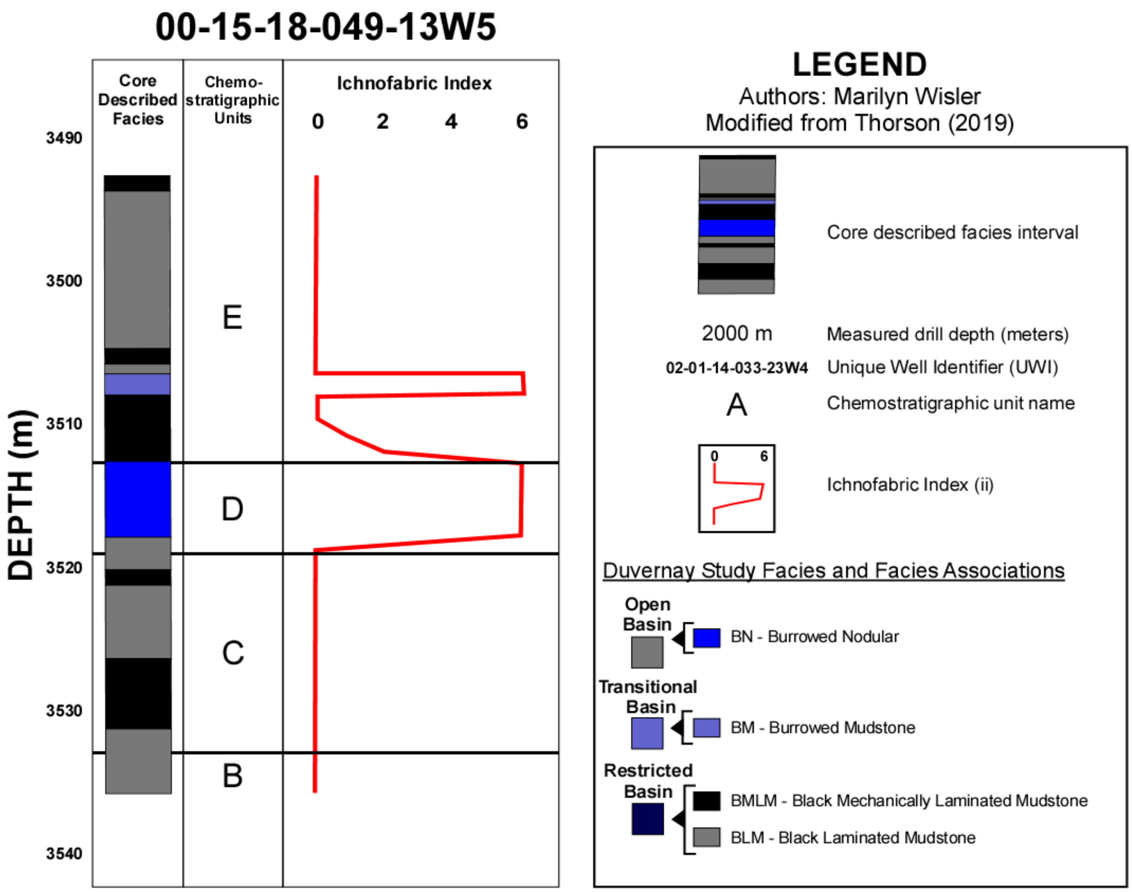


Figure 3.17. Well 00-15-18-049-13W5 depth (m) versus core described facies, chemostratigraphic units, and ichnofabric index (Reineck, 1963). Ichnofabric index was measured approximately every half meter.

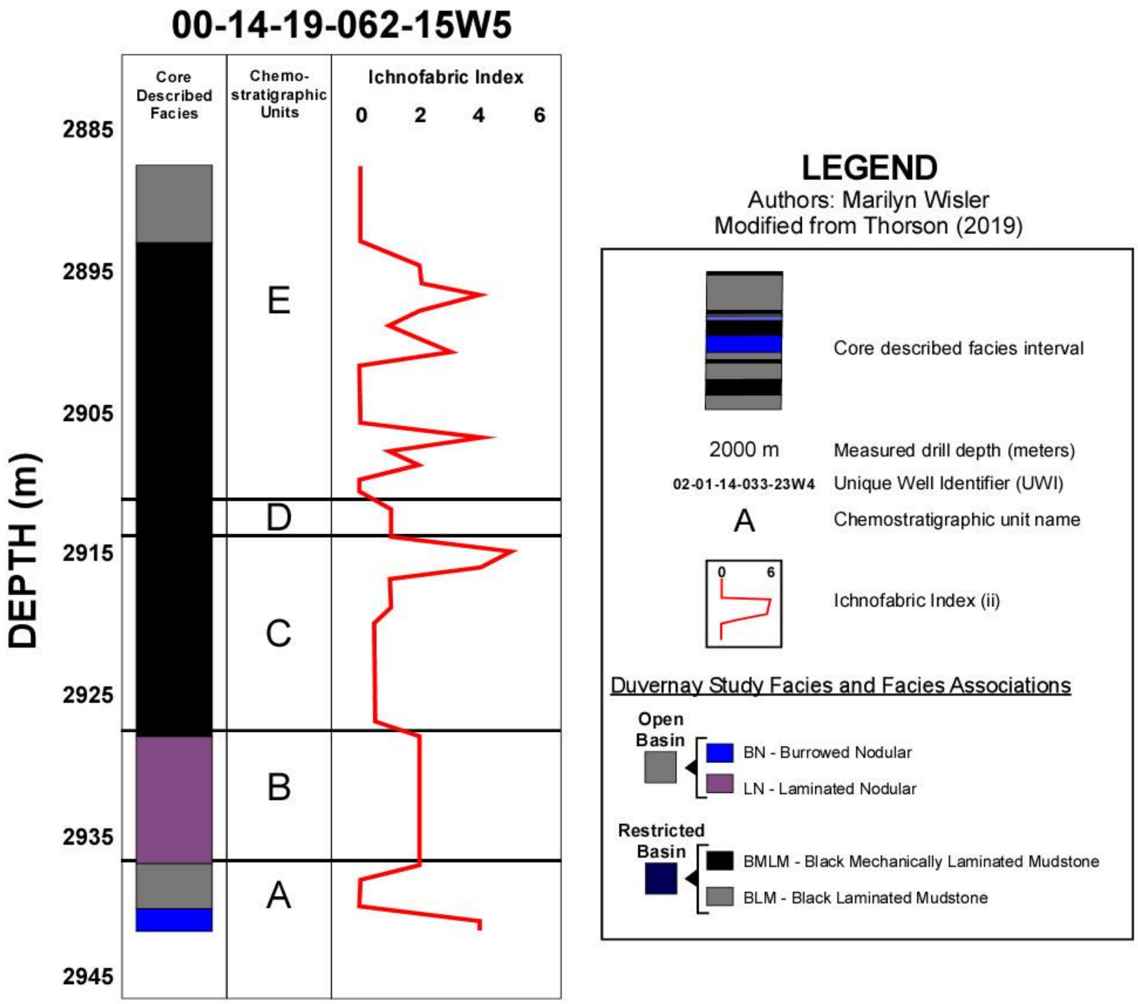


Figure 3.18. Well 00-14-19-062-15W5 depth (m) versus core described facies, chemostratigraphic units, and ichnofabric index (Reineck, 1963). Ichnofabric index was measured approximately every half meter.

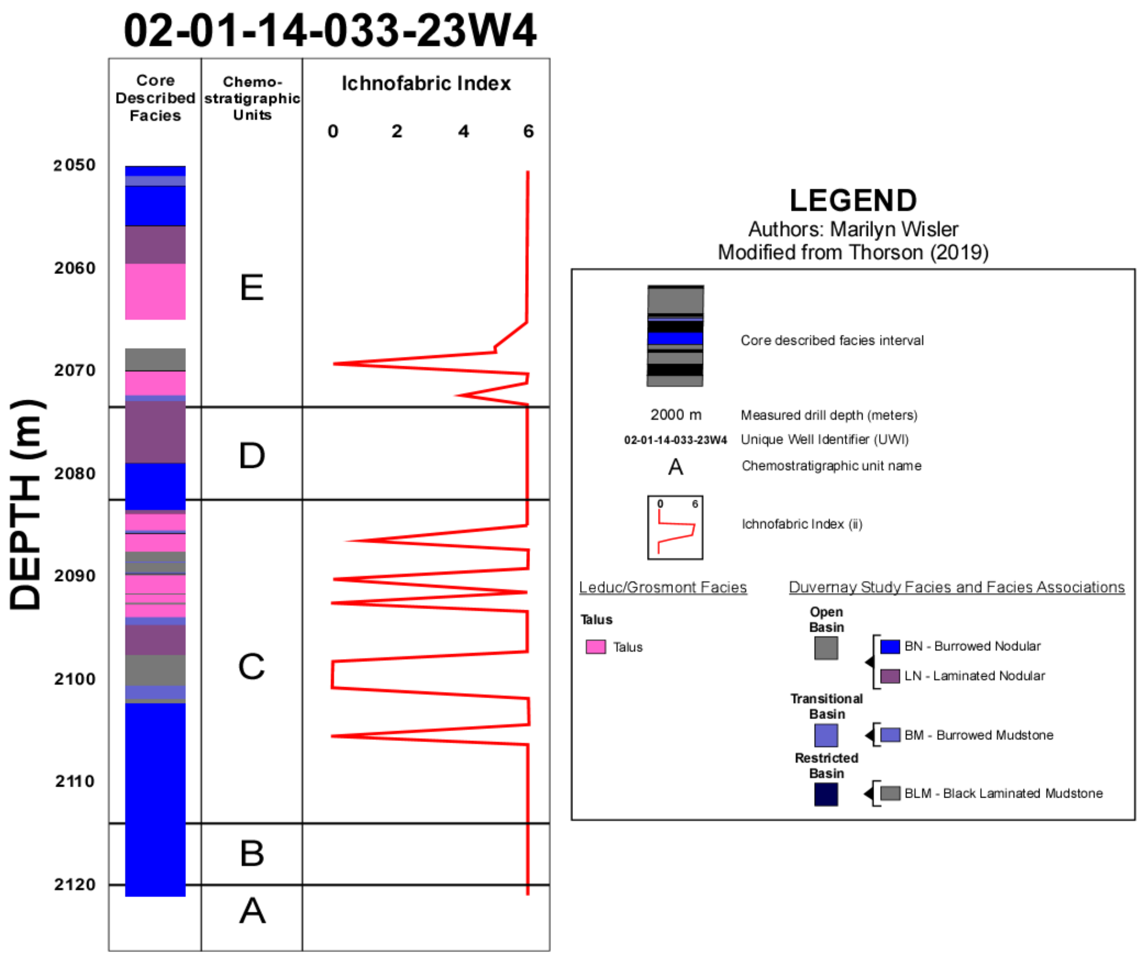


Figure 3.19. Well 02-01-14-033-23W4 depth (m) versus core described facies, chemostratigraphic units, and ichnofabric index (Reineck, 1963). Ichnofabric index was measured approximately every half meter.

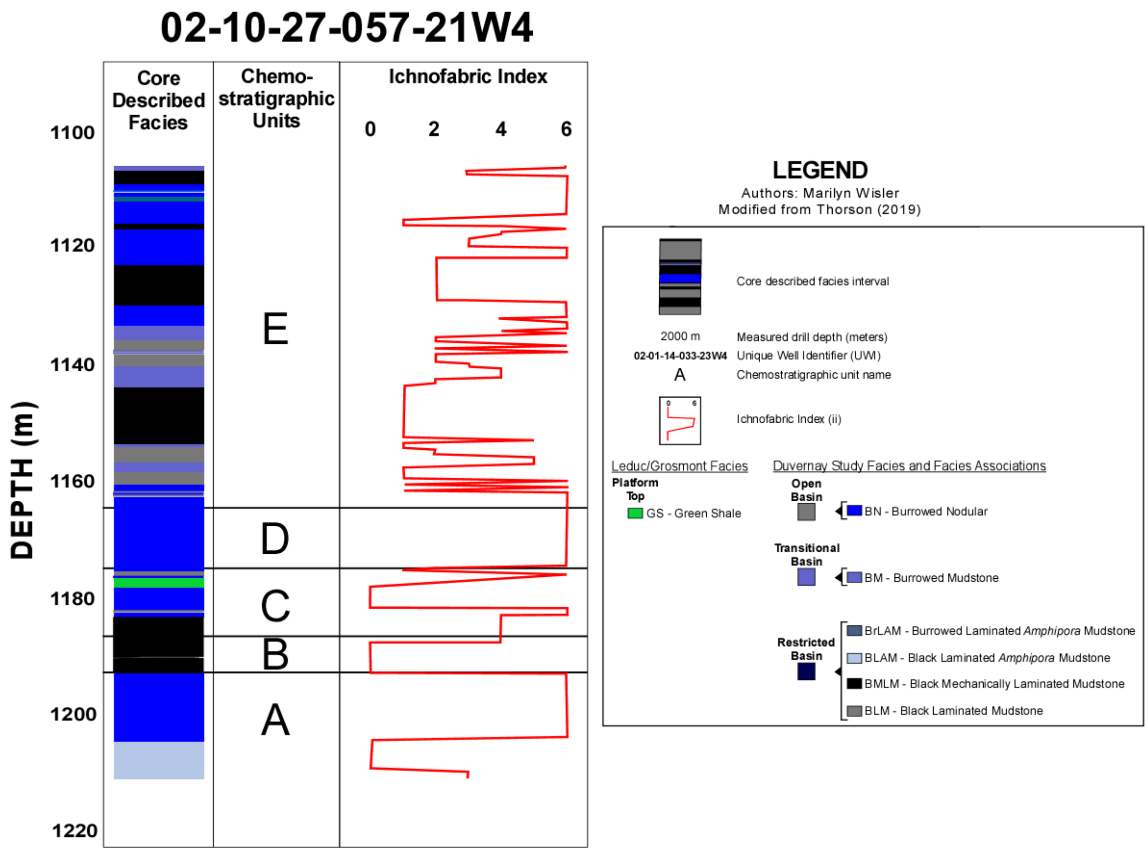


Figure 3.20. Well 02-10-27-057-21W4 depth (m) versus core described facies, chemostratigraphic units, and ichnofabric index (Reineck, 1963). Ichnofabric index was measured approximately every half meter.

Geochemical Trends

A comparison between TOC and the redox-sensitive trace element Mo documents a correlation between these two variables within the chemostratigraphic units. This relationship has been used to investigate hydrographic conditions of a depositional basin (Algeo and Lyons, 2006). The four wells in this study show positive Mo/TOC correlations, particularly in chemostratigraphic units C and E when TOC rises above 2 wt% which coincides with EF Mo values greater than 10 (Figure 3.21). Chemostratigraphic units B and D typically plot close to the axis where TOC is less than 2 wt% and EF Mo is less than 10 (Figure 3.21).

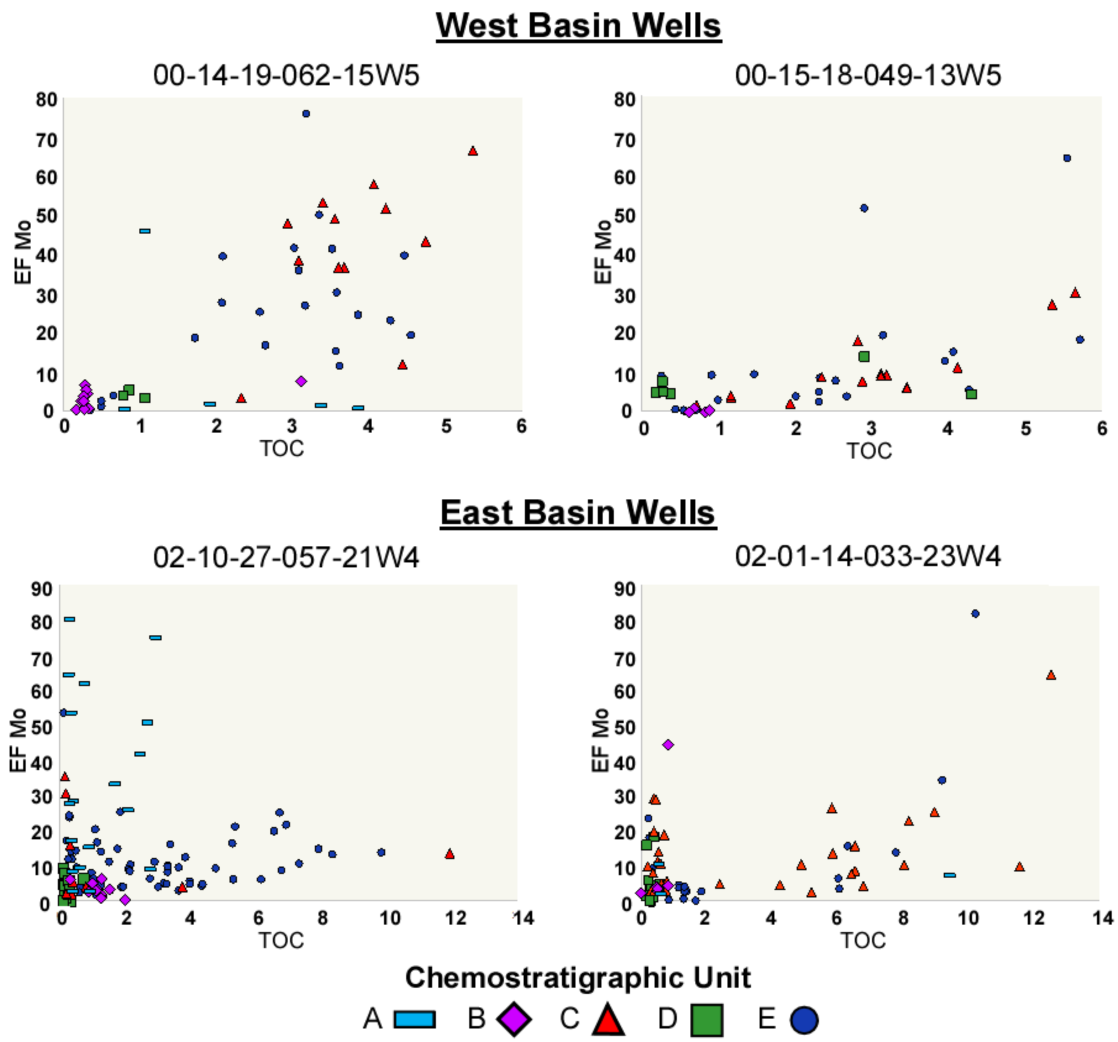


Figure 3.21. EF Mo/TOC plots for West Basin (00-14-19-062-15W5 and 00-15-18-049-13W5) and East Basin (02-10-27-057-21W4 and 02-01-14-033-23W4) wells for each chemostratigraphic unit.

Petrophysical Response to Geochemistry

The gamma ray well log response reflects the concentration of K, U and Th because all these elements have a radioactive isotope that emits gamma rays. A strong correlation was found between the concentrations of K and the GR response (Figure 3.20). K primarily resides in illitic clay. U is also radioactive but does not correlate as well as K does across the basin (Figure 3.22).

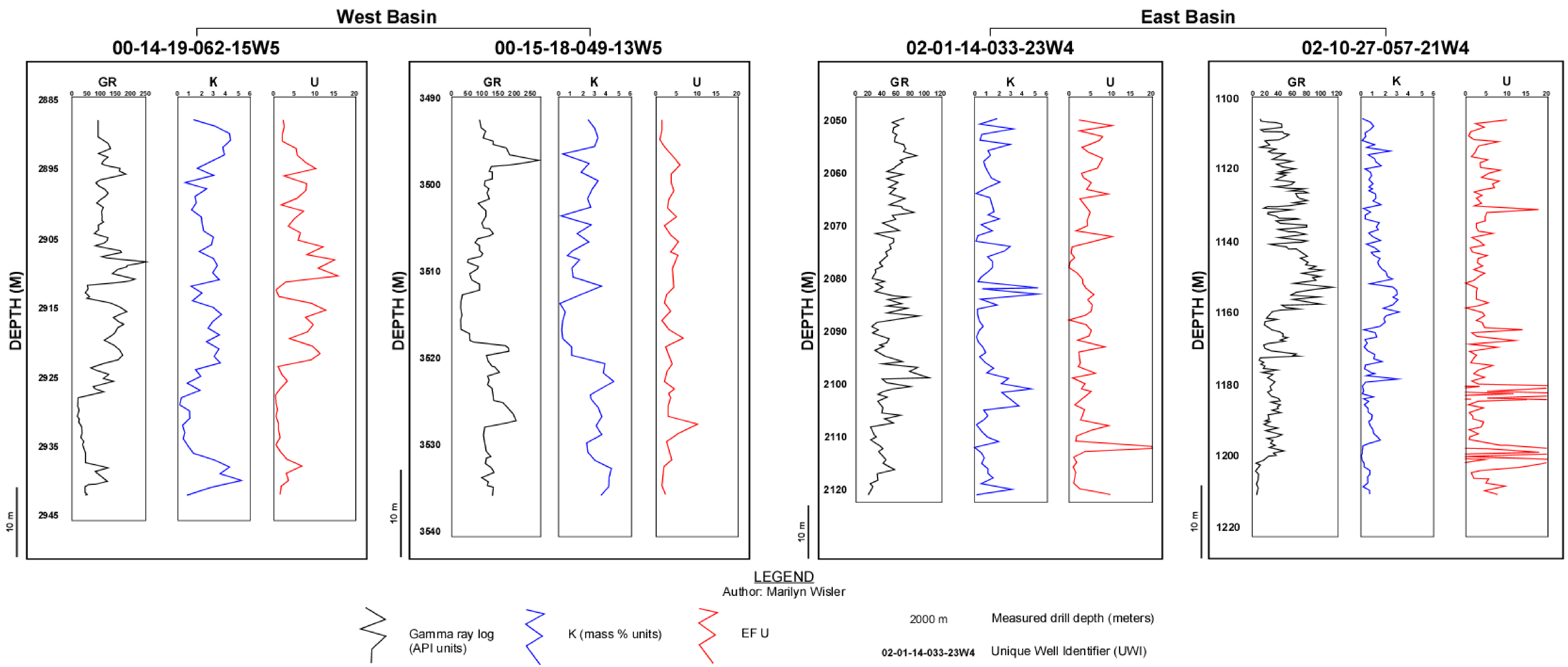


Figure 3.22. Gamma ray (API units), K results (mass % units), and enrichment factor of U plots for West Basin (00-14-19-062-15W5 and 00-15-18-049-13W5) and East Basin (02-10-27-057-21W4 and 02-01-14-033-23W4) wells.

CHAPTER FOUR

Discussion

Paleoceanographic Evolution of the WCSB

This section summarizes the geochemical attributes of each chemostratigraphic unit and interprets their significance with respect to paleoceanographic conditions in the WCSB.

Chemostratigraphic unit A is present in each well except 00-15-18-049-13W5 (West Basin). The geochemical attributes associated with chemostratigraphic unit A include enrichment of the redox-sensitive and productivity trace elements Mo, U, and Cu, and TOC above 2 wt%. These attributes taken together suggest that Unit A was deposited under anoxic conditions. $\delta^{13}C_{org}$ and $\delta^{15}N$ values near the boundary between unit A and B exhibit a positive excursion (Figures 3.14, 3.15, 3.16). Unit A exhibits slightly lower $\delta^{15}N$ values indicating that nitrogen fixation enhanced productivity (Figure 3.12).

The low TOC, high level of carbonate, and low trace metal enrichment factors exhibited in chemostratigraphic unit B illustrates that the Duvernay was deposited under oxic conditions during this period of deposition. This is also supported by the low Mo/TOC ratios and a $\delta^{15}N$ signature showing a positive excursion towards denitrification (Figures 3.13, 3.14, 3.15, 3.16, 3.20). Unit B in Wells 00-14-19-062-15W5 (West Basin) and 02-01-14-033-23W4 (East Basin) is bioturbated, supporting the idea of an oxygenated environment (Figures 3.18, 3.19). During deposition of chemostratigraphic unit B there was an absence of productivity in the WCSB that resulted in the lack of accumulation of organic matter.

Chemostratigraphic unit C represents a change in paleoceanographic conditions that resulted in higher organic matter accumulation. This unit exhibits elevated concentrations of the trace metals Cu, U, and Mo, indicating both elevated productivity and reducing conditions (Figures 3.13, 3.14, 3.14, 3.16). Variance in TOC and trace metals in well 02-01-14-033-23W4 correspond to the ichnofabric index altering from 0 to 6, indicating that minor Talus deposit events punctuated the major paleoceanographic conditions of reducing conditions (Figure 3.19). This unit also has a negative $\delta^{15}N$ excursion indicating nitrogen fixation. Each well exhibits a positive $\delta^{13}C_{org}$ excursion which is probably related to increased productivity. Mo/TOC ratios reveal that organic matter accumulation during deposition occurred under unrestricted marine conditions (Figure 3.21). Reducing conditions that are indicated by the geochemistry discussed above coincides with abundant pyritized grains in the West Basin well 00-15-18-049-13W5, supporting local euxinic conditions. Basin wide, unit C represents anoxia.

The transition from chemostratigraphic unit C to D is marked by a sharp decline in redox-sensitive trace element concentrations of Mo and U with scarce enrichment in Cu. Productivity became very low, as evidenced by the median TOC value of 0.55 (Figure 3.10). In relation to low TOC, GR values in unit D are between 40-50 API units across the basin (Figures 3.13, 3.14, 3.15, 3.16). There is a substantial increase in $\delta^{15}N$ in this unit, suggesting denitrification accompanied by a lack of fixation. Well 00-14-19-062-15W5 (West Basin) is the only well with restricted basin lithofacies in unit D, although low TOC values suggest that this restricted facies was not deposited under productive conditions. Unit D in well 00-15-18-049-13W5 (West Basin) contains bioturbated sediment and pyritized grains, but the pyrite may have resulted from diagenetic processes such as migration of H_2S (hydrogen sulfide) along faults or through permeable reservoirs from below the unit into the reservoir. In contrast, the well's ichnofabric index reflects fully bioturbated sediment (Figure 3.17). The ichnofabric index and geochemistry of unit D indicates that it was deposited under oxic conditions.

Chemostratigraphic unit E is characterized by high TOC values and elevated trace metal enrichment factors signifying a return to anoxic conditions. The East Basin contains Talus, carbonate-rich slope debris, in well 02-01-14-033-23W4 (Figure 3.15). This lithofacies is not representative of the redox conditions but rather, represents a depositional event that brings shallow water carbonates into a basinal setting. The geochemistry of this lithofacies contrasts with Unit E in the other wells at some depths, but still exhibits enrichment of trace metals and TOC much higher than in oxic units B and D.

Relationship between Duvernay Chemostratigraphy and Sequence Stratigraphy

A comparison between sedimentologic observations and geochemical results is useful for placing chemostratigraphic units into a sequence stratigraphic framework. The geochemical results in this study are compared to the sequence stratigraphic interpretation of Thorson (2019) which is calibrated to the work of Wong et al. (2016a). Wong et al. (2016a) relates basinal deposits to platform equivalents from observations of outcrop and subsurface data. In the following sections the chemostratigraphic units interpreted in this study will be integrated with the sequence stratigraphic model of Thorson (2019) (Figures 4.1, 4.2, 4.3, 4.4).

Wells 00-14-19-062-15W5 (West Basin), 02-01-14-033-23W4 (East Basin), and 02-10-27-057-21W4 (East Basin) each have part of the Woodbend composite 1 sequence at the base of the cored interval with the Woodbend composite sequence 2 (WD 2.1) identified within the core (Figures 4.1, 4.3, 4.4). Well 00-15-18-049-13W5 was cored above the base of the WD 2.1 (Figure 4.2). At the base of the WD 2.1, there is an increase in gamma ray in each well which correlates to a U increase in this sequence (Figures 4.1, 4.3, 4.4). The $\delta^{13}C_{org}$ signature between WD 2.1 to 2.2 shows a correlative trend where the composition becomes initially more negative and subsequently more positive (Figures 4.1, 4.2, 4.3, 4.4). This adds confidence that this interval of the Duvernay Formation was deposited contemporaneously as the carbon was sourced from the atmosphere. Additionally, chemostratigraphic unit D corresponds with WD 2.2-2.3 in the West Basin wells (Figures 4.1, 4.2). The East Basin wells contrast in this interval as they correlate to anoxic units that show trace metal and organic matter enrichment (Figures 4.3, 4.4).

Succeeding WD 2.3 is the maximum flooding surface (MFS) that shows more organic matter enrichment in the East Basin than West Basin. Coincident with the MFS, the East Basin is rich in open or transitional basin whereas the West Basin is dominated by restricted basin facies (Figures 4.1, 4.2, 4.3, 4.4). The MFS occurs in chemostratigraphic unit E in the West Basin wells and 02-10-27-057-21W4 (East Basin), but in chemostratigraphic unit C in well 02-01-14-033-23W4 (East Basin). This is likely due to the depositional character of well 02-01-14-033-23W4 because it predominately consists of slope deposits. Chemostratigraphic unit E overlaps with Woodbend composite sequence 3 (WD 3.1) in all wells except 02-01-14-033-23W4 where WD 3.1 coincides with unit D (Figures 4.1, 4.2, 4.3, 4.4).

Extensive review by Thorson (2019) of Duvernay deposition concluded that WD 2.3 to the top of each core represents a key reservoir unit characterized by the thickest organic-rich shale interval across the East and West Basins (Figures 4.1, 4.2, 4.4). Chemostratigraphic unit D is within the key reservoir interval in 02-01-14-033-23W4 but has no organic matter accumulation (Figure 4.3). This may be because slope deposits dominate the Duvernay in this well and may be independent of basin-wide depositional conditions. The key reservoir interval corresponds to chemostratigraphic unit E in the other three cored wells in this study, suggesting that anoxia was driven by productivity (trace element enrichment) that caused organic matter enrichment.

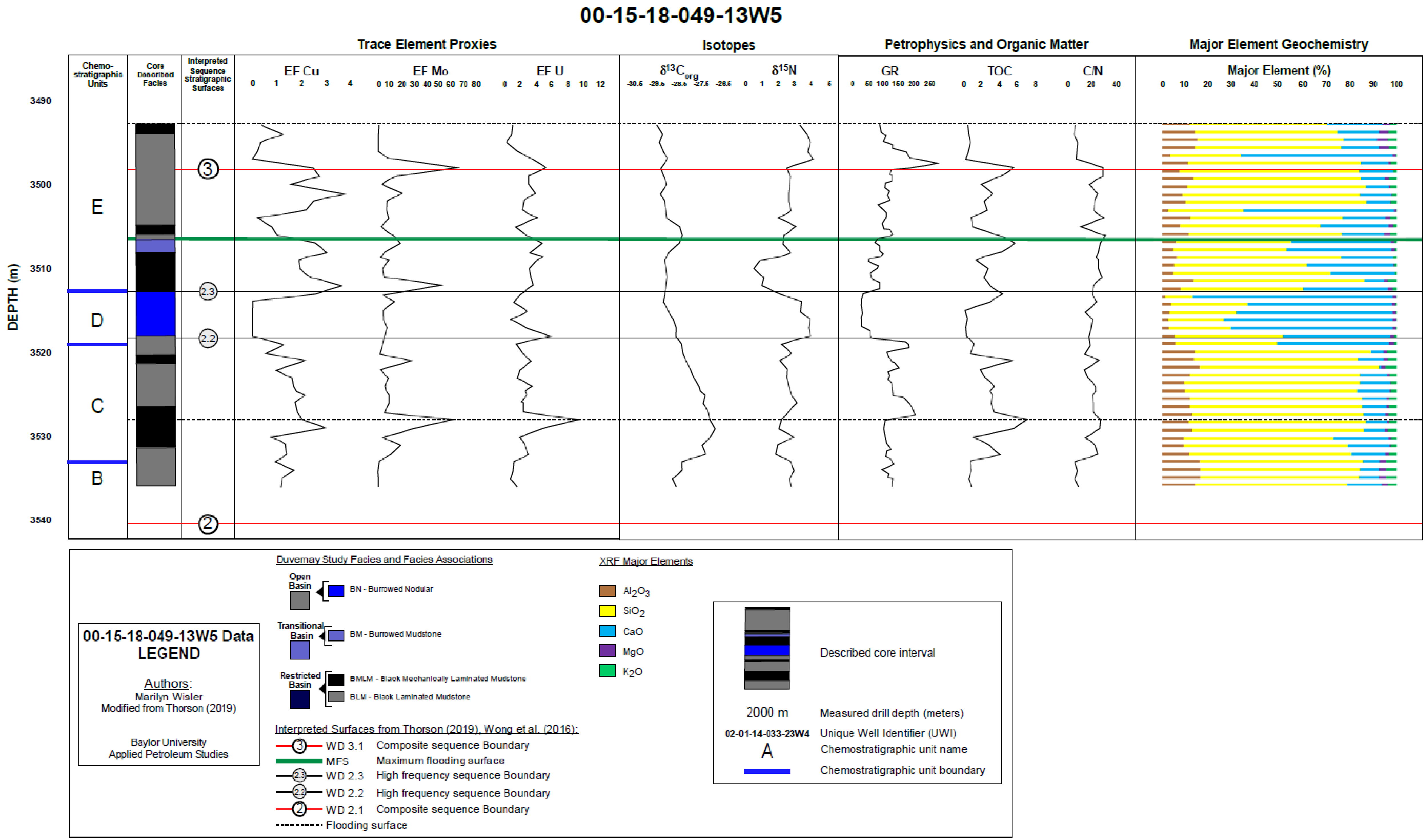


Figure 4.1. Well 00-15-18-049-13W5 depth (m) versus core described facies, chemostratigraphic units, sequence stratigraphic surfaces (via Thorson, 2019), EF Cu, EF Mo, EF U, $\delta^{13}C_{org}$, $\delta^{15}N$, gamma ray from well log, measured TOC, C/N ratio, and proportion of major elements as a percentage. Sequence stratigraphic surfaces in this well contain Woodbend 2.1-3.1 (red and black lines) and second-order maximum flooding surface (green).

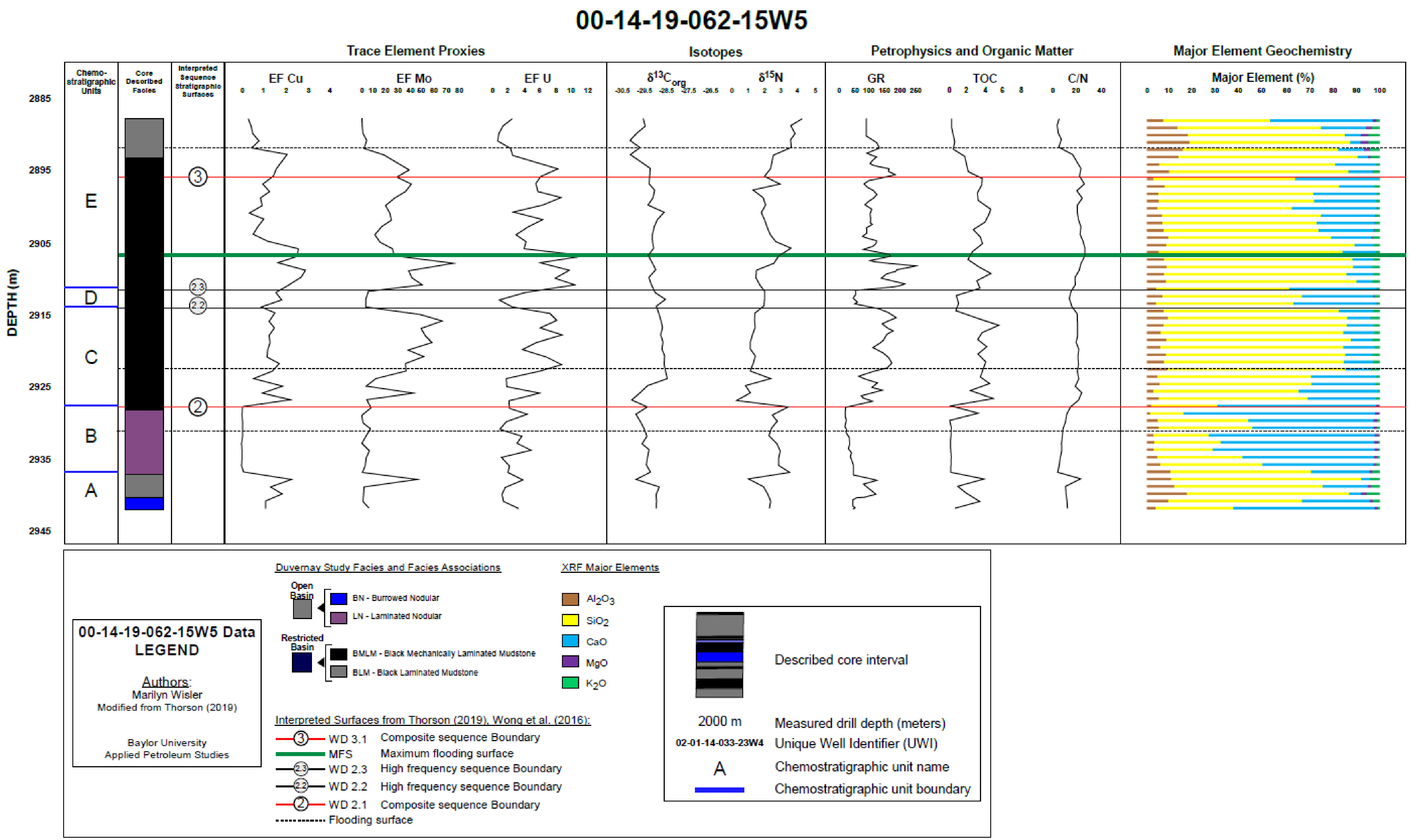


Figure 4.2. Well 00-14-19-062-15W5 depth (m) versus core described facies, chemostratigraphic units, sequence stratigraphic surfaces (via Thorson, 2019), EF Cu, EF Mo, EF U, $\delta^{13}C_{org}$, $\delta^{15}N$, gamma ray from well log, measured TOC, C/N ratio, and proportion of major elements as a percentage. Sequence stratigraphic surfaces in this well contain Woodbend 2.1-3.1 (red and black lines) and second-order maximum flooding surface (green).

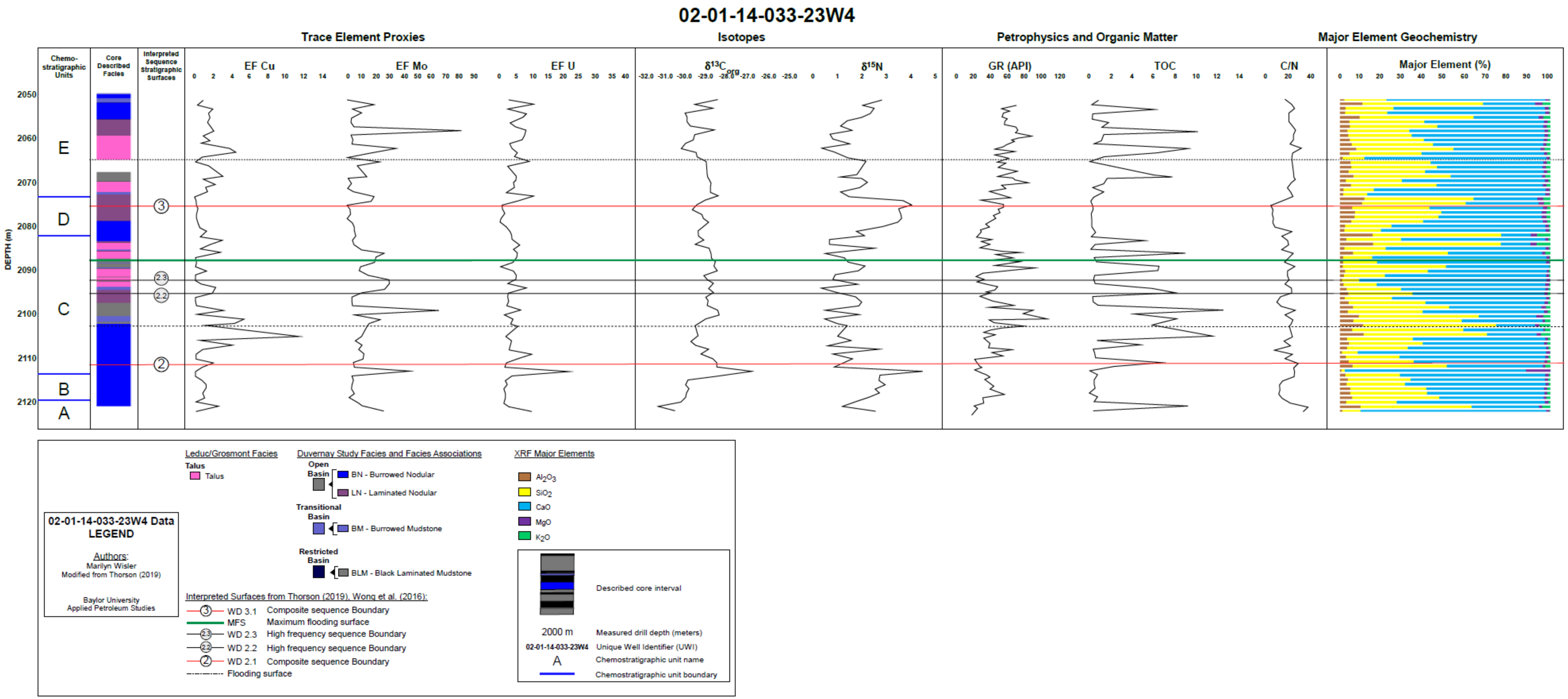


Figure 4.3. Well 02-01-14-033-23W4 depth (m) versus core described facies, chemostratigraphic units, sequence stratigraphic surfaces (via Thorson, 2019), EF Cu, EF Mo, EF U, $\delta^{13}C_{org}$, $\delta^{15}N$, gamma ray from well log, measured TOC, C/N ratio, and proportion of major elements as a percentage. Sequence stratigraphic surfaces in this well contain Woodbend 2.1-3.1 (red and black lines) and second-order maximum flooding surface (green).

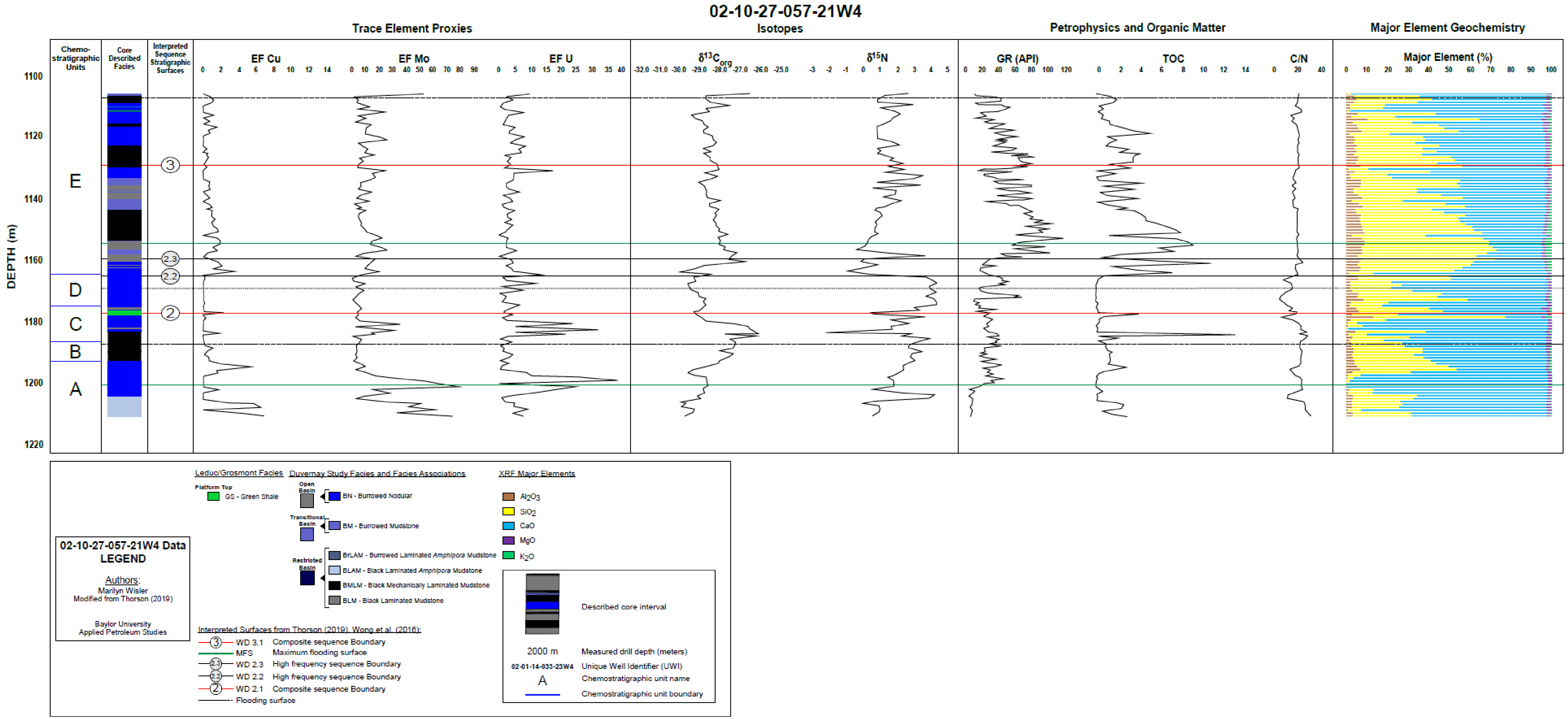


Figure 4.4. Well 02-10-27-057-21W4 depth (m) versus core described facies, chemostratigraphic units, sequence stratigraphic surfaces (via Thorson, 2019), EF Cu, EF Mo, EF U, $\delta^{13}C_{org}$, $\delta^{15}N$, gamma ray from well log, measured TOC, C/N ratio, and proportion of major elements as a percentage. Sequence stratigraphic surfaces in this well contain Woodbend 2.1-3.1 (red and black lines) and second-order maximum flooding surface (green).

CHAPTER FIVE

Conclusions

The Duvernay Formation within the West and East Basins of the WCSB exhibits contrasting geochemical characteristics. The abundant major elements in the Duvernay in the West Basin are Si and Al whereas in the East Basin Ca is more abundant. Trace element enrichment factors of U and Cu are almost twice as high in the East Basin compared to the West Basin and Mo enrichment is similar throughout the WCSB. TOC is higher in the East Basin than the West Basin, but the isotopic composition of preserved organic matter is fairly similar between the basins. In a similar fashion, the nitrogen isotopic composition is also uniform suggesting that a similar nutrient cycle characterized the entire WCSB. Similarities between the carbon isotope ratios confirm that carbon was sourced from the atmosphere.

Five chemostratigraphic units were identified from the stratigraphic distribution of the geochemical data. These chemostratigraphic units demonstrate paleoceanographic conditions during Duvernay deposition that alternated between anoxic and oxic conditions. Anoxic units (A, C, E) have highly variable trace elements and TOC concentrations, representing depositional conditions of high productivity and organic matter accumulation. This was likely caused by coastal upwelling due to nutrient availability as suggested by $\delta^{15}N$ fixation signals and correlation of Mo/TOC. Anoxic units in the West Basin coincide with organic-rich mudrocks and argillaceous carbonates. In contrast, oxic units (B, D) have less variable, more stagnant conditions of increased

$\delta^{15}N$ composition (i.e. denitrification) with little to no trace element enrichment or preserved organic matter. These oxic units contain a higher abundance of carbonate within calcareous shales. Additionally, K, which correlates with the GR activity across the basin, likely indicates that the main clay mineral in the Duvernay is illite.

Seven Duvernay Formation basinal facies within three facies associations (open, transitional, and restricted) were identified from core descriptions. Two other facies identified are consistent with contemporaneous Leduc/Grosmont deposits. The basinal facies' core descriptions detail attributes such as ichnofabric index and pyrite occurrence which complement the geochemical interpretation of redox conditions. The core descriptions are consistent with the work of Thorson (2019). Thorson (2019) identifies a key reservoir unit from WD 2.3 to the top of each core. This reservoir unit corresponds to the thickest organic-rich interval in the WCSB, and to chemostratigraphic anoxic unit E in each well except 02-01-14-033-23W4 which includes chemostratigraphic units C, D, and E.

APPENDICES

APPENDIX A

Core Description Forms

The following scanned images include the core description legend and core description forms in order of well 02-01-14-033-23W4, 00-14-19-062-15W5, 02-10-27-057-21W4, and 00-15-18-049-13W5.

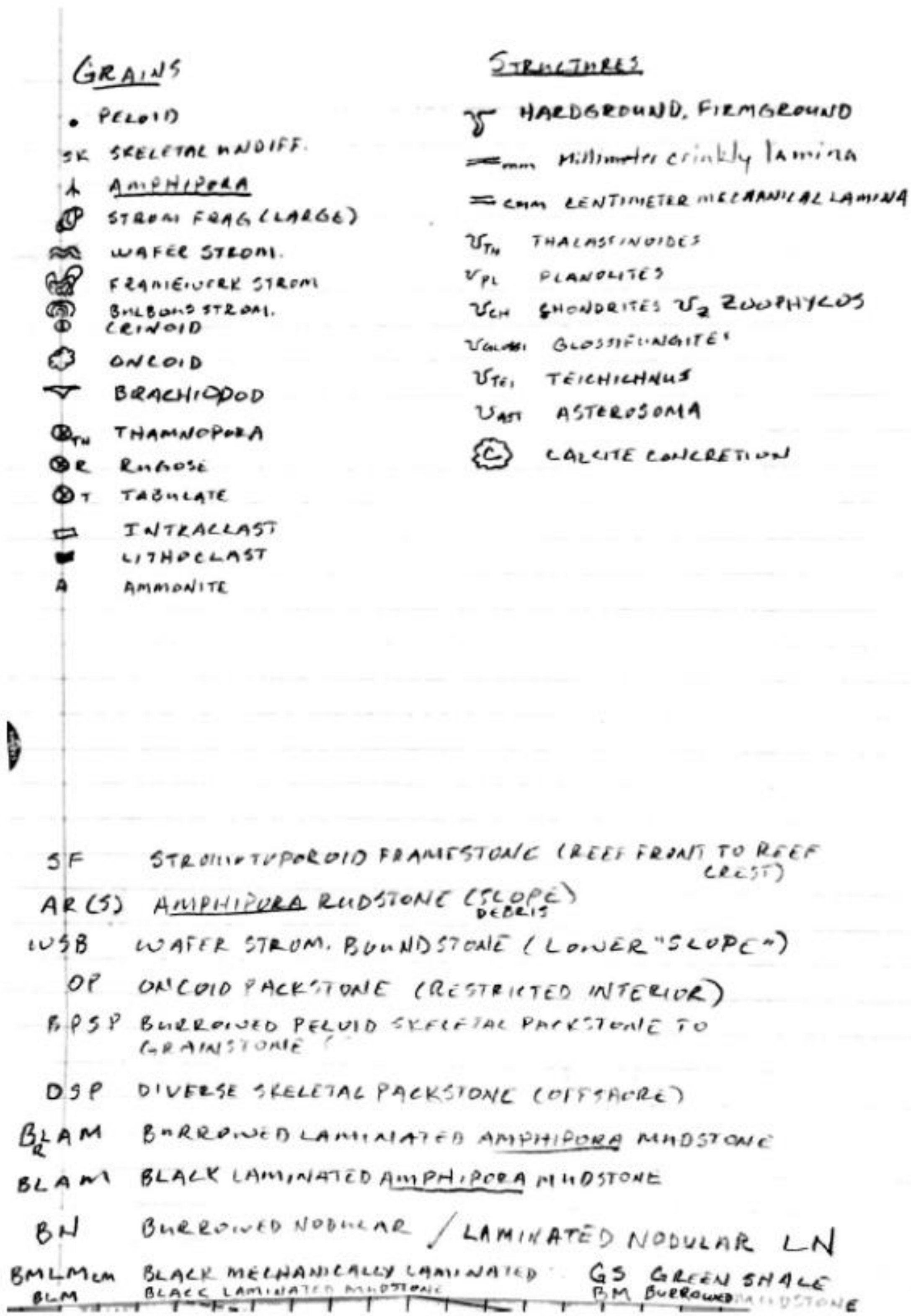
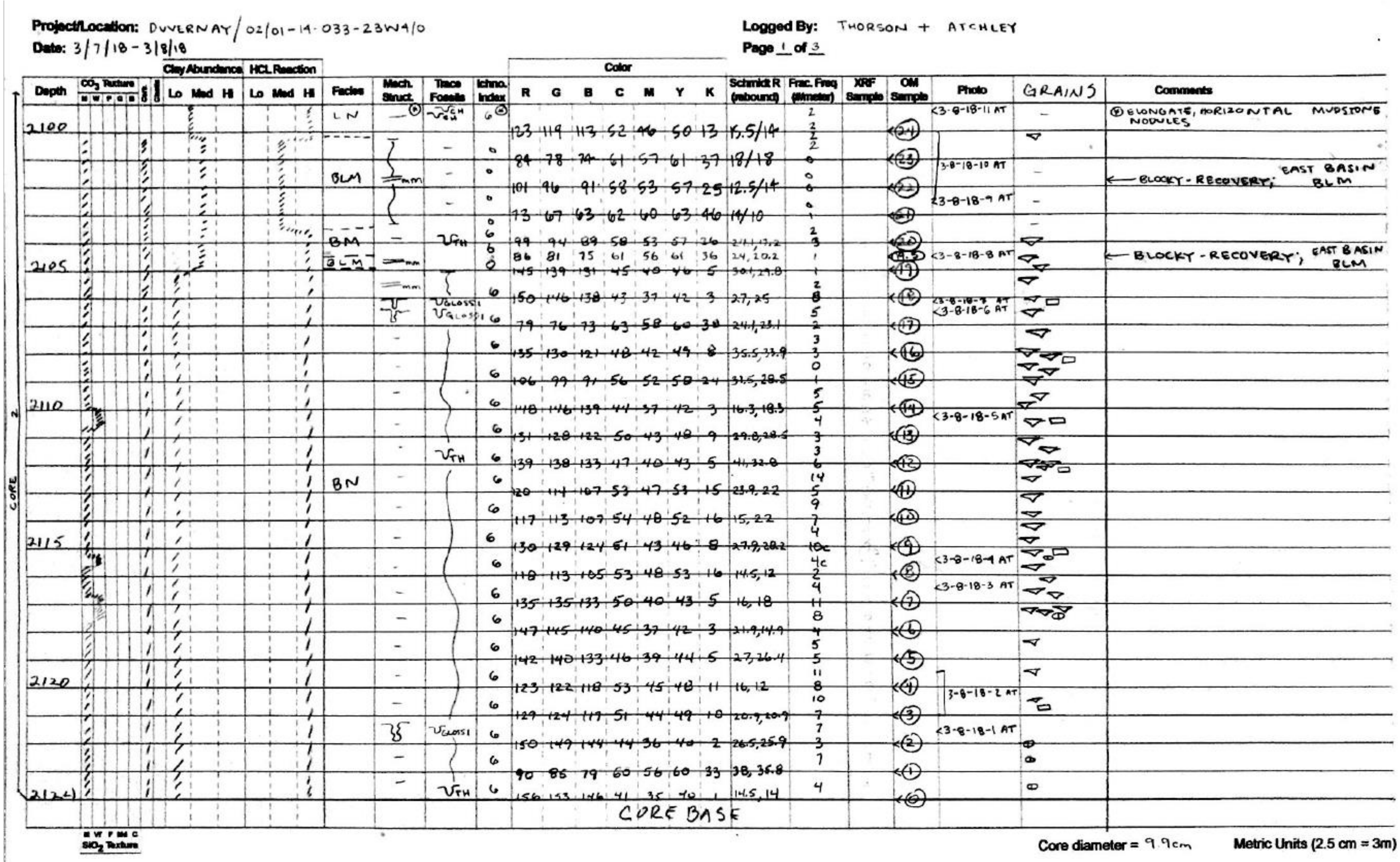


Figure A.1: Core description legend for carbonate grains (top left), sedimentary structures (top right), and facies (bottom).



Project/Location: DUVERNAY / 02/01-14-033-23W4/0
Date: 3/7/18 – 3/8/18
Logged By: THORSON + ATCHLEY
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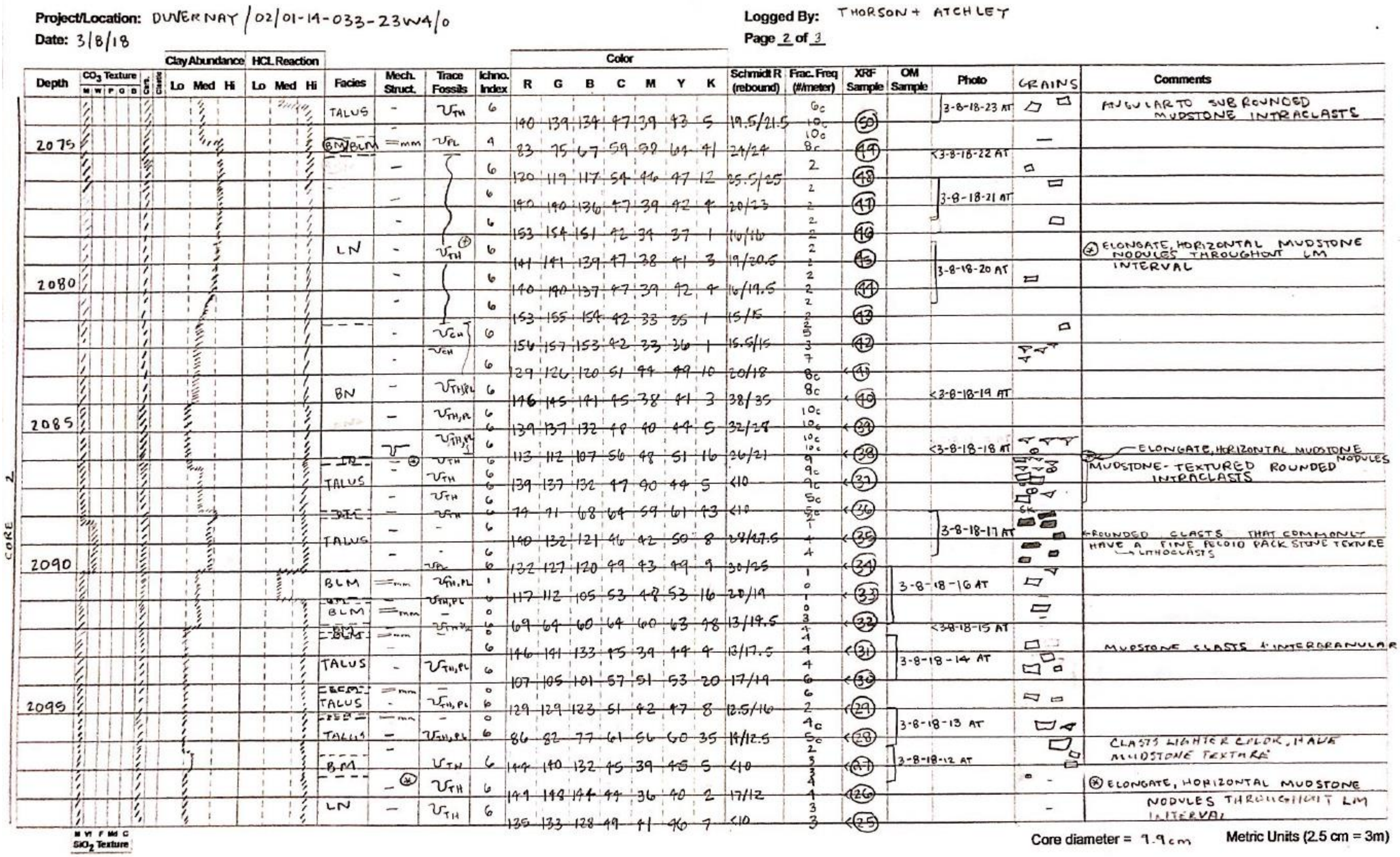
Depth	Facies	Ichno. Index	R	G	B	C	M	Y	K	Schmidt R (rebound)	OM Sample	Photo	Comments
2100	LN	6⊕	123	119	113	52	46	50	13	15.5/14	24	<3-8-18-11 AT	⊕ ELONGATE, HORIZONTAL MUDSTONE NODULES
		0	84	78	74	61	57	61	37	18/18	23		
	BLM	0	101	96	91	58	53	57	25	12.5/14	22	3-8-18-10 AT	← BLOCKY - RECOVERY; EAST BASIN BLM
		0	73	67	63	62	60	63	46	14/10	21	<3-8-18-9 AT	
	BM	6	99	94	89	58	53	57	26	21.1, 17.2	20		
	BLM	6	86	81	75	61	56	61	36	24, 10.2	19.5	<3-8-18-8 AT	← BLOCKY - RECOVERY; EAST BASIN BLM
2105		0	145	139	131	45	40	46	5	30.1, 29.8	19		
		6	150	146	138	43	37	42	3	27, 25	18	<3-8-18-7 AT <3-8-18-6 AT	
		6	79	76	73	63	58	60	38	24.1, 23.1	17		
		6	135	130	121	48	42	49	8	35.5, 33.9	16		
		6	106	99	91	56	52	58	24	31.5, 28.5	15		
2110		6	118	116	139	44	37	42	3	16.3, 18.3	14	<3-8-18-5 AT	
		6	131	128	122	50	43	48	9	29.8, 28.5	13		
		6	139	138	133	47	40	43	5	41, 32.8	12		
	BN	6	120	114	107	53	47	53	15	23.9, 22	11		
		6	117	113	107	54	48	52	16	15, 22	10		
2115		6	130	129	124	51	43	46	8	27.9, 28.2	9		
		6	118	113	105	53	48	53	16	14.5, 12	8	<3-8-18-4 AT	
		6	135	135	133	50	40	43	5	16, 18	7	<3-8-18-3 AT	
		6	147	145	140	45	37	42	3	31.9, 14.9	6		
		6	142	140	133	46	39	44	5	27, 26.4	5		
2120		6	123	122	118	53	45	48	11	16, 12	4	3-8-18-2 AT	
		6	129	124	117	51	44	49	10	20.9, 20.9	3		
		6	150	149	144	44	36	40	2	26.5, 25.9	2	<3-8-18-1 AT	
		6	90	86	79	60	56	60	33	38, 36.8	1		
2122		6	156	153	146	41	35	40	1	14.5, 14	0		
			CORE BASE										

Core diameter = 9.9cm
Metric Units (2.5 cm = 3m)

Figure A.2: 02-01-14-033-23W4 core description form page 1 of 3.



Project/Location: DUVERNAY /02/01-14-033-23W4/0

Date: 3/8/18

Logged By: THORSON + ATCHLEY

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Depth	R	G	B	C	M	Y	K	Schmidt R (rebound)	XRF Sample	Photo
	140	139	134	47	39	43	5	19.5/21.5	50	3-8-18-23 AT
2075	83	75	67	59	52	64	41	24/24	49	3-8-18-22 AT
	120	119	117	54	46	47	12	25.5/25	48	
	140	140	136	47	39	42	4	20/23	47	3-8-18-21 AT
	153	154	151	42	34	37	1	16/16	46	
	141	141	139	47	38	41	3	19/20.5	45	3-8-18-20 AT
2080	140	140	137	47	39	42	4	16/19.5	44	
	153	155	154	42	33	35	1	15/15	43	
	156	157	153	42	33	36	1	15.5/15	42	
	129	126	120	51	44	49	10	20/18	41	
	146	145	141	45	38	41	3	38/35	40	3-8-18-19 AT
2085	139	137	132	48	40	44	5	32/28	39	
	113	112	107	56	48	51	16	26/21	38	3-8-18-18 AT
	139	137	132	47	40	44	5	<10	37	
	74	71	68	64	59	61	43	<10	36	
	140	132	121	46	42	50	8	28/27.5	35	3-8-18-17 AT
2090	132	127	120	49	43	49	9	30/25	34	
	117	112	105	53	48	53	16	20/19	33	3-8-18-16 AT
	69	64	60	64	60	63	48	13/19.5	32	3-8-18-15 AT
	146	141	133	45	39	44	4	13/17.5	31	3-8-18-14 AT
	107	105	101	57	51	53	20	17/19	30	
2095	129	129	123	51	42	47	8	12.5/16	29	3-8-18-13 AT
	86	82	77	61	56	60	35	14/12.5	28	
	144	140	132	45	39	45	5	<10	27	3-8-18-12 AT
	144	148	144	44	36	40	2	17/12	26	
	135	133	128	49	41	46	7	<10	25	

Comments:

ANGULAR TO SUB ROUNDED MUDSTONE INTRACLASTS

(+) ELONGATE, HORIZONTAL MUDSTONE NODULES THROUGHOUT LM INTERVAL

ELONGATE, HORIZONTAL MUDSTONE NODULES

MUDSTONE-TEXTURED ROUNDED INTRACLASTS

ROUNDED CLASTS THAT COMMONLY HAVE A FINE PELOID PACKSTONE TEXTURE → LITHOCLASTS

MUDSTONE CLASTS + INTERGRANULAR

CLASTS LIGHTER COLOR, HAVE MUDSTONE TEXTURE

(*) ELONGATE, HORIZONTAL MUDSTONE NODULES THROUGHOUT LM INTERVAL

Core diameter = 7.9 cm

Metric Units (2.5 cm = 3m)

Figure A.3: 02-01-14-033-23W4 core description form page 2 of 3.

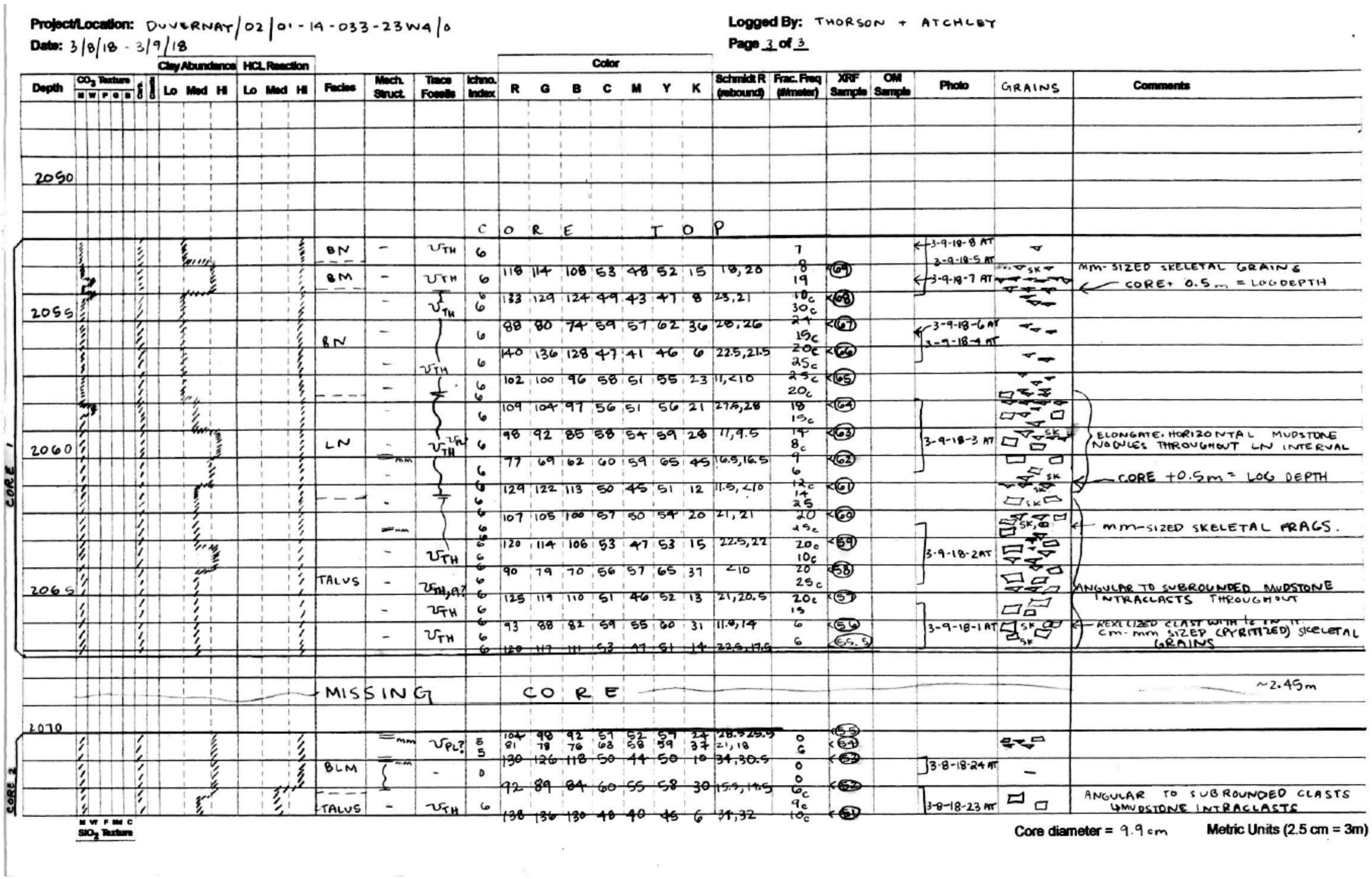
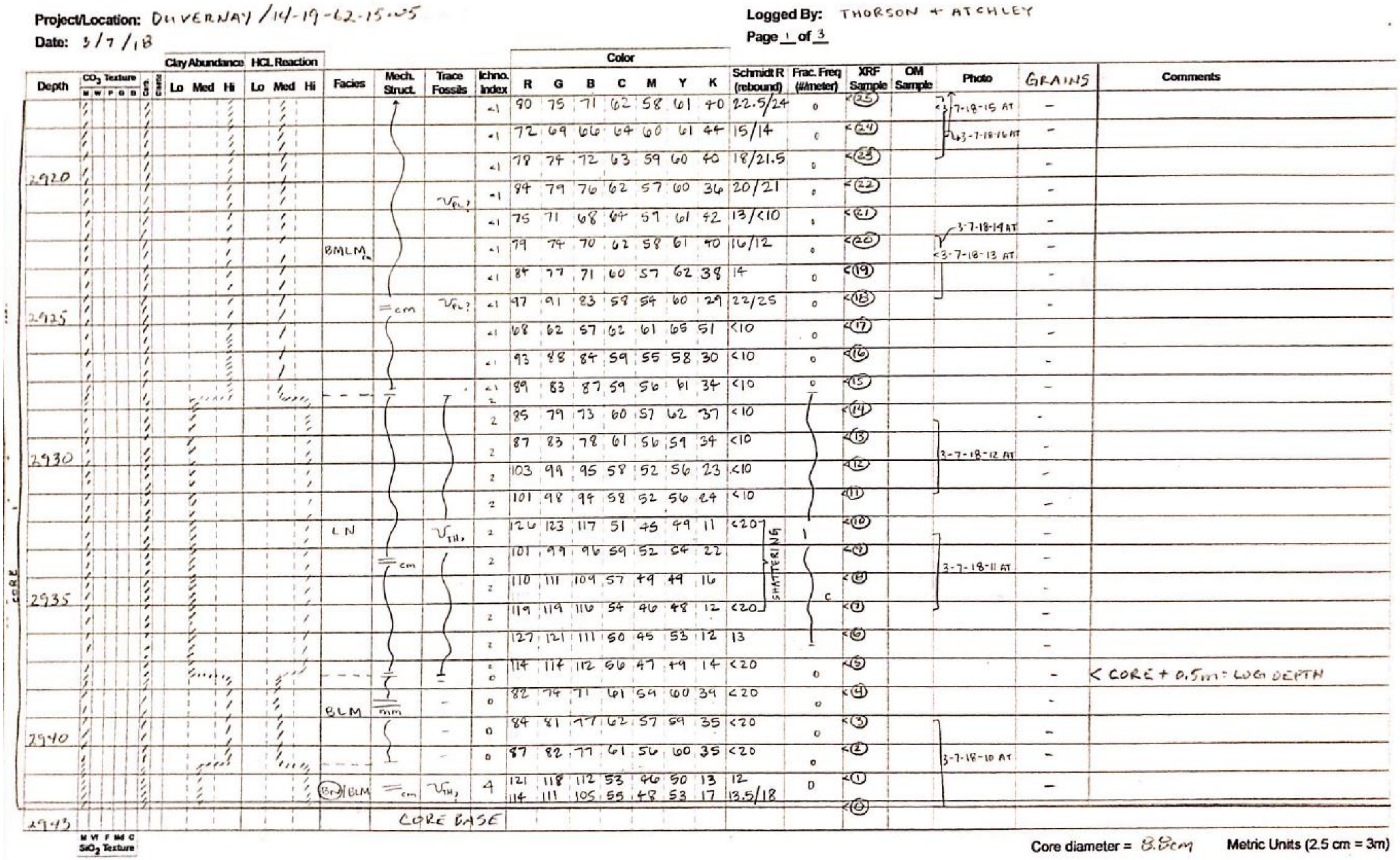


Figure A.4: 02-01-14-033-23W4 core description form page 3 of 3.



Depth	Facies	Mech. Struct.	Trace Fossils	Ichno. Index	R	G	B	C	M	Y	K	Schmidt R (rebound)	Frac. Freq (#/meter)	XRF Sample	OM Sample	Photo	GRAINS	Comments
				<1	90	75	71	62	58	61	40	22.5/24	0	<25		<3-7-18-15 AT	-	
				<1	72	69	66	64	60	61	44	15/14	0	<24		<3-7-18-16 AT	-	
				<1	78	74	72	63	59	60	40	18/21.5	0	<23			-	
2920			V_{PL}?	<1	84	79	76	62	57	60	36	20/21	0	<22			-	
				<1	75	71	68	64	57	61	42	13/<10	0	<21		3-7-18-14 AT	-	
	BMLM			<1	79	74	70	62	58	61	40	16/12	0	<20		<3-7-18-13 AT	-	
				<1	84	77	71	60	57	62	38	14	0	<19			-	
		= cm	V_{PL}?	<1	97	91	83	58	54	60	29	22/25	0	<18			-	
2925				<1	68	62	57	62	61	65	51	<10	0	<17			-	
				<1	93	88	84	59	55	58	30	<10	0	<16			-	
				<1 / 2	89	83	87	59	56	61	34	<10	0	<15			-	
				2	85	79	73	60	57	62	37	<10		<14			-	
				2	87	83	78	61	56	59	34	<10		<13			-	
2930				2	103	99	95	58	52	56	23	<10		<12		3-7-18-12 AT	-	
				2	101	98	94	58	52	56	24	<10		<11			-	
	LN		V_{TH}	2	126	123	117	51	45	49	11	<20 (SHATTERING)	1	<10			-	
		= cm		2	101	99	96	59	52	54	22	(SHATTERING)		<9		3-7-18-11 AT	-	
				2	110	111	109	57	49	49	16	(SHATTERING)	C	<8			-	
2935				2	119	119	116	54	46	48	12	<20 (SHATTERING)		<7			-	
				2	127	121	111	50	45	53	12	13		<6			-	
				2 / 0	114	114	112	56	47	49	14	<20	0	<5			-	< CORE + 0.5m = LOG DEPTH
			-	0	82	74	71	61	59	60	39	<20	0	<4			-	
	BLM	mm	-	0	84	81	77	62	57	59	35	<20	0	<3			-	
2940			-	0	87	82	77	61	56	60	35	<20	0	<2		3-7-18-10 AT	-	
	(Br)/BLM	= cm	V_{TH}?	4	121	118	112	53	46	50	13	12	0	<1			-	
					114	111	105	55	48	53	17	13.5/18		<0				
2943		CORE BASE																

Figure A.5: 00-14-19-062-15W5 core description form page 1 of 3.

Project/Location: DUVERNAY/14-19-62-15W5
Date: 3-7-18

Logged By: THORSON + ATCHLEY
Page 2 **of** 3

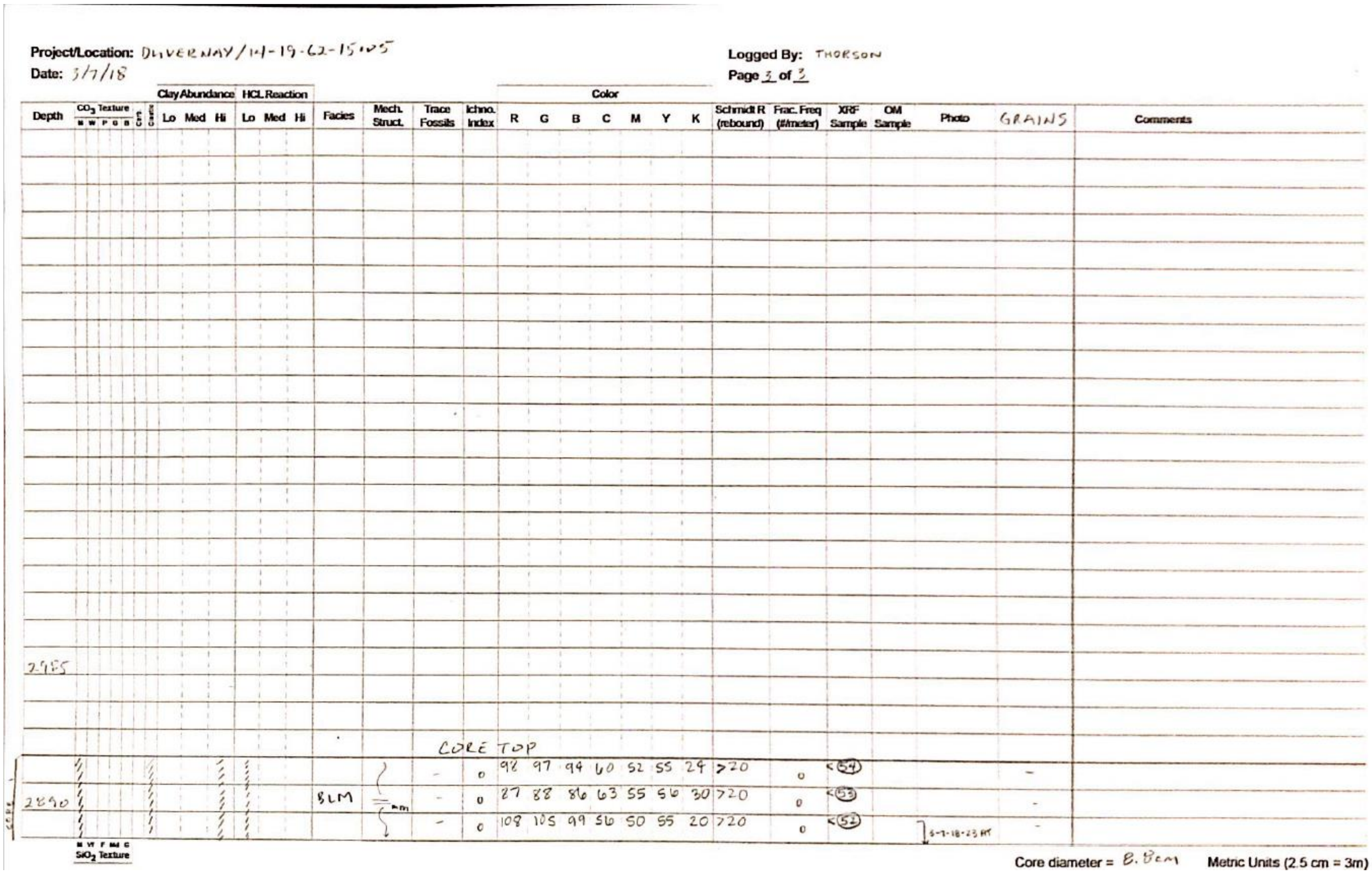
Depth	Facies	Mech. Struct.	Trace Fossils	Ichno. Index	R	G	B	C	M	Y	K	Schmidt R (rebound)	Frac. Freq (#/meter)	XRF Sample	OM Sample	Photo	GRAINS	Comments
			–	0	78	76	73	64	58	60	39	>20	0	<(51)		3-7-18-23 AT	–	
	BLM	=hm	–	0	82	76	70	60	58	62	39	>20	0	<(50)			–	< CORE - 0.5m = LOG DEPTH
	- - - -	–	–	0–2	90	75	70	62	58	62	40	14.5	1	<(49)			–	< CORE ≈ LOG DEPTH
				2–4	85	81	76	61	57	60	35	>20	0	<(48)		<3-7-18-22 AT	–	< CORE = LOG DEPTH
2895		(C)	V_{TH}?	2	98	95	91	59	53	56	26	21/20	0	<(47)			–	
				2	93	88	83	59	55	58	30	>20	0	<(46)			–	
		=cm	V_{PL}?	3	95	91	86	59	54	58	29	16/13	1	<(45)			–	< CORE - 0.5m = LOG DEPTH
				0	88	84	80	60	56	59	33	16.5/19	0	<(44)			–	
				0	96	91	85	58	54	58	29	16.5/15	0	<(43)			–	
2900				0	76	72	67	62	58	62	42	12.5/13.5	0	<(42)			–	
	BMLN		(C)	0	106	100	93	56	52	57	23	14/<20	0	<(41)			–	
				0	91	86	80	59	56	60	32	<20	0	<(40)			–	
				0	90	85	79	60	56	60	33	11.5/<20	0	<(39)			–	
				0	98	93	87	58	53	58	27	14/14	0	<(38)		<3-7-18-21 AT	–	
2905				0	96	91	85	59	54	58	29	<20	0	<(37)			–	< CORE - 0.5m = LOG DEPTH
		=cm	V_{PL}?	4–1	82	76	71	61	58	62	37	<10	0	<(36)			–	
				0	82	77	71	61	58	62	39	14/14	0	<(35)			–	
			V_{PL}?	2	87	82	77	60	56	60	35	15/24	0	<(34)			–	
				0	81	74	68	60	58	63	41	12/12	0	<(33)		3-7-18-20 AT	–	
2910				0	75	71	67	63	59	62	43	18.5/14	0	<(32)			–	
				0–1	79	74	70	62	55	61	40	<20	0	<(31)			–	CORE - 0.5m = LOG DEPTH
			(C)	1	103	97	91	57	52	57	25	18/24	0	<(30)			–	CALCITE(?) STRUCTURE - PRESERVING CONCRETIONS W/ LATER COMPACTION DRAPE
			(C)	1	90	86	81	60	55	59	32	<20	0	<(29)		<3-7-18-19 AT	–	
	BMLN		V_2	5–<1	113	107	101	55	50	54	19	10V/14.5	0	<(28)		<3-7-18-18 AT	–	< HIGHLY BURROWED VERSION OF BMLM
2915	BMLM	cm	V_{PL}?	<1	87	82	76	60	56	61	35	13/20	0	<(27)		3-7-18-17 AT	–	
				<1	87	82	77	60	56	60	35	11.5/15	0	<(26)			–	

CORE

SiO_2 Texture (M VF F M C)

Core diameter = 8.8cm   Metric Units (2.5 cm = 3m)

Figure A.6: 00-14-19-062-15W5 core description form page 2 of 3.



Project/Location: DUVERNAY/14-19-62-15W5
Date: 3/7/18

Logged By: THORSON
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Depth	CO2 Texture	Clay Abundance	HCL Reaction	Facies	Mech. Struct.	Trace Fossils	Ichno. Index	R	G	B	C	M	Y	K	Schmidt R (rebound)	Frac. Freq (#/meter)	XRF Sample	OM Sample	Photo	GRAINS	Comments
2985																					
						CORE TOP															
						-	0	98	97	94	60	52	55	29	>20	0	<54			-	
2890				BLM	mm	-	0	87	88	86	63	55	56	30	>20	0	<53			-	
						-	0	108	105	99	56	50	55	20	>20	0	<52		3-7-18-23 AT	-	

SiO2 Texture

Core diameter = 8.8cm Metric Units (2.5 cm = 3m)

Figure A.7: 00-14-19-062-15W5 core description form page 3 of 3.

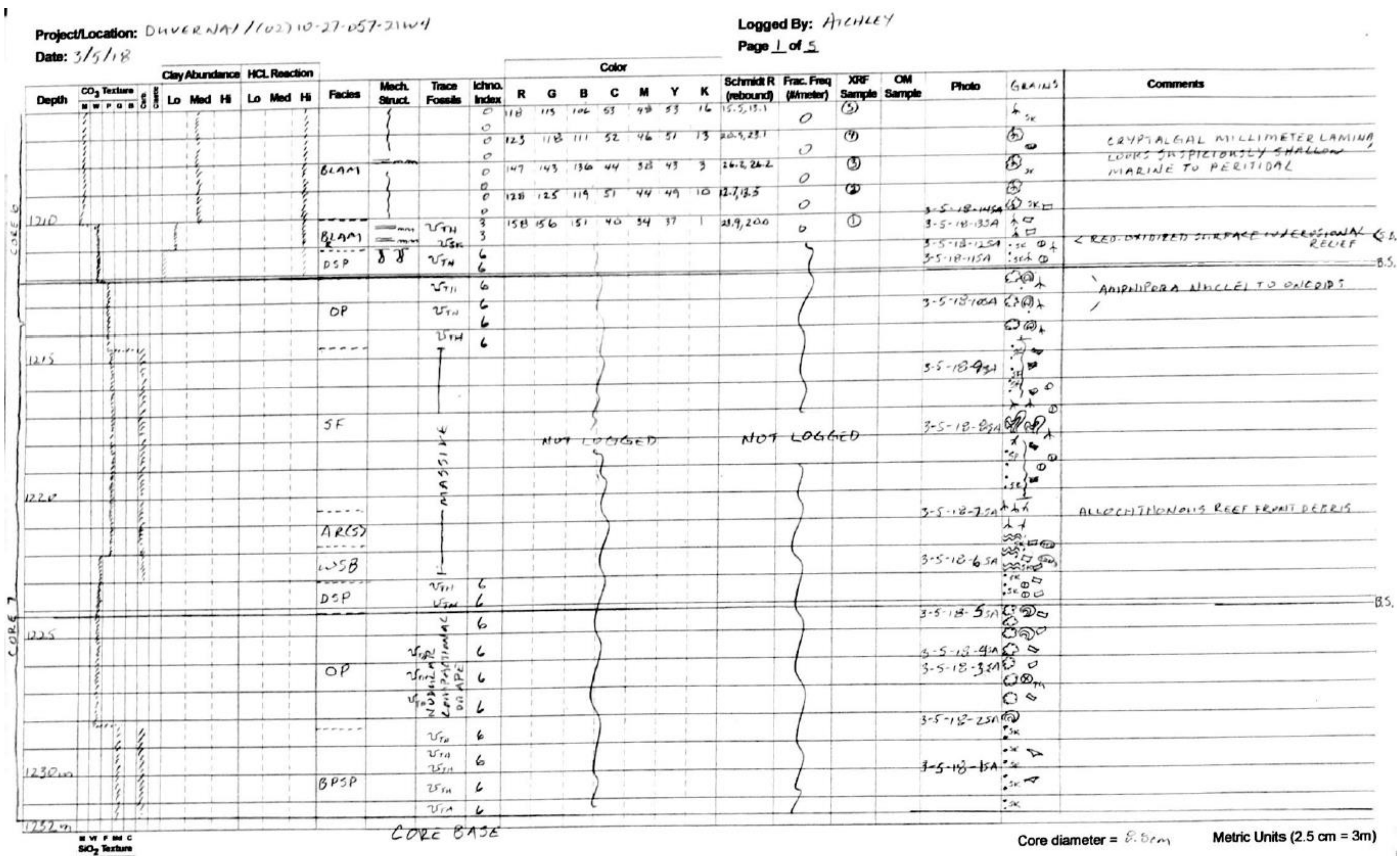
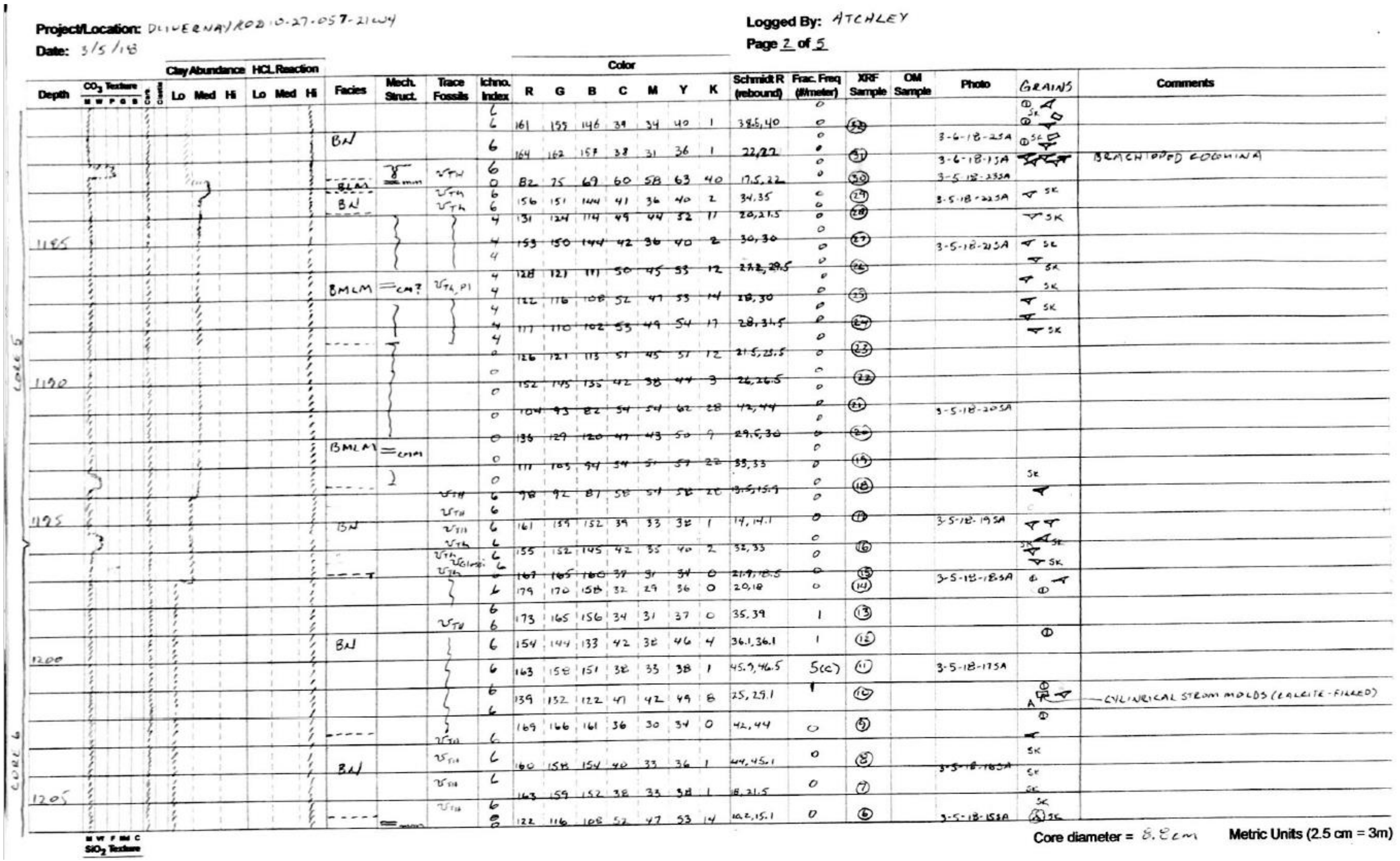


Figure A.8: 02-10-27-057-21W4 core description form page 1 of 5.



Project/Location: DUVERNAY/ROD 10-27-057-21W4
Date: 3/5/18
Logged By: ATCHLEY
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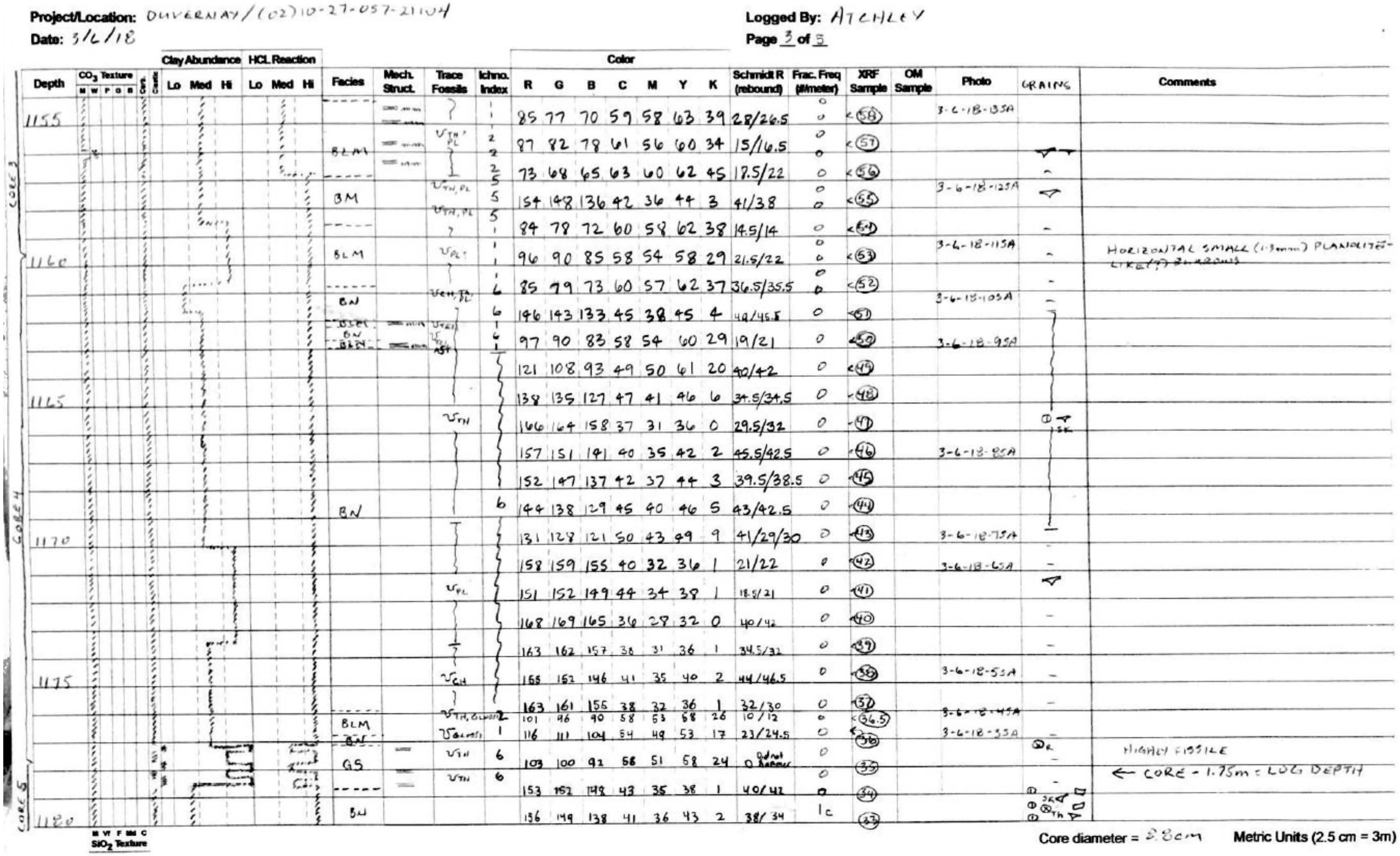
Depth	Facies	Ichno. Index	R	G	B	C	M	Y	K	Schmidt R (rebound)	Frac. Freq (#/meter)	XRF Sample	Photo	Grains	Comments
		6	161	155	146	39	34	40	1	38.5,40	0	32			
	BN	6	164	162	157	38	31	36	1	22,22	•	31	3-6-18-25A		
		6	82	75	69	60	58	63	40	17.5,22	0	30	3-6-18-13A		BRACHIOPOD COQUINA
	BN	6	156	151	144	41	36	40	2	34,35	0	29	3-5-18-22.5A	SK	
		4	131	124	114	49	44	52	11	20,21.5	0	28		SK	
1185		4	153	150	144	42	36	40	2	30,30	0	27	3-5-18-21.5A	SK	
		4	128	121	111	50	45	53	12	27.2,29.5	0	26		SK	
	BMLM	4	122	116	108	52	47	53	14	18,30	0	25		SK	
		4	117	110	102	53	49	54	17	28,34.5	0	24		SK	
		0	126	121	113	51	45	51	12	21.5,25.5	0	23			
1190		0	152	145	135	42	38	44	3	26,26.5	0	22			
		0	104	93	82	54	54	62	28	42,44	0	21	3-5-18-20.5A		
		0	135	127	120	47	43	50	9	29.5,30	0	20			
	BMLM	0	111	103	94	54	51	57	22	33,33	0	19		SK	
		0	98	92	87	58	57	58	26	13.5,15.9	0	18			
1195	BN	6	161	159	152	39	33	38	1	14,14.1	0	17	3-5-18-19.5A		
		6	155	152	145	42	35	40	2	32,33	0	16		SK	
		6	167	165	160	37	31	34	0	21.9,18.5	0	15	3-5-18-18.5A		
		6	179	170	158	32	29	36	0	20,18	0	14			
		6	173	165	156	34	31	37	0	35,39	1	13			
	BN	6	154	144	133	42	38	46	4	36.1,36.1	1	12			
1200		6	163	158	151	38	33	38	1	45.9,46.5	5(c)	11	3-5-18-17.5A		
		6	139	132	122	47	42	49	8	25,25.1		10			CYLINDRICAL STROM MOLDS (CALCITE-FILLED)
		6	169	166	161	36	30	34	0	42,44	0	9			
	BN	6	160	158	154	40	33	36	1	44,45.1	0	8	3-5-18-16.5A	SK	
1205		6	163	159	152	38	33	38	1	18,21.5	0	7		SK	
		6	122	116	108	52	47	53	14	10.2,15.1	0	6	3-5-18-15.5A	SK	

Core diameter = 8.8 cm   Metric Units (2.5 cm = 3m)

Figure A.9: 02-10-27-057-21W4 core description form page 2 of 5.



Project/Location: DUVERNAY/(02)10-27-057-21W4
Date: 3/6/18
Logged By: ATCHLEY
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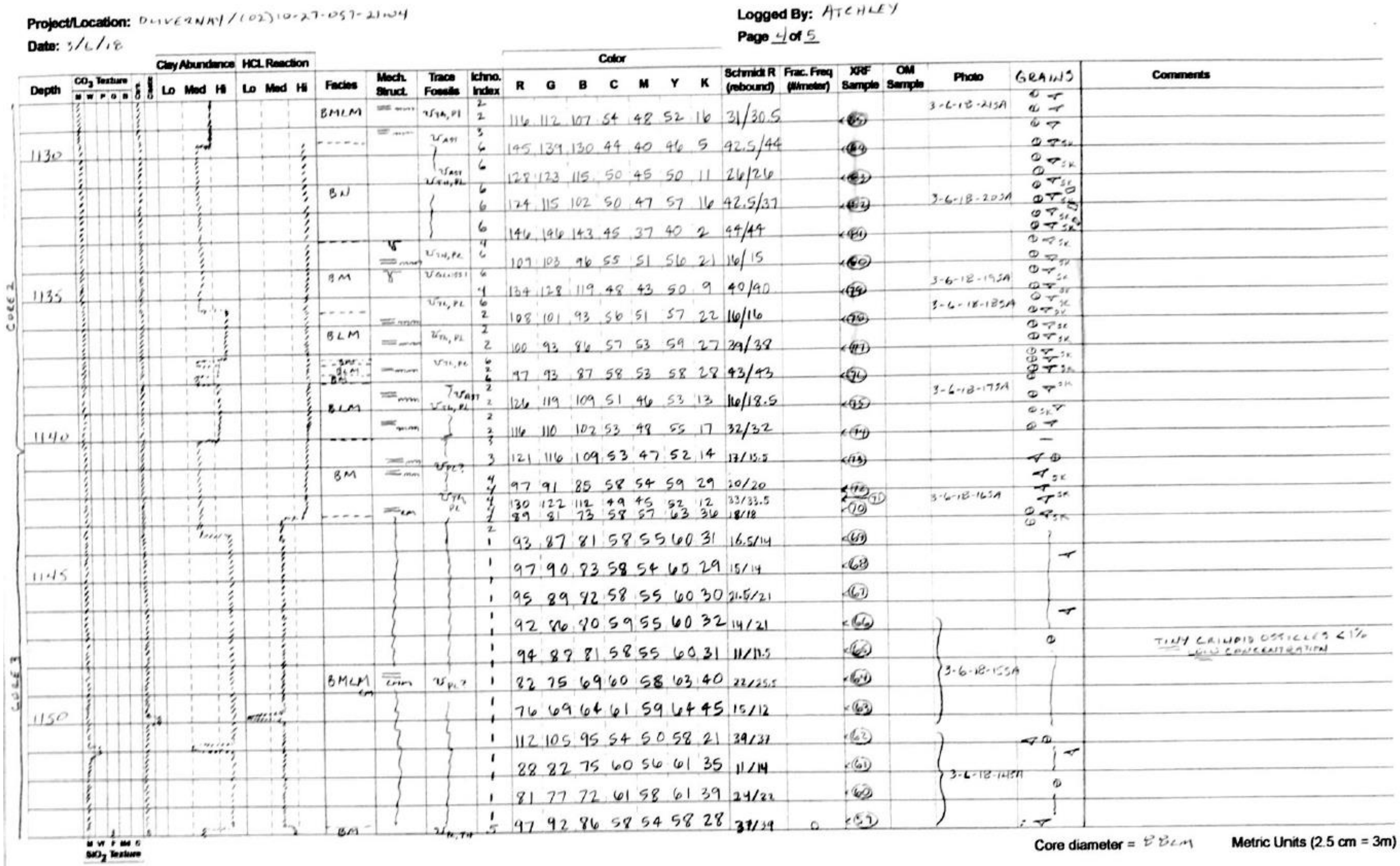
Depth	Facies	Ichno. Index	R	G	B	C	M	Y	K	Schmidt R (rebound)	Frac. Freq (#/meter)	XRF Sample	Photo	Comments
1155		1	85	77	70	59	58	63	39	28/26.5	0	58	3-6-18-135A	
	BLM	2	87	82	78	61	56	60	34	15/16.5	0	57		
		2	73	68	65	63	60	62	45	17.5/22	0	56		
	BM	5	154	148	136	42	36	44	3	41/38	0	55	3-6-18-125A	
		5	84	78	72	60	58	62	38	14.5/14	0	54		
1160	BLM	1	96	90	85	58	54	58	29	21.5/22	0	53	3-6-18-115A	HORIZONTAL SMALL (1-3mm) PLANOLITES-LIKE(?) BURROWS
		6	85	79	73	60	57	62	37	36.5/35.5	0	52		
	BN	6	146	143	133	45	38	45	4	49/45.5	0	51	3-6-18-105A	
	BSCL / BN / BLM	6	97	90	83	58	54	60	29	19/21	0	50	3-6-18-95A	
			121	108	93	49	50	61	20	40/42	0	49		
1165			138	135	127	47	41	46	6	34.5/34.5	0	48		
			166	164	158	37	31	36	0	29.5/32	0	47		
			157	151	141	40	35	42	2	45.5/42.5	0	46	3-6-18-85A	
			152	147	137	42	37	44	3	39.5/38.5	0	45		
	BN	6	144	138	129	45	40	46	5	43/42.5	0	44		
1170			131	128	121	50	43	49	9	41/29/30	0	43	3-6-18-75A	
			158	159	155	40	32	36	1	21/22	0	42	3-6-18-65A	
			151	152	149	44	34	38	1	18.5/21	0	41		
			168	169	165	36	28	32	0	40/42	0	40		
			163	162	157	38	31	36	1	34.5/32	0	39		
1175			165	152	146	41	35	40	2	44/46.5	0	38	3-6-18-55A	
			163	161	155	38	32	36	1	32/30	0	37	3-6-18-45A	
	BLM	2	101	96	90	58	53	68	26	10/12	0	36.5		
	BN	1	116	111	104	54	49	53	17	23/24.5	0	36	3-6-18-35A	
	GS	6	103	100	92	58	51	58	24	0 did not rebound	0	35		HIGHLY FISSILE
		6	153	152	148	43	35	38	1	40/42	0	34		← CORE - 1.75m = LOG DEPTH
1180	BN		156	149	138	41	36	43	2	38/34	1c	33		

Core diameter = 8.8cm
Metric Units (2.5 cm = 3m)

Figure A.10: 02-10-27-057-21W4 core description form page 3 of 5.



Project/Location: DUVERNAY / (02) 10-27-057-21W4
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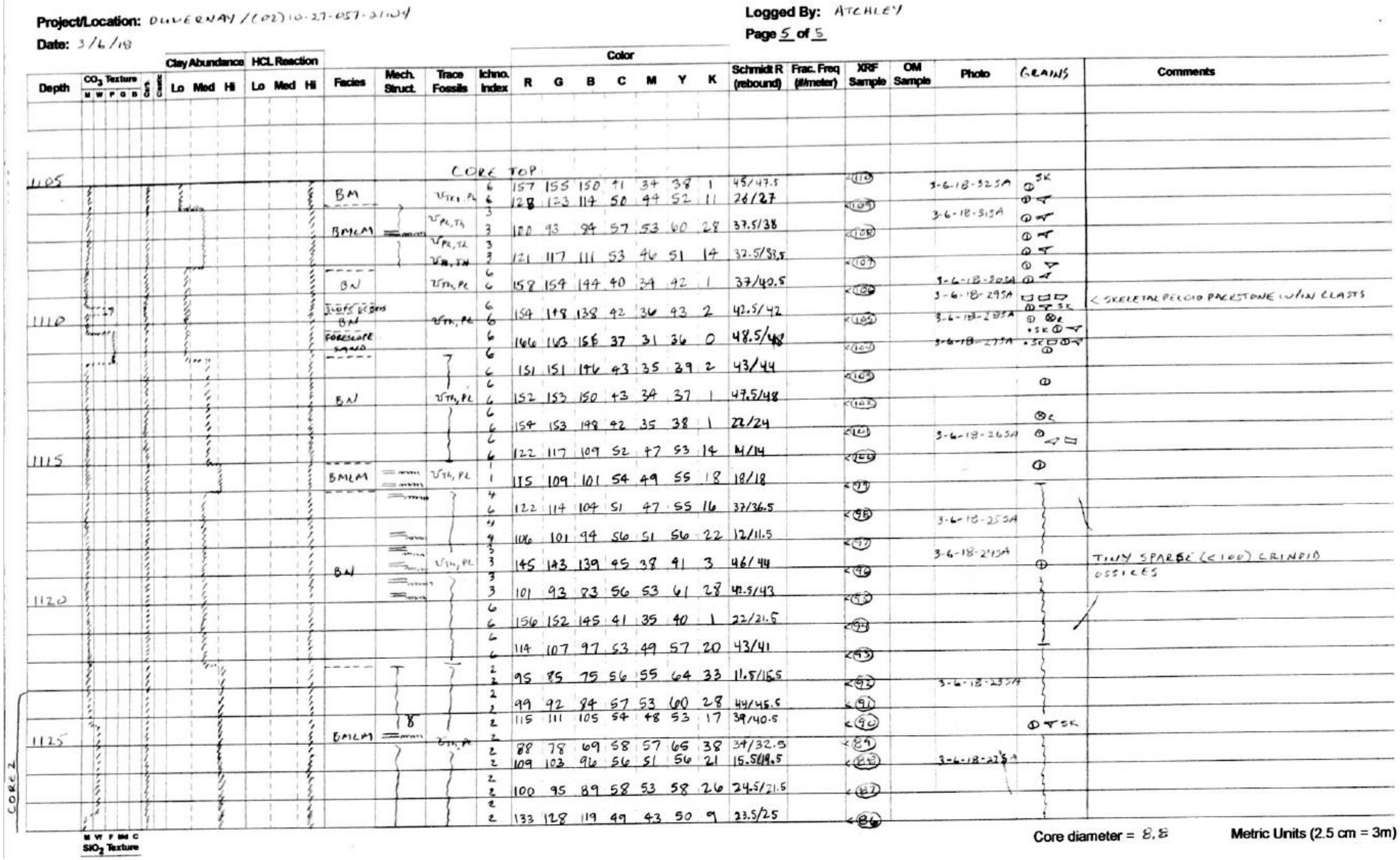
Facies	R	G	B	C	M	Y	K	Schmidt R (rebound)	XRF Sample	Photo
BMLM	116	112	107	54	48	52	16	31/30.5	85	3-6-18-215A
	145	139	130	44	40	46	5	42.5/44	84	
	128	123	115	50	45	50	11	26/26	83	
BN	124	115	102	50	47	57	16	42.5/37	82	3-6-18-205A
	146	146	143	45	37	40	2	44/44	81	
	109	103	96	55	51	56	21	16/15	80	
BM	134	128	119	48	43	50	9	40/40	79	3-6-18-195A
	108	101	93	56	51	57	22	16/16	78	3-6-18-185A
BLM	100	93	86	57	53	59	27	39/38	77	
	97	93	87	58	53	58	28	43/43	76	
BLM	126	119	109	51	46	53	13	16/18.5	75	3-6-18-175A
	116	110	102	53	48	55	17	32/32	74	
	121	116	109	53	47	52	14	17/15.5	73	
BM	97	91	85	58	54	59	29	20/20	72 (71)	3-6-18-165A
	130	122	112	49	45	52	12	33/33.5		
	89	81	73	58	57	63	36	18/18	70	
	93	87	81	58	55	60	31	16.5/14	69	
	97	90	83	58	54	60	29	15/14	68	
	95	89	82	58	55	60	30	21.5/21	67	
	92	86	80	59	55	60	32	14/21	66	
	94	87	81	58	55	60	31	11/11.5	65	
BMLM	82	75	69	60	58	63	40	22/25.5	64	3-6-18-155A
	76	69	64	61	59	64	45	15/12	63	
	112	105	95	54	50	58	21	39/37	62	
	88	82	75	60	56	61	35	11/14	61	3-6-18-145A
	81	77	72	61	58	61	39	24/22	60	
BM	97	92	86	58	54	58	28	37/39	59	

Comments: TINY CRINOID OSSICLES <1% LOW CONCENTRATION

Core diameter = 8 cm   Metric Units (2.5 cm = 3m)

Figure A.11: 02-10-27-057-21W4 core description form page 4 of 5.



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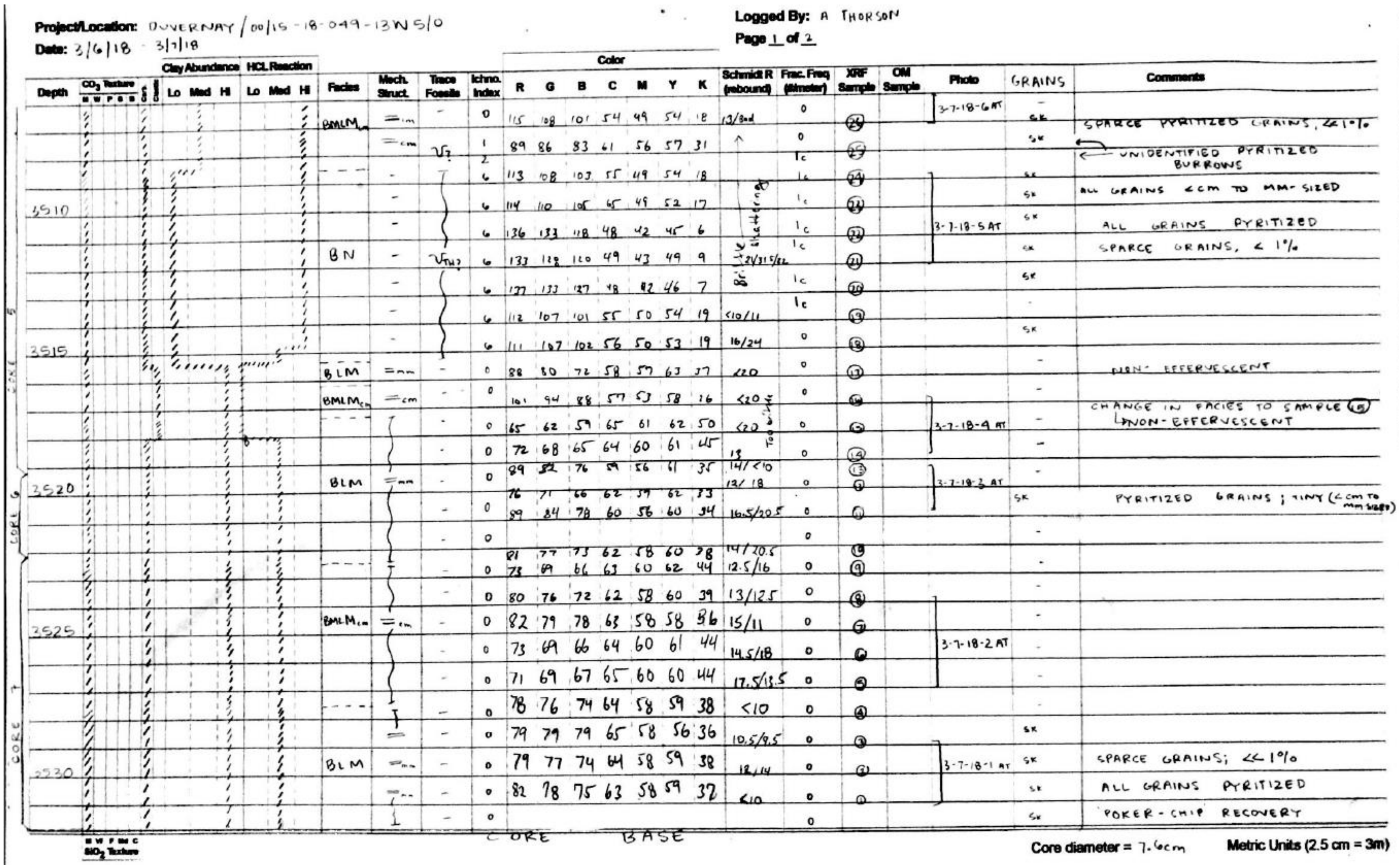
Depth	Facies	Trace Fossils	R	G	B	C	M	Y	K	Schmidt R (rebound)	XRF Sample	Photo
1105 (CORE TOP)	BM		157	155	150	41	34	38	1	45/47.5	110	3-6-18-325A
			128	123	114	50	44	52	11	26/27	109	3-6-18-315A
	BMLM		100	93	94	57	53	60	28	37.5/38	108	
			121	117	111	53	46	51	14	32.5/33.5	107	
	BN		158	154	144	40	34	42	1	37/40.5	106	3-6-18-305A
1110	SLOPE DEBRIS BN		154	148	138	42	36	43	2	42.5/42	105	3-6-18-295A; 3-6-18-285A
	FORESLOPE SAND		166	163	156	37	31	36	0	48.5/48	104	3-6-18-275A
			151	151	146	43	35	39	2	43/44	103	
	BN		152	153	150	43	34	37	1	47.5/48	102	
			154	153	148	42	35	38	1	22/24	101	3-6-18-265A
1115			122	117	109	52	47	53	14	14/14	100	
	BMLM		115	109	101	54	49	55	18	18/18	99	
			122	114	104	51	47	55	16	37/36.5	98	3-6-18-255A
			106	101	94	56	51	56	22	12/11.5	97	3-6-18-245A
	BN		145	143	139	45	38	41	3	46/44	96	
1120			101	93	83	56	53	61	28	41.5/43	95	
			156	152	145	41	35	40	1	22/21.5	94	
			114	107	97	53	49	57	20	43/41	93	
			95	85	75	56	55	64	33	11.5/16.5	92	3-6-18-235A
			99	92	84	57	53	60	28	44/45.5	91	
			115	111	105	54	48	53	17	39/40.5	90	
1125	BMLM		88	78	69	58	57	65	38	34/32.5	89	
			109	103	96	56	51	56	21	15.5/19.5	88	3-6-18-225A
			100	95	89	58	53	58	26	24.5/21.5	87	
			133	128	119	49	43	50	9	23.5/25	86	

Comments: < SKELETAL PELOID PACKSTONE W/IN CLASTS; TINY SPARSE (<100) CRINOID OSSICLES

CORE 2

Core diameter = 8.8 Metric Units (2.5 cm = 3m)

Figure A.12: 02-10-27-057-21W4 core description form page 5 of 5.



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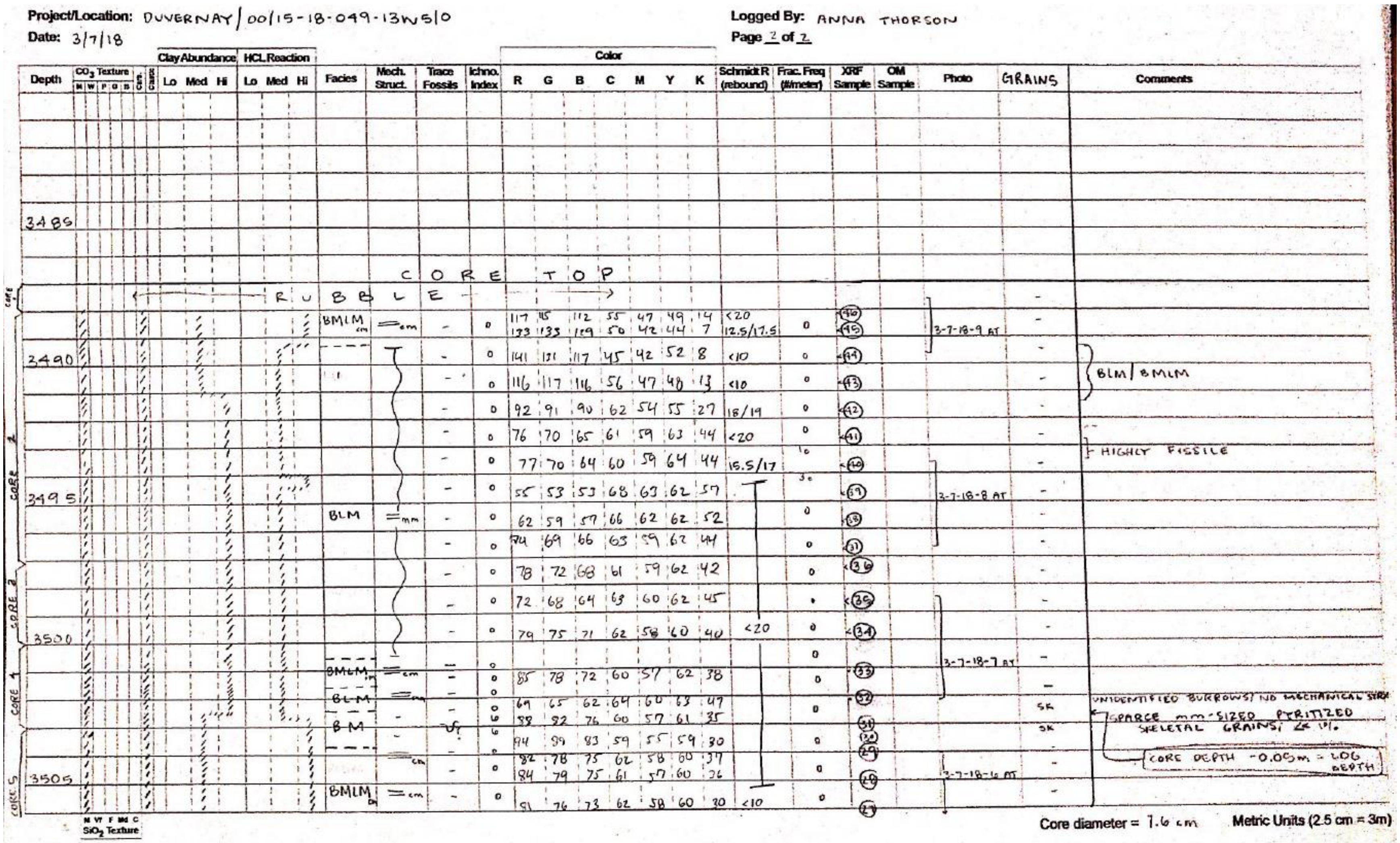
Depth	Facies	Mech. Struct.	Trace Fossils	Ichno. Index	R	G	B	C	M	Y	K	Schmidt R (rebound)	Frac. Freq (#/meter)	XRF Sample	Photo	GRAINS	Comments
	BMLM	=m	-	0	115	108	101	54	49	54	18	13/8nd	0	25	3-7-18-6 AT	SK	SPARCE PYRITIZED GRAINS, <<1%
		=cm		1	89	86	83	61	56	57	31		0	24		SK	UNIDENTIFIED PYRITIZED BURROWS
		-		6	113	108	103	55	49	54	18		1c	24		SK	
3510		-		6	114	110	105	65	49	52	17		1c	23		SK	ALL GRAINS <cm TO MM-SIZED
		-		6	136	133	118	48	42	45	6		1c	22	3-7-18-5 AT	SK	ALL GRAINS PYRITIZED
	BN	-		6	133	128	120	49	43	49	9	24/31.5/22	1c	21		SK	SPARCE GRAINS, < 1%
		-		6	127	133	127	48	42	46	7		1c	20		SK	
		-		6	112	107	101	55	50	54	19	<10/11	1c	19		-	
3515		-		6	111	107	102	56	50	53	19	16/24	0	18		SK	
	BLM	=mm	-	0	88	80	72	58	57	63	37	<20	0	17		-	NON-EFFERVESCENT
	BMLM	=cm	-	0	101	94	88	57	53	58	16	<20	0	16		-	CHANGE IN FACIES TO SAMPLE 15
			-	0	65	62	59	65	61	62	50	<20	0	15	3-7-18-4 AT	-	NON-EFFERVESCENT
			-	0	72	68	65	64	60	61	45	13	0	14		-	
				0	89	82	76	59	56	61	35	14/<10		13		-	
3520	BLM	=mm	-									13/18	0	12	3-7-18-3 AT		
					76	71	66	62	59	62	33						
			-	0	89	84	78	60	56	60	34	16.5/20.5	0	11		SK	PYRITIZED GRAINS; TINY (<cm TO mm-sized)
			-	0									0			-	
					81	77	73	62	58	60	38	14/20.5		10			
			-	0	73	69	66	63	60	62	44	12.5/16	0	9		-	
			-	0	80	76	72	62	58	60	39	13/12.5	0	8		-	
3525	BMLM	=cm	-	0	82	79	78	63	58	58	36	15/11	0	7		-	
			-	0	73	69	66	64	60	61	44	14.5/18	0	6	3-7-18-2 AT	-	
			-	0	71	69	67	65	60	60	44	17.5/13.5	0	5		-	
			-	0	78	76	74	64	58	59	38	<10	0	4		-	
		=	-	0	79	79	79	65	58	56	36	10.5/9.5	0	3		SK	
3530	BLM	=mm	-	0	79	77	74	64	58	59	38	18/14	0	2	3-7-18-1 AT	SK	SPARCE GRAINS; <<1%
		=mm	-	0	82	78	75	63	58	59	37	<10	0	1		SK	ALL GRAINS PYRITIZED
			-	0									0			SK	POKER-CHIP RECOVERY

CORE BASE

Core diameter = 7.6cm Metric Units (2.5 cm = 3m)

Figure A.13: 00-15-18-049-13W5 core description form page 1 of 2.



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Logged By: ANNA THORSON
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Depth	Facies	Mech. Struct.	Trace Fossils	Ichno. Index	R	G	B	C	M	Y	K	Schmidt R (rebound)	Frac. Freq (#/meter)	XRF Sample	Photo	GRAINS	Comments
3485																	
	CORE TOP																
	RUBBLE															-	
	BMLM cm	=cm	-	0	117 / 133	115 / 133	112 / 109	55 / 50	47 / 42	49 / 44	14 / 7	<20 / 12.5/17.5	0	46, 45	3-7-18-9 AT	-	
3490			-	0	141	121	117	45	42	52	8	<10	0	44		-	BLM / BMLM
			-	0	116	117	116	56	47	48	13	<10	0	43		-	
			-	0	92	91	90	62	54	55	27	18/19	0	42		-	
			-	0	76	70	65	61	59	63	44	<20	0	41		-	
			-	0	77	70	64	60	59	64	44	15.5/17	10	40		-	HIGHLY FISSILE
3495			-	0	55	53	53	68	63	62	57		30	39	3-7-18-8 AT	-	
	BLM	=mm	-	0	62	59	57	66	62	62	52		0	38		-	
			-	0	74	69	66	63	59	62	44		0	37		-	
			-	0	78	72	68	61	59	62	42		0	36		-	
			-	0	72	68	64	63	60	62	45		•	35		-	
3500			-	0	79	75	71	62	58	60	40	<20	0	34		-	
			-	0									0		3-7-18-7 AT	-	
	BMLM m	=cm	-	0	85	78	72	60	57	62	38		0	33		-	
	BLM	=m	-	0	69 / 88	65 / 82	62 / 76	64 / 60	60 / 57	63 / 61	47 / 35		0	32		SK	UNIDENTIFIED BURROWS; NO MECHANICAL STR
	BM	-	✓?	6	94	99	83	59	55	59	30		0	31, 30		SK	SPARCE mm-SIZED PYRITIZED SKELETAL GRAINS; << 1%
3505		=cm	-	0	82 / 84	78 / 79	75 / 75	62 / 61	58 / 57	60 / 60	37 / 36		0	29, 28	3-7-18-6 AT	-	CORE DEPTH -0.05m = LOG DEPTH
	BMLM	=cm	-	0	91	76	73	62	58	60	30	<10	0	27		-	

Core diameter = 7.6 cm   Metric Units (2.5 cm = 3m)

Figure A.14: 00-15-18-049-13W5 core description form page 2 of 2.

APPENDIX B

Geochemical Data

Table B.1. Organic geochemical data for all samples.

Well UWI	ID #	Depth (m)	$\delta^{13}C_{org}$	$\delta^{15}N$	Total Nitrogen (wt. %)	Total Organic Carbon (wt. %)
02-01-14-033-23W4	1D	2015	-29.52	1.22	0.22	4.69
02-01-14-033-23W4	2D	2016	-27.31	0.93	0.05	0.29
02-01-14-033-23W4	3D	2053	-28.44	2.78	0.08	0.88
02-01-14-033-23W4	4D	2054	-29.51	2.03	0.04	0.29
02-01-14-033-23W4	5D	2055	-28.69	2.48	0.20	6.07
02-01-14-033-23W4	6D	2056	-29.96	2.32	0.05	0.38
02-01-14-033-23W4	7D	2057	-29.91	1.98	0.05	0.36
02-01-14-033-23W4	8D	2058	-29.92	1.39	0.11	1.87
02-01-14-033-23W4	9D	2059	-29.75	1.09	0.08	1.20
02-01-14-033-23W4	10D	2060	-28.58	1.60	0.26	10.24
02-01-14-033-23W4	11D	2061	-29.57	0.66	0.05	1.43
02-01-14-033-23W4	12D	2062	-29.59	0.82	0.08	1.19
02-01-14-033-23W4	13D	2063	-29.99	1.47	0.05	0.57
02-01-14-033-23W4	14D	2064	-30.16	0.39	0.20	9.24
02-01-14-033-23W4	15D	2065	-29.46	0.91	0.22	6.34
02-01-14-033-23W4	16D	2066	-29.44	1.41	0.08	1.34
02-01-14-033-23W4	17D	2067	-28.99	2.16	0.05	0.26
02-01-14-033-23W4	18D	2070	-28.97	1.78	0.11	6.06
02-01-14-033-23W4	19D	2070.5	-28.92	1.14	0.19	7.81
02-01-14-033-23W4	20D	2071	-28.87	1.96	0.09	1.70
02-01-14-033-23W4	21D	2072	-28.76	2.20	0.10	1.35
02-01-14-033-23W4	22D	2073	-28.82	1.86	0.06	0.40
02-01-14-033-23W4	23D	2074	-28.83	1.16	0.09	1.37
02-01-14-033-23W4	24D	2075	-28.42	1.52	0.00	0.40
02-01-14-033-23W4	25D	2076	-29.11	3.66	0.00	0.19
02-01-14-033-23W4	26D	2077	-29.46	3.99	0.08	0.29
02-01-14-033-23W4	27D	2078	-29.63	3.47	0.07	0.37
02-01-14-033-23W4	28D	2079	-29.20	3.55	0.04	0.17
02-01-14-033-23W4	29D	2080	-29.16	3.60	0.05	0.26
02-01-14-033-23W4	30D	2081	-28.90	3.40	0.05	0.25

Table B.1 Continued

Well UWI	ID #	Depth (m)	$\delta^{13}C_{org}$	$\delta^{15}N$	Total Nitrogen (wt. %)	Total Organic Carbon (wt. %)
02-01-14-033-23W4	31D	2082	-29.17	2.84	0.05	0.32
02-01-14-033-23W4	32D	2083	-29.34	1.74	0.04	0.57
02-01-14-033-23W4	33D	2084	-29.36	2.09	0.00	0.25
02-01-14-033-23W4	34D	2085	-29.13	0.69	0.28	5.21
02-01-14-033-23W4	35D	2086	-29.53	0.65	0.04	0.64
02-01-14-033-23W4	36D	2087	-28.87	2.48	0.00	0.21
02-01-14-033-23W4	37D	2088	-28.79	0.48	0.31	8.97
02-01-14-033-23W4	38D	2089	-28.76	1.27	0.00	0.40
02-01-14-033-23W4	39D	2090	-28.61	1.45	0.06	0.72
02-01-14-033-23W4	40D	2091	-28.64	2.13	0.06	6.54
02-01-14-033-23W4	41D	2092	-28.49	1.84	0.07	6.42
02-01-14-033-23W4	42D	2093	-29.12	0.91	0.00	0.53
02-01-14-033-23W4	43D	2094	-28.96	0.78	0.00	0.39
02-01-14-033-23W4	44D	2095	-28.65	1.81	0.00	0.47
02-01-14-033-23W4	45D	2096	-28.87	0.32	0.12	5.84
02-01-14-033-23W4	46D	2097	-28.63	0.94	0.11	8.03
02-01-14-033-23W4	47D	2098	-29.02	1.74	0.00	0.32
02-01-14-033-23W4	48D	2099	-28.91	1.96	0.06	0.40
02-01-14-033-23W4	49D	2100	-28.95	1.83	0.07	0.78
02-01-14-033-23W4	50D	2101	-28.43	0.46	0.32	12.53
02-01-14-033-23W4	51D	2102	-28.38	1.88	0.14	4.25
02-01-14-033-23W4	52D	2103	-29.02	0.43	0.25	8.19
02-01-14-033-23W4	53D	2104	-29.30	1.02	0.25	6.55
02-01-14-033-23W4	54D	2104.5	-29.51	1.41	0.15	5.85
02-01-14-033-23W4	55D	2107	-29.36	0.99	0.50	11.56
02-01-14-033-23W4	56D	2108	-29.70	1.54	0.06	0.79
02-01-14-033-23W4	57D	2109	-29.48	0.57	0.12	4.91
02-01-14-033-23W4	58D	2110	-28.88	2.68	0.05	0.36
02-01-14-033-23W4	59D	2111	-29.28	0.77	0.00	0.52
02-01-14-033-23W4	60D	2112	-28.63	1.60	0.00	0.59
02-01-14-033-23W4	61D	2113	-28.49	1.25	0.09	6.79
02-01-14-033-23W4	62D	2114	-28.48	0.82	0.10	2.40
02-01-14-033-23W4	63D	2115	-26.84	4.46	0.00	0.17
02-01-14-033-23W4	64D	2116	-28.46	2.70	0.05	0.82
02-01-14-033-23W4	65D	2117	-29.83	2.67	0.05	0.50
02-01-14-033-23W4	66D	2118	-29.96	2.90	0.05	0.48
02-01-14-033-23W4	67D	2119	-29.82	2.53	0.05	0.52

Table B.1 Continued.

Well UWI	ID #	Depth (m)	$\delta^{13}C_{org}$	$\delta^{15}N$	Total Nitrogen (wt. %)	Total Organic Carbon (wt. %)
02-01-14-033-23W4	68D	2120	-29.94	2.68	0.00	0.00
02-01-14-033-23W4	69D	2121	-29.99	2.29	0.07	0.83
02-01-14-033-23W4	70D	2122	-30.26	1.72	0.04	0.47
02-01-14-033-23W4	71D	2123	-31.23	1.18	0.21	9.28
02-01-14-033-23W4	72D	2124	-30.49	2.54	0.04	0.41
00-14-19-062-15W5	73D	2888	-29.44	4.25	0.07	0.33
00-14-19-062-15W5	74D	2889	-29.35	3.58	0.10	0.36
00-14-19-062-15W5	75D	2890	-29.74	3.80	0.10	0.51
00-14-19-062-15W5	76D	2891	-30.06	3.54	0.11	0.66
00-14-19-062-15W5	77D	2892	-29.62	3.57	0.11	0.52
00-14-19-062-15W5	78D	2893	-30.04	2.53	0.11	1.73
00-14-19-062-15W5	79D	2895	-29.15	2.33	0.10	2.10
00-14-19-062-15W5	81D	2896	-29.15	1.96	0.16	3.59
00-14-19-062-15W5	82D	2897	-29.16	2.94	0.05	3.53
00-14-19-062-15W5	83D	2898	-28.94	1.28	0.13	3.09
00-14-19-062-15W5	84D	2899	-29.00	1.88	0.10	3.18
00-14-19-062-15W5	85D	2900	-29.23	2.01	0.09	4.56
00-14-19-062-15W5	86D	2901	-28.51	1.76	0.09	4.29
00-14-19-062-15W5	87D	2902	-28.79	1.99	0.12	3.87
00-14-19-062-15W5	88D	2903	-28.93	2.15	0.11	2.66
00-14-19-062-15W5	89D	2904	-28.99	2.33	0.12	3.63
00-14-19-062-15W5	90D	2905	-29.02	2.67	0.15	3.58
00-14-19-062-15W5	91D	2906	-28.96	3.61	0.13	2.58
00-14-19-062-15W5	92D	2907	-29.19	2.84	0.11	2.09
00-14-19-062-15W5	93D	2908	-29.05	2.53	0.17	3.19
00-14-19-062-15W5	94D	2909	-28.88	1.46	0.23	4.48
00-14-19-062-15W5	95D	2910	-29.19	1.45	0.16	3.03
00-14-19-062-15W5	96D	2911	-29.08	1.66	0.18	3.36
00-14-19-062-15W5	97D	2912	-28.90	1.99	0.08	0.86
00-14-19-062-15W5	98D	2913	-28.42	2.01	0.10	1.06
00-14-19-062-15W5	99D	2914	-28.83	1.92	0.08	0.79
00-14-19-062-15W5	100D	2915	-28.72	1.46	0.19	2.94
00-14-19-062-15W5	101D	2916	-28.64	1.38	0.21	5.36
00-14-19-062-15W5	102D	2917	-28.55	1.42	0.19	3.56
00-14-19-062-15W5	103D	2918	-28.64	1.24	0.15	3.40
00-14-19-062-15W5	104D	2919	-28.56	1.09	0.21	4.06
00-14-19-062-15W5	105D	2920	-28.56	1.15	0.15	3.08

Table B.1 Continued.

Well UWI	ID #	Depth (m)	$\delta^{13}C_{org}$	$\delta^{15}N$	Total Nitrogen (wt. %)	Total Organic Carbon (wt. %)
00-14-19-062-15W5	106D	2921	-28.44	1.43	0.21	4.22
00-14-19-062-15W5	107D	2922	-28.47	1.26	0.17	3.68
00-14-19-062-15W5	108D	2923	-28.39	1.14	0.19	3.60
00-14-19-062-15W5	109D	2924	-28.31	2.37	0.10	4.44
00-14-19-062-15W5	110D	2925	-29.23	0.87	0.14	2.33
00-14-19-062-15W5	111D	2926	-29.58	1.10	0.11	4.74
00-14-19-062-15W5	112D	2927	-29.99	0.36	0.10	0.32
00-14-19-062-15W5	113D	2928	-29.26	3.36	0.12	3.12
00-14-19-062-15W5	114D	2929	-29.78	2.46	0.06	0.17
00-14-19-062-15W5	115D	2930	-29.58	2.73	0.08	0.33
00-14-19-062-15W5	116D	2931	-29.40	2.39	0.08	0.28
00-14-19-062-15W5	117D	2932	-29.31	2.26	0.08	0.23
00-14-19-062-15W5	118D	2933	-29.48	2.71	0.12	0.28
00-14-19-062-15W5	119D	2934	-29.20	2.90	0.11	0.30
00-14-19-062-15W5	120D	2935	-29.28	2.83	0.09	0.27
00-14-19-062-15W5	121D	2936	-29.30	2.81	0.09	0.26
00-14-19-062-15W5	122D	2937	-29.09	3.49	0.19	3.80
00-14-19-062-15W5	123D	2938	-29.78	0.97	0.11	1.01
00-14-19-062-15W5	124D	2939	-28.73	1.96	0.18	1.86
00-14-19-062-15W5	125D	2940	-28.82	2.18	0.11	3.31
00-14-19-062-15W5	126D	2941	-28.81	2.33	0.09	0.74
00-14-19-062-15W5	127D	2942	-28.83	2.28	-	-
02-10-27-057-21W4	128D	1105	-26.58	2.70	0.05	0.18
02-10-27-057-21W4	129D	1106	-28.75	1.31	0.10	1.36
02-10-27-057-21W4	130D	1107	-28.75	0.90	0.14	1.93
02-10-27-057-21W4	131D	1108	-28.56	0.88	0.14	1.59
02-10-27-057-21W4	132D	1109	-27.63	2.92	0.07	0.42
02-10-27-057-21W4	133D	1110	-28.76	1.04	0.07	0.75
02-10-27-057-21W4	134D	1111	-28.56	1.84	0.06	0.34
02-10-27-057-21W4	135D	1112	-29.48	2.20	0.07	0.69
02-10-27-057-21W4	136D	1113	-29.24	1.75	0.06	0.58
02-10-27-057-21W4	137D	1114	-28.97	1.63	0.11	1.25
02-10-27-057-21W4	138D	1115	-28.85	1.31	0.10	1.31
02-10-27-057-21W4	139D	1116	-28.67	0.83	0.14	2.22
02-10-27-057-21W4	140D	1117	-28.86	0.83	0.20	3.35
02-10-27-057-21W4	141D	1118	-28.83	0.82	0.25	4.81
02-10-27-057-21W4	142D	1119	-28.45	0.83	0.09	1.13

Table B.1 Continued.

Well UWI	ID #	Depth (m)	$\delta^{13}C_{org}$	$\delta^{15}N$	Total Nitrogen (wt. %)	Total Organic Carbon (wt. %)
02-10-27-057-21W4	143D	1120	-28.37	0.86	0.12	1.90
02-10-27-057-21W4	144D	1121	-28.28	1.68	0.12	1.29
02-10-27-057-21W4	145D	1122	-28.39	2.09	0.09	1.02
02-10-27-057-21W4	146D	1123	-28.87	0.84	0.19	2.94
02-10-27-057-21W4	238D	1124	-28.51	1.02	0.13	2.17
02-10-27-057-21W4	147D	1124.5	-28.81	0.85	0.21	3.88
02-10-27-057-21W4	148D	1125	-28.71	1.08	0.18	3.43
02-10-27-057-21W4	149D	1126	-28.54	1.76	0.20	3.24
02-10-27-057-21W4	150D	1127	-28.54	1.54	0.21	3.35
02-10-27-057-21W4	151D	1128	-28.22	2.38	0.10	1.32
02-10-27-057-21W4	152D	1129	-28.18	1.53	0.16	3.05
02-10-27-057-21W4	153D	1130	-28.10	2.41	0.05	0.33
02-10-27-057-21W4	154D	1131	-28.80	1.29	0.13	1.83
02-10-27-057-21W4	155D	1132	-28.19	3.51	0.06	0.27
02-10-27-057-21W4	156D	1133	-28.49	2.93	0.06	0.40
02-10-27-057-21W4	157D	1134	-29.09	0.83	0.24	4.03
02-10-27-057-21W4	158D	1135	-28.83	3.36	0.06	0.81
02-10-27-057-21W4	159D	1136	-28.79	0.58	0.19	3.31
02-10-27-057-21W4	160D	1137	-28.71	1.94	0.05	0.54
02-10-27-057-21W4	161D	1138	-28.73	1.90	0.07	1.08
02-10-27-057-21W4	162D	1139	-28.66	1.21	0.21	3.68
02-10-27-057-21W4	163D	1140	-28.05	2.25	0.03	0.31
02-10-27-057-21W4	164D	1141	-28.58	1.71	0.08	1.15
02-10-27-057-21W4	165D	1142	-28.56	1.27	0.17	2.80
02-10-27-057-21W4	166D	1142.5	-28.27	0.84	0.11	1.99
02-10-27-057-21W4	167D	1143	-28.12	0.75	0.18	3.34
02-10-27-057-21W4	168D	1144	-28.30	1.00	0.22	4.02
02-10-27-057-21W4	169D	1145	-28.23	1.13	0.24	4.38
02-10-27-057-21W4	170D	1146	-28.38	0.97	0.25	4.41
02-10-27-057-21W4	171D	1147	-28.26	0.71	0.29	5.36
02-10-27-057-21W4	172D	1148	-28.27	0.81	0.34	6.21
02-10-27-057-21W4	173D	1149	-28.10	0.70	0.35	6.83
02-10-27-057-21W4	174D	1150	-28.12	0.68	0.39	7.37
02-10-27-057-21W4	175D	1151	-27.71	0.87	0.09	1.19
02-10-27-057-21W4	176D	1152	-28.13	0.49	0.38	6.96
02-10-27-057-21W4	177D	1153	-28.02	0.30	0.43	7.94
02-10-27-057-21W4	178D	1154	-28.08	0.25	0.45	8.39

Table B.1 Continued.

Well UWI	ID #	Depth (m)	$\delta^{13}C_{org}$	$\delta^{15}N$	Total Nitrogen (wt. %)	Total Organic Carbon (wt. %)
02-10-27-057-21W4	179D	1155	-27.84	0.09	0.30	5.41
02-10-27-057-21W4	180D	1156	-27.88	-0.32	0.36	6.77
02-10-27-057-21W4	181D	1157	-27.22	1.58	0.14	2.17
02-10-27-057-21W4	182D	1158	-27.47	3.64	0.15	0.67
02-10-27-057-21W4	183D	1159	-27.62	0.07	0.24	5.31
02-10-27-057-21W4	184D	1160	-26.81	-0.15	0.39	9.88
02-10-27-057-21W4	185D	1161	-28.83	0.82	0.09	1.57
02-10-27-057-21W4	186D	1162	-29.30	-0.03	0.19	3.67
02-10-27-057-21W4	187D	1163	-30.06	-0.92	0.34	6.60
02-10-27-057-21W4	188D	1164	-28.55	0.37	0.05	0.78
02-10-27-057-21W4	189D	1165	-29.33	3.67	0.05	0.37
02-10-27-057-21W4	190D	1166	-29.27	4.07	0.05	0.24
02-10-27-057-21W4	191D	1167	-29.60	4.32	0.03	0.15
02-10-27-057-21W4	192D	1168	-29.58	3.88	0.03	0.18
02-10-27-057-21W4	193D	1169	-29.46	3.95	0.03	0.17
02-10-27-057-21W4	194D	1170	-29.13	4.30	0.03	0.14
02-10-27-057-21W4	195D	1171	-29.10	3.71	0.04	0.17
02-10-27-057-21W4	196D	1172	-28.80	4.13	0.04	0.15
02-10-27-057-21W4	197D	1173	-28.87	4.28	0.06	0.29
02-10-27-057-21W4	198D	1174	-28.76	4.30	0.04	0.18
02-10-27-057-21W4	199D	1175	-28.95	3.04	0.04	0.32
02-10-27-057-21W4	200D	1176	-29.10	3.31	0.05	0.36
02-10-27-057-21W4	201D	1176.3	-29.32	0.48	0.20	3.76
02-10-27-057-21W4	202D	1177	-29.21	0.64	0.06	0.82
02-10-27-057-21W4	203D	1178	-29.00	3.60	0.09	0.41
02-10-27-057-21W4	204D	1179	-28.75	1.66	0.05	0.43
02-10-27-057-21W4	205D	1180	-27.41	2.68	0.03	0.16
02-10-27-057-21W4	206D	1181	-26.70	1.64	0.03	0.22
02-10-27-057-21W4	207D	1182	-26.56	1.72	0.03	0.21
02-10-27-057-21W4	208D	1183	-26.21	-2.20	0.45	11.93
02-10-27-057-21W4	209D	1183.5	-27.80	2.78	0.00	0.34
02-10-27-057-21W4	210D	1184	-26.32	2.26	0.09	2.00
02-10-27-057-21W4	211D	1185	-27.55	3.93	0.00	0.36
02-10-27-057-21W4	212D	1186	-27.32	3.11	0.07	1.01
02-10-27-057-21W4	213D	1187	-27.37	2.64	0.07	0.91
02-10-27-057-21W4	214D	1188	-27.41	2.66	0.06	1.17
02-10-27-057-21W4	215D	1189	-28.08	3.44	0.09	1.55

Table B.1 Continued.

Well UWI	ID #	Depth (m)	$\delta^{13}C_{org}$	$\delta^{15}N$	Total Nitrogen (wt. %)	Total Organic Carbon (wt. %)
02-10-27-057-21W4	216D	1190	-27.41	2.84	0.08	1.27
02-10-27-057-21W4	217D	1191	-27.66	2.77	0.08	1.13
02-10-27-057-21W4	218D	1192	-28.07	3.05	0.08	1.29
02-10-27-057-21W4	219D	1193	-28.13	2.70	0.08	1.30
02-10-27-057-21W4	220D	1194	-28.66	2.36	0.15	2.64
02-10-27-057-21W4	221D	1195	-29.38	2.40	0.09	0.81
02-10-27-057-21W4	222D	1196	-29.65	2.08	0.06	0.50
02-10-27-057-21W4	223D	1197	-29.32	1.71	0.04	0.23
02-10-27-057-21W4	224D	1197.5	-28.75	1.50	0.05	0.30
02-10-27-057-21W4	225D	1198.5	-28.74	1.79	0.05	0.22
02-10-27-057-21W4	226D	1199.5	-	-	0.03	0.15
02-10-27-057-21W4	227D	1200.5	-28.67	1.78	0.03	0.18
02-10-27-057-21W4	228D	1201.5	-28.89	0.59	0.06	0.76
02-10-27-057-21W4	229D	1202.5	-28.83	2.39	0.04	0.16
02-10-27-057-21W4	230D	1203.5	-29.14	4.17	0.05	0.26
02-10-27-057-21W4	231D	1204.5	-29.04	3.83	0.05	0.27
02-10-27-057-21W4	232D	1205.5	-29.97	0.69	0.10	1.96
02-10-27-057-21W4	233D	1206	-29.73	0.01	0.12	2.56
02-10-27-057-21W4	234D	1207	-29.92	0.96	0.11	2.33
02-10-27-057-21W4	235D	1208	-29.32	0.99	0.06	0.64
02-10-27-057-21W4	236D	1209	-29.40	0.92	0.08	1.57
02-10-27-057-21W4	237D	1210	-29.78	0.57	0.12	2.81
00-15-18-049-13W5	239D	3488	-29.36	3.29	0.10	0.46
00-15-18-049-13W5	240D	3489	-29.09	3.66	0.11	0.59
00-15-18-049-13W5	241D	3490	-29.19	3.88	0.11	0.72
00-15-18-049-13W5	242D	3491	-29.03	3.74	0.10	0.57
00-15-18-049-13W5	243D	3492	-28.82	4.09	0.06	0.28
00-15-18-049-13W5	244D	3493	-29.14	2.49	0.18	5.55
00-15-18-049-13W5	245D	3494	-29.03	2.68	0.13	4.07
00-15-18-049-13W5	246D	3495	-28.88	2.65	0.12	2.03
00-15-18-049-13W5	247D	3496	-29.18	2.61	0.14	3.16
00-15-18-049-13W5	248D	3497	-29.00	2.62	0.11	2.34
00-15-18-049-13W5	249D	3498	-28.92	2.70	0.12	2.55
00-15-18-049-13W5	250D	3499	-28.87	2.03	0.04	0.93
00-15-18-049-13W5	251D	3500	-28.26	3.02	0.10	1.02
00-15-18-049-13W5	252D	3501	-28.15	2.34	0.12	3.96
00-15-18-049-13W5	253D	3502	-28.25	2.28	0.22	5.73

Table B.1 Continued.

Well UWI	ID #	Depth (m)	$\delta^{13}C_{org}$	$\delta^{15}N$	Total Nitrogen (wt. %)	Total Organic Carbon (wt. %)
00-15-18-049-13W5	254D	3503	-28.75	2.67	0.09	4.28
00-15-18-049-13W5	255D	3503.5	-28.88	2.17	0.11	2.33
00-15-18-049-13W5	256D	3504	-28.98	0.94	0.07	1.48
00-15-18-049-13W5	257D	3505	-28.92	0.59	0.12	2.70
00-15-18-049-13W5	258D	3506	-28.84	1.12	0.10	2.33
00-15-18-049-13W5	259D	3507	-28.91	1.03	0.12	2.92
00-15-18-049-13W5	260D	3508	-29.02	2.13	0.19	4.30
00-15-18-049-13W5	261D	3509	-29.07	3.35	0.15	2.91
00-15-18-049-13W5	262D	3510	-28.76	3.33	0.03	0.20
00-15-18-049-13W5	263D	3511	-28.54	3.83	0.05	0.39
00-15-18-049-13W5	264D	3512	-28.42	3.81	0.04	0.28
00-15-18-049-13W5	265D	3513	-28.43	3.86	0.04	0.30
00-15-18-049-13W5	266D	3514	-28.15	2.17	0.08	1.17
00-15-18-049-13W5	267D	3515	-28.11	2.76	0.07	0.73
00-15-18-049-13W5	268D	3516	-27.98	2.11	0.23	5.35
00-15-18-049-13W5	269D	3517	-27.72	2.49	0.15	1.94
00-15-18-049-13W5	270D	3518	-27.55	2.48	0.16	2.36
00-15-18-049-13W5	271D	3519	-27.32	2.55	0.17	3.46
00-15-18-049-13W5	272D	3519.5	-27.25	2.70	0.14	2.88
00-15-18-049-13W5	273D	3520	-27.06	2.80	0.16	3.20
00-15-18-049-13W5	274D	3521	-27.13	3.11	0.16	3.12
00-15-18-049-13W5	275D	3522	-26.87	2.54	0.18	3.46
00-15-18-049-13W5	276D	3523	-26.74	2.19	0.27	7.01
00-15-18-049-13W5	277D	3524	-26.53	2.06	0.24	5.66
00-15-18-049-13W5	278D	3525	-26.75	2.92	0.11	1.17
00-15-18-049-13W5	279D	3526	-27.17	2.00	0.14	2.82
00-15-18-049-13W5	280D	3527	-26.99	1.87	0.18	4.12
00-15-18-049-13W5	281D	3528	-28.15	2.71	0.13	0.69
00-15-18-049-13W5	282D	3529	-28.16	2.94	0.13	0.83
00-15-18-049-13W5	283D	3530	-28.54	2.66	0.13	0.63
00-15-18-049-13W5	284D	3531	-28.41	2.80	0.12	0.89

Table B.2. Major element concentrations for all samples (Part 1).

Well UWI	ID #	Depth (m)	SiO_2 (wt. %)	TiO_2 (wt. %)	Al_2O_3 (wt. %)	Fe_2O_3 (wt. %)	MnO (wt. %)
02-01-14-033-23W4	1D	2015	55.213	0.48	9.304	2.339	0.002
02-01-14-033-23W4	2D	2016	9.776	0.027	1.058	0.111	0.001
02-01-14-033-23W4	3D	2053	38.079	0.242	5.888	1.709	0.016
02-01-14-033-23W4	4D	2054	12.827	0.031	1.337	0.223	0.001
02-01-14-033-23W4	5D	2055	46.351	0.375	8.665	3.175	0.021
02-01-14-033-23W4	6D	2056	15.158	0.045	1.786	0.36	0
02-01-14-033-23W4	7D	2057	13.18	0.043	1.619	0.25	-0.004
02-01-14-033-23W4	8D	2058	45	0.356	7.952	2.035	0.009
02-01-14-033-23W4	9D	2059	26.535	0.128	3.496	0.802	0.002
02-01-14-033-23W4	10D	2060	31.326	0.137	3.619	2.008	0.005
02-01-14-033-23W4	11D	2061	20.678	0.083	2.576	0.42	-0.001
02-01-14-033-23W4	12D	2062	21.443	0.094	2.818	0.489	-0.001
02-01-14-033-23W4	13D	2063	26.196	0.14	3.51	0.757	0
02-01-14-033-23W4	14D	2064	28.435	0.154	4.16	1.02	-0.004
02-01-14-033-23W4	15D	2065	33.018	0.212	5.512	2.057	0.001
02-01-14-033-23W4	16D	2066	25.084	0.104	3.406	0.566	0
02-01-14-033-23W4	17D	2067	6.148	0.005	0.781	-0.041	-0.004
02-01-14-033-23W4	18D	2070	28.744	0.138	3.856	1.05	0.009
02-01-14-033-23W4	19D	2070.5	30.549	0.148	4.238	1.205	0.006
02-01-14-033-23W4	20D	2071	27.627	0.11	3.238	0.766	0.006
02-01-14-033-23W4	21D	2072	37.354	0.257	5.273	1.148	0.008
02-01-14-033-23W4	22D	2073	18.056	0.072	2.006	0.365	-0.001
02-01-14-033-23W4	23D	2074	30.895	0.179	4.042	1.11	0.004
02-01-14-033-23W4	24D	2075	9.111	0.018	1.055	0.142	0.01
02-01-14-033-23W4	25D	2076	6.849	0.003	0.897	0.219	0.015
02-01-14-033-23W4	26D	2077	43.122	0.308	9.81	2.435	0.016
02-01-14-033-23W4	27D	2078	39.082	0.272	8.454	2.273	0.012
02-01-14-033-23W4	28D	2079	26.906	0.122	4.415	1.006	0.01
02-01-14-033-23W4	29D	2080	30.984	0.163	5.519	1.322	0.01
02-01-14-033-23W4	30D	2081	29.892	0.159	5.242	1.267	0.009
02-01-14-033-23W4	31D	2082	24.438	0.114	3.958	1.051	0.012
02-01-14-033-23W4	32D	2083	14.455	0.031	1.593	0.488	0.018
02-01-14-033-23W4	33D	2084	11.021	0.01	1.35	0.164	0.008
02-01-14-033-23W4	34D	2085	49.495	0.549	12.78	3.343	0.011
02-01-14-033-23W4	35D	2086	17.447	0.051	2.099	0.427	0.009
02-01-14-033-23W4	36D	2087	12.699	0.03	1.389	0.195	0.016
02-01-14-033-23W4	37D	2088	33.936	0.15	4.675	1.782	0.003
02-01-14-033-23W4	38D	2089	8.806	0.010	0.988	-0.032	0.003
02-01-14-033-23W4	39D	2090	10.198	0.016	0.985	-0.044	0.004

Table B.2. Continued.

Well UWI	ID #	Depth (m)	SiO_2 (wt. %)	TiO_2 (wt. %)	Al_2O_3 (wt. %)	Fe_2O_3 (wt. %)	MnO (wt. %)
02-01-14-033-23W4	40D	2091	48.757	0.037	1.446	0.325	0.004
02-01-14-033-23W4	41D	2092	32.219	0.054	2.082	0.279	0.024
02-01-14-033-23W4	42D	2093	12.665	0.024	1.245	0.134	0.008
02-01-14-033-23W4	43D	2094	4.790	-0.008	0.566	-0.053	0.012
02-01-14-033-23W4	44D	2095	9.126	0.023	1.060	1.508	0.064
02-01-14-033-23W4	45D	2096	17.006	0.061	2.119	0.888	0.007
02-01-14-033-23W4	46D	2097	20.955	0.081	2.796	0.629	0.008
02-01-14-033-23W4	47D	2098	14.827	0.020	1.531	0.307	0.016
02-01-14-033-23W4	48D	2099	27.423	0.072	3.192	0.598	0.014
02-01-14-033-23W4	49D	2100	35.482	0.149	4.928	1.410	0.026
02-01-14-033-23W4	50D	2101	24.976	0.091	2.642	1.677	0.006
02-01-14-033-23W4	51D	2102	46.750	0.317	7.545	1.963	0.015
02-01-14-033-23W4	52D	2103	42.125	0.201	5.261	1.597	0.005
02-01-14-033-23W4	53D	2104	53.513	0.430	9.443	2.202	0.004
02-01-14-033-23W4	54D	2104.5	44.955	0.209	5.099	1.290	-0.003
02-01-14-033-23W4	55D	2107	46.364	0.402	9.024	3.064	0.009
02-01-14-033-23W4	56D	2108	22.816	0.059	2.526	0.273	0.003
02-01-14-033-23W4	57D	2109	25.730	0.093	3.180	0.606	0.002
02-01-14-033-23W4	58D	2110	20.427	0.026	2.536	0.214	-0.004
02-01-14-033-23W4	59D	2111	4.349	-0.005	0.601	-0.034	-0.003
02-01-14-033-23W4	60D	2112	17.556	0.051	1.939	0.259	-0.002
02-01-14-033-23W4	61D	2113	21.375	0.096	2.918	0.345	-0.003
02-01-14-033-23W4	62D	2114	35.505	0.188	4.763	0.581	-0.002
02-01-14-033-23W4	63D	2115	0.767	-0.019	0.354	4.486	0.021
02-01-14-033-23W4	64D	2116	17.553	0.041	1.927	0.287	0.011
02-01-14-033-23W4	65D	2117	20.978	0.060	2.782	0.297	-0.003
02-01-14-033-23W4	66D	2118	19.384	0.051	2.328	0.278	-0.001
02-01-14-033-23W4	67D	2119	27.320	0.111	3.738	0.573	-0.003
02-01-14-033-23W4	68D	2120	27.519	0.106	3.795	0.499	-0.004
02-01-14-033-23W4	69D	2121	32.889	0.148	4.781	0.619	-0.004
02-01-14-033-23W4	70D	2122	16.117	0.056	2.030	0.147	-0.002
02-01-14-033-23W4	71D	2123	42.193	0.313	7.791	1.779	-0.006
02-01-14-033-23W4	72D	2124	4.970	-0.003	0.705	-0.011	-0.008
00-14-19-062-15W5	73D	2888	37.942	0.183	5.685	2.328	0.088
00-14-19-062-15W5	74D	2889	54.622	0.467	11.555	4.205	0.063
00-14-19-062-15W5	75D	2890	58.015	0.623	15.155	5.474	0.038
00-14-19-062-15W5	76D	2891	60.664	0.680	16.145	6.142	0.029
00-14-19-062-15W5	77D	2892	59.067	0.518	13.711	4.863	0.038
00-14-19-062-15W5	78D	2893	72.592	0.601	12.832	4.677	0.011

Table B.2. Continued.

Well UWI	ID #	Depth (m)	SiO_2 (wt. %)	TiO_2 (wt. %)	Al_2O_3 (wt. %)	Fe_2O_3 (wt. %)	MnO (wt. %)
00-14-19-062-15W5	79D	2895	78.047	0.257	5.354	4.123	0.018
00-14-19-062-15W5	81D	2896	76.376	0.471	9.390	4.283	0.010
00-14-19-062-15W5	82D	2897	65.256	0.116	2.847	2.157	0.018
00-14-19-062-15W5	83D	2898	76.007	0.360	7.771	3.744	0.013
00-14-19-062-15W5	84D	2899	68.294	0.208	5.007	2.610	0.016
00-14-19-062-15W5	85D	2900	66.415	0.218	5.144	2.866	0.016
00-14-19-062-15W5	86D	2901	56.476	0.173	4.331	1.962	0.014
00-14-19-062-15W5	87D	2902	67.811	0.281	6.417	2.920	0.012
00-14-19-062-15W5	88D	2903	65.029	0.274	6.412	2.442	0.012
00-14-19-062-15W5	89D	2904	64.766	0.315	7.016	2.442	0.014
00-14-19-062-15W5	90D	2905	66.968	0.411	8.806	2.869	0.009
00-14-19-062-15W5	91D	2906	84.378	0.387	8.730	3.780	0.001
00-14-19-062-15W5	92D	2907	86.403	0.175	5.606	2.720	-0.005
00-14-19-062-15W5	93D	2908	85.463	0.373	7.748	2.995	0.002
00-14-19-062-15W5	94D	2909	81.541	0.419	8.580	3.529	0.004
00-14-19-062-15W5	95D	2910	80.652	0.373	7.549	3.517	0.002
00-14-19-062-15W5	96D	2911	82.426	0.426	8.252	3.589	0.002
00-14-19-062-15W5	97D	2912	55.250	0.150	3.884	1.645	0.030
00-14-19-062-15W5	98D	2913	54.628	0.236	6.069	2.396	0.035
00-14-19-062-15W5	99D	2914	57.972	0.145	3.880	1.287	0.035
00-14-19-062-15W5	100D	2915	74.535	0.361	7.046	3.025	0.013
00-14-19-062-15W5	101D	2916	75.094	0.454	8.750	3.212	0.008
00-14-19-062-15W5	102D	2917	79.648	0.353	7.155	3.001	0.007
00-14-19-062-15W5	103D	2918	81.175	0.308	6.124	2.629	0.009
00-14-19-062-15W5	104D	2919	79.321	0.431	8.298	3.127	0.006
00-14-19-062-15W5	105D	2920	81.206	0.310	5.921	2.739	0.012
00-14-19-062-15W5	106D	2921	75.923	0.411	7.991	2.899	0.010
00-14-19-062-15W5	107D	2922	76.433	0.351	7.198	3.306	0.012
00-14-19-062-15W5	108D	2923	73.559	0.453	8.492	3.414	0.011
00-14-19-062-15W5	109D	2924	62.831	0.240	4.183	2.705	0.027
00-14-19-062-15W5	110D	2925	66.896	0.213	5.616	1.868	0.020
00-14-19-062-15W5	111D	2926	73.075	0.097	3.104	1.584	0.015
00-14-19-062-15W5	112D	2927	66.611	0.190	5.236	1.479	0.009
00-14-19-062-15W5	113D	2928	20.849	0.017	1.345	0.247	0.010
00-14-19-062-15W5	114D	2929	8.917	0.001	0.864	0.059	-0.001
00-14-19-062-15W5	115D	2930	30.480	0.115	3.597	1.017	0.005
00-14-19-062-15W5	116D	2931	31.642	0.132	3.977	1.210	0.008
00-14-19-062-15W5	117D	2932	16.224	0.038	1.839	0.312	0.003
00-14-19-062-15W5	118D	2933	20.253	0.055	2.299	0.475	0.005

Table B.2. Continued.

Well UWI	ID #	Depth (m)	SiO_2 (wt. %)	TiO_2 (wt. %)	Al_2O_3 (wt. %)	Fe_2O_3 (wt. %)	MnO (wt. %)
00-14-19-062-15W5	119D	2934	17.548	0.037	1.933	0.347	0.007
00-14-19-062-15W5	120D	2935	28.147	0.104	3.433	0.673	0.007
00-14-19-062-15W5	121D	2936	36.044	0.154	4.809	0.960	0.008
00-14-19-062-15W5	122D	2937	55.334	0.326	9.143	1.978	0.010
00-14-19-062-15W5	123D	2938	81.583	0.443	10.360	3.741	-0.002
00-14-19-062-15W5	124D	2939	57.893	0.359	10.708	2.731	0.011
00-14-19-062-15W5	125D	2940	63.973	0.600	15.792	3.977	0.006
00-14-19-062-15W5	126D	2941	49.976	0.259	8.053	2.396	0.021
00-14-19-062-15W5	127D	2942	24.902	0.058	2.837	0.704	0.022
02-10-27-057-21W4	128D	1105	0.916	0.000	0.320	0.223	0.008
02-10-27-057-21W4	129D	1106	22.542	0.107	2.999	0.782	-0.001
02-10-27-057-21W4	130D	1107	27.828	0.121	3.848	0.841	-0.001
02-10-27-057-21W4	131D	1108	21.856	0.078	2.899	0.659	-0.001
02-10-27-057-21W4	132D	1109	10.306	0.025	1.304	0.462	0.010
02-10-27-057-21W4	133D	1110	9.934	0.015	1.280	0.141	0.003
02-10-27-057-21W4	134D	1111	0.623	0.000	0.296	0.000	0.006
02-10-27-057-21W4	135D	1112	27.024	0.119	3.951	2.564	0.016
02-10-27-057-21W4	136D	1113	13.370	0.032	1.671	1.705	0.009
02-10-27-057-21W4	137D	1114	45.384	0.281	8.660	2.909	0.016
02-10-27-057-21W4	138D	1115	18.856	0.068	2.323	1.830	0.006
02-10-27-057-21W4	139D	1116	28.145	0.132	3.871	2.014	0.010
02-10-27-057-21W4	140D	1117	30.564	0.154	4.283	2.666	0.008
02-10-27-057-21W4	141D	1118	35.294	0.211	5.591	3.184	0.002
02-10-27-057-21W4	142D	1119	12.193	0.020	1.190	0.451	-0.005
02-10-27-057-21W4	143D	1120	22.238	0.087	2.690	2.395	0.002
02-10-27-057-21W4	144D	1121	24.741	0.112	3.171	1.205	0.002
02-10-27-057-21W4	145D	1122	21.085	0.074	2.638	1.096	0.001
02-10-27-057-21W4	146D	1123	28.347	0.135	3.734	2.897	0.004
02-10-27-057-21W4	238D	1124	21.962	0.102	2.875	3.426	0.006
02-10-27-057-21W4	147D	1124.5	28.508	0.130	3.770	2.224	0.003
02-10-27-057-21W4	148D	1125	22.964	0.089	2.717	1.923	0.001
02-10-27-057-21W4	149D	1126	35.138	0.201	4.649	2.003	0.006
02-10-27-057-21W4	150D	1127	37.489	0.206	4.362	2.380	0.006
02-10-27-057-21W4	151D	1128	29.425	0.160	3.599	1.847	0.008
02-10-27-057-21W4	152D	1129	39.054	0.249	5.582	3.194	0.007
02-10-27-057-21W4	153D	1130	5.743	0.000	0.671	0.400	0.013
02-10-27-057-21W4	154D	1131	26.036	0.104	2.973	2.017	0.006
02-10-27-057-21W4	155D	1132	11.716	0.024	1.220	0.319	0.019
02-10-27-057-21W4	156D	1133	13.059	0.037	1.434	0.521	0.010

Table B.2. Continued.

Well UWI	ID #	Depth (m)	SiO_2 (wt. %)	TiO_2 (wt. %)	Al_2O_3 (wt. %)	Fe_2O_3 (wt. %)	MnO (wt. %)
02-10-27-057-21W4	157D	1134	37.649	0.223	5.653	2.589	0.004
02-10-27-057-21W4	158D	1135	34.863	0.207	5.412	4.574	0.022
02-10-27-057-21W4	159D	1136	38.557	0.223	5.688	2.259	0.005
02-10-27-057-21W4	160D	1137	21.965	0.086	2.634	1.402	0.012
02-10-27-057-21W4	161D	1138	29.258	0.152	4.297	3.406	0.014
02-10-27-057-21W4	162D	1139	39.123	0.233	6.310	2.340	0.005
02-10-27-057-21W4	163D	1140	16.596	0.054	2.030	0.831	0.026
02-10-27-057-21W4	164D	1141	32.700	0.168	4.743	2.006	0.013
02-10-27-057-21W4	165D	1142	39.275	0.248	6.340	3.420	0.009
02-10-27-057-21W4	166D	1142.5	27.761	0.128	3.408	1.347	0.002
02-10-27-057-21W4	167D	1143	32.322	0.159	3.882	1.738	0.002
02-10-27-057-21W4	168D	1144	39.781	0.242	5.685	2.768	0.004
02-10-27-057-21W4	169D	1145	37.538	0.218	5.193	2.290	0.004
02-10-27-057-21W4	170D	1146	37.654	0.228	5.474	2.565	0.005
02-10-27-057-21W4	171D	1147	40.649	0.253	5.724	2.355	0.005
02-10-27-057-21W4	172D	1148	41.819	0.277	6.536	2.876	0.005
02-10-27-057-21W4	173D	1149	42.645	0.284	6.379	2.702	0.004
02-10-27-057-21W4	174D	1150	45.586	0.324	7.136	2.969	0.004
02-10-27-057-21W4	175D	1151	26.504	0.086	2.031	0.929	0.004
02-10-27-057-21W4	176D	1152	47.333	0.315	6.454	2.819	0.006
02-10-27-057-21W4	177D	1153	49.270	0.340	7.321	3.049	0.005
02-10-27-057-21W4	178D	1154	49.352	0.337	7.312	2.793	0.004
02-10-27-057-21W4	179D	1155	55.416	0.315	6.614	2.265	0.010
02-10-27-057-21W4	180D	1156	56.926	0.335	6.834	2.406	0.007
02-10-27-057-21W4	181D	1157	51.728	0.325	6.702	2.038	0.013
02-10-27-057-21W4	182D	1158	47.790	0.245	4.548	1.468	0.027
02-10-27-057-21W4	183D	1159	55.075	0.374	7.028	1.917	0.010
02-10-27-057-21W4	184D	1160	44.646	0.231	5.272	2.137	0.006
02-10-27-057-21W4	185D	1161	49.220	0.230	5.089	1.446	0.005
02-10-27-057-21W4	186D	1162	41.272	0.224	5.884	1.644	0.003
02-10-27-057-21W4	187D	1163	35.553	0.188	5.108	1.581	0.001
02-10-27-057-21W4	188D	1164	6.962	0.010	0.922	0.918	0.000
02-10-27-057-21W4	189D	1165	36.484	0.189	4.539	1.432	0.009
02-10-27-057-21W4	190D	1166	36.693	0.200	4.962	0.965	0.023
02-10-27-057-21W4	191D	1167	13.315	0.030	1.433	0.088	0.003
02-10-27-057-21W4	192D	1168	17.043	0.049	1.666	0.255	0.005
02-10-27-057-21W4	193D	1169	13.259	0.031	1.252	0.090	0.001
02-10-27-057-21W4	194D	1170	20.896	0.068	2.330	0.368	0.009
02-10-27-057-21W4	195D	1171	32.288	0.153	4.648	1.023	0.015

Table B.2. Continued.

Well UWI	ID #	Depth (m)	SiO_2 (wt. %)	TiO_2 (wt. %)	Al_2O_3 (wt. %)	Fe_2O_3 (wt. %)	MnO (wt. %)
02-10-27-057-21W4	196D	1172	30.520	0.142	4.382	0.915	0.018
02-10-27-057-21W4	197D	1173	44.138	0.263	7.411	1.562	0.033
02-10-27-057-21W4	198D	1174	11.865	0.018	1.517	0.142	0.002
02-10-27-057-21W4	199D	1175	9.965	0.014	1.183	0.158	0.011
02-10-27-057-21W4	200D	1176	25.951	0.120	3.698	0.956	0.032
02-10-27-057-21W4	201D	1176.3	32.554	0.156	4.926	1.059	0.007
02-10-27-057-21W4	202D	1177	15.477	0.039	1.931	0.309	0.007
02-10-27-057-21W4	203D	1178	58.261	0.534	12.367	3.625	0.013
02-10-27-057-21W4	204D	1179	11.075	0.017	1.412	0.213	0.010
02-10-27-057-21W4	205D	1180	2.579	0.000	0.443	0.424	0.007
02-10-27-057-21W4	206D	1181	4.084	0.000	0.606	0.000	0.000
02-10-27-057-21W4	207D	1182	0.298	0.000	0.260	0.000	0.008
02-10-27-057-21W4	208D	1183	21.710	0.106	2.937	2.811	0.041
02-10-27-057-21W4	209D	1183.5	5.282	0.000	0.678	0.076	0.042
02-10-27-057-21W4	210D	1184	19.226	0.071	2.112	0.603	0.056
02-10-27-057-21W4	211D	1185	10.462	0.025	1.096	0.085	0.073
02-10-27-057-21W4	212D	1186	16.776	0.053	1.768	0.313	0.056
02-10-27-057-21W4	213D	1187	17.862	0.056	1.877	0.328	0.051
02-10-27-057-21W4	214D	1188	24.197	0.098	2.786	0.663	0.061
02-10-27-057-21W4	215D	1189	24.822	0.084	2.684	0.515	0.055
02-10-27-057-21W4	216D	1190	21.944	0.055	2.115	0.366	0.055
02-10-27-057-21W4	217D	1191	26.296	0.067	2.514	0.420	0.050
02-10-27-057-21W4	218D	1192	28.806	0.080	3.053	0.544	0.048
02-10-27-057-21W4	219D	1193	31.046	0.088	3.374	0.654	0.039
02-10-27-057-21W4	220D	1194	37.158	0.101	4.366	0.926	0.027
02-10-27-057-21W4	221D	1195	39.274	0.164	5.647	1.300	0.004
02-10-27-057-21W4	222D	1196	20.536	0.042	2.263	0.321	0.000
02-10-27-057-21W4	223D	1197	3.439	0.000	0.559	0.165	0.000
02-10-27-057-21W4	224D	1197.5	1.656	0.000	0.398	0.022	0.000
02-10-27-057-21W4	225D	1198.5	0.716	0.000	0.275	0.000	0.000
02-10-27-057-21W4	226D	1199.5	0.000	0.000	0.145	0.000	0.000
02-10-27-057-21W4	227D	1200.5	0.000	0.000	0.193	0.000	0.000
02-10-27-057-21W4	228D	1201.5	7.240	0.003	0.876	0.004	0.000
02-10-27-057-21W4	229D	1202.5	7.036	0.007	0.808	0.070	0.000
02-10-27-057-21W4	230D	1203.5	23.089	0.091	2.567	0.441	0.000
02-10-27-057-21W4	231D	1204.5	21.362	0.086	2.381	0.376	0.000
02-10-27-057-21W4	232D	1205.5	15.957	0.053	1.934	0.211	0.000
02-10-27-057-21W4	233D	1206	16.417	0.052	1.934	0.405	0.000
02-10-27-057-21W4	234D	1207	15.385	0.050	1.842	0.344	0.000

Table B.2. Continued.

Well UWI	ID #	Depth (m)	SiO_2 (wt. %)	TiO_2 (wt. %)	Al_2O_3 (wt. %)	Fe_2O_3 (wt. %)	MnO (wt. %)
02-10-27-057-21W4	235D	1208	3.625	0.000	0.551	0.010	0.000
02-10-27-057-21W4	236D	1209	19.859	0.061	2.402	0.413	0.000
02-10-27-057-21W4	237D	1210	19.760	0.067	2.418	0.544	0.000
00-15-18-049-13W5	239D	3488	49.436	0.341	9.772	4.213	0.053
00-15-18-049-13W5	240D	3489	51.380	0.433	11.801	4.464	0.064
00-15-18-049-13W5	241D	3490	53.402	0.491	12.983	4.972	0.055
00-15-18-049-13W5	242D	3491	53.793	0.454	12.116	4.699	0.059
00-15-18-049-13W5	243D	3492	23.182	0.043	2.372	0.594	0.058
00-15-18-049-13W5	244D	3493	67.204	0.422	9.796	5.579	0.018
00-15-18-049-13W5	245D	3494	77.798	0.290	7.664	3.532	0.011
00-15-18-049-13W5	246D	3495	65.994	0.468	12.251	4.503	0.016
00-15-18-049-13W5	247D	3496	73.387	0.398	10.253	4.457	0.011
00-15-18-049-13W5	248D	3497	77.080	0.345	8.953	3.254	0.014
00-15-18-049-13W5	249D	3498	76.044	0.406	9.763	3.700	0.011
00-15-18-049-13W5	250D	3499	25.693	0.039	1.881	0.681	0.019
00-15-18-049-13W5	251D	3500	59.249	0.374	10.751	3.877	0.024
00-15-18-049-13W5	252D	3501	49.767	0.313	6.446	3.384	0.021
00-15-18-049-13W5	253D	3502	53.925	0.424	9.234	5.519	0.020
00-15-18-049-13W5	254D	3503	41.374	0.200	5.199	1.505	0.016
00-15-18-049-13W5	255D	3503.5	41.118	0.140	3.936	1.444	0.019
00-15-18-049-13W5	256D	3504	73.626	0.271	6.769	2.092	0.005
00-15-18-049-13W5	257D	3505	53.017	0.191	4.913	1.454	0.011
00-15-18-049-13W5	258D	3506	73.802	0.189	5.051	1.750	0.011
00-15-18-049-13W5	259D	3507	65.504	0.495	11.811	4.692	0.009
00-15-18-049-13W5	260D	3508	43.426	0.262	6.564	2.427	0.019
00-15-18-049-13W5	261D	3509	7.001	0.000	0.819	0.104	0.008
00-15-18-049-13W5	262D	3510	24.518	0.076	2.856	0.742	0.017
00-15-18-049-13W5	263D	3511	20.560	0.041	2.098	0.432	0.015
00-15-18-049-13W5	264D	3512	16.503	0.036	1.755	0.349	0.018
00-15-18-049-13W5	265D	3513	18.836	0.038	1.962	0.438	0.017
00-15-18-049-13W5	266D	3514	38.669	0.140	4.514	1.541	0.028
00-15-18-049-13W5	267D	3515	35.156	0.143	4.663	1.567	0.038
00-15-18-049-13W5	268D	3516	68.529	0.533	12.779	4.734	0.006
00-15-18-049-13W5	269D	3517	65.650	0.529	12.688	3.551	0.015
00-15-18-049-13W5	270D	3518	71.329	0.669	14.981	4.470	0.005
00-15-18-049-13W5	271D	3519	71.357	0.503	11.333	3.682	0.019
00-15-18-049-13W5	272D	3519.5	75.349	0.402	9.568	3.370	0.020
00-15-18-049-13W5	273D	3520	71.859	0.402	9.399	3.246	0.018
00-15-18-049-13W5	274D	3521	69.672	0.471	11.053	3.850	0.016

Table B.2. Continued.

Well UWI	ID #	Depth (m)	SiO_2 (wt. %)	TiO_2 (wt. %)	Al_2O_3 (wt. %)	Fe_2O_3 (wt. %)	MnO (wt. %)
00-15-18-049-13W5	275D	3522	68.997	0.511	11.747	3.705	0.015
00-15-18-049-13W5	276D	3523	69.396	0.452	10.135	4.428	0.014
00-15-18-049-13W5	277D	3524	67.300	0.523	11.469	4.134	0.015
00-15-18-049-13W5	278D	3525	59.635	0.358	8.678	2.746	0.031
00-15-18-049-13W5	279D	3526	66.524	0.383	8.648	3.587	0.026
00-15-18-049-13W5	280D	3527	61.367	0.468	9.992	4.266	0.029
00-15-18-049-13W5	281D	3528	64.350	0.680	15.095	4.435	0.023
00-15-18-049-13W5	282D	3529	60.543	0.636	14.607	4.574	0.027
00-15-18-049-13W5	283D	3530	60.686	0.630	14.765	4.609	0.025
00-15-18-049-13W5	284D	3531	58.096	0.464	12.650	3.851	0.026

Table B.3. Major element concentrations for all samples (Part 2).

Well UWI	ID #	Depth (m)	MgO (wt. %)	CaO (wt. %)	Na_2O (wt. %)	K_2O (wt. %)	P_2O_5 (wt. %)
02-01-14-033-23W4	1D	2015	1.1	16.936	0.248	4.356	0.128
02-01-14-033-23W4	2D	2016	1.164	47.429	0.12	0.364	0.063
02-01-14-033-23W4	3D	2053	1.828	33.078	0.216	1.885	0.169
02-01-14-033-23W4	4D	2054	1.183	48.066	0.12	0.432	0.235
02-01-14-033-23W4	5D	2055	2.848	20.031	0.227	3.165	0.092
02-01-14-033-23W4	6D	2056	1.183	47.388	0.134	0.557	0.141
02-01-14-033-23W4	7D	2057	1.18	48.95	0.123	0.469	0.125
02-01-14-033-23W4	8D	2058	1.812	26.063	0.229	2.89	0.123
02-01-14-033-23W4	9D	2059	1.258	42.994	0.153	1.091	0.126
02-01-14-033-23W4	10D	2060	1.224	38.427	0.166	1.325	0.139
02-01-14-033-23W4	11D	2061	1.171	45.735	0.137	0.858	0.117
02-01-14-033-23W4	12D	2062	1.141	45.486	0.146	0.91	0.19
02-01-14-033-23W4	13D	2063	1.238	42.706	0.157	1.169	0.117
02-01-14-033-23W4	14D	2064	1.071	38.955	0.161	1.495	0.044
02-01-14-033-23W4	15D	2065	1.403	29.656	0.21	2.019	0.365
02-01-14-033-23W4	16D	2066	1.166	43.3	0.156	1.106	0.144
02-01-14-033-23W4	17D	2067	0.968	51.462	0.109	0.222	0.107
02-01-14-033-23W4	18D	2070	1.321	40.662	0.172	1.309	0.223
02-01-14-033-23W4	19D	2070.5	1.309	38.336	0.171	1.562	0.239
02-01-14-033-23W4	20D	2071	1.344	43.244	0.147	1.133	0.124
02-01-14-033-23W4	21D	2072	1.205	35.374	0.182	2.045	0.084
02-01-14-033-23W4	22D	2073	1.188	46.782	0.142	0.629	0.092
02-01-14-033-23W4	23D	2074	1.309	38.948	0.179	1.418	0.278

Table B.3. Continued.

Well UWI	ID #	Depth (m)	MgO (wt. %)	CaO (wt. %)	Na_2O (wt. %)	K_2O (wt. %)	P_2O_5 (wt. %)
02-01-14-033-23W4	24D	2075	1.172	51.107	0.114	0.283	0.127
02-01-14-033-23W4	25D	2076	1.207	50.168	0.11	0.229	0.036
02-01-14-033-23W4	26D	2077	2.307	25.402	0.342	2.847	0.057
02-01-14-033-23W4	27D	2078	2.116	27.851	0.305	2.411	0.055
02-01-14-033-23W4	28D	2079	1.473	40.07	0.215	1.188	0.051
02-01-14-033-23W4	29D	2080	1.622	36.656	0.252	1.514	0.063
02-01-14-033-23W4	30D	2081	1.684	37.139	0.213	1.458	0.055
02-01-14-033-23W4	31D	2082	1.552	41.176	0.209	1.076	0.056
02-01-14-033-23W4	32D	2083	1.109	47.375	0.137	0.533	0.104
02-01-14-033-23W4	33D	2084	1.132	49.439	0.123	0.387	0.05
02-01-14-033-23W4	34D	2085	2.395	11.514	0.408	5.266	0.915
02-01-14-033-23W4	35D	2086	1.038	46.541	0.144	0.717	0.233
02-01-14-033-23W4	36D	2087	1.067	48.958	0.129	0.448	0.068
02-01-14-033-23W4	37D	2088	1.023	33.906	0.2	1.939	0.456
02-01-14-033-23W4	38D	2089	0.982	52.209	0.111	0.28	0.112
02-01-14-033-23W4	39D	2090	0.996	50.949	0.105	0.315	0.073
02-01-14-033-23W4	40D	2091	0.258	49.213	0.14	0.399	0.121
02-01-14-033-23W4	41D	2092	0.728	46.982	0.135	0.72	0.093
02-01-14-033-23W4	42D	2093	0.983	49.314	0.119	0.436	0.108
02-01-14-033-23W4	43D	2094	0.968	51.595	0.102	0.181	0.112
02-01-14-033-23W4	44D	2095	1.123	46.327	0.12	0.349	0.176
02-01-14-033-23W4	45D	2096	0.967	45.531	0.147	0.724	0.266
02-01-14-033-23W4	46D	2097	1.138	43.701	0.165	0.922	0.278
02-01-14-033-23W4	47D	2098	1.002	48.182	0.154	0.444	0.037
02-01-14-033-23W4	48D	2099	1.229	42.985	0.185	0.929	0.057
02-01-14-033-23W4	49D	2100	1.819	34.363	0.193	1.612	0.051
02-01-14-033-23W4	50D	2101	1.086	40.88	0.147	1.031	0.175
02-01-14-033-23W4	51D	2102	2.875	22.627	0.234	2.791	0.061
02-01-14-033-23W4	52D	2103	0.888	31.605	0.176	2.194	0.095
02-01-14-033-23W4	53D	2104	1.766	15.789	0.242	4.542	0.125
02-01-14-033-23W4	54D	2104.5	0.747	32.477	0.178	2.226	0.126
02-01-14-033-23W4	55D	2107	1.689	18.756	0.252	3.639	0.142
02-01-14-033-23W4	56D	2108	0.958	46.546	0.17	0.848	0.066
02-01-14-033-23W4	57D	2109	1.145	42.705	0.157	1.131	0.114
02-01-14-033-23W4	58D	2110	0.915	47.214	0.16	0.668	0.053
02-01-14-033-23W4	59D	2111	1.045	52.21	0.105	0.167	0.072
02-01-14-033-23W4	60D	2112	1.035	48.225	0.123	0.678	0.045
02-01-14-033-23W4	61D	2113	0.996	43.625	0.16	1.045	0.113
02-01-14-033-23W4	62D	2114	0.918	36.566	0.158	1.947	0.067

Table B.3. Continued.

Well UWI	ID #	Depth (m)	MgO (wt. %)	CaO (wt. %)	Na_2O (wt. %)	K_2O (wt. %)	P_2O_5 (wt. %)
02-01-14-033-23W4	63D	2115	5.528	41.119	0.091	0.064	0.037
02-01-14-033-23W4	64D	2116	1.183	47.959	0.121	0.587	0.039
02-01-14-033-23W4	65D	2117	1.064	45.525	0.141	0.826	0.049
02-01-14-033-23W4	66D	2118	1.015	47.264	0.136	0.687	0.055
02-01-14-033-23W4	67D	2119	1.174	42.836	0.165	1.134	0.06
02-01-14-033-23W4	68D	2120	1.092	42.358	0.163	1.144	0.056
02-01-14-033-23W4	69D	2121	1.078	39.725	0.174	1.53	0.055
02-01-14-033-23W4	70D	2122	1.138	47.801	0.125	0.626	0.06
02-01-14-033-23W4	71D	2123	1.176	25.688	0.196	3.166	0.043
02-01-14-033-23W4	72D	2124	1.056	50.762	0.097	0.214	0.016
00-14-19-062-15W5	73D	2888	1.278	36.195	0.257	1.319	0.076
00-14-19-062-15W5	74D	2889	2.155	17.12	0.413	3.145	0.084
00-14-19-062-15W5	75D	2890	2.906	5.902	0.578	4.287	0.067
00-14-19-062-15W5	76D	2891	3.0	4.029	0.638	4.408	0.068
00-14-19-062-15W5	77D	2892	2.38	9.882	0.6	3.787	0.103
00-14-19-062-15W5	78D	2893	1.078	4.207	0.593	3.866	0.083
00-14-19-062-15W5	79D	2895	0	18.32	0.531	1.61	0.296
00-14-19-062-15W5	81D	2896	0.188	10.334	0.52	2.921	0.192
00-14-19-062-15W5	82D	2897	0	38.514	0.351	0.661	0.185
00-14-19-062-15W5	83D	2898	0	15.431	0.451	2.431	0.128
00-14-19-062-15W5	84D	2899	0	27.881	0.381	1.463	0.18
00-14-19-062-15W5	85D	2900	0	26.721	0.4	1.567	0.19
00-14-19-062-15W5	86D	2901	0.309	35.434	0.329	1.156	0.116
00-14-19-062-15W5	87D	2902	0.131	23.046	0.399	1.972	0.15
00-14-19-062-15W5	88D	2903	0.268	24.479	0.393	2.005	0.145
00-14-19-062-15W5	89D	2904	0.416	23.067	0.446	2.194	0.132
00-14-19-062-15W5	90D	2905	0.549	16.564	0.463	2.973	0.092
00-14-19-062-15W5	91D	2906	0	8.668	0.447	2.777	0.182
00-14-19-062-15W5	92D	2907	0	15.865	0.881	1.83	3.178
00-14-19-062-15W5	93D	2908	0	9.596	0.371	2.943	0.17
00-14-19-062-15W5	94D	2909	0	8.345	0.42	3.325	0.129
00-14-19-062-15W5	95D	2910	0	11.935	0.41	2.941	0.299
00-14-19-062-15W5	96D	2911	0	6.904	0.428	3.431	0.188
00-14-19-062-15W5	97D	2912	0.277	36.439	0.308	1.184	0.18
00-14-19-062-15W5	98D	2913	0.589	27.98	0.322	2.024	0.193
00-14-19-062-15W5	99D	2914	0.192	35.145	0.269	1.27	0.175
00-14-19-062-15W5	100D	2915	0	14.492	0.444	2.941	0.159
00-14-19-062-15W5	101D	2916	0.169	9.821	0.405	3.67	0.117
00-14-19-062-15W5	102D	2917	0	11.6	0.411	2.891	0.109

Table B.3. Continued.

Well UWI	ID #	Depth (m)	MgO (wt. %)	CaO (wt. %)	Na_2O (wt. %)	K_2O (wt. %)	P_2O_5 (wt. %)
00-14-19-062-15W5	103D	2918	0	13.792	0.437	2.582	0.113
00-14-19-062-15W5	104D	2919	0	9.132	0.369	3.396	0.103
00-14-19-062-15W5	105D	2920	0	13.898	0.416	2.387	0.087
00-14-19-062-15W5	106D	2921	0	11.396	0.362	3.35	0.138
00-14-19-062-15W5	107D	2922	0	12.529	0.385	3.016	0.139
00-14-19-062-15W5	108D	2923	0.237	10.692	0.382	3.503	0.119
00-14-19-062-15W5	109D	2924	0	26.695	0.373	1.519	0.085
00-14-19-062-15W5	110D	2925	0.073	28.212	0.326	1.943	0.115
00-14-19-062-15W5	111D	2926	0	40.058	0.223	0.823	0.074
00-14-19-062-15W5	112D	2927	0.047	30.286	0.271	1.819	0.105
00-14-19-062-15W5	113D	2928	0.902	50.009	0.14	0.347	0.039
00-14-19-062-15W5	114D	2929	1.119	51.02	0.111	0.215	0.037
00-14-19-062-15W5	115D	2930	1.197	41.916	0.183	1.014	0.067
00-14-19-062-15W5	116D	2931	1.126	41.039	0.186	1.067	0.055
00-14-19-062-15W5	117D	2932	1.12	48.524	0.128	0.443	0.046
00-14-19-062-15W5	118D	2933	1.162	47.318	0.143	0.558	0.056
00-14-19-062-15W5	119D	2934	1.109	48.03	0.129	0.485	0.048
00-14-19-062-15W5	120D	2935	1.08	43.623	0.172	0.898	0.055
00-14-19-062-15W5	121D	2936	1.028	39.204	0.199	1.336	0.06
00-14-19-062-15W5	122D	2937	1.039	23.1	0.299	3.063	0.056
00-14-19-062-15W5	123D	2938	0.059	3.756	0.355	4.309	0.103
00-14-19-062-15W5	124D	2939	1.412	17.606	0.347	3.545	0.084
00-14-19-062-15W5	125D	2940	2.252	4.685	0.462	5.253	0.094
00-14-19-062-15W5	126D	2941	1.049	25.414	0.296	2.761	0.093
00-14-19-062-15W5	127D	2942	0.948	45.506	0.159	0.775	0.064
02-10-27-057-21W4	128D	1105	1.151	52.075	0.103	0.068	0.038
02-10-27-057-21W4	129D	1106	1.357	44.226	0.206	0.7	0.241
02-10-27-057-21W4	130D	1107	1.383	42.123	0.226	0.901	0.178
02-10-27-057-21W4	131D	1108	1.36	44.691	0.192	0.677	0.194
02-10-27-057-21W4	132D	1109	2.493	47.087	0.139	0.314	0.114
02-10-27-057-21W4	133D	1110	1.775	48.614	0.163	0.315	0.119
02-10-27-057-21W4	134D	1111	1.264	52.287	0.099	0.063	0.044
02-10-27-057-21W4	135D	1112	2.379	37.196	0.274	0.979	0.391
02-10-27-057-21W4	136D	1113	1.781	45.496	0.166	0.396	0.207
02-10-27-057-21W4	137D	1114	2.268	24.973	0.443	2.273	0.328
02-10-27-057-21W4	138D	1115	2.252	42.215	0.195	0.577	0.341
02-10-27-057-21W4	139D	1116	2.297	35.841	0.294	1.063	0.372
02-10-27-057-21W4	140D	1117	1.829	34.935	0.401	1.184	0.692
02-10-27-057-21W4	141D	1118	1.535	30.921	0.377	1.578	0.704

Table B.3. Continued.

Well UWI	ID #	Depth (m)	MgO (wt. %)	CaO (wt. %)	Na_2O (wt. %)	K_2O (wt. %)	P_2O_5 (wt. %)
02-10-27-057-21W4	142D	1119	1.753	47.846	0.152	0.304	0.149
02-10-27-057-21W4	143D	1120	1.773	38.838	0.249	0.722	0.418
02-10-27-057-21W4	144D	1121	1.618	42.244	0.226	0.784	0.318
02-10-27-057-21W4	145D	1122	1.436	45.014	0.217	0.601	0.293
02-10-27-057-21W4	146D	1123	1.545	36.348	0.294	0.928	0.575
02-10-27-057-21W4	238D	1124	1.363	39.642	0.222	0.665	0.333
02-10-27-057-21W4	147D	1124.5	1.361	39.019	0.252	0.86	0.331
02-10-27-057-21W4	148D	1125	1.328	42.101	0.212	0.614	0.234
02-10-27-057-21W4	149D	1126	1.434	35.499	0.256	1.168	0.32
02-10-27-057-21W4	150D	1127	1.226	34.469	0.278	1.154	0.441
02-10-27-057-21W4	151D	1128	1.599	39.157	0.233	0.904	0.294
02-10-27-057-21W4	152D	1129	1.663	31.395	0.298	1.541	0.301
02-10-27-057-21W4	153D	1130	1.253	50.632	0.128	0.151	0.161
02-10-27-057-21W4	154D	1131	1.311	40.024	0.258	0.742	0.484
02-10-27-057-21W4	155D	1132	1.243	49.998	0.129	0.266	0.146
02-10-27-057-21W4	156D	1133	1.284	49.011	0.139	0.314	0.147
02-10-27-057-21W4	157D	1134	1.28	32.435	0.314	1.411	0.436
02-10-27-057-21W4	158D	1135	1.392	31.697	0.344	1.266	0.251
02-10-27-057-21W4	159D	1136	1.359	32.88	0.311	1.387	0.276
02-10-27-057-21W4	160D	1137	1.208	45.236	0.193	0.556	0.273
02-10-27-057-21W4	161D	1138	1.285	36.954	0.272	0.943	0.262
02-10-27-057-21W4	162D	1139	1.307	32.042	0.35	1.506	0.533
02-10-27-057-21W4	163D	1140	1.18	47.607	0.165	0.412	0.217
02-10-27-057-21W4	164D	1141	1.238	37.922	0.266	1.036	0.273
02-10-27-057-21W4	165D	1142	1.257	30.563	0.35	1.437	0.426
02-10-27-057-21W4	166D	1142.5	1.258	41.539	0.233	0.793	0.29
02-10-27-057-21W4	167D	1143	1.207	37.89	0.232	0.999	0.222
02-10-27-057-21W4	168D	1144	1.324	30.547	0.333	1.512	0.469
02-10-27-057-21W4	169D	1145	1.284	33.303	0.297	1.364	0.356
02-10-27-057-21W4	170D	1146	1.345	32.237	0.336	1.466	0.423
02-10-27-057-21W4	171D	1147	1.34	30.344	0.311	1.677	0.324
02-10-27-057-21W4	172D	1148	1.426	27.383	0.356	1.965	0.378
02-10-27-057-21W4	173D	1149	1.341	26.843	0.329	2.094	0.323
02-10-27-057-21W4	174D	1150	1.382	23.173	0.354	2.499	0.248
02-10-27-057-21W4	175D	1151	1.189	43.601	0.164	0.675	0.107
02-10-27-057-21W4	176D	1152	1.237	23.276	0.314	2.521	0.155
02-10-27-057-21W4	177D	1153	1.245	20.69	0.359	2.845	0.209
02-10-27-057-21W4	178D	1154	1.249	21.134	0.356	2.86	0.207
02-10-27-057-21W4	179D	1155	1.122	21.419	0.34	2.589	0.141

Table B.3. Continued.

Well UWI	ID #	Depth (m)	MgO (wt. %)	CaO (wt. %)	Na_2O (wt. %)	K_2O (wt. %)	P_2O_5 (wt. %)
02-10-27-057-21W4	180D	1156	0.926	19.982	0.331	2.778	0.155
02-10-27-057-21W4	181D	1157	1.954	22.473	0.303	2.569	0.082
02-10-27-057-21W4	182D	1158	2.481	25.986	0.247	1.818	0.065
02-10-27-057-21W4	183D	1159	1.61	19.272	0.342	3.008	0.127
02-10-27-057-21W4	184D	1160	1.089	28.103	0.258	1.979	0.115
02-10-27-057-21W4	185D	1161	0.654	32.729	0.262	1.892	0.07
02-10-27-057-21W4	186D	1162	1.126	33.539	0.314	1.907	0.12
02-10-27-057-21W4	187D	1163	1.055	34.36	0.27	1.489	0.199
02-10-27-057-21W4	188D	1164	1.174	49.662	0.132	0.198	0.336
02-10-27-057-21W4	189D	1165	1.226	37.9	0.243	1.129	0.07
02-10-27-057-21W4	190D	1166	1.225	38.036	0.236	1.202	0.066
02-10-27-057-21W4	191D	1167	1.108	50.455	0.136	0.319	0.045
02-10-27-057-21W4	192D	1168	1.113	48.875	0.141	0.393	0.052
02-10-27-057-21W4	193D	1169	1.145	49.986	0.121	0.285	0.046
02-10-27-057-21W4	194D	1170	1.223	47.534	0.151	0.499	0.051
02-10-27-057-21W4	195D	1171	1.378	40.257	0.223	1.042	0.058
02-10-27-057-21W4	196D	1172	1.4	41.014	0.191	0.978	0.051
02-10-27-057-21W4	197D	1173	1.282	33.078	0.32	1.623	0.08
02-10-27-057-21W4	198D	1174	1.135	50.536	0.124	0.302	0.039
02-10-27-057-21W4	199D	1175	1.336	50.279	0.137	0.26	0.067
02-10-27-057-21W4	200D	1176	2.855	40.005	0.25	0.856	0.099
02-10-27-057-21W4	201D	1176.3	1.194	40.313	0.283	1.054	0.275
02-10-27-057-21W4	202D	1177	1.172	49.72	0.153	0.377	0.07
02-10-27-057-21W4	203D	1178	1.613	16.449	0.511	2.993	0.134
02-10-27-057-21W4	204D	1179	1.097	50.051	0.167	0.282	0.528
02-10-27-057-21W4	205D	1180	1.089	52.135	0.127	0.099	0.084
02-10-27-057-21W4	206D	1181	1.144	52.198	0.122	0.132	0.081
02-10-27-057-21W4	207D	1182	1.218	51.84	0.105	0.053	0.077
02-10-27-057-21W4	208D	1183	1.096	37.019	0.189	0.921	0.138
02-10-27-057-21W4	209D	1183.5	1.226	51.191	0.13	0.174	0.022
02-10-27-057-21W4	210D	1184	1.363	45.62	0.175	0.596	0.063
02-10-27-057-21W4	211D	1185	1.476	49.948	0.127	0.29	0.046
02-10-27-057-21W4	212D	1186	1.419	47.311	0.164	0.505	0.067
02-10-27-057-21W4	213D	1187	1.366	47.658	0.155	0.524	0.069
02-10-27-057-21W4	214D	1188	1.428	43.453	0.208	0.813	0.09
02-10-27-057-21W4	215D	1189	1.296	44.422	0.175	0.785	0.073
02-10-27-057-21W4	216D	1190	1.199	46.787	0.16	0.602	0.065
02-10-27-057-21W4	217D	1191	1.118	45.645	0.161	0.723	0.069
02-10-27-057-21W4	218D	1192	1.151	43.773	0.185	0.897	0.069

Table B.3. Continued.

Well UWI	ID #	Depth (m)	MgO (wt. %)	CaO (wt. %)	Na_2O (wt. %)	K_2O (wt. %)	P_2O_5 (wt. %)
02-10-27-057-21W4	219D	1193	1.113	42.615	0.183	0.998	0.07
02-10-27-057-21W4	220D	1194	1.011	39.603	0.217	1.275	0.082
02-10-27-057-21W4	221D	1195	1.193	36.309	0.274	1.49	0.096
02-10-27-057-21W4	222D	1196	1.119	48.152	0.154	0.5	0.072
02-10-27-057-21W4	223D	1197	1.233	51.765	0.123	0.116	0.099
02-10-27-057-21W4	224D	1197.5	1.095	52.175	0.129	0.085	0.08
02-10-27-057-21W4	225D	1198.5	1.051	52.976	0.116	0.06	0.075
02-10-27-057-21W4	226D	1199.5	1.115	52.277	0.107	0.028	0.047
02-10-27-057-21W4	227D	1200.5	1.14	52.672	0.112	0.041	0.056
02-10-27-057-21W4	228D	1201.5	1.178	51.538	0.135	0.217	0.087
02-10-27-057-21W4	229D	1202.5	1.119	51.397	0.115	0.199	0.061
02-10-27-057-21W4	230D	1203.5	1.262	46.562	0.162	0.648	0.052
02-10-27-057-21W4	231D	1204.5	1.241	46.715	0.155	0.627	0.062
02-10-27-057-21W4	232D	1205.5	1.212	47.978	0.154	0.505	0.056
02-10-27-057-21W4	233D	1206	1.356	47.103	0.153	0.523	0.058
02-10-27-057-21W4	234D	1207	1.48	47.248	0.148	0.489	0.041
02-10-27-057-21W4	235D	1208	1.31	51.945	0.127	0.125	0.343
02-10-27-057-21W4	236D	1209	1.206	46.922	0.157	0.624	0.07
02-10-27-057-21W4	237D	1210	1.107	45.924	0.171	0.648	0.078
00-15-18-049-13W5	239D	3488	2.669	19.914	0.326	2.466	0.086
00-15-18-049-13W5	240D	3489	3.401	15.03	0.366	3.035	0.064
00-15-18-049-13W5	241D	3490	3.914	12.116	0.374	3.278	0.073
00-15-18-049-13W5	242D	3491	3.55	13.902	0.412	2.993	0.06
00-15-18-049-13W5	243D	3492	1.06	48.846	0.249	0.404	0.065
00-15-18-049-13W5	244D	3493	0.831	10.476	0.627	2.495	0.245
00-15-18-049-13W5	245D	3494	0	14.428	0.513	1.896	0.156
00-15-18-049-13W5	246D	3495	1.447	9.245	0.685	3.276	0.196
00-15-18-049-13W5	247D	3496	0.485	9.514	0.546	2.781	0.191
00-15-18-049-13W5	248D	3497	0.067	13.57	0.509	2.408	0.186
00-15-18-049-13W5	249D	3498	0.27	9.882	0.559	2.644	0.177
00-15-18-049-13W5	250D	3499	0.782	50.884	0.284	0.276	0.111
00-15-18-049-13W5	251D	3500	1.794	16.635	0.515	2.705	0.088
00-15-18-049-13W5	252D	3501	1.527	24.052	0.735	1.548	0.105
00-15-18-049-13W5	253D	3502	1.811	14.961	0.578	2.509	0.083
00-15-18-049-13W5	254D	3503	1.061	36.198	0.497	1.167	0.124
00-15-18-049-13W5	255D	3503.5	1.288	38.195	0.451	0.845	0.081
00-15-18-049-13W5	256D	3504	0	23.159	0.422	1.738	0.096
00-15-18-049-13W5	257D	3505	0.529	34.462	0.409	1.144	0.121
00-15-18-049-13W5	258D	3506	0	30.255	0.368	1.204	0.11

Table B.3. Continued.

Well UWI	ID #	Depth (m)	MgO (wt. %)	CaO (wt. %)	Na_2O (wt. %)	K_2O (wt. %)	P_2O_5 (wt. %)
00-15-18-049-13W5	259D	3507	1.261	7.631	0.491	3.503	0.135
00-15-18-049-13W5	260D	3508	1.551	29.904	0.39	1.75	0.077
00-15-18-049-13W5	261D	3509	1.042	51.823	0.187	0.134	0.05
00-15-18-049-13W5	262D	3510	1.157	46.289	0.281	0.576	0.074
00-15-18-049-13W5	263D	3511	1.024	47.522	0.279	0.398	0.06
00-15-18-049-13W5	264D	3512	1.056	50.279	0.271	0.306	0.068
00-15-18-049-13W5	265D	3513	1.026	49.416	0.273	0.361	0.061
00-15-18-049-13W5	266D	3514	1.36	38.507	0.371	1.074	0.156
00-15-18-049-13W5	267D	3515	1.743	38.62	0.284	1.076	0.127
00-15-18-049-13W5	268D	3516	1.254	5.142	0.473	3.816	0.101
00-15-18-049-13W5	269D	3517	1.56	10.046	0.413	3.734	0.08
00-15-18-049-13W5	270D	3518	1.694	0.872	0.502	4.512	0.076
00-15-18-049-13W5	271D	3519	0.835	11.484	0.451	3.182	0.132
00-15-18-049-13W5	272D	3519.5	0.262	12.905	0.391	2.691	0.106
00-15-18-049-13W5	273D	3520	0.396	13.323	0.41	2.719	0.117
00-15-18-049-13W5	274D	3521	0.831	9.708	0.435	3.265	0.119
00-15-18-049-13W5	275D	3522	1.029	8.865	0.471	3.545	0.096
00-15-18-049-13W5	276D	3523	0.626	8.349	0.441	3.107	0.116
00-15-18-049-13W5	277D	3524	1.068	8.22	0.429	3.552	0.095
00-15-18-049-13W5	278D	3525	1.024	22.025	0.363	2.375	0.059
00-15-18-049-13W5	279D	3526	0.617	16.736	0.364	2.492	0.093
00-15-18-049-13W5	280D	3527	1.246	12.923	0.398	3.038	0.121
00-15-18-049-13W5	281D	3528	2.36	6.83	0.451	4.365	0.079
00-15-18-049-13W5	282D	3529	2.5	7.434	0.42	4.152	0.069
00-15-18-049-13W5	283D	3530	2.589	7.655	0.409	4.13	0.071
00-15-18-049-13W5	284D	3531	2.077	13.411	0.383	3.512	0.074

Table B.4. Trace elements for all samples.

Well UWI	ID #	Depth (m)	V (ppm)	Cu (ppm)	Zn (ppm)	U (ppm)	Ni (ppm)	Mo (ppm)
02-01-14-033-23W4	1D	2015	64	38	-19	7	79	6
02-01-14-033-23W4	2D	2016	9	0	-33	2	1	1
02-01-14-033-23W4	3D	2053	43	15	-5	3	37	0
02-01-14-033-23W4	4D	2054	9	1	-31	2	3	2
02-01-14-033-23W4	5D	2055	58	47	-2	4	70	2
02-01-14-033-23W4	6D	2056	12	7	-29	3	10	1
02-01-14-033-23W4	7D	2057	14	7	-30	2	6	0
02-01-14-033-23W4	8D	2058	61	29	-5	5	69	2

Table B.4. Continued.

Well UWI	ID #	Depth (m)	V (ppm)	Cu (ppm)	Zn (ppm)	U (ppm)	Ni (ppm)	Mo (ppm)
02-01-14-033-23W4	9D	2059	26	16	-20	3	30	1
02-01-14-033-23W4	10D	2060	45	20	-9	5	79	23
02-01-14-033-23W4	11D	2061	20	7	-26	3	23	1
02-01-14-033-23W4	12D	2062	18	12	-26	3	29	1
02-01-14-033-23W4	13D	2063	21	6	-23	2	24	1
02-01-14-033-23W4	14D	2064	41	43	-26	3	64	11
02-01-14-033-23W4	15D	2065	51	67	-3	5	187	7
02-01-14-033-23W4	16D	2066	22	7	-23	3	27	0
02-01-14-033-23W4	17D	2067	6	-4	-32	1	-1	1
02-01-14-033-23W4	18D	2070	25	14	-20	2	42	2
02-01-14-033-23W4	19D	2070.5	41	35	24	4	96	5
02-01-14-033-23W4	20D	2071	21	7	-23	3	25	0
02-01-14-033-23W4	21D	2072	33	29	-19	4	33	1
02-01-14-033-23W4	22D	2073	12	7	-11	2	8	0
02-01-14-033-23W4	23D	2074	23	15	-23	1	32	1
02-01-14-033-23W4	24D	2075	8	-2	-34	2	1	2
02-01-14-033-23W4	25D	2076	5	-3	-32	1	-3	1
02-01-14-033-23W4	26D	2077	69	5	-3	1	26	0
02-01-14-033-23W4	27D	2078	56	5	-9	1	26	1
02-01-14-033-23W4	28D	2079	28	1	-16	1	7	1
02-01-14-033-23W4	29D	2080	37	3	-16	0	18	0
02-01-14-033-23W4	30D	2081	34	4	-11	0	16	1
02-01-14-033-23W4	31D	2082	25	6	-24	1	17	1
02-01-14-033-23W4	32D	2083	10	5	-31	1	10	1
02-01-14-033-23W4	33D	2084	7	2	-29	1	-2	1
02-01-14-033-23W4	34D	2085	111	99	13	8	200	3
02-01-14-033-23W4	35D	2086	16	9	-28	2	14	1
02-01-14-033-23W4	36D	2087	8	2	-32	1	0	1
02-01-14-033-23W4	37D	2088	43	35	-10	5	102	9
02-01-14-033-23W4	38D	2089	6	-1	-31	1	0	2
02-01-14-033-23W4	39D	2090	4	-4	-32	1	-1	1
02-01-14-033-23W4	40D	2091	11	-1	-32	0	9	1
02-01-14-033-23W4	41D	2092	13	6	-30	2	6	1
02-01-14-033-23W4	42D	2093	8	-3	-34	1	2	1
02-01-14-033-23W4	43D	2094	3	-5	-34	0	-2	1
02-01-14-033-23W4	44D	2095	8	2	-32	0	2	2
02-01-14-033-23W4	45D	2096	20	13	-20	3	37	4
02-01-14-033-23W4	46D	2097	19	14	-11	1	32	2
02-01-14-033-23W4	47D	2098	9	-7	-32	1	1	0

Table B.4. Continued.

Well UWI	ID #	Depth (m)	V (ppm)	Cu (ppm)	Zn (ppm)	U (ppm)	Ni (ppm)	Mo (ppm)
02-01-14-033-23W4	48D	2099	23	-4	-31	2	7	1
02-01-14-033-23W4	49D	2100	35	1	-28	2	18	1
02-01-14-033-23W4	50D	2101	28	23	-15	3	76	13
02-01-14-033-23W4	51D	2102	43	6	-22	2	40	3
02-01-14-033-23W4	52D	2103	39	76	-15	4	70	9
02-01-14-033-23W4	53D	2104	70	109	-17	5	105	12
02-01-14-033-23W4	54D	2104.5	37	15	-17	5	46	5
02-01-14-033-23W4	55D	2107	66	278	-4	2	275	7
02-01-14-033-23W4	56D	2108	14	3	-28	2	11	1
02-01-14-033-23W4	57D	2109	23	35	-28	2	54	3
02-01-14-033-23W4	58D	2110	19	5	-32	1	0	2
02-01-14-033-23W4	59D	2111	4	-3	0	1	0	1
02-01-14-033-23W4	60D	2112	12	-5	-33	2	1	2
02-01-14-033-23W4	61D	2113	19	15	-31	1	34	1
02-01-14-033-23W4	62D	2114	28	10	-30	1	32	2
02-01-14-033-23W4	63D	2115	2	-9	-35	1	-6	1
02-01-14-033-23W4	64D	2116	13	-3	-27	1	2	0
02-01-14-033-23W4	65D	2117	20	5	-33	1	7	1
02-01-14-033-23W4	66D	2118	16	7	-29	1	6	1
02-01-14-033-23W4	67D	2119	22	11	-23	1	12	1
02-01-14-033-23W4	68D	2120	23	8	-8	1	13	1
02-01-14-033-23W4	69D	2121	28	13	-17	1	18	1
02-01-14-033-23W4	70D	2122	12	0	-32	0	4	1
02-01-14-033-23W4	71D	2123	54	52	-22	4	74	6
02-01-14-033-23W4	72D	2124	6	-10	-34	1	-4	1
00-14-19-062-15W5	73D	2888	39	4	8	3	13	0
00-14-19-062-15W5	74D	2889	85	12	18	3	35	-1
00-14-19-062-15W5	75D	2890	128	19	31	2	77	1
00-14-19-062-15W5	76D	2891	145	33	29	2	89	4
00-14-19-062-15W5	77D	2892	109	17	9	6	50	2
00-14-19-062-15W5	78D	2893	161	70	6	6	129	18
00-14-19-062-15W5	79D	2895	123	22	395	8	148	16
00-14-19-062-15W5	81D	2896	214	35	780	10	179	22
00-14-19-062-15W5	82D	2897	39	7	-24	3	57	9
00-14-19-062-15W5	83D	2898	96	26	-13	8	104	21
00-14-19-062-15W5	84D	2899	64	11	-20	8	62	10
00-14-19-062-15W5	85D	2900	45	13	-23	6	37	8
00-14-19-062-15W5	86D	2901	45	4	-20	2	45	8
00-14-19-062-15W5	87D	2902	70	17	-16	7	76	12

Table B.4. Continued.

Well UWI	ID #	Depth (m)	V (ppm)	Cu (ppm)	Zn (ppm)	U (ppm)	Ni (ppm)	Mo (ppm)
00-14-19-062-15W5	88D	2903	70	12	-17	5	57	8
00-14-19-062-15W5	89D	2904	75	10	-18	4	52	6
00-14-19-062-15W5	90D	2905	94	28	-18	7	59	10
00-14-19-062-15W5	91D	2906	184	61	-16	6	132	17
00-14-19-062-15W5	92D	2907	80	38	5	11	90	12
00-14-19-062-15W5	93D	2908	251	34	-16	8	146	45
00-14-19-062-15W5	94D	2909	143	66	-1	14	138	26
00-14-19-062-15W5	95D	2910	121	54	-11	11	138	24
00-14-19-062-15W5	96D	2911	179	48	824	15	160	32
00-14-19-062-15W5	97D	2912	32	16	-26	3	23	2
00-14-19-062-15W5	98D	2913	41	29	-27	1	32	2
00-14-19-062-15W5	99D	2914	27	9	-29	2	17	1
00-14-19-062-15W5	100D	2915	145	28	-18	9	128	26
00-14-19-062-15W5	101D	2916	176	29	110	13	150	45
00-14-19-062-15W5	102D	2917	103	29	-14	8	116	27
00-14-19-062-15W5	103D	2918	133	20	-17	10	114	25
00-14-19-062-15W5	104D	2919	105	28	-7	8	116	37
00-14-19-062-15W5	105D	2920	63	18	-17	4	80	18
00-14-19-062-15W5	106D	2921	152	25	-7	10	133	32
00-14-19-062-15W5	107D	2922	124	32	-17	11	105	20
00-14-19-062-15W5	108D	2923	111	32	-12	9	108	24
00-14-19-062-15W5	109D	2924	29	6	-25	1	32	4
00-14-19-062-15W5	110D	2925	41	28	-19	2	45	1
00-14-19-062-15W5	111D	2926	40	8	17	3	46	10
00-14-19-062-15W5	112D	2927	39	31	47	2	51	2
00-14-19-062-15W5	113D	2928	8	-8	12	1	-4	1
00-14-19-062-15W5	114D	2929	6	-8	-32	1	-4	0
00-14-19-062-15W5	115D	2930	20	-3	-26	1	9	0
00-14-19-062-15W5	116D	2931	22	-3	-26	1	13	2
00-14-19-062-15W5	117D	2932	12	-10	-27	1	-1	0
00-14-19-062-15W5	118D	2933	13	-7	-30	1	0	0
00-14-19-062-15W5	119D	2934	12	-8	-29	2	-1	1
00-14-19-062-15W5	120D	2935	21	-7	-21	1	5	1
00-14-19-062-15W5	121D	2936	30	-3	-24	2	8	1
00-14-19-062-15W5	122D	2937	55	1	-14	3	23	0
00-14-19-062-15W5	123D	2938	211	62	-8	7	148	37
00-14-19-062-15W5	124D	2939	78	38	-10	3	42	1
00-14-19-062-15W5	125D	2940	132	78	2	3	74	1
00-14-19-062-15W5	126D	2941	62	23	-20	2	30	0

Table B.4. Continued.

Well UWI	ID #	Depth (m)	V (ppm)	Cu (ppm)	Zn (ppm)	U (ppm)	Ni (ppm)	Mo (ppm)
00-14-19-062-15W5	127D	2942	24	8	-23	2	7	1
02-10-27-057-21W4	128D	1105	2	-11	-17	1	-6	1
02-10-27-057-21W4	129D	1106	21	6	-13	1	22	0
02-10-27-057-21W4	130D	1107	26	12	-15	3	29	1
02-10-27-057-21W4	131D	1108	20	7	-12	1	20	1
02-10-27-057-21W4	132D	1109	9	-6	-28	0	0	1
02-10-27-057-21W4	133D	1110	11	-7	-31	0	1	0
02-10-27-057-21W4	134D	1111	2	-12	-35	0	-5	1
02-10-27-057-21W4	135D	1112	36	12	-29	2	18	1
02-10-27-057-21W4	136D	1113	13	-4	37	1	4	1
02-10-27-057-21W4	137D	1114	53	16	-21	3	37	1
02-10-27-057-21W4	138D	1115	20	1	-31	1	19	3
02-10-27-057-21W4	139D	1116	30	16	-12	4	33	3
02-10-27-057-21W4	140D	1117	34	7	-16	3	42	3
02-10-27-057-21W4	141D	1118	42	12	-16	3	58	4
02-10-27-057-21W4	142D	1119	10	-7	-28	2	9	2
02-10-27-057-21W4	143D	1120	21	1	-19	3	21	5
02-10-27-057-21W4	144D	1121	23	-1	-25	2	17	1
02-10-27-057-21W4	145D	1122	19	-3	-26	4	10	2
02-10-27-057-21W4	146D	1123	27	4	-18	4	38	3
02-10-27-057-21W4	238D	1124	27	0	-20	4	20	2
02-10-27-057-21W4	147D	1124.5	31	5	-7	3	31	4
02-10-27-057-21W4	148D	1125	18	3	-4	1	34	3
02-10-27-057-21W4	149D	1126	34	7	-20	3	38	2
02-10-27-057-21W4	150D	1127	31	4	-15	2	45	3
02-10-27-057-21W4	151D	1128	25	1	-10	2	20	1
02-10-27-057-21W4	152D	1129	38	6	-11	2	29	2
02-10-27-057-21W4	153D	1130	5	-9	-32	2	-4	1
02-10-27-057-21W4	154D	1131	22	-2	-26	3	23	3
02-10-27-057-21W4	155D	1132	9	-10	-32	1	-2	2
02-10-27-057-21W4	156D	1133	10	-8	-30	1	0	2
02-10-27-057-21W4	157D	1134	42	11	-11	3	54	3
02-10-27-057-21W4	158D	1135	36	9	-24	2	23	3
02-10-27-057-21W4	159D	1136	42	12	-5	3	54	2
02-10-27-057-21W4	160D	1137	18	-4	-27	3	6	3
02-10-27-057-21W4	161D	1138	29	5	-16	1	21	2
02-10-27-057-21W4	162D	1139	43	13	-13	4	55	1
02-10-27-057-21W4	163D	1140	14	-5	-29	2	3	2
02-10-27-057-21W4	164D	1141	27	9	-12	1	25	1

Table B.4. Continued.

Well UWI	ID #	Depth (m)	V (ppm)	Cu (ppm)	Zn (ppm)	U (ppm)	Ni (ppm)	Mo (ppm)
02-10-27-057-21W4	165D	1142	40	17	2	2	45	3
02-10-27-057-21W4	166D	1142.5	22	4	-18	2	27	1
02-10-27-057-21W4	167D	1143	26	11	-19	3	40	3
02-10-27-057-21W4	168D	1144	38	15	-16	3	57	2
02-10-27-057-21W4	169D	1145	35	14	-12	3	61	2
02-10-27-057-21W4	170D	1146	34	19	208	4	65	2
02-10-27-057-21W4	171D	1147	37	15	-8	2	66	3
02-10-27-057-21W4	172D	1148	42	21	1	5	84	3
02-10-27-057-21W4	173D	1149	41	27	2	4	97	4
02-10-27-057-21W4	174D	1150	49	32	7	3	94	6
02-10-27-057-21W4	175D	1151	14	-1	-15	-1	10	3
02-10-27-057-21W4	176D	1152	48	25	-3	4	84	11
02-10-27-057-21W4	177D	1153	53	38	-1	3	95	8
02-10-27-057-21W4	178D	1154	53	37	6	3	101	7
02-10-27-057-21W4	179D	1155	68	21	11	3	88	11
02-10-27-057-21W4	180D	1156	73	28	35	7	104	13
02-10-27-057-21W4	181D	1157	43	10	-9	4	48	4
02-10-27-057-21W4	182D	1158	26	-4	-22	0	12	1
02-10-27-057-21W4	183D	1159	83	18	7	5	92	9
02-10-27-057-21W4	184D	1160	46	24	-6	4	43	6
02-10-27-057-21W4	185D	1161	31	29	243	2	34	4
02-10-27-057-21W4	186D	1162	42	18	40	4	53	4
02-10-27-057-21W4	187D	1163	49	49	198	4	124	8
02-10-27-057-21W4	188D	1164	6	-7	-33	2	4	0
02-10-27-057-21W4	189D	1165	28	2	-21	1	14	0
02-10-27-057-21W4	190D	1166	30	-1	-22	2	12	0
02-10-27-057-21W4	191D	1167	10	-7	-30	3	-1	1
02-10-27-057-21W4	192D	1168	10	-5	-30	0	2	0
02-10-27-057-21W4	193D	1169	6	-7	-31	2	-2	1
02-10-27-057-21W4	194D	1170	13	-6	-26	0	1	1
02-10-27-057-21W4	195D	1171	28	-3	-18	2	10	1
02-10-27-057-21W4	196D	1172	29	-4	-17	1	10	0
02-10-27-057-21W4	197D	1173	49	3	-2	1	21	1
02-10-27-057-21W4	198D	1174	8	-7	-31	2	-2	1
02-10-27-057-21W4	199D	1175	9	-3	-28	1	2	1
02-10-27-057-21W4	200D	1176	22	1	-23	1	12	1
02-10-27-057-21W4	201D	1176.3	36	29	-17	2	77	2
02-10-27-057-21W4	202D	1177	13	-2	-23	1	7	1
02-10-27-057-21W4	203D	1178	88	12	5	3	37	2

Table B.4. Continued.

Well UWI	ID #	Depth (m)	V (ppm)	Cu (ppm)	Zn (ppm)	U (ppm)	Ni (ppm)	Mo (ppm)
02-10-27-057-21W4	204D	1179	10	-5	-31	1	4	1
02-10-27-057-21W4	205D	1180	4	-10	-34	2	-1	1
02-10-27-057-21W4	206D	1181	5	-9	-33	1	-5	0
02-10-27-057-21W4	207D	1182	3	-10	-33	1	-5	1
02-10-27-057-21W4	208D	1183	24	14	-13	3	24	3
02-10-27-057-21W4	209D	1183.5	4	-11	-32	3	-5	1
02-10-27-057-21W4	210D	1184	16	-3	-29	1	6	0
02-10-27-057-21W4	211D	1185	8	-8	-31	0	-2	1
02-10-27-057-21W4	212D	1186	10	-3	-28	1	5	1
02-10-27-057-21W4	213D	1187	12	1	-28	0	6	0
02-10-27-057-21W4	214D	1188	15	8	-26	1	12	1
02-10-27-057-21W4	215D	1189	18	4	-28	1	9	1
02-10-27-057-21W4	216D	1190	14	1	-29	2	6	0
02-10-27-057-21W4	217D	1191	19	4	-28	2	8	1
02-10-27-057-21W4	218D	1192	23	6	-27	0	11	0
02-10-27-057-21W4	219D	1193	29	19	-26	2	18	2
02-10-27-057-21W4	220D	1194	34	63	-15	1	27	3
02-10-27-057-21W4	221D	1195	35	23	-17	1	21	1
02-10-27-057-21W4	222D	1196	17	10	-26	3	8	2
02-10-27-057-21W4	223D	1197	2	0	-27	1	-1	1
02-10-27-057-21W4	224D	1197.5	4	-7	-35	2	-3	1
02-10-27-057-21W4	225D	1198.5	5	-9	-32	2	-7	1
02-10-27-057-21W4	226D	1199.5	4	-9	-34	0	-6	1
02-10-27-057-21W4	227D	1200.5	2	-8	-34	1	-5	1
02-10-27-057-21W4	228D	1201.5	10	4	-31	3	5	1
02-10-27-057-21W4	229D	1202.5	7	-9	-32	2	-6	2
02-10-27-057-21W4	230D	1203.5	15	-6	-27	2	3	2
02-10-27-057-21W4	231D	1204.5	15	-6	-27	1	3	0
02-10-27-057-21W4	232D	1205.5	20	15	-24	1	34	4
02-10-27-057-21W4	233D	1206	28	29	-27	2	46	8
02-10-27-057-21W4	234D	1207	23	32	-30	2	31	6
02-10-27-057-21W4	235D	1208	10	-1	-33	1	0	3
02-10-27-057-21W4	236D	1209	43	31	-26	2	30	6
02-10-27-057-21W4	237D	1210	48	45	-26	3	30	14
00-15-18-049-13W5	239D	3488	75	9	6	2	43	0
00-15-18-049-13W5	240D	3489	92	39	10	2	40	0
00-15-18-049-13W5	241D	3490	99	11	16	1	43	0
00-15-18-049-13W5	242D	3491	94	6	10	4	37	0
00-15-18-049-13W5	243D	3492	18	0	-28	1	1	2

Table B.4. Continued.

Well UWI	ID #	Depth (m)	V (ppm)	Cu (ppm)	Zn (ppm)	U (ppm)	Ni (ppm)	Mo (ppm)
00-15-18-049-13W5	244D	3493	218	64	794	9	187	49
00-15-18-049-13W5	245D	3494	93	55	65	4	92	9
00-15-18-049-13W5	246D	3495	113	52	330	7	80	4
00-15-18-049-13W5	247D	3496	204	102	0	7	108	15
00-15-18-049-13W5	248D	3497	120	60	27	4	77	6
00-15-18-049-13W5	249D	3498	123	58	44	4	91	6
00-15-18-049-13W5	250D	3499	13	1	-21	1	8	1
00-15-18-049-13W5	251D	3500	76	22	10	3	39	2
00-15-18-049-13W5	252D	3501	63	17	-13	3	49	6
00-15-18-049-13W5	253D	3502	87	62	-6	8	77	13
00-15-18-049-13W5	254D	3503	37	42	13	3	39	2
00-15-18-049-13W5	255D	3503.5	28	24	-15	3	31	1
00-15-18-049-13W5	256D	3504	60	34	-4	5	80	5
00-15-18-049-13W5	257D	3505	41	25	-7	3	54	1
00-15-18-049-13W5	258D	3506	43	32	-8	3	59	2
00-15-18-049-13W5	259D	3507	270	113	751	8	201	47
00-15-18-049-13W5	260D	3508	51	45	47	2	44	2
00-15-18-049-13W5	261D	3509	8	-8	-32	0	-2	1
00-15-18-049-13W5	262D	3510	19	-4	-27	1	9	1
00-15-18-049-13W5	263D	3511	13	-3	-25	0	4	1
00-15-18-049-13W5	264D	3512	13	-3	-30	1	1	1
00-15-18-049-13W5	265D	3513	13	-4	-31	2	2	1
00-15-18-049-13W5	266D	3514	31	15	-24	1	26	1
00-15-18-049-13W5	267D	3515	30	7	-24	2	16	1
00-15-18-049-13W5	268D	3516	193	73	11	8	157	27
00-15-18-049-13W5	269D	3517	101	33	14	4	76	2
00-15-18-049-13W5	270D	3518	170	64	18	4	96	10
00-15-18-049-13W5	271D	3519	133	50	-1	7	73	6
00-15-18-049-13W5	272D	3519.5	134	45	22	5	68	6
00-15-18-049-13W5	273D	3520	150	53	65	5	76	7
00-15-18-049-13W5	274D	3521	157	51	162	4	77	8
00-15-18-049-13W5	275D	3522	131	57	22	5	84	6
00-15-18-049-13W5	276D	3523	260	53	2510	17	177	49
00-15-18-049-13W5	277D	3524	261	91	13	10	106	27
00-15-18-049-13W5	278D	3525	64	17	6	3	32	3
00-15-18-049-13W5	279D	3526	104	31	-6	4	71	12
00-15-18-049-13W5	280D	3527	100	37	2	6	66	9
00-15-18-049-13W5	281D	3528	129	37	31	3	67	1
00-15-18-049-13W5	282D	3529	128	64	26	3	62	0

Table B.4. Continued.

Well UWI	ID #	Depth (m)	V (ppm)	Cu (ppm)	Zn (ppm)	U (ppm)	Ni (ppm)	Mo (ppm)
00-15-18-049-13W5	283D	3530	137	46	32	2	74	0
00-15-18-049-13W5	284D	3531	107	38	17	4	60	0

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