ABSTRACT

Characterizing the Reservoir Quality of Marcellus Formation Mudrocks through a Comparison of Chemostratigraphic Character and Petrophysical Response in North-Central Pennsylvania

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This study combines robust geochemical data with core descriptions and wireline logs to gain new insight into the paleoceanographic conditions during Marcellus deposition and the resulting quality and distribution of reservoir facies. Three cores penetrating the Marcellus Formation in Pennsylvania were described and samples were taken at two-foot intervals. The geochemistry of the 502 samples was characterized and used to identify chemofacies. Lithofacies descriptions and chemofacies characterization indicate the production and preservation of TOC-enriched intervals occurred during periods of euxinia/anoxia coupled with high production. GR log response in the Marcellus Formation is principally controlled by uranium. The relationship of uranium to organic matter allows for the creation of synthetic TOC logs from GR logs and the prediction of TOC in wells lacking core control. Subsurface correlation indicates relative thinning of facies to the northwest and a general increase of organic enrichment thicknesses to the northeast of our study area.

Characterizing the Reservoir Quality of Marcellus Formation Mudrocks through a Comparison of Chemostratigraphic Character and Petrophysical Response in North-Central Pennsylvania

by

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A Thesis

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DEDICATION

To my wife

CHAPTER ONE

Introduction

The Marcellus Formation is considered one of the largest unconventional shale-gas resources in the United States (Wang and Carr, 2013; Zagorski et al., 2012). The modern era of Marcellus gas production began in 2004 when hydraulic fracture stimulation, a.k.a., fracing, proved it an economically viable resource. Since that time, thousands of wells have been drilled and many studies done to understand and exploit this world-class resource.

Before the advent of horizontal drilling and hydraulic fracture stimulation, oil and gas exploration and development focused on conventional reservoirs of relatively high porosity and permeability and studies of mudrocks, such as the Marcellus Formation, received relatively little attention. Now that mudrocks are targets of drilling and completion, it is important to understand the nature of mudrock deposition and key reservoir characteristics such as organic enrichment and relative brittleness (Wang and Carr, 2013; Ver Straeten et al., 2011). Due to their relatively homogenous nature and fine-grained features, the depositional architecture and setting of organic-rich mudrocks are best described through a combination of geochemical analyses and conventional core descriptions.

Access to three whole cores penetrating the entire Marcellus Formation and an additional 6 wells with wireline logs in north-central Pennsylvania (Fig. 1.1, 1.2) were provided for description and sampling. Mineralogy, organic matter geochemistry, lithofacies descriptions, and trends in element concentrations sensitive to paleo-redox and paleo-productivity conditions are important to understand the means of organic-rich shale deposition and the associated reservoir quality and variations (Chen and Sharma, 2016; Kohl et al., 2014; Wang and Carr, 2013; Ver Straeten et al., 2011). Many studies have performed geochemical analyses on Marcellus mudrocks in combination with traditional core description and petrophysical characterization (Mason, 2017; Offurum, 2016; Wonnell, 2015; Sexton, 2011;; Ver Straeten et al., 2011; Sageman et al., 2003). However, no such study has been performed in north-central Pennsylvania on multiple cores at a high resolution (one sample every two feet) resulting in the quantity of geochemical data acquired in this study. The combination of a robust geochemical analysis, core description, and correlation to petrophysical response provides a unique perspective on Marcellus Formation depositional controls and the lateral and vertical variation of reservoir characteristics.

The objectives of this study are to: 1) produce a core-calibrated lithofacies model of the Marcellus Formation, 2) generate a robust set (sample every 2') of geochemical data and identify chemofacies, 3) interpret the paleoceanographic conditions associated with each chemofacies, 4) quantify the correlation between key geochemical data and wireline log responses in order to develop an equation(s) for the prediction of geochemical data in wells lacking core control, and (5) generate subsurface correlations in all wells and map the lateral variation of key reservoir characteristics.

Figure 1.1. Location map indicating the study area (red box) and its geographical location within the state of Pennsylvania. Devonian outcrop belt indicated in brown.

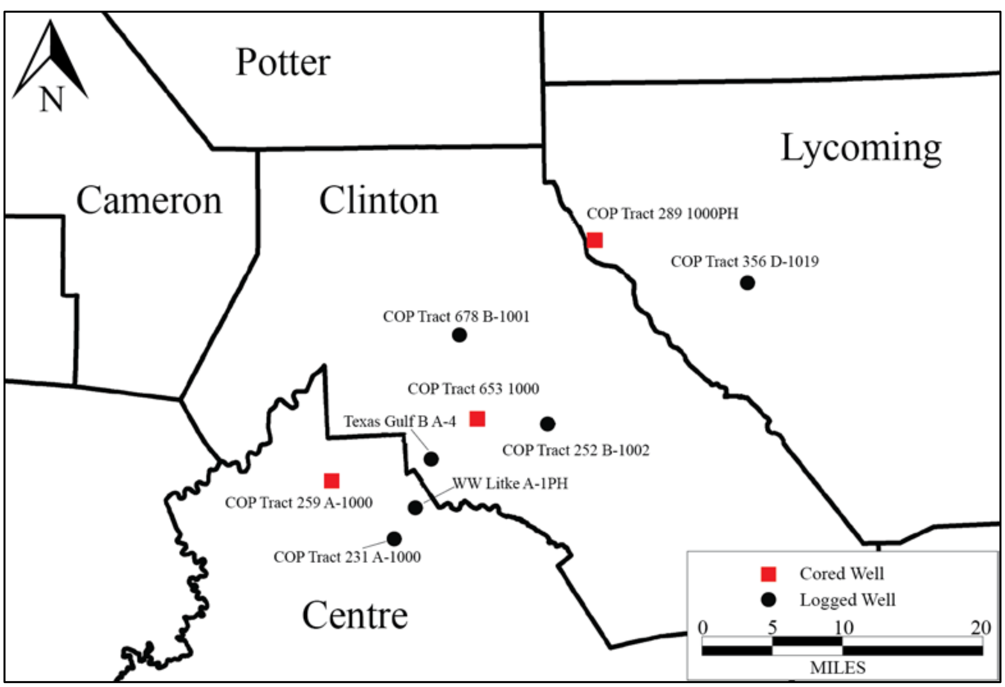

Figure 1.2. Location map and names of the 9 wells used in this study. Blue rectangles indicate the three cored wells. Black circles represent un-cored wells with logs. Black lines represent county boundaries. Within the text, wells will be referred to by shortened names as follows: COP 259, COP 231, WW Litke, Texas Gulf, COP 653, COP 252, COP 678, COP 289, and COP 356.

CHAPTER TWO

Paleogeography and Regional Stratigraphy

Geologic Setting of the Appalachian Basin

This study investigates the Marcellus Formation in north-central Pennsylvania within the Appalachian Basin. The Appalachian Basin underwent several major tectonic events in the Paleozoic as landmasses collided with what is now the eastern margin of North America. These major tectonic events include the Taconic, Acadian, and Alleghanian (Marathon-Ouachita) orogenies (Faill, 1997). The basin formed by these tectonic events is collectively referred to as the Appalachian Basin that extends NE-SW throughout much of the northeastern United States and part of Canada. The stratigraphic intervals of this study were deposited in the Middle Devonian Acadian foreland basin of eastern North America situated approximately 30° south of the paleoequator (Ver Straeten et al., 2011; Joachimski et al., 2009; Scotese and McKerrow, 1990; Witzke, 1990). This elongate foreland basin formed due to thrust-load-induced subsidence caused by an oblique collision between Laurentia and the Avalonia microplate (Kohl et al., 2014; Lash and Engelder, 2011; Faill, 1985) that began in the latest Silurian or earliest Devonian (Ver Straeten, 2007).

The basin was deepest to the east/southeast (foredeep) and shallowed to the west/northwest. The Acadian mountains bounded this semi-restricted basin to the southeast (Fig. 2.1) and the Findlay-Algonquin Arch, a topographic high, bounded the basin to the northwest (Wang and Carr, 2013; Ettensohn, 1985). Studies by Sageman et al. (2003) and Scotese and McKerrow (1990) indicate open connections to the subtropical

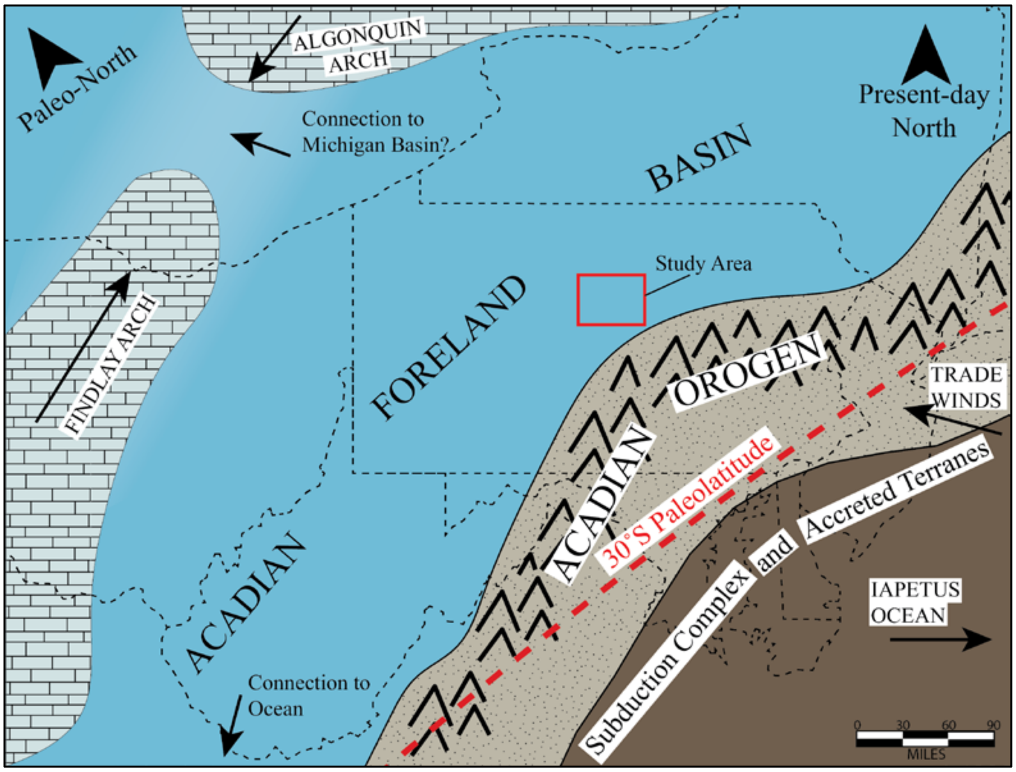

Figure 2.1. Paleogeographic setting of the Acadian foreland basin, Acadian orogen, and the Findlay-Algonquin Arch (modified from Castle, 2001 and Blakey, 2013). Dashed lines represent present-day state lines.

Devonian ocean through a passageway to the southwest (Fig. 2.1). However, due to the restricted nature of the basin, Kohl et al. (2014) interpreted that the circulation was quasi-estuarine and driven by freshwater runoff from the Acadian highlands. Drowned reefs throughout the basin and foredeep development near the orogenic front suggest that periods of increased crustal loading caused subsidence to outpace carbonate sediment production (Kohl et al., 2014).

Paleogeographic reconstructions indicate the likelihood of trade winds toward the Acadian basin from the Iapetus Ocean in a present-day westerly direction (Fig. 2.1;

Werne et al., 2002). However, the Acadian mountains likely formed a rain shadow which caused an arid to semi-arid climate with seasonal variability and the likelihood of intense storms (Werne et al., 2002; Witzke, 1990; Woodrow, 1985). The existence of tropical-type fossils within the Onondaga Formation reefs and supporting $\delta^{18}O$ signatures from brachiopods suggest warm (25°-35°C) waters in the Middle Devonian Acadian basin (Kohl et al., 2014).

Regional Stratigraphy

The Marcellus Formation is the targeted interval of this study and it overlies the Onondaga Formation and is overlain by the Mahantango Formation. Collectively, the Marcellus Formation and Mahantango Formation constitute the Hamilton Group. The Tully Limestone overlies the Hamilton Group. These units are a part of the Catskill Delta Complex, an eastward thickening wedge of marine to terrigenous sediment, predominantly derived from the Acadian orogen and these clastic sediments include occasional carbonate input (Ver Straeten et al., 2011; Ettensohn, 1985; Woodrow, 1985).The stratigraphic nomenclature of these units has been addressed in several studies (Chen and Sharma, 2016; Kohl et al., 2014; Lash and Engelder, 2011; Ver Straeten and Brett, 2006; Werne et al., 2002), and this study uses the stratigraphic nomenclature of Lash and Engelder (2011) provided in Figure 2.2.

The Onondaga Formation consists predominantly of limestones exhibiting open marine fauna, calcareous shales, and the Tioga ash beds (Wendt et al., 2015; Ver Straeten, 2009) all overlying the “sub-Onondaga unconformity”. The Onondaga Formation is overlain by the Marcellus Formation which consists predominantly of black- to gray-, fissile, thinly laminated shale with occasional carbonate beds.

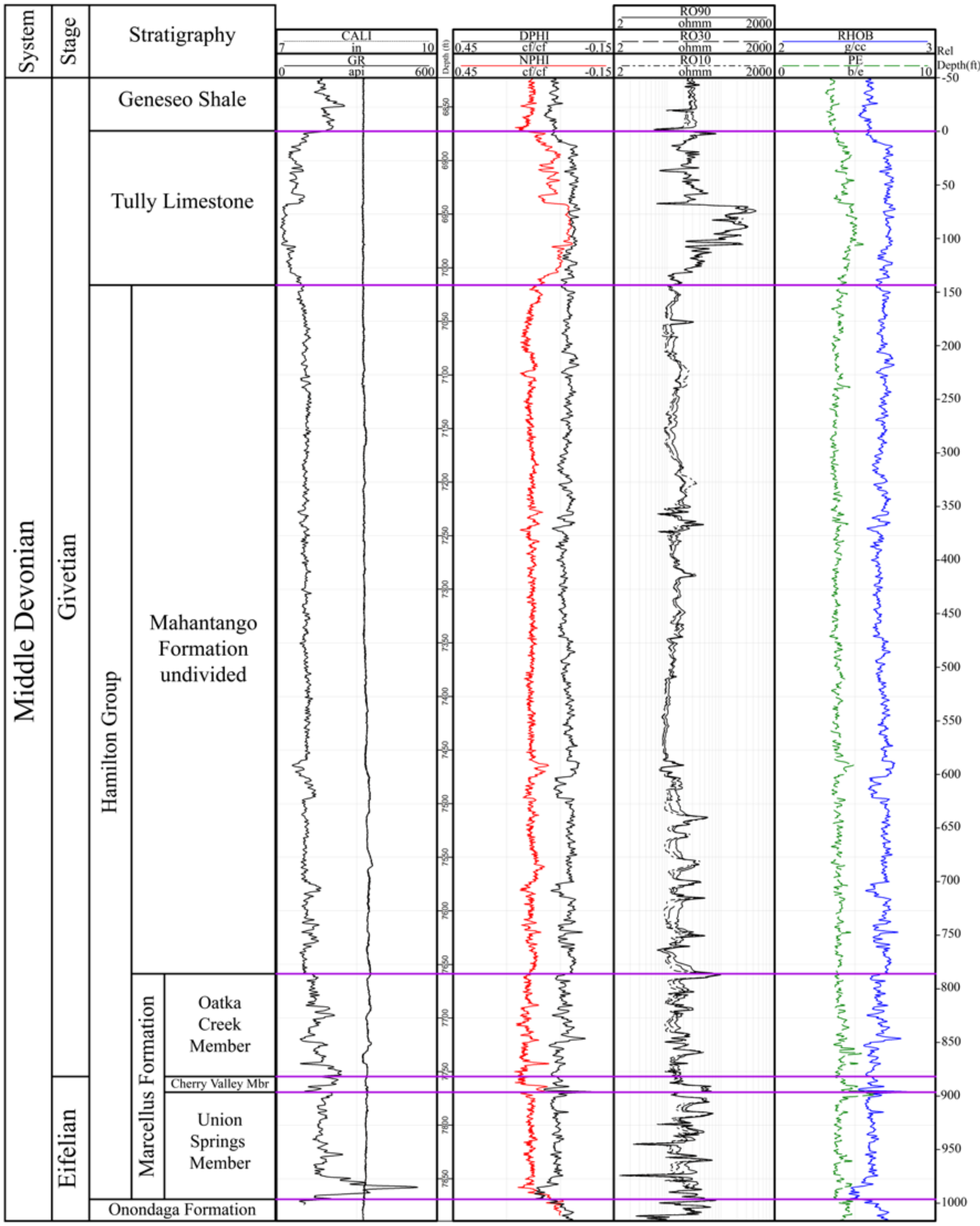

Figure 2.2. Type log and stratigraphic column for the stratigraphic intervals in this study. Logs from the COP Tract 678 well.

The Union Springs Member of the Marcellus Formation overlies the Onondaga Formation and consists of highly organic rich, black to dark gray shales and occasional calcareous-rich mudrocks. There can be a sharp or transitional boundary between the Onondaga Formation and the Union Springs Member. On gamma ray log, the Union Springs Member is typically represented by a sharp spike to >450 API units followed by a sharp and then gradual decrease in API values until the Cherry Valley Member (Fig. 2.2). The Cherry Valley Member represents pulses of carbonate and clastic detrital material that thicken towards the orogenic front to the east/southeast and thin to the west/northwest (Wendt et al., 2015). The Cherry Valley Member is a bioclastic limestone (Werne et al., 2002) and is divided into two main facies. The first is a classic, deep water 'cephalopodenkalk' limestone facies (Ver Straeten, 2007, Ver Straeten et al., 1994, Griffing & Ver Straeten 1991, Wendt and Aigner, 1985) containing thin, calcareous shales. Towards the orogen to the east/southeast, the Cherry Valley Member grades into a clastic-dominated facies composed of calcareous shale, nodular limestones in shale, and bioturbated sandstones and mudstones (Ver Straeten, 2007).

The Oatka Creek Member overlies the Cherry Valley Member and is dominated by black and gray shales with occasional calcareous bedding. The top of the Oatka Creek Member is defined as the base of the Stafford Limestone of the Mahantango Formation and its lateral equivalents. The Mahantango Formation is characterized by coarsening upward cycles of predominantly gray shales and siltstones with occasional interstratified limestones and fine-grained sandstones. The Tully Limestone overlies the Mahantango Formation and is highly fossiliferous and heavily burrowed in the study area.

Cyclostratigraphy

In his study on the relationship between deposits from the Catskill Delta complex and the Acadian orogeny, Ettensohn (1985) identified four episodes of increased convergence which he labeled "tectophases". As the Avalon Terrane and the North American Craton (Laurentia) obliquely collided, cratonic promontories became loci of increased deformation as interpreted from resulting distinct clastic wedges (Ettensohn, 1985). Patterns within the sedimentary record suggest four stages within the evolution of each tectophase: *Stage 1*. Commencement of increased tectonism and formation of basin. Marked by regional transgression and deposition of black shales. *Stage II*. Increase of clastic input and decrease of subsidence marked by regional regression. *Stage III*. Collision of landmasses during which regional uplift produces regional disconformity. *Stage IV*. Return to relatively quiescent conditions. Often associated with moderate transgression and extensive carbonate deposition (Ettensohn, 1985).

Rocks in this study have been attributed to tectophases I and II. Upper Onondaga Formation limestones are assigned to Stage IV of tectophase I during the period of relative quiescence before the initiation of tectophase II. The Hamilton Group and Tully Limestone lithostratigraphic units constitute the deposits of tectophase II. The Marcellus Formation is assigned to Stage I during initial basin subsidence and deposition of black shales. The Hamilton Group constitutes Stages II and III and the laterally extensive Tully Limestone is assigned to Stage IV and marks a period of relative quiescence and widespread, shallow carbonate deposition (Ettensohn, 1985).

CHAPTER THREE

Methods

Data and Core Description

Data for this study includes an assortment of digital wireline logs that document the Marcellus Formation at 9 different well locations (Fig. 1.2) and the observations and geochemical data from approximately 1010 feet (308 m) of continuous core associated with three of these wells (COP 259, COP 289, and COP 653). The cored wells were described and sampled in the Core Laboratories facility in Houston, Texas at a rate of 1 sample every 2 feet, which approximates the average resolution of common wireline logs (AAPG Wiki). A total of 502 samples were obtained for geochemical analysis. Core descriptions include the documentation of Dunham carbonate texture every 3 to 6 inches (Dunham, 1962), grain size, grain type, mechanical sedimentary structures, and biological sedimentary structures as rated on a relative scale of 0.0-1.0 burrowing with a value of 1.0 meaning 100% bioturbation. It also includes a relative effervescence to HCl and the Munsell (Munsell Color Company, 2016) color when dry (Appendix A).

Geochemical Analysis

Approximately 30 g of each of the 502 samples was crushed to a fine powder using a SPEX Shatterbox® in preparation for the geochemical analyses.

Combustion Analysis and Isotope Mass Spectroscopy

Samples were prepared for combustion analysis and organic matter isotope mass spectroscopy by destroying inorganic carbon in about 20 mg of bulk shale using 10% HCl acid in silver capsules and then wrapping them in tin once decarbonation was complete. Samples were stored in a desiccator to prevent rehydration before being analyzed. Total organic carbon (TOC), nitrogen (N) abundance as well as carbon (C) and nitrogen isotope ratios were obtained (Appendix B) using a Costech EA model 4010 connected to a Thermo Scientific™ Delta V™ Isotope Ratio Mass Spectrometer (Baylor University Stable Isotope Laboratory). Elemental Analysis Software – Clarity 2.6.6.574 and ISODAT 3.0 software were used for the EA and IRMS, respectively. USGS-40 and USGS-41 laboratory standards were used for data normalization and N and C standards. Acetanilide (ACET) was used as an internal standard to measure the reproducibility of isotope analyses. These laboratory standards reported standard deviations (1σ) for TOC wt.% and N wt.% of 0.27.and 0.02, respectively (n=20). Carbon isotope values are reported in ‰ relative to V-PDB. Nitrogen isotope values are reported in ‰ relative to AIR. 60 ACET standard analyses produced a total standard deviation (1σ) of 0.16 ‰ for $\delta^{13}C$ and 0.16 ‰ for $\delta^{15}N$.

Total carbon (TC) weight percent values were acquired (Appendix B) by analysis of each sample on a FlashEA® series 1112 nitrogen and carbon analyzer. The Medium Organic Content Soil (MOCS) Organic Analytical Standard (OAS) was used as a laboratory standard and 25 analyses produced a standard deviation of 0.01 N wt.% and 0.05 C wt.%. Inorganic carbon (IC) weight percent was calculated by subtracting OC wt.% from TC wt.%.

Major and Trace Elements

In preparation for XRF analysis, 6.00 g of each sample was measured and mixed thoroughly with 1.00 g of cellulose binder. The mixture was pressed into a pellet by applying 24 tons of pressure for 1-2 minutes. Major and trace elemental concentrations were determined for 502 samples using a Rigaku ZSX Primus II x-ray fluorescence instrument (Appendix C). Analytical drift was corrected through repetitive analysis of standard TS-1. Standard deviations of the TS-1 standards are displayed in Table 3.1.

Table 3.1: Standard Deviations (1 sigma) from XRF Standards (TS-1)

Element	SiO2	TiO2	Al2O3	Fe2O3	MnO	CaO	K2O	P2O5
Unit	mass%	mass%	mass%	mass%	mass%	mass%	mass%	mass%
STDEV	0.090	0.0019	0.032	0.0095	0.0004	0.0006	0.018	0.0024
Element	V	Cu	Zn	U	Ni	Th	Mo	S
Unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	mass%
STDEV	5.2	1.6	1.1	0.78	1.4	1.4	0.60	0.0005

X-ray Diffraction Analysis

Random powder mount x-ray diffraction (XRD) patterns were generated for one sample from each chemofacies using a Siemens D5000 x-ray diffractometer. Each sample was analyzed from a 2θ of 2° to 60° with a 0.05° step and a 5 second dwell time (Appendix D).

Geochemical Calculations

Multiple calculations were performed on the data to produce: inorganic carbon (IC) wt.%, calcite wt.%, Mo enrichment factor (EF), V EF, and U EF. IC wt.% was calculated by subtracting OC from TC. With the assumption that all inorganic carbon came from calcite, the value for IC wt.% was multiplied by 8.33 to produce calcite wt.%. However, later XRD and SEM analyses suggest an abundance of dolomite within the samples, suggesting that not all IC came from calcite. Enrichment factors were calculated for the redox-sensitive elements using metal concentrations from the "average shale" (Tribovillard et al., 2006):

$$\frac{\left(\mathrm{Mo_{sample}}/\mathrm{Al_{sample}}\right)}{\left(\mathrm{Mo_{avg.\ shale}}/\mathrm{Al_{avg.\ shale}}\right)} = \mathrm{Mo\ EF}$$

$$\frac{\left(\mathrm{V_{sample}}/\mathrm{Al_{sample}}\right)}{\left(\mathrm{V_{avg.\ shale}}/\mathrm{Al_{avg.\ shale}}\right)} = \mathrm{V\ EF}$$

$$\frac{\left(\mathrm{U_{sample}}/\mathrm{Al_{sample}}\right)}{\left(\mathrm{U_{avg.\ shale}}/\mathrm{Al_{avg.\ shale}}\right)} = \mathrm{U\ EF}$$

EF values >1 suggest that the rock is enriched in that metal relative to the average shale. Values <1 suggest relative depletion of that metal.

Geochemical Facies

Plots of geochemical data vs depth were analyzed for each of the cored wells. Trends and deviations which were recognizable from well to well and in multiple geochemical vs. depth plots were marked and identified as chemofacies. 10 chemofacies consistent throughout the wells were identified and labeled A through J from oldest to youngest (Appendix E).

Stratigraphic Correlation

The nine wells in this study were stratigraphically correlated from wireline logs using IHS Petra® software. The wells were initially correlated by identifying the top of the Onondaga Formation and the top of the Tully Limestone. These formation tops are easily recognizable on a gamma-ray log (Schlanser et al., 2016; Wang and Carr, 2013; Lash and Engelder, 2011) by their low (50-100 API) signatures topped by abrupt increases in gamma ray (Figure 2.2). The wells were further correlated on a finer scale by identifying gamma-ray "highs" and other trends that extend throughout the study area (Fig. 3.1).

Lithofacies and Chemofacies Prediction

Lithofacies, chemofacies, and digitized key wireline logs were statistically correlated with each other to determine whether wireline logs can be used to predict lithofacies and/or chemofacies data. Comparisons of chemofacies to lithofacies suggest that chemofacies cannot be predicted by lithofacies descriptions (Appendix H). Chemofacies tops were distinguishable from well to well using a combination of wireline logs and those tops were extended to the 6 wells lacking core control. Relationships were found between specific geochemical data and wireline logs. These relationships were used to predict some geochemical data in wells lacking core control. GR has a strong linear correlation with U and TOC and can also be used to predict other redox-sensitive elements like Mo and V.

Structure Maps

Subsea structure maps were created in Petra by gridding and contouring the subsea depth to lithologic and chemofacies tops that were picked. Figure 5.9 shows the subsea structure map for the top of the Marcellus Formation.

Isopach Maps

Tops correlated from well to well were used to calculate thicknesses of chemofacies and lithostratigraphic units. These thicknesses were gridded and contoured to create isopach maps of each unit (Appendix F).

TOC Maps

The equation expression of the relationship of TOC to GR was used to create continuous, calculated TOC logs. Several cutoffs for TOC (i.e. >3%) were applied to the logs to calculate net thickness of section meeting the cutoff. These thicknesses were gridded and contoured to created maps of net thickness of TOC meeting the designated cutoffs (Appendix G).

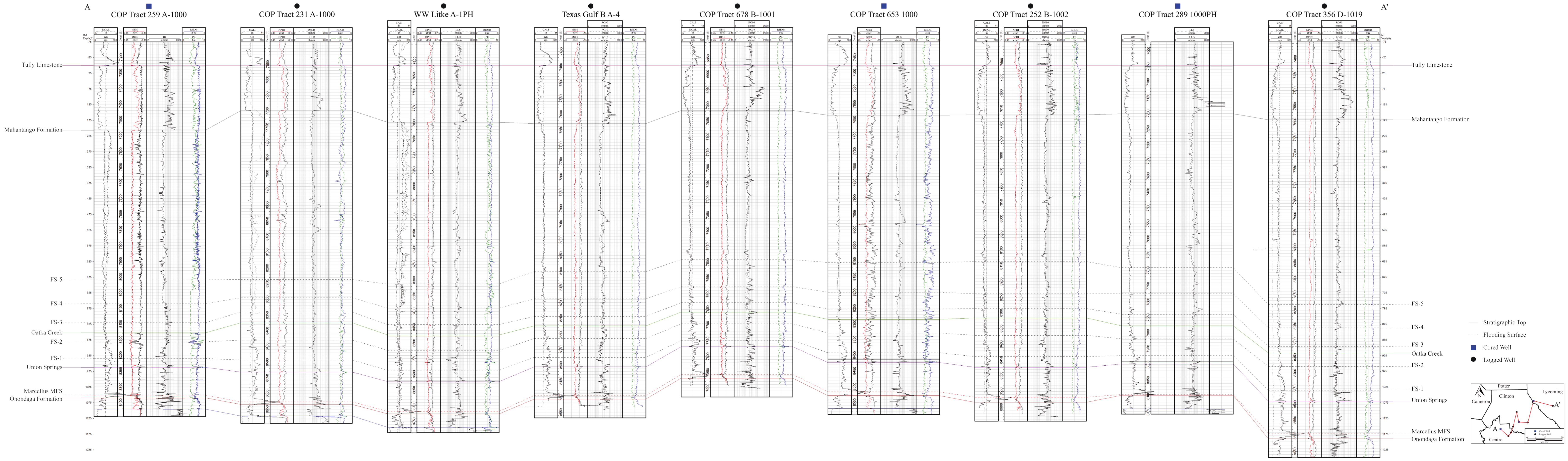

Figure 3.1. Correlation from well to well was done initially on the Tully Limestone (magenta) and Onondaga Formation (red) tops. This cross-section is hung on the Tully Limestone top. Dashed lines represent flooding surfaces used in the correlation and solid lines represent lithostratigraphic tops.

CHAPTER FOUR

Lithofacies and Chemofacies Depositional Environments

Introduction

The Onondaga Formation and Hamilton Group sediments were deposited in the semi-enclosed Acadian foreland basin. The lithology and geochemistry of these deposits were heavily influenced by the regional geography, water chemistry, biology, sedimentation rates, and relative sea level changes. The interplay of carbonate reef development, especially to the northwest and west (Fig. 2.1), combined with siliciclastic sedimentation from the orogenic front to the east and southeast created a mixed carbonate-clastic system. The upper Onondaga Formation represents carbonate reef development in shallow marine platform to peritidal depositional environments (Castle, 2001). The black shales of the Marcellus Formation were historically interpreted to be deposited in a deep, basinal setting under permanent stagnant water-column, euxinic conditions (Brett and Baird, 1996; Ettensohn, 1985). Recent studies indicate that not all black shales in this study were deposited under strictly euxinic, stagnant conditions as supported by the observation of calcareous fossils and bioturbation in parts of the Marcellus Formation (Wendt et al., 2015; Smith and Leone, 2013; Werne et al., 2002). Lithofacies description combined with geochemical analysis from this study suggests that highly organic-rich intervals were deposited under conditions of euxinia/anoxia combined with high levels of production, and that intervals with less organic enrichment were likely deposited in dysoxic to oxic conditions with lower rates of organic matter production.

Core description identified 8 depositional lithofacies within the 3 cored wells (Fig. 4.1-4.3, A.1-A.3) based on their Dunham carbonate classification (Dunham, 1962), grain size, relative effervescence, abundance and nature of allochems, mechanical sedimentary structures, and amount of bioturbation (Table 4.1). Relative effervescence was recorded on a scale of 0 to 5 with 0 representing no effervescence and 5 representing the most energetic and abundant effervescence such as from calcite veins. Bioturbation was represented on a scale of 0 to 1 with 0 representing no bioturbation and 1 representing 100% bioturbation and lack of preservation of any original sedimentary structure. Ten chemofacies were identified from geochemical analysis based on the values and trends of geochemical data from C and N stable isotope analysis, OC and N abundance and ratios, and major and trace element analysis including: Si, Ti, Al, Fe, Mn, Ca, K, P, V, Cu, Zn, U, Ni, Th, Mo, and S (Fig. 4.4 and Appendix E).

Lithofacies Description

Lithofacies 1 – Black Laminated Mudstone (BLM)

This facies consists of black, predominantly siliciclastic mudstones with little or no effervescence (≤ 1), mm lamina, rare bioturbation (0.0-0.2), and few fossils (<10%). These facies are often associated with high concentrations of TOC, especially in the Union Springs Member and lower Oatka Creek Member. Pelagic to hemipelagic deposition is interpreted in deep water deposits with predominantly dysoxic to euxinic oxidation levels.

Table 4.1. Lithofacies classification and key characteristics. Representative core photos located in Appendix A.

Name	Black Laminated Mudstone	Mottled Black Mudstone	Calcareous Black Laminated Mudstone	Massive Mudstone	Skeletal Black Mudstone	Mud-supported Carbonate	Grain-supported Carbonate	Cryptalgal Boundstone
Environment	offshore	offshore	offshore	offshore	offshore to distal slope	offshore to distal slope	offshore to distal slope	shallow marine to distal slope
Inferred process	pelagic to hemipelagic	pelagic to hemipelagic	pelagic to hemipelagic	burrowed pelagic to hemipelagic	turbidity flow	turbidity flow	turbidity flow	in situ
Effervescence	≤1	0 to 1	>1	4 to 5	≤2	>2	3 to 5	3 to 5
Physical sedimentary structures	mm lamina	discontinuous mm lamina	mm lamina	none	mm lamina	mm lamina, normal grading	normal grading	none
Bioturbation index	0-.2	.3 -.9	0-.2	.9-1.0	0-.3	0-.6	0-1	<.1
Dunham classification	N/A	N/A	Mudstone	Mudstone	Wackestone	Wackestone	Packestone	Boundstone
Representative core photo	653_8289, 259_8093	289_8065	653_8333	289_8110	653_8447, 653_8325	259_8388	259_8227, 259_8289	653_8548.5
Fossils Abundance	<10%	<10%	<10%	<10%	>10%	>10%	>10%	>50%
Fossil Types	brachiopods nautiloids crinoids bryozoans coral red algae skeletal fragments	N/A	nautiloids skeletal fragments	brachiopods nautiloids skeletal fragments	brachiopods nautiloids crinoids gastropods serpulid worm tubes skeletal fragments	brachiopods nautiloids skeletal fragments	brachiopods nautiloids bivalves bryozoans gastropods red algae skeletal fragments	red algae
Facies	BLM	MBM	CBLM	MM	SBM	MSC	GSC	CAB

Lithofacies 2 – Mottled Black Mudstone (MBM)

This facies includes black mudstones with bioturbation in the range of 0.3-0.9 and discontinuous, mm lamina. This facies typically has an effervescence of 0-1, but can occasionally be higher. It contains few fossil (<10%) and pelagic to hemipelagic sedimentation is inferred.

Lithofacies 3 – Calcareous Black Laminated Mudstone (CBLM)

This facies consists of black, laminated mudstones with moderate effervescence (typically 1-3, up to 5), rare bioturbation (0.0-0.2), and few fossils (<10%). This facies is interpreted to have been deposited under pelagic to hemipelagic sedimentation, but with more calcareous influence than BLM, likely due to increased carbonate cement.

Lithofacies 4 – Massive Mudstone (MM)

This facies consists of mudstones with massive bedding. They are highly effervescent (4-5), contain few fossils (<10%). Often has a sharp lower contact. Lack of bedding may be attributed to complete bioturbation (0.9-1.0) or high-energy turbidity current deposition.

Lithofacies 5 – Skeletal Black Mudstone (SBM)

This facies consists of black, laminated mudstones with >10% skeletal grains and low effervescence (≤ 2). They have moderate to no bioturbation (0.0-0.3) and exhibit mm-scale laminations. Allochem abundance and low effervescence indicate intermixed deposition of fine-grained siliciclastics and carbonate material, likely in a distal, low-energy turbidity flow.

Lithofacies 6 – Mud-supported Carbonate (MSC)

This facies is classified as a wackestone according to the Dunham classification scheme (Dunham, 1962). It includes calcareous mudstones with moderate to strong effervescence (>2) and >10% skeletal grains by volume. Bioturbation ranges from 0 to 0.6. Lower contact is often sharp and it is interpreted as low-energy turbidity flows.

Lithofacies 7 – Grain-supported Carbonate (GSC)

This facies includes all calcareous rocks that are grain-supported. They are highly effervescent (3-5) and typically lighter in color (3/N to 6/N). Bioturbation was difficult to identify and bedding is massive. The contact at the base of this unit is often sharp or scoured into basinal mudstone deposits, indicating deposition as turbidity flows.

Lithofacies 8 – Cryptalgal Boundstone (CAB)

Lithofacies 8 consists of rocks exhibiting cryptalgal laminated fabric. This is interpreted to have been created by red algal mats. These rocks are highly effervescent (3-5), contain few fossils, and have little to no bioturbation. This facies is found in all three cored wells in the transition area from the Onondaga Limestone to the Marcellus Shale and was also identified within the Cherry Valley Member in well COP 259 (Fig. 4.1 and A.1). This facies is typically interbedded with BLM and CBLM which indicates periods of algal mat deposition with intervening periods of relative quiescence in which the black, laminated muds were deposited. Unaltered structure suggests *in situ* deposition.

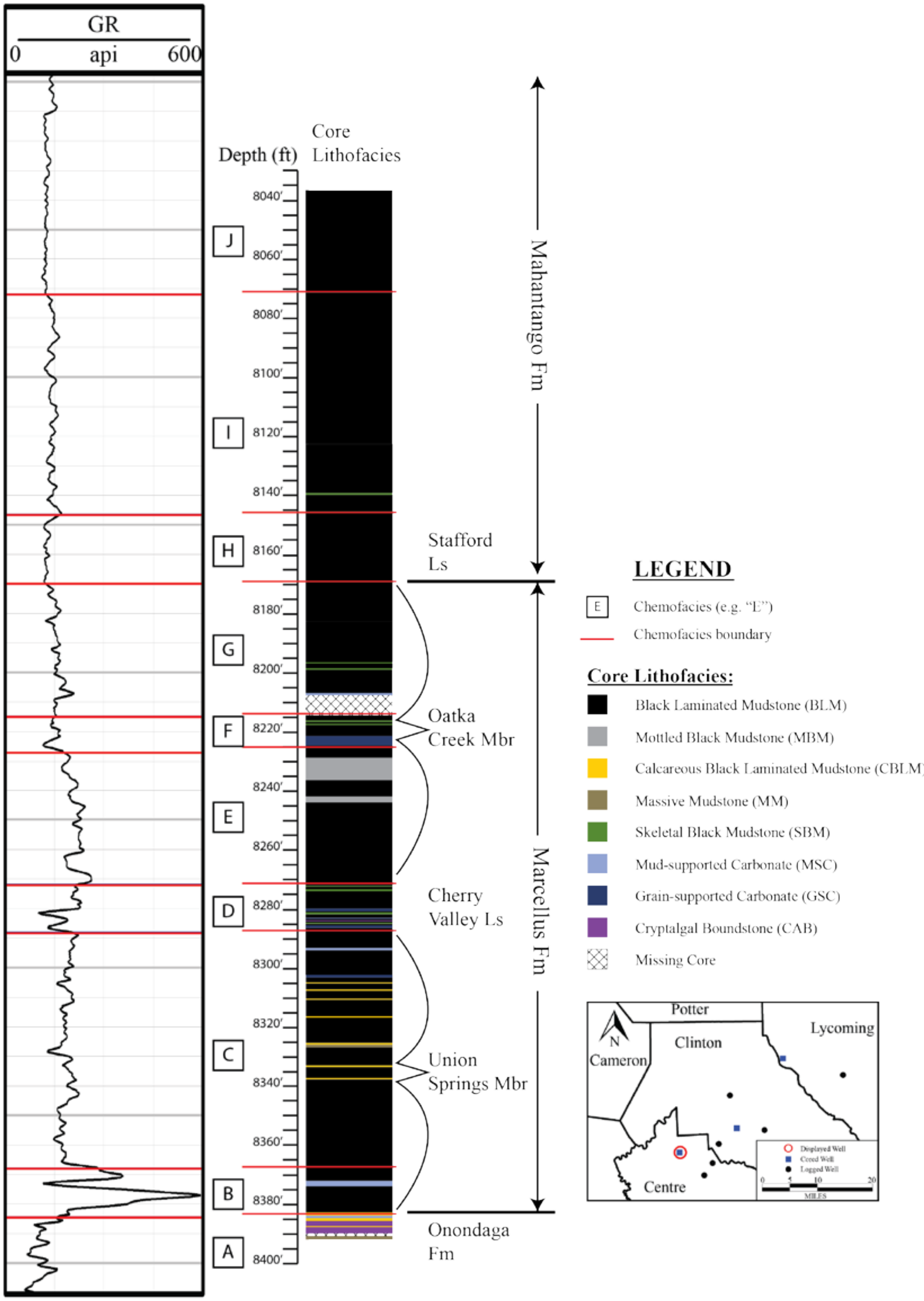

Figure 4.1. Lithofacies core description for the COP 259 well. Lithofacies are color-coded on the right. Gamma ray log depicted on left. Chemofacies boundaries designated by red horizontal lines and associated letter of chemofacies (i.e. "B"). Stratigraphic designation shown to right of lithofacies bar.

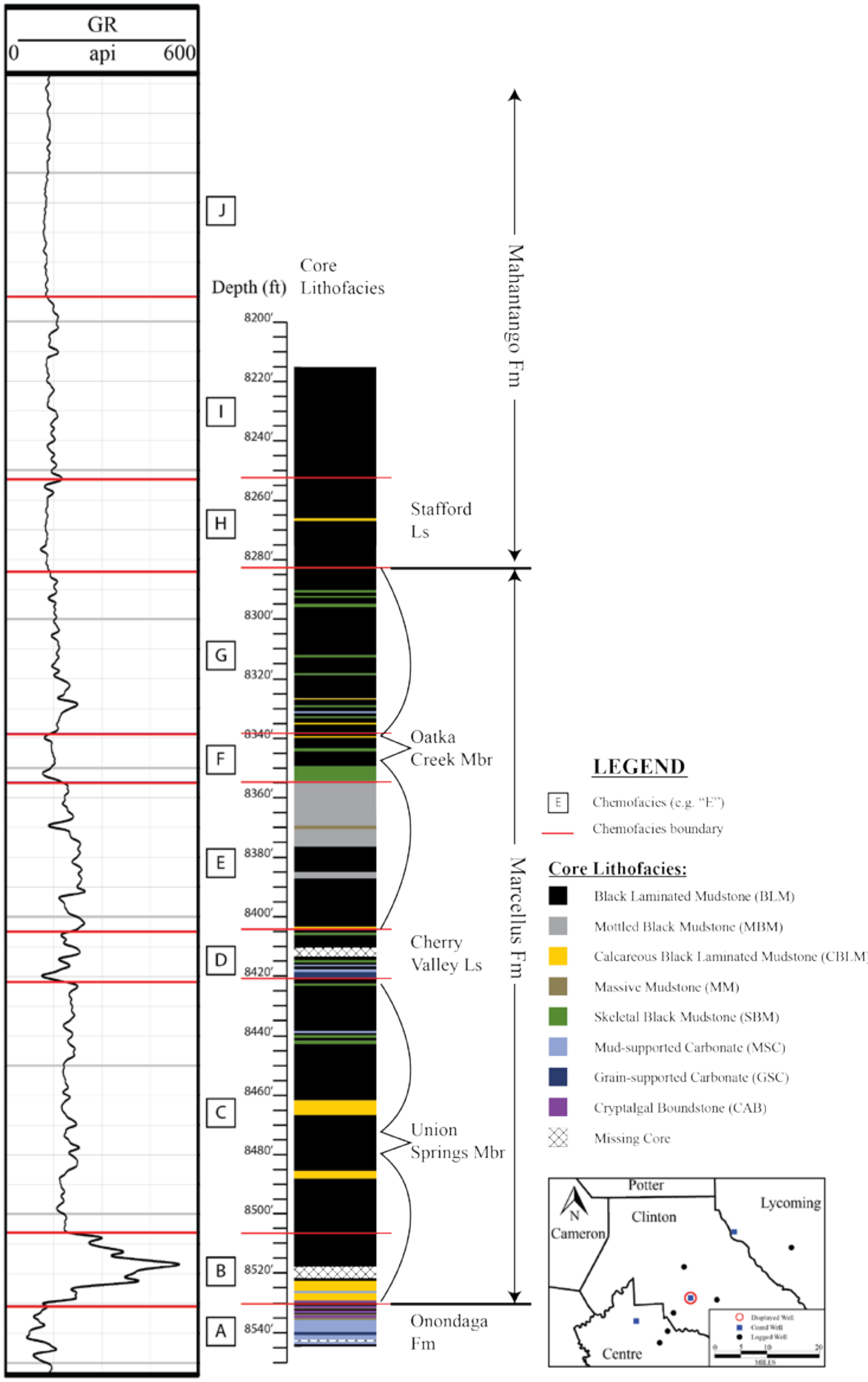

Figure 4.2. Lithofacies core description for the COP 653 well. Lithofacies are color-coded on the right. Gamma ray log depicted on left. Chemofacies boundaries designated by red horizontal lines and associated letter of chemofacies (i.e. "B"). Stratigraphic designation shown to right of lithofacies bar.

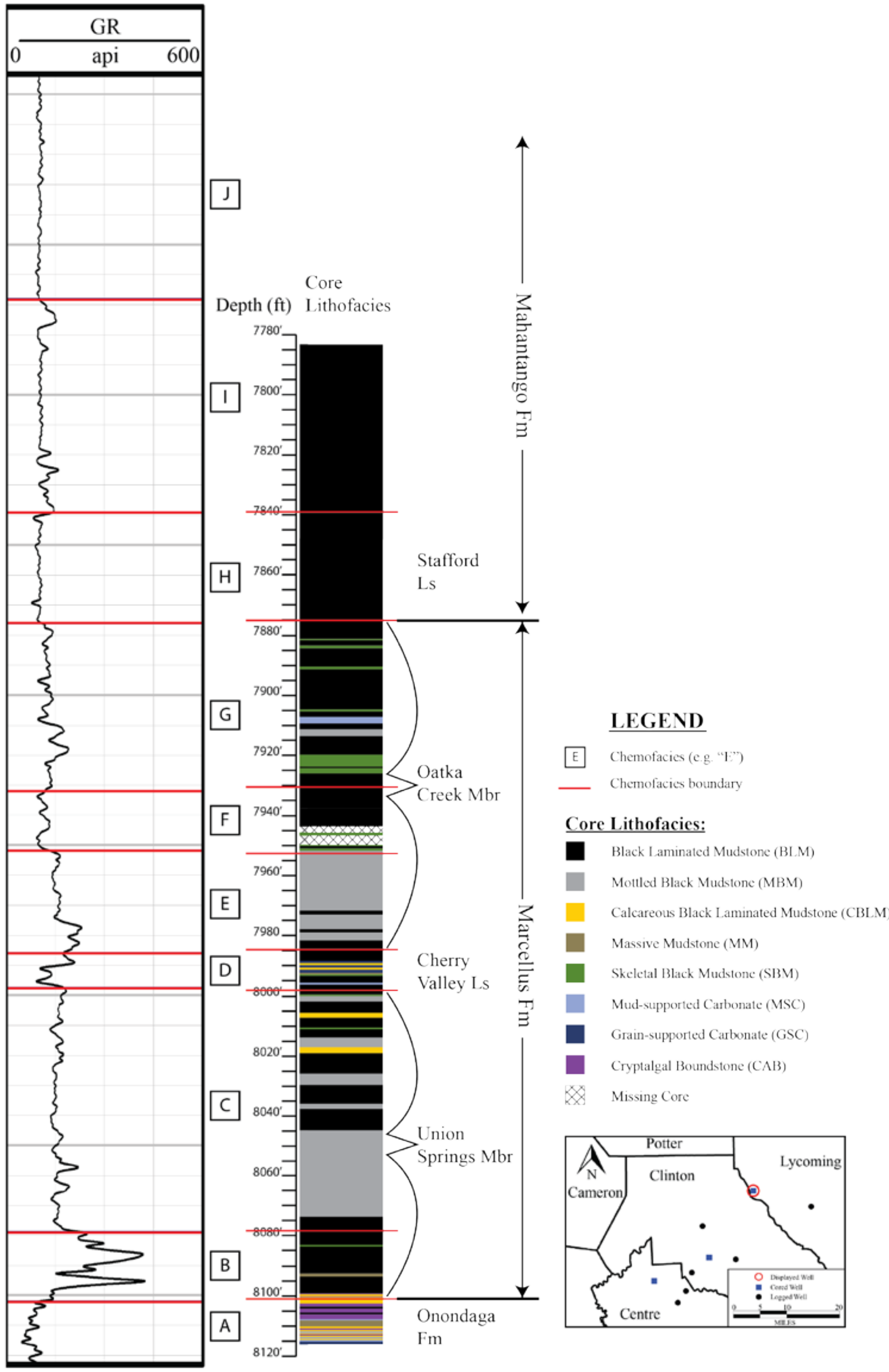

Figure 4.3. Lithofacies core description for the COP 289 well. Lithofacies are color-coded on the right. Gamma ray log depicted on left. Chemofacies boundaries designated by red horizontal lines and associated letter of chemofacies (i.e. "B"). Stratigraphic designation shown to right of lithofacies bar.

Chemofacies Description

Introduction

Trends in major element concentrations, isotope data, and paleo-redox and paleo-productivity sensitive element concentrations were plotted for each cored well (Appendix E). Geochemical trends recognizable in all three wells were used to identify ten chemofacies. Each chemofacies consists of distinct geochemical trends.

Chemofacies A (CF-A)

The top of chemofacies A (CF-A) closely follows the top pick for the Onondaga Formation and no base was picked in these wells due to lack of data. Moving up section in CF-A, calcite abundance is high and then progressively declines, $\delta^{13}C$‰ PDB values reach -29‰ and then become lighter (more negative), the amounts of redox-sensitive elements (Mo, U, V) are relatively low, and production-sensitive (Cu, Ni) elements are variable, though they tend to increase upward. The geochemical trends suggest a gradational change from open-marine deposition of the Onondaga Formation to deep-water, restricted marine deposition of the Marcellus Formation.

Chemofacies B (CF-B)

Chemofacies B (CF-B) has the highest abundance of organic matter, redox-sensitive and production-sensitive elements, and sulfur. It is also characterized, initially, by greater amounts of SiO_2 (>75 wt.%) and very little Al_2O_3 (<5 wt.%), and then later by decreasing SiO_2 (to ~60%) and increasing Al_2O_3 (to ~14%). The trends of SiO_2 and Al_2O_3 suggest greater abundance of quartz and less clay content during the initial deposition of CF-B and increasing clay content and less quartz moving up section.

Calcite abundance continues to decrease through this facies and $\delta^{13}C$‰ PDB values reach the apex of their negative excursion (-31.4‰) and begin to gradually trend towards more positive values. These geochemical data taken together indicate an initial period of very high production accompanied by heightened preservation due to conditions of anoxia/euxinia (Yeates, 2017). It is likely that the $\delta^{13}C$‰ values become extremely negative due to the reintroduction of ^{13}C-depleted carbon into the system as organic matter settling through the water column decays (Meyers, 2014). If rates of production and decay are high enough, this reintroduction creates a positive feedback and an excursion of $\delta^{13}C$‰ values towards the negative. This chemofacies represents the best reservoir target due to extreme enrichment in TOC and high quantities of SiO_2 and $CaCO_3$, which increases brittleness and the susceptibility to induced fracturing.

Chemofacies C (CF-C)

Geochemical signatures in chemofacies C (CF-C) remain relatively constant through 80-90' of section. Values for $\delta^{13}C$‰ PDB gradually become more positive throughout and values of TOC, Mo, U, V, Ni, and Cu increase near the top of CF-C and suggest relative enrichment throughout the interval. The top of this interval matches the top of the Union Springs Member of the Marcellus Formation.

Chemofacies D (CF-D)

The boundaries of chemofacies D (CF-D) correlate to the top and bottom boundaries of the Cherry Valley Member of the Marcellus Formation. This interval is thin (12-17') and is characterized by variable geochemical signatures. Overall, calcite wt.% increases whereas SiO_2, Al_2O_3, and Fe_2O_3 decrease. Amounts of Ni and Cu vary wildly and this chemofacies has some of the highest TOC values (excluding CF-B). CF-D is also marked by a distinct bench in the $\delta^{13}C$‰ curve as it moves abruptly to more positive values. The variability is interpreted to be a result of episodes of carbonate, oxygen, and nutrient introduction to the area during periodic turbidity flows (as evidenced by periodic episodes of SBM, MSC, and GSC lithofacies) during a relative lowstand in sea-level. CF-D represents the second-best reservoir interval because it contains high TOC values within the interval and immediately above and below, and the introduction of increased $CaCO_3$ makes it more susceptible to induced fracturing.

Chemofacies E (CF-E)

Chemofacies E (CF-E) is similar to CF-C in that the geochemical signatures remain relatively constant throughout the section (35’-50’). $\delta^{13}C$‰ PDB values continue their gradual trend towards enrichment with respect to ^{13}C. Production- and redox-sensitive elements decrease slightly moving up section and Al_2O_3 increases slightly.

Chemofacies F (CF-F)

Sharp decreases in most geochemical attributes (TOC, C/N, $\delta^{15}N$‰, Mo EF, U EF, Cu, and Ni) characterizes chemofacies F (CF-F). Chemofacies F also includes another sharp shift to more positive $\delta^{13}C$‰ values. This chemofacies is interpreted to be a result of increased turbidity flow deposition (due to increases in SBM, MSC, and GSC lithofacies), but without increased production and preservation of organic matter like that seen in CF-D.

Chemofacies G (CF-G)

Amounts of redox- and production-sensitive elements increase again in chemofacies G (CF-G) although not as high as in CF-E or CF-C. $\delta^{13}C$‰ values make an excursion to the left before continuing towards positive values. The top of CF-G is equivalent to the top of the Marcellus Formation.

Chemofacies H (CF-H)

Chemofacies H (CF-H) is correlative to the stratigraphic equivalent of the Stafford Limestone Member of the Mahantango Formation, and is marked by an increase in $CaCO_3$ and slight decrease in Al_2O_3, S, and Ni. Sharp decreases are seen in Cu, TOC, C/N, and EF-Mo, and the $\delta^{13}C$‰ values make a sharp positive excursion, i.e., relatively more enriched with respect to ^{13}C. Core description and lithofacies designations (Appendix A) do not differentiate this unit which highlights the importance of geochemical analyses in mudrocks.

Chemofacies I (CF-I)

This chemofacies is fully present only in COP 259. In all three wells, it is marked by an increase in productivity- and redox-sensitive elements, although the concentrations don't reach the values seen in the Marcellus Formation. The one exception is in the lower 16 feet of CF-I in COP 289 where TOC and associated productivity- and redox-sensitive elements are anomalously high. CF-I is interpreted to have been deposited under dysoxic conditions and relatively low rates of organic matter production.

Chemofacies J (CF-J)

Part of chemofacies J (CF-J) is only seen in COP 259 and the associated chemical signatures are remarkably similar to those seen in CF-H. $CaCO_3$ values increase and values of Al_2O_3, S, and Ni decrease slightly. Cu, TOC, C/N, and EF-Mo decrease sharply and the $\delta^{13}C$‰ values make a sharp excursion towards the positive

CHAPTER FIVE

Subsurface Correlation and Mapping of Chemofacies and Lithofacies

Prediction of Chemofacies Using Wireline Logs

TOC Prediction from Wireline Logs

TOC abundance is one of the most important characteristics of an unconventional reservoir. As such, predicting TOC in wells lacking core control is essential in determining target zones when drilling. Many methods have been used to predict TOC using wireline logs including: natural gamma ray (GR) logs, spectral gamma ray logs, pulsed-neutron spectral logs, gamma ray/sonic combinations, density logs, resistivity (R) logs, and resistivity/porosity combinations (Passey et al., 1990). All 9 wells in this study have gamma ray and resistivity logs. All wells, except for COP 289, have porosity logs and density logs. Six of the wells have sonic logs and only 3 wells have spectral gamma ray logs. None of the wells have pulsed-neutron spectral logs. Based on the available data and correlations to TOC, two separate methods were used to predict TOC: gamma ray and a resistivity/porosity combination.

TOC prediction from gamma ray logs. The gamma ray log records natural gamma-ray emissions from the rock. The principal sources of radiation are potassium-40 (K) and elements in the uranium (U) and thorium (Th) decay series (Schmoker, 1981). Plotting Th and K concentrations vs. GR for the three cored wells produces R^2 values of 0.01 and 0.001, respectively (n=414). Plotting U concentrations vs. GR (Fig. 5.1)

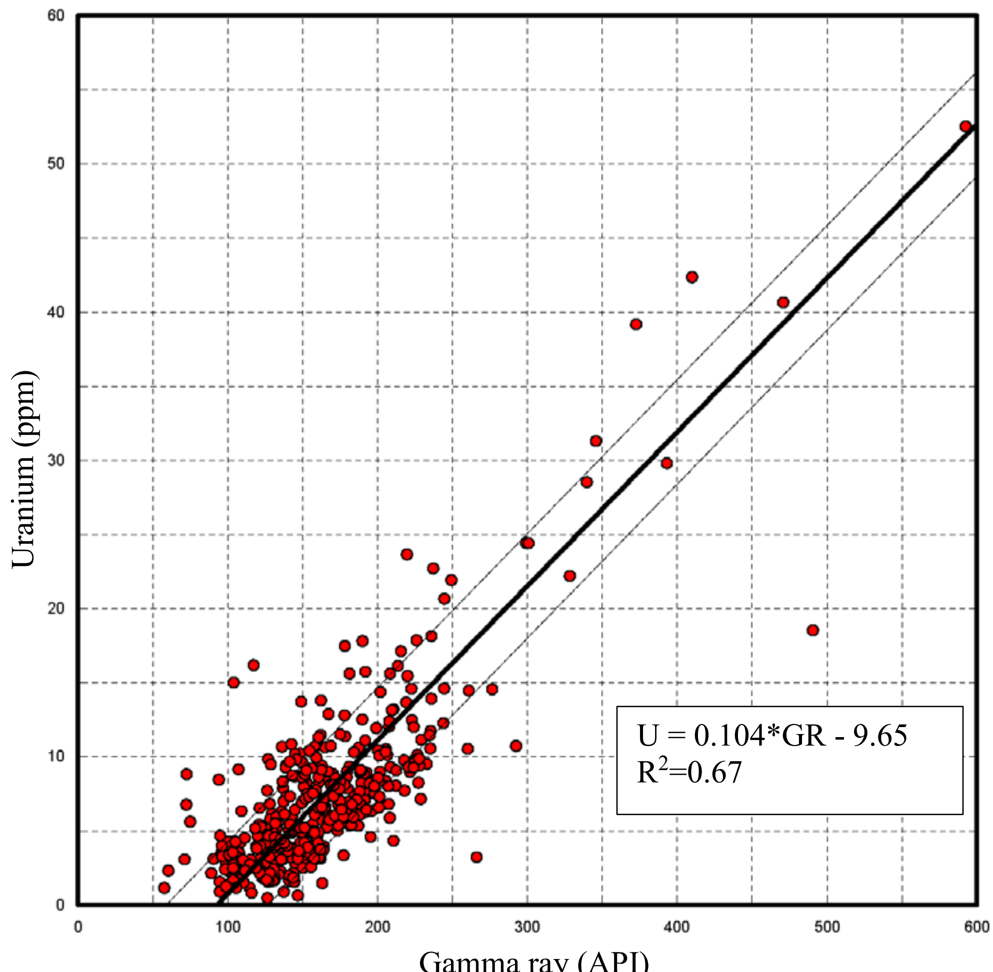

Figure 5.1. Plot of gamma-ray log values vs uranium concentrations acquired from XRF analysis for the three cored wells (n=414).

suggests that variations in the gamma ray log are principally controlled by changes in uranium concentration and that thorium and potassium concentrations remain relatively constant. Research by Schmoker (1981) and Swanson (1960) identified similar control of gamma ray intensity by variations in uranium concentration.

Zones of anomalously high gamma ray activity have been used historically to identify organic-rich rocks. This method is based on the association of uranium and organic matter and is most accurate when uranium concentration controls variations of

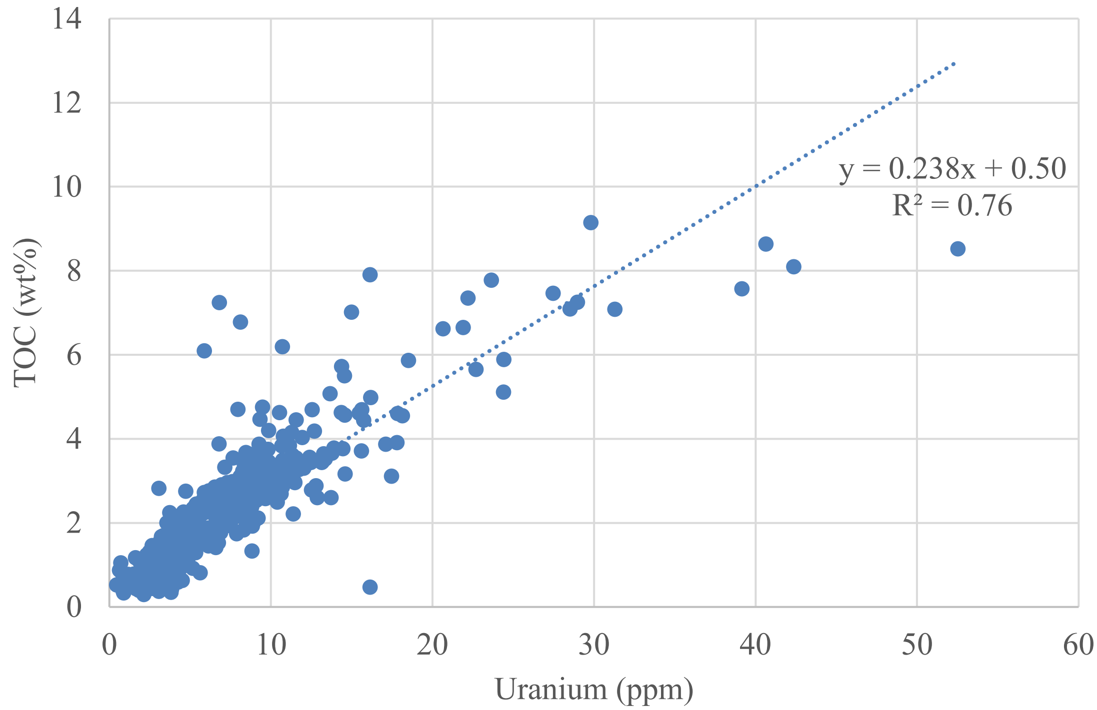

Figure 5.2. Plot of U vs TOC for the three cored wells (n=502). Indicates high correlation between U concentration and amount of organic matter.

gamma ray intensity (Passey et al., 1990; Schmoker, 1981). Under anoxic conditions, U(VI) is reduced to U(IV) (Tribovillard et al., 2006) and studies indicate that the removal of reduced U from the water column to the sediment can be accelerated by the presence of organic substrates (McManus et al., 2005; Algeo and Maynard, 2004; Klinkhammer and Palmer, 1991). As both organic matter accumulation and uranium precipitation are linked to conditions of anoxia (Tribovillard et al., 2006; McManus et al., 2005; Algeo and Maynard, 2004) and the presence of organic matter can enhance U precipitation (Algeo and Maynard, 2004; Klinkhammer and Palmer, 1991), U and TOC usually correlate well (Tribovillard et al., 2006; McManus et al., 2005). A plot of U concentration from XRF analyses against measured TOC supports the relationship of U and TOC (Fig. 5.2).

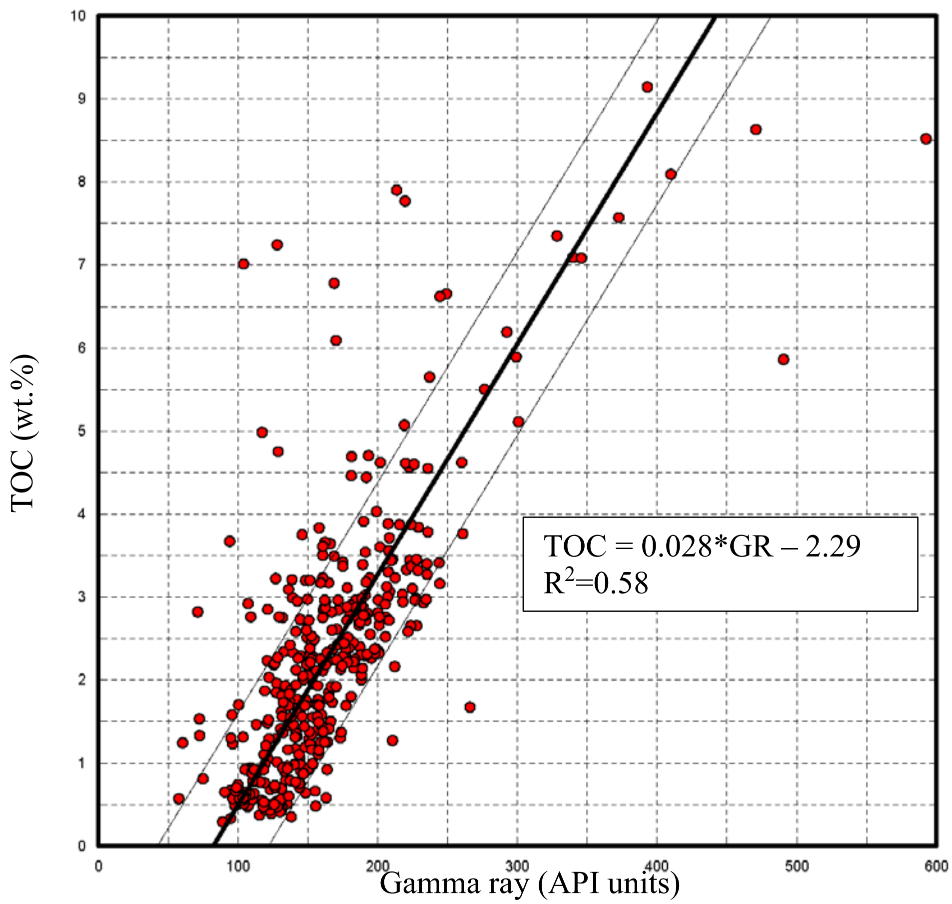

Figure 5.3. Plot of GR intensity from wireline logs against TOC measured through pyrolysis.

Schmoker (1981) developed an equation based on the relationship between organic richness and gamma ray response for Devonian shales in the western Appalachian Basin. This study employs a similar, though simpler, equation based on the linear correlation of TOC and GR (Fig. 5.3):

$$TOC = 0.0278*GR - 2.286 \qquad (5.1)$$

This equation was used to calculate a predicted TOC curve from normalized GR logs. GR logs were normalized using a range of 5^{th} to 95^{th} percentile (Schafer, 2011). Figure 5.4 shows plots of predicted TOC curves with measured TOC values for the cored wells. The predicted TOC curve tracks measured TOC accurately except within chemofacies D (aka Cherry Valley Mbr). Because this equation is calibrated specifically for the three cored wells in this study, it cannot be universally applied to any other organic-rich shale and should not be used for the Marcellus Formation across large regions of the basin, although it was used for the 6 un-cored wells in this study (Passey et al., 1990; Schmoker, 1981).

TOC prediction from resistivity/porosity log combination. Passey et al. (1990) developed an equation that uses an overlay of properly scaled resistivity and sonic transit time logs (or other porosity curves) to predict organic matter content. The prediction is based on the sensitivity of resistivity to generated hydrocarbons in the formation fluid and the response of sonic transit time to low-density, low-velocity kerogen. In an immature source rock, separation of the two curves is due solely to the increase of sonic transit time through kerogen. In a mature source rock that has generated hydrocarbons, curve separation is due both to increased sonic transit time and increased resistivity.

The logs were adjusted such that their relative scaling was one logarithmic resistivity cycle (i.e. 0.1 to 1.0 Ohms) per -50 μsec/ft (-169 μsec/m). A baseline was established in the Onondaga Formation where the two curves overlap and the equation (Equation 5.2) developed by Passey et al. (1990) was applied in order to calculate Δ log R

$$\Delta \log R = \log_{10} (R/R_{\mathrm{baseline}}) + [0.02 * (\Delta t - \Delta t_{\mathrm{baseline}})] \qquad (5.2)$$

Where R is the resistivity measurement at a given depth, R_{baseline} is the baseline resistivity measurement in the Onondaga Formation, Δt is the sonic transit time at a given depth, and $\Delta t_{\mathrm{baseline}}$ is the baseline sonic transit time measurement in the Onondaga Formation.

The overlain logs and resulting Δ log R curve are shown in Figure 5.5. The generated Δ log R curve was then used as an input to the equation for TOC prediction (Equation 5.3) developed by Passey et al. (1990)

$$TOC = \Delta\ log\ R * 10^{(2.297-(0.1688*LOM))} \qquad (5.3)$$

Where *Δ log R* is the result of Equation (5.2) and *LOM* is the level of organic metamorphism.

LOM (level of organic metamorphism) is a measurement developed by Hood et al. (1975) that describes the level of thermal metamorphism to which organic matter has progressed during burial. For oil-prone kerogen, onset of petroleum generation begins at LOM 7 and onset of over-maturity starts at LOM 12 (Passey et al., 1990; Hood et al., 1975). Hood et al. (1975) correlates LOM to other measurements of thermal maturation such as CAI (conodont color alteration index) and $\%R_o$ (vitrinite reflectance). Maps of thermal maturity from CAI and $\%R_o$ (Repetski and Geological Survey (U.S.), 2008) indicates that the Marcellus Formation in the study area is in the dry gas generation window. Devonian CAI_{max} values range from 3.0 to 4.5 within the study area. Devonian $\%R_{o(mean)}$ values in the study area range from 2.0 to 2.5. Correlating these values back to LOM, suggests that LOM values in the study area range from 12 to 16 (Repetski and Geological Survey (U.S.), 2008; Voldman et al., 2008; Hood et al., 1975).

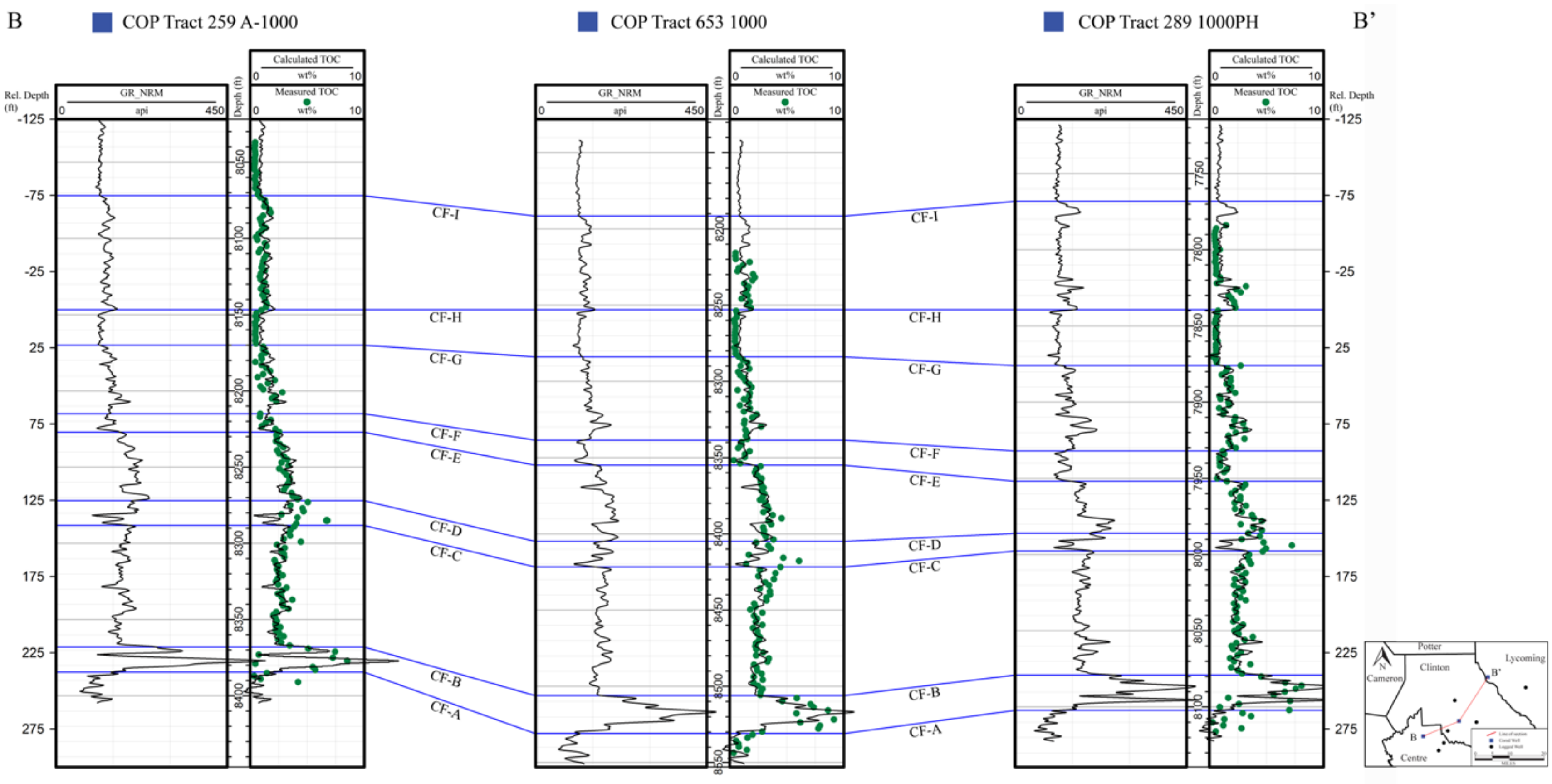

Figure 5.4. Cross section comparing predicted TOC (black, track 2) to measured TOC (green dots, track 2). The predicted TOC is fairly accurate, although it under-predicts in CF-D (Cherry Valley Mbr) for each well. Blue lines represent tops of chemofacies (Appendix E).

When an LOM value of 12 is used in the Δ log R equation, the generated curve under-predicts TOC. The most accurate TOC prediction using the Δ log R method is generated when an LOM value of 10 is used, even though this value is too low for the degree of maturation of the Marcellus Formation in the area of interest. This suggests that caution need be applied when calculating TOC using the Δ log R method and that calibration to measured TOC values is needed when applying this method.

Predicted TOC from both GR and Δ log R methods were plotted with measured TOC values to compare their accuracy (Fig. 5.5). The GR method was more accurate in the lower Union Springs zone of maximum organic enrichment (CF-B) whereas the Δ log R method more accurately predicted the high TOC values associated with the Cherry Valley Member (CF-D). Except for those two zones of increased organic enrichment, both methods accurately predicted TOC +/- 0.75 wt.%.

As all 9 wells in the study area have GR logs and the GR method more accurately predicts the targeted zone of maximum organic enrichment (CF-B) in the lower Union Springs Member, the GR method was applied to all 9 wells in the study area to generate predicted TOC curves.

Prediction of Redox-Sensitive Elements

Conditions of reduction/oxidation are important controls on the accumulation and preservation of organic matter in the rock record (Tribovillard et al., 2006; Thunell et al., 2000; Calvert et al., 1996; Arthur and Sageman, 1994; Calvert and Pedersen, 1993; Pedersen and Calvert, 1990; Demaison and Moore, 1980).   Molybdenum (Mo), uranium (U), and vanadium (V) are redox-sensitive elements whose concentrations, when normalized

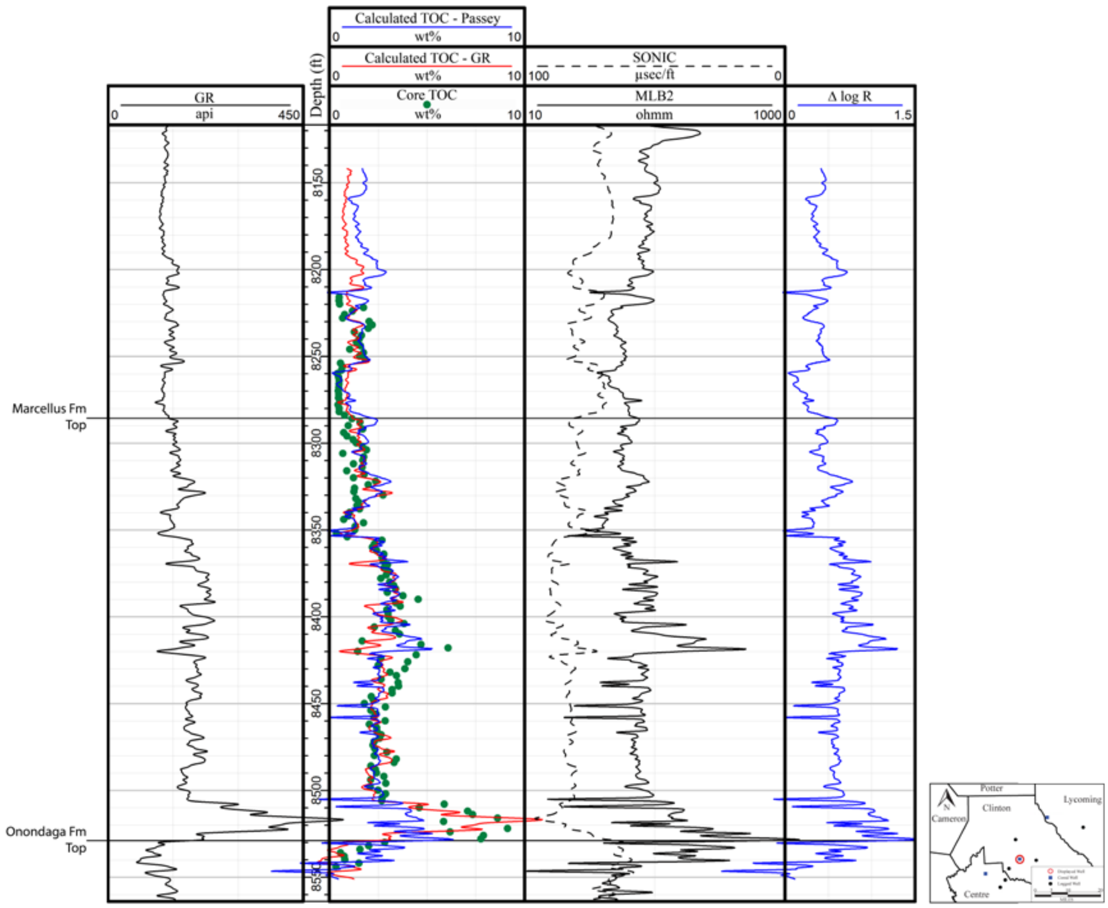

Figure 5.5. Comparison of TOC prediction using GR log (red) and Δ log R (blue) techniques against measured TOC (green dots) for COP Tract 653 1000. The GR method is more accurate at predicting TOC in the lower Union Springs area of high organic enrichment whereas the Δ log R method more accurately predicts the high TOC values associated with the Cherry Valley mbr. Overall, predicted TOC from GR is slightly more accurate. Track 3 shows the overlay of sonic transit time (dashed line) and resistivity (solid line). Track 4 (far right) depicts the resulting Δ log R curve that was then used to calculate TOC.

to standard shale values, indicate relative grades of enrichment and/or depletion where values greater than one indicate relative enrichment and values less than one indicate relative depletion (EF Mo, EF U, EF V). High organic matter content within the Marcellus Formation is attributed to high productivity (Cu and Ni curves) and conditions of anoxia/euxinia. For more information on paleo-redox and paleo-ocean chemistry for the three cored wells, see Yeates (2017).

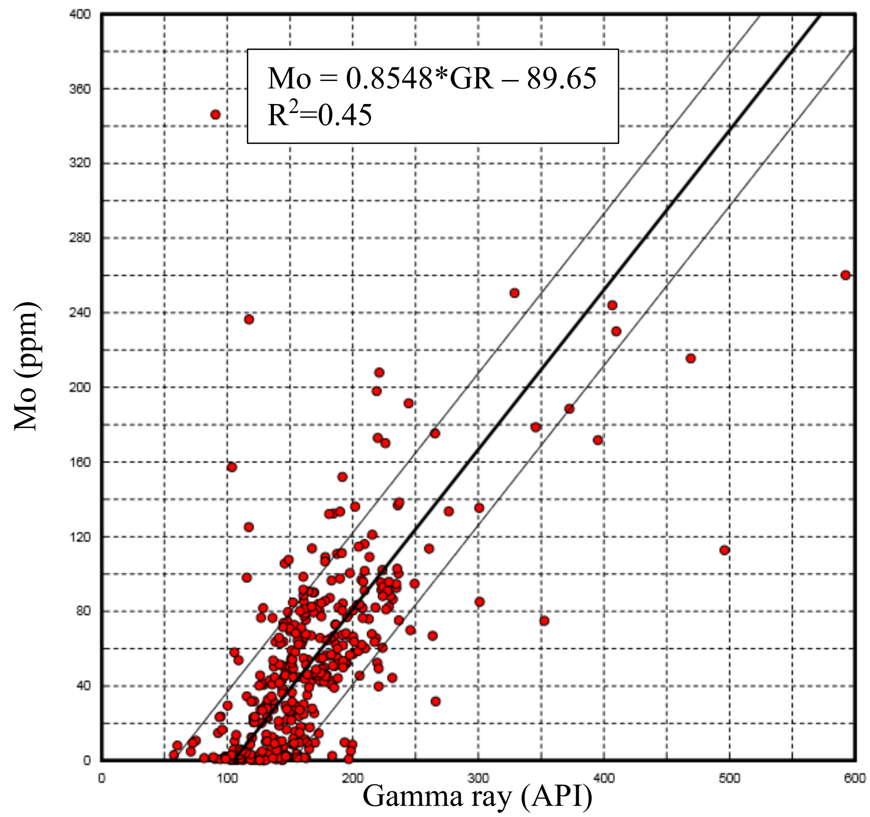

Figure 5.6. Plot of GR intensity from wireline logs against Mo measured from XRF analysis. n=397

As previously noted, GR intensity is heavily influenced by U concentration, which has a strong correlation to other redox-sensitive geochemical data such as Mo, V, and TOC (Fig.5.6). Therefore, GR can be used to predict trends in redox-sensitive elements. This relationship and others were used to extrapolate chemofacies tops to wells lacking core control (Fig. 5.7 and 5.8).

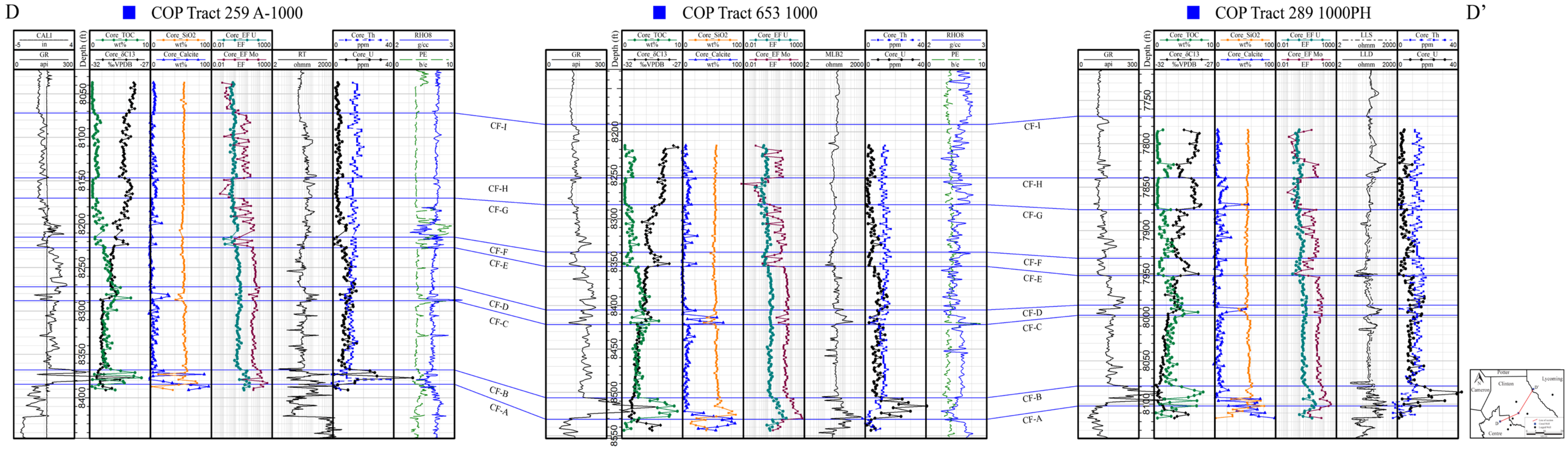

Figure 5.7. Cross section showing the correlation of key geochemical data to standard wireline logs. Blue lines represent the tops of chemofacies. Variations in GR are useful in identifying chemofacies because GR is controlled by uranium concentration and most chemofacies are delineated in part by TOC, EF U, EF V, and EF Mo which, like U, are controlled to some extent by redox conditions.

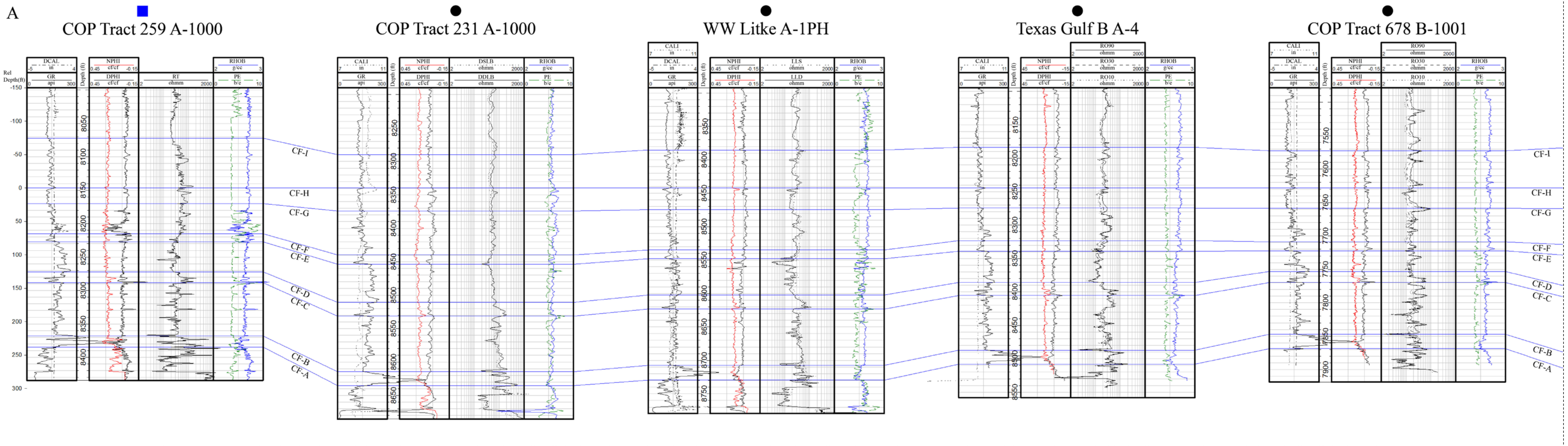

Figure 5.8a. Cross-section showing the correlation of chemofacies tops throughout all wells in the study. Continues into the next figure (Fig 5.8b). Wells are hung on the top of CF-H because it is an easily recognizable flooding surface that extends through all wells in the study area.

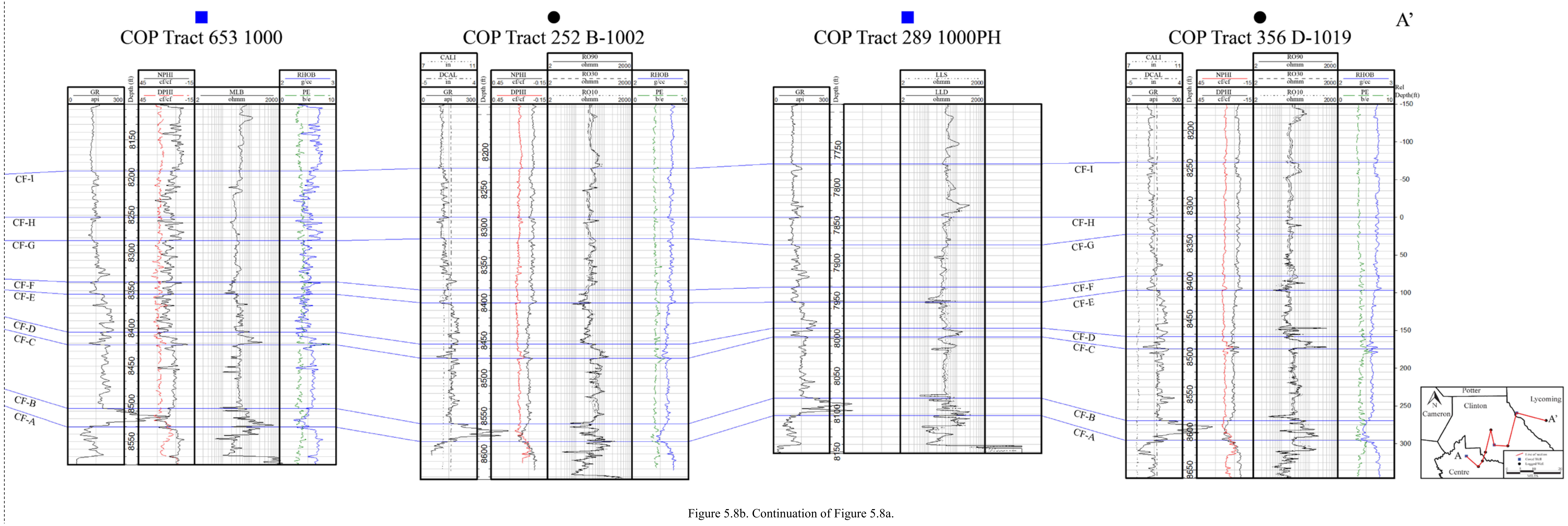

Figure 5.8b. Continuation of Figure 5.8a.

Structure Map

Mapping the subsea depth to the top of the Marcellus Formation indicates structural deepening towards the southeastern portion of the study area (Fig. 5.9).

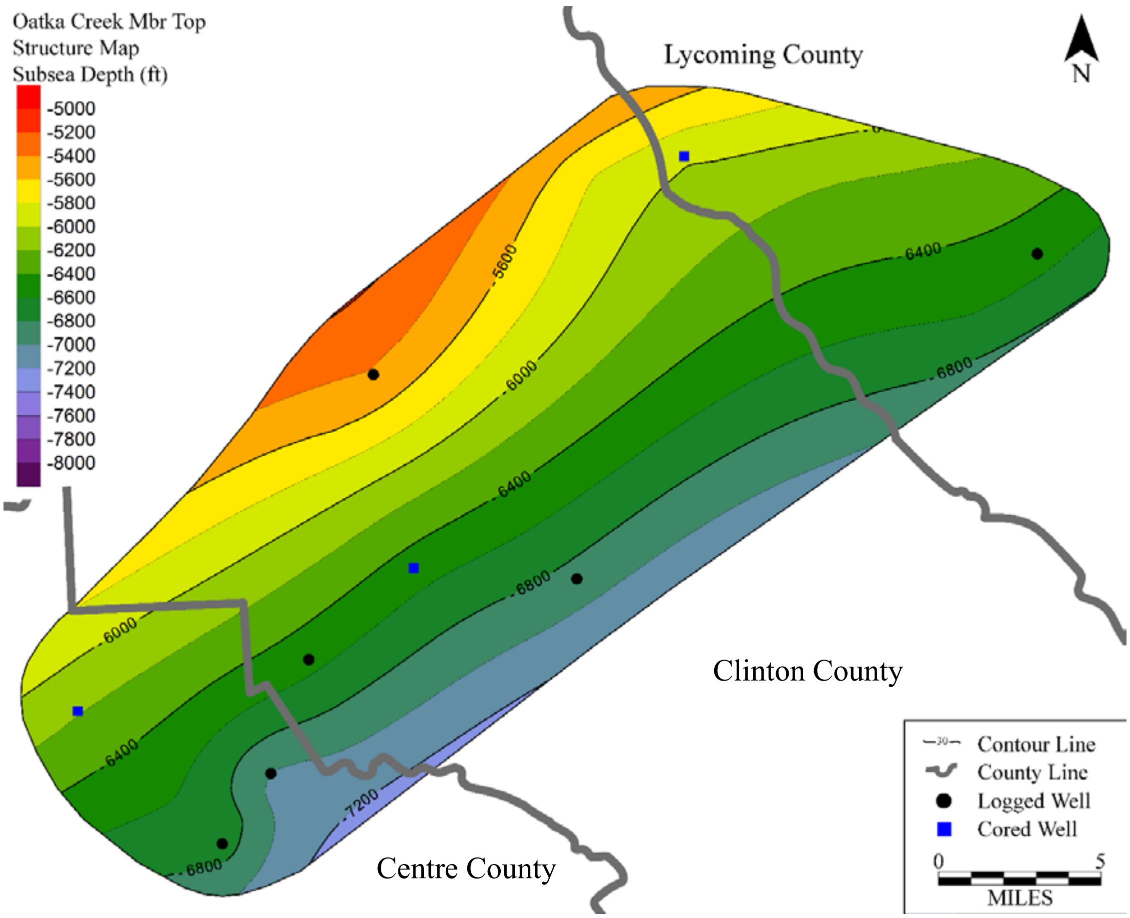

Figure 5.9. Structure map of the subsea depth to the top of the Marcellus Formation. This area of the Appalachian Basin deepens to the southeast.

Lithostratigraphic Isopach Maps

Lithostratigraphic isopach maps are found in Appendix F. The isopach map of the Hamilton Group (Fig. F.1) indicates a general thickening toward the orogenic front to the east/southeast. The Marcellus Formation isopach (Fig. F.2) indicates thickening at a near-constant rate to the southeast, toward the orogenic front. The Mahantango Formation also thickens to the east/southeast but has greater lateral variation and is much thicker at the location of COP 356 (Fig. F.3). The Mahantango Formation is interpreted as deltaic deposits prograding westward/northwestward across the basin as the Acadian Orogeny propagates further inland and the greater lateral variation when compared to the Marcellus Formation is due to different depositional environments.

Isopach maps for the Union Springs and Oatka Creek Members (Fig. F.4-F.5) also indicate fairly constant rates of thickening towards the orogenic front to the east/southeast. These units consist mostly of BLM, CBLM, MBM, SBM and occasional MSC and GSC and a deep water, relatively quiescent depositional environment is interpreted. The isopach map of the Cherry Valley Member (Fig. F.8) indicates higher rates of deposition to the south/southeast. This trend indicates greater input and/or growth of carbonate material to the south.

Chemofacies Isopach Maps

CF-B represents the interval of maximum organic production and preservation and the isopach (Fig. F.6) indicates that it thickens to the east/southeast. CF-C represents most of Union Springs Member thickness and follows the same trendline (Fig. F.7). CF-D and the Cherry Valley Member are roughly equivalent and the isopach (Fig. F.8) indicates a thickening to the south/southeast. CF-E is similar to the trend for the Oatka Creek Member which thickens to the southeast (Fig. F.9). The thickness of CF-F is different from the main trend and thickens to the northeast (Fig. F.10). This unit is geochemically and lithologically similar to CF-D and the trend indicates that the area to the northeast was more compatible for carbonate growth and/or deposition during this time. CF-G is the last chemofacies unit in the Marcellus Formation and follows the trend of the Oatka Creek Member and thickens to the southeast (Fig. F.11).

CF-H is comparable to the stratigraphic equivalent of the Stafford Limestone Member of the Mahantango Formation. Isopach thickness trends (Fig. F.12) indicate a northeast-striking depocenter and two wells off that trend (COP 259 and COP 356) indicate areas of relative thinning. CF-I overlies CF-H and trends in thickness (Fig. F.13) are reversed from those of CF-H indicating that areas of relative thinning during CF-H time became areas of relative thickening during CF-I deposition.

TOC Net Thickness Maps

One of the primary reservoir characteristics of an unconventional play is the amount of organic matter present (Wang and Carr, 2013). Predicted TOC curves from GR for each well were used to calculate net thickness values of TOC that meet a certain cutoff. Cutoffs of 1%, 2%, 3%, 4%, 5%, 6% 7.5%, and 10% were applied to the wells and net thicknesses were calculated for two stratigraphic intervals: the entire Marcellus Formation, and the Union Springs Member. The values for net thickness were gridded and contoured to show trends in relative concentration of organic matter. As the Union Springs Member is the only interval where predicted TOC values exceed 5 wt.%, maps for TOC cutoffs greater than 4% were only created for the Union Springs Member (Appendix G).

The general trend of the TOC >1 wt.% map (Figures H.1) indicates thickening toward the orogenic front to the southeast and follows the isopach of the Marcellus Formation (Fig. G.3). This is because majority of the Marcellus Formation has TOC values greater than 1 wt.% in the study area so the trends are dependent upon gross lithostratigraphic thicknesses. Net TOC >2 wt.% for the Marcellus Formation (Fig. H.2) also generates a map that thickens to the southeast and follows lithostratigraphic thickness trends. However, the same TOC cutoff generates a map for the Union Springs Member (Fig. H.6) that thickens to the east. The net TOC >3 wt.% for both intervals thickens to the east/northeast (Fig. H.3 and H.7). And maps for TOC cutoffs of 4, 5, and 6 wt.% generate maps that indicate thickening of high TOC values to the north/northeast (Fig. H.4, and H.8-H.10). The succession of thickness trends for cutoffs of 1 to 6 wt.% TOC indicates a shift the factors controlling net TOC thicknesses. Lower TOC (1 to 3 wt.%) net thicknesses are mostly controlled by lithostratigraphic thickness trends whereas higher TOC (≥4 wt.%) net thicknesses are likely controlled by local variations in paleo-productivity and paleo-redox conditions. These maps indicate that the north/northeast section of the study area had conditions more conducive to high concentrations of organic matter production and preservation.

The net TOC >7.5 wt.% map (Fig. H.11) also indicates a general trend of increased TOC thickness to the northeast and the TOC >10 wt.% map (Fig. H.12) suggests thickening of the highest TOC values to the northwest. However, as seen in the plot of GR vs TOC (Fig. 5.3), the correlation begins to break down at higher TOC values. Therefore, the trends seen in maps for cutoffs of 7.5 and 10 wt.% are less accurate although they also indicate that high concentrations of organic matter don’t follow lithostratigraphic thickness trends.

CHAPTER SIX

Conclusions

1. Chemofacies B represents the best reservoir interval due to high concentrations in TOC and SiO_2 which, combined, form an interval that is susceptible to fracture stimulation and has the potential to produce the most hydrocarbons. Chemofacies D represents an additional reservoir target because it typically has high concentrations of TOC and $CaCO_3$.
2. Trends in paleo-redox and paleo-production sensitive elements (Mo, U, V, Cu, Ni) suggest that high concentrations in organic matter were deposited in euxinic to anoxic conditions likely driven by high rates of production, especially in chemofacies B. Later Marcellus deposition occurred during periods of relatively more oxic conditions.
3. Control of GR intensity by U concentration, and close association of U and TOC allows for the prediction of TOC using the linear relationship of GR and TOC. This method predicts TOC more accurately in the key reservoir interval (CF-B) than the ΔlogR method, whereas the ΔlogR method predicts TOC more accurately in the secondary reservoir interval (CF-D). Because GR is controlled by a redox-sensitive element (U), it can also be used to predict trends in Mo and V, and is useful in correlating trends in $\delta^{13}C$, Cu, and Ni.

4. Lithostratigraphic isopach maps suggest general thickening towards the Acadian orogen to the present-day east/southeast. The Marcellus Formation isopach thickness trend suggests constant rates of thickening toward the southeast.
5. TOC enrichment net thickness maps indicate that the northeastern portion of the study area was more conducive to the production and preservation of organic matter.

APPENDICES

APPENDIX A

Core description sheets and key core photos

This appendix contains the digitized versions of core description sheets for each of the three cored wells in order from SW to NE as follows: COP 259, COP 653, and COP 289. It also contains key core photos.

Project/Well: Marcellus COP Tract 259 A-1000 **Logged By: Jared Hanson/Bart Yeates**

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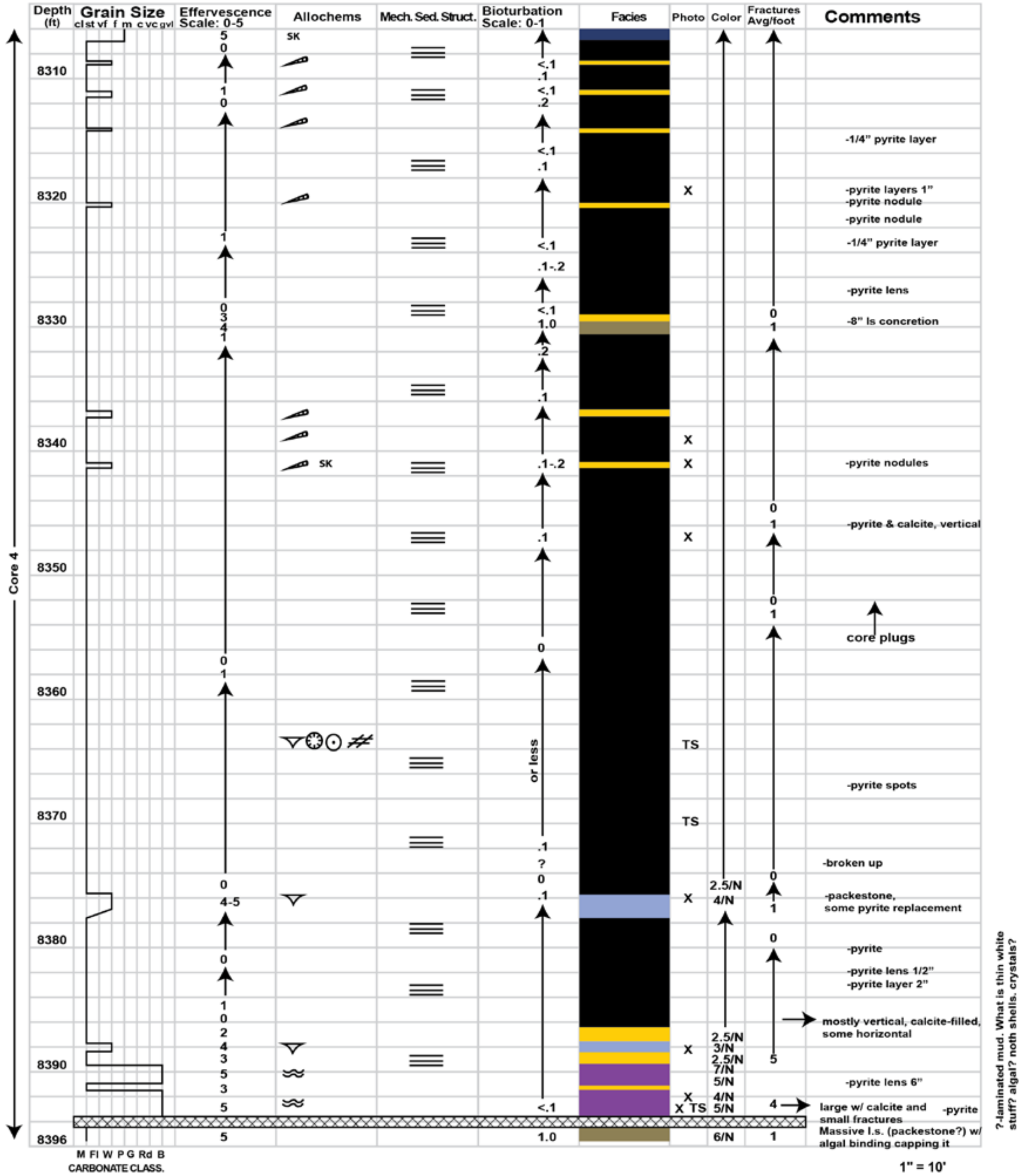
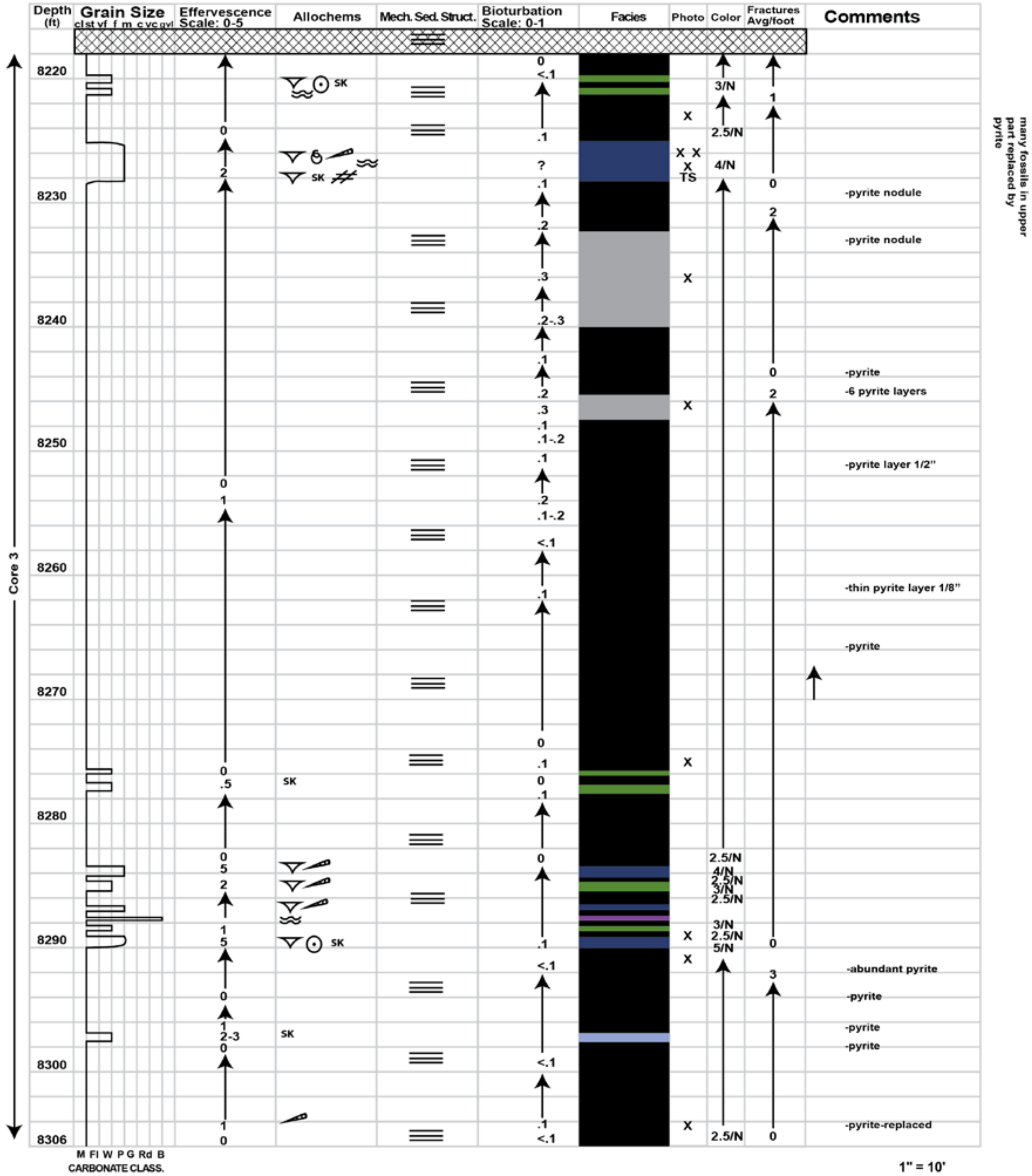
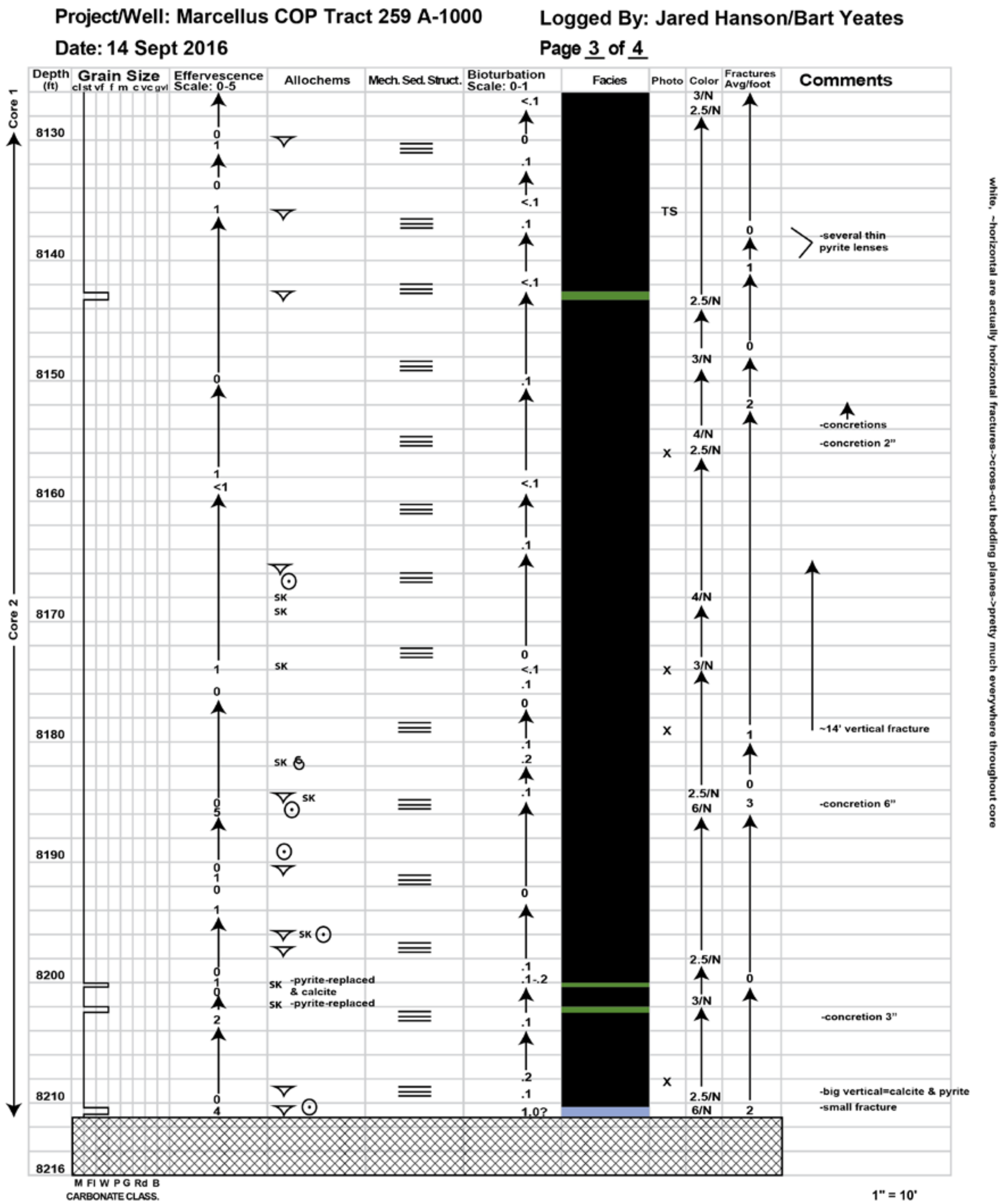


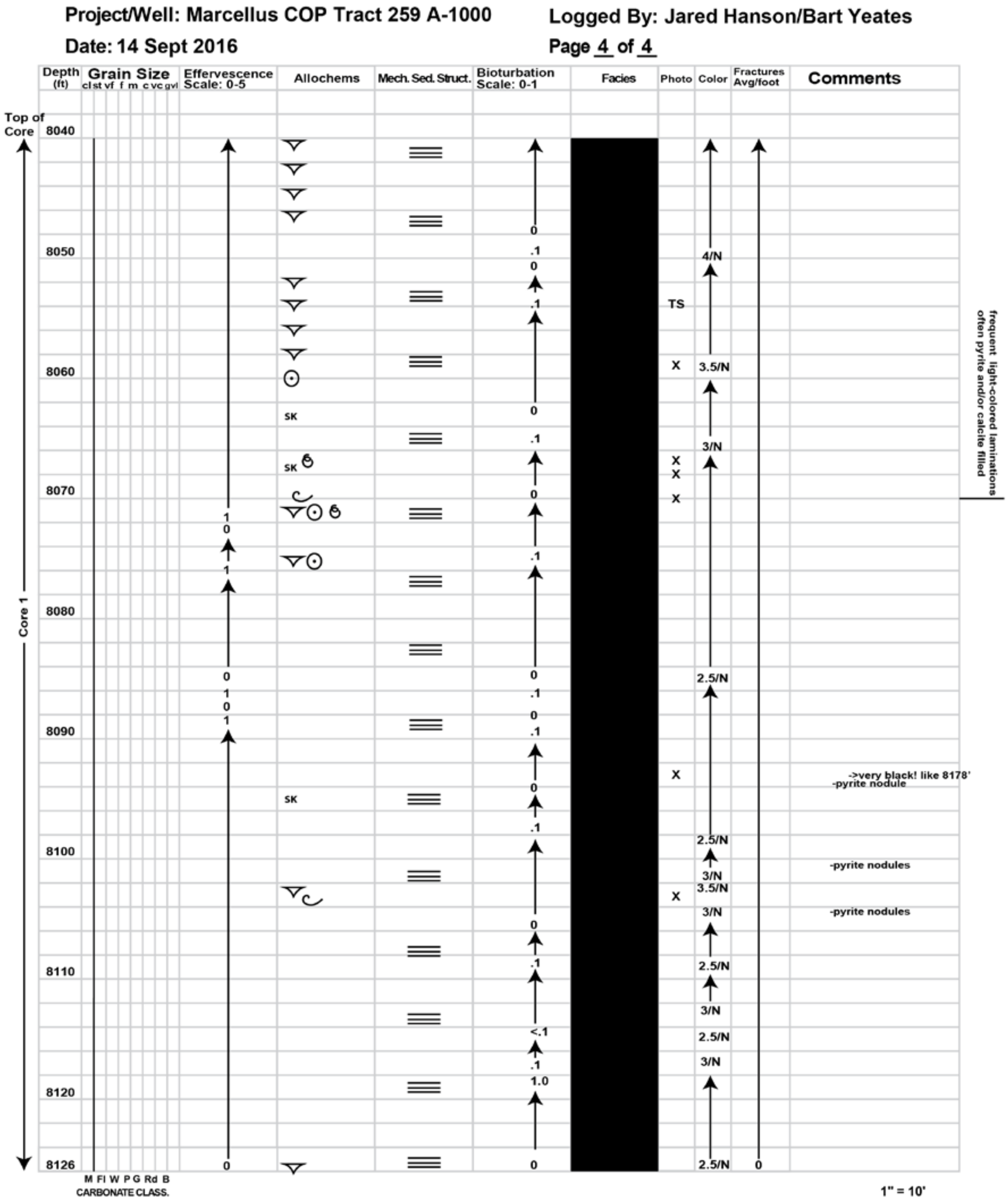
Project/Well: Marcellus COP Tract 259 A-1000 Logged By: Jared Hanson/Bart Yeates

Date: 14 Sept 2016 Page 2 of 4



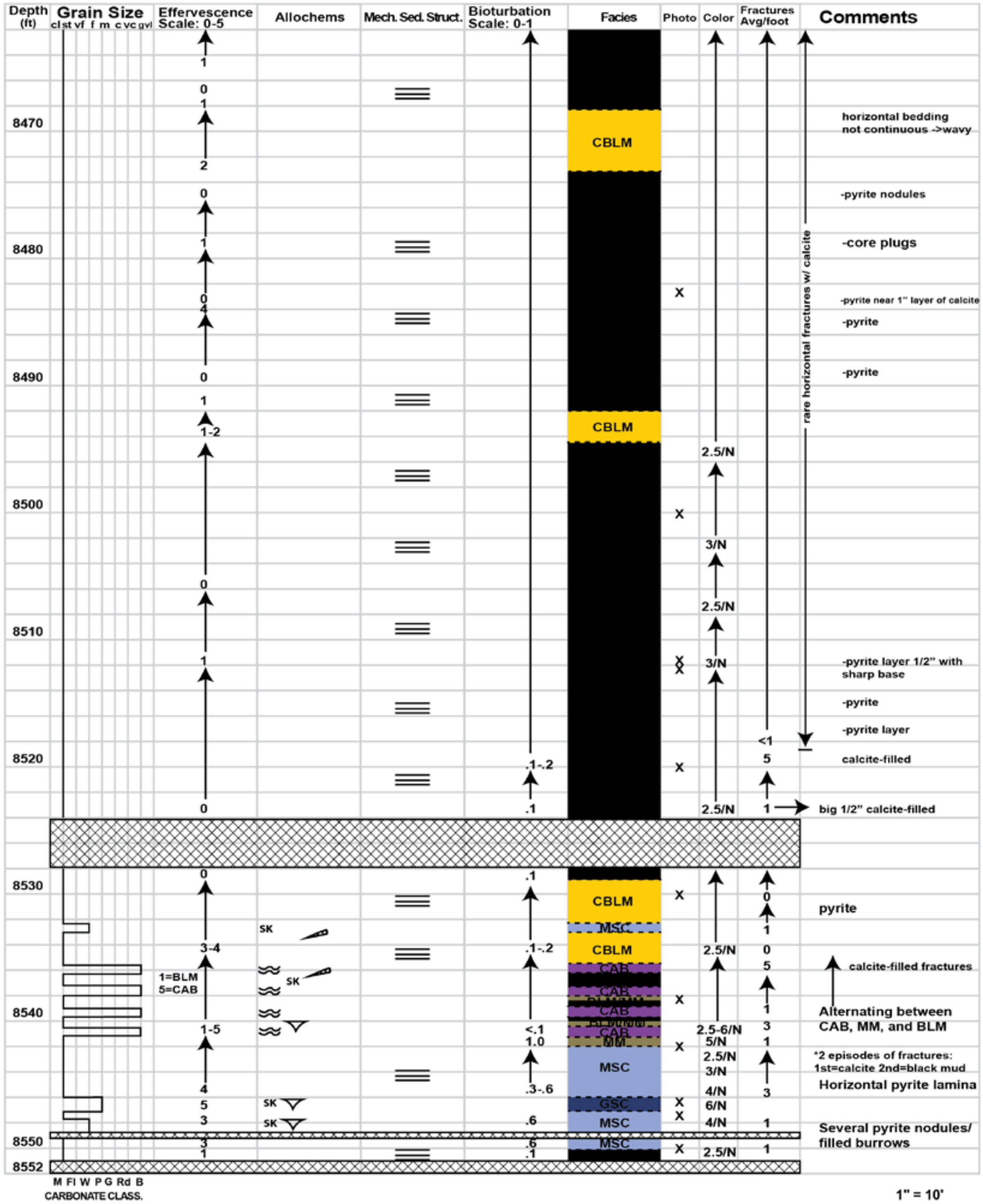


Project/Well: Marcellus COP Tract 259 A-1000
Logged By: Jared Hanson/Bart Yeates
Date: 14 Sept 2016
Page 3 of 4
Depth (ft)
Grain Size
cl st vf f m c vc gvl
Effervescence Scale: 0-5
Allochems
Mech. Sed. Struct.
Bioturbation Scale: 0-1
Facies
Photo
Color
Fractures Avg/foot
Comments
Core 1
Core 2
8130
8140
8150
8160
8170
8180
8190
8200
8210
8216
TS
-several thin pyrite lenses
-concretions
-concretion 2"
~14' vertical fracture
-concretion 6"
-concretion 3"
-big vertical=calcite & pyrite
-small fracture
SK -pyrite-replaced & calcite
SK -pyrite-replaced
white, ~horizontal are actually horizontal fractures->cross-cut bedding planes->pretty much everywhere throughout core
M Fl W P G Rd B
CARBONATE CLASS.
1" = 10'


Project/Well: Marcellus COP Tract 259 A-1000
Logged By: Jared Hanson/Bart Yeates
Date: 14 Sept 2016
Page 4 of 4
Depth (ft)
Grain Size cl st vf f m c vc gvl
Effervescence Scale: 0-5
Allochems
Mech. Sed. Struct.
Bioturbation Scale: 0-1
Facies
Photo
Color
Fractures Avg/foot
Comments
Top of Core
Core 1
8040
8050
8060
8070
8080
8090
8100
8110
8120
8126
TS
4/N
3.5/N
3/N
2.5/N
frequent light-colored laminations often pyrite and/or calcite filled
->very black! like 8178'
-pyrite nodule
-pyrite nodules
-pyrite nodules
M Fl W P G Rd B
CARBONATE CLASS.
1" = 10'

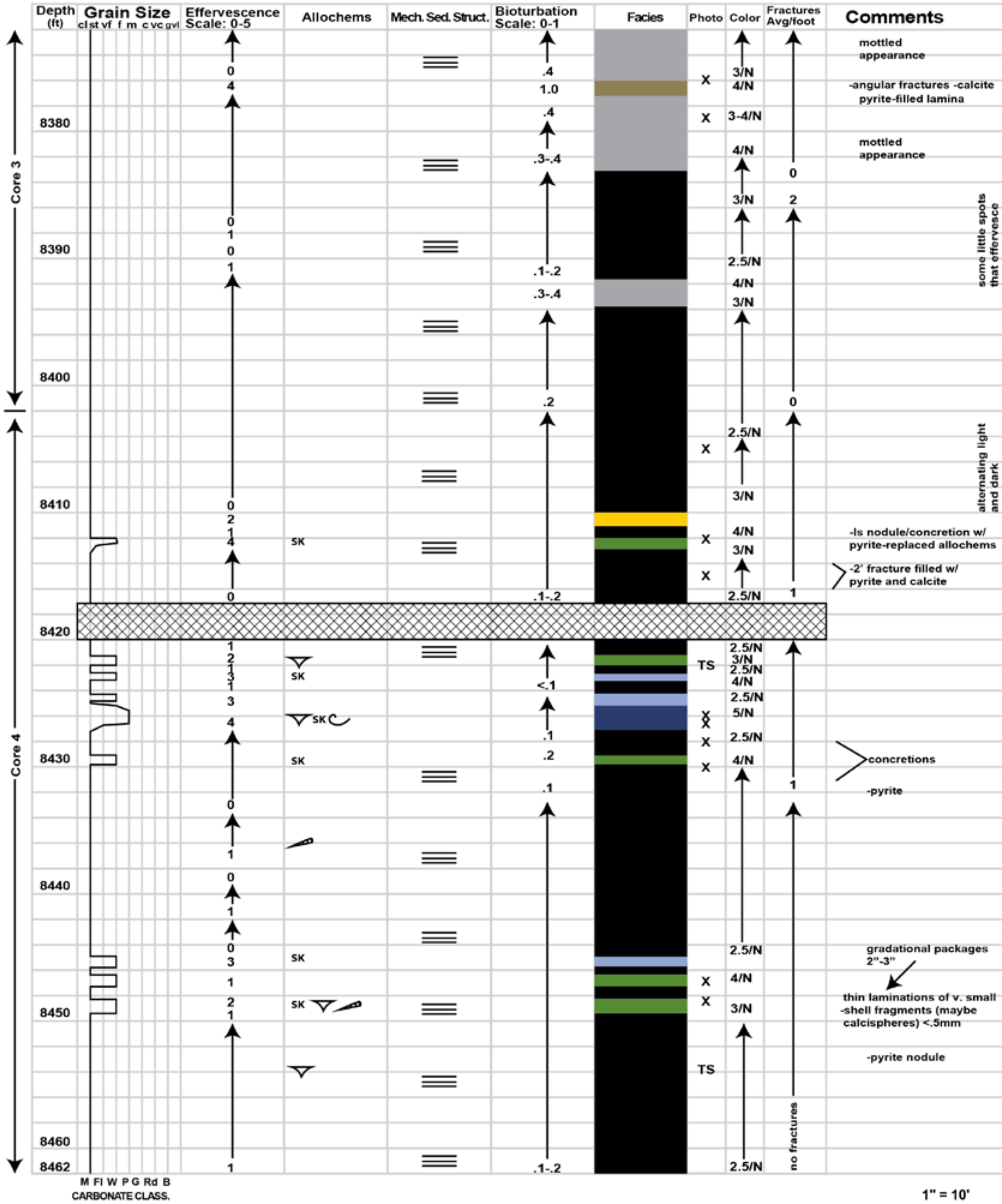
Project/Well: Marcellus COP Tract 653 #1000 **Logged By: Jared Hanson/Bart Yeates**

Date: 12 Sept 2016 **Page 1 of 4**



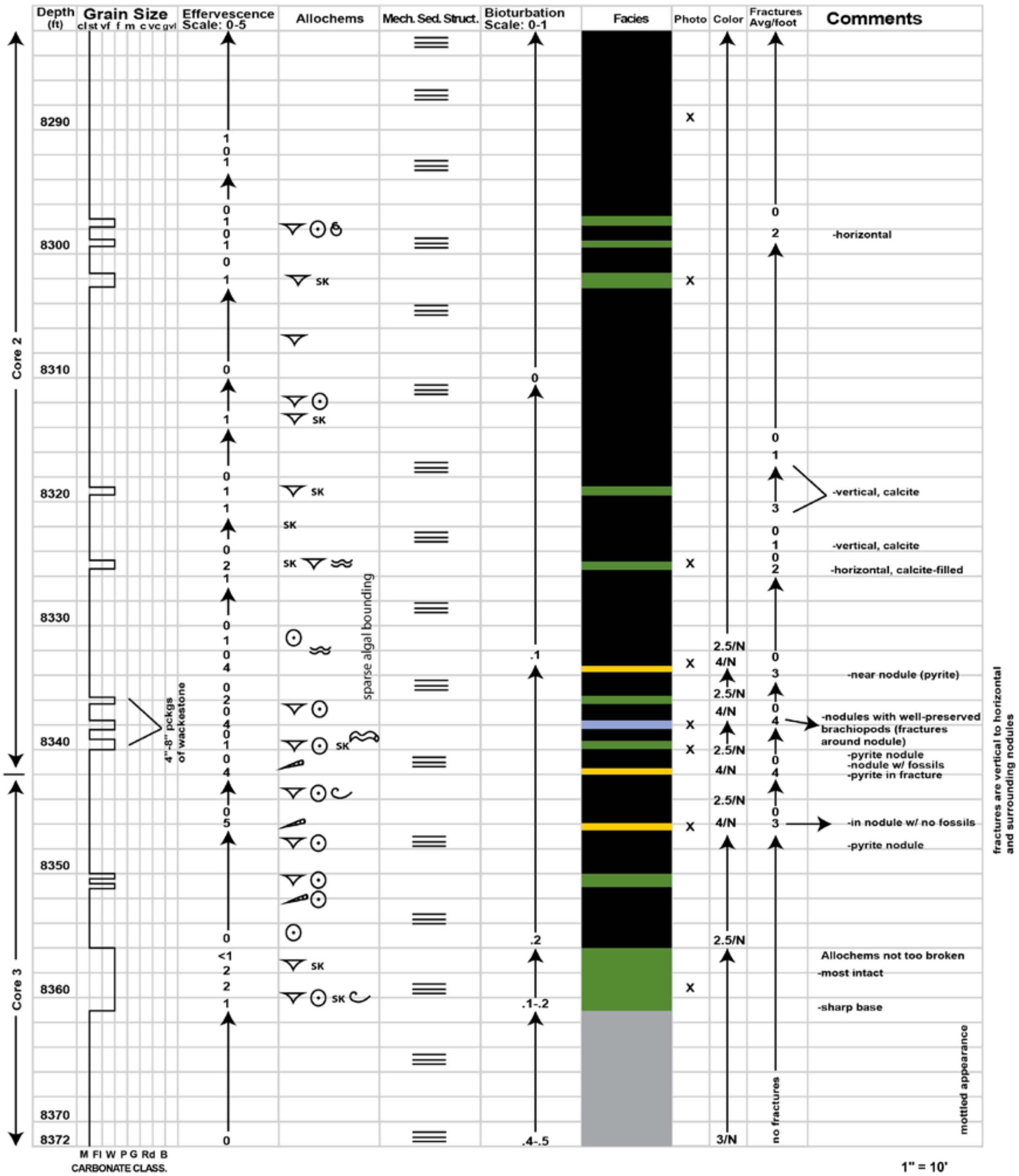
Project/Well: Marcellus COP Tract 653 #1000 **Logged By: Jared Hanson/Bart Yeates**

Date: 12 Sept 2016 **Page 2 of 4**



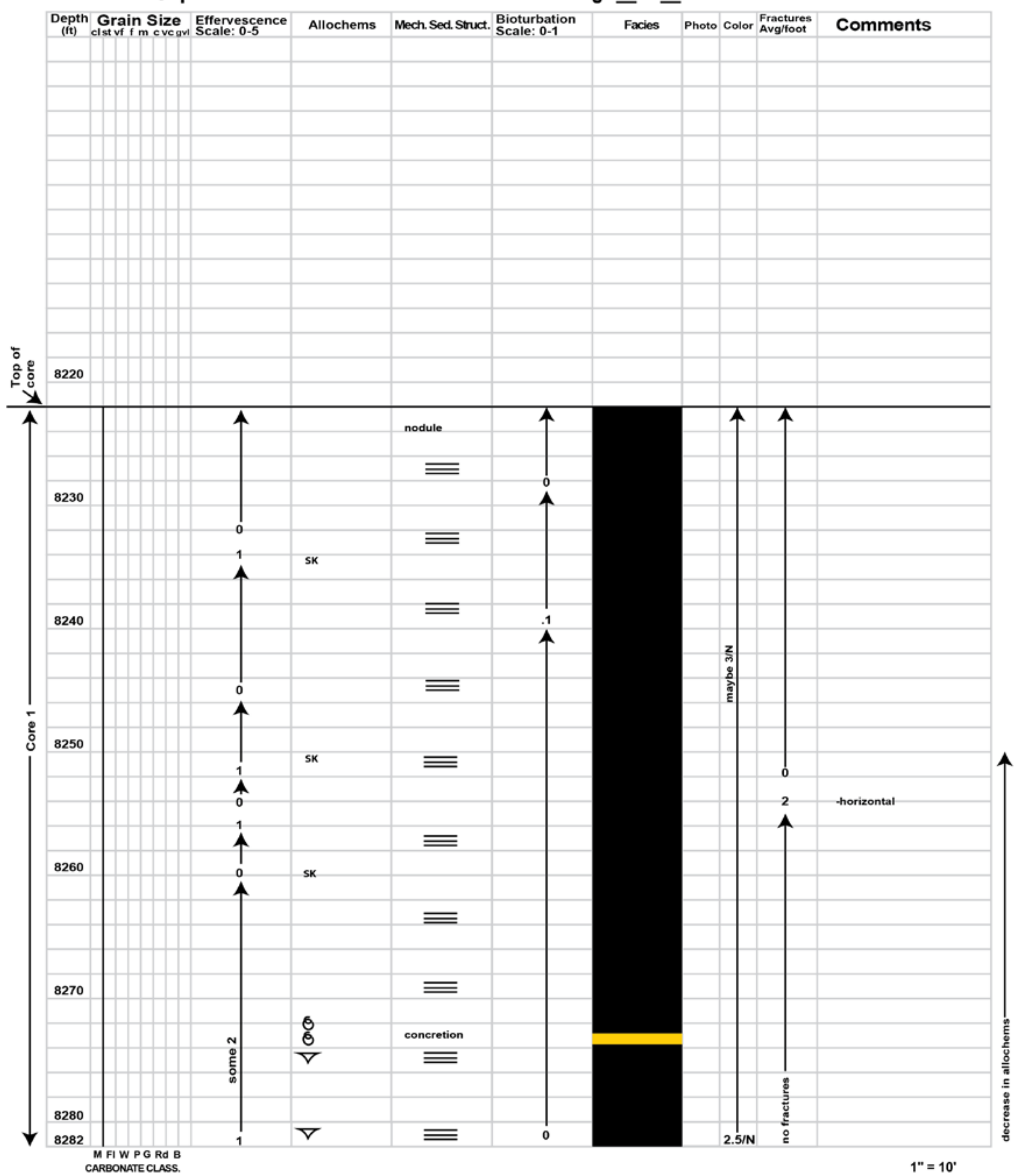
Project/Well: Marcellus COP Tract 653 #1000 | Logged By: Jared Hanson/Bart Yeates

Date: 12 Sept 2016 | Page 3 of 4



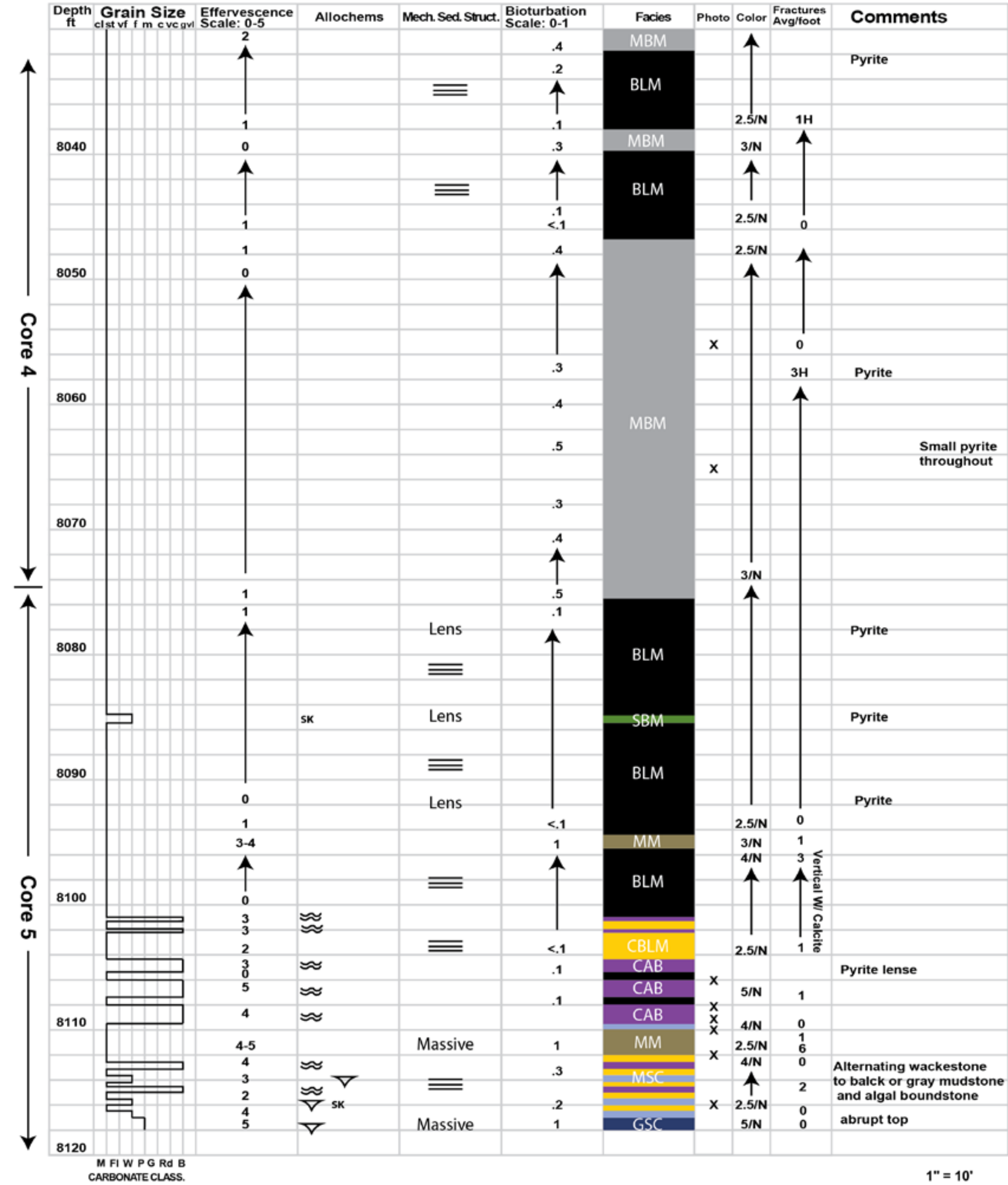
Project/Well: Marcellus COP Tract 653 #1000 **Logged By: Jared Hanson/Bart Yeates**

Date: 13 Sept 2016 **Page 4 of 4**



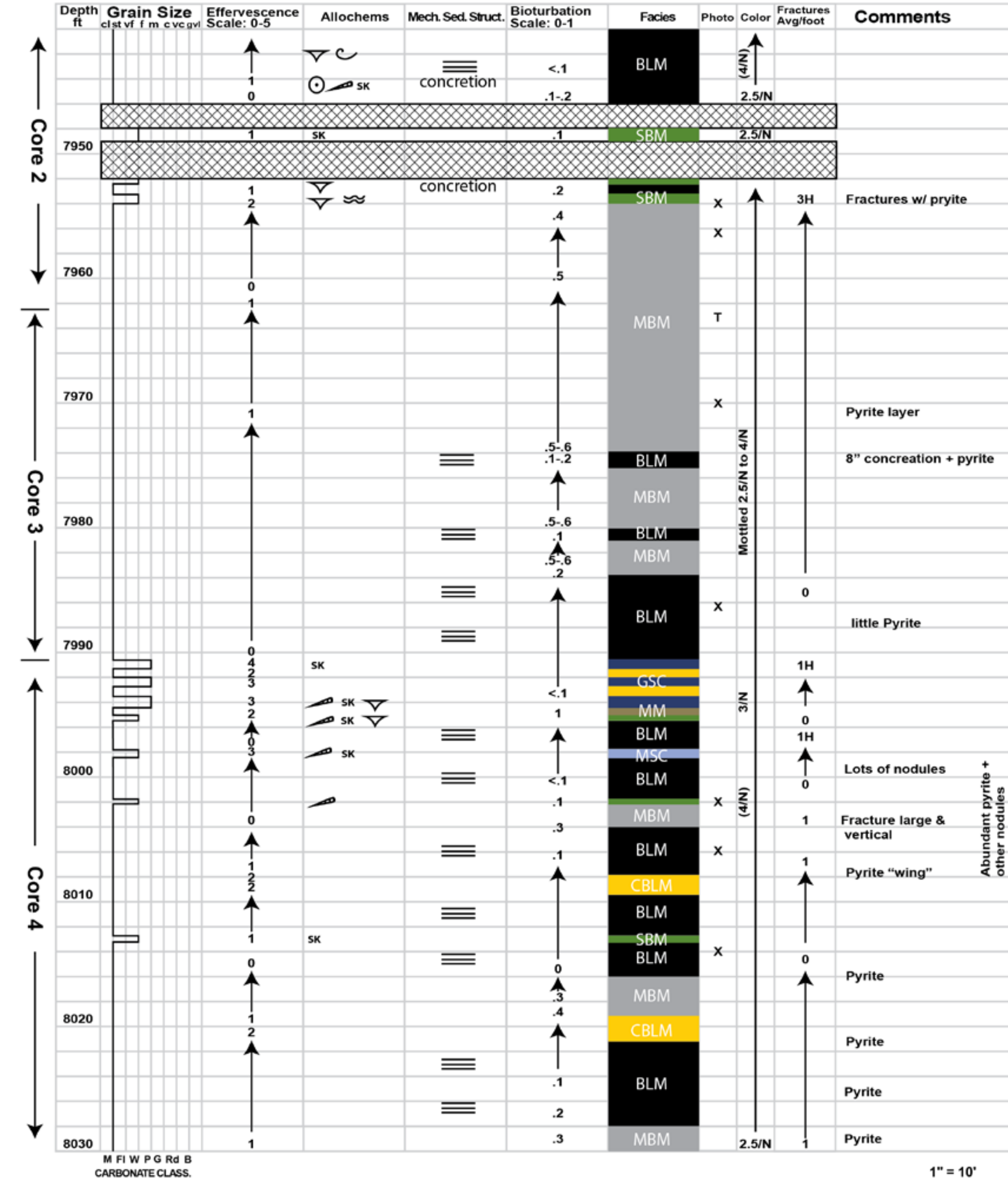
Project/Well: Marcellus COP 289 **Logged By: Jared Hanson/Bart Yeates**

Date: 13 Sept 2016 **Page 1 of 4**



Project/Well: Marcellus COP 289 Logged By: Jared Hanson/Bart Yeates

Date: 13 Sept 2016 Page 2 of 4

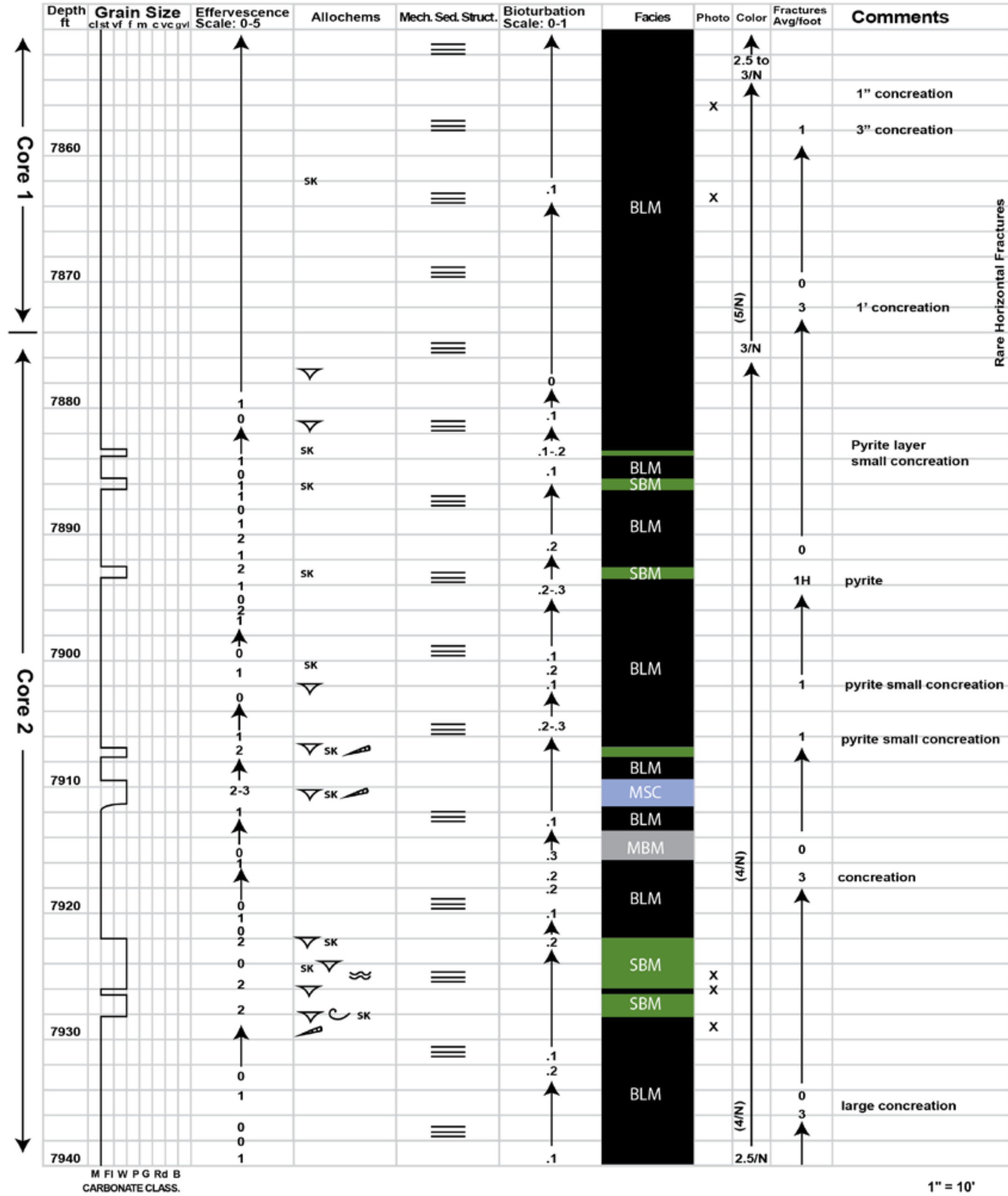


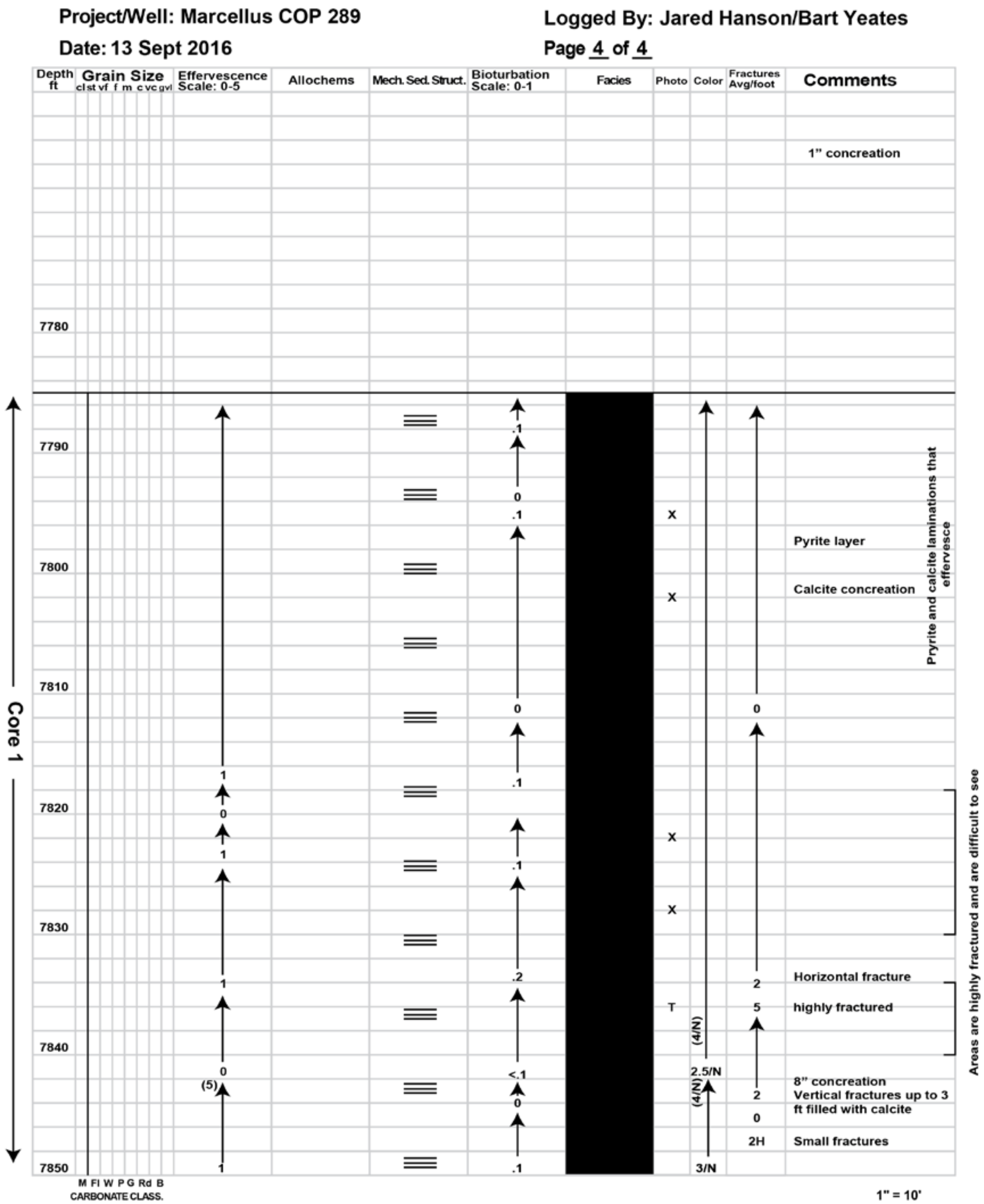
Project/Well: Marcellus COP 289

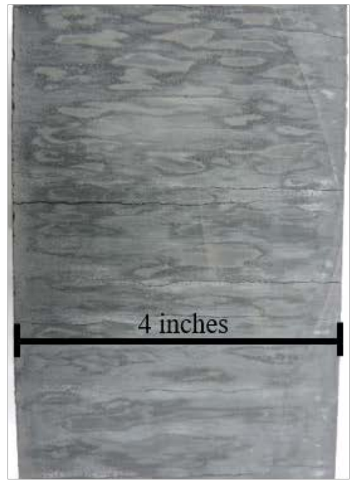
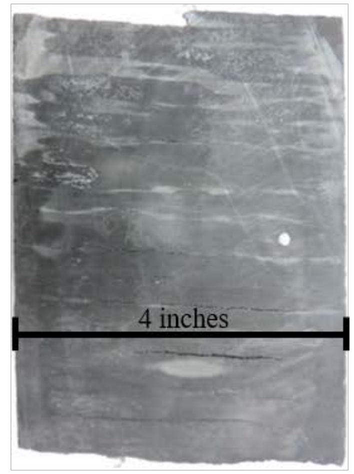
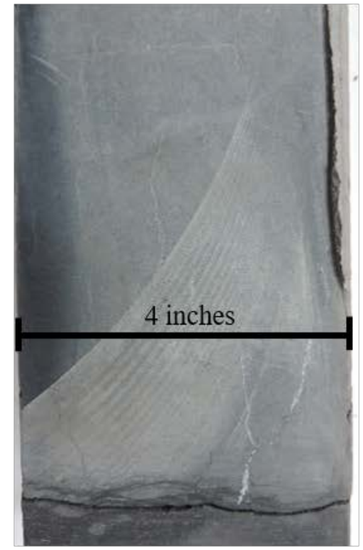
Date: 13 Sept 2016

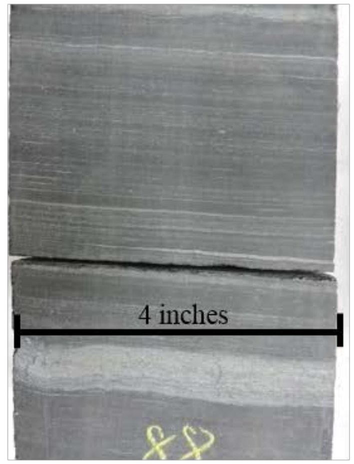
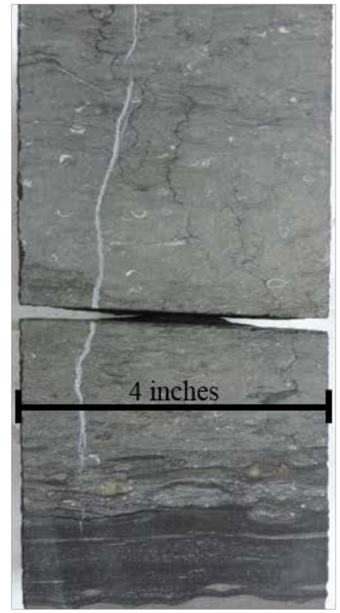
Logged By: Jared Hanson/Bart Yeates

Page 3 of 4




Project/Well: Marcellus COP 289
Date: 13 Sept 2016
Logged By: Jared Hanson/Bart Yeates
Page 4 of 4
Depth ft
Grain Size
cl st vf f m c vc gvl
Effervescence Scale: 0-5
Allochems
Mech. Sed. Struct.
Bioturbation Scale: 0-1
Facies
Photo
Color
Fractures Avg/foot
Comments
1" concreation
7780
7790
7800
7810
7820
7830
7840
7850
Core 1
Pyrite layer
Calcite concreation
Pryrite and calcite laminations that effervesce
Horizontal fracture
highly fractured
8" concreation
Vertical fractures up to 3 ft filled with calcite
Small fractures
Areas are highly fractured and are difficult to see
(4/N)
2.5/N
3/N
M Fl W P G Rd B
CARBONATE CLASS.
1" = 10'

Core Lithofacies Name	Black Laminated Mudstone	Mottled Black Mudstone	Calcareous Black Laminated Mudstone	Massive Mudstone
Representative Photo				
Photo well/depth	COP 259/8093’	COP 289/8065’	COP 653/8333’	COP 289/8110’
Facies Color	**BLM**	**MBM**	**CBLM**	**MM**

Core Lithofacies Name	Skeletal Black Mudstone	Mud-supported Carbonate	Grain-supported Carbonate	Crypt Algal Boundstone
Representative Photo				
Photo well/depth	COP 653/8447’	COP 259/8388’	COP 259/8289’	COP 653/8548.5’
Facies Color	SBM	MSC	GSC	CAB

APPENDIX B

Combustion Analysis and Isotope Mass Spectroscopy Data

This appendix contains a table of all data from combustion and mass spectroscopy analysis split up by each cored well. Tables often extend from one page to another.

Table B.1: Well COP 259 isotope and organic matter analysis.

Sample Depth (ft)	$\delta^{13}C$ ‰ PDB	$\delta^{15}N$ ‰ AIR	OC wt. %	N wt. %	TC wt.%	IC wt.%	$CaCO_3$ wt.%
8040	-28.38	1.81	0.45	0.12	1.04	0.59	4.89
8042	-28.28	2.04	0.44	0.11	1.22	0.78	6.46
8044	-28.32	2.27	0.41	0.12	1.13	0.72	5.99
8046	-28.64	2.23	0.46	0.12	1.24	0.78	6.48
8048	-28.27	1.98	0.47	0.13	1.02	0.55	4.57
8050	-28.32	2.05	0.42	0.12	1.13	0.71	5.92
8052	-28.29	1.97	0.44	0.12	1.28	0.84	7.00
8054	-28.44	2.29	0.42	0.11	1.28	0.86	7.16
8056	-28.49	2.32	0.39	0.1	1.44	1.05	8.73
8058	-28.41	2.08	0.42	0.11	1.25	0.83	6.89
8060	-28.72	2.34	0.7	0.1	1.62	0.92	7.69
8062	-28.64	2.01	0.47	0.12	1.24	0.77	6.39
8064	-28.50	1.87	0.43	0.12	1.32	0.89	7.44
8066	-28.57	1.88	0.51	0.12	1.34	0.83	6.88
8068	-28.56	1.88	0.5	0.11	1.26	0.76	6.30
8070	-28.29	1.52	0.48	0.13	1.24	0.76	6.35
8072	-28.77	1.56	0.73	0.14	1.51	0.78	6.50
8074	-28.72	1.37	0.67	0.14	1.23	0.56	4.63
8076	-28.97	1.60	0.9	0.14	1.54	0.64	5.33
8078	-29.00	1.83	1.3	0.15	1.39	0.09	0.78

Table B.1: Well COP 259 isotope and organic matter analysis. Continued.

Sample Depth (ft)	$\delta^{13}C$ ‰ PDB	$\delta^{15}N$ ‰ AIR	OC wt. %	N wt. %	TC wt.%	IC wt.%	$CaCO_3$ wt.%
8080	-29.23	2.00	1.36	0.16	1.49	0.13	1.06
8082	-29.09	1.73	1.26	0.15	1.38	0.12	0.98
8084	-29.14	1.87	1.69	0.16	1.80	0.11	0.94
8086	-29.19	1.81	1.82	0.17	1.75	-0.07	-0.60
8088	-28.84	1.94	1.16	0.15	1.49	0.33	2.78
8090	-28.72	2.07	0.89	0.15	1.69	0.80	6.70
8092	-29.01	0.95	0.98	0.15	1.35	0.37	3.10
8094	-28.92	1.47	1.05	0.16	1.21	0.16	1.34
8096	-29.31	1.44	1.38	0.18	1.32	-0.06	-0.46
8098	-29.27	1.47	1.02	0.17	1.04	0.02	0.15
8100	-29.03	1.36	0.76	0.16	1.16	0.40	3.31
8102	-28.61	1.18	0.52	0.14	1.12	0.60	5.00
8104	-28.81	1.59	0.66	0.15	0.99	0.33	2.78
8106	-29.35	1.85	1.31	0.18	1.33	0.02	0.14
8108	-29.48	1.41	1.45	0.18	1.45	0.00	0.03
8110	-29.11	1.55	0.93	0.17	1.00	0.07	0.56
8112	-28.98	1.60	0.77	0.16	1.17	0.40	3.35
8114	-29.32	2.06	1.43	0.19	1.35	-0.08	-0.65
8116	-29.23	1.97	1.25	0.17	1.36	0.11	0.90
8118	-29.20	1.16	1.15	0.18	1.13	-0.02	-0.19
8120	-29.21	1.99	1.1	0.17	1.31	0.21	1.75
8122	-29.14	1.59	1.02	0.16	1.55	0.53	4.38
8124	-29.25	1.46	1.31	0.18	1.29	-0.02	-0.18
8126	-29.16	2.12	0.96	0.16	1.88	0.92	7.69
8128	-29.11	1.33	0.88	0.16	1.44	0.56	4.64
8130	-29.24	2.07	0.94	0.16	1.93	0.99	8.24
8132	-29.31	1.91	1.29	0.18	1.29	0.00	0.01
8134	-29.22	1.38	1.16	0.16	1.66	0.50	4.20
8136	-29.08	1.89	0.96	0.16	2.16	1.20	10.01
8138	-29.44	1.67	1.46	0.17	1.53	0.07	0.56

Table B.1: Well COP 259 isotope and organic matter analysis. Continued.

Sample Depth (ft)	$\delta^{13}C$ ‰ PDB	$\delta^{15}N$ ‰ AIR	OC wt. %	N wt. %	TC wt.%	IC wt.%	$CaCO_3$ wt.%
8140	-29.20	1.32	1.1	0.16	1.82	0.72	5.98
8142	-29.01	1.66	1.28	0.16	2.30	1.02	8.52
8144	-29.23	1.35	1.36	0.16	1.70	0.34	2.83
8146	-29.31	1.20	1.48	0.18	1.44	-0.04	-0.33
8148	-29.57	1.48	1.41	0.18	1.66	0.25	2.09
8150	-29.11	1.57	1.01	0.17	1.35	0.34	2.83
8152	-28.74	2.56	0.56	0.16	2.00	1.44	11.99
8154	-28.89	1.11	0.47	0.15	1.41	0.94	7.85
8156	-28.68	1.26	0.6	0.15	1.17	0.57	4.72
8158	-28.63	1.12	0.45	0.15	1.09	0.64	5.35
8160	-28.52	0.90	0.47	0.14	1.47	1.00	8.30
8162	-28.57	0.84	0.5	0.15	1.71	1.21	10.08
8164	-28.73	0.98	0.47	0.15	1.53	1.06	8.82
8166	-28.95	1.12	0.46	0.15	1.59	1.13	9.43
8168	-28.48	1.27	0.5	0.16	1.49	0.99	8.21
8170	-29.05	1.12	0.47	0.14	1.59	1.12	9.30
8172	-28.63	1.49	0.53	0.15	1.52	0.99	8.28
8174	-28.64	1.02	1.16	0.17	1.44	0.28	2.32
8176	-28.84	1.09	1.16	0.17	1.31	0.15	1.24
8178	-29.12	0.97	1.38	0.17	1.73	0.35	2.93
8180	-28.97	1.17	0.99	0.17	1.30	0.31	2.59
8182	-28.91	1.33	1.04	0.17	1.18	0.14	1.13
8184	-29.19	1.11	0.48	0.17	1.12	0.64	5.31
8186	-29.17	1.35	1.03	0.17	1.52	0.49	4.07
8188	-28.89	1.61	1.44	0.2	1.39	-0.05	-0.39
8190	-29.40	1.28	1.77	0.2	2.09	0.32	2.69
8192	-29.16	1.45	1.15	0.17	1.55	0.40	3.36
8194	-29.11	1.81	0.67	0.17	1.97	1.30	10.81
8196	-28.81	2.86	2.18	0.22	2.25	0.07	0.59
8198	-29.54	0.94	1.58	0.2	1.62	0.04	0.34

Table B.1: Well COP 259 isotope and organic matter analysis. Continued.

Sample Depth (ft)	$\delta^{13}C$ ‰ PDB	$\delta^{15}N$ ‰ AIR	OC wt. %	N wt. %	TC wt.%	IC wt.%	$CaCO_3$ wt.%
8200	-29.86	1.33	0.92	0.18	1.83	0.91	7.60
8202	-30.08	1.59	1.18	0.17	3.40	2.22	18.54
8204	-29.49	1.63	2.84	0.23	2.81	-0.03	-0.28
8206	-29.73	2.19	2.18	0.23	2.12	-0.06	-0.53
8208	-29.70	1.61	1.92	0.21	1.97	0.05	0.42
8210	-29.35	0.99	2.3	0.23	2.31	0.01	0.04
8218	-29.92	1.30	0.91	0.19	1.31	0.40	3.31
8220	-29.80	1.46	0.87	0.21	0.92	0.05	0.44
8222	-29.23	1.54	1.82	0.22	1.82	0.00	0.01
8224	-29.26	1.51	1.38	0.21	1.27	-0.11	-0.93
8226	-28.86	1.41	1.05	0.18	2.12	1.07	8.94
8228	-29.96	1.80	2.23	0.21	2.08	-0.15	-1.21
8230	-30.05	1.55	2.56	0.2	2.47	-0.09	-0.75
8232	-30.06	1.79	2.32	0.21	2.22	-0.10	-0.81
8234	-30.07	1.98	2.37	0.21	2.34	-0.03	-0.22
8236	-30.13	1.75	2.27	0.2	2.13	-0.14	-1.16
8238	-30.26	2.02	2.62	0.21	2.44	-0.18	-1.51
8240	-30.05	2.06	2.94	0.21	2.88	-0.06	-0.49
8242	-30.03	2.25	2.39	0.19	2.35	-0.04	-0.30
8244	-30.28	1.75	2.55	0.2	2.67	0.12	0.97
8246	-30.32	1.89	2.97	0.21	3.18	0.21	1.72
8248	-30.30	1.51	3.27	0.22	3.35	0.08	0.69
8250	-30.15	2.58	2.77	0.2	2.59	-0.18	-1.50
8252	-30.30	2.30	3.37	0.23	3.33	-0.04	-0.37
8254	-30.16	1.93	2.57	0.2	3.20	0.63	5.25
8256	-30.22	2.47	2.97	0.2	3.25	0.28	2.32
8258	-30.29	2.24	3.19	0.21	3.26	0.07	0.57
8260	-30.24	1.46	3.45	0.21	3.62	0.17	1.41
8262	-30.15	1.63	3.45	0.21	3.78	0.33	2.77
8264	-29.94	1.65	3.32	0.22	3.46	0.14	1.16

Table B.1: Well COP 259 isotope and organic matter analysis. Continued.

Sample Depth (ft)	$\delta^{13}C$ ‰ PDB	$\delta^{15}N$ ‰ AIR	OC wt. %	N wt. %	TC wt.%	IC wt.%	$CaCO_3$ wt.%
8266	-30.22	1.65	3.1	0.22	3.24	0.14	1.15
8268	-30.11	1.65	2.98	0.23	2.99	0.01	0.12
8270	-30.26	1.61	3.64	0.25	3.57	-0.07	-0.54
8272	-30.26	1.61	3.76	0.25	3.84	0.08	0.70
8274	-30.26	1.58	4.18	0.25	4.08	-0.10	-0.80
8276	-30.12	1.55	5.07	0.26	5.80	0.73	6.06
8278	-30.10	1.94	3.54	0.24	3.52	-0.02	-0.18
8280	-29.92	1.70	4.61	0.25	4.48	-0.13	-1.11
8282	-29.82	1.91	4.69	0.26	4.80	0.11	0.95
8284	-29.79	1.48	2.75	0.2	6.18	3.43	28.58
8286	-30.18	1.62	4.15	0.22	7.81	3.66	30.54
8288	-30.38	1.78	6.78	0.29	0.00	-6.78	-56.50
8290	-31.10	1.69	4.06	0.23	4.44	0.38	3.18
8292	-30.90	2.11	3.87	0.25	4.38	0.51	4.24
8294	-30.95	1.55	3.58	0.25	3.97	0.39	3.25
8296	-30.91	1.52	3.44	0.23	4.23	0.79	6.62
8298	-30.98	1.54	3.52	0.22	4.79	1.27	10.56
8300	-30.92	1.92	2.96	0.21	4.52	1.56	12.98
8302	-30.95	1.85	4.45	0.25	4.43	-0.02	-0.15
8304	-30.86	2.22	2.38	0.22	3.76	1.38	11.48
8306	-30.86	1.31	3.04	0.22	2.76	-0.28	-2.36
8308	-30.95	1.79	2.75	0.23	2.95	0.20	1.66
8310	-30.98	1.69	2.98	0.22	4.52	1.54	12.83
8312	-31.04	1.63	3	0.23	3.41	0.41	3.42
8314	-30.95	1.60	2.15	0.22	3.35	1.20	9.97
8316	-30.99	1.40	2.26	0.22	2.76	0.50	4.17
8318	-30.99	1.42	2.51	0.23	3.13	0.62	5.15
8320	-30.88	1.32	2.37	0.23	2.57	0.20	1.69
8322	-30.90	1.60	2.5	0.23	3.15	0.65	5.39
8324	-30.98	1.97	2.87	0.23	4.24	1.37	11.42

Table B.1: Well COP 259 isotope and organic matter analysis. Continued.

Sample Depth (ft)	$\delta^{13}C$ ‰ PDB	$\delta^{15}N$ ‰ AIR	OC wt. %	N wt. %	TC wt.%	IC wt.%	$CaCO_3$ wt.%
8326	-30.79	1.24	2.44	0.22	2.96	0.52	4.33
8328	-30.93	1.35	2.28	0.21	3.19	0.91	7.58
8330	-30.90	1.37	2.48	0.22	3.85	1.37	11.38
8332	-31.04	1.51	3.2	0.23	3.51	0.31	2.59
8334	-31.12	1.61	2.85	0.23	3.10	0.25	2.12
8336	-30.89	-0.15	2.44	0.23	3.00	0.56	4.67
8338	-31.09	0.03	2.75	0.24	3.79	1.04	8.65
8340	-31.00	0.16	3.71	0.25	4.83	1.12	9.34
8342	-31.03	0.56	2.85	0.25	3.16	0.31	2.60
8344	-30.99	0.79	2.91	0.24	3.00	0.09	0.79
8346	-31.04	0.46	3.37	0.25	3.76	0.39	3.22
8348	-30.87	1.23	2.31	0.23	2.45	0.14	1.16
8350	-30.89	0.40	2.06	0.21	2.65	0.59	4.88
8352	-30.73	0.83	2.22	0.23	2.64	0.42	3.52
8354	-30.90	0.24	2.35	0.23	2.90	0.55	4.59
8356	-30.96	0.62	2.22	0.22	2.58	0.36	3.01
8358	-30.89	1.12	2.65	0.23	3.31	0.66	5.50
8360	-30.81	1.21	2.24	0.22	3.18	0.94	7.85
8362	-30.82	1.37	2.55	0.23	2.86	0.31	2.59
8364	-31.11	1.36	2.96	0.24	3.24	0.28	2.37
8366	-30.44	0.40	2.48	0.23	3.63	1.15	9.55
8368	-30.95	1.77	2.72	0.23	3.58	0.86	7.19
8370	-31.14	2.17	3.47	0.24	3.70	0.23	1.89
8372	-31.28	2.95	5.11	0.21	7.67	2.56	21.37
8374	-31.32	1.75	7.46	0.31	7.94	0.48	4.01
8376	-30.83	-4.88	0.77	0.06	11.39	10.62	88.48
8378	-31.42	1.81	7.25	0.32	7.75	0.50	4.17
8380	-31.42	2.44	8.52	0.33	8.39	-0.13	-1.06
8382	-29.51	1.54	0.47	0.61	0.35	-0.12	-0.99
8384	-31.14	2.52	5.5	0.19	8.04	2.54	21.17

Table B.1: Well COP 259 isotope and organic matter analysis. Continued.

Sample Depth (ft)	$\delta^{13}C$ ‰ PDB	$\delta^{15}N$ ‰ AIR	OC wt. %	N wt. %	TC wt.%	IC wt.%	$CaCO_3$ wt.%
8386	-31.13	3.14	5.72	0.17	10.01	4.29	35.75
8388	-30.91	2.66	1.49	0.07	9.47	7.98	66.47
8390	-30.93	7.20	0.38	0.01	11.86	11.48	95.67
8392	-30.17	1.15	0.94	0.05	10.61	9.67	80.57
8394	-30.68	2.65	4.2	0.17	11.74	7.54	62.83

Table B.2: Well COP 653 isotope and organic matter analysis.

Sample Depth (ft)	$\delta^{13}C$ ‰ PDB	$\delta^{15}N$ ‰ AIR	OC wt. %	N wt. %	TC wt.%	IC wt.%	$CaCO_3$ wt.%
8222	-27.76	0.64	0.52	0.14	1.15	0.63	5.27
8224	-27.39	0.03	0.51	0.13	1.02	0.51	4.27
8226	-28.41	0.42	0.54	0.13	1.21	0.67	5.57
8228	-28.55	0.10	1.76	0.18	1.70	-0.06	-0.46
8230	-28.57	0.62	1.19	0.17	1.18	-0.01	-0.07
8232	-28.35	0.57	0.79	0.15	1.63	0.84	7.04
8234	-28.41	0.11	0.69	0.14	1.18	0.49	4.08
8236	-28.54	0.14	2.05	0.19	1.98	-0.07	-0.57
8238	-28.68	0.24	2.21	0.19	2.22	0.01	0.06
8240	-28.36	0.31	2	0.18	2.10	0.10	0.86
8242	-28.58	0.64	1.29	0.16	1.77	0.48	3.98
8244	-28.91	0.63	1.66	0.18	1.79	0.13	1.09
8246	-28.52	0.73	1.55	0.16	2.22	0.67	5.58
8248	-28.61	0.77	1.41	0.16	2.49	1.08	9.01
8250	-28.65	0.38	1.6	0.18	1.62	0.02	0.15
8252	-28.68	0.90	1.06	0.15	2.85	1.79	14.88
8254	-28.74	0.56	1.76	0.17	2.14	0.38	3.19
8256	-28.57	0.71	1.56	0.17	2.32	0.76	6.36
8258	-28.59	0.38	1.85	0.2	1.84	-0.01	-0.07
8260	-28.95	1.46	0.58	0.15	3.10	2.52	21.03
8262	-28.45	1.01	0.68	0.15	1.79	1.11	9.25
8264	-29.06	1.29	0.64	0.16	1.61	0.97	8.08
8266	-28.67	0.84	0.43	0.16	1.38	0.95	7.89
8268	-28.43	0.91	0.48	0.16	1.72	1.24	10.37

Table B.2: Well COP 653 isotope and organic matter analysis. Continued.

Sample Depth (ft)	$\delta^{13}C$ ‰ PDB	$\delta^{15}N$ ‰ AIR	OC wt. %	N wt. %	TC wt.%	IC wt.%	$CaCO_3$ wt.%
8270	-28.59	1.18	0.52	0.15	2.05	1.53	12.78
8272	-28.62	0.99	0.51	0.15	1.73	1.22	10.20
8274	-28.46	1.00	0.49	0.15	1.58	1.09	9.10
8276	-28.61	1.11	0.47	0.14	1.78	1.31	10.93
8278	-28.75	0.84	0.49	0.16	1.45	0.96	7.97
8280	-28.72	1.05	0.48	0.16	1.49	1.01	8.39
8282	-28.87	0.75	0.55	0.16	1.44	0.89	7.46
8284	-28.50	0.99	0.46	0.15	1.70	1.24	10.33
8286	-28.56	1.02	0.52	0.16	1.44	0.92	7.64
8288	-28.71	1.03	0.52	0.16	1.64	1.12	9.36
8290	-28.92	1.13	0.79	0.16	2.51	1.72	14.36
8292	-29.31	0.20	1.17	0.16	1.60	0.43	3.56
8294	-29.55	0.24	1.58	0.18	1.73	0.15	1.26
8296	-29.33	0.32	0.98	0.16	1.50	0.52	4.32
8298	-29.43	-0.02	1.72	0.19	1.70	-0.02	-0.14
8300	-29.14	0.45	0.75	0.16	1.85	1.10	9.14
8302	-29.18	0.86	0.92	0.18	1.55	0.63	5.22
8304	-29.47	0.39	1.23	0.17	1.99	0.76	6.36
8306	-29.67	0.59	1.39	0.18	2.28	0.89	7.45
8308	-29.82	0.42	1.7	0.2	1.63	-0.07	-0.56
8310	-30.34	-0.21	1.92	0.19	2.25	0.33	2.76
8312	-29.41	1.05	0.7	0.17	2.18	1.48	12.33
8314	-29.95	0.42	1.77	0.2	1.83	0.06	0.53
8316	-29.94	0.21	1.73	0.2	1.80	0.07	0.61
8318	-29.65	0.03	1.25	0.2	1.28	0.03	0.22
8320	-30.01	0.73	1.69	0.18	2.85	1.16	9.66
8322	-29.63	0.17	0.9	0.17	1.79	0.89	7.43
8324	-30.05	0.69	1.79	0.21	2.19	0.40	3.30
8326	-29.95	1.13	1.25	0.16	4.16	2.91	24.27
8328	-29.99	0.13	2.38	0.22	2.57	0.19	1.56
8330	-29.91	0.18	2	0.21	2.28	0.28	2.34
8332	-29.93	0.65	1.3	0.2	1.81	0.51	4.27
8334	-29.88	1.39	1.27	0.18	3.12	1.85	15.38
8336	-30.06	0.64	2.76	0.24	2.69	-0.07	-0.55
8338	-29.74	0.39	1.37	0.2	1.90	0.53	4.41
8340	-29.76	0.10	1.5	0.22	2.01	0.51	4.25

Table B.2: Well COP 653 isotope and organic matter analysis. Continued.

Sample Depth (ft)	$\delta^{13}C$ ‰ PDB	$\delta^{15}N$ ‰ AIR	OC wt. %	N wt. %	TC wt.%	IC wt.%	$CaCO_3$ wt.%
8342	-29.63	0.26	1.43	0.21	1.41	-0.02	-0.15
8344	-29.53	0.73	1.56	0.22	1.54	-0.02	-0.18
8346	-29.65	-0.83	1.05	0.2	1.28	0.23	1.92
8348	-29.29	-0.04	0.98	0.2	1.33	0.35	2.92
8350	-28.80	-0.62	0.75	0.2	0.87	0.12	0.99
8352	-29.38	0.36	1.76	0.21	2.00	0.24	2.01
8354	-29.01	0.48	1.34	0.22	1.25	-0.09	-0.77
8356	-29.33	-0.33	1.32	0.22	1.27	-0.05	-0.42
8358	-28.10	0.32	0.37	0.17	3.00	2.63	21.88
8360	-29.04	0.42	0.93	0.19	2.18	1.25	10.38
8362	-29.85	0.50	2.71	0.24	2.61	-0.10	-0.86
8364	-29.99	0.56	2.33	0.23	2.34	0.01	0.08
8366	-30.08	-0.09	2.22	0.24	2.23	0.01	0.06
8368	-29.93	0.46	2.44	0.24	2.38	-0.06	-0.54
8370	-30.09	0.47	2.8	0.24	2.67	-0.13	-1.10
8372	-30.05	0.24	2.72	0.24	2.79	0.07	0.57
8374	-29.93	0.89	2.77	0.24	2.64	-0.13	-1.04
8376	-30.09	0.84	2.99	0.23	2.94	-0.05	-0.44
8378	-30.17	0.75	2.81	0.23	2.83	0.02	0.16
8380	-30.22	0.71	3.06	0.24	3.27	0.21	1.73
8382	-30.07	1.02	2.93	0.23	2.85	-0.08	-0.63
8384	-30.14	0.80	2.65	0.23	2.74	0.09	0.76
8386	-30.21	0.84	3.1	0.22	3.26	0.16	1.29
8388	-30.04	0.99	3.3	0.23	3.35	0.05	0.40
8390	-30.15	0.65	3.4	0.24	3.42	0.02	0.14
8392	-30.08	1.45	2.98	0.23	3.12	0.14	1.19
8394	-30.14	0.97	3.78	0.25	3.78	0.00	-0.03
8396	-30.12	1.05	4.56	0.27	4.53	-0.03	-0.25
8398	-30.07	1.64	3.41	0.22	3.94	0.53	4.45
8400	-29.99	0.74	3.64	0.23	3.83	0.19	1.57
8402	-29.96	0.94	2.96	0.23	2.86	-0.10	-0.83
8404	-30.12	1.00	3.02	0.23	3.18	0.16	1.35
8406	-30.26	0.87	3.03	0.25	3.27	0.24	2.04
8408	-30.37	1.83	3.16	0.26	3.84	0.68	5.63
8410	-30.27	0.59	3.84	0.25	4.80	0.96	8.03
8412	-30.12	1.26	2.32	0.19	4.83	2.51	20.89

Table B.2: Well COP 653 isotope and organic matter analysis. Continued.

Sample Depth (ft)	$\delta^{13}C$ ‰ PDB	$\delta^{15}N$ ‰ AIR	OC wt. %	N wt. %	TC wt.%	IC wt.%	$CaCO_3$ wt.%
8414	-29.80	1.31	3.39	0.24	3.47	0.08	0.68
8416	-29.92	1.20	3.6	0.24	3.61	0.01	0.08
8420	-29.60	1.89	1.69	0.12	8.46	6.77	56.39
8422	-30.06	0.97	4.7	0.27	5.65	0.95	7.90
8424	-29.99	1.15	6.09	0.25	9.53	3.44	28.66
8426	-30.38	1.38	1.46	0.09	9.48	8.02	66.81
8428	-30.75	0.61	4.46	0.31	4.77	0.31	2.60
8430	-30.66	1.38	2.65	0.25	3.83	1.18	9.86
8432	-30.48	1.59	4.03	0.24	5.40	1.37	11.44
8434	-30.63	1.51	2.52	0.23	3.54	1.02	8.50
8436	-30.53	1.50	3.88	0.23	4.85	0.97	8.04
8438	-30.67	1.39	3.12	0.22	4.44	1.32	10.98
8440	-30.59	1.49	3.45	0.23	4.43	0.98	8.20
8442	-30.60	1.82	2.66	0.19	5.00	2.34	19.54
8444	-30.58	1.43	3.54	0.23	4.16	0.62	5.20
8446	-30.77	0.98	3.56	0.26	3.88	0.32	2.65
8448	-30.55	1.49	3.23	0.22	5.04	1.81	15.06
8450	-30.77	1.30	3.23	0.25	4.46	1.23	10.25
8452	-30.86	0.76	2.16	0.23	3.01	0.85	7.12
8454	-30.71	1.14	2.26	0.25	2.87	0.61	5.11
8456	-30.78	0.86	1.8	0.23	2.92	1.12	9.35
8458	-30.65	1.03	2.88	0.23	3.78	0.90	7.46
8460	-30.86	0.65	2.14	0.24	3.14	1.00	8.35
8462	-30.65	0.89	2.4	0.23	3.05	0.65	5.38
8464	-30.69	0.95	2.29	0.23	3.01	0.72	6.00
8466	-30.89	1.89	2.87	0.25	3.73	0.86	7.20
8468	-30.69	1.04	2.06	0.23	2.84	0.78	6.51
8470	-30.61	1.43	2.44	0.22	3.54	1.10	9.13
8472	-30.69	1.38	2.45	0.21	3.82	1.37	11.43
8474	-30.99	0.82	2.66	0.24	3.29	0.63	5.24
8476	-30.84	1.67	2.58	0.24	3.64	1.06	8.87
8478	-30.56	1.26	2.3	0.22	2.86	0.56	4.65
8480	-30.71	1.14	2.25	0.23	2.56	0.31	2.57
8482	-30.71	1.31	2.34	0.24	2.71	0.37	3.12
8484	-30.83	1.78	2.96	0.23	3.75	0.79	6.61
8486	-30.84	1.85	2.32	0.24	3.03	0.71	5.89

Table B.2: Well COP 653 isotope and organic matter analysis. Continued.

Sample Depth (ft)	$\delta^{13}C$ ‰ PDB	$\delta^{15}N$ ‰ AIR	OC wt. %	N wt. %	TC wt.%	IC wt.%	$CaCO_3$ wt.%
8488	-30.89	0.58	3.44	0.25	3.54	0.10	0.85
8490	-30.91	5.05	2.09	0.07	4.18	2.09	17.45
8492	-30.84	0.76	2.14	0.21	3.32	1.18	9.83
8494	-30.70	0.77	2.37	0.23	3.06	0.69	5.78
8496	-30.85	0.94	2.43	0.23	2.91	0.48	3.97
8498	-30.91	0.72	2.81	0.25	2.88	0.07	0.57
8500	-31.01	0.63	2.13	0.22	3.03	0.90	7.46
8502	-30.92	0.81	2.9	0.23	3.51	0.61	5.08
8504	-30.94	1.02	2.11	0.22	2.49	0.38	3.20
8506	-30.94	0.88	2.51	0.25	3.00	0.49	4.05
8508	-31.01	1.40	2.89	0.24	3.90	1.01	8.42
8510	-30.96	0.98	2.73	0.25	3.49	0.76	6.33
8512	-31.11	0.87	2.69	0.25	3.00	0.31	2.57
8514	-31.16	1.43	5.89	0.3	6.25	0.36	2.97
8516	-31.32	1.47	4.62	0.24	5.36	0.74	6.18
8518	-31.23	1.87	7.09	0.3	7.67	0.58	4.79
8520	-31.16	3.68	7.35	0.29	8.51	1.16	9.63
8522	-31.17	3.07	8.63	0.35	9.30	0.67	5.61
8524	-31.17	3.87	5.86	0.26	6.75	0.89	7.44
8528	-31.15	3.34	9.14	0.28	9.51	0.37	3.12
8530	-30.96	2.52	6.19	0.19	10.34	4.15	34.55
8532	-31.22	0.92	16.53	1.19	10.08	-6.45	-53.72
8534	-31.40	6.14	6.9	0.23	13.88	6.98	58.15
8536	-31.20	0.64	13.51	1.14	12.54	-0.97	-8.07
8538	-30.65	1.58	2.03	0.13	9.84	7.81	65.06
8540	-30.76	1.78	1.58	0.12	11.25	9.67	80.61
8542	-30.00	4.14	0.36	0.04	10.90	10.54	87.83
8544	-28.82	1.97	0.77	0.09	9.67	8.90	74.16
8546	-29.51	1.92	0.81	0.1	7.64	6.83	56.95
8548	-29.72	1.51	1.53	0.21	4.62	3.09	25.75
8550	-29.51	2.93	0.35	0.07	6.90	6.55	54.60

Table B.3: Well COP 289 isotope and organic matter analysis.

Sample Depth (ft)	$\delta^{13}C$ ‰ PDB	$\delta^{15}N$ ‰ AIR	OC wt. %	N wt. %	TC wt.%	IC wt.%	$CaCO_3$ wt.%
7786	-29.54	-0.94	1.48	0.18	2.03	0.55	4.61
7788	-28.94	-1.31	0.63	0.15	1.35	0.72	5.99
7790	-28.27	-1.19	0.52	0.15	1.02	0.50	4.16
7792	-28.44	-1.53	0.47	0.14	1.05	0.58	4.84
7794	-28.45	-1.33	0.49	0.14	1.20	0.71	5.92
7796	-28.47	-1.23	0.51	0.14	1.28	0.77	6.40
7798	-28.53	-0.55	0.56	0.14	1.29	0.73	6.10
7800	-28.47	-1.57	0.58	0.15	1.16	0.58	4.79
7802	-29.06	-1.78	0.93	0.13	2.20	1.27	10.59
7804	-28.55	-1.42	0.54	0.15	1.04	0.50	4.17
7806	-28.63	-1.23	0.56	0.15	1.17	0.61	5.09
7808	-28.59	-1.23	0.58	0.15	1.12	0.54	4.49
7810	-28.35	-0.76	0.51	0.14	1.47	0.96	7.96
7812	-28.69	-1.27	0.63	0.17	1.15	0.52	4.36
7814	-28.67	-1.68	0.62	0.16	1.25	0.63	5.29
7816	-28.62	-0.63	0.63	0.16	1.32	0.69	5.77
7818	-28.84	-0.54	0.60	0.16	1.18	0.58	4.84
7820	-29.22	-0.50	0.92	0.17	1.07	0.15	1.27
7822	-29.23	-0.71	1.01	0.18	1.69	0.68	5.63
7824	-28.99	-0.97	0.67	0.17	1.55	0.88	7.31
7826	-30.13	1.16	3.22	0.24	3.18	-0.04	-0.37
7828	-29.92	0.73	2.34	0.21	2.42	0.08	0.69
7830	-30.01	0.32	2.76	0.23	2.88	0.12	0.96
7832	-29.65	-1.63	1.70	0.22	2.08	0.38	3.16
7834	-29.74	-0.70	1.96	0.21	2.05	0.09	0.74
7836	-29.86	0.37	2.18	0.21	2.40	0.22	1.84
7838	-29.88	0.31	2.20	0.21	2.43	0.23	1.94
7840	-29.93	-0.42	2.29	0.21	2.99	0.70	5.85
7842	-28.93	-1.07	0.78	0.17	2.89	2.11	17.61
7844	-28.71	0.22	0.67	0.16	2.55	1.88	15.69
7846	-28.81	0.24	0.65	0.17	1.97	1.32	11.01
7848	-28.58	-0.46	0.55	0.16	1.52	0.97	8.10
7850	-28.45	-0.45	0.49	0.17	1.20	0.71	5.91
7852	-28.93	-0.89	0.65	0.16	3.10	2.45	20.41
7854	-28.68	0.44	0.57	0.16	2.75	2.18	18.19
7856	-28.74	-0.08	0.55	0.17	2.14	1.59	13.24

Table B.3: Well COP 289 isotope and organic matter analysis. Continued.

Sample Depth (ft)	$\delta^{13}C$ ‰ PDB	$\delta^{15}N$ ‰ AIR	OC wt. %	N wt. %	TC wt.%	IC wt.%	$CaCO_3$ wt.%
7858	-28.62	0.12	0.55	0.16	1.77	1.22	10.20
7860	-28.64	0.03	0.57	0.17	1.76	1.19	9.94
7862	-28.93	-0.15	0.74	0.17	1.93	1.19	9.95
7864	-28.77	-0.28	0.59	0.17	1.66	1.07	8.92
7866	-28.61	-0.32	0.59	0.16	1.50	0.91	7.62
7868	-28.71	0.19	0.61	0.17	1.66	1.05	8.73
7870	-28.67	-0.14	0.60	0.17	1.59	0.99	8.22
7872	-28.13	-4.55	0.33	0.06	6.75	6.42	53.52
7874	-28.26	-1.33	0.58	0.18	2.69	2.11	17.60
7876	-28.71	-0.53	0.66	0.17	2.45	1.79	14.90
7878	-30.14	-0.18	2.76	0.25	1.51	-1.25	-10.44
7880	-29.84	-0.45	1.62	0.21	2.16	0.54	4.53
7882	-29.51	-1.29	1.46	0.21	1.96	0.50	4.14
7884	-29.26	0.65	1.10	0.17	3.10	2.00	16.63
7886	-29.97	-0.80	1.85	0.22	2.38	0.53	4.38
7888	-29.95	0.08	1.87	0.21	1.91	0.04	0.35
7890	-29.88	-0.06	1.52	0.20	2.55	1.03	8.56
7892	-30.20	0.25	1.93	0.25	2.00	0.07	0.62
7894	-30.14	-1.28	1.81	0.22	2.20	0.39	3.28
7896	-30.43	-0.15	2.27	0.20	3.93	1.66	13.84
7898	-29.57	-0.60	0.91	0.21	1.98	1.07	8.90
7900	-29.74	-0.11	0.99	0.18	2.34	1.35	11.25
7902	-29.91	0.38	1.69	0.22	2.72	1.03	8.62
7904	-30.10	-0.39	1.74	0.18	4.21	2.47	20.58
7906	-29.53	-1.57	0.87	0.21	2.27	1.40	11.65
7908	-29.97	0.03	1.29	0.21	1.84	0.55	4.61
7910	-29.91	-0.85	1.23	0.17	4.43	3.20	26.63
7912	-30.54	-0.22	2.28	0.25	2.45	0.17	1.43
7914	-30.47	-1.04	2.21	0.23	3.42	1.21	10.11
7916	-30.58	-0.40	2.97	0.27	2.81	-0.16	-1.30
7918	-30.52	-1.38	2.05	0.24	2.18	0.13	1.10
7920	-30.56	-0.70	3.18	0.27	3.11	-0.07	-0.56
7922	-30.31	-1.11	2.33	0.25	2.47	0.14	1.16
7924	-30.11	-1.94	1.69	0.23	2.43	0.74	6.17
7926	-30.35	-1.04	3.09	0.28	3.49	0.40	3.36
7928	-30.00	-1.74	1.73	0.24	2.29	0.56	4.68

Table B.3: Well COP 289 isotope and organic matter analysis. Continued.

Sample Depth (ft)	$\delta^{13}C$ ‰ PDB	$\delta^{15}N$ ‰ AIR	OC wt. %	N wt. %	TC wt.%	IC wt.%	$CaCO_3$ wt.%
7930	-30.21	-1.21	1.88	0.25	2.03	0.15	1.24
7932	-30.14	-0.55	2.33	0.26	2.17	-0.16	-1.30
7934	-29.83	-1.15	1.21	0.23	1.57	0.36	3.01
7936	-29.73	-0.75	1.30	0.20	3.51	2.21	18.38
7938	-29.45	-1.44	0.91	0.22	1.63	0.72	6.01
7940	-29.29	-1.74	0.92	0.22	1.67	0.75	6.27
7942	-29.11	-1.72	0.92	0.22	1.72	0.80	6.63
7944	-29.18	-1.24	0.94	0.22	1.33	0.39	3.25
7946	-29.55	-0.09	1.56	0.23	1.50	-0.06	-0.48
7948	-29.43	-0.94	1.31	0.23	2.69	1.38	11.49
7952	-28.35	-1.16	0.70	0.20	2.07	1.37	11.42
7954	-29.81	-2.06	1.55	0.19	2.59	1.04	8.70
7956	-30.44	-0.30	3.17	0.27	3.00	-0.17	-1.46
7958	-30.36	-0.55	2.94	0.25	2.69	-0.25	-2.11
7960	-30.10	1.39	2.29	0.23	2.14	-0.15	-1.23
7962	-30.12	1.30	1.94	0.19	2.07	0.13	1.12
7964	-30.28	1.07	2.72	0.22	2.54	-0.18	-1.48
7966	-30.47	1.97	2.73	0.22	2.88	0.15	1.29
7968	-30.22	0.55	2.22	0.21	3.13	0.91	7.58
7970	-30.37	1.37	3.23	0.23	3.28	0.05	0.44
7972	-30.29	1.14	2.25	0.21	2.29	0.04	0.37
7974	-30.30	1.32	2.86	0.23	2.69	-0.17	-1.38
7976	-31.08	2.29	3.75	0.24	3.84	0.09	0.73
7978	-30.33	0.19	3.91	0.24	3.92	0.01	0.06
7980	-30.36	0.19	4.60	0.24	4.73	0.13	1.09
7982	-30.01	0.28	2.76	0.21	2.76	0.00	0.01
7984	-30.27	0.07	3.87	0.23	3.73	-0.14	-1.15
7986	-30.31	0.21	4.62	0.26	5.33	0.71	5.88
7988	-30.06	0.53	3.42	0.25	3.35	-0.07	-0.56
7990	-30.08	0.89	4.44	0.25	4.89	0.45	3.77
7992	-29.86	1.41	2.84	0.14	8.96	6.12	50.99
7994	-30.18	1.63	4.75	0.19	9.96	5.21	43.42
7996	-30.43	0.82	7.24	0.28	9.55	2.31	19.22
7998	-30.85	0.48	4.98	0.30	6.38	1.40	11.67
8000	-30.85	0.37	4.69	0.29	5.61	0.92	7.70
8002	-30.83	0.33	3.49	0.28	4.66	1.17	9.72

Table B.3: Well COP 289 isotope and organic matter analysis. Continued.

Sample Depth (ft)	$\delta^{13}C$ ‰ PDB	$\delta^{15}N$ ‰ AIR	OC wt. %	N wt. %	TC wt.%	IC wt.%	$CaCO_3$ wt.%
8004	-30.82	0.69	3.37	0.25	4.98	1.61	13.40
8006	-30.93	0.42	3.50	0.26	4.01	0.51	4.28
8008	-30.88	0.95	3.66	0.24	4.84	1.18	9.81
8010	-30.93	0.13	2.82	0.24	3.44	0.62	5.14
8012	-30.91	0.63	2.51	0.23	3.58	1.07	8.94
8014	-31.00	-0.05	3.21	0.25	3.82	0.61	5.08
8016	-31.07	-0.73	2.87	0.26	3.07	0.20	1.69
8018	-30.93	3.18	2.24	0.25	3.25	1.01	8.45
8020	-30.86	1.49	3.17	0.24	4.93	1.76	14.69
8022	-30.94	0.56	2.17	0.27	2.75	0.58	4.87
8024	-31.23	0.16	2.61	0.26	3.13	0.52	4.35
8026	-31.27	0.89	2.95	0.25	4.35	1.40	11.69
8028	-31.12	0.39	2.25	0.26	2.64	0.39	3.25
8030	-31.15	0.76	2.72	0.25	4.18	1.46	12.15
8032	-31.06	1.35	3.20	0.25	4.49	1.29	10.78
8034	-31.12	0.61	2.18	0.26	3.32	1.14	9.48
8036	-31.09	0.27	2.45	0.25	2.97	0.52	4.33
8038	-31.00	0.32	2.26	0.24	2.85	0.59	4.89
8040	-31.14	0.90	2.38	0.24	3.49	1.11	9.22
8044	-31.04	1.25	2.42	0.24	3.65	1.23	10.26
8046	-31.04	0.81	2.12	0.25	3.01	0.89	7.40
8048	-31.31	0.49	2.96	0.27	3.46	0.50	4.21
8050	-31.27	0.66	2.60	0.27	2.83	0.23	1.89
8052	-31.26	0.63	2.21	0.25	2.99	0.78	6.51
8054	-31.27	0.54	2.58	0.26	2.83	0.25	2.08
8056	-31.20	0.80	3.83	0.27	3.63	-0.20	-1.71
8058	-31.46	0.78	3.11	0.26	4.90	1.79	14.91
8060	-31.33	0.22	2.37	0.27	2.89	0.52	4.34
8062	-31.40	0.33	1.95	0.27	3.01	1.06	8.84
8064	-31.42	0.46	2.11	0.27	3.13	1.02	8.47
8066	-31.48	0.35	2.78	0.26	3.49	0.71	5.91
8068	-31.25	2.24	2.49	0.26	3.37	0.88	7.37
8070	-31.47	0.60	1.83	0.25	2.95	1.12	9.31
8072	-31.44	1.03	2.18	0.25	3.03	0.85	7.11
8074	-31.40	1.17	3.61	0.26	4.36	0.75	6.25
8076	-31.48	0.87	1.93	0.22	3.52	1.59	13.21

Table B.3: Well COP 289 isotope and organic matter analysis. Continued.

Sample Depth (ft)	$\delta^{13}C$ ‰ PDB	$\delta^{15}N$ ‰ AIR	OC wt. %	N wt. %	TC wt.%	IC wt.%	$CaCO_3$ wt.%
8078	-31.54	2.45	2.53	0.25	3.38	0.85	7.09
8080	-31.84	0.64	2.88	0.25	4.03	1.15	9.59
8082	-31.71	1.53	4.55	0.27	5.93	1.38	11.49
8086	-31.58	1.46	6.65	0.29	9.37	2.72	22.65
8088	-31.70	2.48	8.09	0.34	9.08	0.99	8.29
8090	-31.62	2.12	7.57	0.29	7.95	0.38	3.13
8092	-31.73	1.95	6.62	0.31	7.08	0.46	3.80
8094	-31.54	1.49	5.65	0.34	5.77	0.12	0.96
8096	-31.09	3.17	1.67	0.16	10.64	8.97	74.73
8098	-31.70	2.61	7.08	0.29	7.79	0.71	5.92
8100	-31.64	5.54	2.60	0.08	10.92	8.32	69.36
8102	-31.40	2.35	0.93	0.05	8.79	7.86	65.47
8104	-31.25	3.65	7.01	0.19	9.73	2.72	22.65
8106	-31.20	1.63	2.92	0.10	9.87	6.95	57.88
8108	-31.14	3.74	3.67	0.13	12.05	8.38	69.83
8110	-30.39	2.36	1.33	0.15	5.68	4.35	36.24
8112	-29.41	5.98	0.29	0.04	10.17	9.88	82.37
8114	-29.18	4.05	1.24	0.14	8.42	7.18	59.83
8116	-30.10	7.72	2.82	0.10	11.51	8.69	72.45
8118	-30.32	0.87	0.57	0.03	12.38	11.81	98.39

APPENDIX C

X-ray Fluorescence Data Sheets

This appendix contains data sheets associated with XRF analyses.

Table C.1a. Trace and major element analyses results for COP 259.

Core Depth ft	Log-corrected Depth ft	SiO2 mass %	SiO2/ Al2O3	TiO2 mass %	TiO2/ Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass %	MgO mass %	CaO mass%	Na2O mass%	K2O mass%	P2O5 mass%	V ppm	V/ Al2O3
8040	8037	55.60	3.52			15.81	6.80	0.08		1.54		3.40	0.07	206.10	13.04
8042	8039	54.72	3.64			15.02	6.95	0.09		2.05		3.19	0.07	195.26	13.00
8044	8041	55.24	3.70			14.93	6.82	0.09		2.04		3.12	0.07	200.18	13.41
8046	8043	54.87	3.72			14.73	7.07	0.09		2.19		3.03	0.07	191.29	12.99
8048	8045	54.41	3.50			15.55	7.30	0.07		1.60		3.27	0.07	208.20	13.39
8050	8047	54.80	3.64			15.04	7.33	0.09		1.88		3.12	0.08	192.30	12.79
8052	8049	54.39	3.64			14.95	7.26	0.09		2.35		3.07	0.08	197.15	13.19
8054	8051	54.84	3.64			15.07	6.97	0.10		2.22		3.09	0.07	195.82	12.99
8056	8053	55.08	3.95			13.95	7.48	0.11		2.85		2.73	0.08	177.58	12.73
8058	8055	54.93	3.72			14.75	7.20	0.09		2.34		3.01	0.08	193.07	13.09
8060	8057	50.24	3.88			12.96	12.16	0.10		2.94		2.15	0.10	188.84	14.57
8062	8059	54.88	3.65			15.05	6.87	0.08		2.22		3.14	0.07	195.61	12.99
8064	8061	58.17	3.64			15.98	7.41	0.10		2.54		3.23	0.07	196.32	12.28
8066	8063	54.02	3.53			15.30	6.92	0.09		2.17		3.20	0.07	200.36	13.10
8068	8065	53.59	3.65			14.68	7.44	0.08		2.12		3.02	0.09	197.89	13.48
8070	8067	54.93	3.56			15.42	6.72	0.08		1.97		3.28	0.07	200.12	12.98
8072	8069	55.93	3.68			15.20	6.18	0.06		2.43		3.32	0.05	202.99	13.35
8074	8071	55.37	3.54			15.63	6.36	0.05		1.81		3.42	0.05	205.79	13.17
8076	8073	55.59	3.64			15.27	6.54	0.06		1.96		3.31	0.06	209.26	13.71
8078	8075	55.89	3.65			15.33	7.30	0.04		0.71		3.23	0.05	231.76	15.12
8080	8077	55.08	3.51			15.69	7.35	0.03		0.46		3.33	0.05	237.05	15.11
8082	8079	55.71	3.66			15.24	7.26	0.04		0.62		3.21	0.05	221.87	14.56

Table C.1a. Trace and major element analyses results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass %	SiO2/ Al2O3	TiO2 mass %	TiO2/ Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass %	MgO mass %	CaO mass%	Na2O mass%	K2O mass%	P2O5 mass%	V ppm	V/ Al2O3
8084	8081	55.11	3.51			15.70	7.15	0.03		0.52		3.36	0.05	238.07	15.16
8086	8083	53.65	3.40			15.77	7.09	0.03		0.25		3.47	0.05	237.08	15.03
8088	8085	54.90	3.55			15.47	7.11	0.04		1.13		3.35	0.05	212.60	13.74
8090	8087	54.40	3.59			15.14	6.54	0.06		2.42		3.34	0.06	209.20	13.82
8092	8089	54.41	3.44			15.83	6.78	0.05		1.27		3.48	0.06	220.61	13.94
8094	8091	54.79	3.38			16.19	6.78	0.04		0.81		3.55	0.05	224.75	13.88
8096	8093	53.46	3.22			16.60	7.11	0.03		0.19		3.60	0.06	237.13	14.29
8098	8095	54.63	3.42			15.97	7.35	0.03		0.48		3.41	0.06	224.79	14.08
8100	8097	54.90	3.43			16.00	6.84	0.05		1.29		3.46	0.05	206.67	12.92
8102	8099	54.85	3.56			15.41	7.04	0.07		1.77		3.30	0.06	200.50	13.01
8104	8101	55.64	3.48			15.99	6.66	0.05		1.10		3.46	0.06	221.65	13.86
8106	8103	54.30	3.42			15.90	7.60	0.03		0.36		3.39	0.05	241.81	15.21
8108	8105	53.60	3.42			15.65	7.49	0.03		0.22		3.39	0.05	235.40	15.04
8110	8107	53.88	3.33			16.18	6.95	0.03		0.58		3.52	0.05	217.48	13.44
8112	8109	55.20	3.53			15.64	7.01	0.05		1.33		3.35	0.05	203.15	12.99
8114	8111	53.07	3.28			16.20	7.10	0.03		0.21		3.53	0.06	229.95	14.19
8116	8113	55.34	3.50			15.81	6.99	0.04		0.78		3.41	0.06	225.32	14.25
8118	8115	55.19	3.42			16.12	6.99	0.03		0.24		3.46	0.05	233.29	14.48
8120	8117	54.71	3.52			15.55	7.37	0.04		0.82		3.33	0.05	221.48	14.24
8122	8119	55.11	3.57			15.42	6.84	0.04		1.50		3.33	0.07	214.21	13.89
8124	8121	54.30	3.40			15.99	7.30	0.03		0.28		3.47	0.06	236.45	14.79
8126	8123	54.03	3.69			14.63	7.43	0.06		2.76		3.12	0.07	205.98	14.08

Table C.1a. Trace and major element analyses results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass %	SiO2/ Al2O3	TiO2 mass %	TiO2/ Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass %	MgO mass %	CaO mass%	Na2O mass%	K2O mass%	P2O5 mass%	V ppm	V/ Al2O3
8128	8125	55.46	3.57			15.53	6.77	0.05		1.54		3.37	0.06	206.58	13.31
8130	8127	53.90	3.77			14.30	7.54	0.07		2.95		3.05	0.07	203.21	14.21
8132	8129	54.26	3.47			15.65	7.54	0.03		0.30		3.35	0.05	226.51	14.48
8134	8131	55.12	3.59			15.36	7.07	0.04		1.32		3.31	0.06	219.39	14.28
8136	8133	53.74	3.77			14.26	6.56	0.06		3.63		3.11	0.07	195.53	13.72
8138	8135	54.97	3.57			15.38	6.87	0.03		0.67		3.33	0.05	218.48	14.21
8140	8137	55.25	3.72			14.85	6.63	0.05		2.33		3.23	0.06	205.67	13.85
8142	8139	54.10	3.67			14.75	6.60	0.06		3.00		3.23	0.06	196.34	13.31
8144	8141	55.29	3.57			15.47	6.63	0.04		1.41		3.39	0.06	216.36	13.99
8146	8143	53.75	3.35			16.06	7.03	0.03		0.23		3.49	0.05	223.09	13.89
8148	8145	53.93	3.36			16.04	7.03	0.04		1.04		3.49	0.06	231.15	14.41
8150	8147	55.01	3.40			16.19	6.76	0.04		1.26		3.48	0.05	208.87	12.90
8152	8149	53.34	3.64			14.66	6.81	0.08		4.27		3.18	0.05	180.17	12.29
8154	8151	54.67	3.51			15.57	6.44	0.06		2.56		3.43	0.05	188.28	12.09
8156	8153	55.23	3.45			16.01	6.12	0.05		1.63		3.57	0.05	205.71	12.85
8158	8155	53.76	3.43			15.66	7.40	0.06		1.84		3.40	0.06	199.82	12.76
8160	8157	54.16	3.50			15.48	6.17	0.06		2.75		3.46	0.06	201.54	13.02
8162	8159	53.85	3.49			15.45	6.41	0.07		3.20		3.41	0.06	194.91	12.62
8164	8161	53.88	3.46			15.59	6.37	0.06		2.86		3.45	0.05	196.92	12.63
8166	8163	54.28	3.50			15.50	6.28	0.06		3.01		3.42	0.06	196.45	12.67
8168	8165	54.74	3.49			15.66	6.54	0.06		2.64		3.44	0.06	197.90	12.63
8170	8167	53.29	3.46	0.80	0.05	15.42	7.05	0.07	2.67	3.39	0.63	3.31	0.07	159.54	10.35

Table C.1a. Trace and major element analyses results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass %	SiO2/ Al2O3	TiO2 mass %	TiO2/ Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass %	MgO mass %	CaO mass%	Na2O mass%	K2O mass%	P2O5 mass%	V ppm	V/ Al2O3
8172	8169	54.43	3.39	0.80	0.05	16.05	6.66	0.07	2.67	2.86	0.65	3.48	0.06	165.84	10.33
8174	8171	54.27	3.18	0.88	0.05	17.09	6.64	0.03	2.52	0.94	0.71	3.78	0.06	183.90	10.76
8176	8173	54.60	3.18	0.93	0.05	17.15	6.62	0.03	2.50	0.68	0.72	3.79	0.06	199.80	11.65
8178	8175	54.34	3.29	0.87	0.05	16.53	6.67	0.03	2.36	1.24	0.73	3.63	0.07	188.41	11.40
8180	8177	55.19	3.31	0.82	0.05	16.68	6.62	0.04	2.43	1.05	0.74	3.67	0.06	181.19	10.86
8182	8179	52.34	3.29	0.78	0.05	15.91	8.74	0.03	2.35	1.07	0.75	3.35	0.05	170.09	10.69
8184	8181	54.01	3.13	0.82	0.05	17.28	6.28	0.05	2.68	1.69	0.70	3.83	0.06	178.39	10.33
8186	8183	54.24	3.24	0.81	0.05	16.75	6.85	0.04	2.49	1.32	0.71	3.67	0.06	173.29	10.35
8188	8185	53.01	3.02	0.89	0.05	17.55	6.74	0.03	2.54	0.32	0.74	3.90	0.05	195.97	11.17
8190	8187	52.48	3.03	0.88	0.05	17.33	6.88	0.03	2.48	0.83	0.73	3.82	0.05	195.42	11.28
8192	8189	53.11	3.28	0.80	0.05	16.19	7.06	0.04	2.37	1.60	0.70	3.55	0.06	189.82	11.72
8194	8191	52.96	3.35	0.73	0.05	15.80	6.05	0.06	2.50	3.85	0.63	3.50	0.06	166.89	10.56
8196	8193	52.93	3.03	0.87	0.05	17.45	6.75	0.02	2.39	0.28	0.74	3.91	0.05	244.91	14.04
8198	8195	52.74	2.99	0.88	0.05	17.64	6.70	0.02	2.47	0.23	0.74	3.94	0.05	242.70	13.76
8200	8197	53.02	3.29	0.77	0.05	16.11	6.64	0.05	2.47	2.67	0.66	3.57	0.06	193.59	12.02
8202	8199	51.95	3.59	0.57	0.04	14.46	5.79	0.07	2.20	6.86	0.60	3.16	0.06	165.60	11.45
8204	8201	51.09	2.88	0.89	0.05	17.72	6.54	0.02	2.46	0.11	0.77	4.05	0.05	265.21	14.97
8206	8203	50.97	2.95	0.87	0.05	17.30	7.26	0.02	2.38	0.10	0.74	3.89	0.05	233.03	13.47
8208	8205	52.09	2.99	0.84	0.05	17.42	7.95	0.03	2.52	0.32	0.71	3.82	0.06	241.62	13.87
8210	8207	48.07	2.77	0.89	0.05	17.36	8.19	0.02	2.48	0.16	0.70	3.86	0.07	244.98	14.11
8218	8215	52.74	3.03	0.81	0.05	17.43	6.68	0.04	2.60	1.17	0.72	3.90	0.05	200.68	11.52
8220	8217	53.79	2.98	0.86	0.05	18.03	5.97	0.03	2.57	0.45	0.75	4.06	0.05	197.47	10.95

Table C.1a. Trace and major element analyses results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass %	SiO2/ Al2O3	TiO2 mass %	TiO2/ Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass %	MgO mass %	CaO mass%	Na2O mass%	K2O mass%	P2O5 mass%	V ppm	V/ Al2O3
8222	8219	52.11	2.98	0.84	0.05	17.47	6.73	0.03	2.32	0.51	0.77	3.92	0.05	254.69	14.58
8224	8221	53.17	2.96	0.92	0.05	17.97	6.47	0.02	2.31	0.20	0.78	3.99	0.05	208.74	11.61
8226	8223	52.17	3.33	0.72	0.05	15.66	7.36	0.06	2.35	3.60	0.68	3.31	0.06	153.17	9.78
8228	8225	50.95	2.92	0.88	0.05	17.46	7.46	0.03	2.31	0.40	0.77	3.82	0.05	180.50	10.34
8230	8227	52.70	2.98	0.86	0.05	17.66	6.80	0.02	2.33	0.14	0.77	3.94	0.05	222.59	12.60
8232	8229	52.41	3.07	0.86	0.05	17.08	7.24	0.02	2.29	0.23	0.77	3.81	0.05	192.34	11.26
8234	8231	53.25	3.09	0.88	0.05	17.21	6.82	0.02	2.33	0.26	0.75	3.86	0.05	188.98	10.98
8236	8233	52.64	3.19	0.86	0.05	16.49	7.58	0.02	2.21	0.26	0.76	3.68	0.05	193.59	11.74
8238	8235	49.74	3.15	0.81	0.05	15.80	7.91	0.02	2.24	0.38	0.75	3.50	0.05	208.81	13.22
8240	8237	53.12	3.09	0.83	0.05	17.20	7.17	0.02	2.33	0.32	0.74	3.86	0.05	213.59	12.42
8242	8239	53.61	3.24	0.85	0.05	16.52	7.78	0.02	2.22	0.45	0.73	3.61	0.05	205.38	12.43
8244	8241	55.18	3.38	0.86	0.05	16.35	6.53	0.02	2.12	0.56	0.71	3.72	0.05	203.19	12.43
8246	8243	55.08	3.55	0.76	0.05	15.52	7.26	0.03	1.99	1.00	0.72	3.48	0.05	234.93	15.14
8248	8245	54.56	3.42	0.83	0.05	15.93	6.87	0.02	2.17	0.98	0.71	3.58	0.06	231.23	14.52
8250	8247	55.49	3.52	0.83	0.05	15.77	7.81	0.02	2.03	0.44	0.73	3.42	0.06	239.45	15.18
8252	8249	55.58	3.53	0.83	0.05	15.73	6.96	0.02	1.98	0.34	0.74	3.55	0.06	232.94	14.81
8254	8251	55.49	3.70	0.77	0.05	15.00	7.35	0.04	2.04	1.67	0.64	3.33	0.05	214.09	14.27
8256	8253	55.12	3.52	0.80	0.05	15.66	7.66	0.02	2.00	0.82	0.72	3.47	0.06	226.88	14.49
8258	8255	52.35	3.63	0.79	0.05	14.43	6.65	0.02	1.83	0.41	0.68	3.32	0.05	237.21	16.43
8260	8257	55.85	3.76	0.79	0.05	14.87	7.34	0.03	1.93	1.34	0.69	3.30	0.07	276.88	18.62
8262	8259	56.11	3.70	0.80	0.05	15.18	6.97	0.03	2.01	1.27	0.70	3.38	0.05	273.66	18.02
8264	8261	55.75	3.55	0.86	0.05	15.72	6.85	0.02	2.04	0.80	0.70	3.56	0.07	215.75	13.73

Table C.1a. Trace and major element analyses results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass %	SiO2/ Al2O3	TiO2 mass %	TiO2/ Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass %	MgO mass %	CaO mass%	Na2O mass%	K2O mass%	P2O5 mass%	V ppm	V/ Al2O3
8266	8263	56.47	3.41	0.87	0.05	16.56	6.22	0.02	2.10	0.47	0.72	3.81	0.05	265.19	16.02
8268	8265	55.63	3.38	0.87	0.05	16.48	6.36	0.02	2.27	0.72	0.72	3.78	0.05	228.04	13.84
8270	8267	53.88	3.24	0.85	0.05	16.64	6.91	0.02	2.26	0.68	0.74	3.79	0.04	244.96	14.73
8272	8269	54.69	3.34	0.86	0.05	16.35	6.54	0.02	2.17	0.94	0.71	3.76	0.05	256.02	15.66
8274	8271	54.20	3.37	0.87	0.05	16.09	7.39	0.02	2.12	0.81	0.73	3.62	0.05	298.18	18.53
8276	8273	52.97	3.50	0.75	0.05	15.13	6.26	0.03	1.97	3.20	0.74	3.49	0.07	374.23	24.74
8278	8275	55.62	3.44	0.90	0.06	16.15	6.75	0.02	2.06	0.72	0.78	3.63	0.06	265.27	16.42
8280	8277	55.29	3.46	0.88	0.05	15.97	6.10	0.02	1.98	0.69	0.81	3.63	0.05	293.25	18.36
8282	8279	54.63	3.44	0.86	0.05	15.87	6.44	0.02	2.04	1.01	0.87	3.50	0.06	303.61	19.13
8284	8281	46.22	3.67	0.58	0.05	12.59	5.86	0.05	3.01	10.61	0.73	2.48	0.05	125.05	9.93
8286	8283	49.19	4.14	0.59	0.05	11.89	4.42	0.04	1.80	12.18	0.66	2.60	0.06	300.50	25.27
8288	8285	51.52	3.97	0.68	0.05	12.97	3.93	0.03	1.74	8.55	0.69	2.93	0.08	398.89	30.76
8290	8287	41.09	3.44	0.56	0.05	11.96	3.41	0.00	1.67	1.81	0.66	2.89	0.39	424.26	35.48
8292	8289	54.13	3.47	0.82	0.05	15.60	5.69	0.02	1.88	1.14	0.74	3.64	0.06	552.08	35.39
8294	8291	55.18	3.70	0.80	0.05	14.92	5.68	0.03	1.78	2.39	0.73	3.48	0.05	452.09	30.30
8296	8293	57.31	4.07	0.77	0.05	14.09	5.60	0.02	1.44	2.42	0.65	3.30	0.06	395.48	28.07
8298	8295	58.76	4.72	0.66	0.05	12.45	5.15	0.03	1.10	4.83	0.62	2.90	0.06	357.04	28.69
8300	8297	57.80	4.67	0.66	0.05	12.39	5.57	0.03	1.27	5.01	0.60	2.84	0.05	338.75	27.35
8302	8299	56.73	3.99	0.86	0.06	14.21	6.02	0.02	1.53	0.94	0.74	3.32	0.06	430.76	30.32
8304	8301	58.39	4.30	0.77	0.06	13.59	5.53	0.03	1.36	3.35	0.67	3.12	0.06	306.36	22.54
8306	8303	56.14	3.66	0.83	0.05	15.36	7.08	0.02	1.73	1.00	0.72	3.43	0.05	311.50	20.28
8308	8305	55.06	3.52	0.90	0.06	15.63	7.01	0.02	1.85	0.83	0.75	3.49	0.05	296.04	18.94

Table C.1a. Trace and major element analyses results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass %	SiO2/ Al2O3	TiO2 mass %	TiO2/ Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass %	MgO mass %	CaO mass%	Na2O mass%	K2O mass%	P2O5 mass%	V ppm	V/ Al2O3
8310	8307	53.94	3.86	0.76	0.05	13.96	5.87	0.03	1.73	4.65	0.67	3.16	0.06	269.92	19.34
8312	8309	55.58	3.60	0.88	0.06	15.46	5.99	0.02	1.79	1.34	0.71	3.55	0.05	317.68	20.55
8314	8311	54.59	3.67	0.80	0.05	14.87	5.87	0.03	1.78	3.59	0.68	3.35	0.06	259.90	17.48
8316	8313	56.21	3.65	0.88	0.06	15.39	6.14	0.03	1.80	1.94	0.71	3.48	0.05	276.50	17.96
8318	8315	55.66	3.65	0.90	0.06	15.26	6.28	0.03	1.85	1.99	0.70	3.43	0.05	281.65	18.45
8320	8317	56.55	3.57	0.92	0.06	15.83	6.17	0.02	1.86	1.22	0.71	3.59	0.04	273.09	17.25
8322	8319	55.88	3.68	0.86	0.06	15.21	6.18	0.02	1.83	2.18	0.68	3.44	0.05	283.43	18.64
8324	8321	55.00	4.10	0.73	0.05	13.40	5.50	0.03	1.51	5.13	0.60	3.07	0.08	243.77	18.19
8326	8323	56.93	3.74	0.85	0.06	15.24	5.99	0.02	1.64	1.54	0.66	3.53	0.06	279.13	18.31
8328	8325	56.64	3.92	0.81	0.06	14.45	5.81	0.03	1.60	3.36	0.65	3.30	0.06	240.32	16.63
8330	8327	53.27	3.64	0.80	0.05	14.63	5.30	0.03	1.71	4.80	0.64	3.45	0.08	234.59	16.04
8332	8329	55.52	3.48	0.89	0.06	15.95	6.01	0.02	1.87	0.99	0.73	3.69	0.06	296.59	18.59
8334	8331	57.52	3.63	0.86	0.05	15.83	6.10	0.02	1.72	0.80	0.69	3.67	0.05	287.54	18.16
8336	8333	56.85	3.85	0.83	0.06	14.78	6.30	0.03	1.72	2.40	0.64	3.35	0.07	256.90	17.38
8338	8335	56.67	3.75	0.83	0.05	15.11	5.77	0.02	1.80	2.05	0.65	3.52	0.07	300.64	19.89
8340	8337	54.20	3.55	0.83	0.05	15.25	5.67	0.03	2.13	3.00	0.63	3.52	0.09	446.80	29.30
8342	8339	55.24	3.54	0.92	0.06	15.62	6.28	0.02	1.91	1.32	0.66	3.61	0.05	305.60	19.57
8344	8341	56.06	3.67	0.86	0.06	15.26	6.60	0.02	1.74	0.66	0.70	3.52	0.05	363.30	23.81
8346	8343	57.60	3.80	0.83	0.05	15.17	5.85	0.02	1.67	1.48	0.68	3.54	0.05	348.23	22.96
8348	8345	55.81	3.73	0.82	0.05	14.98	8.47	0.02	1.62	1.06	0.63	3.33	0.05	288.41	19.26
8350	8347	59.71	4.22	0.84	0.06	14.15	5.86	0.02	1.48	2.00	0.64	3.25	0.06	275.80	19.50
8352	8349	58.87	4.09	0.84	0.06	14.40	5.85	0.02	1.52	1.64	0.65	3.31	0.06	264.58	18.37

Table C.1a. Trace and major element analyses results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass %	SiO2/ Al2O3	TiO2 mass %	TiO2/ Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass %	MgO mass %	CaO mass%	Na2O mass%	K2O mass%	P2O5 mass%	V ppm	V/ Al2O3
8354	8351	57.74	3.97	0.81	0.06	14.55	5.87	0.02	1.60	2.34	0.62	3.35	0.06	251.90	17.32
8356	8353	58.15	3.92	0.87	0.06	14.85	5.83	0.02	1.65	1.06	0.67	3.39	0.06	282.25	19.01
8358	8355	59.35	4.22	0.78	0.06	14.05	5.29	0.02	1.41	2.66	0.61	3.28	0.06	265.32	18.89
8360	8357	58.70	4.31	0.75	0.05	13.63	5.38	0.03	1.42	3.82	0.60	3.17	0.06	223.58	16.40
8362	8359	59.02	4.39	0.77	0.06	13.45	7.31	0.02	1.27	1.49	0.67	2.96	0.06	230.42	17.13
8364	8361	58.09	4.00	0.82	0.06	14.54	6.38	0.02	1.50	1.13	0.67	3.32	0.06	280.56	19.30
8366	8363	53.10	3.61	0.74	0.05	14.70	6.81	0.04	2.26	3.67	0.75	3.11	0.08	301.56	20.51
8368	8365	57.90	4.18	0.75	0.05	13.86	5.21	0.02	1.45	3.42	0.65	3.19	0.06	258.46	18.65
8370	8367	59.35	4.46	0.74	0.06	13.31	6.65	0.02	1.21	1.41	0.67	3.01	0.06	332.60	24.99
8372	8369	60.45	7.35	0.36	0.04	8.22	5.52	0.02	0.45	11.05	0.46	1.85	0.17	466.15	56.69
8374	8371	56.99	4.98	0.58	0.05	11.45	8.42	0.01	1.08	1.89	0.66	2.57	0.06	911.10	79.54
8376	8373	12.98	22.69	-0.01	-0.02	0.57	1.71	0.06	1.48	44.13	0.10	0.11	0.41	10.44	18.24
8378	8375	57.10	4.63	0.61	0.05	12.33	7.62	0.01	1.15	2.31	0.73	2.76	0.08	769.13	62.40
8380	8377	53.29	4.30	0.65	0.05	12.40	9.39	0.01	1.23	0.63	0.79	2.79	0.06	674.25	54.40
8382	8379	45.85	1.96	0.65	0.03	23.45	1.25	0.00	2.79	0.19	1.34	3.71	0.08	84.60	3.61
8384	8381	74.03	13.69	0.24	0.04	5.41	3.30	0.01	-0.13	13.27	0.34	1.15	0.05	341.87	63.24
8386	8383	76.64	25.21	0.09	0.03	3.04	1.95	0.01	-0.34	22.32	0.22	0.61	0.07	375.44	123.50
8388	8385	46.66	28.61	0.02	0.01	1.63	1.76	0.04	0.26	39.92	0.16	0.26	0.09	105.24	64.52
8390	8387	1.43	7.67	-0.03	-0.15	0.19	0.27	0.03	0.90	49.24	0.07	0.05	0.09	14.89	80.04
8392	8389	20.30	15.27	0.02	0.02	1.33	0.59	0.02	0.88	45.20	0.12	0.29	0.05	27.22	20.48
8394	8391	36.76	6.29	0.24	0.04	5.84	1.54	0.02	1.55	28.29	0.27	1.51	0.15	139.77	23.93

Table C.1b. Trace and major element analyses results for COP 259.

Core Depth ft	Log-corrected Depth ft	Cr ppm	Cu ppm	Co ppm	Zn ppm	As ppm	Pb ppm	U ppm	U/Al2O3	Rb ppm	Sr ppm	Zr ppm	Y ppm	Nb ppm
8040	8037		18		46			3.18	0.20					
8042	8039		18		49			3.80	0.25					
8044	8041		22		163			3.11	0.21					
8046	8043		24		81			1.70	0.12					
8048	8045		21		53			2.39	0.15					
8050	8047		16		107			2.20	0.15					
8052	8049		15		92			2.61	0.17					
8054	8051		21		71			2.90	0.19					
8056	8053		41		123			1.83	0.13					
8058	8055		16		112			1.82	0.12					
8060	8057		11		115			2.85	0.22					
8062	8059		11		197			3.56	0.24					
8064	8061		21		89			3.86	0.24					
8066	8063		18		104			2.65	0.17					
8068	8065		17		79			2.17	0.15					
8070	8067		15		68			2.80	0.18					
8072	8069		28		29			4.23	0.28					
8074	8071		37		26			3.34	0.21					
8076	8073		39		24			3.19	0.21					
8078	8075		47		26			4.63	0.30					
8080	8077		55		25			5.32	0.34					
8082	8079		47		24			4.03	0.26					
8084	8081		60		50			5.25	0.33					

Table C.1b. Trace and major element analyses results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	Cr ppm	Cu ppm	Co ppm	Zn ppm	As ppm	Pb ppm	U ppm	U/Al2O3	Rb ppm	Sr ppm	Zr ppm	Y ppm	Nb ppm
8086	8083		54		41			5.54	0.35					
8088	8085		57		73			4.02	0.26					
8090	8087		35		103			3.89	0.26					
8092	8089		41		159			3.63	0.23					
8094	8091		48		47			1.98	0.12					
8096	8093		38		31			4.21	0.25					
8098	8095		63		23			3.28	0.21					
8100	8097		36		43			3.96	0.25					
8102	8099		16		22			3.02	0.20					
8104	8101		35		58			3.40	0.21					
8106	8103		58		22			3.88	0.24					
8108	8105		55		30			6.15	0.39					
8110	8107		49		47			4.28	0.26					
8112	8109		31		208			1.98	0.13					
8114	8111		57		1268			4.23	0.26					
8116	8113		51		56			3.13	0.20					
8118	8115		52		122			4.30	0.27					
8120	8117		59		122			1.84	0.12					
8122	8119		43		82			4.41	0.29					
8124	8121		45		29			5.06	0.32					
8126	8123		57		60			3.92	0.27					
8128	8125		37		61			3.12	0.20					
8130	8127		56		522			3.08	0.22					

Table C.1b. Trace and major element analyses results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	Cr ppm	Cu ppm	Co ppm	Zn ppm	As ppm	Pb ppm	U ppm	U/Al2O3	Rb ppm	Sr ppm	Zr ppm	Y ppm	Nb ppm
8132	8129		58		67			5.33	0.34					
8134	8131		52		37			3.28	0.21					
8136	8133		42		46			4.21	0.30					
8138	8135		54		464			4.75	0.31					
8140	8137		75		75			3.02	0.20					
8142	8139		51		476			3.74	0.25					
8144	8141		43		88			2.85	0.18					
8146	8143		56		31			6.43	0.40					
8148	8145		68		27			6.58	0.41					
8150	8147		59		83			3.58	0.22					
8152	8149		20		14			2.40	0.16					
8154	8151		27		89			3.06	0.20					
8156	8153		50		270			3.05	0.19					
8158	8155		28		31			3.16	0.20					
8160	8157		14		30			2.55	0.16					
8162	8159		16		30			2.84	0.18					
8164	8161		14		29			2.16	0.14					
8166	8163		21		30			2.76	0.18					
8168	8165		12		49			1.69	0.11					
8170	8167	102	20	17	52	7	7	2.70	0.17	159	318	127	9	14
8172	8169	106	18	15	71	6	10	2.51	0.16	170	262	125	8	13
8174	8171	105	70	17	47	14	30	3.51	0.21	192	238	140	9	14
8176	8173	101	60	17	48	15	29	3.07	0.18	193	256	148	11	16

Table C.1b. Trace and major element analyses results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	Cr ppm	Cu ppm	Co ppm	Zn ppm	As ppm	Pb ppm	U ppm	U/Al2O3	Rb ppm	Sr ppm	Zr ppm	Y ppm	Nb ppm
8178	8175	99	66	17	28	18	32	4.31	0.26	183	274	141	13	15
8180	8177	97	58	16	32	15	29	3.89	0.23	188	262	128	9	13
8182	8179	102	96	26	369	28	39	3.35	0.21	158	247	113	10	11
8184	8181	99	42	14	73	8	13	2.57	0.15	193	305	131	8	14
8186	8183	101	63	17	32	14	27	3.56	0.21	185	265	124	8	13
8188	8185	98	75	19	30	21	32	3.65	0.21	200	257	136	6	15
8190	8187	98	86	20	33	23	37	5.34	0.31	196	261	136	8	14
8192	8189	99	70	19	21	22	28	4.87	0.30	176	279	125	8	13
8194	8191	89	27	14	173	9	8	2.29	0.14	174	308	119	7	12
8196	8193	100	98	20	83	24	39	7.04	0.40	206	274	137	5	14
8198	8195	100	82	22	117	22	36	4.75	0.27	205	260	136	4	14
8200	8197	93	65	16	20	19	21	3.71	0.23	177	296	119	8	12
8202	8199	75	49	13	15	10	19	4.32	0.30	155	282	95	11	9
8204	8201	102	108	25	113	24	36	9.00	0.51	218	278	134	4	14
8206	8203	100	91	25	64	25	33	8.21	0.47	200	265	130	6	13
8208	8205	106	99	18	98	29	35	8.85	0.51	186	208	120	8	13
8210	8207	102	127	30	48	31	41	8.58	0.49	194	257	124	9	14
8218	8215	101	71	15	23	14	20	2.58	0.15	194	252	120	5	13
8220	8217	99	43	13	62	12	13	0.63	0.03	214	289	134	3	14
8222	8219	97	112	23	211	22	32	4.73	0.27	205	281	126	3	14
8224	8221	93	66	24	68	22	30	3.21	0.18	205	283	136	5	14
8226	8223	90	64	22	10	14	21	0.71	0.05	159	287	111	8	11
8228	8225	94	74	29	16	25	34	5.43	0.31	195	271	124	6	13

Table C.1b. Trace and major element analyses results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	Cr ppm	Cu ppm	Co ppm	Zn ppm	As ppm	Pb ppm	U ppm	U/Al2O3	Rb ppm	Sr ppm	Zr ppm	Y ppm	Nb ppm
8230	8227	100	83	27	309	23	30	8.89	0.50	203	283	134	6	13
8232	8229	93	82	25	51	24	27	7.52	0.44	195	289	129	8	14
8234	8231	96	69	22	44	24	28	6.02	0.35	199	273	132	8	14
8236	8233	96	63	25	46	24	27	7.74	0.47	182	246	133	11	14
8238	8235	95	76	32	177	27	26	8.91	0.56	174	237	130	12	13
8240	8237	96	75	26	120	31	24	7.71	0.45	192	254	128	11	14
8242	8239	96	66	25	128	32	27	6.35	0.38	176	253	129	10	13
8244	8241	88	68	22	507	24	23	8.18	0.50	191	297	140	12	14
8246	8243	88	89	22	324	25	28	9.05	0.58	175	278	123	12	12
8248	8245	85	86	22	183	24	24	11.74	0.74	179	279	137	16	13
8250	8247	94	82	28	136	28	26	10.03	0.64	159	239	137	15	13
8252	8249	88	94	30	23	25	25	12.01	0.76	176	275	135	14	13
8254	8251	83	73	17	91	19	22	8.28	0.55	161	267	124	14	11
8256	8253	91	79	20	61	24	29	11.47	0.73	168	261	124	14	12
8258	8255	85	83	38	155	24	24	10.96	0.76	170	255	141	15	13
8260	8257	84	88	24	801	23	26	9.86	0.66	157	240	131	21	12
8262	8259	82	84	26	220	23	21	9.56	0.63	163	269	135	18	13
8264	8261	84	74	22	248	22	23	7.16	0.46	174	269	137	17	13
8266	8263	82	76	20	177	23	21	8.11	0.49	193	279	140	11	15
8268	8265	84	70	18	85	21	20	9.10	0.55	187	274	140	13	14
8270	8267	85	77	20	84	24	23	13.27	0.80	187	288	132	11	13
8272	8269	84	78	21	169	22	21	14.45	0.88	188	295	137	16	13
8274	8271	89	95	36	88	29	26	12.69	0.79	172	261	135	15	14

Table C.1b. Trace and major element analyses results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	Cr ppm	Cu ppm	Co ppm	Zn ppm	As ppm	Pb ppm	U ppm	U/Al2O3	Rb ppm	Sr ppm	Zr ppm	Y ppm	Nb ppm
8276	8273	74	142	31	159	24	34	13.67	0.90	164	348	133	21	11
8278	8275	84	85	25	12	24	30	11.56	0.72	175	262	145	14	14
8280	8277	85	97	27	77	22	26	15.46	0.97	180	281	147	14	14
8282	8279	83	115	45	38	27	25	12.56	0.79	169	261	149	13	14
8284	8281	69	166	17	-4	22	23	4.73	0.38	111	282	105	14	9
8286	8283	59	145	20	280	21	18	11.28	0.95	114	319	118	19	10
8288	8285	81	147	47	1548	13	9	8.11	0.63	132	367	157	18	13
8290	8287	23	67	16	1	13	17	10.76	0.90	83	822	97	10	7
8292	8289	77	105	21	124	26	26	9.27	0.59	169	344	141	9	13
8294	8291	80	90	19	19	23	24	8.53	0.57	166	295	135	11	13
8296	8293	78	92	18	3	24	25	13.14	0.93	157	302	146	11	14
8298	8295	64	81	20	177	20	23	13.37	1.07	138	256	117	17	11
8300	8297	66	74	17	251	22	21	8.58	0.69	134	315	118	15	11
8302	8299	79	82	41	358	23	22	11.56	0.81	160	287	160	13	14
8304	8301	72	68	21	303	18	17	8.62	0.63	147	269	134	16	13
8306	8303	81	80	20	13	25	24	8.75	0.57	156	247	126	8	13
8308	8305	86	69	20	173	22	22	6.55	0.42	155	239	144	11	14
8310	8307	74	70	18	213	20	23	7.63	0.55	145	323	127	15	11
8312	8309	78	79	22	155	22	22	8.01	0.52	168	279	150	12	14
8314	8311	72	65	17	137	19	23	7.01	0.47	155	306	132	16	13
8316	8313	80	66	18	145	19	22	7.08	0.46	162	278	143	13	14
8318	8315	81	62	17	144	20	19	7.23	0.47	156	271	157	14	15
8320	8317	86	70	22	154	20	24	5.97	0.38	169	274	146	10	15

Table C.1b. Trace and major element analyses results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	Cr ppm	Cu ppm	Co ppm	Zn ppm	As ppm	Pb ppm	U ppm	U/Al2O3	Rb ppm	Sr ppm	Zr ppm	Y ppm	Nb ppm
8322	8319	76	69	18	158	19	23	7.76	0.51	160	299	141	13	13
8324	8321	68	57	17	162	17	20	10.30	0.77	141	306	136	21	12
8326	8323	79	70	21	200	20	27	6.90	0.45	168	283	137	12	14
8328	8325	71	53	16	110	17	22	7.02	0.49	152	304	138	14	13
8330	8327	72	63	16	43	17	25	8.07	0.55	158	311	132	15	13
8332	8329	82	85	25	166	21	28	10.24	0.64	175	281	145	12	14
8334	8331	80	96	25	468	22	27	10.71	0.68	174	279	139	11	14
8336	8333	77	70	18	44	19	26	6.43	0.44	155	287	136	17	13
8338	8335	81	69	22	227	16	17	9.91	0.66	168	311	137	16	13
8340	8337	78	55	20	2741	11	12	15.61	1.02	164	303	144	22	14
8342	8339	82	76	25	9	18	27	7.61	0.49	169	274	154	17	15
8344	8341	81	81	30	265	27	26	10.32	0.68	167	267	133	12	14
8346	8343	79	76	19	517	18	21	10.05	0.66	171	277	139	15	14
8348	8345	86	86	24	2	45	32	6.43	0.43	141	232	115	11	12
8350	8347	78	61	18	11	18	18	6.67	0.47	154	272	146	17	14
8352	8349	75	67	20	159	23	24	6.51	0.45	158	275	142	15	13
8354	8351	80	66	21	12	19	21	5.90	0.41	159	295	135	16	14
8356	8353	84	70	23	68	19	25	6.78	0.46	164	285	152	15	14
8358	8355	71	70	19	314	17	18	6.64	0.47	159	297	135	16	13
8360	8357	73	65	16	8	13	19	3.75	0.27	149	305	128	17	12
8362	8359	64	69	52	6	42	25	5.83	0.43	133	244	127	13	12
8364	8361	84	81	20	255	41	24	7.69	0.53	154	258	134	14	13
8366	8363	81	102	103	254	24	25	5.76	0.39	147	220	122	21	11

Table C.1b. Trace and major element analyses results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	Cr ppm	Cu ppm	Co ppm	Zn ppm	As ppm	Pb ppm	U ppm	U/Al2O3	Rb ppm	Sr ppm	Zr ppm	Y ppm	Nb ppm
8368	8365	73	71	18	146	18	23	8.11	0.59	151	314	132	17	12
8370	8367	76	106	40	1	36	41	11.04	0.83	140	258	128	18	12
8372	8369	40	128	50	200	36	31	24.40	2.97	84	296	79	53	5
8374	8371	85	195	189	738	58	44	27.47	2.40	112	226	105	25	9
8376	8373	5	2	-1	-30	3	4	0.82	1.43	8	275	23	20	2
8378	8375	75	182	94	563	55	44	28.97	2.35	121	243	105	25	9
8380	8377	91	242	97	7	60	77	52.52	4.24	115	208	111	33	9
8382	8379	12	11	2	-31	16	-1	16.14	0.69	177	759	273	27	18
8384	8381	33	139	72	-11	23	27	14.54	2.69	55	317	76	24	5
8386	8383	20	155	62	955	16	11	14.37	4.73	29	332	53	26	2
8388	8385	7	78	1	-33	20	9	3.13	1.92	14	264	31	17	2
8390	8387	2	-2	-2	-36	3	3	0.84	4.53	4	218	17	1	2
8392	8389	5	28	-1	-31	6	2	1.97	1.48	15	402	36	16	2
8394	8391	41	210	17	-28	10	17	9.87	1.69	57	549	88	10	6

Table C.1c. Trace and major element analysis results for COP 259.

Core Depth ft	Log-corrected Depth ft	Ba ppm	Ni ppm	Th ppm	Sc ppm	Mo ppm	Mo/Al2O3	S mass%	EF-Mo	EF-U	EF-V	Mo/Ti ppm/wt.%
8040	8037		70.67	13.00		0.18	0.01	0.21	0.08	0.60	0.89	
8042	8039		69.70	15.89		1.07	0.07	0.31	0.49	0.75	0.89	
8044	8041		67.76	15.89		1.02	0.07	0.20	0.47	0.62	0.92	
8046	8043		65.83	15.89		0.37	0.03	0.24	0.17	0.34	0.89	
8048	8045		74.54	15.89		-0.26	-0.02	0.32	-0.11	0.46	0.92	
8050	8047		69.70	14.44		0.38	0.03	0.13	0.17	0.43	0.87	
8052	8049		69.70	14.44		0.30	0.02	0.14	0.14	0.52	0.90	
8054	8051		65.83	17.33		0.55	0.04	0.14	0.25	0.57	0.89	
8056	8053		64.86	14.44		0.28	0.02	0.16	0.14	0.39	0.87	
8058	8055		66.80	15.89		0.41	0.03	0.18	0.19	0.37	0.90	
8060	8057		64.86	11.56		0.64	0.05	0.12	0.34	0.65	1.00	
8062	8059		64.86	13.00		-0.31	-0.02	0.08	-0.14	0.70	0.89	
8064	8061		65.83	13.00		0.85	0.05	0.16	0.37	0.72	0.84	
8066	8063		65.83	15.89		-0.15	-0.01	0.16	-0.06	0.51	0.90	
8068	8065		69.70	14.44		0.41	0.03	0.20	0.19	0.44	0.92	
8070	8067		59.05	14.44		0.45	0.03	0.19	0.20	0.54	0.89	
8072	8069		68.73	14.44		3.77	0.25	0.25	1.69	0.82	0.91	
8074	8071		59.05	15.89		2.16	0.14	0.40	0.95	0.63	0.90	
8076	8073		63.89	11.56		4.13	0.27	0.53	1.85	0.62	0.94	
8078	8075		89.06	15.89		16.74	1.09	1.13	7.46	0.89	1.03	
8080	8077		95.84	14.44		18.71	1.19	1.17	8.16	1.01	1.03	
8082	8079		88.09	17.33		16.03	1.05	1.12	7.19	0.78	1.00	
8084	8081		101.65	14.44		21.99	1.40	0.98	9.58	0.99	1.04	

Table C.1c. Trace and major element analysis results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	Ba ppm	Ni ppm	Th ppm	Sc ppm	Mo ppm	Mo/Al2O3	S mass%	EF-Mo	EF-U	EF-V	Mo/Ti ppm/wt.%
8086	8083		102.62	15.89		36.55	2.32	1.10	15.85	1.04	1.03	
8088	8085		83.25	13.00		11.76	0.76	0.74	5.20	0.77	0.94	
8090	8087		64.86	10.11		6.14	0.41	0.50	2.77	0.76	0.95	
8092	8089		72.60	10.11		8.18	0.52	0.68	3.53	0.68	0.95	
8094	8091		86.16	18.78		11.16	0.69	0.66	4.72	0.36	0.95	
8096	8093		100.68	18.78		21.62	1.30	1.03	8.91	0.75	0.98	
8098	8095		89.06	15.89		13.11	0.82	1.04	5.62	0.61	0.96	
8100	8097		62.92	14.44		0.94	0.06	0.55	0.40	0.73	0.88	
8102	8099		60.02	17.33		0.25	0.02	0.41	0.11	0.58	0.89	
8104	8101		73.57	15.89		3.65	0.23	0.37	1.56	0.63	0.95	
8106	8103		104.55	15.89		24.75	1.56	1.28	10.65	0.72	1.04	
8108	8105		106.49	15.89		29.01	1.85	1.27	12.67	1.16	1.03	
8110	8107		82.29	17.33		4.46	0.28	0.84	1.89	0.78	0.92	
8112	8109		60.99	15.89		1.47	0.09	0.49	0.64	0.37	0.89	
8114	8111		112.30	20.22		22.10	1.36	1.13	9.33	0.77	0.97	
8116	8113		82.29	17.33		11.41	0.72	0.81	4.94	0.59	0.97	
8118	8115		83.25	17.33		15.78	0.98	0.92	6.70	0.79	0.99	
8120	8117		84.22	15.89		10.37	0.67	0.98	4.56	0.35	0.97	
8122	8119		70.67	15.89		8.10	0.52	0.67	3.59	0.85	0.95	
8124	8121		96.81	18.78		21.06	1.32	1.17	9.01	0.94	1.01	
8126	8123		91.97	13.00		10.26	0.70	0.82	4.79	0.79	0.96	
8128	8125		65.83	13.00		2.98	0.19	0.48	1.31	0.60	0.91	
8130	8127		83.25	14.44		9.36	0.65	0.86	4.48	0.64	0.97	

Table C.1c. Trace and major element analysis results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	Ba ppm	Ni ppm	Th ppm	Sc ppm	Mo ppm	Mo/Al2O3	S mass%	EF-Mo	EF-U	EF-V	Mo/Ti ppm/wt.%
8132	8129		110.36	14.44		27.39	1.75	1.23	11.97	1.01	0.99	
8134	8131		91.97	11.56		13.37	0.87	0.82	5.95	0.63	0.98	
8136	8133		64.86	14.44		7.51	0.53	0.59	3.60	0.88	0.94	
8138	8135		94.87	15.89		22.20	1.44	1.01	9.87	0.92	0.97	
8140	8137		82.29	15.89		9.61	0.65	0.63	4.43	0.60	0.95	
8142	8139		72.60	13.00		11.41	0.77	0.59	5.29	0.75	0.91	
8144	8141		84.22	14.44		22.58	1.46	0.69	9.98	0.55	0.96	
8146	8143		112.30	15.89		38.63	2.41	1.11	16.45	1.19	0.95	
8148	8145		105.52	18.78		39.15	2.44	0.99	16.70	1.22	0.99	
8150	8147		84.22	13.00		11.61	0.72	0.68	4.90	0.66	0.88	
8152	8149		59.05	13.00		0.24	0.02	0.42	0.11	0.49	0.84	
8154	8151		60.02	13.00		1.09	0.07	0.35	0.48	0.58	0.83	
8156	8153		73.57	10.11		1.30	0.08	0.29	0.56	0.56	0.88	
8158	8155		75.51	11.56		0.52	0.03	0.68	0.23	0.60	0.87	
8160	8157		60.02	11.56		-0.36	-0.02	0.17	-0.16	0.49	0.89	
8162	8159		66.80	13.00		0.31	0.02	0.28	0.14	0.54	0.86	
8164	8161		62.92	13.00		-0.99	-0.06	0.25	-0.43	0.41	0.86	
8166	8163		62.92	13.00		-0.71	-0.05	0.18	-0.31	0.53	0.87	
8168	8165		65.83	13.00		0.12	0.01	0.29	0.05	0.32	0.86	
8170	8167	930	64	13	16	1.37	0.09	0.39	0.61	0.52	0.71	1.70
8172	8169	937	59	9	17	0.60	0.04	0.27	0.26	0.46	0.71	0.75
8174	8171	986	77	12	18	11.40	0.67	0.67	4.56	0.61	0.74	12.93
8176	8173	1024	74	15	19	12.73	0.74	0.76	5.08	0.53	0.80	13.75

Table C.1c. Trace and major element analysis results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	Ba ppm	Ni ppm	Th ppm	Sc ppm	Mo ppm	Mo/Al2O3	S mass%	EF-Mo	EF-U	EF-V	Mo/Ti ppm/wt.%
8178	8175	1011	81	13	20	22.97	1.39	0.92	9.50	0.77	0.78	26.40
8180	8177	1024	64	12	19	9.25	0.55	0.68	3.79	0.69	0.74	11.26
8182	8179	1177	97	12	20	43.64	2.74	1.63	18.75	0.62	0.73	56.31
8184	8181	1101	52	16	17	1.58	0.09	0.41	0.63	0.44	0.71	1.92
8186	8183	1030	69	13	18	5.88	0.35	0.73	2.40	0.63	0.71	7.29
8188	8185	1121	86	14	19	27.43	1.56	0.96	10.69	0.62	0.76	30.85
8190	8187	1122	95	15	19	46.51	2.68	1.04	18.35	0.91	0.77	53.03
8192	8189	1023	76	13	18	14.98	0.92	1.12	6.33	0.89	0.80	18.67
8194	8191	1026	48	10	14	1.45	0.09	0.43	0.63	0.43	0.72	1.98
8196	8193	1171	129	15	22	69.31	3.97	1.12	27.17	1.20	0.96	79.40
8198	8195	1137	120	13	21	50.06	2.84	1.09	19.41	0.80	0.94	56.69
8200	8197	1042	65	14	16	9.80	0.61	0.78	4.16	0.68	0.82	12.77
8202	8199	1027	65	11	13	31.02	2.15	0.51	14.67	0.89	0.78	54.13
8204	8201	1268	140	17	22	85.16	4.81	1.15	32.87	1.50	1.02	95.90
8206	8203	1201	119	16	21	70.93	4.10	1.43	28.03	1.41	0.92	81.43
8208	8205	1237	104	14	20	45.54	2.61	1.39	17.88	1.51	0.95	53.95
8210	8207	1284	132	15	22	80.98	4.66	2.12	31.90	1.46	0.97	91.40
8218	8215	1494	60	13	19	5.23	0.30	0.84	2.05	0.44	0.79	6.44
8220	8217	1312	57	15	18	2.19	0.12	0.60	0.83	0.10	0.75	2.55
8222	8219	1378	123	12	21	58.18	3.33	1.31	22.77	0.80	1.00	69.01
8224	8221	1507	91	15	21	24.92	1.39	1.27	9.48	0.53	0.79	27.15
8226	8223	1194	59	12	15	1.72	0.11	1.22	0.75	0.13	0.67	2.40
8228	8225	1349	62	15	18	23.04	1.32	1.94	9.02	0.92	0.71	26.27

Table C.1c. Trace and major element analysis results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	Ba ppm	Ni ppm	Th ppm	Sc ppm	Mo ppm	Mo/Al2O3	S mass%	EF-Mo	EF-U	EF-V	Mo/Ti ppm/wt.%
8230	8227	1521	128	15	22	72.52	4.11	1.49	28.07	1.49	0.86	84.62
8232	8229	1323	95	14	20	65.84	3.85	1.58	26.36	1.30	0.77	76.29
8234	8231	1346	92	15	19	54.06	3.14	1.34	21.48	1.04	0.75	61.50
8236	8233	1324	98	13	20	65.60	3.98	1.85	27.21	1.39	0.80	75.93
8238	8235	1264	112	13	20	89.94	5.69	1.92	38.93	1.67	0.90	111.59
8240	8237	1298	121	16	21	82.00	4.77	1.49	32.61	1.33	0.85	98.56
8242	8239	1301	100	11	20	59.93	3.63	1.63	24.81	1.14	0.85	70.50
8244	8241	1286	117	14	22	68.23	4.17	1.35	28.54	1.48	0.85	79.62
8246	8243	1136	162	12	22	98.97	6.38	1.66	43.62	1.73	1.04	129.54
8248	8245	1206	144	12	21	102.83	6.46	1.37	44.14	2.18	0.99	123.45
8250	8247	1288	127	12	21	72.73	4.61	1.72	31.54	1.88	1.04	88.05
8252	8249	1658	134	15	22	93.06	5.91	1.50	40.45	2.26	1.01	111.58
8254	8251	1092	122	11	20	82.32	5.49	1.57	37.53	1.64	0.98	107.61
8256	8253	1179	133	12	22	94.59	6.04	1.76	41.32	2.17	0.99	118.09
8258	8255	1304	141	11	22	93.00	6.44	1.41	44.06	2.25	1.12	117.42
8260	8257	1076	144	11	22	90.87	6.11	1.52	41.78	1.96	1.27	115.61
8262	8259	1108	134	12	21	96.50	6.36	1.35	43.46	1.87	1.23	120.32
8264	8261	1276	118	11	20	95.83	6.10	1.32	41.69	1.35	0.94	111.82
8266	8263	1280	125	15	20	84.68	5.11	1.11	34.98	1.45	1.10	97.56
8268	8265	1311	109	14	20	82.02	4.98	1.11	34.04	1.64	0.95	94.28
8270	8267	1485	143	12	22	95.96	5.77	1.41	39.45	2.36	1.01	113.16
8272	8269	1339	134	12	21	113.52	6.94	1.42	47.47	2.62	1.07	131.54
8274	8271	1331	172	13	22	122.56	7.62	1.87	52.09	2.34	1.27	140.55

Table C.1c. Trace and major element analysis results for COP 259. Continued.

Core Depth ft	Log-corrected Depth ft	Ba ppm	Ni ppm	Th ppm	Sc ppm	Mo ppm	Mo/Al2O3	S mass%	EF-Mo	EF-U	EF-V	Mo/Ti ppm/wt.%
8276	8273	1525	184	13	21	197.96	13.08	1.43	89.48	2.68	1.69	264.65
8278	8275	1213	138	10	22	103.18	6.39	1.62	43.69	2.12	1.12	114.38
8280	8277	1352	163	11	22	172.85	10.82	1.31	74.00	2.87	1.26	197.09
8282	8279	1277	173	11	23	164.26	10.35	1.50	70.78	2.35	1.31	191.22
8284	8281	941	69	8	11	23.62	1.88	1.42	12.83	1.11	0.68	40.66
8286	8283	911	152	8	13	101.32	8.52	0.94	58.26	2.81	1.73	171.44
8288	8285	898	170	12	15	46.06	3.55	0.70	24.29	1.85	2.10	67.34
8290	8287	79032	110	5	19	48.20	4.03	2.81	27.57	2.67	2.43	86.54
8292	8289	6566	202	13	22	88.08	5.65	1.55	38.61	1.76	2.42	107.28
8294	8291	1424	174	11	22	97.68	6.55	1.56	44.77	1.69	2.07	121.95
8296	8293	1565	178	9	20	101.59	7.21	1.52	49.32	2.76	1.92	131.42
8298	8295	1059	156	10	18	88.35	7.10	1.42	48.54	3.18	1.96	133.86
8300	8297	1799	140	9	19	66.39	5.36	1.41	36.66	2.05	1.87	100.29
8302	8299	1286	192	10	23	127.54	8.98	1.76	61.40	2.41	2.07	147.96
8304	8301	1217	137	13	18	64.38	4.74	1.40	32.39	1.88	1.54	83.72
8306	8303	1339	125	11	20	53.66	3.49	1.89	23.89	1.69	1.39	64.73
8308	8305	1406	135	12	20	65.61	4.20	1.78	28.70	1.24	1.30	72.81
8310	8307	1202	128	10	17	69.35	4.97	1.45	33.97	1.62	1.32	91.73
8312	8309	1310	138	12	20	62.07	4.02	1.42	27.46	1.54	1.41	70.21
8314	8311	1368	109	13	17	43.49	2.92	1.37	20.00	1.40	1.20	54.63
8316	8313	1331	106	12	19	42.60	2.77	1.38	18.92	1.36	1.23	48.18
8318	8315	1292	116	11	19	51.16	3.35	1.48	22.92	1.40	1.26	56.78
8320	8317	1308	118	12	20	42.22	2.67	1.48	18.24	1.12	1.18	46.04

Table C.1c. Trace and major element analysis results for COP 259. Continued.

Core Depth	Log-corrected Depth	Ba	Ni	Th	Sc	Mo	Mo/Al2O3	S	EF-Mo	EF-U	EF-V	Mo/Ti
ft	ft	ppm	ppm	ppm	ppm	ppm		mass%				ppm/wt.%
8322	8319	1296	124	13	19	53.77	3.54	1.54	24.18	1.51	1.27	62.82
8324	8321	1246	105	11	16	50.84	3.79	1.31	25.95	2.28	1.24	69.46
8326	8323	1297	122	14	19	48.44	3.18	1.43	21.73	1.34	1.25	57.25
8328	8325	1190	103	11	18	49.06	3.39	1.35	23.21	1.44	1.14	60.79
8330	8327	1190	99	11	16	56.32	3.85	1.26	26.33	1.63	1.10	70.41
8332	8329	1280	132	13	20	79.53	4.99	1.41	34.09	1.90	1.27	89.36
8334	8331	1271	131	14	21	77.12	4.87	1.47	33.31	2.00	1.24	89.88
8336	8333	1189	107	13	19	54.95	3.72	1.32	25.43	1.29	1.19	66.45
8338	8335	1220	115	16	19	72.47	4.80	1.29	32.79	1.94	1.36	87.74
8340	8337	1120	108	13	18	95.84	6.28	1.06	42.97	3.03	2.00	115.75
8342	8339	1253	120	14	20	65.26	4.18	1.61	28.58	1.44	1.34	70.85
8344	8341	1560	192	11	24	83.72	5.49	1.77	37.52	2.00	1.63	97.69
8346	8343	1396	146	13	20	94.56	6.23	1.41	42.64	1.96	1.57	113.38
8348	8345	1396	152	8	22	49.91	3.33	2.35	22.79	1.27	1.32	60.94
8350	8347	1175	108	13	18	51.88	3.67	1.38	25.08	1.40	1.33	61.68
8352	8349	1188	137	12	21	53.99	3.75	1.32	25.64	1.34	1.26	64.42
8354	8351	1210	109	12	19	45.44	3.12	1.42	21.36	1.20	1.18	56.10
8356	8353	1220	128	13	21	56.76	3.82	1.33	26.14	1.35	1.30	65.16
8358	8355	1144	132	12	19	63.57	4.53	1.18	30.95	1.40	1.29	81.40
8360	8357	1080	83	10	16	43.70	3.21	1.23	21.92	0.81	1.12	58.43
8362	8359	1062	154	9	21	45.81	3.41	2.06	23.29	1.28	1.17	59.50
8364	8361	1193	132	12	20	81.03	5.57	1.62	38.12	1.57	1.32	99.18
8366	8363	1976	108	11	18	57.04	3.88	1.19	26.53	1.16	1.40	76.66

Table C.1c. Trace and major element analysis results for COP 259. Continued.

Core Depth	Log-corrected Depth	Ba	Ni	Th	Sc	Mo	Mo/Al2O3	S	EF-Mo	EF-U	EF-V	Mo/Ti
ft	ft	ppm	ppm	ppm	ppm	ppm		mass%				ppm/wt.%
8368	8365	1154	122	11	18	85.55	6.17	1.25	42.22	1.73	1.28	113.46
8370	8367	1065	176	9	23	113.89	8.56	1.91	58.53	2.46	1.71	153.69
8372	8369	724	240	5	17	135.40	16.47	2.14	112.60	8.79	3.88	378.21
8374	8371	1450	381	9	29	215.53	18.82	2.84	128.68	7.11	5.44	371.60
8376	8373	1189	1	-1	-7	5.00	8.74	1.02	59.75	4.24	1.25	-384.46
8378	8375	1031	321	9	28	184.07	14.93	2.64	102.13	6.96	4.27	301.76
8380	8377	1189	401	9	31	260.04	20.98	3.61	143.47	12.56	3.72	402.54
8382	8379	2893	24	38	14	11.67	0.50	0.24	3.40	2.04	0.25	18.01
8384	8381	461	218	4	15	133.49	24.69	1.41	168.86	7.97	4.32	560.89
8386	8383	262	183	-1	10	180.75	59.46	0.90	406.60	14.00	8.45	1986.30
8388	8385	217	62	0	-2	27.17	16.66	1.09	113.94	5.69	4.41	1132.25
8390	8387	70	14	0	-9	4.93	26.53	0.46	181.40	13.43	5.47	-176.21
8392	8389	86	20	4	-6	5.91	4.45	0.36	30.41	4.40	1.40	246.21
8394	8391	250	133	5	4	24.50	4.19	0.59	28.68	5.01	1.64	104.25

Table C.2a. Trace and major element analyses results for COP 653.

Core Depth ft	Log-corrected Depth ft	SiO2 mass%	SiO2/Al2O3	TiO2 mass%	TiO2/Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass%	MgO mass%	CaO mass%	Na2O mass%	K2O mass%	P2O5 mass%
8222	8215.8	55.55	3.41	0.91	0.06	16.29	6.38	0.06	2.74	1.92	0.73	3.49	0.07
8224	8217.8	55.07	3.39	0.89	0.05	16.25	6.65	0.06	2.70	1.62	0.74	3.48	0.06
8226	8219.8	54.99	3.54	0.84	0.05	15.55	6.74	0.07	2.56	2.02	0.75	3.28	0.07
8228	8221.8	53.99	3.19	0.94	0.06	16.92	6.63	0.03	2.53	0.24	0.75	3.78	0.06
8230	8223.8	53.97	3.35	0.88	0.05	16.11	7.51	0.04	2.41	0.70	0.76	3.47	0.06
8232	8225.8	54.45	3.48	0.76	0.05	15.65	6.61	0.06	2.46	2.77	0.73	3.40	0.06
8234	8227.8	56.05	3.47	0.82	0.05	16.14	6.63	0.05	2.51	1.53	0.76	3.46	0.05
8236	8229.8	52.89	3.26	0.89	0.05	16.24	6.86	0.03	2.38	0.38	0.74	3.65	0.05
8238	8231.8	52.89	3.25	0.87	0.05	16.29	7.38	0.03	2.40	0.57	0.75	3.60	0.06
8240	8233.8	54.29	3.36	0.83	0.05	16.16	6.86	0.03	2.37	0.82	0.79	3.55	0.05
8242	8235.8	55.54	3.48	0.81	0.05	15.96	6.71	0.04	2.37	1.69	0.75	3.44	0.06
8244	8237.8	54.07	3.28	0.90	0.05	16.46	6.97	0.03	2.46	0.48	0.74	3.64	0.06
8246	8239.8	54.21	3.55	0.75	0.05	15.26	6.74	0.05	2.30	2.73	0.72	3.31	0.06
8248	8241.8	51.46	3.56	0.70	0.05	14.44	6.06	0.06	2.21	3.87	0.69	3.24	0.07
8250	8243.8	54.12	3.23	0.88	0.05	16.76	7.16	0.03	2.46	0.41	0.78	3.65	0.06
8252	8245.8	52.90	3.83	0.64	0.05	13.83	5.92	0.07	2.16	6.30	0.62	3.03	0.07
8254	8247.8	55.66	3.47	0.78	0.05	16.05	6.25	0.04	2.27	1.30	0.79	3.53	0.06
8256	8249.8	53.76	3.46	0.73	0.05	15.52	6.29	0.04	2.34	2.62	0.75	3.41	0.07
8258	8251.8	53.60	3.10	0.86	0.05	17.30	6.56	0.03	2.48	0.20	0.84	3.86	0.05
8260	8253.8	52.08	3.90	0.57	0.04	13.37	5.19	0.08	2.07	8.56	0.64	2.91	0.05
8262	8255.8	54.04	3.61	0.68	0.05	14.97	6.30	0.07	2.23	4.15	0.72	3.27	0.05
8264	8257.8	53.44	3.48	0.78	0.05	15.37	6.16	0.07	2.52	3.55	0.70	3.34	0.06
8266	8259.8	51.44	3.42	0.80	0.05	15.06	6.42	0.07	2.56	2.56	0.71	3.32	0.07

Table C.2a. Trace and major element analyses results for COP 653. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass%	SiO2/Al2O3	TiO2 mass%	TiO2/Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass%	MgO mass%	CaO mass%	Na2O mass%	K2O mass%	P2O5 mass%
8268	8261.8	53.36	3.41	0.79	0.05	15.63	6.23	0.07	2.65	3.76	0.68	3.39	0.07
8270	8263.8	52.15	3.48	0.76	0.05	14.98	6.03	0.07	2.61	4.98	0.67	3.25	0.07
8272	8265.8	53.30	3.40	0.79	0.05	15.67	6.23	0.07	2.68	3.75	0.68	3.39	0.06
8274	8267.8	53.79	3.37	0.80	0.05	15.96	6.42	0.07	2.76	3.41	0.69	3.41	0.06
8276	8269.8	52.94	3.48	0.80	0.05	15.22	7.00	0.08	2.71	4.11	0.65	3.19	0.07
8278	8271.8	51.62	3.40	0.80	0.05	15.18	6.15	0.06	2.55	2.89	0.70	3.35	0.06
8280	8273.8	53.83	3.35	0.83	0.05	16.08	6.23	0.07	2.75	3.20	0.69	3.47	0.07
8282	8275.8	53.88	3.37	0.84	0.05	16.01	6.57	0.07	2.74	2.75	0.70	3.42	0.07
8284	8277.8	53.52	3.45	0.81	0.05	15.53	6.51	0.08	2.69	3.72	0.68	3.32	0.07
8286	8279.8	52.83	3.41	0.83	0.05	15.49	6.46	0.07	2.65	2.93	0.69	3.36	0.07
8288	8281.8	54.04	3.49	0.79	0.05	15.49	6.31	0.07	2.57	3.55	0.70	3.35	0.06
8290	8283.8	53.63	3.71	0.62	0.04	14.44	5.60	0.06	2.21	5.90	0.71	3.14	0.05
8292	8285.8	54.04	3.31	0.80	0.05	16.31	6.58	0.04	2.44	1.83	0.74	3.54	0.06
8294	8287.8	53.84	3.20	0.86	0.05	16.84	6.64	0.03	2.47	0.77	0.77	3.70	0.06
8296	8289.8	55.49	3.39	0.79	0.05	16.39	6.32	0.04	2.42	1.80	0.77	3.56	0.05
8298	8291.8	53.46	3.13	0.84	0.05	17.07	6.62	0.03	2.42	0.57	0.85	3.76	0.05
8300	8293.8	53.47	3.39	0.74	0.05	15.77	6.24	0.06	2.55	3.40	0.70	3.44	0.06
8302	8295.8	53.16	3.30	0.74	0.05	16.11	6.77	0.05	2.47	2.52	0.74	3.49	0.06
8304	8297.8	53.95	3.36	0.78	0.05	16.03	6.59	0.05	2.34	2.44	0.75	3.49	0.06
8306	8299.8	53.90	3.39	0.79	0.05	15.91	6.21	0.04	2.24	3.38	0.72	3.44	0.06
8308	8301.8	53.11	3.10	0.91	0.05	17.16	7.37	0.03	2.42	0.44	0.78	3.68	0.06
8310	8303.8	51.27	3.17	0.85	0.05	16.19	6.69	0.03	2.32	0.95	0.77	3.59	0.06
8312	8305.8	51.92	3.48	0.71	0.05	14.90	5.97	0.07	2.37	4.99	0.67	3.25	0.06

Table C.2a. Trace and major element analyses results for COP 653. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass%	SiO2/Al2O3	TiO2 mass%	TiO2/Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass%	MgO mass%	CaO mass%	Na2O mass%	K2O mass%	P2O5 mass%
8314	8307.8	53.73	3.11	0.88	0.05	17.28	6.21	0.03	2.32	0.70	0.80	3.80	0.06
8316	8309.8	53.10	3.10	0.84	0.05	17.11	6.52	0.03	2.39	0.80	0.79	3.78	0.05
8318	8311.8	52.71	3.14	0.88	0.05	16.79	7.09	0.03	2.42	0.84	0.78	3.67	0.06
8320	8313.8	52.91	3.42	0.73	0.05	15.46	6.15	0.06	2.14	4.02	0.71	3.40	0.05
8322	8315.8	53.05	3.30	0.78	0.05	16.09	6.48	0.06	2.53	2.99	0.71	3.50	0.06
8324	8317.8	53.29	3.13	0.75	0.04	17.02	6.42	0.03	2.35	1.66	0.80	3.72	0.06
8326	8319.8	48.56	3.72	0.50	0.04	13.07	5.24	0.08	1.94	9.85	0.65	2.78	0.06
8328	8321.8	52.70	2.97	0.84	0.05	17.71	6.37	0.02	2.45	0.25	0.84	3.90	0.05
8330	8323.8	53.11	3.10	0.78	0.05	17.11	6.28	0.03	2.39	0.99	0.82	3.77	0.05
8332	8325.8	53.14	3.26	0.80	0.05	16.28	6.99	0.04	2.40	1.84	0.75	3.53	0.06
8334	8327.8	50.53	3.54	0.65	0.05	14.29	7.55	0.07	2.39	5.18	0.66	2.93	0.06
8336	8329.8	50.16	2.97	0.85	0.05	16.91	7.62	0.02	2.37	0.28	0.83	3.69	0.07
8338	8331.8	49.66	3.01	0.80	0.05	16.48	7.19	0.03	2.60	2.55	0.76	3.59	0.06
8340	8333.8	51.72	3.08	0.79	0.05	16.79	7.01	0.03	2.43	1.75	0.81	3.66	0.05
8342	8335.8	52.06	2.95	0.86	0.05	17.67	6.91	0.02	2.47	0.26	0.81	3.91	0.05
8344	8337.8	52.57	2.93	0.92	0.05	17.92	6.60	0.02	2.58	0.23	0.82	3.93	0.06
8346	8339.8	45.93	2.80	0.88	0.05	16.42	7.21	0.03	2.71	1.04	0.84	3.70	0.06
8348	8341.8	51.30	3.12	0.83	0.05	16.46	7.05	0.04	2.47	1.62	0.82	3.59	0.05
8350	8343.8	52.63	2.96	0.84	0.05	17.76	6.39	0.03	2.66	0.96	0.84	3.89	0.05
8352	8345.8	50.95	3.05	0.75	0.04	16.72	7.79	0.03	2.37	1.51	0.83	3.56	0.05
8354	8347.8	52.30	2.92	0.87	0.05	17.89	6.83	0.02	2.37	0.22	0.80	3.89	0.05
8356	8349.8	52.35	3.02	0.88	0.05	17.35	6.48	0.03	2.31	0.66	0.82	3.82	0.04
8358	8351.8	49.65	3.54	0.70	0.05	14.01	7.44	0.10	2.85	7.38	0.64	2.83	0.07

Table C.2a. Trace and major element analyses results for COP 653. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass%	SiO2/Al2O3	TiO2 mass%	TiO2/Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass%	MgO mass%	CaO mass%	Na2O mass%	K2O mass%	P2O5 mass%
8360	8353.8	50.93	3.26	0.76	0.05	15.61	7.10	0.06	2.55	4.11	0.76	3.29	0.05
8362	8355.8	50.42	3.10	0.81	0.05	16.26	7.71	0.02	2.12	0.41	0.71	3.59	0.06
8364	8357.8	52.04	3.10	0.86	0.05	16.80	7.17	0.02	2.24	0.20	0.76	3.71	0.06
8366	8359.8	52.13	3.12	0.86	0.05	16.72	7.68	0.02	2.33	0.32	0.76	3.65	0.06
8368	8361.8	51.72	3.08	0.88	0.05	16.80	7.11	0.02	2.27	0.21	0.71	3.73	0.05
8370	8363.8	51.95	3.21	0.87	0.05	16.20	7.46	0.02	2.15	0.19	0.76	3.59	0.05
8372	8365.8	50.25	3.16	0.82	0.05	15.91	8.69	0.02	2.16	0.40	0.70	3.41	0.05
8374	8367.8	51.76	3.20	0.84	0.05	16.18	7.65	0.02	2.07	0.24	0.69	3.59	0.06
8376	8369.8	48.94	3.21	0.81	0.05	15.22	7.54	0.02	2.02	1.09	0.66	3.48	0.06
8378	8371.8	54.40	3.40	0.86	0.05	16.02	6.93	0.02	2.07	0.31	0.71	3.58	0.05
8380	8373.8	53.15	3.28	0.82	0.05	16.21	6.63	0.02	2.14	0.78	0.82	3.66	0.05
8382	8375.8	53.22	3.47	0.80	0.05	15.32	8.05	0.02	2.00	0.37	0.76	3.34	0.06
8384	8377.8	53.94	3.48	0.83	0.05	15.50	7.53	0.02	2.07	0.60	0.79	3.41	0.07
8386	8379.8	54.15	3.57	0.82	0.05	15.19	7.39	0.03	2.06	0.69	0.81	3.35	0.06
8388	8381.8	53.22	3.69	0.78	0.05	14.44	7.54	0.03	1.99	0.79	0.77	3.23	0.06
8390	8383.8	54.72	3.53	0.82	0.05	15.51	6.78	0.02	1.96	0.55	0.76	3.54	0.05
8392	8385.8	53.85	3.47	0.82	0.05	15.50	7.51	0.02	2.04	0.71	0.75	3.46	0.06
8394	8387.8	54.62	3.47	0.86	0.05	15.74	7.10	0.02	2.05	0.42	0.79	3.51	0.06
8396	8389.8	55.13	3.46	0.84	0.05	15.91	6.33	0.02	2.01	0.50	0.79	3.65	0.05
8398	8391.8	55.18	3.89	0.77	0.05	14.19	6.84	0.03	1.86	1.99	0.74	3.16	0.08
8400	8393.8	54.73	3.61	0.83	0.06	15.16	7.17	0.02	1.92	0.75	0.77	3.41	0.06
8402	8395.8	56.04	3.57	0.86	0.05	15.70	6.32	0.02	2.02	0.65	0.79	3.59	0.05
8404	8397.8	54.74	3.38	0.89	0.05	16.20	6.52	0.02	2.21	0.53	0.76	3.71	0.05

Table C.2a. Trace and major element analyses results for COP 653. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass%	SiO2/Al2O3	TiO2 mass%	TiO2/Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass%	MgO mass%	CaO mass%	Na2O mass%	K2O mass%	P2O5 mass%
8406	8399.8	53.29	3.25	0.86	0.05	16.39	6.61	0.02	2.24	0.76	0.76	3.73	0.04
8408	8401.8	53.12	3.25	0.88	0.05	16.36	6.83	0.02	2.22	0.70	0.78	3.73	0.05
8410	8403.8	51.65	3.31	0.81	0.05	15.61	6.88	0.03	2.17	2.27	0.78	3.50	0.05
8412	8405.8	51.95	3.98	0.65	0.05	13.05	6.65	0.05	2.04	6.50	0.66	2.82	0.08
8414	8407.8	55.18	3.47	0.91	0.06	15.91	6.55	0.02	2.00	0.50	0.82	3.63	0.06
8416	8409.8	54.71	3.57	0.86	0.06	15.31	6.66	0.02	1.89	0.91	0.88	3.45	0.06
8420	8413.8	39.41	5.73	0.26	0.04	6.88	3.49	0.07	1.70	25.84	0.48	1.33	0.06
8422	8415.8	52.20	3.35	0.85	0.05	15.58	5.83	0.03	2.27	2.92	0.88	3.43	0.06
8424	8417.8	47.79	4.60	0.52	0.05	10.38	3.99	0.04	1.54	14.64	0.66	2.17	0.08
8426	8419.8	34.55	7.62	0.22	0.05	4.53	4.24	0.07	2.04	33.84	0.34	0.76	0.10
8428	8421.8	52.75	3.33	0.81	0.05	15.84	6.31	0.02	1.96	1.32	0.84	3.64	0.06
8430	8423.8	54.76	3.66	0.77	0.05	14.97	5.36	0.03	1.68	2.90	0.76	3.49	0.07
8432	8425.8	54.26	3.94	0.74	0.05	13.78	5.47	0.03	1.52	4.70	0.73	3.22	0.06
8434	8427.8	58.54	4.11	0.77	0.05	14.23	5.80	0.02	1.41	2.23	0.74	3.25	0.05
8436	8429.8	56.57	4.38	0.70	0.05	12.91	5.64	0.03	1.28	4.67	0.71	2.91	0.05
8438	8431.8	56.95	4.45	0.71	0.06	12.79	6.28	0.03	1.37	3.92	0.69	2.89	0.05
8440	8433.8	56.61	4.21	0.73	0.05	13.45	5.80	0.03	1.40	3.54	0.70	3.06	0.06
8442	8435.8	56.58	5.07	0.62	0.06	11.16	5.24	0.04	1.15	8.29	0.60	2.49	0.09
8444	8437.8	56.91	4.36	0.75	0.06	13.06	5.82	0.03	1.38	3.92	0.70	2.96	0.07
8446	8439.8	55.43	3.55	0.92	0.06	15.61	6.26	0.02	1.86	0.66	0.83	3.53	0.05
8448	8441.8	52.73	4.13	0.68	0.05	12.76	5.46	0.03	1.51	7.42	0.68	2.86	0.10
8450	8443.8	53.49	3.71	0.82	0.06	14.42	6.11	0.03	1.86	3.01	0.75	3.26	0.05
8452	8445.8	55.60	3.71	0.82	0.05	15.00	6.35	0.02	1.78	2.20	0.75	3.37	0.06

Table C.2a. Trace and major element analyses results for COP 653. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass%	SiO2/Al2O3	TiO2 mass%	TiO2/Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass%	MgO mass%	CaO mass%	Na2O mass%	K2O mass%	P2O5 mass%
8454	8447.8	55.26	3.62	0.84	0.06	15.29	6.18	0.03	1.86	2.52	0.75	3.38	0.05
8456	8449.8	55.05	3.63	0.86	0.06	15.15	6.37	0.03	1.85	2.31	0.72	3.41	0.05
8458	8451.8	53.85	3.84	0.81	0.06	14.02	6.11	0.03	1.77	3.87	0.71	3.14	0.07
8460	8453.8	55.45	3.63	0.89	0.06	15.29	6.40	0.02	1.87	1.78	0.75	3.42	0.05
8462	8455.8	55.57	3.87	0.84	0.06	14.36	6.55	0.03	1.81	2.36	0.72	3.18	0.05
8464	8457.8	56.76	3.90	0.81	0.06	14.54	6.06	0.03	1.70	2.60	0.72	3.22	0.05
8466	8459.8	55.81	3.77	0.85	0.06	14.79	5.77	0.02	1.66	1.94	0.72	3.37	0.07
8468	8461.8	56.94	3.87	0.84	0.06	14.70	5.93	0.02	1.65	2.05	0.72	3.32	0.05
8470	8463.8	55.79	4.05	0.77	0.06	13.79	5.65	0.03	1.55	4.32	0.67	3.14	0.06
8472	8465.8	54.64	4.11	0.72	0.05	13.30	5.48	0.03	1.54	5.67	0.65	3.02	0.07
8474	8467.8	55.94	3.66	0.89	0.06	15.26	6.15	0.02	1.82	1.30	0.74	3.46	0.06
8476	8469.8	54.94	3.66	0.82	0.05	15.03	5.59	0.02	1.77	2.58	0.70	3.47	0.08
8478	8471.8	57.09	3.96	0.80	0.06	14.42	5.85	0.02	1.66	2.38	0.68	3.25	0.06
8480	8473.8	57.42	3.90	0.81	0.06	14.72	6.84	0.02	1.69	1.49	0.72	3.26	0.06
8482	8475.8	56.16	3.77	0.85	0.06	14.90	6.17	0.02	1.77	1.42	0.71	3.38	0.06
8484	8477.8	52.28	3.77	0.82	0.06	13.86	6.24	0.03	1.79	3.42	0.73	3.15	0.11
8486	8479.8	55.25	3.67	0.89	0.06	15.05	6.15	0.02	1.86	1.84	0.72	3.41	0.05
8488	8481.8	55.81	3.68	0.89	0.06	15.16	5.95	0.02	1.79	0.87	0.76	3.47	0.06
8490	8483.8	55.29	3.90	0.80	0.06	14.19	5.59	0.03	1.65	3.08	0.68	3.32	0.07
8492	8485.8	57.27	4.07	0.81	0.06	14.08	5.72	0.03	1.59	2.65	0.71	3.22	0.06
8494	8487.8	57.46	4.07	0.82	0.06	14.13	5.87	0.03	1.61	2.12	0.69	3.22	0.06
8496	8489.8	57.76	4.07	0.83	0.06	14.20	5.88	0.02	1.56	1.95	0.71	3.24	0.06
8498	8491.8	57.87	3.85	0.88	0.06	15.04	5.64	0.02	1.63	0.99	0.72	3.43	0.06

Table C.2a. Trace and major element analyses results for COP 653. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass%	SiO2/Al2O3	TiO2 mass%	TiO2/Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass%	MgO mass%	CaO mass%	Na2O mass%	K2O mass%	P2O5 mass%
8500	8493.8	57.49	4.11	0.78	0.06	13.98	5.56	0.03	1.58	3.18	0.71	3.15	0.05
8502	8495.8	58.62	4.24	0.79	0.06	13.81	5.26	0.02	1.39	2.30	0.71	3.20	0.05
8504	8497.8	57.09	4.08	0.77	0.06	13.99	6.98	0.02	1.52	1.82	0.72	3.08	0.05
8506	8499.8	59.13	4.28	0.79	0.06	13.81	5.64	0.02	1.38	2.11	0.73	3.09	0.06
8508	8501.8	58.09	4.32	0.73	0.05	13.46	5.11	0.02	1.35	3.97	0.68	3.06	0.07
8510	8503.8	58.67	4.22	0.79	0.06	13.89	5.30	0.02	1.45	3.06	0.73	3.11	0.06
8512	8505.8	61.03	4.41	0.73	0.05	13.83	5.65	0.02	1.24	1.14	0.78	3.00	0.05
8514	8507.8	57.09	4.23	0.74	0.05	13.49	6.22	0.02	1.44	1.86	0.76	3.11	0.08
8516	8509.8	63.78	6.13	0.54	0.05	10.41	6.49	0.02	0.70	2.98	0.63	2.33	0.05
8518	8511.8	61.49	5.37	0.58	0.05	11.45	6.44	0.01	0.86	2.18	0.70	2.60	0.06
8520	8513.8	57.56	5.31	0.52	0.05	10.85	6.12	0.02	0.91	5.86	0.67	2.47	0.05
8522	8515.8	52.89	4.02	0.64	0.05	13.16	7.22	0.02	1.36	2.99	0.79	2.98	0.06
8524	8517.8	65.59	6.47	0.52	0.05	10.14	5.05	0.01	0.50	4.57	0.63	2.30	0.06
8528	8521.8	81.57	16.85	0.21	0.04	4.84	3.05	0.01	-0.42	5.92	0.36	1.14	0.06
8530	8523.8	75.03	21.03	0.12	0.03	3.57	1.40	0.01	-0.30	20.73	0.30	0.74	0.07
8532	8525.8	87.52	27.73	0.12	0.04	3.16	0.93	0.01	-0.49	15.25	0.29	0.71	0.09
8534	8527.8	55.49	13.37	0.17	0.04	4.15	2.65	0.01	0.28	24.40	0.36	0.90	0.09
8536	8529.8	22.81	39.81	-0.02	-0.03	0.57	0.32	0.02	0.55	47.90	0.08	0.12	0.05
8538	8531.8	37.81	7.54	0.14	0.03	5.01	0.74	0.01	0.84	32.03	0.27	1.18	0.04
8540	8533.8	15.11	4.04	0.05	0.01	3.74	0.48	0.02	0.90	40.44	0.16	0.74	0.06
8542	8535.8	13.01	10.49	0.02	0.02	1.24	0.35	0.02	1.06	44.07	0.08	0.33	0.04
8544	8537.8	21.75	5.23	0.10	0.02	4.16	1.29	0.02	1.72	35.33	0.16	0.96	0.06
8546	8539.8	36.15	5.27	0.27	0.04	6.87	1.96	0.02	2.33	25.31	0.23	1.76	0.12

Table C.2a. Trace and major element analyses results for COP 653. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass%	SiO2/Al2O3	TiO2 mass%	TiO2/Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass%	MgO mass%	CaO mass%	Na2O mass%	K2O mass%	P2O5 mass%
8548	8541.8	40.56	2.81	0.76	0.05	14.46	3.32	0.02	2.92	9.08	0.38	4.02	0.08
8550	8543.8	38.86	5.41	0.32	0.04	7.18	1.84	0.04	1.61	24.64	0.24	2.04	0.04

Table C.2b. Trace and major element analyses results for COP 653.

Core Depth ft	Log-corrected Depth ft	V ppm	V/Al2O3	Cr ppm	Cu ppm	Co ppm	Zn ppm	As ppm	Pb ppm	U ppm	U/Al2O3	Rb ppm	Sr ppm	Zr ppm
8222	8215.8	171.74	10.54	108	22	8	31	5	3	2.61	0.16	172	217	146
8224	8217.8	180.80	11.12	110	20	16	71	6	10	2.28	0.14	173	186	140
8226	8219.8	169.44	10.90	107	30	17	73	8	19	3.79	0.24	162	179	141
8228	8221.8	207.90	12.29	104	48	17	34	14	31	4.86	0.29	197	175	153
8230	8223.8	195.12	12.11	106	86	20	45	22	48	3.79	0.24	172	171	138
8232	8225.8	178.97	11.43	96	40	14	40	10	20	2.06	0.13	169	229	118
8234	8227.8	178.34	11.05	108	29	14	112	9	10	1.91	0.12	175	187	129
8236	8229.8	218.35	13.45	99	37	23	62	16	29	4.46	0.27	195	176	144
8238	8231.8	250.47	15.38	99	84	19	24	29	50	5.73	0.35	185	167	137
8240	8233.8	196.24	12.14	101	85	16	50	18	39	3.55	0.22	185	178	131
8242	8235.8	191.43	11.99	100	62	17	53	15	31	4.19	0.26	175	178	130
8244	8237.8	214.14	13.01	106	64	17	58	22	36	4.97	0.30	188	176	141
8246	8239.8	173.20	11.35	96	70	15	84	14	35	3.69	0.24	166	196	116

Table C.2b. Trace and major element analyses results for COP 653. Continued.

Core Depth ft	Log-corrected Depth ft	V ppm	V/Al2O3	Cr ppm	Cu ppm	Co ppm	Zn ppm	As ppm	Pb ppm	U ppm	U/Al2O3	Rb ppm	Sr ppm	Zr ppm
8248	8241.8	185.28	12.83	84	50	11	53	9	25	3.82	0.26	168	217	113
8250	8243.8	209.28	12.49	103	82	17	1736	24	47	6.06	0.36	184	163	135
8252	8245.8	159.49	11.53	85	51	9	62	9	20	3.83	0.28	148	244	109
8254	8247.8	196.98	12.28	100	66	15	208	10	23	4.79	0.30	185	172	127
8256	8249.8	195.79	12.61	95	77	13	79	10	28	3.15	0.20	175	198	117
8258	8251.8	221.67	12.81	103	67	17	27	18	47	6.65	0.38	206	168	132
8260	8253.8	125.10	9.36	73	41	11	160	6	18	1.48	0.11	141	300	101
8262	8255.8	151.15	10.10	93	35	16	32	11	21	1.83	0.12	162	241	109
8264	8257.8	161.37	10.50	97	35	15	98	8	20	3.44	0.22	165	244	125
8266	8259.8	159.94	10.62	104	20	14	21	5	1	1.66	0.11	168	218	125
8268	8261.8	163.38	10.45	102	13	12	25	5	1	3.12	0.20	166	254	124
8270	8263.8	159.08	10.62	96	14	9	23	6	-1	0.46	0.03	158	260	123
8272	8265.8	160.88	10.27	104	12	19	57	6	8	1.64	0.10	167	244	125
8274	8267.8	165.95	10.40	103	23	11	50	4	0	1.56	0.10	168	228	125
8276	8269.8	163.58	10.75	103	24	10	55	5	-1	1.89	0.12	153	222	122
8278	8271.8	161.72	10.66	97	25	10	56	5	-3	2.53	0.17	171	224	128
8280	8273.8	171.43	10.66	104	21	12	57	6	-1	1.60	0.10	169	229	131
8282	8275.8	173.53	10.84	101	32	18	65	5	5	2.52	0.16	169	212	130
8284	8277.8	162.62	10.47	101	19	12	79	6	6	2.36	0.15	161	221	125
8286	8279.8	167.85	10.84	100	22	13	30	5	7	2.39	0.15	167	214	129
8288	8281.8	159.57	10.31	97	16	10	45	5	6	2.81	0.18	165	223	121
8290	8283.8	144.63	10.02	87	37	11	162	7	10	0.88	0.06	157	250	104
8292	8285.8	173.19	10.62	99	58	17	63	14	30	1.63	0.10	180	185	126

Table C.2b. Trace and major element analyses results for COP 653. Continued.

Core Depth	Log-corrected Depth	V	V/Al2O3	Cr	Cu	Co	Zn	As	Pb	U	U/Al2O3	Rb	Sr	Zr
ft	ft	ppm		ppm	ppm	ppm	ppm	ppm	ppm	ppm		ppm	ppm	ppm
8294	8287.8	203.86	12.10	103	64	18	103	17	37	4.67	0.28	192	170	133
8296	8289.8	177.18	10.81	100	46	16	33	12	25	3.35	0.20	183	181	119
8298	8291.8	180.48	10.57	100	82	20	50	19	36	4.91	0.29	200	174	126
8300	8293.8	164.91	10.46	98	45	12	27	7	17	1.56	0.10	173	224	114
8302	8295.8	163.94	10.18	96	47	21	90	13	26	3.07	0.19	175	200	113
8304	8297.8	175.20	10.93	93	62	14	39	16	29	2.71	0.17	176	196	120
8306	8299.8	169.92	10.68	89	63	11	47	16	27	5.07	0.32	173	200	124
8308	8301.8	174.84	10.19	106	67	19	86	21	34	5.45	0.32	185	168	136
8310	8303.8	221.07	13.65	99	80	20	67	17	35	5.52	0.34	188	180	131
8312	8305.8	154.13	10.35	81	28	12	14	8	10	1.93	0.13	162	252	114
8314	8307.8	206.78	11.97	92	64	19	127	17	26	6.89	0.40	202	187	133
8316	8309.8	222.07	12.98	101	83	20	100	17	34	5.74	0.34	200	182	126
8318	8311.8	211.61	12.60	100	65	17	95	16	33	4.44	0.26	186	169	130
8320	8313.8	193.37	12.51	83	75	14	72	15	25	6.08	0.39	170	184	113
8322	8315.8	184.68	11.48	96	56	14	38	13	19	3.73	0.23	176	202	116
8324	8317.8	207.09	12.17	96	65	18	63	19	27	6.32	0.37	192	180	114
8326	8319.8	142.45	10.90	63	39	13	91	9	16	3.95	0.30	137	252	84
8328	8321.8	247.16	13.95	98	86	20	131	20	31	8.34	0.47	213	179	124
8330	8323.8	232.85	13.61	97	79	20	70	17	27	8.92	0.52	205	184	118
8332	8325.8	198.50	12.19	95	65	17	119	19	23	5.01	0.31	179	186	117
8334	8327.8	175.02	12.25	78	57	10	47	13	18	4.32	0.30	137	299	96
8336	8329.8	247.77	14.65	100	119	22	234	27	29	10.50	0.62	193	164	120
8338	8331.8	213.79	12.97	99	118	16	33	22	28	5.34	0.32	177	233	120

Table C.2b. Trace and major element analyses results for COP 653. Continued.

Core Depth	Log-corrected Depth	V	V/Al2O3	Cr	Cu	Co	Zn	As	Pb	U	U/Al2O3	Rb	Sr	Zr
ft	ft	ppm		ppm	ppm	ppm	ppm	ppm	ppm	ppm		ppm	ppm	ppm
8340	8333.8	193.69	11.54	97	88	18	24	18	26	5.25	0.31	186	221	112
8342	8335.8	223.81	12.67	100	84	23	107	21	25	4.19	0.24	203	169	123
8344	8337.8	222.25	12.40	101	72	19	140	18	24	4.98	0.28	206	184	133
8346	8339.8	202.05	12.30	100	96	20	25	20	28	3.10	0.19	194	180	124
8348	8341.8	197.22	11.99	96	71	19	26	17	24	2.85	0.17	182	194	120
8350	8343.8	195.43	11.01	105	29	14	63	12	12	2.18	0.12	201	202	126
8352	8345.8	217.19	12.99	98	107	22	119	28	30	4.20	0.25	174	186	109
8354	8347.8	225.44	12.60	98	86	20	152	23	29	3.60	0.20	204	177	123
8356	8349.8	205.01	11.81	95	76	23	105	24	27	3.17	0.18	202	185	127
8358	8351.8	132.66	9.47	80	10	7	7	3	5	3.06	0.22	129	225	108
8360	8353.8	154.25	9.88	86	42	13	11	15	16	2.50	0.16	158	205	112
8362	8355.8	186.27	11.46	95	95	28	50	24	33	6.25	0.38	188	172	116
8364	8357.8	212.88	12.67	99	75	19	198	22	28	6.34	0.38	195	172	125
8366	8359.8	207.63	12.42	97	70	23	126	25	25	6.52	0.39	183	170	126
8368	8361.8	191.93	11.42	98	69	23	56	24	24	6.05	0.36	197	174	127
8370	8363.8	193.04	11.91	99	68	26	56	21	24	8.91	0.55	184	171	131
8372	8365.8	212.76	13.37	101	85	25	47	32	26	5.87	0.37	169	158	119
8374	8367.8	219.45	13.57	96	78	32	52	31	28	8.83	0.55	181	162	125
8376	8369.8	206.42	13.56	94	92	30	115	29	25	9.41	0.62	177	183	127
8378	8371.8	236.76	14.78	89	75	20	747	24	26	10.43	0.65	182	170	133
8380	8373.8	208.24	12.85	91	83	21	259	24	28	9.30	0.57	189	187	126
8382	8375.8	216.54	14.13	96	84	29	114	30	27	9.51	0.62	162	157	125
8384	8377.8	225.35	14.54	92	80	23	122	28	25	9.39	0.61	166	169	130

Table C.2b. Trace and major element analyses results for COP 653. Continued.

Core Depth	Log-corrected Depth	V	V/Al2O3	Cr	Cu	Co	Zn	As	Pb	U	U/Al2O3	Rb	Sr	Zr
ft	ft	ppm		ppm	ppm	ppm	ppm	ppm	ppm	ppm		ppm	ppm	ppm
8386	8379.8	236.60	15.58	92	88	26	515	28	24	9.82	0.65	161	163	135
8388	8381.8	218.65	15.14	93	81	25	29	24	22	12.03	0.83	156	172	127
8390	8383.8	220.66	14.22	87	78	26	107	20	25	10.55	0.68	178	170	128
8392	8385.8	222.17	14.33	91	70	20	553	23	26	8.26	0.53	168	169	122
8394	8387.8	250.62	15.92	89	85	32	129	27	24	13.91	0.88	175	168	137
8396	8389.8	297.71	18.71	82	96	34	618	22	22	14.58	0.92	186	185	140
8398	8391.8	260.12	18.33	84	78	30	196	21	20	12.27	0.86	154	179	127
8400	8393.8	226.39	14.94	86	86	34	322	22	28	8.62	0.57	167	173	130
8402	8395.8	252.18	16.06	84	65	15	130	21	19	7.30	0.46	180	183	133
8404	8397.8	227.96	14.07	87	70	23	94	21	21	8.09	0.50	186	181	136
8406	8399.8	207.61	12.67	82	66	17	77	21	21	9.77	0.60	191	186	129
8408	8401.8	249.14	15.23	87	77	26	50	24	25	14.59	0.89	187	183	131
8410	8403.8	283.46	18.16	87	92	28	58	25	25	11.15	0.71	169	194	125
8412	8405.8	298.66	22.89	69	105	17	298	22	23	8.20	0.63	128	221	113
8414	8407.8	268.84	16.90	84	75	28	10	24	28	9.04	0.57	177	166	144
8416	8409.8	258.31	16.87	86	92	32	9	25	27	9.00	0.59	168	181	141
8420	8413.8	72.65	10.56	33	41	1	9	7	7	3.35	0.49	60	405	67
8422	8415.8	399.81	25.66	92	158	50	176	31	29	7.96	0.51	160	189	146
8424	8417.8	275.65	26.55	68	253	122	3409	16	15	5.88	0.57	93	309	122
8426	8419.8	43.75	9.65	31	27	-2	46	9	2	2.65	0.59	36	427	83
8428	8421.8	538.51	34.00	87	140	32	16	32	33	9.32	0.59	174	192	130
8430	8423.8	385.01	25.73	73	87	18	7	22	28	9.55	0.64	169	228	127
8432	8425.8	382.75	27.78	69	91	20	3	22	25	11.94	0.87	150	224	130

Table C.2b. Trace and major element analyses results for COP 653. Continued.

Core Depth ft	Log-corrected Depth ft	V ppm	V/Al2O3	Cr ppm	Cu ppm	Co ppm	Zn ppm	As ppm	Pb ppm	U ppm	U/Al2O3	Rb ppm	Sr ppm	Zr ppm
8434	8427.8	393.12	27.63	75	85	19	280	24	28	8.35	0.59	155	190	128
8436	8429.8	397.19	30.78	68	85	32	432	23	25	6.80	0.53	135	213	121
8438	8431.8	351.92	27.52	72	82	22	298	26	21	10.13	0.79	134	196	119
8440	8433.8	378.22	28.12	70	78	28	450	23	21	13.19	0.98	146	211	125
8442	8435.8	258.24	23.14	59	45	15	303	14	13	7.21	0.65	115	214	115
8444	8437.8	297.01	22.74	73	62	18	370	18	22	7.67	0.59	139	211	123
8446	8439.8	397.70	25.48	87	94	29	204	23	25	12.39	0.79	169	182	151
8448	8441.8	259.04	20.30	64	66	16	208	16	18	8.25	0.65	131	246	117
8450	8443.8	291.44	20.21	76	74	18	397	19	18	9.07	0.63	155	195	135
8452	8445.8	306.56	20.44	80	72	19	257	24	24	8.04	0.54	158	186	123
8454	8447.8	260.89	17.07	76	66	14	113	20	23	4.59	0.30	159	213	133
8456	8449.8	270.41	17.85	81	65	16	144	20	24	5.40	0.36	159	196	133
8458	8451.8	264.71	18.88	74	58	17	195	17	17	9.00	0.64	146	208	134
8460	8453.8	284.04	18.58	83	64	18	170	19	20	6.56	0.43	159	186	143
8462	8455.8	266.97	18.60	78	65	17	179	21	28	5.33	0.37	148	183	136
8464	8457.8	274.97	18.91	78	66	15	183	19	22	7.06	0.49	153	200	126
8466	8459.8	293.41	19.84	78	65	23	345	17	18	10.30	0.70	163	204	149
8468	8461.8	253.62	17.25	77	58	17	76	18	20	6.82	0.46	161	203	135
8470	8463.8	240.22	17.43	70	56	15	183	17	16	6.58	0.48	149	215	126
8472	8465.8	221.30	16.63	62	55	12	100	16	21	5.39	0.40	142	243	120
8474	8467.8	276.56	18.12	81	76	20	220	18	25	10.08	0.66	165	185	144
8476	8469.8	297.74	19.81	76	72	18	252	17	12	8.97	0.60	169	229	137
8478	8471.8	255.31	17.71	76	73	15	7	17	24	6.09	0.42	158	205	129

Table C.2b. Trace and major element analyses results for COP 653. Continued.

Core Depth ft	Log-corrected Depth ft	V ppm	V/Al2O3	Cr ppm	Cu ppm	Co ppm	Zn ppm	As ppm	Pb ppm	U ppm	U/Al2O3	Rb ppm	Sr ppm	Zr ppm
8480	8473.8	265.94	18.06	84	83	17	6	22	30	5.93	0.40	153	178	123
8482	8475.8	272.98	18.33	77	84	20	13	19	22	6.58	0.44	165	194	138
8484	8477.8	256.61	18.52	73	76	28	2	18	29	10.13	0.73	149	191	133
8486	8479.8	299.39	19.89	80	74	19	8	19	24	8.35	0.55	164	188	140
8488	8481.8	316.71	20.90	81	74	22	576	18	18	12.47	0.82	170	188	147
8490	8483.8	299.05	21.08	71	65	18	662	15	15	9.31	0.66	157	185	133
8492	8485.8	274.02	19.46	76	57	18	339	16	15	8.22	0.58	156	207	136
8494	8487.8	277.17	19.61	79	61	14	11	16	18	5.73	0.41	157	195	133
8496	8489.8	283.60	19.97	75	64	17	371	18	17	6.04	0.43	157	195	134
8498	8491.8	274.13	18.23	82	46	15	124	15	10	7.85	0.52	170	196	148
8500	8493.8	270.42	19.35	73	54	13	3	15	17	6.81	0.49	152	212	128
8502	8495.8	251.76	18.23	70	55	18	105	12	13	6.95	0.50	160	210	135
8504	8497.8	240.86	17.22	80	65	16	1	18	24	4.91	0.35	141	175	118
8506	8499.8	245.96	17.81	71	67	18	10	21	19	6.31	0.46	153	206	131
8508	8501.8	282.91	21.02	65	67	18	244	16	12	7.68	0.57	149	226	125
8510	8503.8	270.11	19.45	70	63	18	71	16	17	7.10	0.51	151	216	133
8512	8505.8	255.59	18.49	72	84	23	-4	30	30	10.63	0.77	146	180	135
8514	8507.8	448.05	33.21	73	74	94	186	18	16	24.42	1.81	150	195	123
8516	8509.8	635.50	61.05	71	135	101	14	43	26	10.53	1.01	111	169	96
8518	8511.8	713.29	62.32	68	172	170	514	42	32	28.53	2.49	126	181	103
8520	8513.8	682.77	62.93	68	182	178	1189	44	28	22.20	2.05	112	211	94
8522	8515.8	701.42	53.28	73	217	284	61	50	56	40.64	3.09	135	189	106
8524	8517.8	515.44	50.83	53	187	131	994	36	46	18.52	1.83	110	215	111

Table C.2b. Trace and major element analyses results for COP 653. Continued.

Core Depth ft	Log-corrected Depth ft	V ppm	V/Al2O3	Cr ppm	Cu ppm	Co ppm	Zn ppm	As ppm	Pb ppm	U ppm	U/Al2O3	Rb ppm	Sr ppm	Zr ppm
8528	8521.8	511.58	105.66	25	222	479	121	25	31	29.81	6.16	58	182	72
8530	8523.8	364.54	102.17	23	199	216	38	15	14	10.72	3.00	38	361	66
8532	8525.8	517.97	164.12	4	260	516	316	15	12	16.14	5.11	37	289	59
8534	8527.8	698.07	168.21	20	358	752	855	36	32	23.64	5.70	44	358	79
8536	8529.8	116.60	203.48	0	35	8	373	2	9	6.53	11.40	8	318	24
8538	8531.8	53.61	10.69	13	119	20	-21	8	19	4.03	0.80	46	637	76
8540	8533.8	45.94	12.28	6	58	0	-16	7	3	3.52	0.94	22	390	54
8542	8535.8	16.07	12.95	4	7	23	87	1	3	2.68	2.16	14	311	30
8544	8537.8	18.75	4.51	9	32	2	-30	6	18	1.16	0.28	33	433	56
8546	8539.8	77.89	11.35	26	141	29	-20	9	20	5.62	0.82	69	531	81
8548	8541.8	110.89	7.67	40	81	10	-2	24	50	6.76	0.47	125	505	214
8550	8543.8	133.62	18.62	28	32	5	22	6	14	3.82	0.53	77	476	82

Table C.2c. Trace and major element analyses results for COP 653.

Core Depth ft	Log-corrected Depth ft	Y ppm	Nb ppm	Ba ppm	Ni ppm	Th ppm	Sc ppm	Mo ppm	Mo/Al2O3	S mass%	EF-Mo	EF-U	EF-V	Mo/Ti
8222	8215.75	13	15	1144	60	13	17	0.24	0.01	0.13	0.10	0.47	0.72	0.26
8224	8217.75	12	14	1106	67	12	18	-0.40	-0.02	0.31	-0.17	0.42	0.76	-0.45
8226	8219.75	15	15	1081	70	12	18	1.77	0.11	0.42	0.78	0.72	0.75	2.10
8228	8221.75	12	16	1229	89	15	21	29.94	1.77	0.85	12.10	0.85	0.84	31.92

Table C.2c. Trace and major element analyses results for COP 653. Continued.

Core Depth	Log-corrected Depth	Y	Nb	Ba	Ni	Th	Sc	Mo	Mo/Al2O3	S	EF-Mo	EF-U	EF-V	Mo/Ti
ft	ft	ppm	ppm	ppm	ppm	ppm	ppm	ppm		mass%				
8230	8223.75	13	15	1185	100	12	20	15.64	0.97	1.20	6.64	0.70	0.83	17.79
8232	8225.75	11	12	1187	66	11	16	1.29	0.08	0.53	0.56	0.39	0.78	1.70
8234	8227.75	10	14	1162	57	11	18	0.93	0.06	0.37	0.40	0.35	0.76	1.14
8236	8229.75	11	15	1293	87	14	20	36.42	2.24	1.09	15.34	0.81	0.92	40.93
8238	8231.75	12	14	1323	124	13	20	42.73	2.62	1.26	17.94	1.04	1.05	49.34
8240	8233.75	12	13	1264	100	13	20	26.61	1.65	0.96	11.26	0.65	0.83	32.25
8242	8235.75	13	14	1125	73	13	18	10.04	0.63	0.66	4.30	0.78	0.82	12.33
8244	8237.75	12	15	1276	102	14	20	29.39	1.79	0.93	12.21	0.89	0.89	32.69
8246	8239.75	10	12	1087	82	11	18	10.09	0.66	0.82	4.52	0.72	0.78	13.42
8248	8241.75	10	11	1095	80	10	16	18.04	1.25	0.59	8.55	0.78	0.88	25.96
8250	8243.75	9	15	1264	121	13	20	37.79	2.26	1.01	15.42	1.07	0.85	42.89
8252	8245.75	14	11	982	63	11	13	9.61	0.69	0.59	4.75	0.82	0.79	14.94
8254	8247.75	8	13	1165	89	12	19	29.56	1.84	0.65	12.60	0.88	0.84	38.05
8256	8249.75	10	12	1160	91	11	17	20.05	1.29	0.67	8.83	0.60	0.86	27.42
8258	8251.75	6	13	1306	107	14	21	45.30	2.62	0.86	17.91	1.14	0.88	52.99
8260	8253.75	11	10	1036	47	11	12	1.14	0.08	0.37	0.58	0.33	0.64	1.99
8262	8255.75	6	11	1163	60	9	15	2.29	0.15	0.64	1.05	0.36	0.69	3.35
8264	8257.75	9	13	1201	70	11	16	2.48	0.16	0.46	1.10	0.66	0.72	3.16
8266	8259.75	8	13	1242	54	13	16	0.02	0.00	0.35	0.01	0.33	0.73	0.02
8268	8261.75	8	13	1233	58	11	16	0.28	0.02	0.34	0.12	0.59	0.71	0.36
8270	8263.75	9	12	1162	56	11	14	0.27	0.02	0.26	0.12	0.09	0.73	0.36
8272	8265.75	7	13	1223	69	10	16	-0.38	-0.02	0.29	-0.17	0.31	0.70	-0.48
8274	8267.75	8	12	1241	62	14	16	0.20	0.01	0.19	0.09	0.29	0.71	0.25

Table C.2c. Trace and major element analyses results for COP 653. Continued.

Core Depth	Log-corrected Depth	Y	Nb	Ba	Ni	Th	Sc	Mo	Mo/Al2O3	S	EF-Mo	EF-U	EF-V	Mo/Ti
ft	ft	ppm	ppm	ppm	ppm	ppm	ppm	ppm		mass%				
8276	8269.75	9	13	1164	63	12	15	0.37	0.02	0.20	0.16	0.37	0.73	0.46
8278	8271.75	7	12	1198	61	14	16	-0.62	-0.04	0.21	-0.28	0.49	0.73	-0.78
8280	8273.75	8	13	1268	62	11	15	0.41	0.03	0.24	0.18	0.29	0.73	0.49
8282	8275.75	9	14	1211	71	14	17	1.47	0.09	0.40	0.63	0.47	0.74	1.75
8284	8277.75	9	13	1187	62	12	16	0.56	0.04	0.34	0.25	0.45	0.72	0.69
8286	8279.75	9	13	1226	68	11	16	0.50	0.03	0.39	0.22	0.46	0.74	0.60
8288	8281.75	8	13	1209	57	12	15	0.00	0.00	0.27	0.00	0.54	0.70	0.00
8290	8283.75	10	10	1112	57	9	14	3.16	0.22	0.32	1.50	0.18	0.68	5.10
8292	8285.75	10	13	1263	71	12	18	7.60	0.47	0.75	3.19	0.30	0.73	9.50
8294	8287.75	11	14	1294	85	15	19	26.63	1.58	0.81	10.81	0.82	0.83	30.86
8296	8289.75	11	13	1254	63	12	18	8.71	0.53	0.52	3.63	0.61	0.74	11.07
8298	8291.75	8	14	1373	86	16	20	26.96	1.58	1.00	10.80	0.85	0.72	32.29
8300	8293.75	11	12	1395	55	14	16	2.00	0.13	0.50	0.87	0.29	0.71	2.71
8302	8295.75	10	12	1361	64	12	17	2.02	0.13	0.89	0.86	0.56	0.70	2.72
8304	8297.75	10	12	1283	59	12	17	6.25	0.39	0.76	2.67	0.50	0.75	8.00
8306	8299.75	14	12	1253	61	14	17	16.64	1.05	0.75	7.15	0.94	0.73	21.20
8308	8301.75	9	15	1418	84	14	20	35.10	2.05	1.25	13.99	0.94	0.70	38.40
8310	8303.75	8	14	1384	103	14	20	42.26	2.61	1.04	17.85	1.01	0.93	49.60
8312	8305.75	9	12	1302	49	10	14	1.67	0.11	0.53	0.77	0.38	0.71	2.35
8314	8307.75	5	15	1472	100	14	20	44.71	2.59	0.91	17.70	1.18	0.82	50.74
8316	8309.75	5	14	1438	110	14	21	48.52	2.84	1.04	19.40	0.99	0.89	57.63
8318	8311.75	9	14	1398	100	17	20	30.20	1.80	1.29	12.30	0.78	0.86	34.52
8320	8313.75	12	13	1201	84	12	17	25.39	1.64	0.82	11.23	1.17	0.86	34.98

Table C.2c. Trace and major element analyses results for COP 653. Continued.

Core Depth	Log-corrected Depth	Y	Nb	Ba	Ni	Th	Sc	Mo	Mo/Al2O3	S	EF-Mo	EF-U	EF-V	Mo/Ti
ft	ft	ppm	ppm	ppm	ppm	ppm	ppm	ppm		mass%				
8322	8315.75	9	13	1347	59	12	16	8.55	0.53	0.71	3.63	0.69	0.78	11.03
8324	8317.75	5	13	1406	101	14	19	62.60	3.68	0.95	25.16	1.10	0.83	83.24
8326	8319.75	17	9	1561	61	9	10	27.82	2.13	0.59	14.56	0.90	0.75	55.42
8328	8321.75	5	13	1579	124	16	21	65.52	3.70	0.95	25.30	1.39	0.95	78.47
8330	8323.75	8	13	1524	103	13	20	56.96	3.33	0.83	22.77	1.54	0.93	72.65
8332	8325.75	11	13	1464	70	13	18	14.53	0.89	1.02	6.10	0.91	0.83	18.23
8334	8327.75	16	10	5547	60	10	15	17.77	1.24	1.13	8.50	0.90	0.84	27.29
8336	8329.75	9	13	1630	141	13	22	80.32	4.75	1.72	32.48	1.84	1.00	94.94
8338	8331.75	10	12	1884	98	13	17	31.49	1.91	1.45	13.07	0.96	0.89	39.17
8340	8333.75	6	12	1867	83	12	19	31.79	1.89	1.11	12.95	0.93	0.79	40.40
8342	8335.75	6	13	1692	96	15	21	38.36	2.17	1.15	14.85	0.70	0.87	44.50
8344	8337.75	8	15	1697	92	16	20	35.97	2.01	0.91	13.73	0.82	0.85	39.31
8346	8339.75	8	14	1714	80	13	18	26.11	1.59	1.18	10.87	0.56	0.84	29.74
8348	8341.75	8	14	1629	67	14	18	8.60	0.52	1.19	3.57	0.51	0.82	10.32
8350	8343.75	6	14	1779	54	17	17	1.50	0.08	0.75	0.58	0.36	0.75	1.78
8352	8345.75	8	12	1569	110	12	21	34.36	2.06	1.64	14.06	0.74	0.89	46.00
8354	8347.75	4	14	1736	92	14	20	23.68	1.32	1.24	9.05	0.60	0.86	27.21
8356	8349.75	5	15	1787	82	14	20	9.69	0.56	1.25	3.82	0.54	0.81	10.96
8358	8351.75	14	11	1422	31	10	11	0.76	0.05	0.47	0.37	0.65	0.65	1.09
8360	8353.75	9	12	1485	39	12	15	2.50	0.16	1.12	1.09	0.47	0.68	3.28
8362	8355.75	9	12	1650	99	12	21	49.91	3.07	2.10	20.99	1.14	0.78	61.92
8364	8357.75	8	13	1722	121	12	21	61.77	3.68	1.54	25.15	1.12	0.87	72.25
8366	8359.75	12	13	1649	122	15	21	60.22	3.60	1.65	24.64	1.16	0.85	70.27

Table C.2c. Trace and major element analyses results for COP 653. Continued.

Core Depth	Log-corrected Depth	Y	Nb	Ba	Ni	Th	Sc	Mo	Mo/Al2O3	S	EF-Mo	EF-U	EF-V	Mo/Ti
ft	ft	ppm	ppm	ppm	ppm	ppm	ppm	ppm		mass%				
8368	8361.75	10	14	1811	99	14	21	56.10	3.34	1.51	22.83	1.07	0.78	63.60
8370	8363.75	12	15	1669	101	15	21	74.40	4.59	1.80	31.40	1.63	0.81	85.12
8372	8365.75	14	12	1630	128	14	22	80.46	5.06	2.40	34.58	1.09	0.91	98.48
8374	8367.75	12	13	1931	125	14	22	75.86	4.69	1.87	32.07	1.62	0.93	90.63
8376	8369.75	13	13	1766	132	12	22	86.48	5.68	2.12	38.85	1.83	0.93	106.51
8378	8371.75	13	14	1676	148	15	22	88.11	5.50	1.48	37.61	1.93	1.01	102.22
8380	8373.75	12	14	1747	133	13	21	95.46	5.89	1.31	40.27	1.70	0.88	116.27
8382	8375.75	15	13	1596	128	13	21	91.08	5.94	1.97	40.64	1.84	0.97	113.28
8384	8377.75	16	13	1690	120	12	21	75.11	4.84	1.60	33.13	1.79	0.99	90.71
8386	8379.75	17	13	1637	136	14	21	82.34	5.42	1.65	37.08	1.92	1.07	100.78
8388	8381.75	14	13	1683	125	13	21	92.55	6.41	1.72	43.82	2.47	1.04	118.04
8390	8383.75	13	14	1697	140	12	21	91.43	5.89	1.51	40.31	2.01	0.97	111.50
8392	8385.75	16	13	1863	128	12	21	100.20	6.46	1.73	44.21	1.58	0.98	121.61
8394	8387.75	16	14	1701	157	12	23	113.61	7.22	1.61	49.35	2.62	1.09	132.72
8396	8389.75	15	14	1846	179	11	22	132.32	8.32	1.26	56.87	2.72	1.28	158.09
8398	8391.75	26	12	1541	131	11	21	84.22	5.93	1.34	40.58	2.56	1.25	109.95
8400	8393.75	16	14	1618	125	12	21	102.11	6.74	1.48	46.07	1.69	1.02	122.44
8402	8395.75	15	14	1925	110	15	21	69.88	4.45	1.09	30.44	1.38	1.10	81.54
8404	8397.75	14	14	1734	116	16	20	81.00	5.00	1.20	34.18	1.48	0.96	91.42
8406	8399.75	15	13	1862	104	13	20	79.97	4.88	1.26	33.36	1.77	0.87	93.20
8408	8401.75	16	14	1823	139	13	22	110.78	6.77	1.51	46.31	2.64	1.04	126.46
8410	8403.75	18	12	1732	154	10	22	115.96	7.43	1.58	50.80	2.12	1.24	144.05
8412	8405.75	33	10	1378	95	9	15	44.33	3.40	1.26	23.23	1.86	1.57	68.72

Table C.2c. Trace and major element analyses results for COP 653. Continued.

Core Depth ft	Log-corrected Depth ft	Y ppm	Nb ppm	Ba ppm	Ni ppm	Th ppm	Sc ppm	Mo ppm	Mo/Al2O3	S mass%	EF-Mo	EF-U	EF-V	Mo/Ti
8414	8407.75	15	14	1768	137	15	21	90.04	5.66	1.48	38.71	1.68	1.16	98.84
8416	8409.75	16	14	1628	132	14	21	100.41	6.56	1.65	44.85	1.74	1.15	116.89
8420	8413.75	29	6	1750	21	3	1	5.15	0.75	0.48	5.12	1.44	0.72	19.59
8422	8415.75	12	14	1580	217	13	20	111.25	7.14	1.29	48.83	1.51	1.75	131.50
8424	8417.75	19	9	1068	156	8	12	39.72	3.83	1.04	26.16	1.68	1.82	75.95
8426	8419.75	16	5	672	30	4	-1	5.16	1.14	0.82	7.78	1.73	0.66	23.13
8428	8421.75	8	13	2228	240	12	24	114.57	7.23	1.93	49.47	1.74	2.33	142.32
8430	8423.75	14	13	1833	158	9	21	76.43	5.11	1.61	34.92	1.89	1.76	99.26
8432	8425.75	18	12	1739	171	9	20	81.81	5.94	1.74	40.61	2.57	1.90	110.85
8434	8427.75	13	13	1671	158	12	20	81.77	5.75	1.52	39.30	1.74	1.89	106.33
8436	8429.75	16	11	2534	179	10	19	96.49	7.48	1.70	51.13	1.56	2.10	138.44
8438	8431.75	16	12	1495	158	10	19	76.74	6.00	1.73	41.03	2.35	1.88	108.09
8440	8433.75	18	12	1578	185	10	21	96.79	7.20	1.66	49.22	2.91	1.92	131.87
8442	8435.75	26	10	1306	112	10	13	52.13	4.67	1.39	31.94	1.92	1.58	83.94
8444	8437.75	18	12	1548	142	10	19	67.71	5.18	1.64	35.45	1.74	1.56	90.40
8446	8439.75	13	14	1854	186	14	22	109.05	6.99	1.64	47.77	2.35	1.74	119.18
8448	8441.75	25	11	1457	126	10	16	67.26	5.27	1.51	36.05	1.92	1.39	99.35
8450	8443.75	14	13	1695	154	11	19	87.12	6.04	1.79	41.32	1.86	1.38	105.99
8452	8445.75	12	12	1721	120	9	20	45.79	3.05	1.53	20.87	1.59	1.40	55.91
8454	8447.75	14	13	1775	105	14	18	42.49	2.78	1.45	19.01	0.89	1.17	50.35
8456	8449.75	14	14	1653	111	12	19	44.16	2.92	1.64	19.94	1.06	1.22	51.53
8458	8451.75	19	13	1628	115	14	18	54.90	3.92	1.62	26.77	1.90	1.29	67.70
8460	8453.75	15	14	1707	118	11	19	52.64	3.44	1.50	23.55	1.27	1.27	59.22

Table C.2c. Trace and major element analyses results for COP 653. Continued.

Core Depth ft	Log-corrected Depth ft	Y ppm	Nb ppm	Ba ppm	Ni ppm	Th ppm	Sc ppm	Mo ppm	Mo/Al2O3	S mass%	EF-Mo	EF-U	EF-V	Mo/Ti
8462	8455.75	16	14	1669	123	11	19	50.60	3.52	1.62	24.10	1.10	1.27	60.46
8464	8457.75	15	13	1622	115	12	18	44.77	3.08	1.42	21.06	1.44	1.29	55.41
8466	8459.75	17	15	1744	136	12	20	66.81	4.52	1.57	30.89	2.06	1.36	78.41
8468	8461.75	12	14	1673	102	12	18	45.44	3.09	1.50	21.13	1.38	1.18	54.22
8470	8463.75	16	13	1572	106	12	17	52.39	3.80	1.38	25.99	1.41	1.19	67.87
8472	8465.75	18	12	1492	100	12	15	51.77	3.89	1.29	26.61	1.20	1.14	71.81
8474	8467.75	14	15	1732	130	13	20	72.94	4.78	1.48	32.68	1.96	1.24	82.23
8476	8469.75	19	14	1690	112	13	18	83.31	5.54	1.38	37.91	1.77	1.35	101.85
8478	8471.75	15	13	1630	108	13	19	49.29	3.42	1.31	23.38	1.25	1.21	61.69
8480	8473.75	15	13	1615	117	15	19	58.66	3.98	1.52	27.24	1.19	1.24	72.32
8482	8475.75	16	14	1649	124	13	20	60.35	4.05	1.49	27.71	1.31	1.25	71.08
8484	8477.75	25	14	1559	155	12	19	63.58	4.59	1.55	31.37	2.17	1.27	77.53
8486	8479.75	18	14	1683	124	13	20	59.98	3.98	1.57	27.25	1.64	1.36	67.77
8488	8481.75	19	14	1877	153	13	22	90.03	5.94	1.53	40.62	2.44	1.43	100.82
8490	8483.75	23	14	1563	129	13	18	83.86	5.91	1.32	40.43	1.95	1.44	105.35
8492	8485.75	19	13	1617	133	13	19	65.45	4.65	1.40	31.78	1.73	1.33	80.80
8494	8487.75	16	13	1600	103	12	19	54.68	3.87	1.47	26.46	1.20	1.34	66.85
8496	8489.75	16	14	1637	128	12	20	56.52	3.98	1.44	27.21	1.26	1.37	67.77
8498	8491.75	16	14	1816	108	14	20	63.96	4.25	1.43	29.09	1.55	1.25	72.60
8500	8493.75	18	13	1573	77	12	17	40.68	2.91	1.32	19.90	1.44	1.32	51.89
8502	8495.75	16	14	1600	108	12	18	72.82	5.27	1.22	36.05	1.49	1.25	92.65
8504	8497.75	13	12	1600	98	11	19	39.09	2.79	1.79	19.11	1.04	1.18	50.50
8506	8499.75	15	14	1603	125	12	20	53.24	3.85	1.41	26.36	1.35	1.22	67.82

Table C.2c. Trace and major element analyses results for COP 653. Continued.

Core Depth ft	Log-corrected Depth ft	Y ppm	Nb ppm	Ba ppm	Ni ppm	Th ppm	Sc ppm	Mo ppm	Mo/ Al2O3	S mass%	EF-Mo	EF-U	EF-V	Mo/Ti
8508	8501.75	21	12	1581	126	11	16	85.01	6.32	1.26	43.20	1.69	1.44	116.14
8510	8503.75	16	13	1577	111	14	19	66.80	4.81	1.26	32.89	1.51	1.33	84.77
8512	8505.75	18	14	1840	128	11	20	74.92	5.42	1.34	37.06	2.28	1.26	102.20
8514	8507.75	25	13	1663	209	11	22	250.53	18.57	1.99	127.00	5.37	2.27	338.55
8516	8509.75	21	9	1307	232	7	22	112.69	10.82	2.05	74.02	3.00	4.17	207.14
8518	8511.75	26	10	1475	316	7	26	215.42	18.82	2.07	128.71	7.39	4.26	370.78
8520	8513.75	20	9	1428	321	9	24	171.72	15.83	2.29	108.24	6.06	4.30	332.79
8522	8515.75	34	10	1910	343	10	27	243.94	18.53	2.74	126.72	9.15	3.64	384.16
8524	8517.75	32	9	1244	272	10	22	175.30	17.29	1.78	118.21	5.41	3.48	337.76
8528	8521.75	26	5	659	320	3	22	207.83	42.92	1.20	293.52	18.24	7.23	989.65
8530	8523.75	21	4	494	173	3	10	97.99	27.46	0.63	187.80	8.90	6.99	790.20
8532	8525.75	20	3	526	229	2	14	236.39	74.90	0.46	512.21	15.16	11.22	2055.57
8534	8527.75	26	4	591	301	3	12	346.12	83.40	1.48	570.34	16.88	11.50	2097.70
8536	8529.75	22	1	129	52	-2	-6	57.96	101.16	0.25	691.76	33.78	13.92	-3864.20
8538	8531.75	6	6	292	59	2	0	10.44	2.08	0.54	14.24	2.38	0.73	76.78
8540	8533.75	14	2	248	34	4	-4	10.64	2.85	0.38	19.46	2.79	0.84	200.81
8542	8535.75	17	3	157	7	0	-6	1.27	1.02	0.18	6.98	6.39	0.89	63.35
8544	8537.75	11	5	177	37	5	-2	4.11	0.99	0.68	6.75	0.83	0.31	40.64
8546	8539.75	7	6	324	46	4	1	11.13	1.62	0.63	11.08	2.42	0.78	41.67
8548	8541.75	23	19	473	103	10	11	14.73	1.02	1.25	6.97	1.39	0.52	19.51
8550	8543.75	10	8	268	25	7	2	2.80	0.39	0.26	2.67	1.58	1.27	8.90

Table C.3a. Trace and major element analyses results for COP 289

Core Depth	Log-corrected Depth	SiO2	SiO2/Al2O3	Al2O3	Fe2O3	MnO	CaO	K2O	P2O5	V	V/Al2O3	Cu
ft	ft	mass%		mass%	mass%	mass%	mass%	mass%	mass%	ppm		ppm
7788	7786	55.42	3.52	15.75	6.34	0.06	2.57	3.49	0.06	199.14	12.65	26
7790	7788	54.21	3.48	15.59	7.00	0.07	1.64	3.42	0.06	202.51	12.99	18
7792	7790	55.42	3.51	15.79	6.44	0.07	1.70	3.42	0.07	207.27	13.13	15
7794	7792	55.25	3.64	15.17	7.06	0.08	2.31	3.22	0.09	205.92	13.57	18
7796	7794	54.40	3.60	15.11	7.35	0.09	2.46	3.16	0.09	197.84	13.10	24
7798	7796	55.02	3.73	14.76	7.46	0.09	2.46	3.04	0.09	192.52	13.04	33
7800	7798	55.46	3.63	15.28	7.05	0.08	2.06	3.20	0.08	201.22	13.17	15
7802	7800	51.70	4.20	12.30	9.89	0.15	4.91	2.15	0.11	175.9	14.30	16
7804	7802	54.37	3.48	15.63	7.39	0.06	1.65	3.33	0.06	207.41	13.27	8
7806	7804	54.87	3.55	15.48	6.95	0.07	2.01	3.31	0.06	203.98	13.18	16
7808	7806	54.82	3.47	15.82	6.82	0.06	1.86	3.45	0.06	202.51	12.80	12
7810	7808	55.74	3.83	14.53	7.11	0.12	2.65	3.01	0.06	186.51	12.83	56
7812	7810	54.60	3.48	15.69	6.51	0.06	1.94	3.46	0.06	204.03	13.01	18
7814	7812	55.06	3.56	15.47	6.75	0.07	2.09	3.34	0.06	194.86	12.60	24
7816	7814	55.17	3.58	15.39	6.41	0.07	2.40	3.39	0.06	199.92	12.99	17
7818	7816	56.41	3.63	15.53	6.19	0.07	2.17	3.40	0.06	194.86	12.55	17
7820	7818	56.26	3.49	16.13	6.06	0.04	0.94	3.64	0.05	213.07	13.21	61
7822	7820	54.44	3.60	15.11	6.36	0.06	2.73	3.39	0.04	197.92	13.10	55
7824	7822	56.30	3.72	15.15	6.33	0.07	2.89	3.32	0.05	191.4	12.64	21
7826	7824	53.15	3.29	16.17	7.03	0.03	0.32	3.69	0.04	342.8	21.20	120
7828	7826	54.54	3.49	15.62	6.87	0.04	1.09	3.49	0.04	257.3	16.47	104
7830	7828	54.24	3.49	15.56	6.67	0.03	0.79	3.54	0.05	265.5	17.06	113
7832	7830	55.62	3.54	15.70	6.15	0.04	1.50	3.57	0.05	237.31	15.12	64

Table C.3a. Trace and major element analyses results for COP 289. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass%	SiO2/Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass%	CaO mass%	K2O mass%	P2O5 mass%	V ppm	V/Al2O3	Cu ppm
7834	7832	54.91	3.51	15.64	6.21	0.04	1.07	3.58	0.05	248.88	15.92	78
7836	7834	55.15	3.53	15.61	6.32	0.06	1.23	3.56	0.05	234.1	15.00	69
7838	7836	53.75	3.53	15.22	6.08	0.04	1.17	3.52	0.05	229.3	15.06	88
7840	7838	52.92	3.49	15.15	7.22	0.08	1.99	3.34	0.05	233.95	15.45	103
7842	7840	52.38	3.77	13.91	4.80	0.06	7.45	3.17	0.04	155.4	11.18	38
7844	7842	52.50	3.89	13.49	5.67	0.07	6.90	3.01	0.05	156.92	11.63	36
7846	7844	53.70	3.73	14.38	5.72	0.07	4.65	3.23	0.05	179.81	12.51	28
7848	7846	54.20	3.61	15.03	6.32	0.07	3.34	3.33	0.06	183.17	12.19	18
7850	7848	54.66	3.48	15.70	6.53	0.06	2.27	3.46	0.06	198.86	12.66	12
7852	7850	50.76	3.79	13.39	5.24	0.08	8.44	2.96	0.06	157.28	11.74	22
7854	7852	52.10	3.80	13.73	5.54	0.09	7.28	3.03	0.06	157.99	11.51	9
7856	7854	53.02	3.59	14.78	6.10	0.08	4.56	3.26	0.06	184.55	12.49	13
7858	7856	53.33	3.54	15.04	6.15	0.07	3.73	3.34	0.06	188.98	12.56	83
7860	7858	54.06	3.56	15.17	6.20	0.07	3.67	3.32	0.06	191.71	12.63	15
7862	7860	53.15	3.63	14.65	6.20	0.07	3.93	3.24	0.06	184.58	12.60	16
7864	7862	53.91	3.60	14.99	6.42	0.07	3.28	3.28	0.06	192.57	12.85	20
7866	7864	53.89	3.56	15.15	6.48	0.07	2.98	3.31	0.06	195.63	12.92	18
7868	7866	53.64	3.60	14.89	6.16	0.07	3.54	3.29	0.06	190	12.76	18
7870	7868	52.96	3.51	15.09	6.10	0.06	3.42	3.36	0.06	195.5	12.96	15
7872	7870	43.93	10.53	4.17	4.73	0.28	27.10	0.73	0.12	50.948	12.22	-8
7874	7872	53.66	3.67	14.63	6.22	0.08	3.84	3.20	0.06	185.54	12.68	23
7876	7874	53.44	3.65	14.65	6.50	0.08	4.40	3.15	0.06	185.86	12.68	26
7878	7876	51.88	3.10	16.71	6.57	0.03	0.39	3.82	0.05	236.69	14.16	127

Table C.3a. Trace and major element analyses results for COP 289. Continued.

Core Depth	Log-corrected Depth	SiO2	SiO2/Al2O3	Al2O3	Fe2O3	MnO	CaO	K2O	P2O5	V	V/Al2O3	Cu
ft	ft	mass%		mass%	mass%	mass%	mass%	mass%	mass%	ppm		ppm
7880	7878	55.27	3.57	15.48	6.17	0.04	2.10	3.44	0.04	208.63	13.48	73
7882	7880	54.60	3.62	15.07	6.32	0.04	2.33	3.32	0.04	186.9	12.40	88
7884	7882	52.74	3.88	13.58	5.82	0.07	6.37	3.00	0.05	162.31	11.95	62
7886	7884	54.90	3.50	15.69	5.96	0.04	2.00	3.53	0.05	220.38	14.05	83
7886	7884	54.25	3.50	15.50	6.22	0.04	2.04	3.42	0.05	206.75	13.34	91
7888	7886	53.69	3.32	16.19	6.32	0.03	0.82	3.62	0.05	220.8	13.64	86
7890	7888	53.46	3.50	15.27	5.87	0.04	3.63	3.34	0.05	191.05	12.51	59
7892	7890	53.00	3.25	16.31	6.63	0.03	0.88	3.56	0.05	219.17	13.44	83
7894	7892	53.07	3.43	15.46	6.86	0.03	1.77	3.38	0.05	204.48	13.23	83
7896	7894	52.14	3.81	13.67	6.00	0.05	5.47	2.99	0.06	198.59	14.52	93
7898	7896	50.42	3.31	15.22	6.27	0.05	4.06	3.24	0.06	175.44	11.52	40
7900	7898	53.82	3.73	14.43	6.14	0.06	4.44	3.15	0.06	198.32	13.75	56
7902	7900	52.70	3.59	14.66	6.15	0.04	3.98	3.23	0.06	230.85	15.74	84
7904	7902	50.64	3.93	12.90	5.42	0.06	9.19	2.77	0.05	188.38	14.60	68
7906	7904	52.52	3.66	14.33	6.12	0.06	4.48	3.15	0.05	188.12	13.13	41
7908	7906	53.60	3.51	15.27	6.19	0.04	3.12	3.36	0.05	210.25	13.77	76
7910	7908	49.13	4.21	11.66	4.23	0.07	10.84	2.60	0.06	147.61	12.66	37
7912	7910	52.51	3.14	16.70	7.15	0.02	0.16	3.69	0.05	279.74	16.75	112
7914	7912	53.90	3.69	14.60	5.50	0.04	4.20	3.23	0.05	236.74	16.21	86
7916	7914	52.13	3.10	16.80	6.67	0.02	0.27	3.74	0.05	278.22	16.56	103
7918	7916	50.28	3.24	15.54	6.89	0.02	0.56	3.43	0.04	242.3	15.59	97
7920	7918	53.02	3.28	16.18	6.60	0.02	0.53	3.60	0.05	293.72	18.16	105
7922	7920	52.47	3.24	16.19	6.82	0.03	0.92	3.59	0.06	266.02	16.43	109

Table C.3a. Trace and major element analyses results for COP 289. Continued.

Core Depth	Log-corrected Depth	SiO2	SiO2/Al2O3	Al2O3	Fe2O3	MnO	CaO	K2O	P2O5	V	V/Al2O3	Cu
ft	ft	mass%		mass%	mass%	mass%	mass%	mass%	mass%	ppm		ppm
7924	7922	51.87	3.37	15.39	6.62	0.04	2.71	3.38	0.05	229.19	14.90	119
7926	7924	51.68	3.22	16.03	6.36	0.03	1.89	3.58	0.05	252.21	15.73	108
7928	7926	52.64	3.36	15.65	6.67	0.04	2.12	3.44	0.05	213.15	13.62	92
7930	7928	52.41	3.20	16.39	7.14	0.03	0.85	3.58	0.05	242.85	14.81	84
7932	7930	52.45	3.09	16.97	6.70	0.02	0.26	3.75	0.05	261.15	15.39	96
7934	7932	51.33	3.20	16.03	7.56	0.04	1.16	3.51	0.05	243.72	15.20	87
7936	7934	51.08	3.74	13.66	6.53	0.10	6.56	2.94	0.05	174.31	12.76	61
7938	7936	51.20	3.32	15.41	6.65	0.05	2.45	3.46	0.05	215.35	13.97	57
7940	7938	50.77	3.33	15.26	6.72	0.05	2.48	3.43	0.05	221.64	14.52	79
7942	7940	51.22	3.44	14.90	7.19	0.05	2.63	3.31	0.05	199.74	13.41	64
7944	7942	53.72	3.34	16.08	6.21	0.04	1.52	3.62	0.05	234.08	14.56	63
7946	7944	53.29	3.15	16.93	6.60	0.02	0.17	3.75	0.04	256.09	15.13	93
7948	7946	52.95	3.45	15.34	5.21	0.05	4.69	3.37	0.04	189.53	12.35	60
7952	7950	53.63	3.55	15.09	6.21	0.08	4.05	3.33	0.07	179.08	11.86	20
7954	7952	48.46	3.76	12.87	9.61	0.08	4.91	2.60	0.06	169.32	13.16	69
7956	7954	50.64	3.25	15.60	8.10	0.02	0.10	3.44	0.05	235.94	15.13	84
7958	7956	52.81	3.30	16.02	7.43	0.02	0.08	3.49	0.05	250.89	15.66	82
7960	7958	53.51	3.40	15.74	7.76	0.02	0.17	3.36	0.05	232.53	14.77	79
7962	7960	52.53	3.55	14.80	9.37	0.03	0.79	3.07	0.09	200.13	13.52	59
7964	7962	53.81	3.47	15.50	7.04	0.02	0.18	3.35	0.04	218.25	14.09	65
7966	7964	53.14	3.39	15.69	7.09	0.03	0.60	3.46	0.05	230.36	14.68	62
7968	7966	51.66	3.62	14.27	8.72	0.04	2.54	3.01	0.05	208.76	14.63	72
7970	7968	53.56	3.45	15.51	7.49	0.02	0.39	3.40	0.05	244.02	15.73	79

Table C.3a. Trace and major element analyses results for COP 289. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass%	SiO2/Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass%	CaO mass%	K2O mass%	P2O5 mass%	V ppm	V/Al2O3	Cu ppm
7972	7970	53.52	3.50	15.29	7.59	0.02	0.32	3.29	0.05	237.12	15.51	63
7974	7972	54.98	3.68	14.95	7.27	0.02	0.27	3.18	0.05	228.18	15.26	76
7976	7974	54.71	3.73	14.67	6.86	0.02	0.23	3.19	0.05	259.5	17.69	85
7978	7976	53.56	3.54	15.11	7.43	0.02	0.46	3.27	0.07	290.28	19.21	103
7980	7978	51.00	3.46	14.72	8.08	0.02	0.42	3.17	0.06	337.52	22.93	119
7982	7980	53.40	3.43	15.58	7.78	0.02	0.34	3.36	0.05	289.69	18.59	74
7984	7982	52.45	3.41	15.39	8.20	0.02	0.36	3.33	0.05	293.25	19.05	88
7986	7984	49.90	3.36	14.84	8.48	0.02	1.79	3.19	0.04	335.43	22.61	116
7988	7986	53.90	3.34	16.16	6.59	0.02	0.49	3.54	0.04	322.49	19.96	81
7990	7988	53.58	3.40	15.78	6.66	0.02	0.85	3.40	0.05	324.84	20.59	107
7992	7990	38.83	5.21	7.45	4.63	0.06	21.69	1.47	0.05	155.8	20.91	110
7994	7992	40.95	4.63	8.85	3.63	0.03	18.76	1.82	0.18	337.2	38.10	328
7996	7994	49.25	4.39	11.22	4.10	0.03	11.20	2.37	0.08	265.12	23.63	175
7998	7996	51.47	3.71	13.87	4.89	0.03	5.68	3.12	0.07	562.31	40.56	115
8000	7998	53.74	3.75	14.34	5.62	0.03	3.58	3.19	0.06	595.65	41.54	107
8002	8000	53.94	3.77	14.30	5.85	0.03	3.41	3.18	0.06	427.5	29.90	91
8004	8002	53.91	4.13	13.04	5.09	0.03	6.17	2.89	0.06	437.96	33.58	80
8006	8004	58.29	4.27	13.65	5.50	0.02	2.31	3.01	0.04	456.12	33.42	86
8008	8006	57.89	4.65	12.45	5.04	0.03	4.92	2.74	0.05	381.81	30.67	79
8010	8008	58.28	4.15	14.04	6.78	0.02	1.86	2.98	0.04	358.71	25.55	94
8012	8010	57.05	4.55	12.55	6.78	0.03	3.99	2.64	0.06	295.88	23.58	64
8014	8012	58.64	4.31	13.62	5.77	0.02	1.94	2.94	0.05	344.03	25.26	71
8016	8014	56.62	3.81	14.84	6.37	0.02	0.83	3.22	0.04	364.1	24.53	89

Table C.3a. Trace and major element analyses results for COP 289. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass%	SiO2/Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass%	CaO mass%	K2O mass%	P2O5 mass%	V ppm	V/Al2O3	Cu ppm
8018	8016	55.66	4.00	13.92	6.10	0.03	4.01	2.97	0.05	279.46	20.07	62
8020	8018	53.48	4.11	13.03	5.99	0.03	5.63	2.80	0.06	288.18	22.12	70
8022	8020	55.71	3.63	15.35	6.38	0.02	1.33	3.29	0.04	314.68	20.50	74
8024	8022	55.48	3.63	15.28	6.17	0.02	1.28	3.32	0.04	326.4	21.37	76
8026	8024	52.92	3.84	13.80	5.82	0.03	3.36	3.04	0.05	305.13	22.11	75
8028	8026	56.11	3.74	15.01	6.56	0.02	1.09	3.22	0.04	319.95	21.31	67
8030	8028	53.35	3.96	13.47	6.03	0.03	4.32	2.90	0.06	281.69	20.91	57
8032	8030	53.83	4.08	13.21	5.76	0.03	5.04	2.86	0.05	265.1	20.07	56
8034	8032	55.86	3.90	14.32	6.31	0.03	2.39	3.08	0.05	277.09	19.35	76
8036	8034	56.71	4.00	14.19	6.05	0.02	1.87	3.07	0.04	314.53	22.16	69
8038	8036	57.07	4.04	14.14	5.89	0.02	1.85	3.06	0.04	326.11	23.06	65
8040	8038	57.94	4.18	13.85	5.63	0.02	2.79	3.01	0.06	294.25	21.24	61
8044	8042	55.55	4.17	13.33	5.86	0.03	4.33	2.88	0.06	267.92	20.09	62
8046	8044	55.44	3.99	13.90	5.85	0.03	2.94	3.02	0.05	277.65	19.98	60
8048	8046	56.86	3.84	14.79	5.77	0.02	1.04	3.28	0.05	310.76	21.01	67
8050	8048	57.53	3.86	14.92	6.57	0.02	0.68	3.23	0.05	319.77	21.43	94
8052	8050	56.94	4.05	14.08	6.53	0.02	1.88	3.04	0.05	288.33	20.48	75
8054	8052	57.42	3.99	14.39	6.43	0.02	1.35	3.13	0.06	309.53	21.51	92
8056	8054	56.69	4.01	14.15	5.94	0.03	1.82	3.12	0.07	314.35	22.22	72
8058	8056	56.62	3.98	14.23	5.23	0.02	2.65	3.18	0.10	483.92	34.02	98
8060	8058	55.30	3.74	14.80	7.21	0.02	1.15	3.18	0.04	286.67	19.37	67
8062	8060	55.50	3.69	15.03	6.11	0.02	1.56	3.29	0.05	326.7	21.74	73
8064	8062	55.63	3.76	14.80	6.28	0.02	1.70	3.20	0.05	337.34	22.80	71

Table C.3a. Trace and major element analyses results for COP 289. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass%	SiO2/Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass%	CaO mass%	K2O mass%	P2O5 mass%	V ppm	V/Al2O3	Cu ppm
8066	8064	54.93	3.84	14.31	5.86	0.02	1.16	3.22	0.04	390.97	27.33	78
8068	8066	56.54	3.95	14.30	5.64	0.02	2.53	3.13	0.06	322.52	22.56	74
8070	8068	57.03	3.93	14.50	6.90	0.02	1.96	3.07	0.04	300.11	20.70	76
8072	8070	57.03	4.06	14.05	6.45	0.02	2.48	2.99	0.04	317.53	22.59	72
8074	8072	58.04	4.48	12.94	5.19	0.02	3.39	2.84	0.04	324.92	25.11	74
8076	8074	57.22	4.66	12.27	7.74	0.02	3.68	2.49	0.05	285.04	23.24	87
8078	8076	61.59	4.99	12.35	4.93	0.02	1.70	2.67	0.05	309.13	25.04	74
8080	8078	59.30	4.44	13.36	6.07	0.02	1.24	2.86	0.04	378.6	28.35	116
8082	8080	60.82	4.84	12.57	5.67	0.02	2.36	2.69	0.05	581.56	46.27	135
8086	8084	51.39	4.90	10.50	5.64	0.02	9.96	2.24	0.07	465	44.31	136
8088	8086	53.80	4.21	12.77	6.23	0.02	3.57	2.83	0.05	667.62	52.28	225
8090	8088	59.01	5.97	9.89	6.20	0.00	1.69	2.12	0.06	525.51	53.15	174
8092	8090	61.76	5.37	11.50	5.30	0.01	3.11	2.47	0.05	473.99	41.23	177
8094	8092	58.67	5.22	11.24	10.34	0.00	1.16	1.93	0.07	875.6	77.91	155
8096	8094	26.69	5.20	5.13	2.35	0.19	21.93	0.73	0.04	83.941	16.37	13
8098	8096	75.60	10.32	7.33	3.93	0.01	5.24	1.37	0.07	631.75	86.22	142
8100	8098	52.96	21.10	2.51	0.93	0.02	35.26	0.46	0.09	197.19	78.57	78
8102	8100	54.05	81.93	0.66	0.72	0.02	38.67	0.13	0.04	72.328	109.64	23
8104	8102	81.28	17.22	4.72	1.54	0.01	12.33	0.94	0.04	551.78	116.89	284
8106	8104	54.97	28.91	1.90	1.13	0.02	33.26	0.38	0.04	47.968	25.23	57
8108	8106	29.58	7.79	3.80	1.59	0.01	32.80	0.91	0.06	88.607	23.34	308
8110	8108	46.10	4.30	10.71	2.38	0.02	14.32	2.89	0.11	174.64	16.31	133
8112	8110	21.73	7.88	2.76	0.82	0.02	37.87	0.73	0.04	42.529	15.43	14

Table C.3a. Trace and major element analyses results for COP 289. Continued.

Core Depth ft	Log-corrected Depth ft	SiO2 mass%	SiO2/Al2O3	Al2O3 mass%	Fe2O3 mass%	MnO mass%	CaO mass%	K2O mass%	P2O5 mass%	V ppm	V/Al2O3	Cu ppm
8114	8112	28.93	3.79	7.63	1.82	0.02	25.08	1.95	0.08	42.07	5.51	58
8116	8114	29.29	5.88	4.98	1.74	0.02	27.94	1.40	0.06	56.922	11.42	166
8118	8116	1.47	4.25	0.35	0.20	0.02	46.28	0.10	0.04	17.607	50.98	5

Table C.3b. Trace and major element analyses results for COP 289

Core Depth ft	Log-corrected Depth ft	Zn ppm	U ppm	U/Al2O3	Ni ppm	Th ppm	Mo ppm	Mo/Al2O3	S mass%	EF-Mo	EF-U	EF-V
7788	7786	26	4.17	0.26	80.35	11.56	4.69	0.30	0.34	2.04	0.79	0.86
7790	7788	77	2.29	0.15	79.381	14.44	1.14	0.07	0.34	0.50	0.44	0.89
7792	7790	27	3.17	0.20	68.733	13.00	-0.55	-0.03	0.01	-0.24	0.60	0.90
7794	7792	27	3.53	0.23	72.605	13.00	0.27	0.02	0.02	0.12	0.69	0.93
7796	7794	27	2.83	0.19	73.573	15.89	-0.17	-0.01	0.12	-0.08	0.55	0.90
7798	7796	49	3.88	0.26	72.605	14.44	1.03	0.07	0.17	0.48	0.78	0.89
7800	7798	42	3.19	0.21	70.669	13.00	0.45	0.03	0.04	0.20	0.62	0.90
7802	7800	157	2.68	0.22	70.669	10.11	0.42	0.03	0.17	0.23	0.65	0.98
7804	7802	119	2.37	0.15	72.605	14.44	-0.07	0.00	0.14	-0.03	0.45	0.91
7806	7804	55	2.72	0.18	73.573	17.33	-0.14	-0.01	0.21	-0.06	0.52	0.90
7808	7806	55	2.94	0.19	82.286	14.44	-0.21	-0.01	0.25	-0.09	0.55	0.88
7810	7808	64	2.88	0.20	70.669	14.44	0.79	0.05	0.32	0.37	0.59	0.88
7812	7810	41	4.52	0.29	77.445	15.89	0.50	0.03	0.29	0.22	0.85	0.89

Table C.3b. Trace and major element analyses results for COP 289. Continued.

Core Depth ft	Log-corrected Depth ft	Zn ppm	U ppm	U/Al2O3	Ni ppm	Th ppm	Mo ppm	Mo/Al2O3	S mass%	EF-Mo	EF-U	EF-V
7814	7812	110	2.94	0.19	82.286	14.44	0.99	0.06	0.36	0.44	0.56	0.86
7816	7814	44	3.30	0.21	74.541	11.56	0.91	0.06	0.25	0.40	0.64	0.89
7818	7816	55	1.58	0.10	68.733	13.00	1.21	0.08	0.22	0.53	0.30	0.86
7820	7818	3425	4.29	0.27	75.509	14.44	5.69	0.35	0.31	2.41	0.79	0.90
7822	7820	33	3.24	0.21	80.35	11.56	4.96	0.33	0.57	2.24	0.63	0.90
7824	7822	29	1.56	0.10	62.924	11.56	-0.51	-0.03	0.31	-0.23	0.31	0.86
7826	7824	41	9.84	0.61	171.35	17.33	76.50	4.73	1.06	32.35	1.80	1.45
7828	7826	18	5.19	0.33	105.52	13.00	28.36	1.82	0.87	12.41	0.98	1.13
7830	7828	31	6.15	0.40	121.01	13.00	40.66	2.61	0.88	17.87	1.17	1.17
7832	7830	84	4.28	0.27	110.36	11.56	29.42	1.87	0.56	12.82	0.81	1.03
7834	7832	338	5.46	0.35	106.49	8.67	41.15	2.63	0.64	18.00	1.03	1.09
7836	7834	91	5.36	0.34	98.743	15.89	40.06	2.57	0.62	17.55	1.02	1.03
7838	7836	400	7.72	0.51	105.52	13.00	45.53	2.99	0.71	20.46	1.50	1.03
7840	7838	61	6.41	0.42	113.26	8.67	63.65	4.20	0.93	28.74	1.25	1.06
7842	7840	31	1.52	0.11	52.276	11.56	1.16	0.08	0.31	0.57	0.32	0.76
7844	7842	121	2.94	0.22	60.988	8.67	2.25	0.17	0.56	1.14	0.65	0.80
7846	7844	58	3.29	0.23	68.733	13.00	2.33	0.16	0.34	1.11	0.68	0.86
7848	7846	17	1.50	0.10	66.797	13.00	1.53	0.10	0.48	0.70	0.30	0.83
7850	7848	20	3.49	0.22	60.988	13.00	-0.55	-0.04	0.36	-0.24	0.66	0.87
7852	7850	12	3.11	0.23	53.244	11.56	0.86	0.06	0.27	0.44	0.69	0.80
7854	7852	12	3.29	0.24	58.084	11.56	-0.35	-0.03	0.23	-0.17	0.71	0.79
7856	7854	21	1.67	0.11	65.829	15.89	-0.58	-0.04	0.27	-0.27	0.34	0.85
7858	7856	391	3.07	0.20	63.892	13.00	0.21	0.01	0.25	0.10	0.60	0.86

Table C.3b. Trace and major element analyses results for COP 289. Continued.

Core Depth ft	Log-corrected Depth ft	Zn ppm	U ppm	U/Al2O3	Ni ppm	Th ppm	Mo ppm	Mo/Al2O3	S mass%	EF-Mo	EF-U	EF-V
7860	7858	57	3.39	0.22	64.86	14.44	-0.04	0.00	0.24	-0.02	0.66	0.86
7862	7860	46	2.32	0.16	71.637	10.11	1.15	0.08	0.36	0.54	0.47	0.86
7864	7862	117	4.26	0.28	74.541	14.44	1.15	0.08	0.33	0.52	0.84	0.88
7866	7864	53	1.14	0.08	71.637	14.44	0.91	0.06	0.34	0.41	0.22	0.88
7868	7866	36	3.55	0.24	69.701	17.33	0.82	0.06	0.28	0.38	0.71	0.87
7870	7868	29	2.82	0.19	72.605	11.56	0.66	0.04	0.30	0.30	0.55	0.89
7872	7870	47	0.89	0.21	26.138	1.44	0.75	0.18	0.11	1.22	0.63	0.84
7874	7872	30	2.71	0.18	58.084	14.44	0.77	0.05	0.22	0.36	0.55	0.87
7876	7874	76	2.41	0.16	61.956	10.11	1.55	0.11	0.33	0.72	0.49	0.87
7878	7876	380	6.33	0.38	147.15	15.89	53.77	3.22	0.75	22.00	1.12	0.97
7880	7878	24	4.78	0.31	72.605	10.11	13.93	0.90	0.54	6.16	0.92	0.92
7882	7880	21	4.01	0.27	69.701	10.11	5.54	0.37	0.67	2.51	0.79	0.85
7884	7882	33	2.49	0.18	59.052	7.22	3.44	0.25	0.47	1.73	0.54	0.82
7886	7884	56	4.67	0.30	80.35	14.44	20.11	1.28	0.37	8.77	0.88	0.96
7886	7884	76	4.63	0.30	89.062	11.56	20.46	1.32	0.62	9.03	0.88	0.91
7888	7886	26	3.83	0.24	85.19	13.00	31.67	1.96	0.75	13.38	0.70	0.93
7890	7888	63	3.97	0.26	66.797	14.44	20.61	1.35	0.61	9.23	0.77	0.86
7892	7890	36	5.63	0.35	92.934	15.89	42.85	2.63	0.84	17.96	1.02	0.92
7894	7892	19	4.57	0.30	84.222	13.00	28.29	1.83	1.05	12.51	0.88	0.90
7896	7894	40	5.79	0.42	90.998	8.67	27.90	2.04	0.80	13.95	1.25	0.99
7898	7896	54	2.31	0.15	57.116	15.89	3.13	0.21	0.57	1.41	0.45	0.79
7900	7898	60	3.82	0.26	66.797	11.56	12.40	0.86	0.51	5.88	0.78	0.94
7902	7900	72	6.10	0.42	98.743	13.00	32.07	2.19	0.85	14.95	1.23	1.08

Table C.3b. Trace and major element analyses results for COP 289. Continued.

Core Depth ft	Log-corrected Depth ft	Zn ppm	U ppm	U/Al2O3	Ni ppm	Th ppm	Mo ppm	Mo/Al2O3	S mass%	EF-Mo	EF-U	EF-V
7904	7902	156	7.88	0.61	77.445	10.11	27.53	2.13	0.74	14.60	1.81	1.00
7906	7904	55	3.04	0.21	56.148	10.11	6.14	0.43	0.48	2.93	0.63	0.90
7908	7906	36	5.28	0.35	78.413	11.56	23.52	1.54	0.74	10.53	1.02	0.94
7910	7908	9	3.99	0.34	53.244	7.22	16.45	1.41	0.34	9.65	1.01	0.87
7912	7910	228	7.48	0.45	128.75	13.00	72.69	4.35	1.02	29.76	1.33	1.15
7914	7912	56	11.38	0.78	94.87	10.11	45.04	3.08	0.57	21.09	2.31	1.11
7916	7914	135	9.60	0.57	124.88	14.44	70.93	4.22	0.93	28.88	1.69	1.13
7918	7916	21	8.71	0.56	98.743	11.56	45.68	2.94	0.95	20.10	1.66	1.07
7920	7918	633	11.09	0.69	132.63	13.00	80.32	4.97	0.89	33.96	2.03	1.24
7922	7920	133	7.17	0.44	119.07	13.00	46.29	2.86	0.90	19.56	1.31	1.12
7924	7922	34	6.30	0.41	99.711	13.00	40.75	2.65	0.94	18.11	1.21	1.02
7926	7924	94	10.66	0.67	121.01	13.00	76.34	4.76	0.86	32.57	1.97	1.08
7928	7926	51	5.95	0.38	88.094	13.00	32.62	2.08	0.85	14.25	1.13	0.93
7930	7928	169	6.12	0.37	102.62	13.00	44.50	2.71	0.92	18.56	1.11	1.01
7932	7930	3476	7.31	0.43	117.14	14.44	51.64	3.04	0.92	20.82	1.28	1.05
7934	7932	71	4.65	0.29	69.701	17.33	12.21	0.76	1.07	5.21	0.86	1.04
7936	7934	6	4.66	0.34	60.988	10.11	23.57	1.73	0.57	11.80	1.01	0.87
7938	7936	29	2.72	0.18	65.829	14.44	4.19	0.27	0.84	1.86	0.52	0.96
7940	7938	106	5.17	0.34	73.573	10.11	8.64	0.57	0.91	3.87	1.00	0.99
7942	7940	20	2.32	0.16	73.573	15.89	5.00	0.34	1.04	2.30	0.46	0.92
7944	7942	95	4.05	0.25	73.573	13.00	10.31	0.64	0.57	4.39	0.75	1.00
7946	7944	108	5.50	0.32	105.52	17.33	27.88	1.65	1.02	11.27	0.96	1.03
7948	7946	54	2.50	0.16	69.701	15.89	2.86	0.19	0.61	1.28	0.48	0.84

Table C.3b. Trace and major element analyses results for COP 289. Continued.

Core Depth ft	Log-corrected Depth ft	Zn ppm	U ppm	U/Al2O3	Ni ppm	Th ppm	Mo ppm	Mo/Al2O3	S mass%	EF-Mo	EF-U	EF-V
7952	7950	11	1.25	0.08	50.339	17.33	0.87	0.06	0.59	0.39	0.24	0.81
7954	7952	9	4.17	0.32	56.148	5.78	9.13	0.71	1.69	4.85	0.96	0.90
7956	7954	22	10.64	0.68	138.43	18.78	90.70	5.81	1.80	39.76	2.02	1.03
7958	7956	18	9.40	0.59	131.66	15.89	75.49	4.71	1.32	32.23	1.74	1.07
7960	7958	267	5.21	0.33	117.14	17.33	54.87	3.49	1.38	23.84	0.98	1.01
7962	7960	98	5.44	0.37	88.094	8.67	41.58	2.81	1.47	19.22	1.09	0.92
7964	7962	64	10.19	0.66	102.62	17.33	73.66	4.75	1.22	32.51	1.95	0.96
7966	7964	69	8.66	0.55	110.36	15.89	71.51	4.56	1.13	31.16	1.63	1.00
7968	7966	12	8.27	0.58	86.158	11.56	54.82	3.84	1.81	26.26	1.72	1.00
7970	7968	17	11.23	0.72	131.66	11.56	88.48	5.70	1.40	39.01	2.15	1.08
7972	7970	30	7.75	0.51	111.33	17.33	62.15	4.07	1.37	27.80	1.50	1.06
7974	7972	15	8.89	0.59	134.56	15.89	77.56	5.19	1.44	35.47	1.76	1.04
7976	7974	690	9.83	0.67	154.89	11.56	105.54	7.19	1.43	49.19	1.98	1.21
7978	7976	210	17.79	1.18	174.25	17.33	133.35	8.83	1.40	60.36	3.49	1.31
7980	7978	542	17.85	1.21	236.21	11.56	170.06	11.55	1.79	79.00	3.59	1.57
7982	7980	31	7.30	0.47	107.46	14.44	63.64	4.08	1.31	27.93	1.39	1.27
7984	7982	14	17.12	1.11	157.79	13.00	120.97	7.86	1.63	53.74	3.30	1.30
7986	7984	22	14.36	0.97	161.67	14.44	136.11	9.17	1.92	62.74	2.87	1.55
7988	7986	14	8.34	0.52	138.43	14.44	77.27	4.78	1.23	32.70	1.53	1.36
7990	7988	16	15.74	1.00	172.32	14.44	151.97	9.63	1.34	65.87	2.96	1.41
7992	7990	-2	8.57	1.15	94.87	1.44	45.40	6.09	1.30	41.66	3.41	1.43
7994	7992	6054	9.48	1.07	166.51	7.22	81.64	9.23	1.13	63.09	3.18	2.61
7996	7994	379	6.81	0.61	172.32	11.56	26.74	2.38	0.97	16.30	1.80	1.62

Table C.3b. Trace and major element analyses results for COP 289. Continued.

Core Depth ft	Log-corrected Depth ft	Zn ppm	U ppm	U/Al2O3	Ni ppm	Th ppm	Mo ppm	Mo/Al2O3	S mass%	EF-Mo	EF-U	EF-V
7998	7996	8	16.17	1.17	230.4	13.00	125.11	9.02	1.37	61.70	3.46	2.77
8000	7998	39	15.62	1.09	217.81	13.00	132.10	9.21	1.38	63.00	3.23	2.84
8002	8000	10	10.73	0.75	167.48	13.00	79.36	5.55	1.38	37.97	2.22	2.05
8004	8002	219	11.52	0.88	167.48	10.11	84.30	6.46	1.36	44.20	2.62	2.30
8006	8004	290	8.62	0.63	178.12	15.89	91.60	6.71	1.44	45.90	1.87	2.29
8008	8006	227	13.79	1.11	158.76	11.56	78.92	6.34	1.33	43.35	3.28	2.10
8010	8008	241	9.01	0.64	151.99	11.56	66.95	4.77	1.56	32.61	1.90	1.75
8012	8010	205	6.89	0.55	138.43	13.00	50.44	4.02	1.70	27.49	1.63	1.61
8014	8012	232	9.26	0.68	149.08	14.44	63.51	4.66	1.38	31.89	2.02	1.73
8016	8014	248	9.11	0.61	153.92	13.00	67.75	4.56	1.44	31.21	1.82	1.68
8018	8016	48	7.32	0.53	103.58	14.44	46.80	3.36	1.39	22.99	1.56	1.37
8020	8018	264	9.94	0.76	130.69	11.56	71.25	5.47	1.34	37.41	2.26	1.51
8022	8020	138	7.84	0.51	119.07	13.00	46.89	3.05	1.38	20.89	1.51	1.40
8024	8022	138	8.10	0.53	125.85	15.89	48.78	3.19	1.34	21.84	1.57	1.46
8026	8024	44	10.85	0.79	136.5	14.44	62.84	4.55	1.23	31.14	2.33	1.51
8028	8026	113	8.24	0.55	124.88	13.00	44.76	2.98	1.46	20.39	1.63	1.46
8030	8028	322	7.97	0.59	117.14	13.00	53.60	3.98	1.35	27.20	1.75	1.43
8032	8030	174	8.66	0.66	121.01	11.56	58.95	4.46	1.34	30.53	1.94	1.37
8034	8032	9	8.62	0.60	113.26	11.56	50.75	3.54	1.34	24.23	1.78	1.32
8036	8034	197	7.48	0.53	126.82	10.11	49.46	3.48	1.35	23.83	1.56	1.52
8038	8036	313	8.74	0.62	151.99	14.44	51.04	3.61	1.26	24.68	1.83	1.58
8040	8038	247	8.82	0.64	125.85	15.89	52.24	3.77	1.23	25.79	1.89	1.45
8044	8042	199	6.98	0.52	123.91	10.11	50.23	3.77	1.24	25.76	1.55	1.37

Table C.3b. Trace and major element analyses results for COP 289. Continued.

Core Depth ft	Log-corrected Depth ft	Zn ppm	U ppm	U/Al2O3	Ni ppm	Th ppm	Mo ppm	Mo/Al2O3	S mass%	EF-Mo	EF-U	EF-V
8046	8044	116	7.33	0.53	111.33	11.56	51.50	3.71	1.22	25.34	1.56	1.37
8048	8046	129	11.48	0.78	122.94	14.44	81.41	5.50	1.27	37.64	2.30	1.44
8050	8048	6	12.87	0.86	151.99	13.00	82.44	5.53	1.42	37.78	2.56	1.47
8052	8050	28	7.16	0.51	121.98	14.44	54.10	3.84	1.40	26.28	1.51	1.40
8054	8052	4	9.67	0.67	140.37	11.56	65.82	4.57	1.45	31.28	1.99	1.47
8056	8054	3016	10.66	0.75	124.88	11.56	80.09	5.66	1.21	38.71	2.23	1.52
8058	8056	2152	17.47	1.23	155.86	15.89	108.99	7.66	0.98	52.39	3.64	2.33
8060	8058	2	8.01	0.54	121.98	14.44	56.58	3.82	1.62	26.15	1.60	1.32
8062	8060	6	7.32	0.49	141.34	17.33	58.18	3.87	1.31	26.47	1.44	1.49
8064	8062	4	9.21	0.62	128.75	14.44	64.35	4.35	1.36	29.74	1.85	1.56
8066	8064	551	12.51	0.87	167.48	10.11	97.49	6.81	1.33	46.60	2.59	1.87
8068	8066	8	10.40	0.73	146.18	11.56	68.28	4.78	1.14	32.66	2.16	1.54
8070	8068	-4	8.32	0.57	121.98	5.78	53.61	3.70	1.43	25.29	1.70	1.42
8072	8070	-4	6.60	0.47	109.39	8.67	51.35	3.65	1.31	24.99	1.39	1.55
8074	8072	228	11.32	0.87	140.37	8.67	98.48	7.61	1.20	52.04	2.59	1.72
8076	8074	122	7.51	0.61	160.7	7.22	62.25	5.07	1.97	34.70	1.81	1.59
8078	8076	-2	9.08	0.74	130.69	8.67	84.63	6.85	1.11	46.88	2.18	1.71
8080	8078	-1	12.79	0.96	165.54	13.00	106.59	7.98	1.58	54.58	2.84	1.94
8082	8080	36	18.14	1.44	237.18	11.56	136.75	10.88	1.35	74.40	4.28	3.16
8086	8084	80	21.91	2.09	226.53	10.11	94.78	9.03	2.00	61.76	6.19	3.03
8088	8086	451	42.36	3.32	340.76	13.00	229.91	18.00	1.81	123.11	9.83	3.58
8090	8088	38	39.16	3.96	270.09	2.89	188.47	19.06	2.68	130.36	11.74	3.63
8092	8090	235	20.65	1.80	277.84	8.67	191.36	16.65	1.64	113.83	5.32	2.82

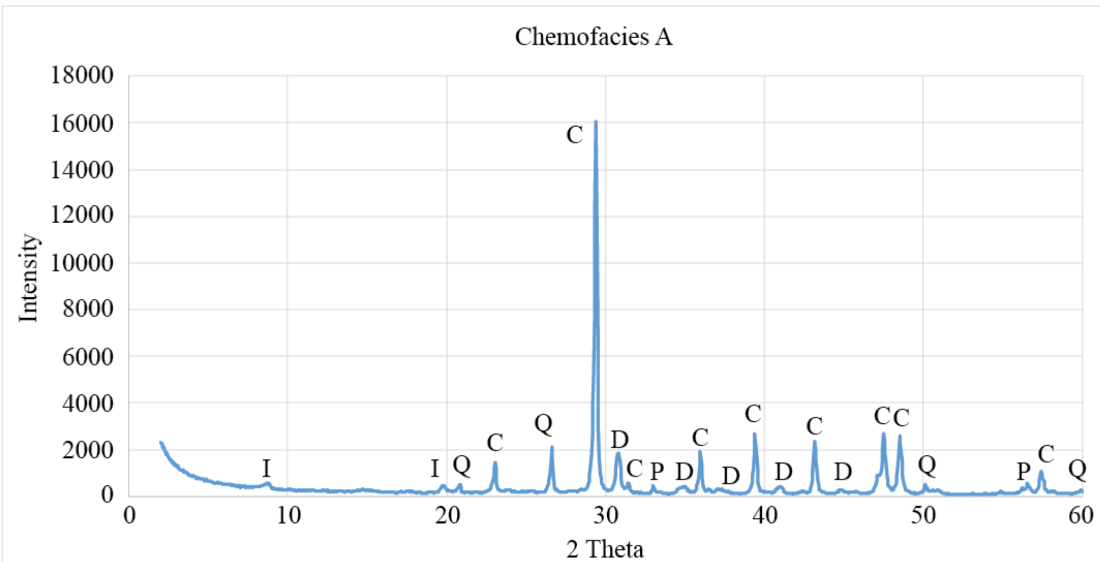
Table C.3b. Trace and major element analyses results for COP 289. Continued.

Core Depth ft	Log-corrected Depth ft	Zn ppm	U ppm	U/Al2O3	Ni ppm	Th ppm	Mo ppm	Mo/Al2O3	S mass%	EF-Mo	EF-U	EF-V
8094	8092	0	22.70	2.02	266.22	7.22	138.26	12.30	3.14	84.13	5.99	5.33
8096	8094	-31	3.23	0.63	35.818	8.67	31.64	6.17	0.39	42.18	1.86	1.12
8098	8096	108	31.29	4.27	320.43	7.22	178.57	24.37	1.27	166.66	12.65	5.90
8100	8098	1687	13.72	5.47	84.222	-2.89	107.61	42.88	0.54	293.23	16.20	5.37
8102	8100	-7	4.44	6.73	34.85	-1.44	34.35	52.06	0.37	356.04	19.94	7.50
8104	8102	51	14.99	3.18	246.86	2.89	157.20	33.30	0.46	227.73	9.41	7.99
8106	8104	-6	9.14	4.81	53.244	-1.44	13.73	7.22	0.30	49.37	14.25	1.73
8108	8106	12	8.45	2.22	123.91	1.44	23.21	6.12	0.72	41.83	6.59	1.60
8110	8108	-14	8.82	0.82	72.605	8.67	9.31	0.87	0.42	5.95	2.44	1.12
8112	8110	-21	2.14	0.78	11.617	-2.89	1.83	0.66	0.25	4.53	2.30	1.05
8114	8112	-26	2.32	0.30	49.371	11.56	7.95	1.04	0.70	7.12	0.90	0.38
8116	8114	-24	3.07	0.62	89.062	0.00	4.83	0.97	0.37	6.63	1.83	0.78
8118	8116	54	1.15	3.33	6.7765	-2.89	3.00	8.69	0.06	59.39	9.88	3.49

APPENDIX D

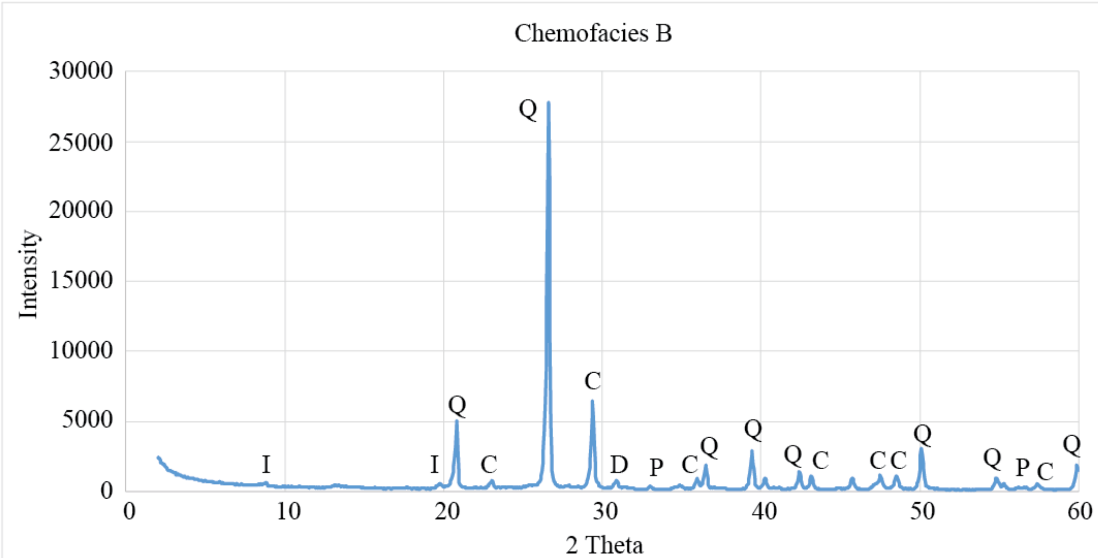
Figures from X-ray Diffraction Analyses

This appendix contains figures from XRD analyses. One random powder mount XRD analysis was performed for each chemofacies.



Peak Identification Key
Q - Quartz C - Calcite D - Dolomite P - Pyrite I - Illite

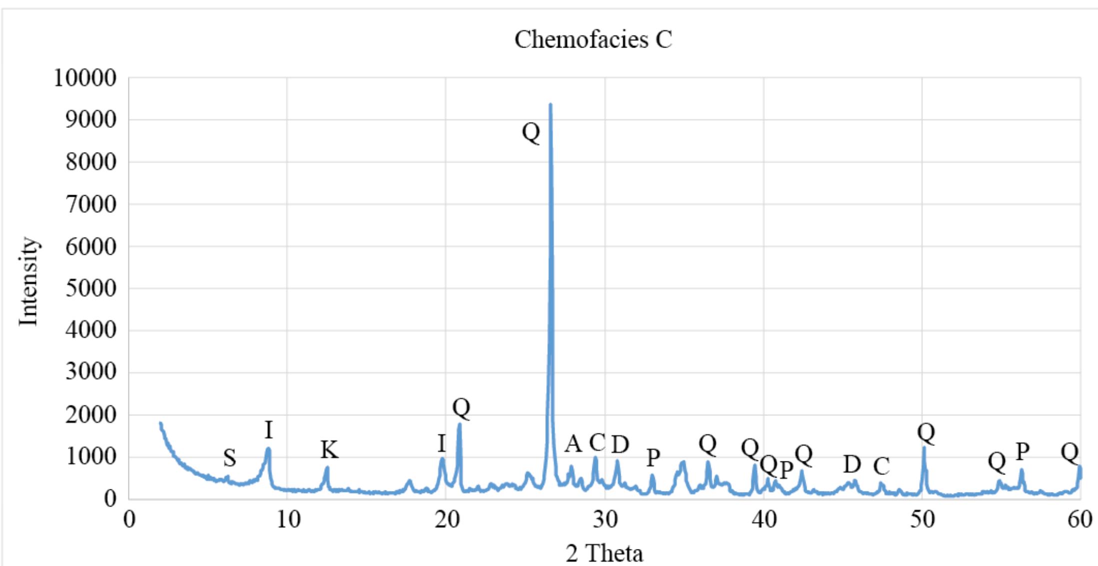
Figure D.1. XRD results for Chemofacies A from COP 653 – Sample Depth: 8544'



Peak Identification Key

Q - Quartz C - Calcite D - Dolomite P - Pyrite I - Illite

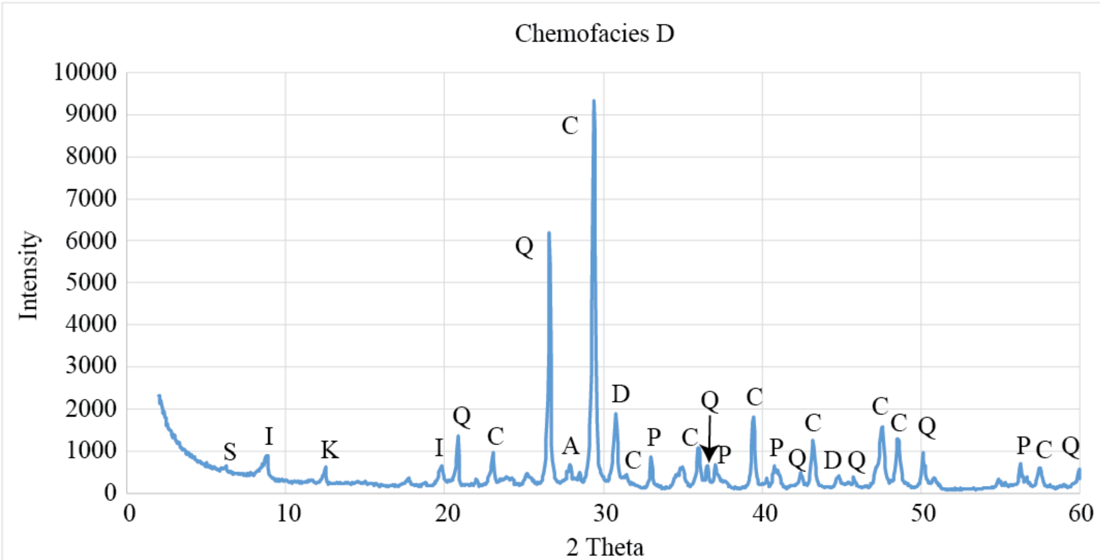
Figure D.2. XRD results for Chemofacies B from COP 653 – Sample Depth: 8532’



Peak Identification Key

Q - Quartz C - Calcite D - Dolomite P - Pyrite I - Illite S - Smectite K - Kaolinite A - Albite

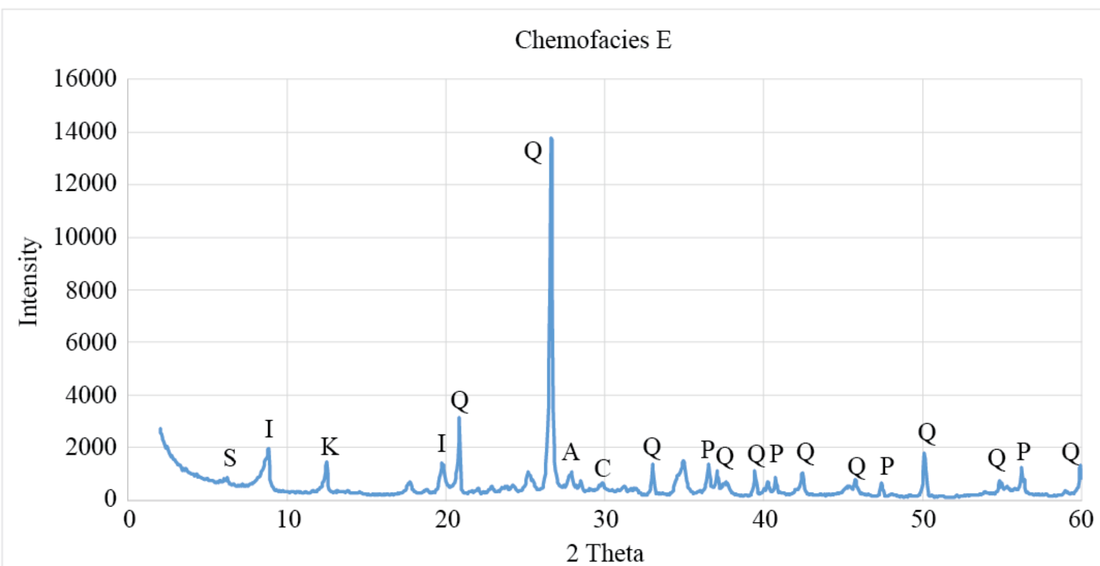
Figure D.3. XRD results for Chemofacies C from COP 259 – Sample Depth: 8340’



Peak Identification Key

Q - Quartz C - Calcite D - Dolomite P - Pyrite I - Illite S - Smectite K - Kaolinite A - Albite

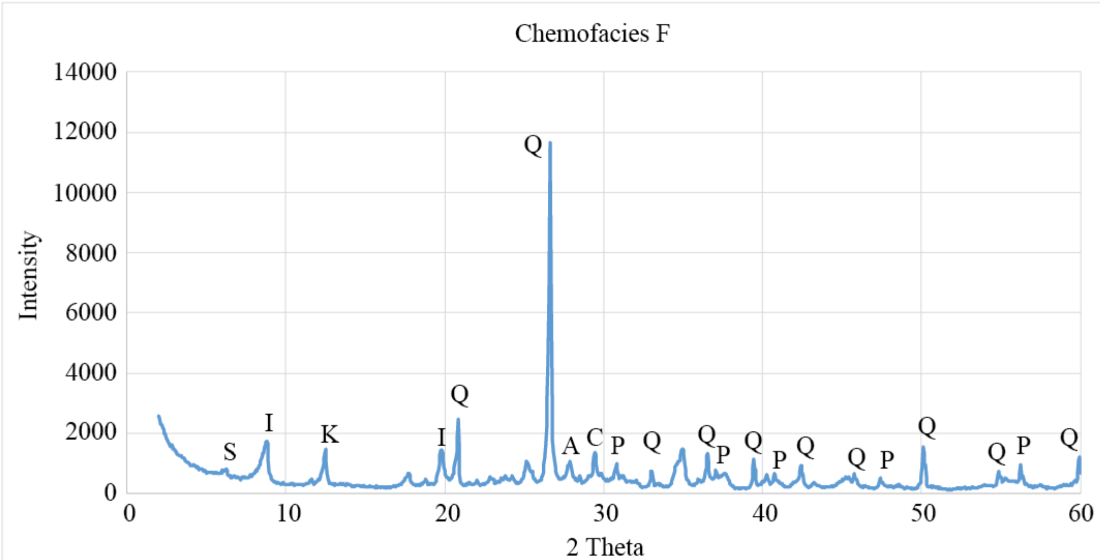
Figure D.4. XRD results for Chemofacies D from COP 259 – Sample Depth: 7992’



Peak Identification Key

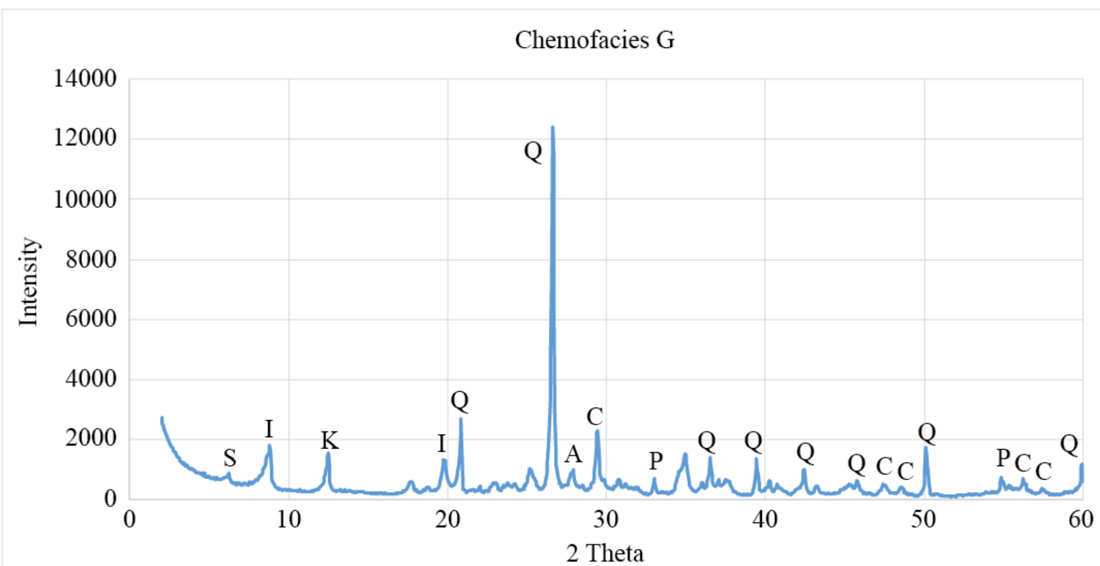
Q - Quartz C - Calcite P - Pyrite I - Illite S - Smectite K - Kaolinite A - Albite

Figure D.5. XRD results for Chemofacies E from COP 289 – Sample Depth: 7972’



Peak Identification Key
Q - Quartz C - Calcite P - Pyrite I - Illite S - Smectite K - Kaolinite A - Albite

Figure D.6. XRD results for Chemofacies F from COP 289 – Sample Depth: 7940’



Peak Identification Key
Q - Quartz C - Calcite P - Pyrite I - Illite S - Smectite K - Kaolinite A - Albite

Figure D.7. XRD results for Chemofacies G from COP 653 – Sample Depth: 8320’

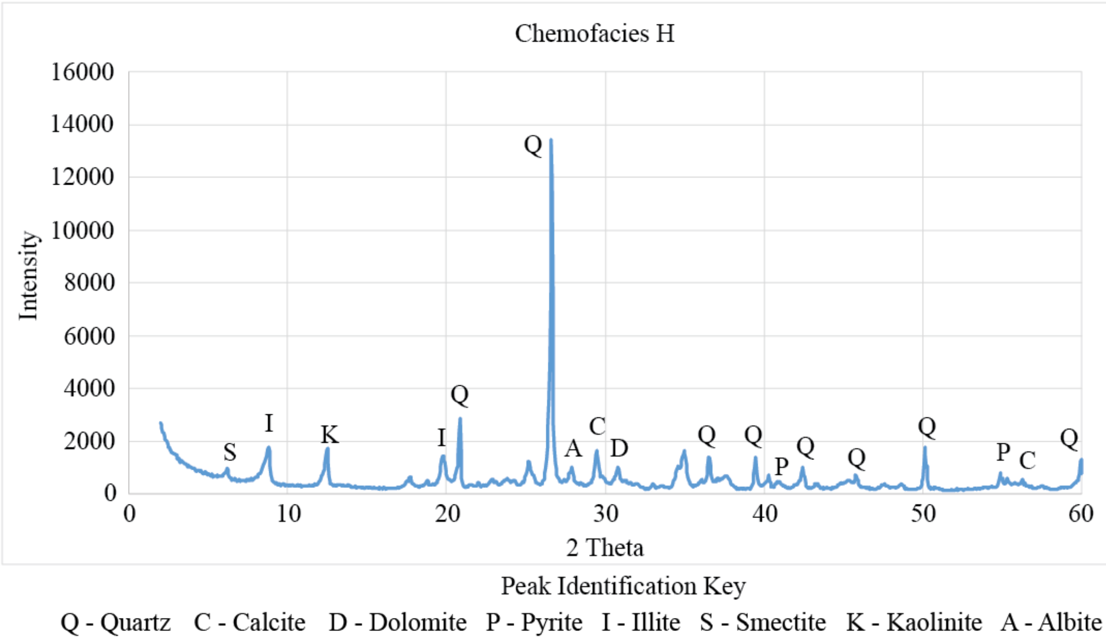


Figure D.8. XRD results for Chemofacies H from COP 259 – Sample Depth: 8162’

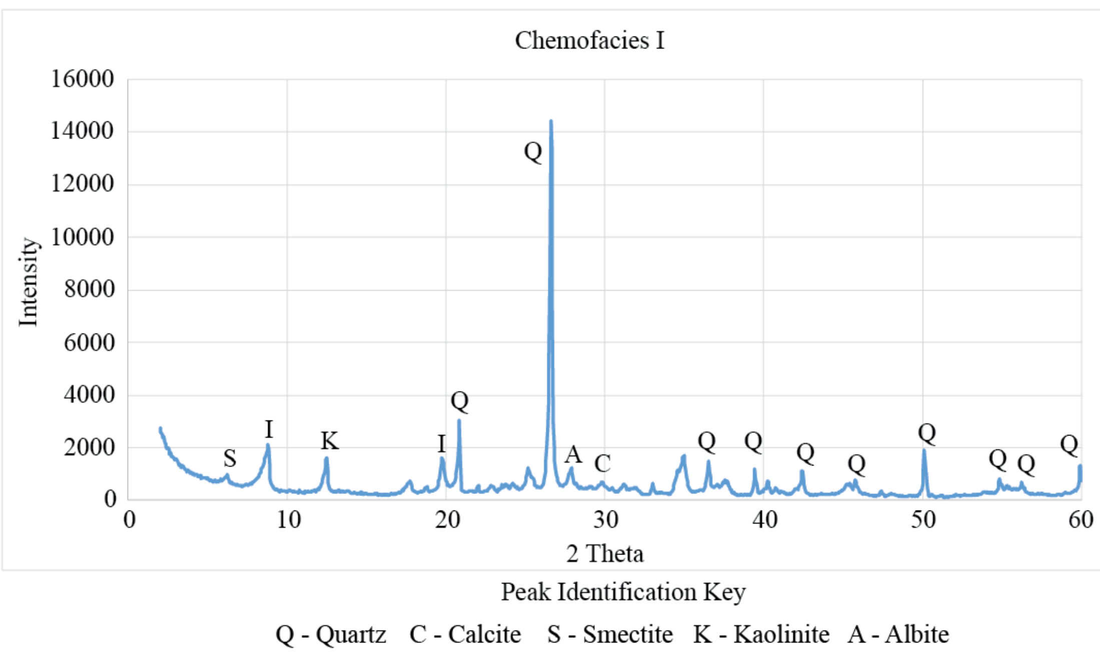
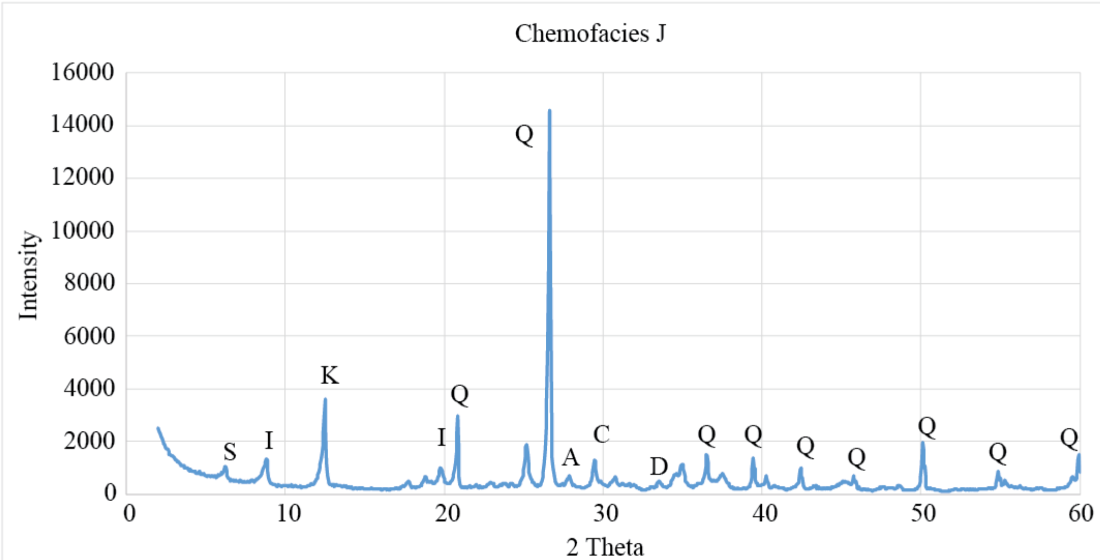


Figure D.9. XRD results for Chemofacies I from COP 653 – Sample Depth: 8258’



Peak Identification Key

Q - Quartz C - Calcite D - Dolomite P - Pyrite I - Illite S - Smectite K - Kaolinite A - Albite

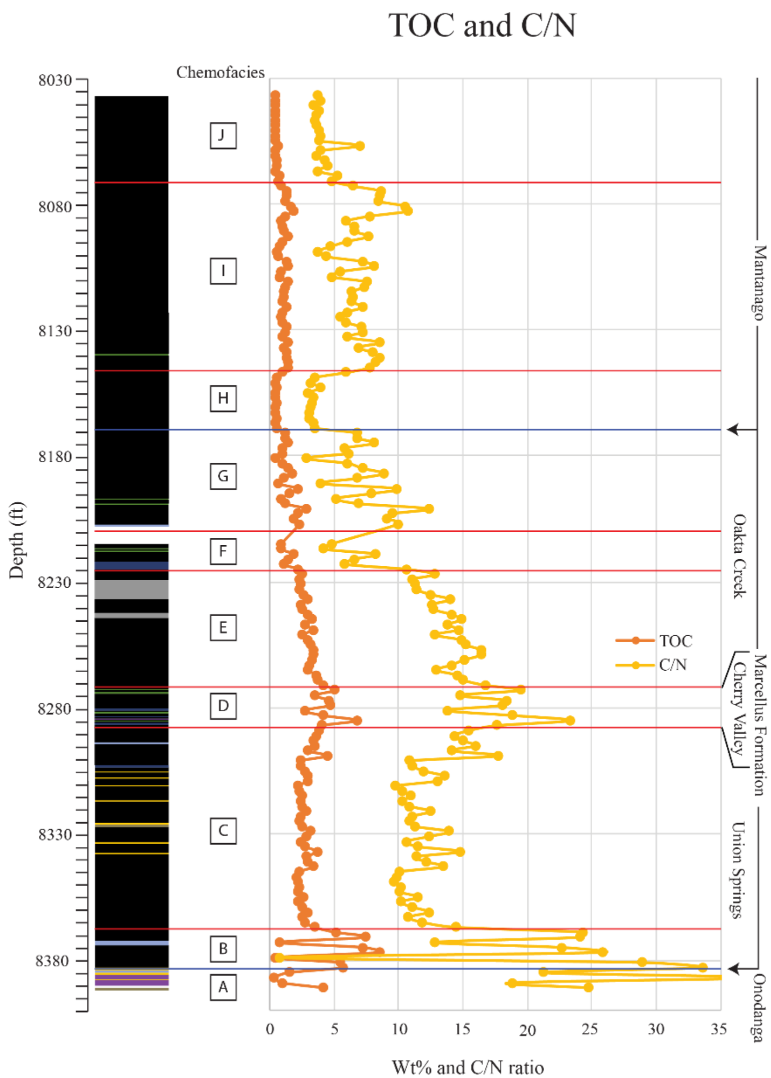
Figure D.10. XRD results for Chemofacies J from COP 259 – Sample Depth: 8060’

APPENDIX E

Chemofacies and Geochemical Signatures in Cored Wells

This appendix contains figures for key geochemical data and the designated chemofacies.

COP TRACT 259 A-1000 Chemofacies



(A)

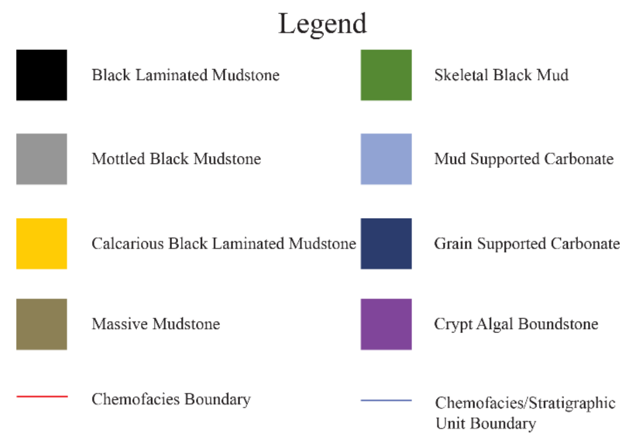
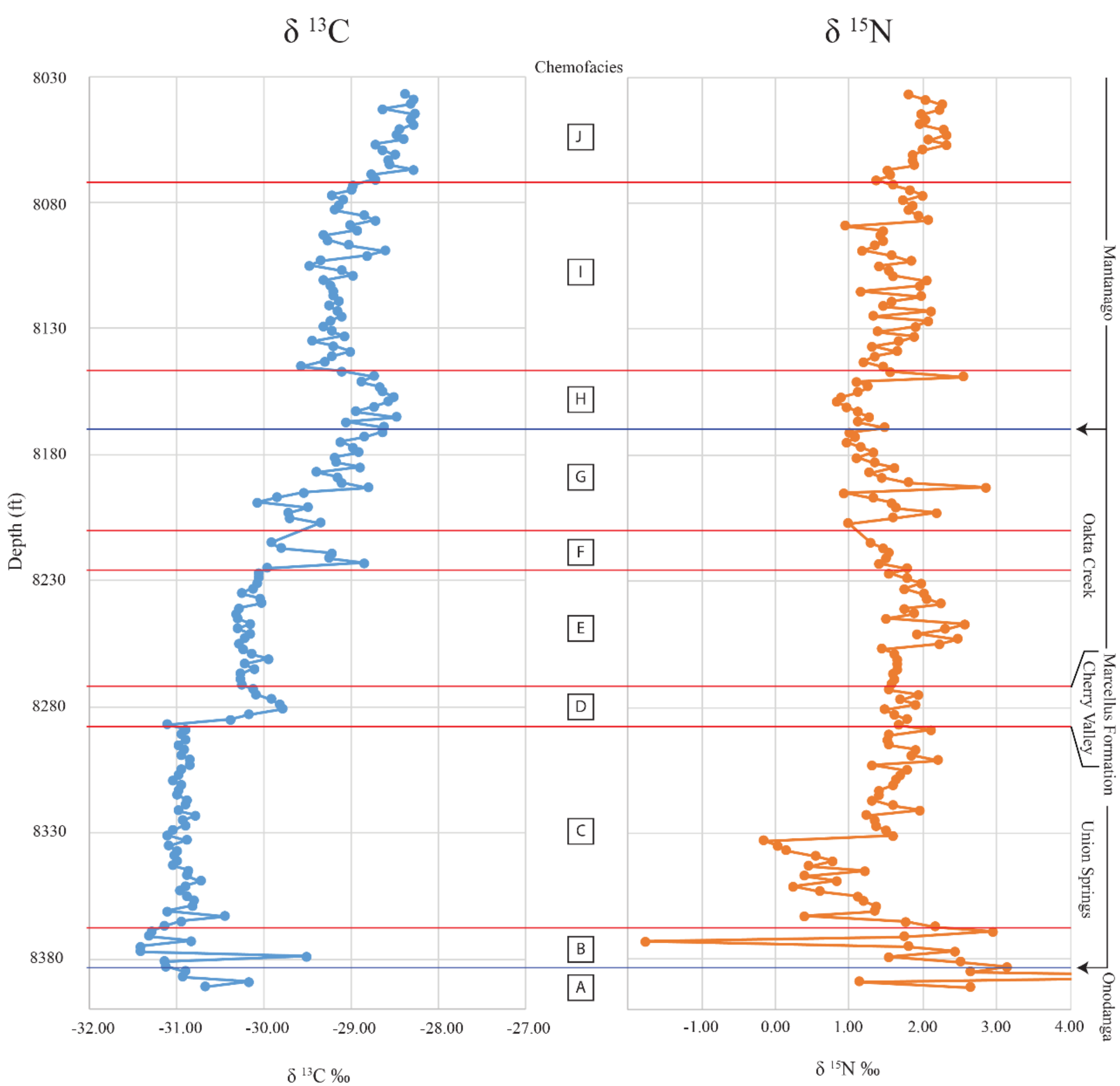
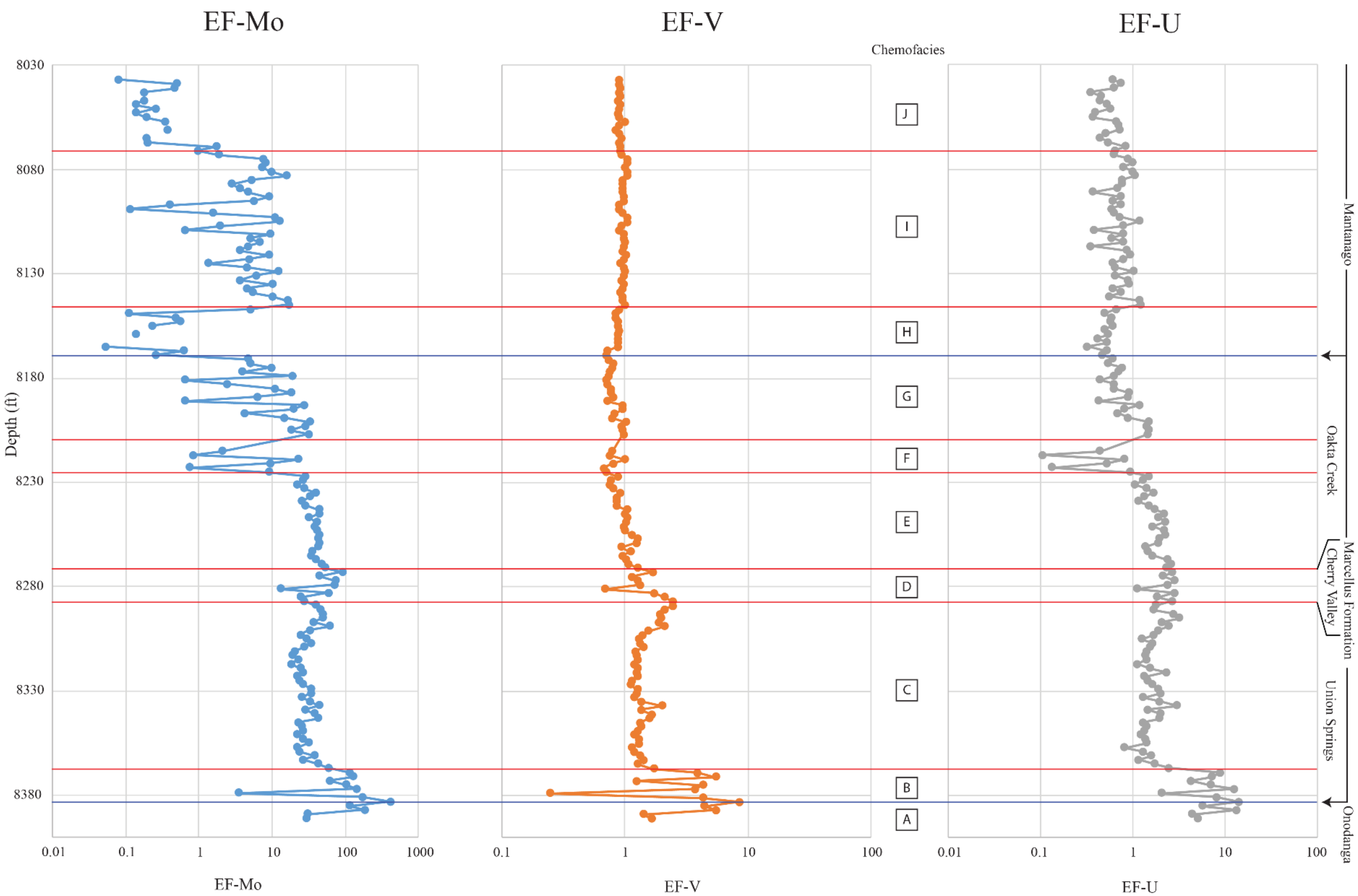


Figure E.1. COP 259 chemofacies. The red lines show boundaries of chemofacies. Letter in square box designates chemofacies name. Blue lines represent both chemofacies boundaries and lithostratigraphic formation boundaries. (A) TOC, C/N ratios, and lithofacies comparison. (B) Isotopic C and N composition of the organic material. (C) Redox-sensitive trace elements enrichment factors, logarithmic scale. (D) Paleo-productivity indicators. (E) Aluminum and silica content. (F) Calcite, total iron, and sulfur abundance.



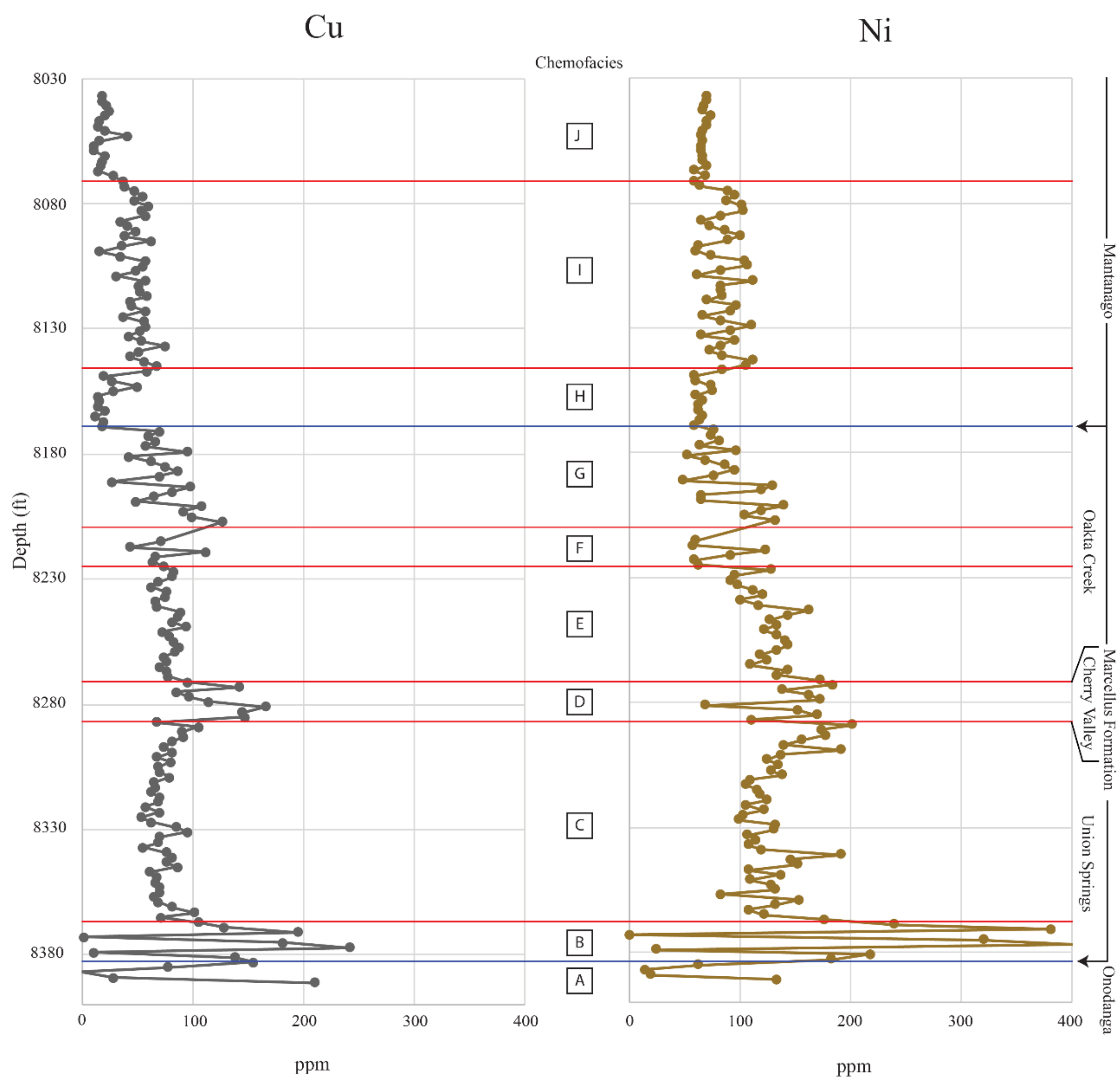
δ 13C
δ 15N
Chemofacies
Depth (ft)
8030
8080
8130
8180
8230
8280
8330
8380
J
I
H
G
F
E
D
C
B
A
-32.00
-31.00
-30.00
-29.00
-28.00
-27.00
δ 13C ‰
-1.00
0.00
1.00
2.00
3.00
4.00
δ 15N ‰
Mantanago
Oakta Creek
Marcellus Formation
Cherry Valley
Union Springs
Onodanga

(B)

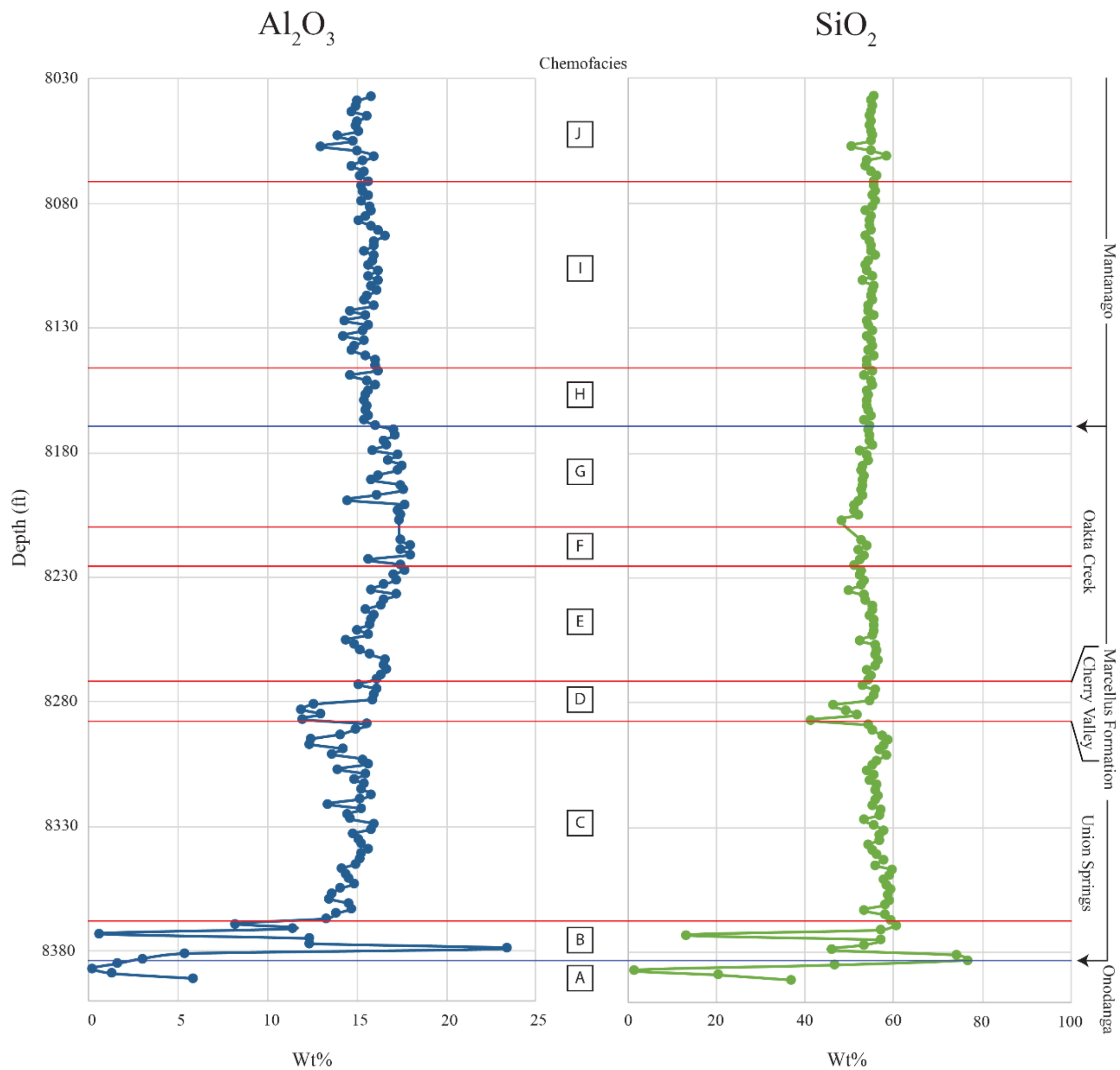


EF-Mo
EF-V
EF-U
Chemofacies
Depth (ft)
8030
8080
8130
8180
8230
8280
8330
8380
J
I
H
G
F
E
D
C
B
A
0.01
0.1
1
10
100
1000
EF-Mo
0.1
1
10
100
EF-V
0.01
0.1
1
10
100
EF-U
Mantanago
Oakta Creek
Marcellus Formation
Cherry Valley
Union Springs
Onodanga

(C)

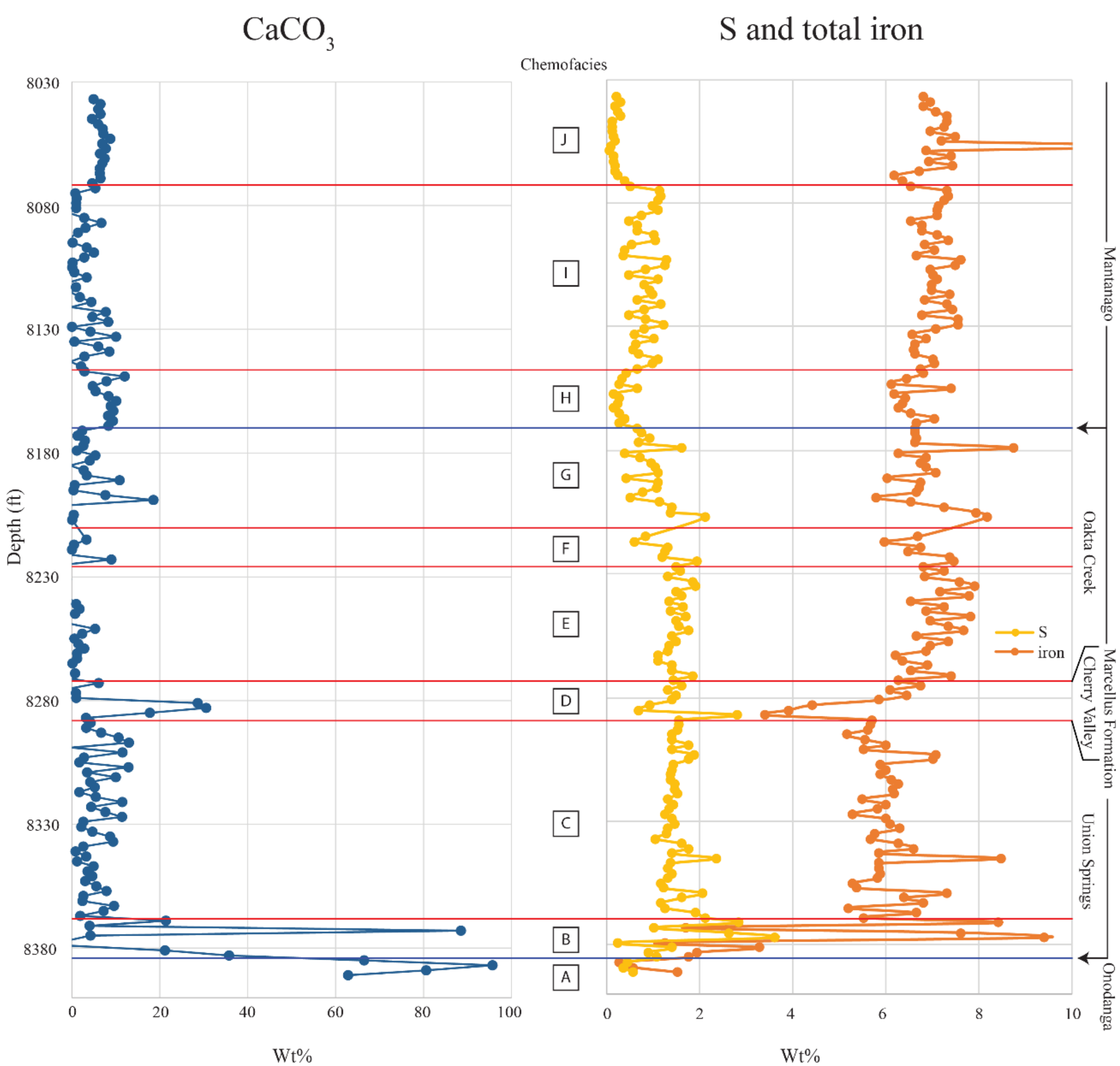

Cu
Ni
Chemofacies
Depth (ft)
8030
8080
8130
8180
8230
8280
8330
8380
J
I
H
G
F
E
D
C
B
A
0
100
200
300
400
ppm
Mantanago
Oakta Creek
Marcellus Formation
Cherry Valley
Union Springs
Onodanga

(D)



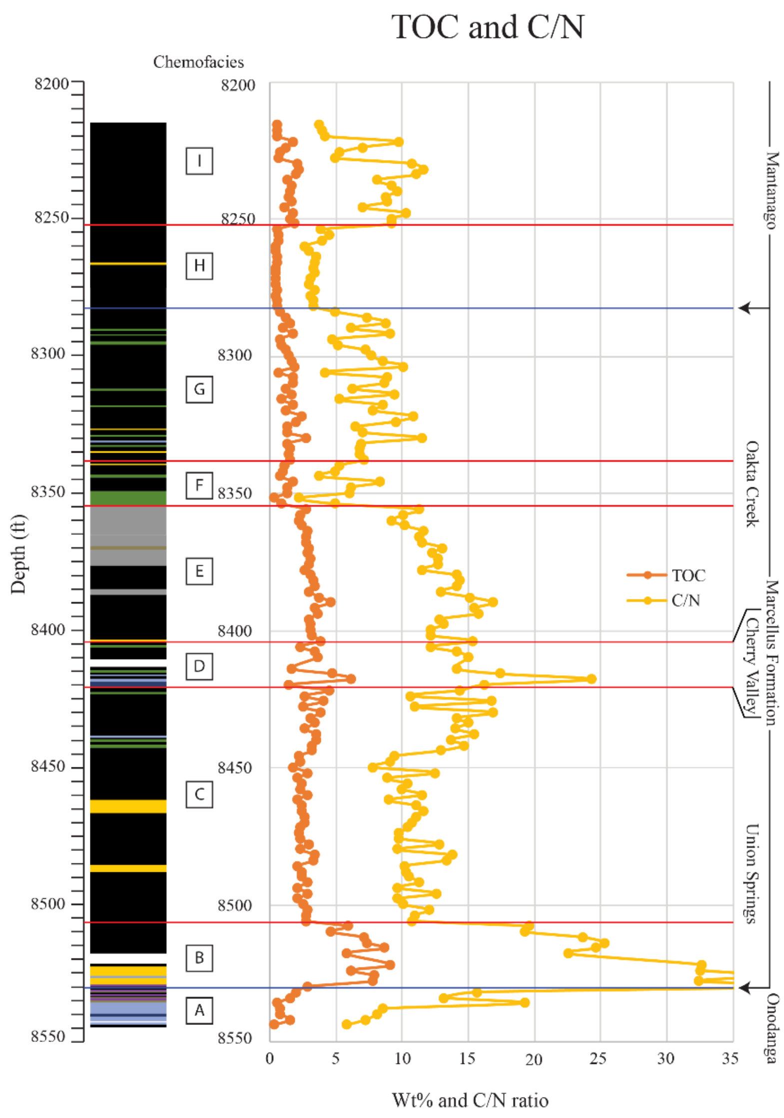
Al_2O_3
SiO_2
Chemofacies
Depth (ft)
8030
8080
8130
8180
8230
8280
8330
8380
J
I
H
G
F
E
D
C
B
A
0
5
10
15
20
25
0
20
40
60
80
100
Wt%
Wt%
Mantanago
Oakta Creek
Cherry Valley
Marcellus Formation
Union Springs
Onodanga

(E)



CaCO$_3$
S and total iron
Chemofacies
Depth (ft)
8030
8080
8130
8180
8230
8280
8330
8380
J
I
H
G
F
E
D
C
B
A
0
20
40
60
80
100
Wt%
0
2
4
6
8
10
Wt%
S
iron
Mantango
Oakta Creek
Marcellus Formation
Cherry Valley
Union Springs
Onodanga

(F)



(A)

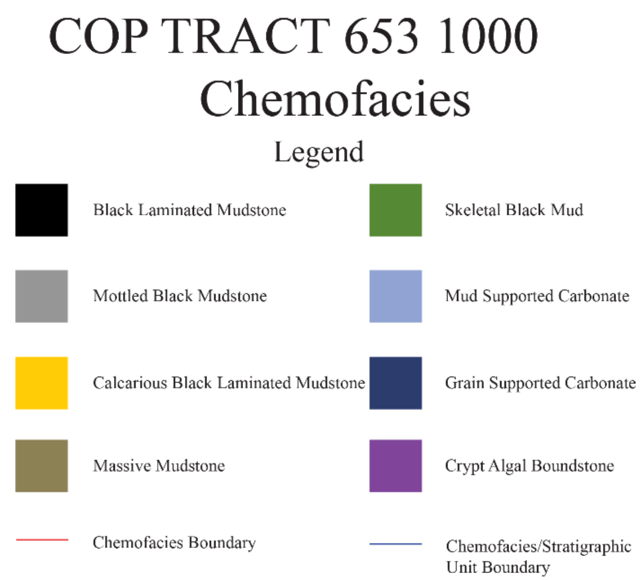
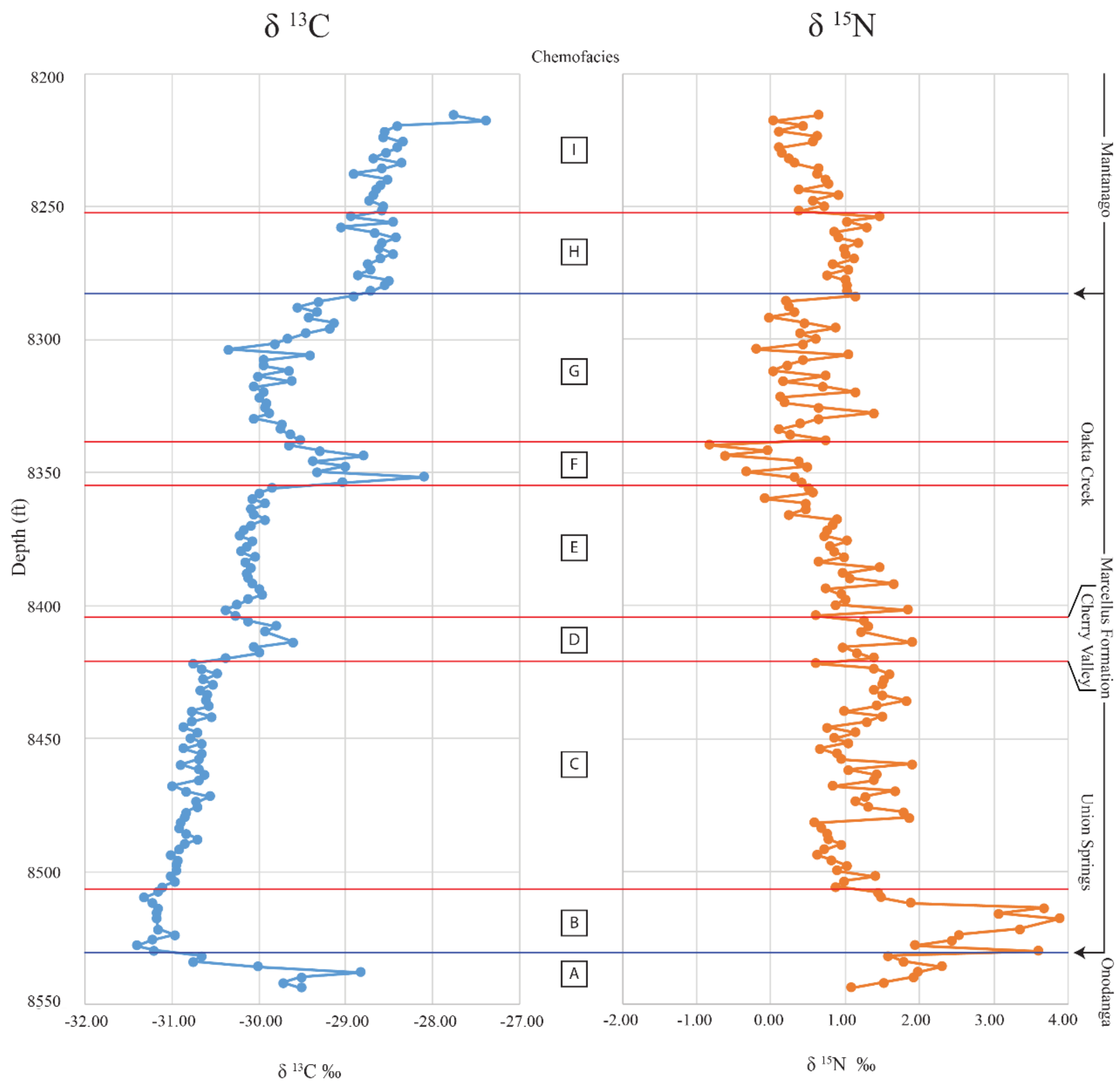
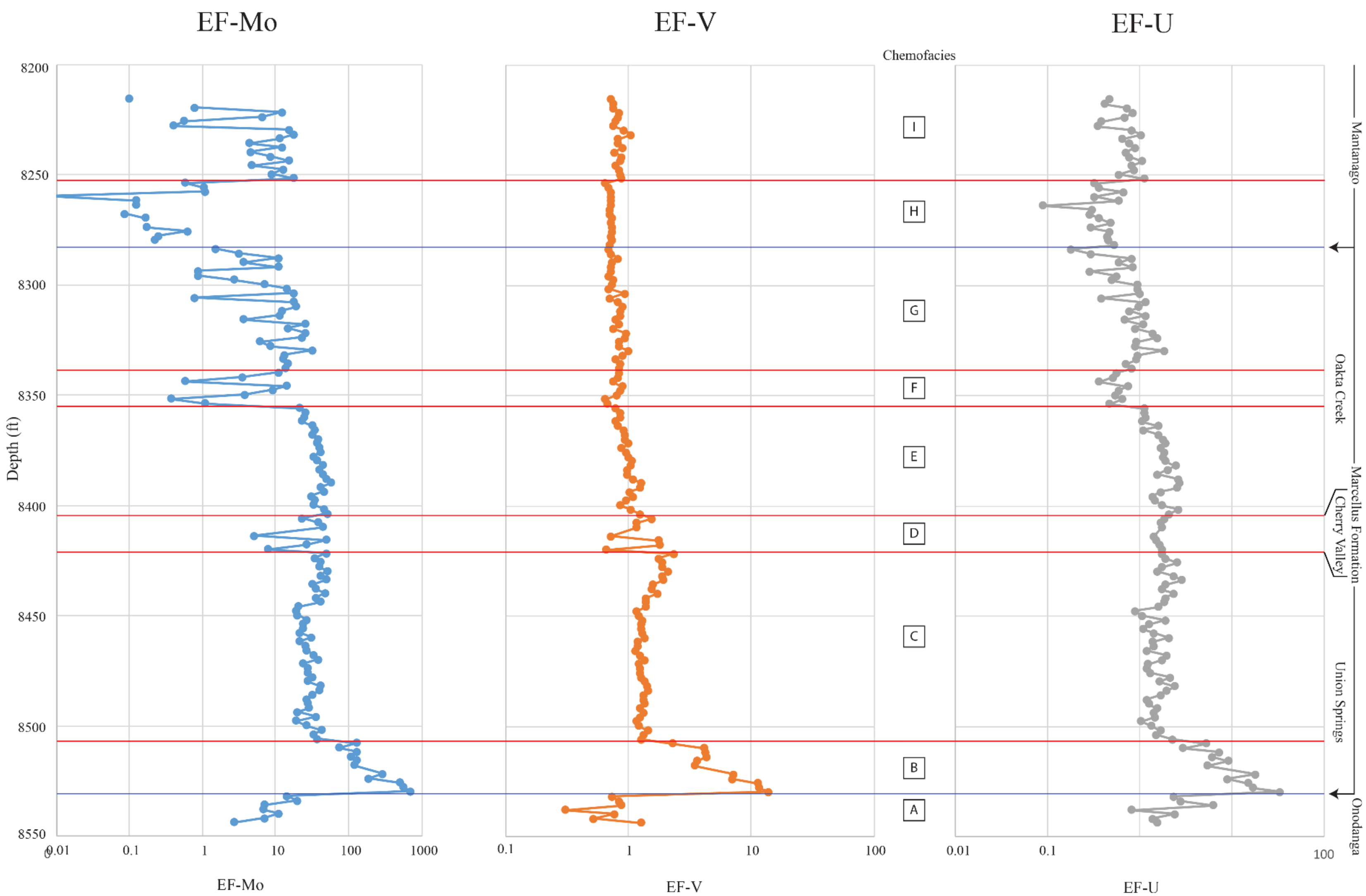


Figure E.2. COP 653 chemofacies. The red lines show boundaries of chemofacies. Letter in square box designates chemofacies name. Blue lines represent both chemofacies boundaries and lithostratigraphic formation boundaries. (A) TOC, C/N ratios, and lithofacies comparison. (B) Isotopic C and N composition of the organic material. (C) Redox-sensitive trace elements enrichment factors, logarithmic scale. (D) Paleo-productivity indicators. (E) Aluminum and silica content. (F) Calcite, total iron, and sulfur abundance.

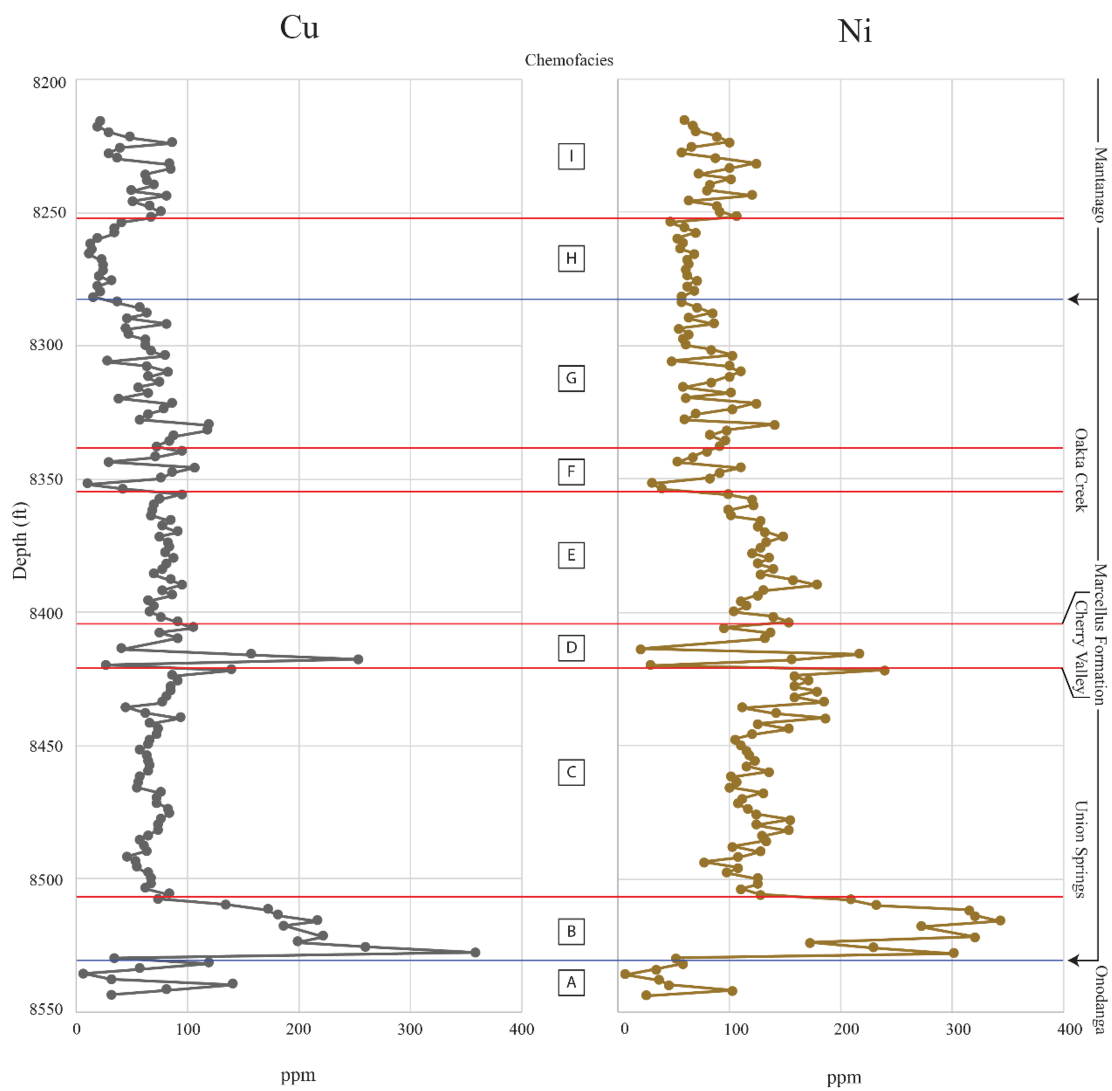


δ 13C
δ 15N
Chemofacies
I
H
G
F
E
D
C
B
A
Depth (ft)
8200
8250
8300
8350
8400
8450
8500
8550
-32.00
-31.00
-30.00
-29.00
-28.00
-27.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
δ 13C ‰
δ 15N ‰
Mantango
Oakta Creek
Marcellus Formation
Cherry Valley
Union Springs
Onondaga

(B)

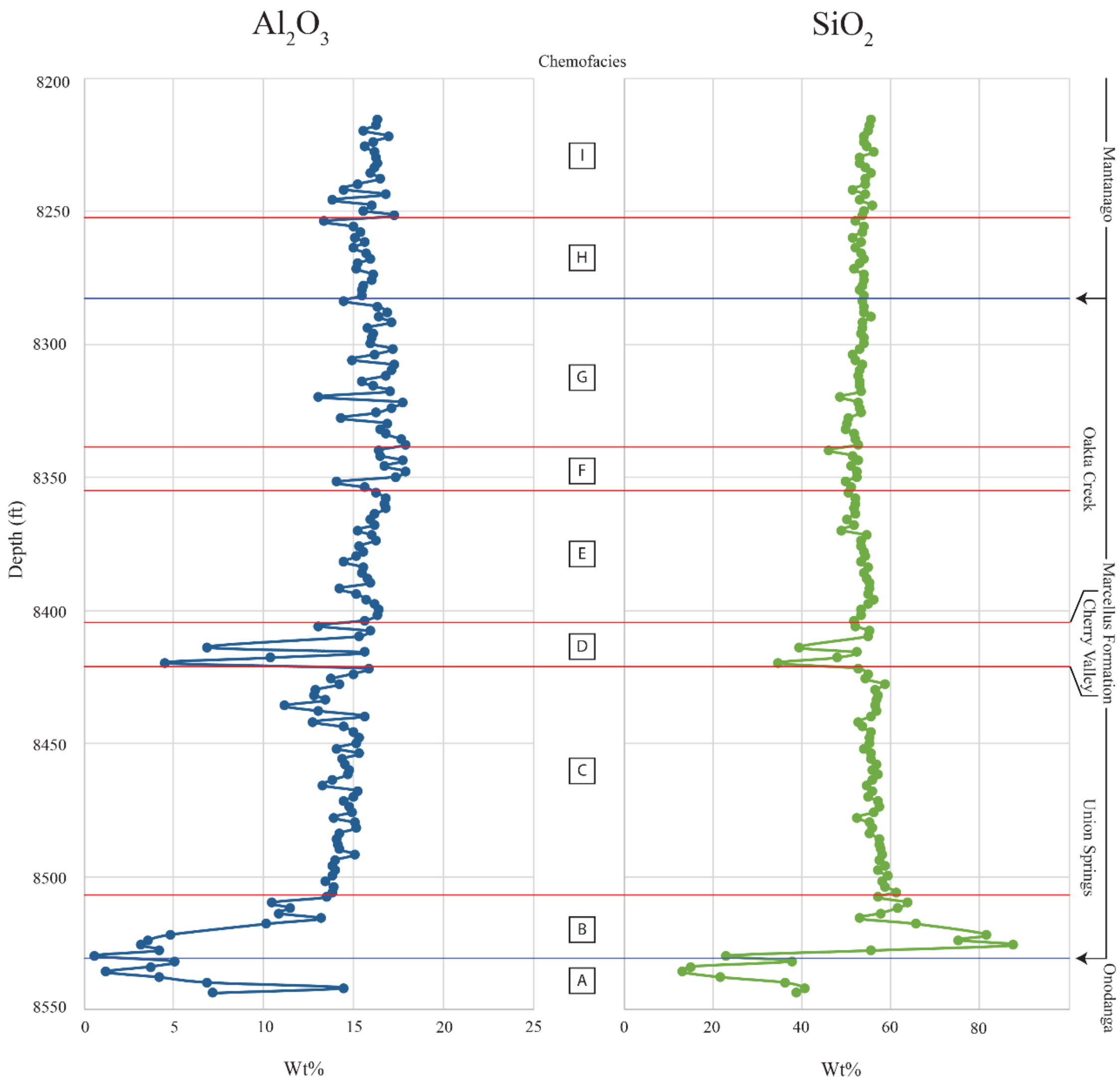

EF-Mo
EF-V
EF-U
Chemofacies
Depth (ft)
8200
8250
8300
8350
8400
8450
8500
8550
0.01
0.1
1
10
100
1000
EF-Mo
0.1
1
10
100
EF-V
0.01
0.1
100
EF-U
I
H
G
F
E
D
C
B
A
Mantango
Oakta Creek
Marcellus Formation
Cherry Valley
Union Springs
Onodanga

(C)



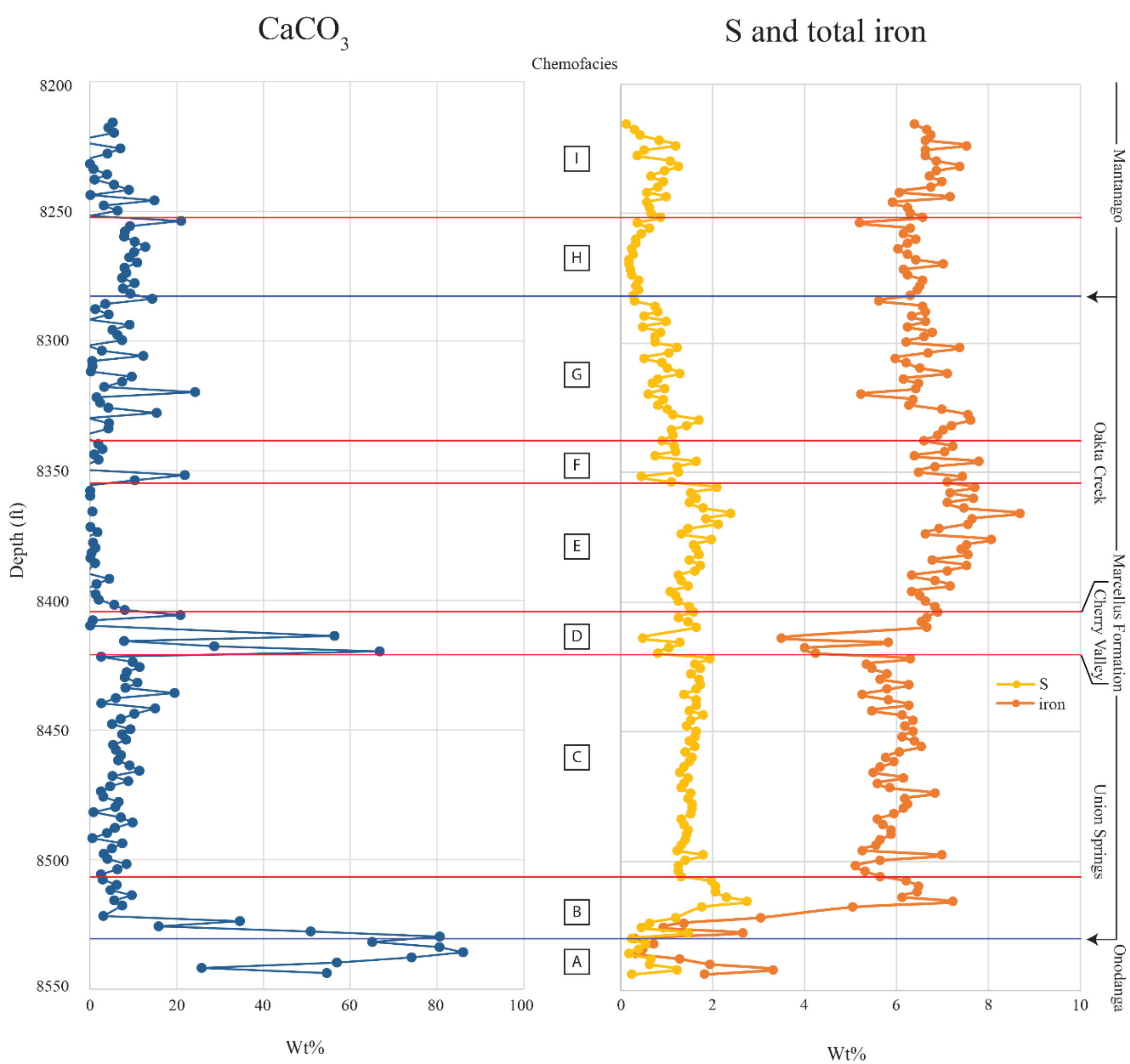
Cu
Ni
Chemofacies
Depth (ft)
8200
8250
8300
8350
8400
8450
8500
8550
I
H
G
F
E
D
C
B
A
0
100
200
300
400
ppm
Marcellus Formation
Mantango
Oakta Creek
Cherry Valley
Union Springs
Onodanga

(D)



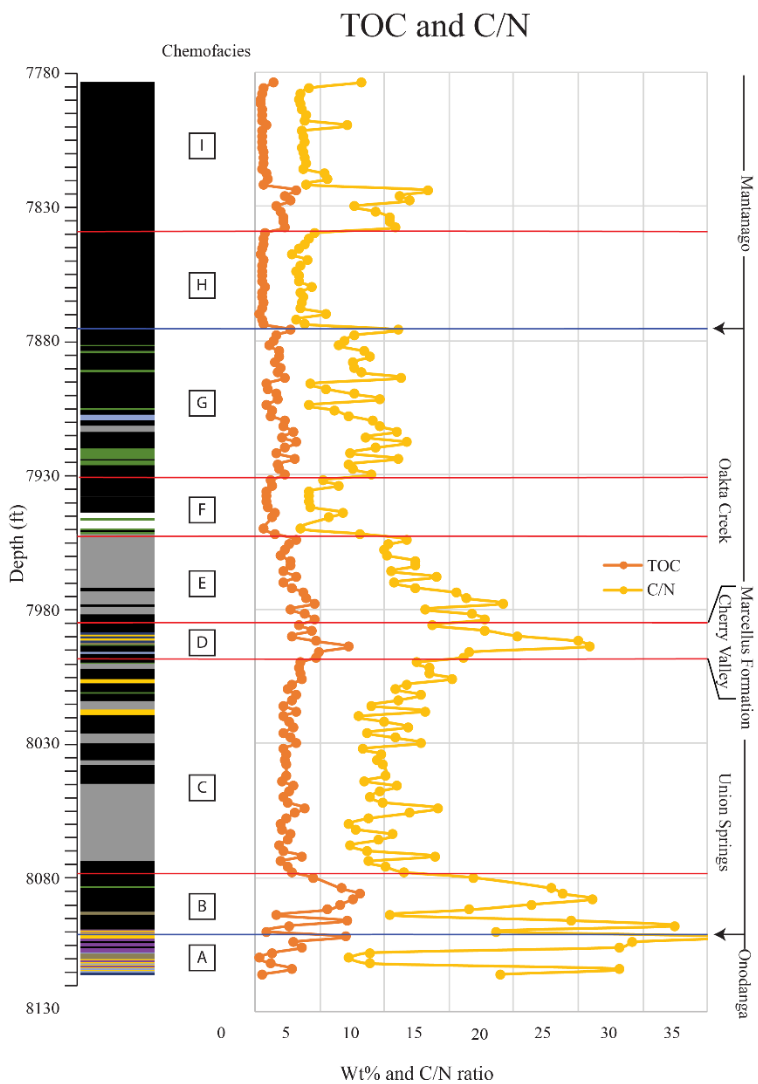
Al2O3
SiO2
Chemofacies
8200
8250
8300
8350
8400
8450
8500
8550
Depth (ft)
I
H
G
F
E
D
C
B
A
0
5
10
15
20
25
0
20
40
60
80
Wt%
Wt%
Mantango
Oakta Creek
Marcellus Formation
Cherry Valley
Union Springs
Onodanga

(E)



CaCO$_3$
S and total iron
Chemofacies
Depth (ft)
Wt%
Wt%
I
H
G
F
E
D
C
B
A
S
iron
Marcellus Formation
Mantango
Oakta Creek
Cherry Valley
Union Springs
Onodanga

(F)



(A)

COP TRACT 289 1000PH Chemofacies

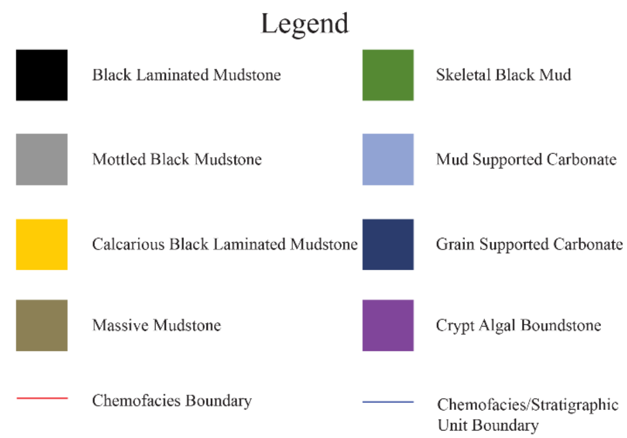
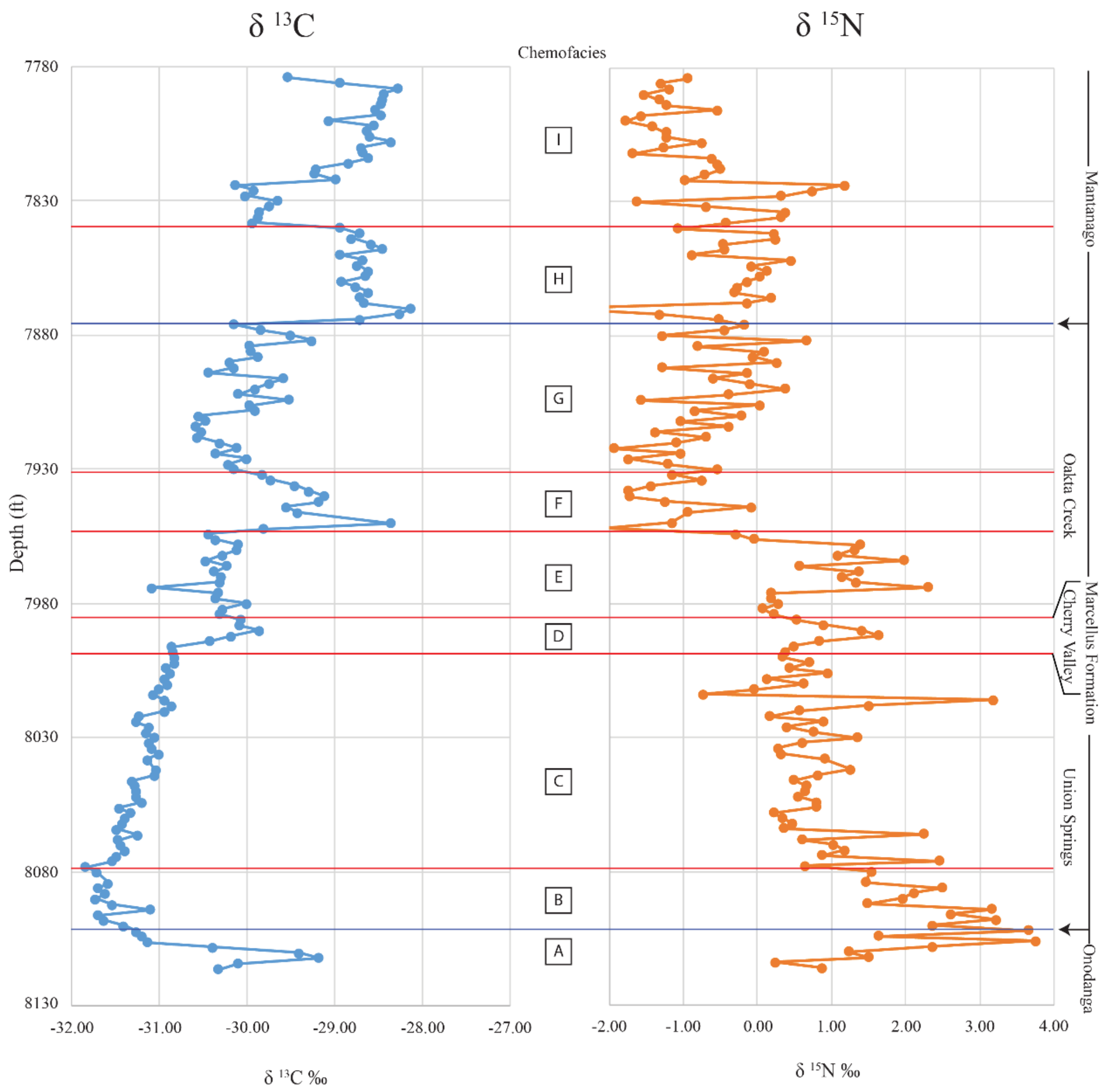
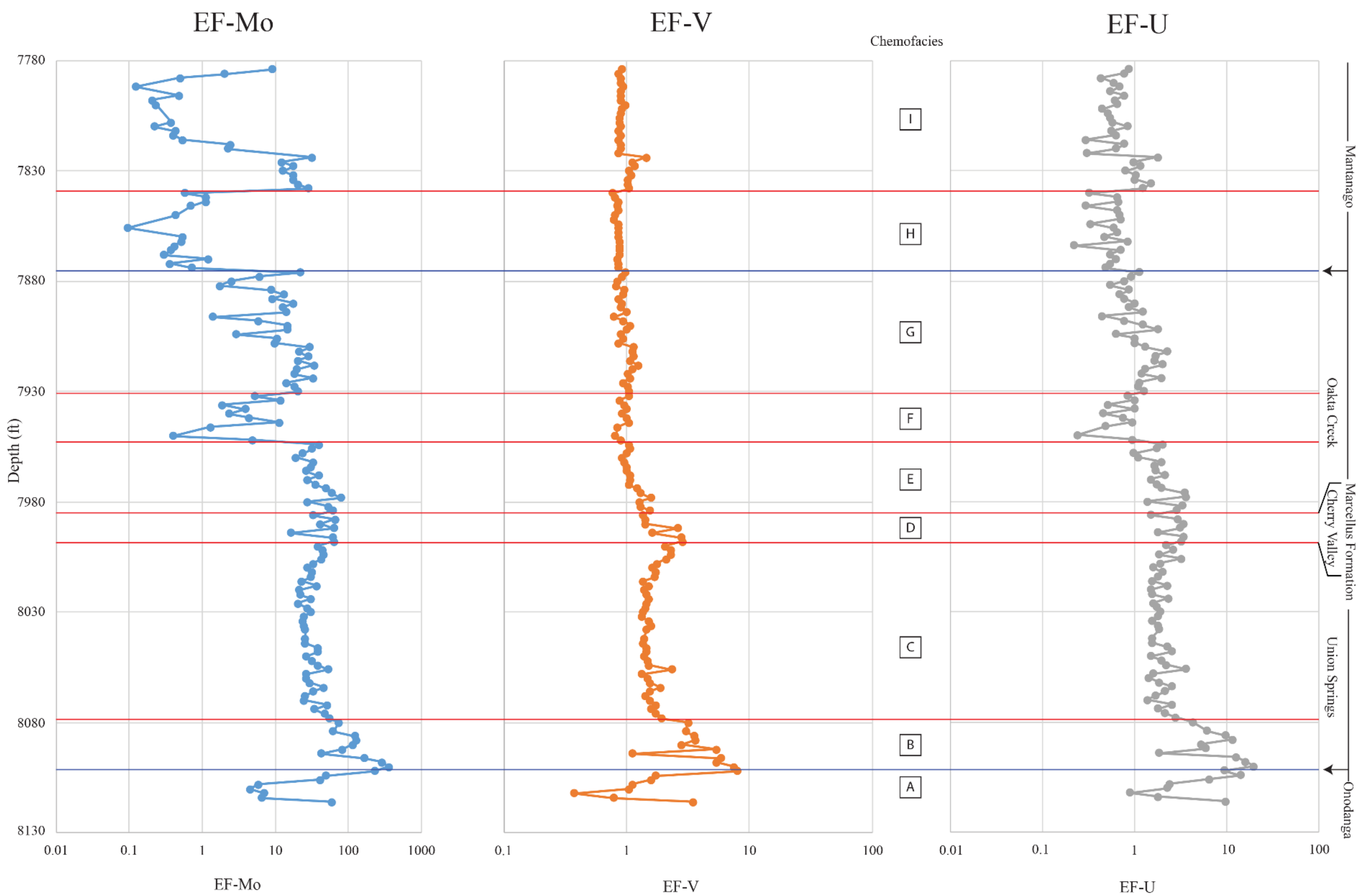


Figure E.3. COP 289 chemofacies. The red lines show boundaries of chemofacies. Letter in square box designates chemofacies name. Blue lines represent both chemofacies boundaries and lithostratigraphic formation boundaries. (A) TOC, C/N ratios, and lithofacies comparison. (B) Isotopic C and N composition of the organic material. (C) Redox-sensitive trace elements enrichment factors, logarithmic scale. (D) Paleo-productivity indicators. (E) Aluminum and silica content. (F) Calcite, total iron, and sulfur abundance.

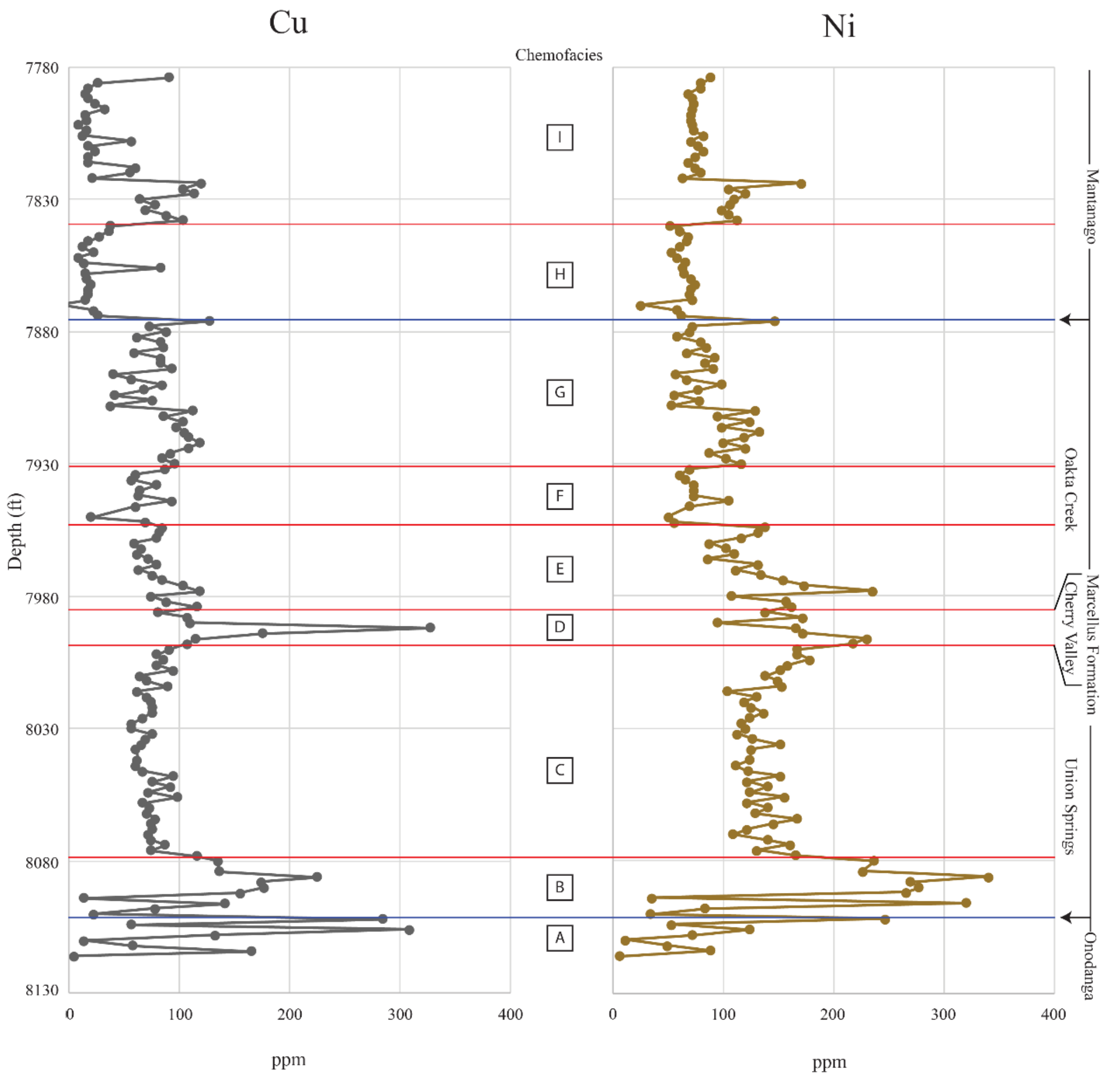

δ ¹³C
δ ¹⁵N
Chemofacies
Depth (ft)
7780
7830
7880
7930
7980
8030
8080
8130
-32.00
-31.00
-30.00
-29.00
-28.00
-27.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
δ ¹³C ‰
δ ¹⁵N ‰
I
H
G
F
E
D
C
B
A
Mantango
Oakta Creek
Marcellus Formation
Cherry Valley
Union Springs
Onodanga

(B)



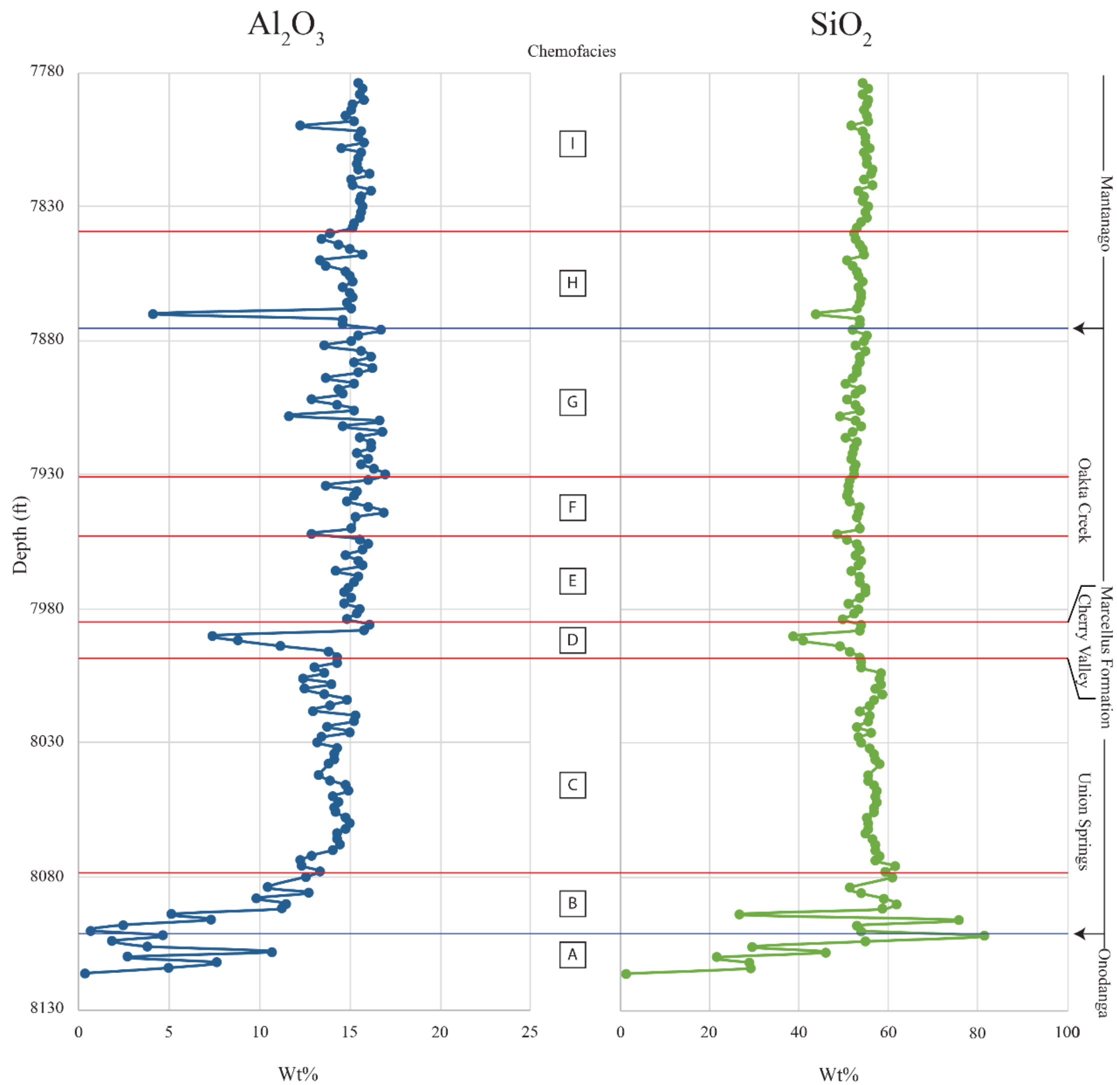
EF-Mo
EF-V
Chemofacies
EF-U
Depth (ft)
7780
7830
7880
7930
7980
8030
8080
8130
0.01
0.1
1
10
100
1000
EF-Mo
0.1
1
10
100
EF-V
0.01
0.1
1
10
100
EF-U
I
H
G
F
E
D
C
B
A
Mantanago
Oakta Creek
Marcellus Formation
Cherry Valley
Union Springs
Onodanga

(C)



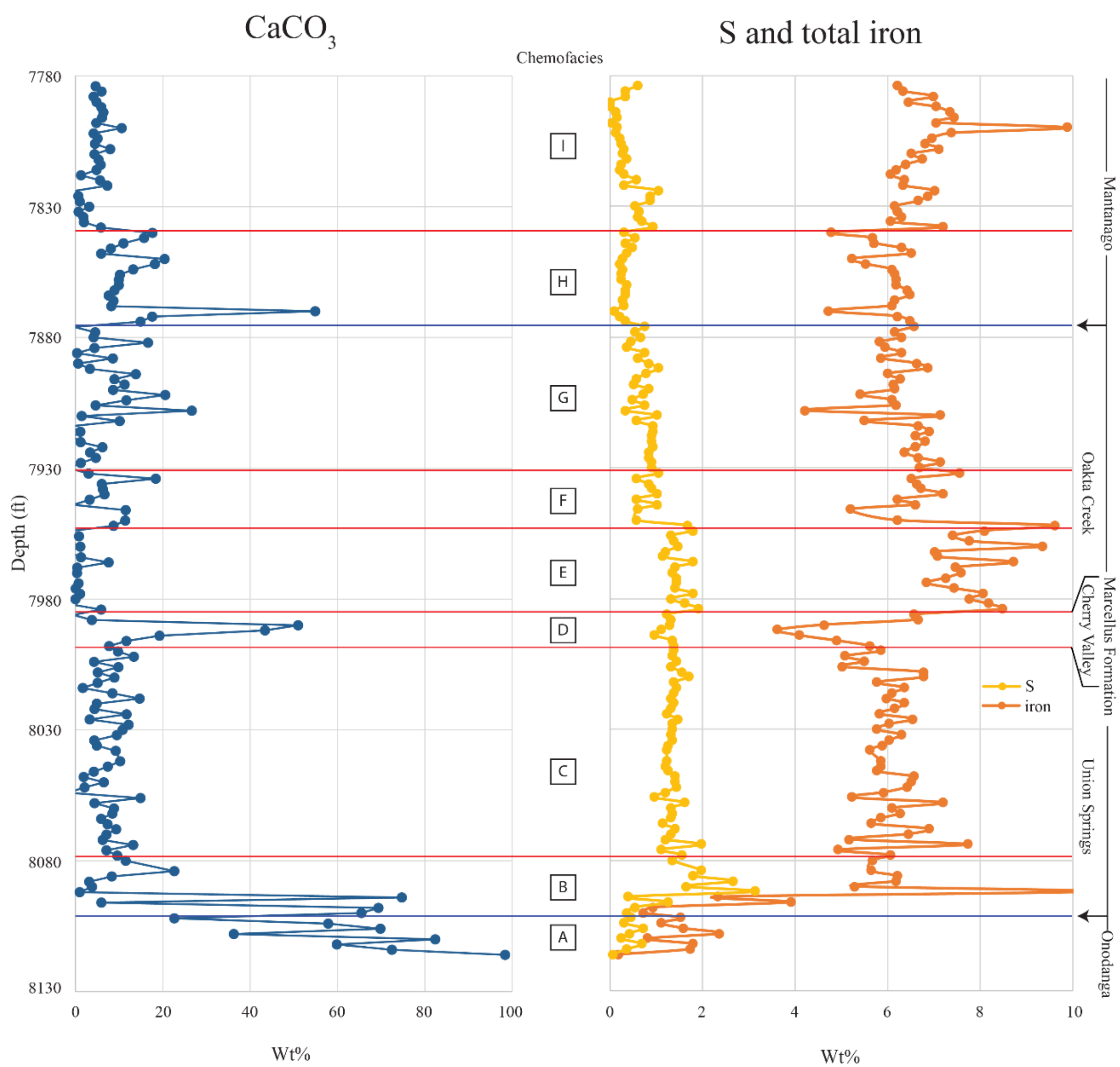
Cu
Ni
Chemofacies
Depth (ft)
7780
7830
7880
7930
7980
8030
8080
8130
0
100
200
300
400
ppm
I
H
G
F
E
D
C
B
A
Marcellus Formation
Mamtango
Oakta Creek
Cherry Valley
Union Springs
Onodanga

(D)



Al_2O_3
SiO_2
Chemofacies
7780
7830
7880
7930
7980
8030
8080
8130
Depth (ft)
I
H
G
F
E
D
C
B
A
0
5
10
15
20
25
0
20
40
60
80
100
Wt%
Wt%
Mantanago
Oakta Creek
Marcellus Formation
Cherry Valley
Union Springs
Onodanga

(E)


CaCO$_3$
S and total iron
Chemofacies
Depth (ft)
7780
7830
7880
7930
7980
8030
8080
8130
0
20
40
60
80
100
Wt%
0
2
4
6
8
10
Wt%
I
H
G
F
E
D
C
B
A
S
iron
Mantanago
Oakta Creek
Cherry Valley
Marcellus Formation
Union Springs
Onodanga

(F)

APPENDIX F

Lithostratigraphic and Chemostratigraphic Isopach Maps

This appendix contains isopach thickness maps for lithostratigraphic units and chemofacies.

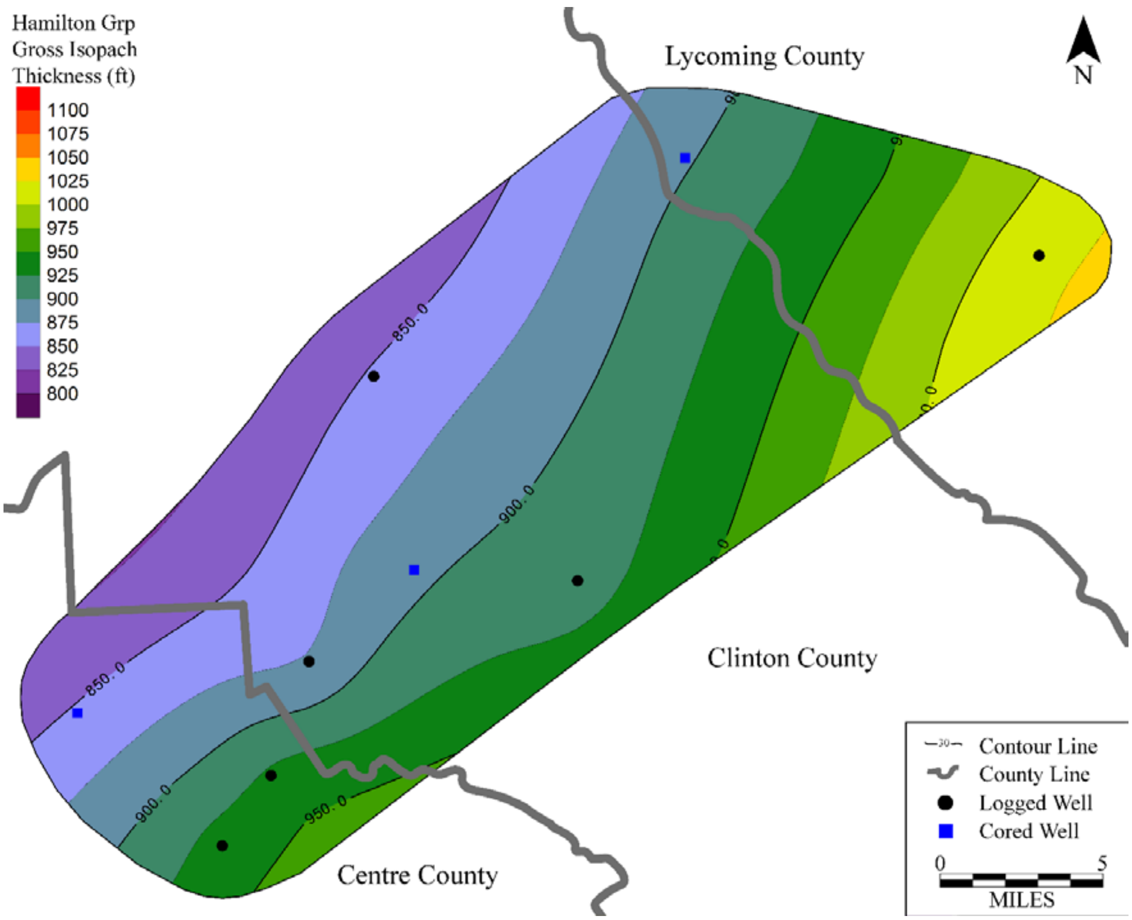


Figure F.1. Isopach map of the entire Hamilton Group. General thickening towards the orogenic front to the east/southeast.

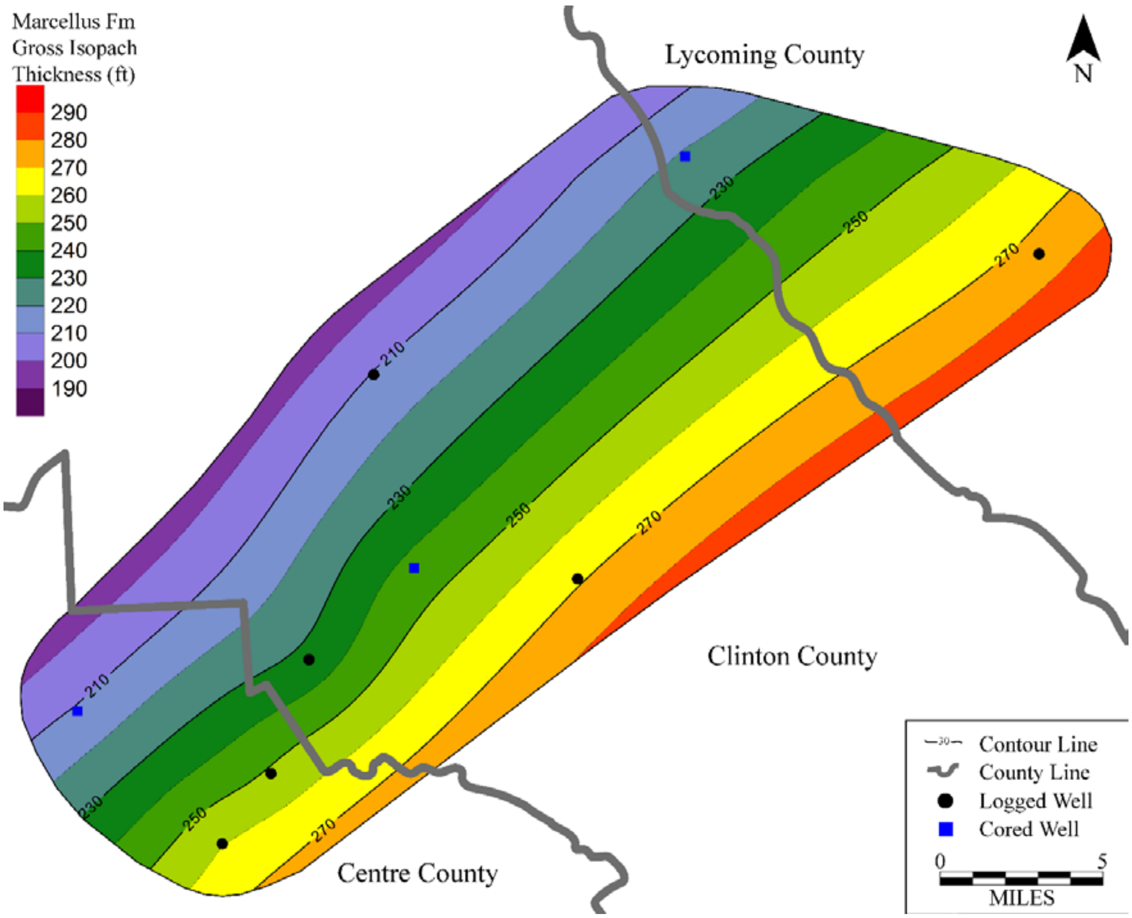


Figure F.2. Isopach map of the Marcellus Formation. The Marcellus Formation thins at a constant rate moving away from the orogenic front to the east/southeast.

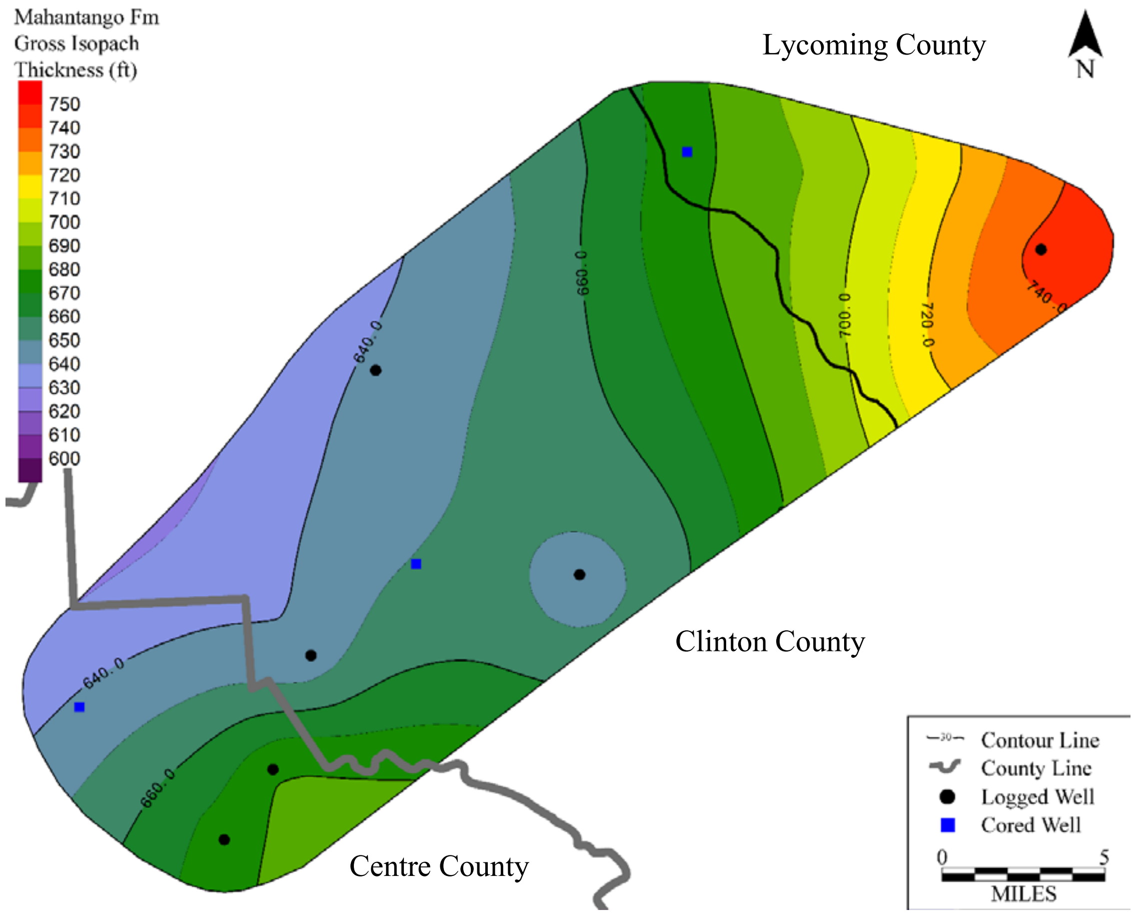


Figure F.3. Isopach map of the Mahantango Formation. The Mahantango Formation does not thin uniformly to the west like the Marcellus Formation. The thickest portion is to the east but the area in the center of the map is anonymously thin which could be an artifact of coarse well control.

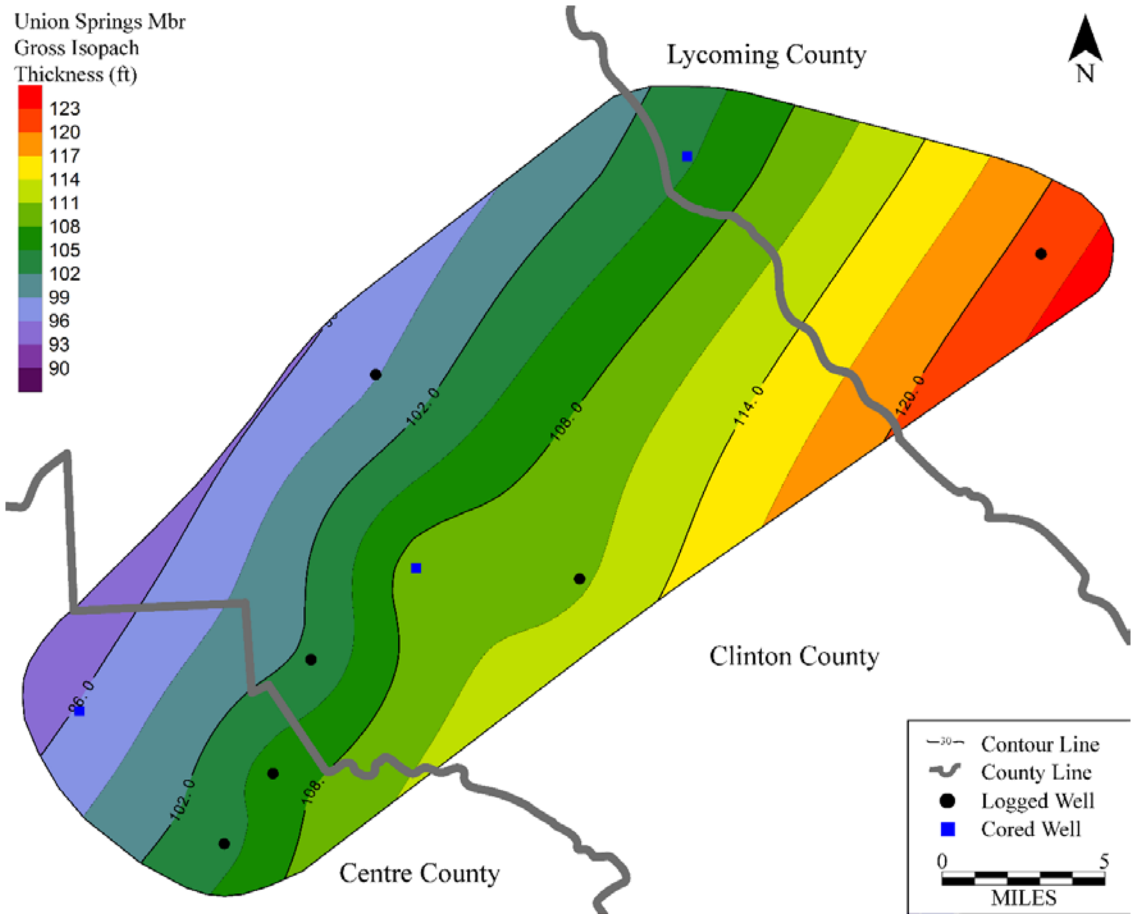


Figure F.4. Isopach map for the Union Springs Member of the Marcellus Formation. The Union Springs Member thickens towards the orogenic front to the east/southeast in a predictable manner. The overall thickness change across the mapped area is 26'.

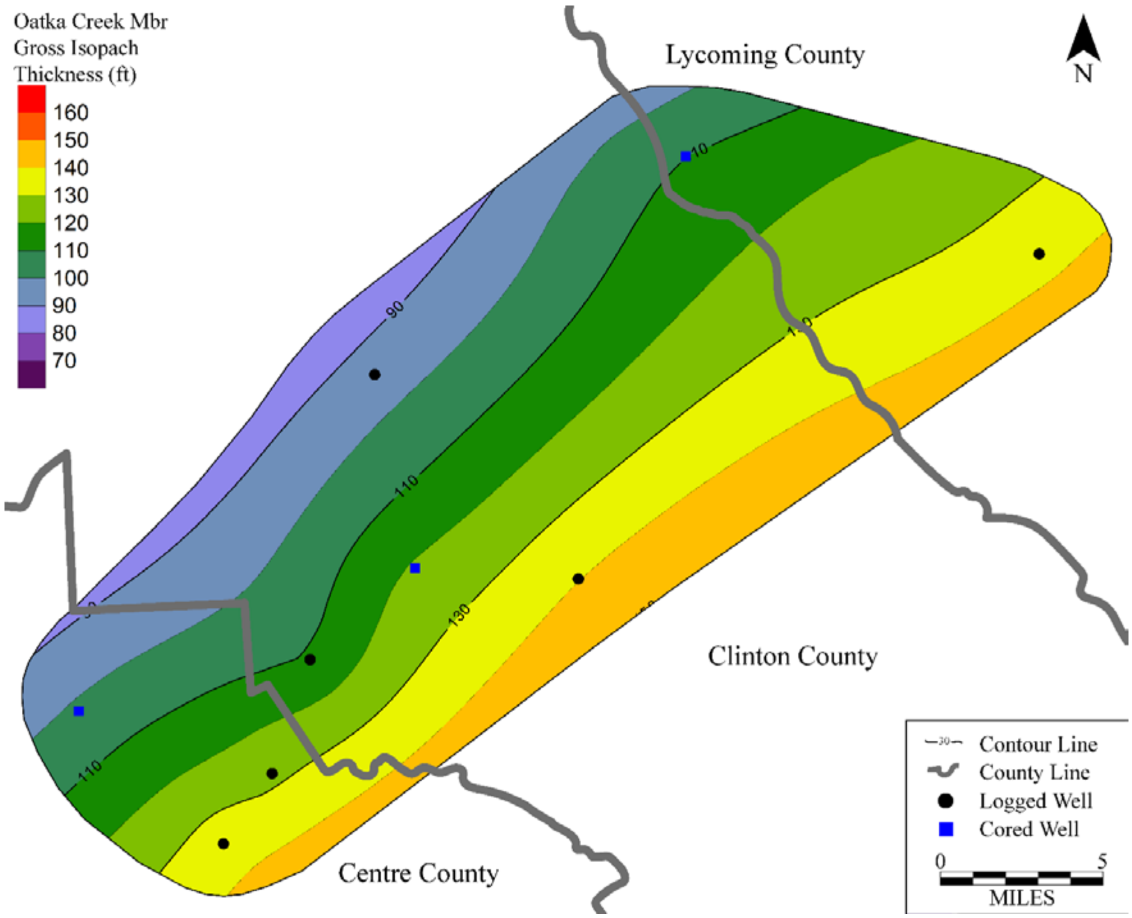


Figure F.5. Isopach map of the Oatka Creek Member of the Marcellus Formation. The Oatka Creek Member thins away from the orogenic front but in a more northwesterly direction than the Unions Springs Member (Fig. F.4). Just like the Union Springs Member, the thinning occurs at a nearly constant rate.

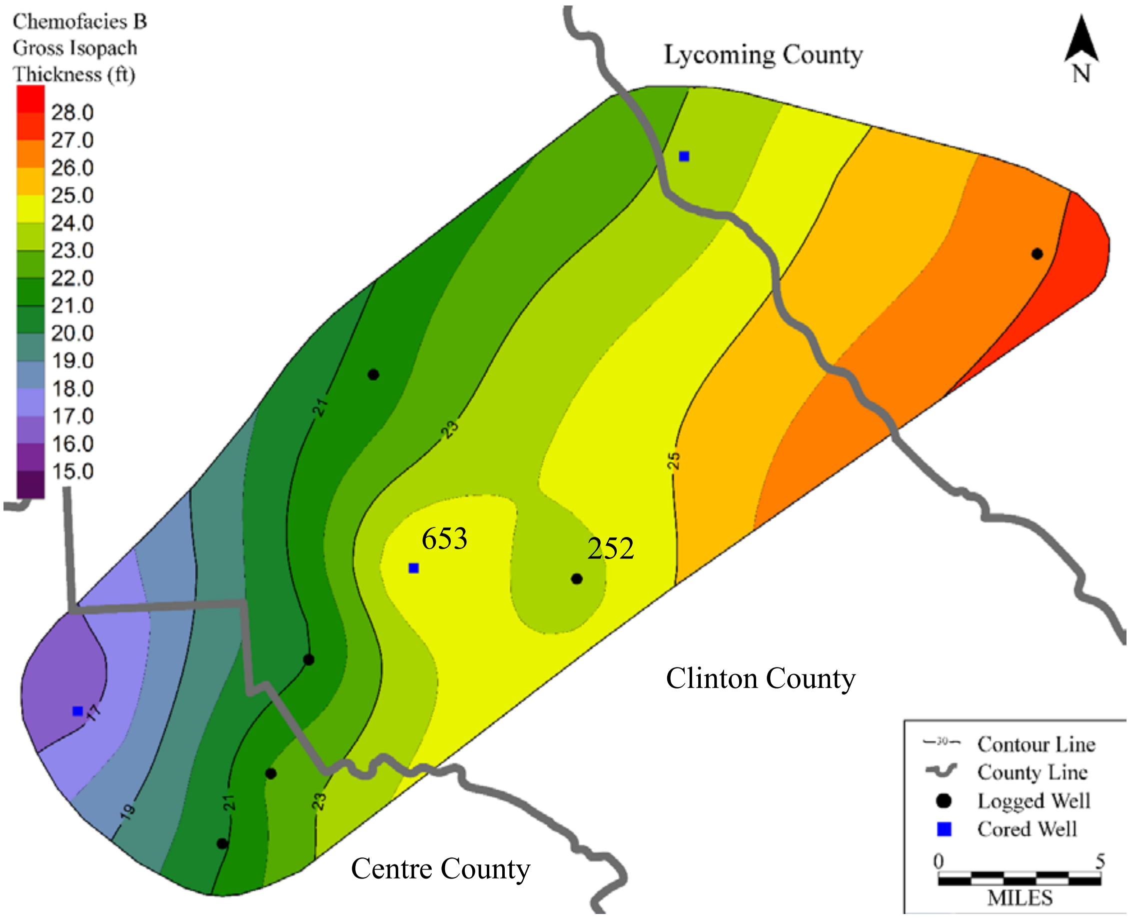


Figure F.6. Isopach map of Chemofacies B. CF-B thickens westward towards the orogenic front with an overall thickness change over the mapped area of 10'. Wells 653 and 252 are anomalies to the trend (indicated near center of map), however user error in picking the tops could account for the contour windup.

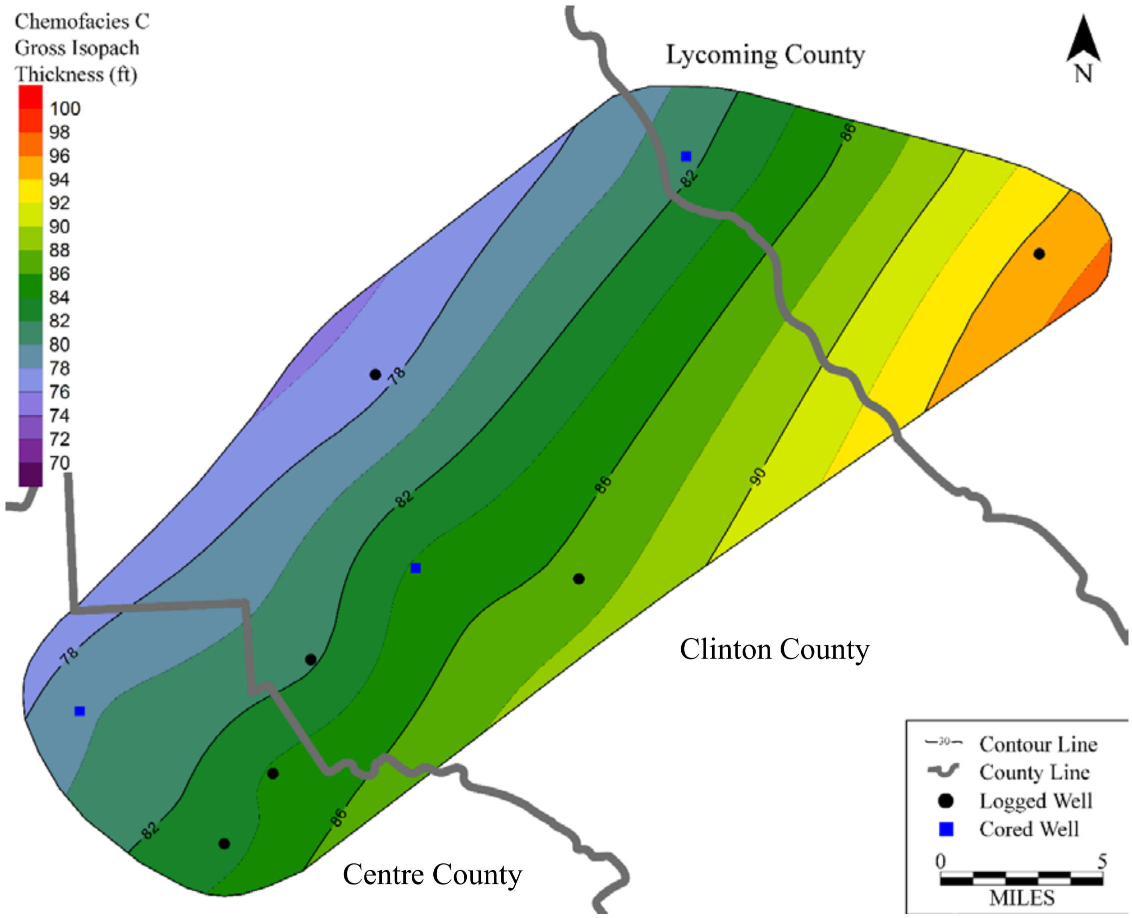


Figure F.7. Isopach map of CF-C. CF-C represents over half of the thickness of the Union Springs Member (Fig. F.4) and the trends in thinning/thickening are very similar.

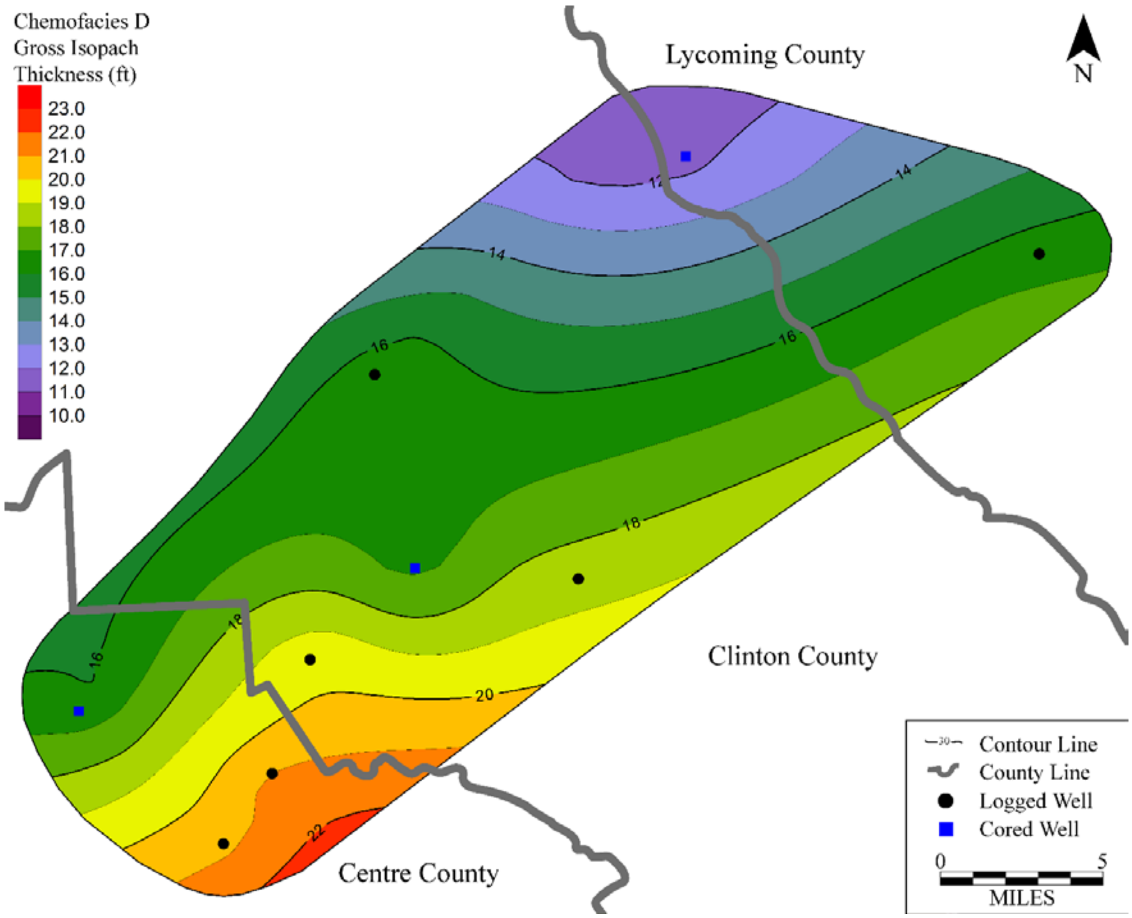


Figure F.8. Isopach map of CF-D. CF-D and the Cherry Valley Member are essentially the same units. These units increase in thickness to the south and decrease in thickness to the north. This unit is carbonate and fossil-rich and the map indicates a more compatible environment to the south.

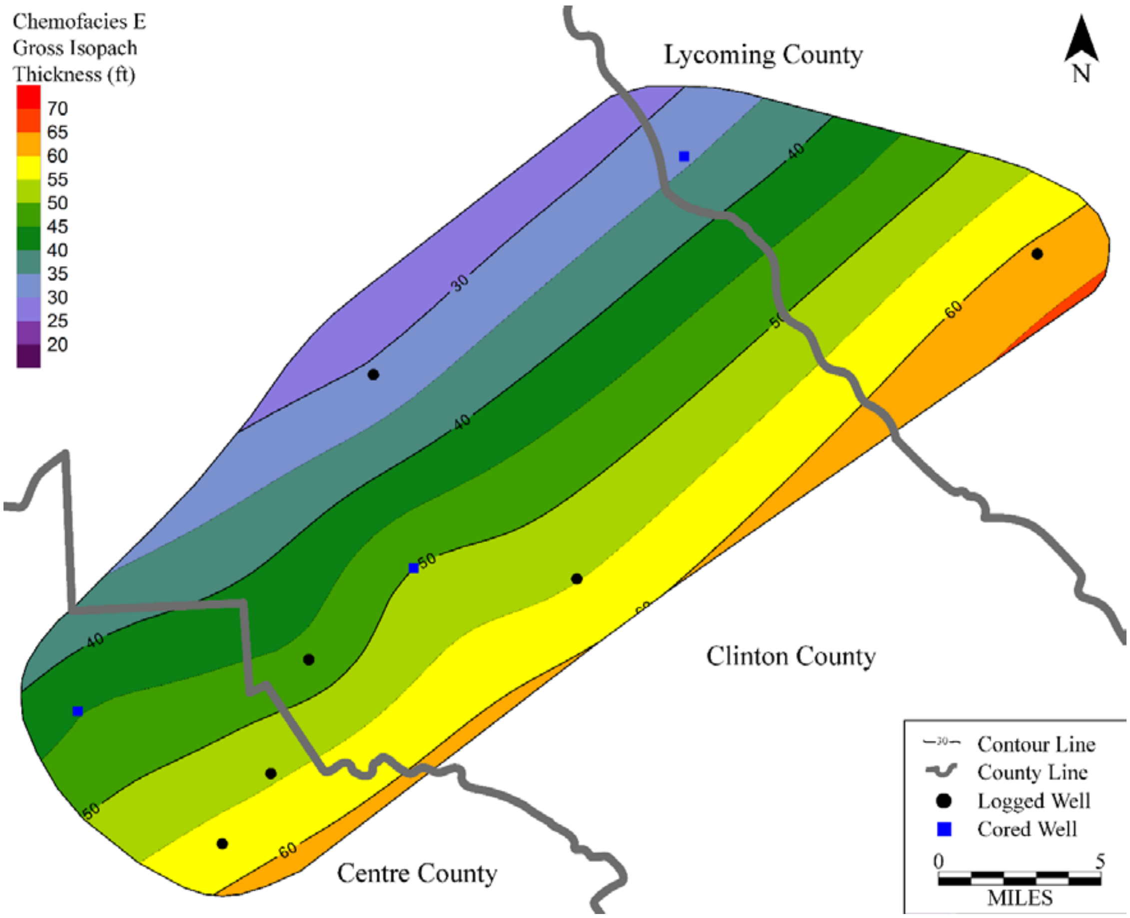


Figure F.9. Isopach map of CF-E. CF-E follows the same general trend of the Oatka Creek Member of which it is part. It increases in thickness to the southeast.

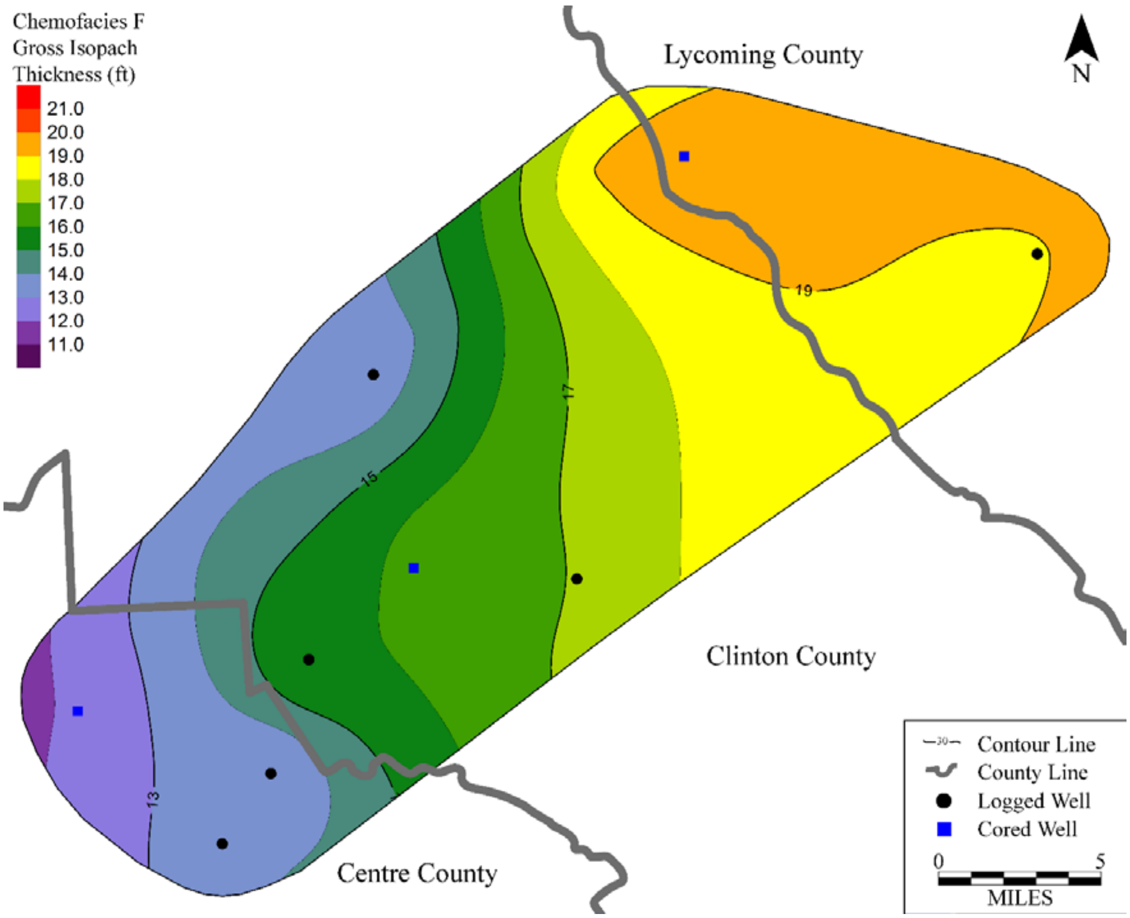


Figure F.10. Isopach map of CF-F. CF-F represents a relative increase in carbonate amount and fossil content. This indicates a relative increase in compatibility for such facies to the northeast.

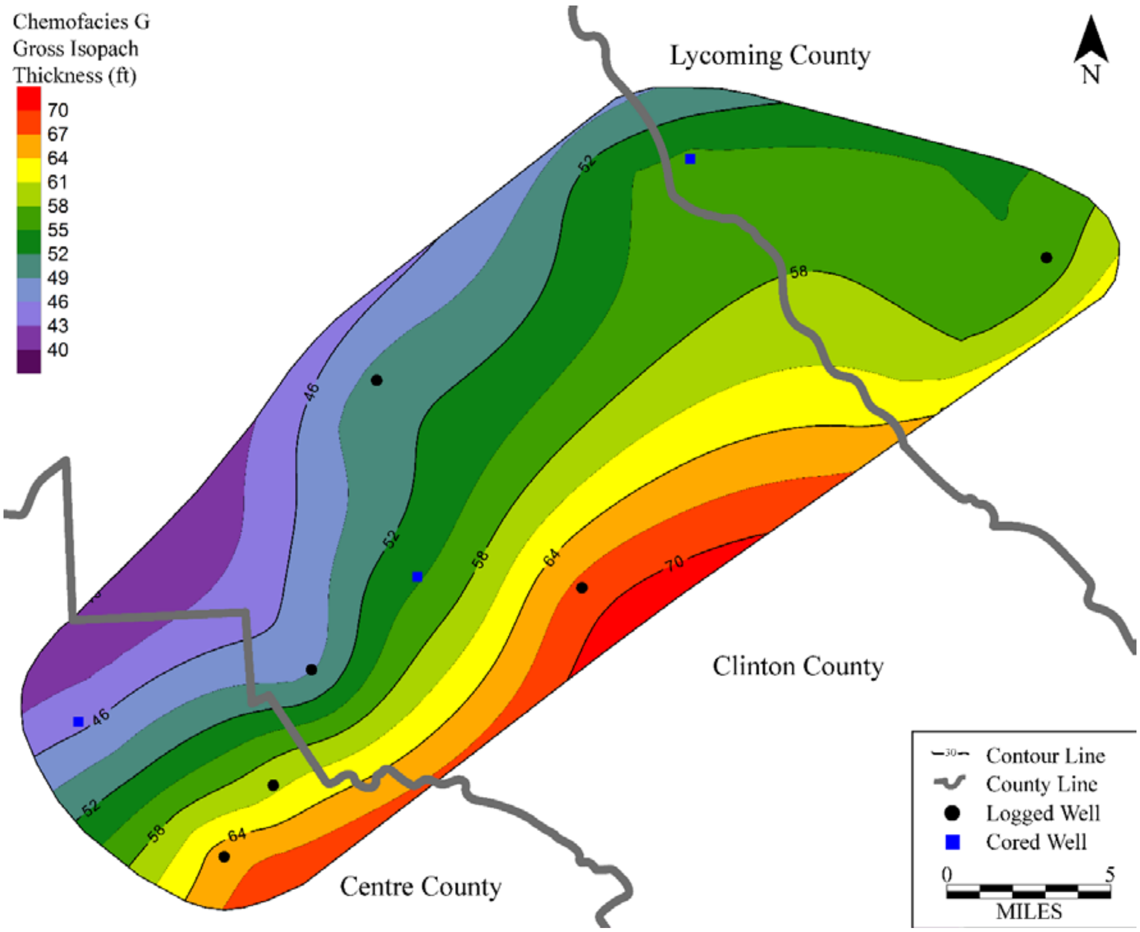


Figure F.11. Isopach map of CF-G. CF-G follows the same basic trend of the Oatka Creek Member of which it is part and increases in thickness to the southeast. However, the rate of thickness change isn't as uniform.

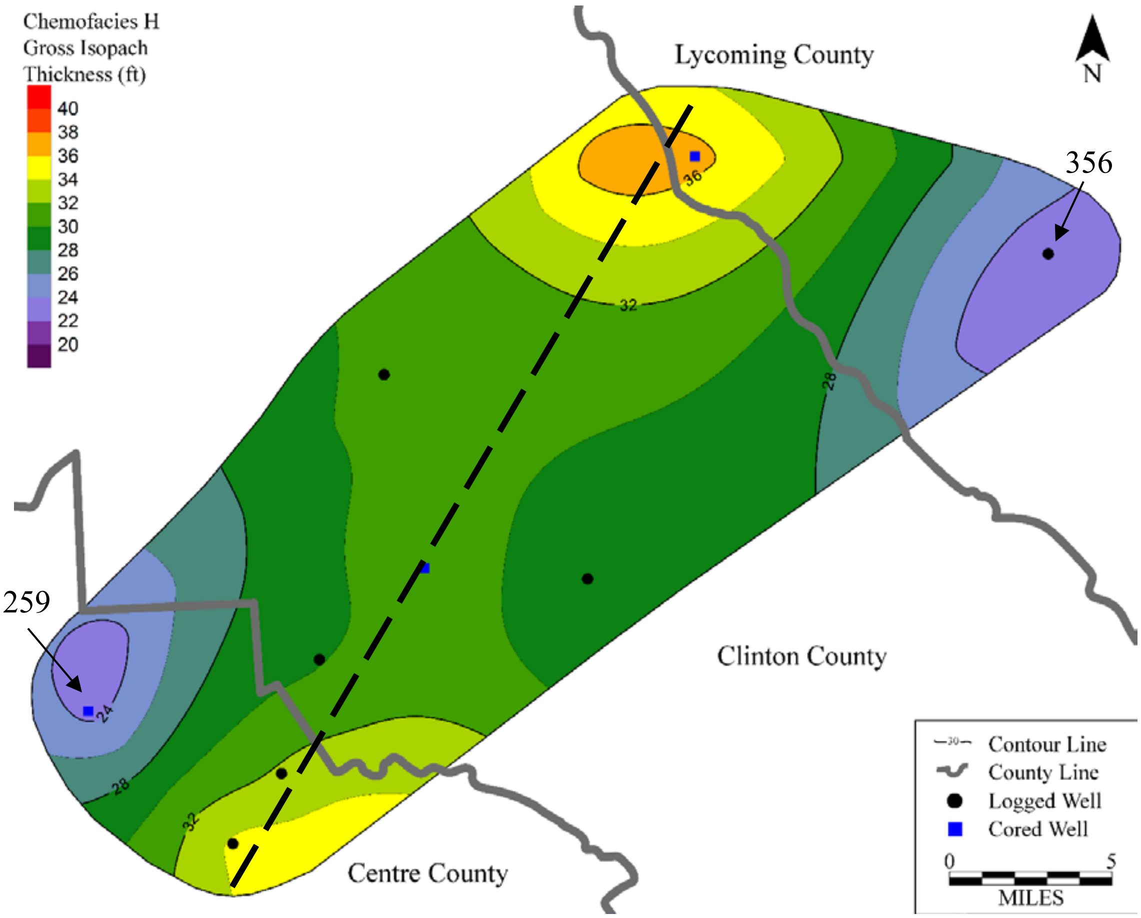


Figure F.12. Isopach map of CF-H. This map indicates a roughly southwest-northeast trend of thickening (indicated by dashed line) of CF-H, a unit that also corresponds to the lateral equivalent of the Stafford Limestone. Note also that wells COP 259 and COP 356 (labeled) have relatively thin intervals of CF-H.

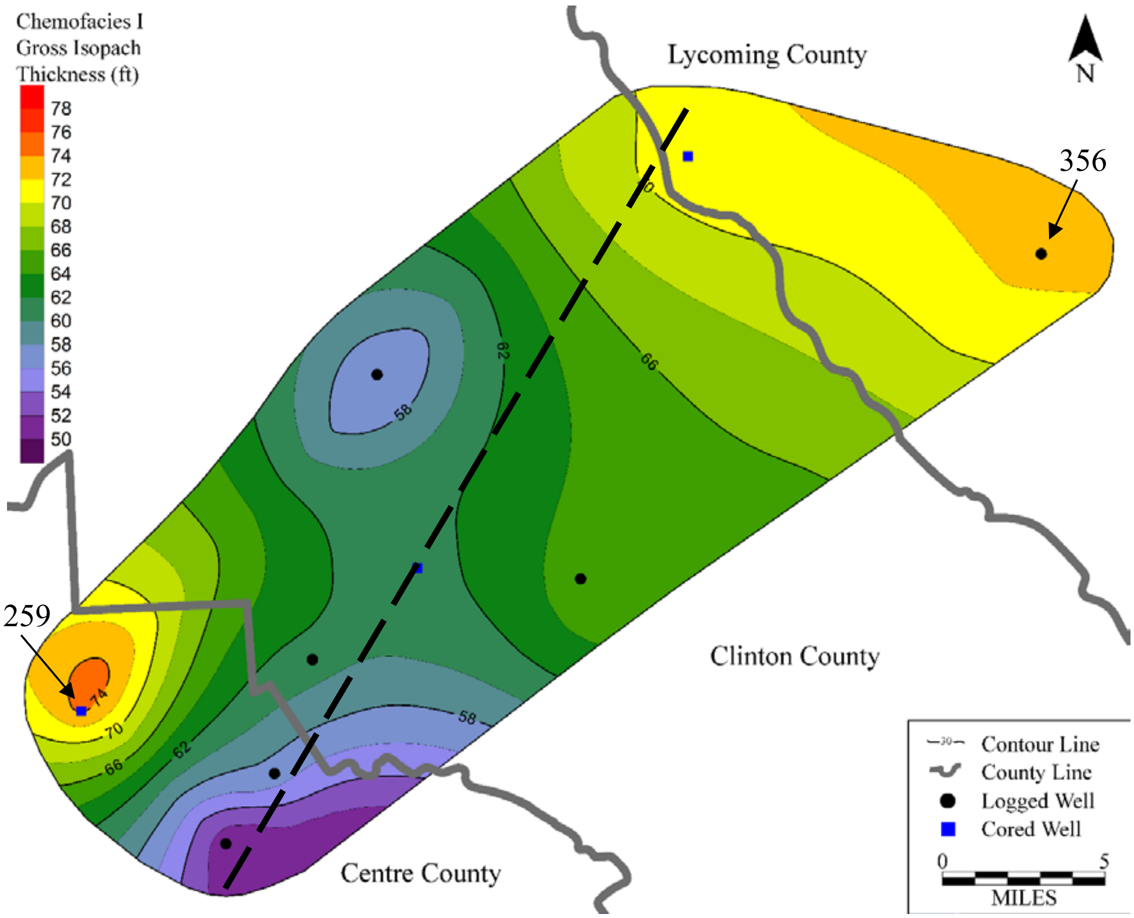


Figure F.13. Isopach map of CF-I. Dashed line from the CF-H isopach map included to show that the areas where CF-H was thick are areas of relative thinness in CF-I. This indicates that the trends in thickness for this unit could be attributed to structural variations during deposition. Wells 259 and 356 (labeled) had the thinnest CF-H intervals but they are now the location of the thickest CF-I intervals.

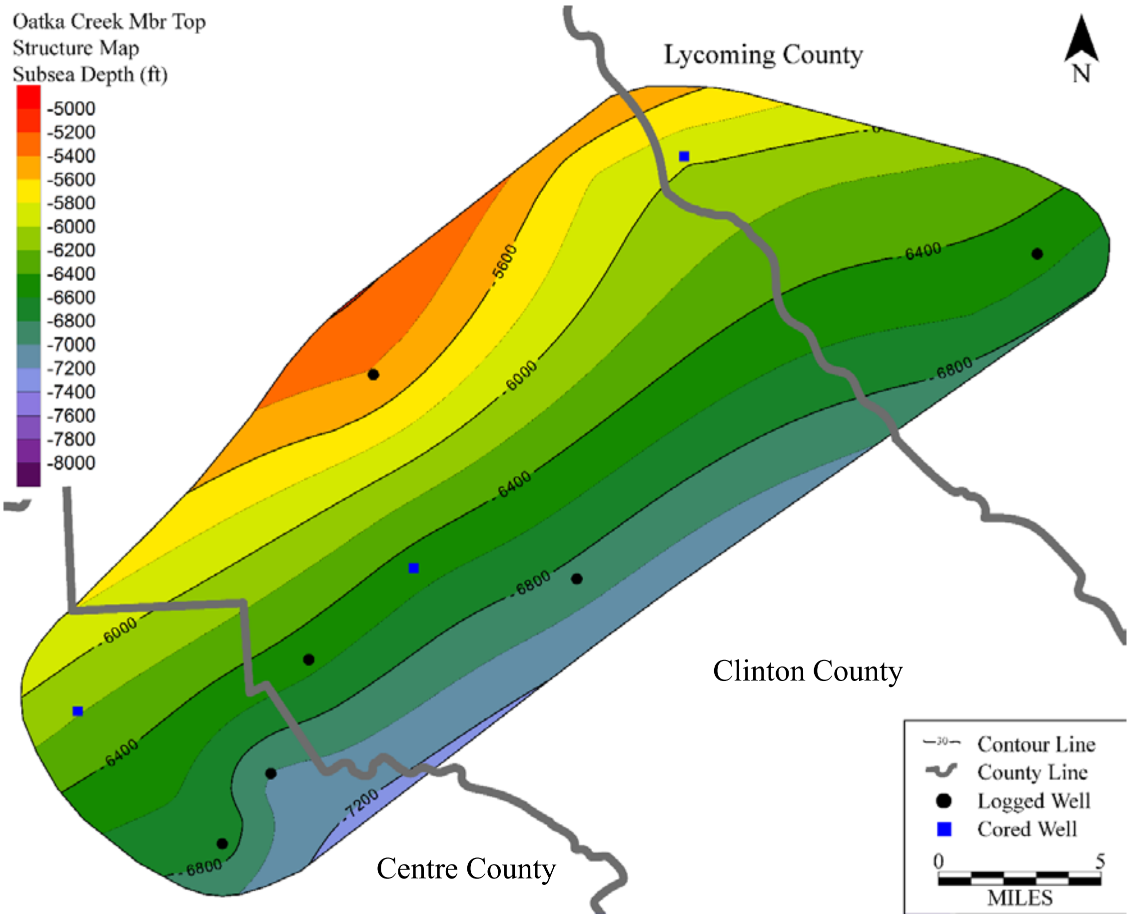


Figure F.14. Structure map of the subsea depth to the top of the Marcellus Formation. This area of the Appalachian Basin deepens to the southeast and shallows to the northwest.

APPENDIX G

TOC wt.% Net Thickness Maps

This appendix contains maps of TOC wt.% net thickness.

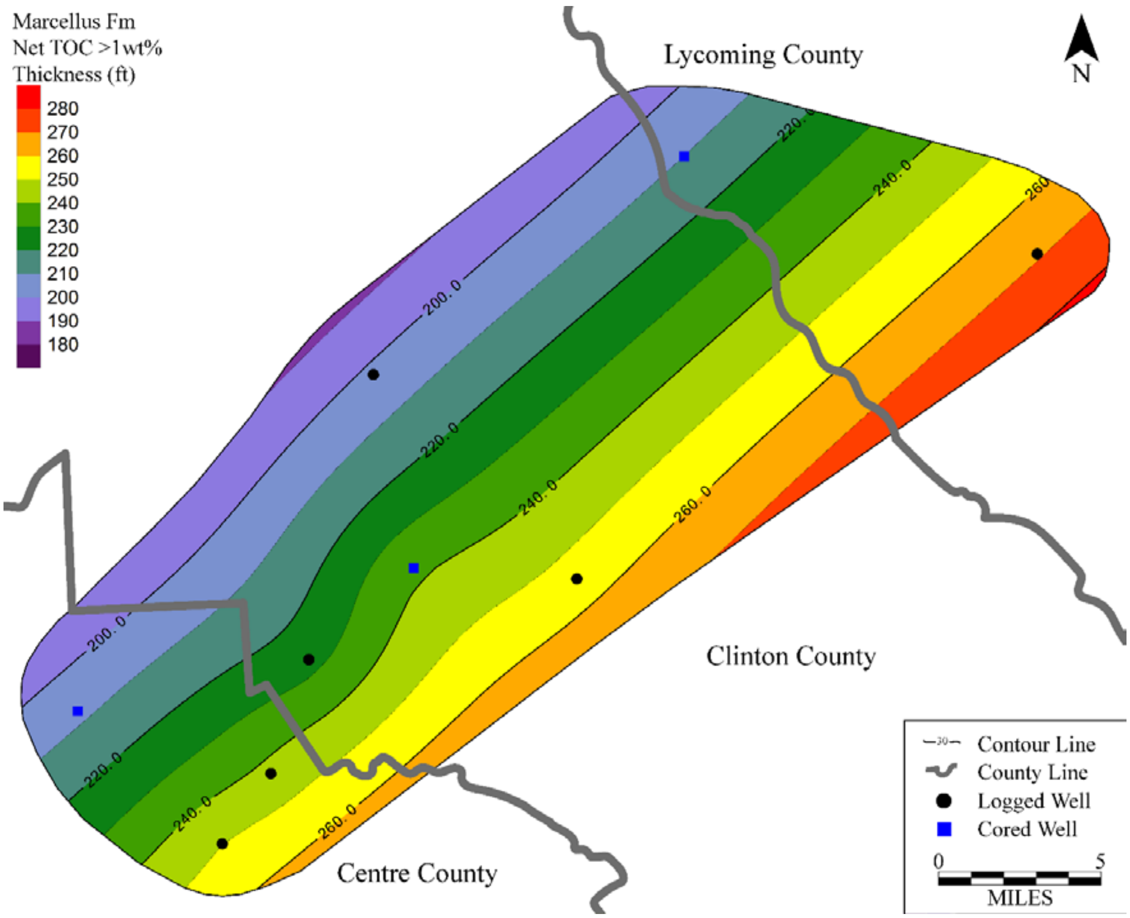


Figure G.1. Net TOC >1 wt.% thickness map for the Marcellus Formation. Essentially the entire Marcellus Formation is >1 wt.% TOC and this map is almost identical to the Marcellus Formation isopach map (Fig.F.2), showing a constant rate of thickening towards the orogenic front to the east/southeast.

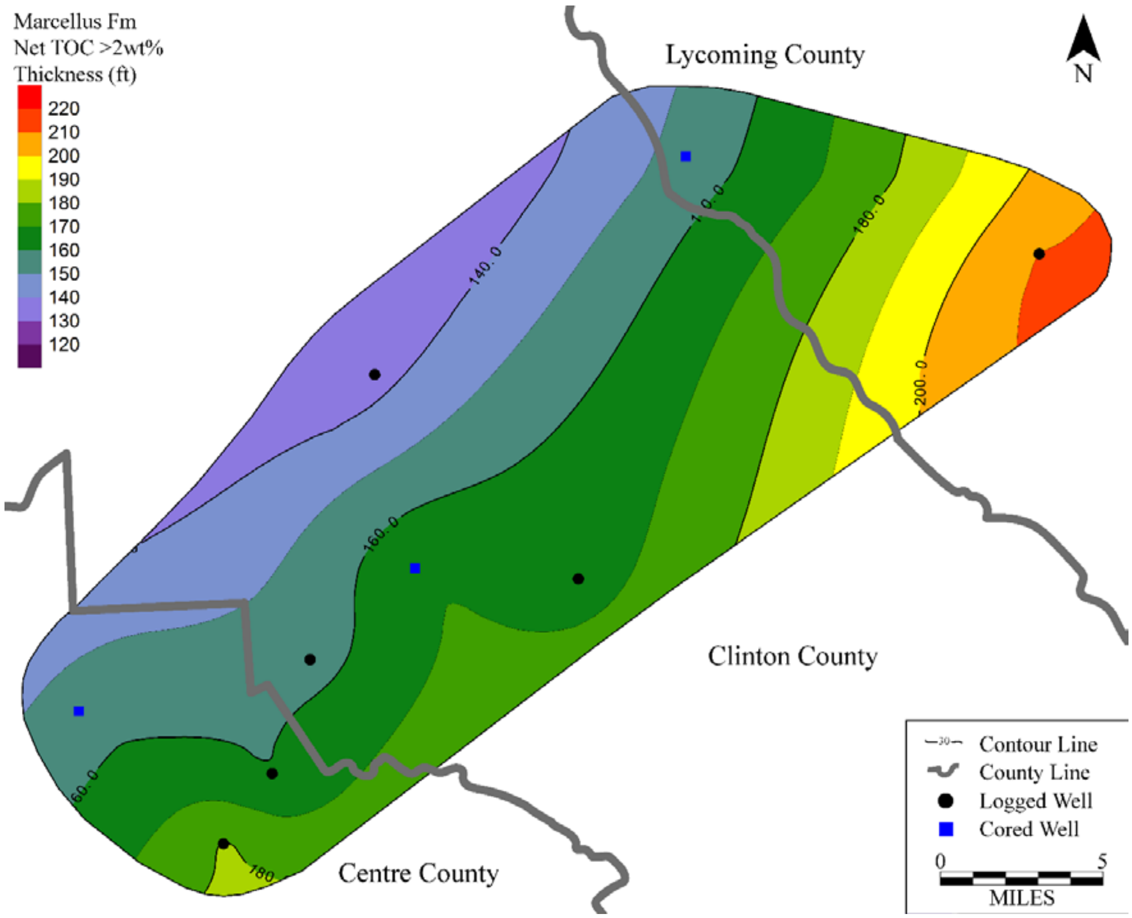


Figure G.2. Net TOC >2 wt.% thickness map for the Marcellus Formation. The contouring isn't as smooth as the >1 wt.% TOC map (Fig.G.1) but it still shows a general thickening towards the east/southeast.

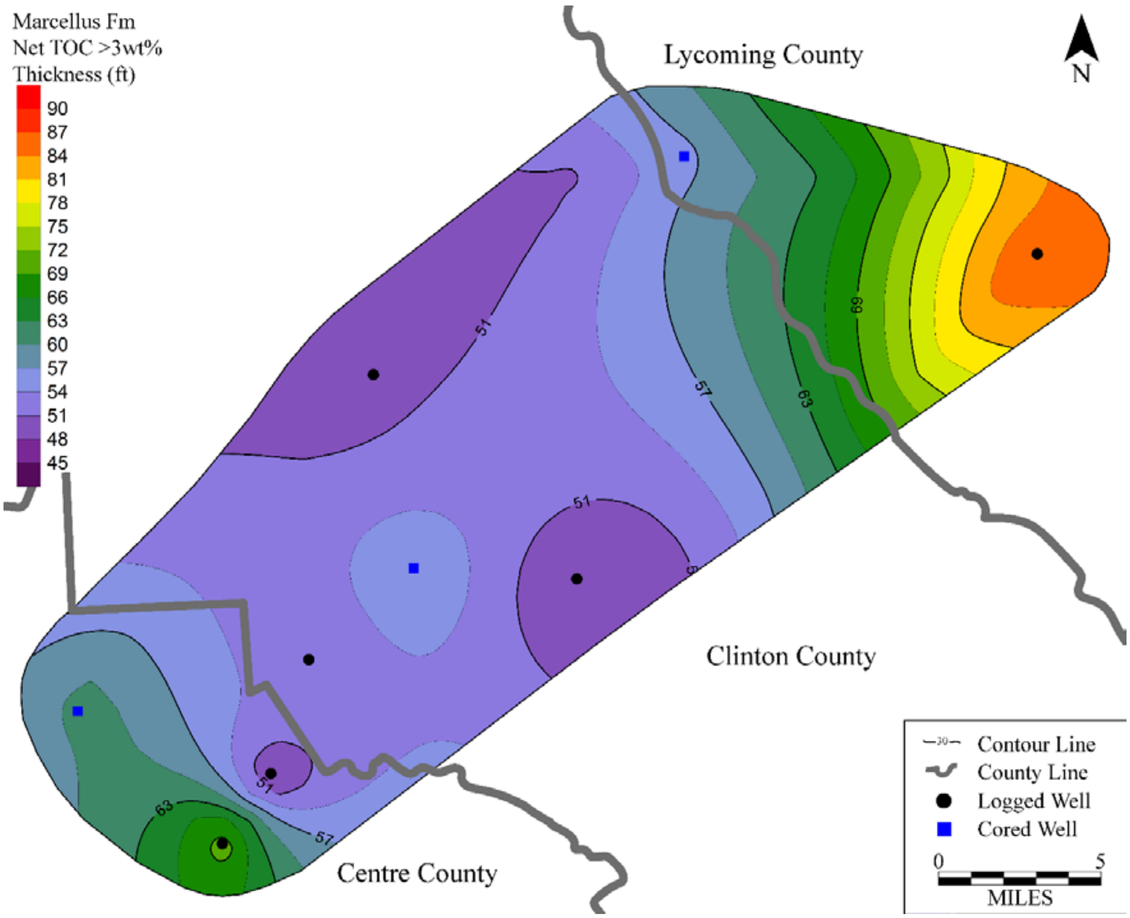


Figure G.3. Net TOC >3 wt.% thickness map for the Marcellus Formation. Some aspects of this map may be due to the uncertainty of the TOC prediction curve from GR. The TOC for most of the Marcellus formation averages ~3 wt.% so any error due to incorrect gamma ray log normalization can significantly change net TOC >3 wt.% thickness by decreasing or increasing it. That being said, this map indicates a general thickening to the east.

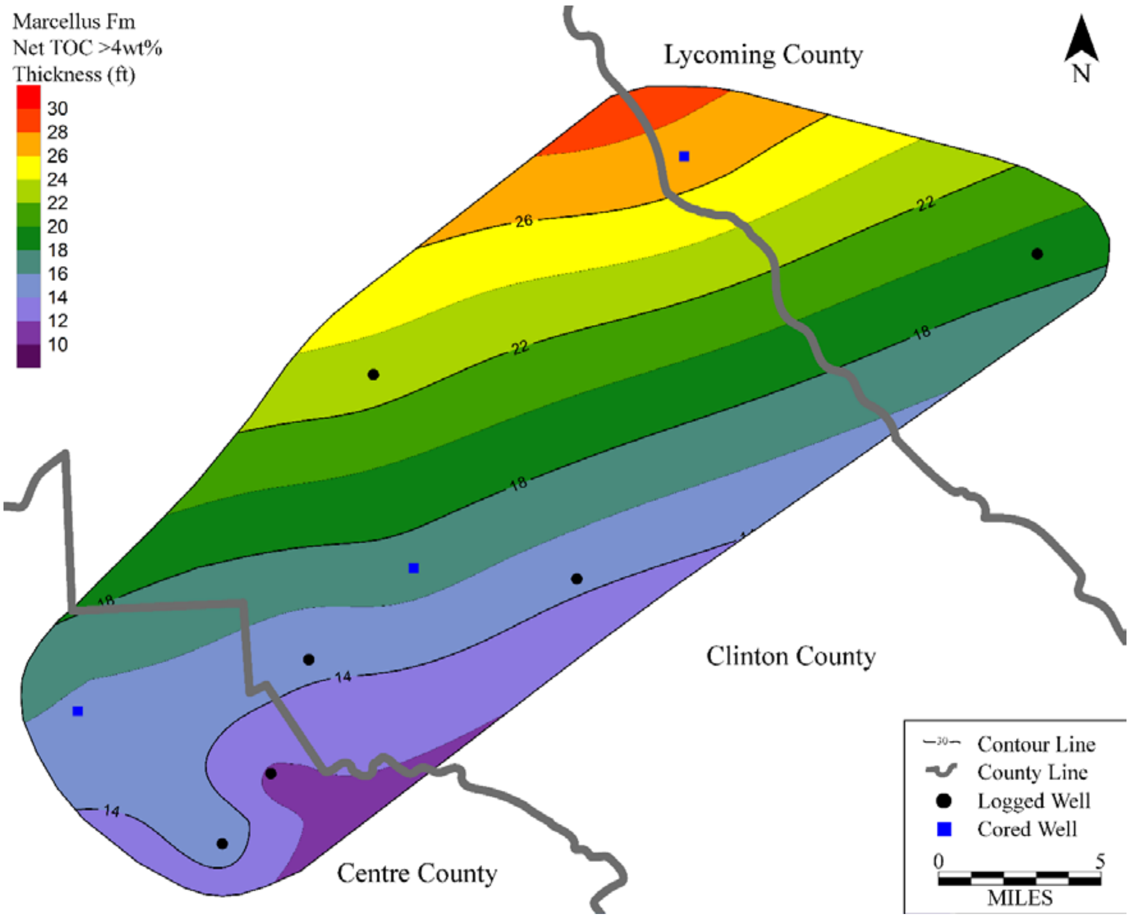


Figure G.4. Net TOC >4 wt.% thickness map for the Marcellus Formation. This map indicates a thickening of TOC >4 wt.% to the north which is the first real shift from the trend of thickening to the ~east.

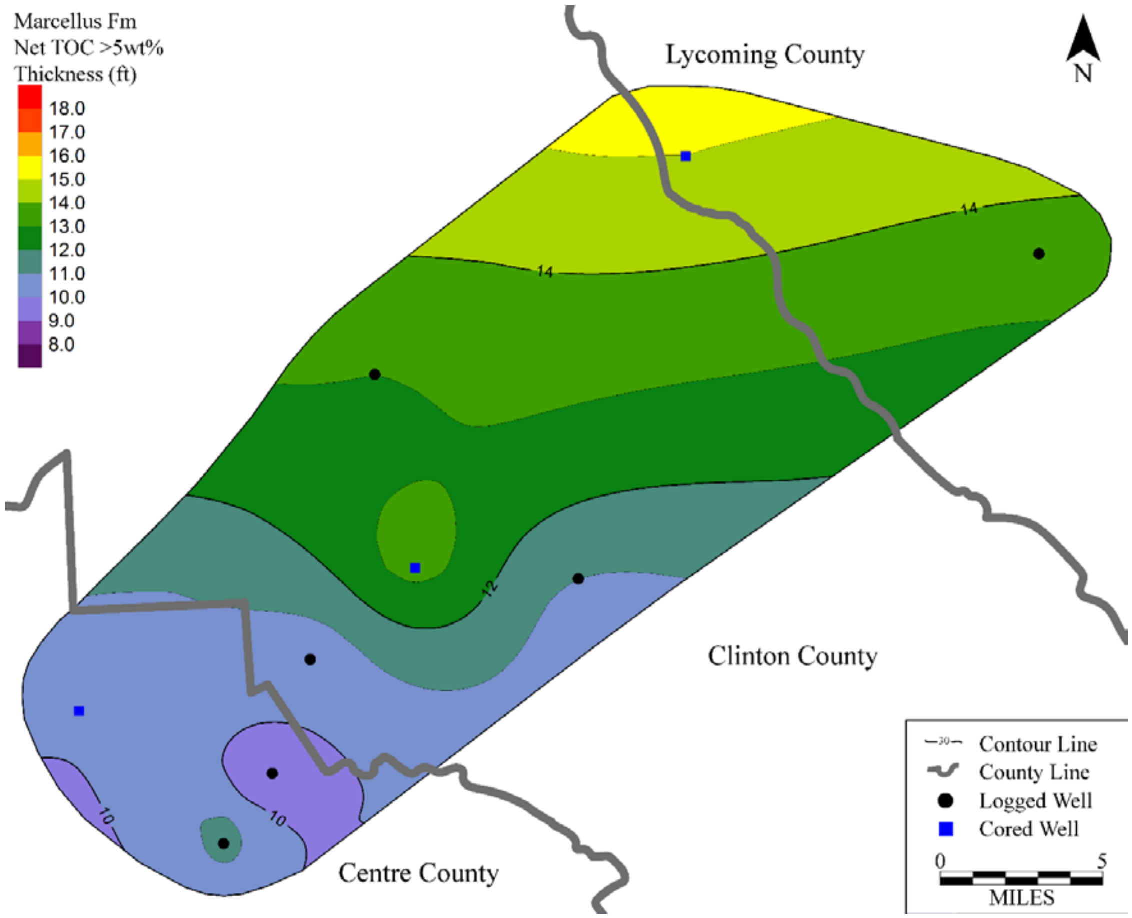


Figure G.5. Net TOC >5 wt.% thickness map for the Marcellus Formation. This is essentially for CF-B because only through this interval does the GR-to-TOC equation predict TOC ≥5 wt.%. This map indicates a thickening of TOC >5 wt.% to the north which follows the >4 wt.% map.

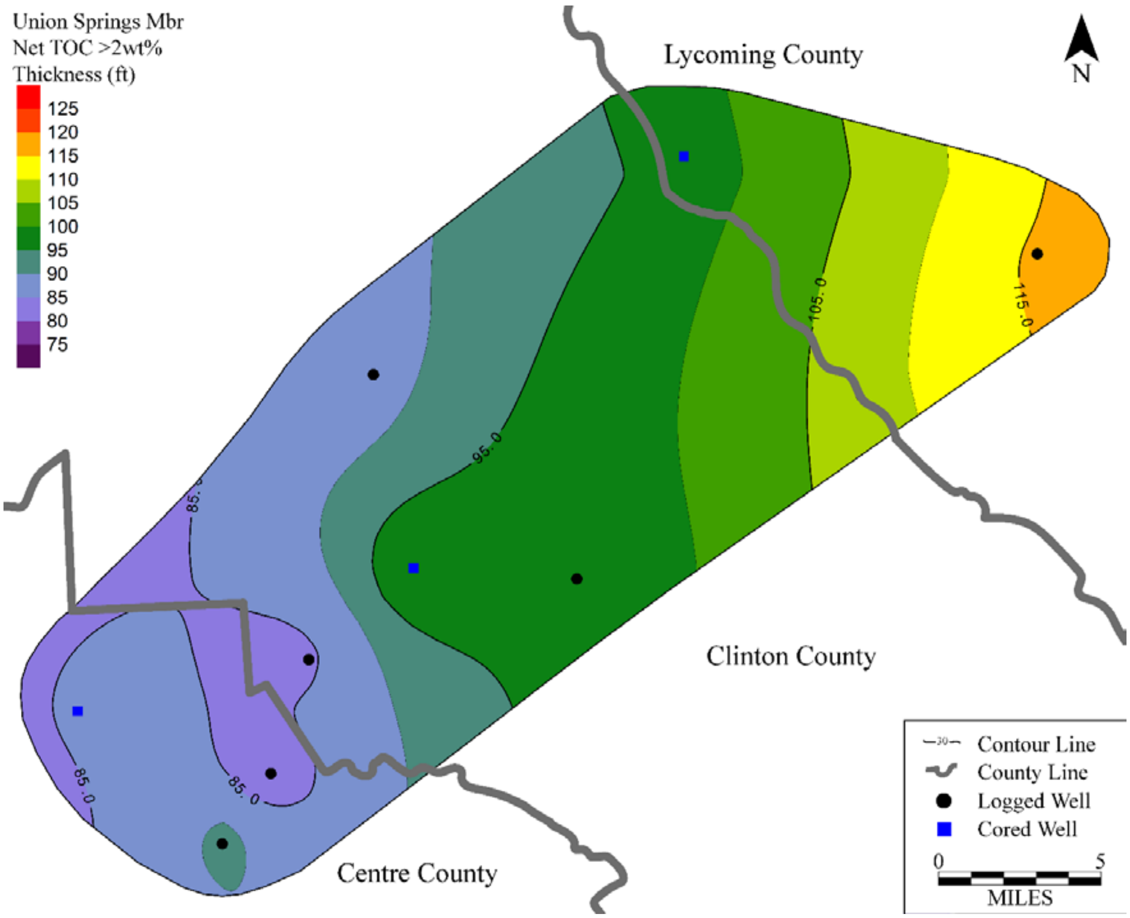


Figure G.6. Net TOC >2 wt.% thickness map for the Union Springs Member of the Marcellus Formation. This map shows a general thickening towards the orogenic front to the east.

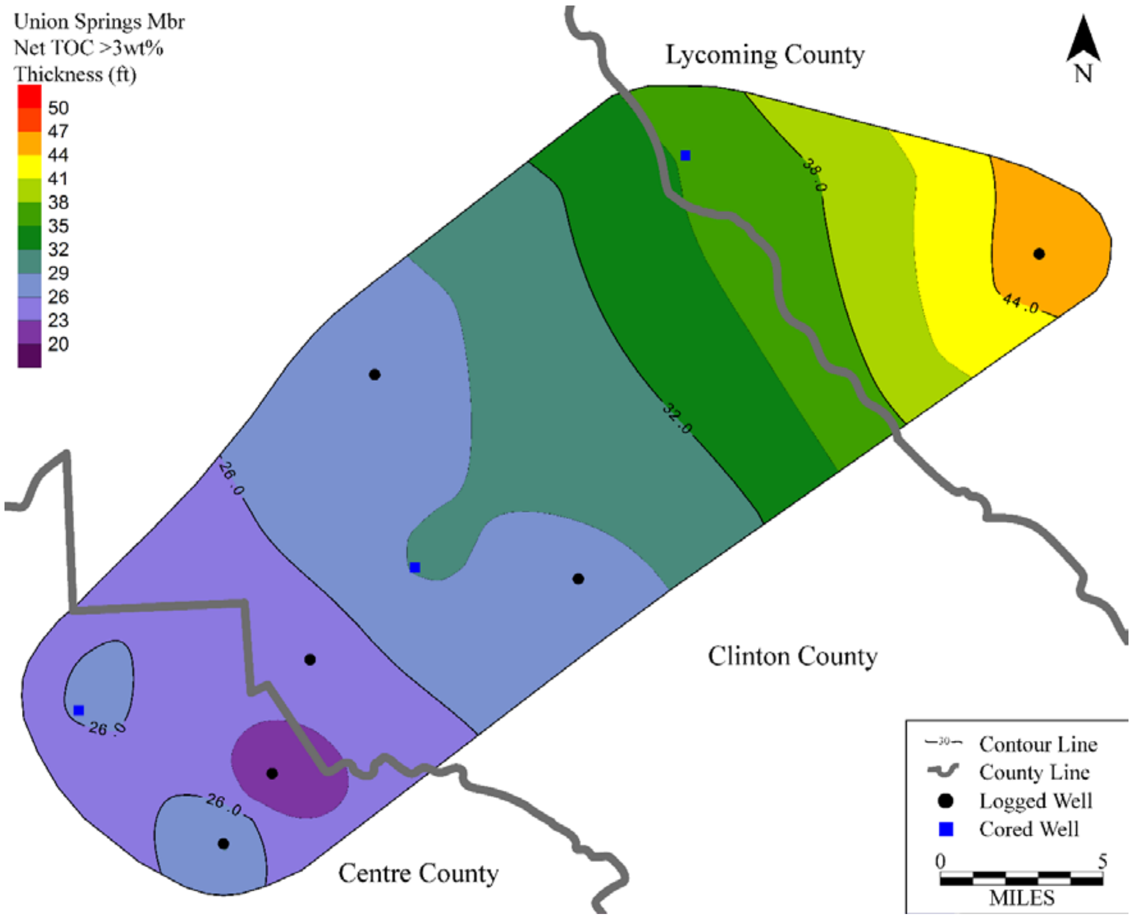


Figure G.7. Net TOC >3 wt.% thickness map for the Union Springs Member of the Marcellus Formation. Some aspects of this map may be due to the uncertainty of the TOC prediction curve from GR. The TOC for most of the Marcellus formation averages ~3 wt.% so any error due to incorrect gamma ray log normalization can significantly change net TOC >3 wt.% thickness by decreasing or increasing it. This map indicates a general thickening to the northeast.

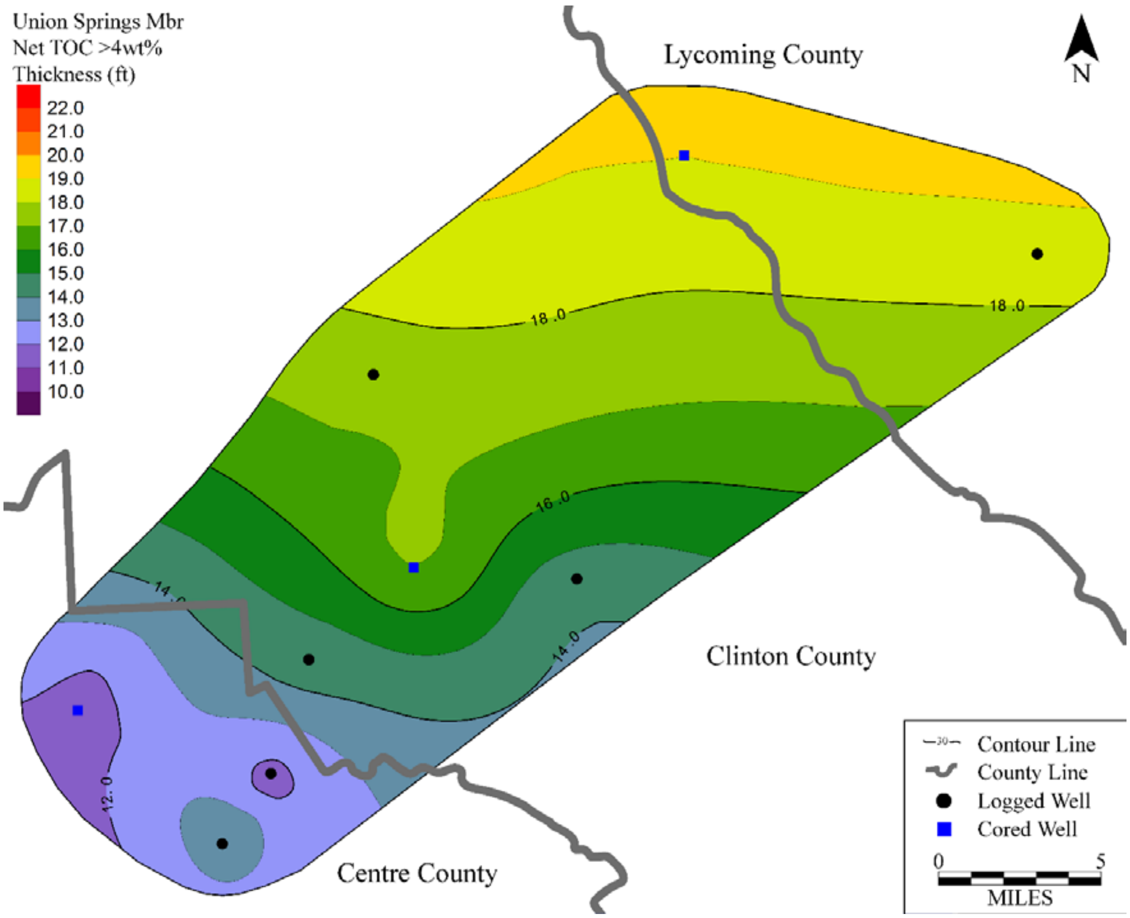


Figure G.8. Net TOC >4 wt.% thickness map for the Union Springs Member of the Marcellus Formation. As with the >4 wt.% thickness map for the Marcellus Formation, this map indicates a trend of thickening to the north and thinning to the south.

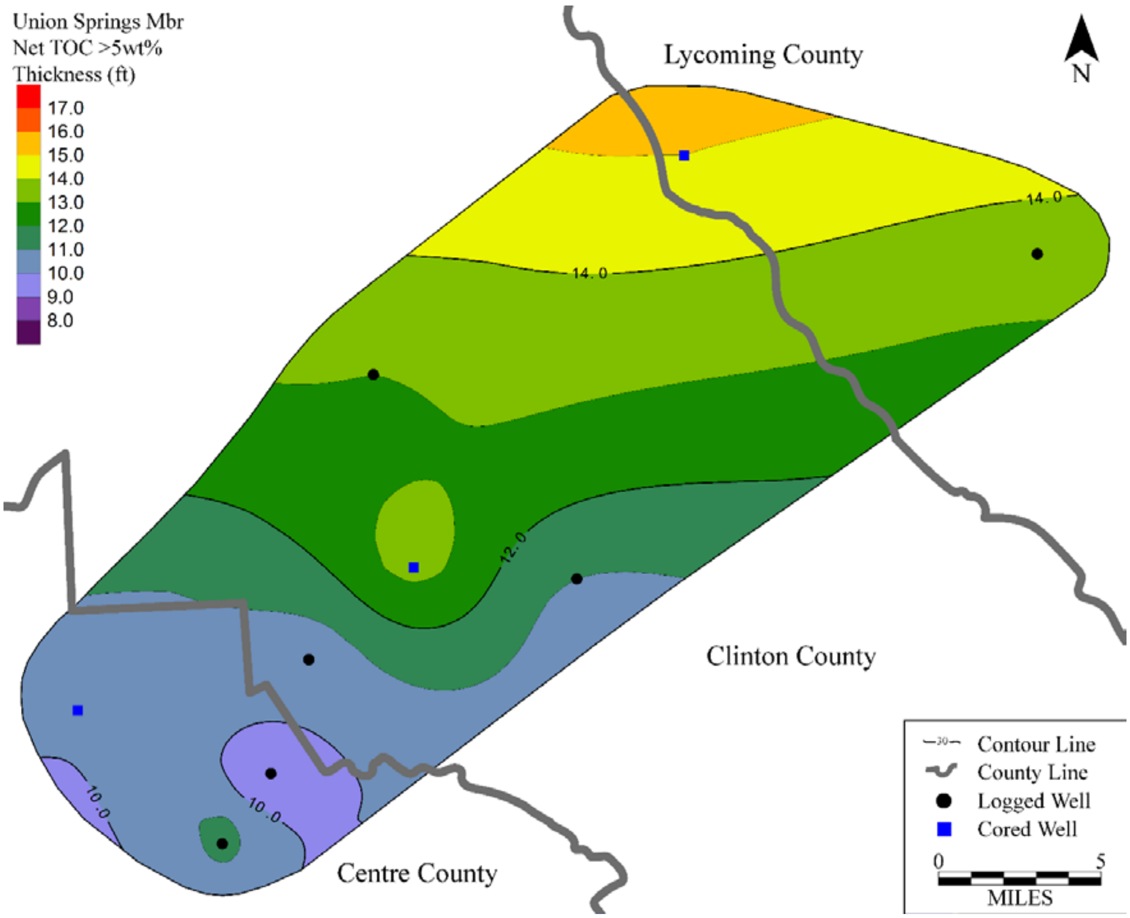


Figure G.9. Net TOC >5 wt.% thickness map for the Union Springs Member of the Marcellus Formation. This is essentially for CF-B because only through this interval does the GR-to-TOC equation predict TOC ≥5 wt.%. General trend of thickening to the north.

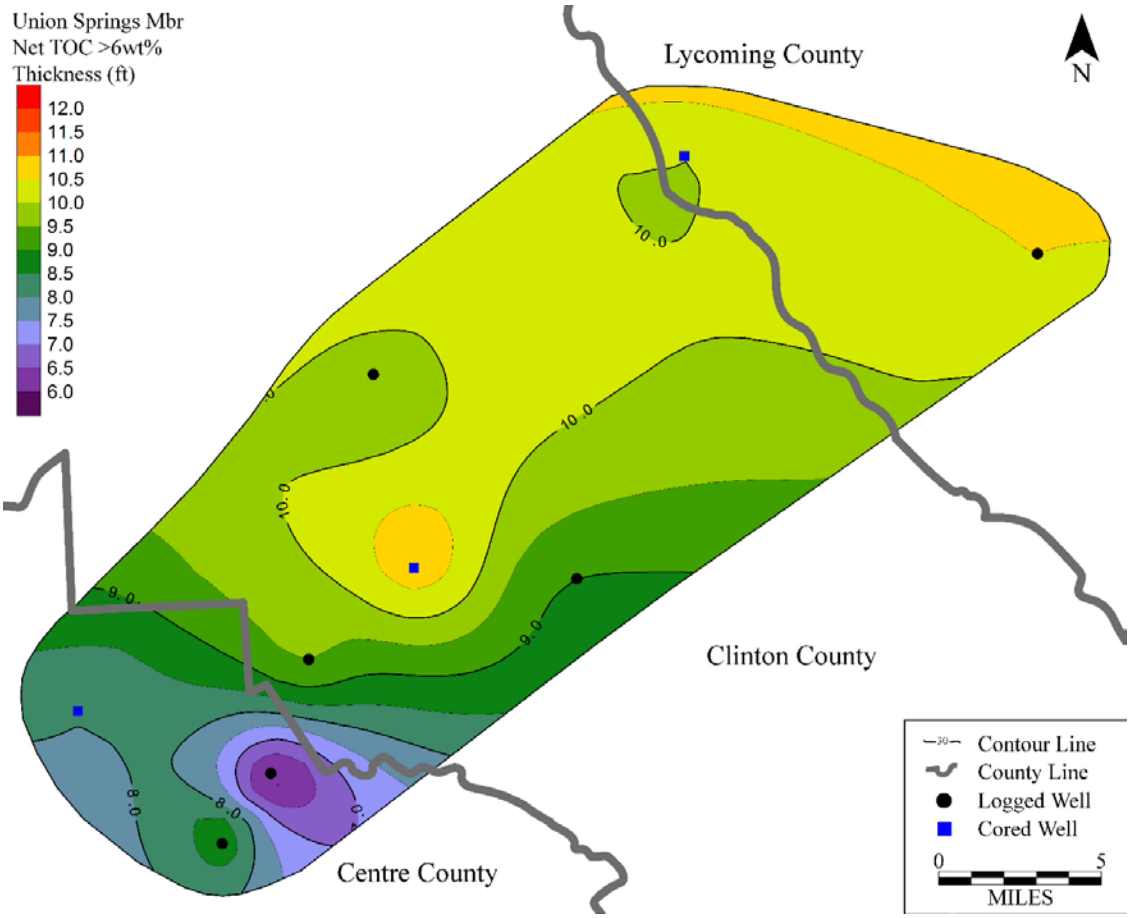


Figure G.10. Net TOC >6 wt.% thickness map for the Union Springs Member of the Marcellus Formation. This is essentially for CF-B because only through this interval does the GR-to-TOC equation predict TOC ≥5 wt.%. There are some anomalies in thickness (i.e. to the south) but the general trend indicates thickening to the northeast.

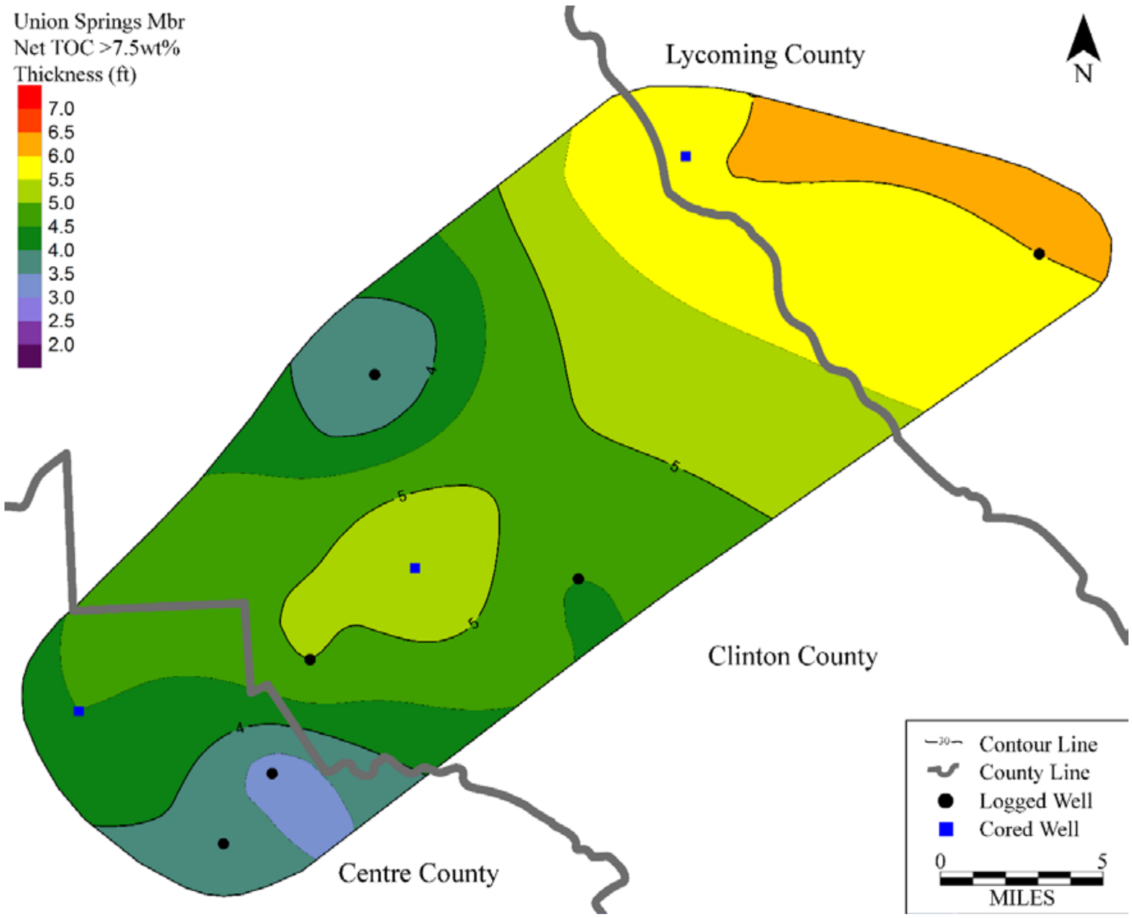


Figure G.11. Net TOC >7.5 wt.% thickness map for the Union Springs Member of the Marcellus Formation. This is essentially for CF-B because only through this interval does the GR-to-TOC equation predict TOC ≥5 wt.%. The general trend is thickening to the east/northeast.

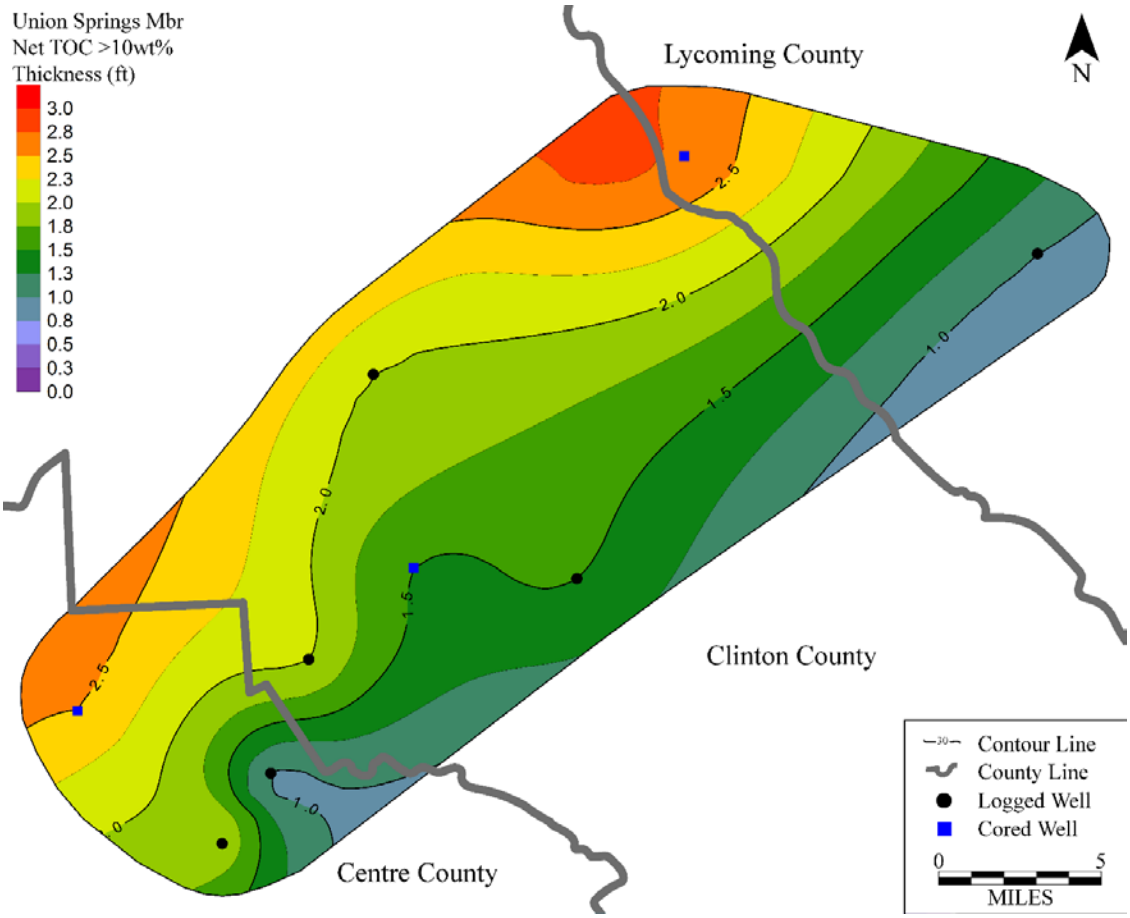


Figure G.12. Net TOC >10 wt.% thickness map for the Union Springs Member of the Marcellus Formation. This is essentially for CF-B because only through this interval does the GR-to-TOC equation predict TOC ≥5 wt.%. The general trend is thickening to the northwest. Notice that the net thickness only ranges from 1-3 feet and therefore the GR-TOC function highly affects it.

APPENDIX H

Box Plots of Chemofacies, Lithofacies, and Geochemical Signatures

This appendix contains box plots comparing specific geochemical signatures to lithofacies to determine any relationships.

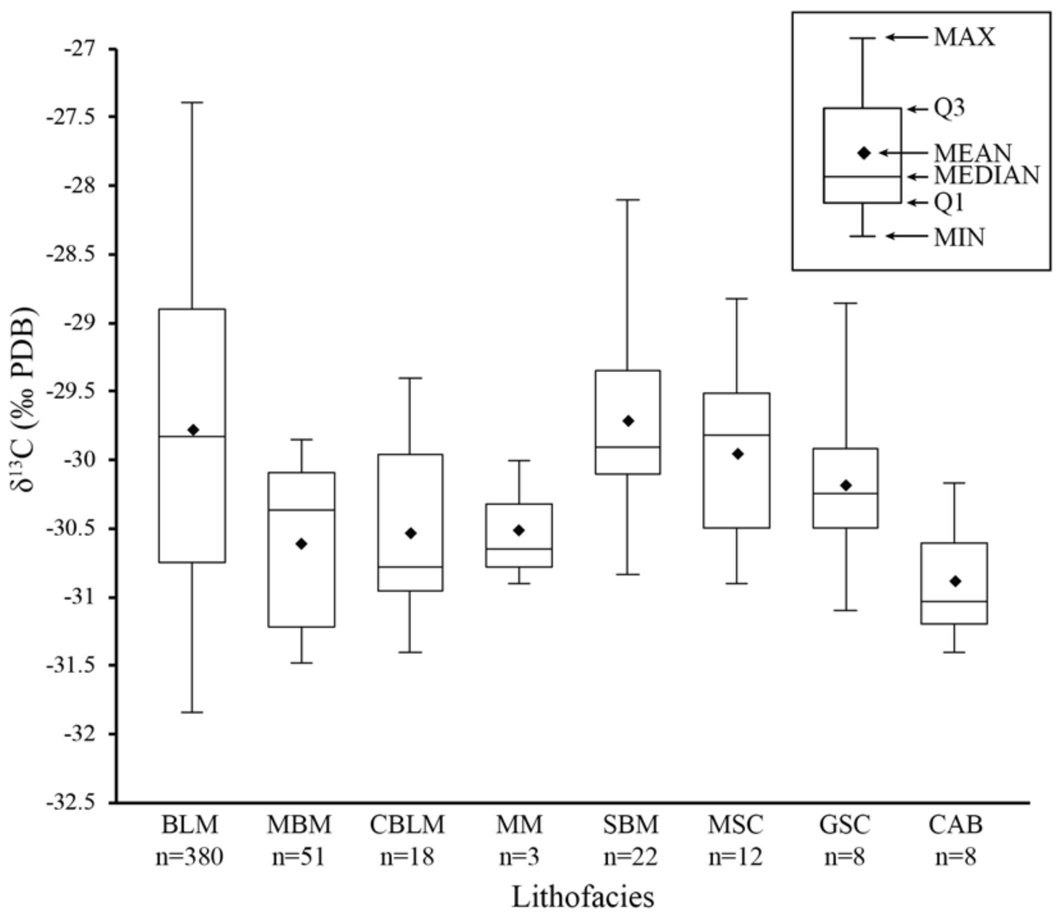


Figure H.1. Box plot comparison of lithofacies and $\delta^{13}C$ values. Lithofacies are designated in abbreviated form. There are no clear correlations between lithofacies and C isotope values except for CAB, which coincides with more negative values of $\delta^{13}C$.

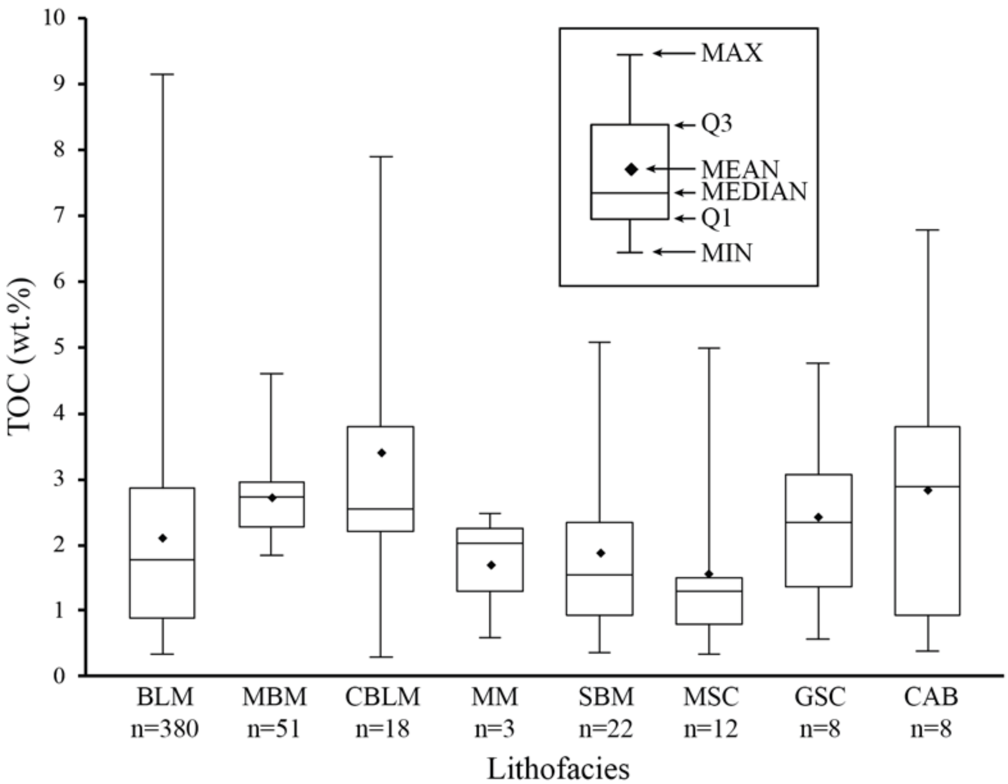


Figure H.2. Box plots of lithofacies vs. TOC. There are no apparent correlations except that MBM lithofacies correlates with higher TOC values (2-5 wt.%).

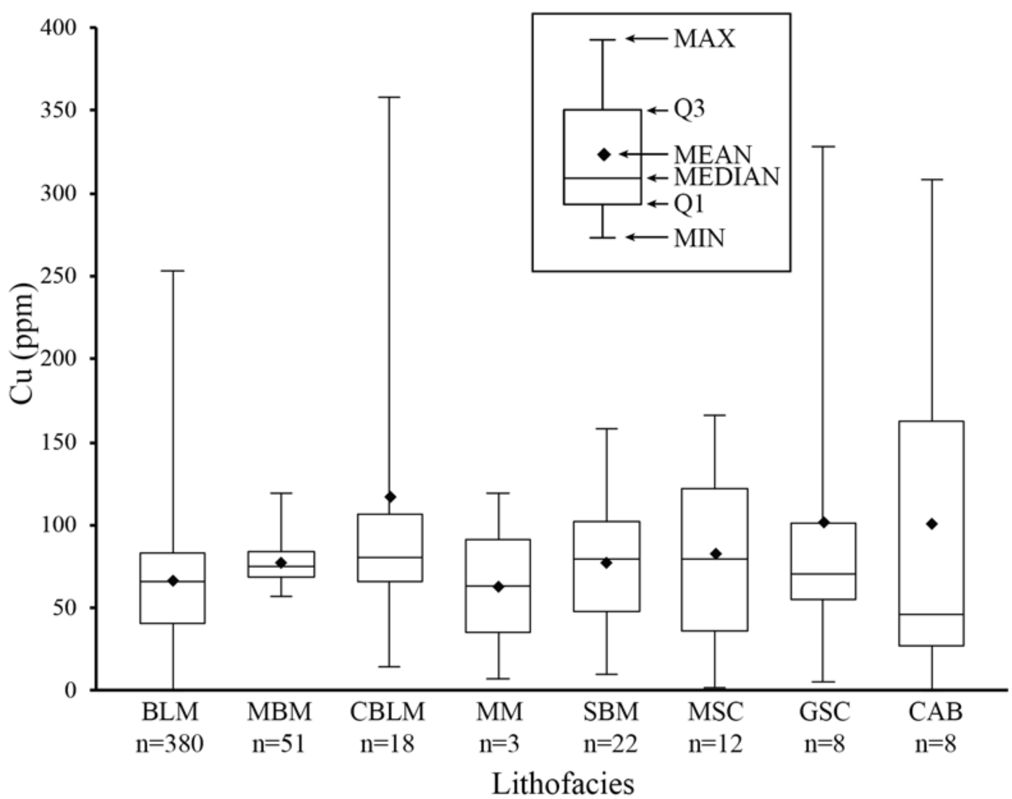


Figure H.3. Box plot of lithofacies vs Cu concentration showing minimal correlation. The MBM facies does have a well-constrained range of Cu concentration.

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