Geochemistry and depositional history of the Union Springs Member, Marcellus Formation in central Pennsylvania

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Abstract

1 Debate continues over paleoenvironmental conditions that prevail during deposition of organic-carbon (C)-rich marine source rocks in foreland basins and epicontinental seas. The focus of disagreement centers largely on paleowater depth and the prevalence of anoxia/euxinia. The issues of paleodepth and water column conditions are important for prediction of lateral variations in source quality within a basin because the viability of a hydrocarbon play depends on a thorough understanding of the distribution of source rock quality and depositional environments. We used inorganic geochemical data from the Middle Devonian Marcellus Shale in the Appalachian Basin to illustrate interpretive strategies that provided constraints on conditions during deposition. Source evaluation typically relies on the analysis and interpretation of organic geochemical indicators, potentially also providing evidence of the degree of thermal maturity and conditions of the preservation of the organic matter. The Marcellus Formation is thermally mature, making the evaluation of the organic-carbon fraction for geologic interpretation inadequate. Because most labile organic matter has largely been destroyed in the Marcellus Formation, analysis of inorganic elements may be used as an alternative interpretative technique. Several inorganic elements have been correlated to varying depositional settings, allowing for their use as proxies for understanding the paleodepositional environments of formations. A high-resolution geochemical data set has been constructed for the Union Springs Member along a transect of cores from proximal to distal in the Appalachian Basin in central Pennsylvania using major, minor, and trace elemental data. Our results suggested that during deposition, the sediment-water interface, and a portion of the water column, was anoxic to euxinic. As deposition continued, euxinia was periodically interrupted by dysoxia and even oxic conditions, and a greater influx of clastic material occurred. Such variations were likely related to fluctuations in water depth and progradation of deltaic complexes from the eastern margin of the Appalachian Basin.

Introduction

The black shales of the Appalachian Basin have gained renewed and widespread attention over the past decade. Even though gas has been produced from the Appalachian Basin for more than 150 years (Van Tyne, 1983), the low recovery had made these Marcellus source rocks uneconomical to companies in the past (Curtis, 2002). However, over the past several decades, technological advances in horizontal drilling and hydraulic fracturing, as well as an increase in global demand, coupled with an inevitable decline in conventional oil and gas sources, have made extraction from nonconventional plays attractive (Bentley, 2002; Sorrell et al., 2010). Recent interest has been directed at the Middle Devonian Marcellus Formation, which extends throughout much of the Appalachian Basin, and it has been estimated to contain up to 500 trillion cubic feet of gas (Engelder and Lash, 2008) and approximately 84 trillion cubic feet of undiscovered natural gas resources (Coleman et al., 2011).

In this paper, we use a high-resolution geochemical data from a transect of cores to argue that the Marcellus Formation was deposited under intermittent bottom-water conditions that were anoxic or euxinic, and that changing sea level, as well as productivity were major factors in the amount and quality of organic matter (Sageman et al., 2003; Arthur and Sageman, 2005). Currently, no publicly available geochemical data set exists for the Union Springs Member (Mbr.) in Central Pennsylvania. A high-resolution geochemical data set has been constructed of the Union Springs Mbr. along a transect from more proximal to more distal in the basin from drill cores. Some trace metals that have multiple valence states may be enriched in the authigenic frac-

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tion of the sediment due to differences in solubilities related to changing redox conditions of the bottom water and sediment, flux of the organic matter, and the sedimentation rate (Calvert and Pedersen, 2007). Here, we use the Union Springs Mbr. as an example for interpreting such data to determine the environment during initial depositional of black shales in the Middle Devonian and specifically to discuss the paleoenvironmental conditions that prevailed during deposition of the Union Springs Mbr. (Shamokin Mbr. of Kohl et al. [2014]) of the Middle Devonian Marcellus Shale.

The viability of all plays, either unconventional or conventional, relies on the amount and quality of organic carbon (C), thermal maturity, and volume of the source rock (McCarthy et al., 2011). A solid understanding of the nature and origin of the Marcellus source and reservoir rock, including sediment-water chemistry and organic C-flux, is required to most effectively and efficiently explore and develop the play. However, debate continues over the environmental conditions that persisted when the Marcellus Formation was deposited, specifically, over the relative importance of primary productivity (C-flux) versus the initial preservation of organic matter (Arthur and Sageman, 2005).

It has long been thought that most “black shales” were deposited under a strongly stratified water column that allowed for permanent bottom water anoxia, whereas sediment starvation allowed for the accumulation of relatively undiluted organic matter (Ettensohn, 1985a, 1985b; Arthur and Sageman, 2005). Ettensohn (1985a, 1985b) argues that during the Middle Devonian, the relationship between the warm climate and relative sea level rise prevented physical mixing that led to the formation of a stagnant water column and limited the supply of oxygen to the deep waters in the Appalachian Basin. In the Ettensohn model, water stratification was further enhanced due to the creation of a rain shadow by the Acadian mountains, which reduced rainfall to the basinal side of the mountain range, reducing runoff and sediment supply to the basin. Thus, coupling of the anoxic bottom water conditions with sediment starvation allowed for the accumulation of organic-C-rich facies (Ettensohn, 1985a, 1985b). Ettensohn (1985a, 1985b) continues to argue that tectonic quiescence was interrupted, subsidence halted, and erosion outpaced uplift, resulting in progradation of delta facies over basinal facies and the return to oxygenated bottom water conditions.

This model, however, does not address the relative importance of primary productivity in the basin, and it also does not necessarily support the observed lithofacies, such as the presence of bioturbation and calcareous fossils, in parts of the Marcellus Formation (Ettensohn, 1985a, 1985b; Werne et al., 2002; Kohl et al., 2014). Additionally, Sageman et al. (2003) propose that few organic-C-rich units in the Devonian sequence are deposited under pervasive anoxic to sulfidic water columns, and the establishment and breakdown of seasonal thermoclines were the predominant mode of water stratification during Marcellus Shale deposition. However, their study was primarily confined to the Oatka Creek Mbr. of the Marcellus Formation and other stratigraphically higher black shale units in New York State (Werne et al., 2002; Sageman et al., 2003), where paleowater depths were likely much shallower (Kohl et al., 2014).

Even though organic geochemical techniques such as total hydrogen pyrolysis and biomarker analysis may be used to provide information regarding the thermal maturity, hydrocarbon type, generation potential, and depositional conditions (McCarthy et al., 2011), the Marcellus source rock is thermally mature. It has modern vitrinite reflectance R_o values of greater than 2% in our study area, and pyrolysis S2 indices are low, mostly less than 20 mgHC/gOC in the present day. Petrographic analysis suggests that the organic matter in the Union Springs Mbr. of the Marcellus Formation was predominantly type II kerogen. This organic matter was subject to sufficient temperature and pressures to generate first oil, then wet gas, and then dry gas. Under such conditions, traditional organic geochemical techniques for analysis are not ideal for interpretation of water column chemistry, implied water depth, and siliciclastic input because they may only provide more data regarding thermal maturity and kerogen type. Additionally, biomarkers begin to degrade during late catagenesis and metagenesis (Peters et al., 2005) and hydrogen pyrolysis analysis most likely would not provide added data because most of the kerogen has been converted to hydrocarbons (McCarthy et al., 2011).

As an alternative to organic geochemical analyses, we can analyze samples for major, minor, and trace elemental data, as well as for total organic C (TOC). Trace elements show a wide range of variability in chemical behavior in the sediments and water column under different environmental conditions. Therefore, trace elemental data can be used as proxies for understanding the paleodepositional environments of formations, including paleoredox history and biological activity (Algeo and Maynard, 2004, 2008; Tribovillard et al., 2006). In addition, major and minor elemental data can be used to determine the nature of the detrital fraction of the sediments and its relative importance volumetrically (e.g., Sageman et al., 2003).

Geologic history and stratigraphic nomenclature

The Marcellus Formation was deposited during the Middle Devonian in the northeast–southwest-trending Acadian foreland basin, which is estimated to have water depths of at least 140 m (450 ft) in the deeper parts of the basin at the onset of deposition (Ettensohn, 1985a; Castle, 2001; Kohl et al., 2014). Formation of the basin resulted from thrust-loading subsidence due to the oblique collision of the Avalonia microcontinent with Laurentia during the Acadian Orogeny in the Late Silurian though the Late Devonian (Lash and Engelder, 2011). The semirestricted basin was bounded by the Acadian mountains to the southeast and by the Findlay-Algonquin Arch, a topographic high to the northwest

(Ettensohn, 1985a), but had open connections to the warm subtropical Devonian ocean to the southwest (Scotese and McKerrow, 1990; Sageman et al., 2003). A warm subtropical climate promoted the deposition of carbonates that combined with the clastic detritus from the Acadian highlands was shed into the basin from the southeast, leading to a mixed clastic-carbonate depositional system (Brett and Baird, 1985).

The stratigraphy of the Appalachian Basin of New York and Pennsylvania during the Middle Devonian has been revised many times, resulting in a complex and often redundant nomenclature (Van Tyne, 1983; Ver Straeten and Brett, 2006). These stratigraphic designations are based on outcrop studies and cannot often be differentiated in the subsurface (Lash and Engelder, 2011). Kohl et al. (2014) integrate these outcrop studies with cores, well logs, and limited geochemical data to construct a sequence-stratigraphic and depositional model for the Onondaga Formation through the Union Springs and Purcell Mbrs. of the Marcellus Formation. The stratigraphic nomenclature is presented in the aforementioned paper, so only a brief review will be presented here.

The Marcellus Formation overlies the Eifelian stage (392 million years) Onondaga Formation that is comprised of limestones and calcareous shales and the Tioga ash beds (Kohl et al., 2014). The upper Eifelian and lower Givetian (388–390 million years) Marcellus Formation comprises of organic- and pyrite-rich black to dark gray shale intervals that are separated by a sequence of limestone, shale, and sandstone of variable thicknesses (Rickard, 1975; Lash and Engelder, 2011; Kohl et al., 2014). Although the Marcellus Formation has been elevated to subgroup status in New York State (ver Straeten, 2007), the Marcellus Formation in Pennsylvania is divided into three members (Kohl et al., 2014).

The first black shale interval is the highly organic-carbon-rich Union Springs Mbr. (Shamokin Mbr. of the Marcellus Formation; Cooper, 1930; ver Straeten, 2007) and is generally characterized in well logs by a pronounced increase in the gamma ray signature (Figure 1). The contact between the Onondaga Formation and the Union Springs Mbr. is defined as a regional unconformity in the eastern parts of the basin and amalgamated with the Walbridge unconformity in the northeastern portion of the basin, but it is conformable in central Pennsylvania and New York (Johnson et al., 1985; ver Straeten and Brett, 2000; Kohl et al., 2014).

The Union Springs Mbr. is overlain by the Cherry Valley Mbr. in Western New York (Clarke, 1903), the Purcell Limestone in West Virginia and Pennsylvania (Cate, 1963), and by the Turkey Ridge Mbr. with which it also interfingers (Kohl et al., 2014) in eastern Pennsylvania. The Cherry Valley Mbr. is composed of nodular and bedded limestone, shale, and siltstone in central and western Pennsylvania (Lash and Engelder, 2011), and the Turkey Ridge Mbr. is composed primarily of sandstones (Kohl et al., 2014). The Cherry Valley and Union Springs Mbrs. are missing along a northeast–southwest-trending region of western New York and northwestern Pennsylvania, most likely as a result of erosion or nondeposition (Johnson et al., 1985).

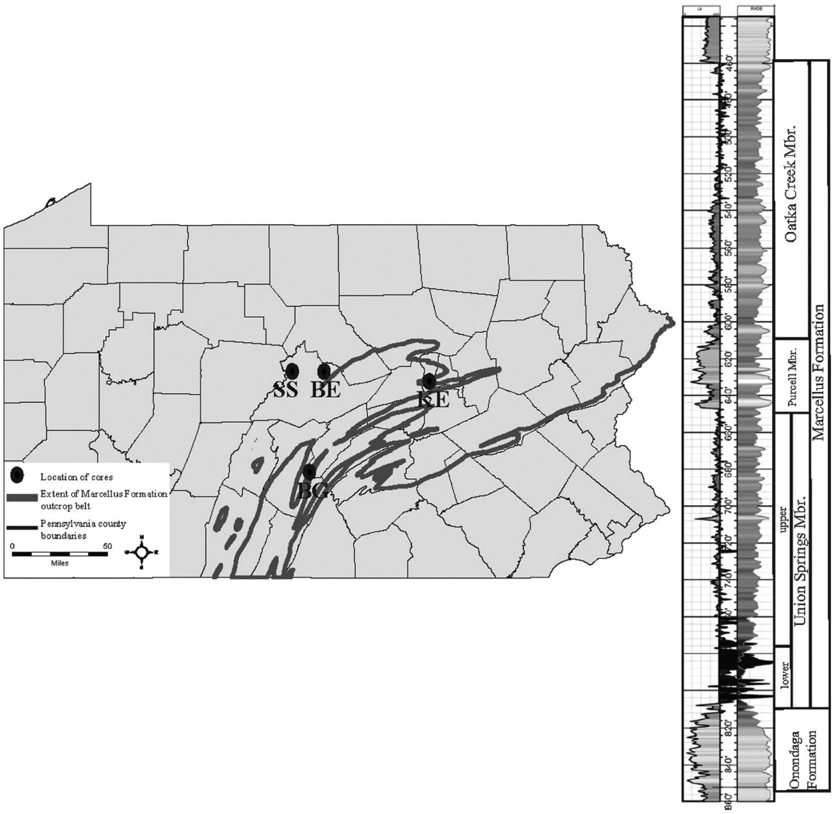

Figure 1. Approximate locations of sampled core in the Appalachian Basin stored in the Appalachian Basin Black Shale Group core lab at The Pennsylvania State University. Well location KE is the location of the Erb core. Samples were collected from the lower Union Springs Mbr. from well locations Bilger, Kenny Erb, and Snow Shoe cores (BG, KE, and SS), respectively. Bulk rock samples were collected from the lower Union Springs Mbr. into the (Cherry Valley) Purcell Mbr. from well location BE. XRF geochemical data for the entire Union Springs Mbr. were provided by EnerPlus Resources (Chevron Corporation) for the Snow Shoe core. Additional chemical data were supplemented by XRF for the remaining cores. The corresponding well log data (gamma ray [GR]; 0–200 API) and bulk density logs (RHOB; 2.4 – 2.8 g/cm^3, values increasing to the right) and related lithology for the KE core are to the right. A higher density and low gamma ray signatures characterize the Onondaga and Purcell-Cherry Valley limestones. The upper Union Springs Mbr. is characterized as having a higher gamma ray signature than the upper Union Springs Mbr.

The Cherry Valley Mbr. is overlain by the Oatka Creek Mbr. (Cooper, 1930), which is comprised of shale and irregularly interbedded limestone layers (Lash and Engelder, 2011). The basal interval of the Oatka Creek Mbr. is characterized as having a radioactive (gamma ray) spike, the amplitude of which decreases when moving up in the section. Density also increases up the section, suggesting an overall decrease in organic C concentration in the Oatka Creek Mbr. (Figure 1; Lash and Engelder, 2011).

Methods

All samples were collected from four different drill cores, the Bilger, Kenny Erb, Bald Eagle, and Snow Shoe, housed in the Appalachian Basin Black Shales Group core lab at The Pennsylvania State University (Figure 1) to create a high-resolution data set along a transect from more proximal to more distal in the basin. Core samples provide more pristine, unweathered samples for analysis as opposed to outcrop samples that have been oxidized, allowing organic matter and metals to become mobilized from the rock (Crusius and Thomson, 2000; Zheng et al., 2002b; Tribovillard et al., 2006). The analysis of a suite of proxies may also allow for us to ascertain if there has been diagenetic alteration.

The Bilger core was donated by Samson Resources of Tulsa, Oklahoma, and was collected near the town of Newton Hamilton, Pennsylvania, within the Valley and Ridge Province and is believed to represent a more proximal portion of the basin. The Kenny Erb core was collected by the Appalachian Basin Black Shales Group and is located near Sunbury, Pennsylvania, whereas the Bald Eagle core was collected from Bald Eagle State Park in collaboration with the Pennsylvania Department of Conservation and Natural Resources. Both cores are from within the Valley and Ridge Province. EnerPlus Resources (and Chevron) donated the Snow Shoe core, collected from the EnerPlus Snow Shoe 4, 8HG well near the town of Snow Shoe, on the Appalachian Plateau in central Pennsylvania, and this represents the most distal site in the basin.

Samples were collected from the Union Springs Mbr. of The Marcellus Formation at a resolution of six one-inch samples per foot for the Bilger core and three one-inch samples per foot for the Bald Eagle core. Samples were collected across the lower Union Springs Mbr. for the Erb and Snow Shoe cores at a resolution of three one-inch samples per foot. Chemical data collected using an X-ray fluorescence (XRF) scanner were collected across the Upper Union Springs Mbr. of the Erb and Bilger cores at Penn State using an Olympus Innov-X XRF spectrometer hand-held detector attached on a Geotek Ltd. multisensor core logger system, at the same resolution at which bulk geochemical samples were collected, when possible. EnerPlus Resources of Calgary, Canada, provided XRF data collected every half-foot across the Union Springs Mbr. for the Snow Shoe core. XRF data were compared against the bulk geochemical data and should be considered semiquantitative; however, XRF allowed for reasonable expansion of the geochemical data set in which bulk geochemical samples were not processed.

All bulk samples collected at The Pennsylvania State University were powdered using a silica nitride vial in a Spex 8000 ball mill/mixer and passed through a 200-mesh stainless steel sieve. Powdered samples were digested using sodium peroxide fusion, followed by elemental analysis by inductively coupled plasma mass spectrometry and inductively coupled plasma atomic emission spectroscopy at SGS Mineral Services, Inc. Samples from the Bald Eagle and Snow Shoe cores were analyzed for sulfur (S) concentrations, at half the resolution, by infrared combustion, also by SGS Mineral Services, Inc. All samples were decarbonated by reacting approximately two grams of material with 10% hydrochloric acid for 48 h and were analyzed for TOC using an UIC, Inc., 5014 CO_2 coulometer with a 5200 autosampler. Accuracy and precision of the coulometer was assessed by running a calcium carbonate ($CaCO_3$) standard for every 50 samples run. Analysis of decarbonated samples by X-ray diffraction shows that no carbonate or dolomite remained in the samples prior to analysis for organic C. Bulk geochemical results are available in Appendix A. 3

Results and discussion

Reduction and oxidation proxies

Uranium (U) and molybdenum (Mo) concentrations may be used as reduction and oxidation (redox) proxies, providing information regarding the chemical composition of bottom water conditions at the time of deposition. U tends to concentrate in sediments in oxygen-deficient waters, whereas Mo will reduce under anoxia. Mo is further concentrated when free hydrogen sulfide (H_2S) is available, resulting in a strong covariance between U and Mo under euxinic conditions with relative high concentrations in Mo (Klinkhammer and Palmer, 1991; Zheng et al., 2002a, 2002b; Algeo and Maynard, 2004; McManus et al., 2005; Tribovillard et al., 2006). Manganese (Mn) on the other hand will display opposite behavior, and concentrations of Mn will increase under oxic conditions, except that reduced Mn can substitute freely into authigenic carbonates, which do occur in the Union Springs Fm. (Raiswell et al., 1988; Calvert and Pederson, 1993; Sageman et al., 2003; Tribovillard et al., 2006). Concentrations of barium (Ba), S, and iron (Fe) may also provide information about ancient redox conditions (Brumsack, 1986; Arthur and Sageman, 1994; Helz et al., 1996; Lyons et al., 2003; Tribovillard et al., 2004; Lyons and Severmann, 2006).

Results for the Union Springs Mbr. have been compared to gray shale mean (GSM) values (Raiswell et al., 4
1988; Sageman et al., 2003; Lyons and Severmann, 2006) to determine the extent of anomalies from background continental or oxic values. Comparison to GSM values allows for the quantification and comparison of environmental conditions so that relative trends may be assessed (Sageman et al., 2003).

U concentrations are generally greater than the GSM value of 5 parts per million (ppm) (Figures 2–5; Raiswell et al., 1988; Brett et al., 1991) for the lower and upper Union Springs Mbr. in all core samples. U concentrations range from 5 to 90 ppm in the lower Union Springs Mbr., whereas concentration and variability in U decreases up the section in the Bald Eagle core. U concentrations are above the GSM value near the top of the Onondaga Limestone in the Snow Shoe core, most likely because that limestone contains more organic-C-rich shale there than it does in other areas of the basin. U concentrations appear to increase toward the basin center. The dominant form of U in oxic waters is the soluble uranyl carbonate complex (Algeo and Maynard, 2004), and high sedimentary U concentrations are not expected under oxic conditions because the uranyl carbonate ion is soluble, although uranyl carbonate can substitute into aragonite (Kelly et al., 2003). Under anoxic conditions, U reduction is thought to take place primarily in the sediments, precipitating as organometallic ligands or as uraninite. The decrease in U concentration in pore waters drives U diffusion from the water column to the sediments allowing for higher U concentrations, which may also be enhanced by slower sediment accumulations (Klinkhammer and Palmer, 1991; Zheng et al., 2002a, 2002b; Algeo and Maynard, 2004; McManus et al., 2005; Tribovillard et al., 2006). Thus, we would expect lower U concentrations under euxinic conditions closer to the clastic sediment sources.

Mo concentrations range from approximately 50 to 350 ppm and are significantly above the GSM value of 0.22 (Figures 2–5; Sageman et al., 2003) throughout

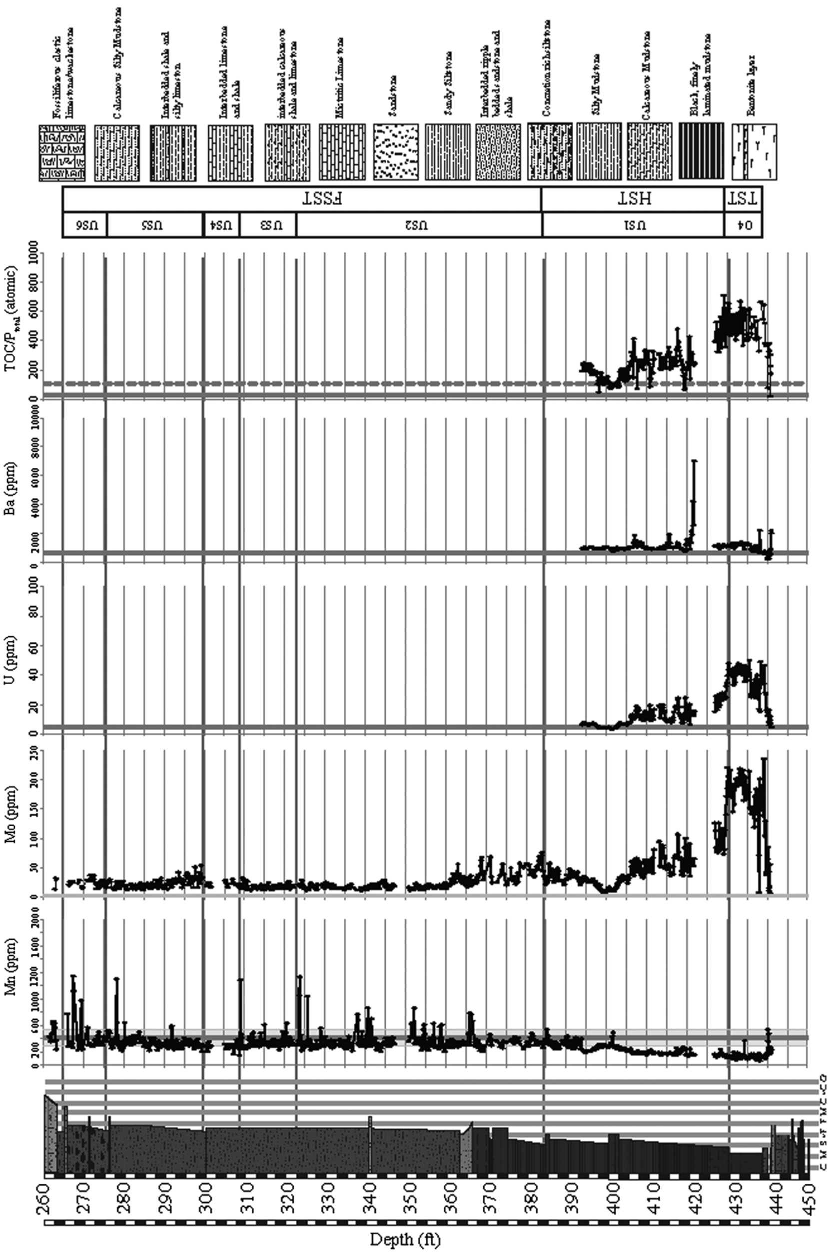

Figure 2. Mn, U, Mo, and Ba concentrations in ppm are plotted versus depth for the Union Spring Mbr. for the Bilger core, central Pennsylvania. Data from 260′ to approximately 395′ depth were collected by XRF analysis. Chemical data were correlated with the seven parasequences O4 and US1–US6 and correlating sequence stratigraphic interpretation, TST, HSST, and FSST (modified after Kohl et al., 2014). Gray-shaded areas represent the mean gray shale (MGS) of 419, 5, 0.22, and 650 ppm for Mn, U, Mo, and Ba, respectively. Mn concentrations range from 100 to 1400 ppm, U concentrations range from 4 to 60 ppm, and Mo concentrations range from 10 to 250 ppm. The highest U and Mo values are observed in the lowest Union Springs Mbr.

the Union Springs Mbr in all cores. U and Mo concentration variations appear to be coeval across the study area, are similar in the Bilger and Erb cores, most proximal to the shoreline, and increase in the Bald Eagle and Snow Shoe cores, which are located more distally in the basin (inferred to be deeper water), in the lower and upper Union Springs Mbr, Mo exists in oxic waters as molybdate and is neither enriched by ordinary plankton nor will it adsorb onto clays, carbonates, or Fe-oxyhydroxides at marine pH values (Brumsack, 1989; Goldberg et al., 1998; Tribovillard et al., 2006). Mo is, however, readily captured by Mn-oxyhydroxides in oxic settings, generally at the sediment surface, and is subsequently released in reducing environments (Calvert and Pederson, 1993; Crusius et al., 1996). U uptake in the sediments is expected to be greater than Mo under less reducing conditions (Algeo and Tribovillard, 2009), whereas Mo concentrations are enhanced under euxinic conditions and can form organic thiomolybdates and settle in the sediments, leading to enrichments greater than approximately 350 ppm (Calvert and Pederson, 1993; Algeo and Maynard, 2004, 2008; Tribovillard et al., 2006, 2008). Mo concentrations in the sediment could decrease, whereas U concentrations remain relatively high if basinal Mo availability declines during protracted euxinic episode. In our study area, U and Mo concentrations are highly correlated, which would indicate that Mo availability was not controlled by sediment accumulations. The upward (stratigraphically) decrease in Mo concentration may be due to increasing availability of oxygen, an increase in sediment dilution, or a combination of these factors.

Although dependent on H_2S activity, Mo may be scavenged by forming bonds with Fe-rich particles, S-rich organic compounds and Fe sulfides, including pyrite (Helz et al., 1996; Tribovillard et al., 2004). Under anoxic conditions, sulfate is reduced to sulfide (Arthur and Sageman, 1994), and S concentrations tend to follow trends observed in Mo concentrations (Figures 2–5). Enrichment of reactive Fe in sulfidic waters is necessary for the formation of pyrite (Lyons et al., 2003; Lyons and Severmann, 2006), resulting in observed increases in Fe (Fe/Al) concentrations (Figures 678–9; Lyons and Severmann, 2006). In the Lower Union Springs Mbr.,

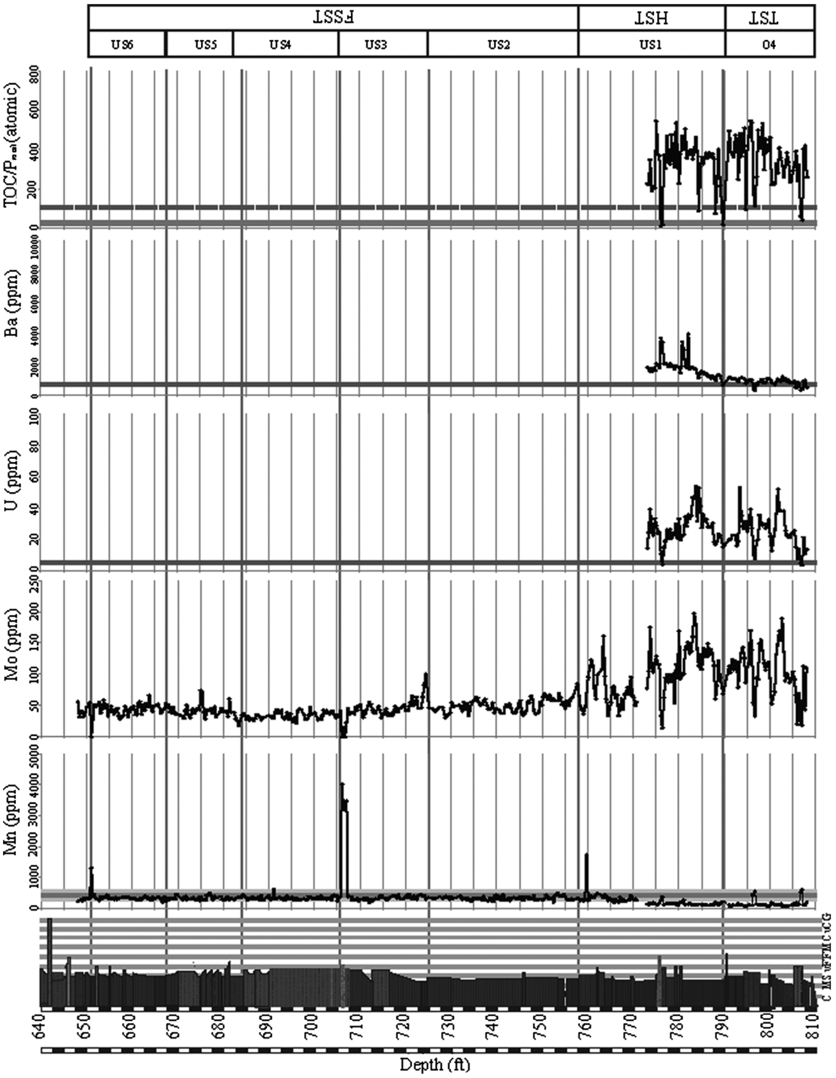

Figure 3. Mn, U, M, and Ba concentrations in ppm are plotted versus depth for the Union Spring Mbr. for the Kenny Erb core, Central Pennsylvania. Data from 647′ to approximately 775′ depth were collected by XRF analysis. Chemical data were correlated with the seven parasequences O4 and US1–US6 and correlating sequence stratigraphic interpretation, TST, HSST, and FSST (modified after Kohl et al., 2014). Gray-shaded areas represent the GMS of 419, 5, 0.22, and 650 ppm for Mn, U, Mo, and Ba, respectively. Mn concentrations range from 100 to 500 ppm, U concentrations range from 4 to 60 ppm, and Mo concentrations range from 10 to 200 ppm.

Fe concentrations closely follow S concentrations and abundant pyrite is observed in the cores.

Enriched Mn concentrations, with respect to the GSM value of 419 ppm (Figures 2–5; Raiswell et al., 1988; Sageman et al., 2003), are observed at some levels in the Union Springs Mbr. Mn concentrations are also high in the underlying Onondaga Formation in the Snow

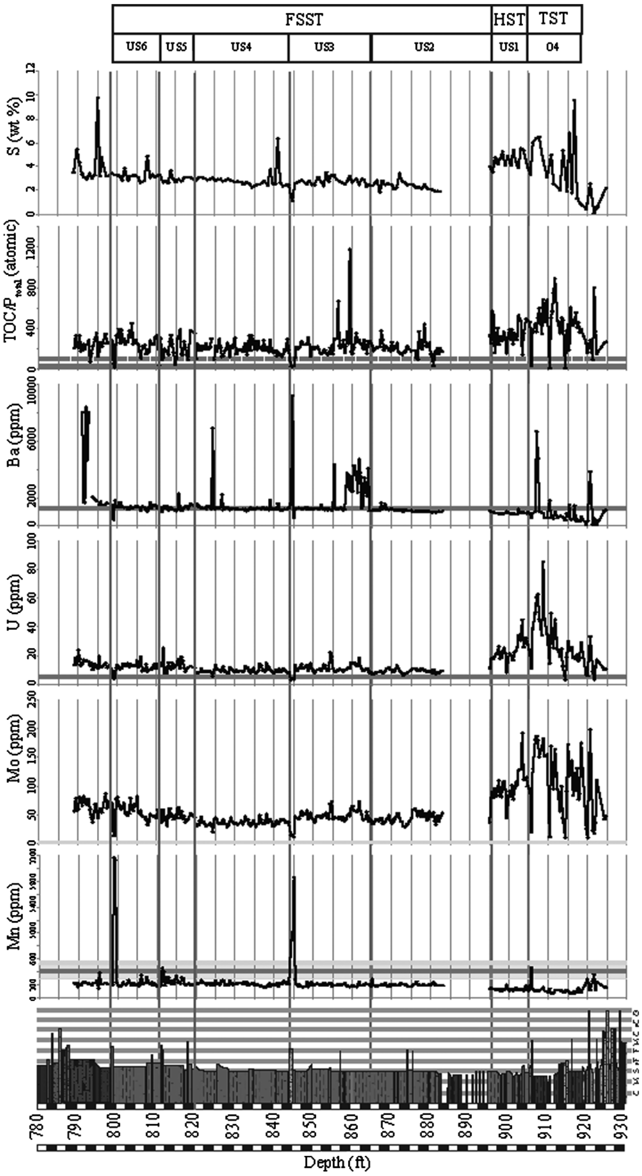

Figure 4. Mn, U, Mo, and Ba concentrations in ppm and S (wt%) are plotted versus depth for the Union Spring Mbr. for the Bald Eagle core, central Pennsylvania. Chemical data were correlated with the seven parasequences O4 and US1–US6 and correlating sequence stratigraphic interpretation; TST, HSST, and FSST (modified after Kohl et al., 2014). Gray-shaded areas represent the GMS of 419, 5, 0.22, and 650 ppm for Mn, U, Mo, and Ba, respectively. Mn concentrations range from 100 to 500 ppm, U concentrations range from 4 to 90 ppm, and Mo concentrations range from 10 to 200 ppm. S concentrations were determined at half the resolution of the other samples and range from 0 to 10 wt%. The TOC/P_{total} ratio is also plotted versus depth, where the gray lines represent the MGS values of 25. The dashed line is the Redfield ratio of 106 for atomic C:P.

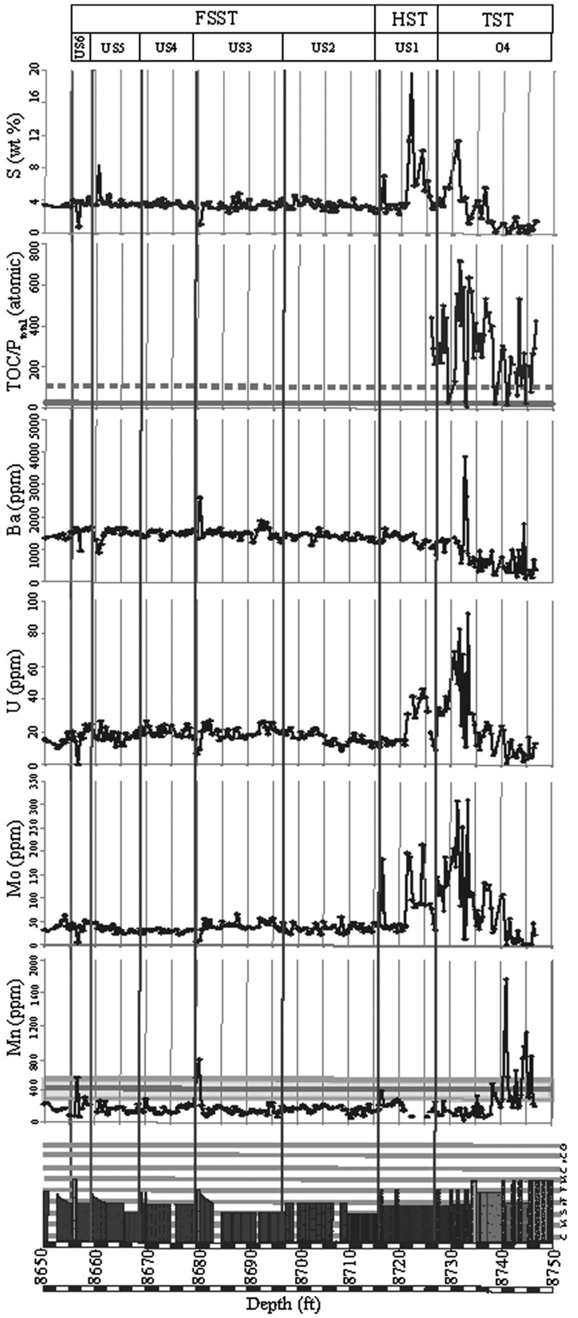

Figure 5. Mn, U, Mo, and Ba concentrations in ppm and S (wt %) are plotted versus depth for the Union Spring Mbr. for the Snow Shoe core, Central Pennsylvania. Data from 8650′ to approximately 8725′ depth were collected by XRF analysis and provided by EnerPlus Resources (Chevron). Geochemical data were correlated with the seven parasequences O4 and US1–US6 and correlating sequence stratigraphic interpretation; TST, HSST, and FSST (modified after Kohl et al., 2014). Gray-shaded areas represent the GMS of 419, 5, 0.22, and 650 ppm for Mn, U, Mo, and Ba, respectively. Due to scaling, the GMS values for U and Ba cannot be seen. Mn concentrations range from 100 to 1800 ppm, U concentrations range from 3 to 90 ppm, and Mo concentrations range from 0.5–350 ppm. S concentrations were determined at half the resolution of the other bulk samples, and range from 0 to 20 wt%. The TOC/P_{total} ratio is also plotted versus depth, where the gray lines represent the MGS values of 25. The dashed line is the Redfield ratio of 106 for atomic C:P.

Shoe core and decrease near the interface with the base of the lower Union Springs Mbr. Mn relative enrichment appears to correspond to carbonate-rich layers with weight percent $CaCO_3$ greater than 40% in the Union Springs Mbr. The Mn values in the Union Springs Mbr throughout the four cores average around 200 ppm, suggesting that the Union Springs Mbr. was deposited under oxygen-deficient waters. Under oxic conditions, Mn exists as insoluble Mn oxides or Mn-oxyhydroxides, in which reactive Mn is delivered to the ocean as oxide coatings on particulate material by winds or rivers and by diffusion out of shelf sediments (Tribovillard et al., 2006; Calvert and Pedersen, 2007). Under dysoxic to anoxic conditions, either in the water column or in sediment pore waters, Mn remains soluble (Calvert and Pederson, 1993; Tribovillard et al., 2006). The increases in Mn concentration appear to correspond with decreasing U and Mo concentrations, suggesting that Mn is preferentially incorporated into the authigenic carbonate minerals under dysoxic or anoxic conditions. Many of the observed Mn and carbonate spikes within our data occur at parasequence boundaries, which were independently determined, below marine flooding surfaces. However, the anticorrelation of Mn with Mo and U could be due to displacive carbonate nodule growth or "dilution" of Mo/U signals.

Ba concentrations are near the GSM value of 650 ppm (Figures 2–5; Wedepohl, 1971, 1991) for the lower Union Springs Mbr., but they are higher than the GSM value on average in the upper part of the member at all sites. Overall, maximum Ba concentrations decrease in more distal parts of the basin. Increases in Ba concentration near 6000–9000 ppm are primarily associated with increased Mn concentration within more carbonate-rich intervals. Ba concentrations are lower within the Onondaga Formation in the Snow Shoe core, in comparison with that in the Union Springs Mbr Even though it has been suggested that Ba concentration in marine sediments is biologically influenced in the upper water column (Bishop, 1988), Ba most likely precipitates as highly insoluble barite ($BaSO_4$) crystals and nodules when some oxygen becomes available and sulfate concentrations rise. However, with subsequent bacterial sulfate reduction and elimination of dissolved sulfate in anoxic pore waters, barite dissolves and Ba typically diffuses upward in response to the Ba concentration gradient within the sediment column. Precipitation and preservation of barite occurs near the sediment/water interface as the result of oxygenation events and reduced sedimentation rates (Brumsack, 1986; Arthur and Sageman, 1994) as long as barite is not subsequently dissolved as burial continues. Widespread nodular barite does occur in the lower part of the Cherry Valley limestone at the transition from the
7 uppermost Union Springs Mbr (J. Wang, personal communication).

Elemental proxies for nutrient cycling

Phosphorus is the major limiting nutrient for marine primary productivity on geologic time scales (Algeo and Ingall, 2007), and its accumulation in marine sediments has been used as a proxy for paleoproductivity (Calvert and Pedersen, 2007). The comparison of TOC versus total phosphorus (P_{total}) may serve as a proxy for redox conditions on digenetic pathways of C and P remobilization (Ingall and van Cappellen, 1990; Ingall and Jahnke, 1997; Algeo and Ingall, 2007). This information also has implications for understanding paleoproductivity in the surface waters. Greater primary productivity in the surface waters will increase the sinking flux of organic C, which depletes oxygen in the water column, enhancing the flux of benthic P back to the surface waters, creating a positive feedback loop (Algeo and Ingall, 2007).

The ratio TOC/P_{total} in sediment may provide a proxy for efficiency of nutrient cycling because the P is linked strongly to the supply of organic matter, whereas preferential P regeneration would reduce the TOC/P_{total} (van Cappellen and Ingall, 1994; Ingall and Jahnke, 1997; Tribovillard et al., 2006). Lower TOC/P_{total} values may result from organic matter catagenesis, but the burial diagenetic factors here are unlikely to render the ratio useless for interpretation (Algeo and Ingall, 2007). TOC/P_{total} ratios are above the GSM value of 25 and generally above the atomic Redfield ratio of 106 for $C:P_{total}$ (Figures 2–5; Redfield et al., 1963; Sageman et al., 2003). Values above the Redfield ratio suggest that there was efficient recycling of P to the surface waters (Sageman et al., 2003; Arthur and Sageman, 2005). Due to microbial activity and redox changes in the Fe phases carrying P, the burial efficiency of P declines when bottom waters progressively become more anoxic, allowing for the recycling of the nutrient from bottom waters to further enhance plankton productivity (Arthur and Sageman, 2005; Jenkyns, 2010).

TOC concentrations range from 2 to 10 wt% and are greater than GSM value of 0.5 wt% (Figures 6–9; Sageman et al., 2003), with the exception of a few points. The greatest TOC concentrations are located in the basal Union Springs Mbr., whereas overall values decrease and vary less, ranging from 2 to 4 wt%, up section. TOC concentrations remain fairly consistent across the basin (Figure 11). Spikes in TOC concentration correlate well with increases in U and Mo concentrations, and are found in the finely laminated, unbioturbated mudstone to calcareous mudstone facies. The elevated TOC values suggest that there was significant generation of organic C in the surface waters and that conditions existed such that the organic C was also well preserved. TOC values less than 1 wt% correspond to relatively carbonate-rich facies or to bentonite layers (Kohl et al., 2014).

Clastic fraction: Condensation and dilution proxies

Comparison of the total Fe (Fe_T), titanium (Ti), and silicon (Si) against aluminum (Al) concentrations provides information pertaining to detrital input, from aeolian and fluvial sources (Sageman et al., 2003; Calvert and Pederson, 2007). Al is generally considered to reflect clay mineral fluxes in fine-grained sediments, and the comparison to Si, Fe, and Ti allows for the identification of coarser and finer grained core material (Arthur and Dean, 1991; Calvert and Pederson, 2007). Even though Fe may serve as a proxy for redox conditions in the water column, Fe/Al will vary with changes in temporal and spatial gradients in detrital flux as well (Lyons et al., 2003). Therefore, changes in grain size of the detrital flux may be reflected in elements generally associated with coarser material, which may allow for the interpretation 8 of variability in clastic flux or energy (Calvert and Pedersen, 2007).

The (Fe_T)/Al concentrations tend to be near to or greater than the GSM value of 0.5 (Figures 6–9; Taylor and McLennan, 1985; Lyons and Severmann, 2006) and decrease in the Upper Union Springs Mbr. Fe_T/Al values greater than the GSM usually correlate with elevated Mn concentrations and the relatively carbonate-rich intervals, and in the Snow Shoe core, are observed in the underlying Onondaga Formation. The lower Union Springs Mbr., however, also contains Fe_T/Al values that are greater than the GSM value that appear to be associated with the presence of significant pyrite and elevated S concentrations. Even though relatively high Fe concentrations appear to be associated with increased S concentrations and pyrite, elevated Fe_T/Al ratios may indicate a condensed section, in which sedimentation rate was lower, allowing for the diffusion of Fe from the water column into the sediments (Calvert and Pedersen, 2007) or transport from margin to basin center within a water-column chemocline and then precipitated as pyrite (Raiswell and Canfield, 1998; Wilkin and Arthur, 2001).

The Si/Al concentrations are greater than the GSM value of 3.14 (Figures 7–9; Sageman et al., 2003) in the lower Union Springs Mbr., and they generally increase from more proximal to more distal in the basin. Values greatly decrease across a distinctive shift to concentrations near or below the GSM in the lower part of the Upper Union Springs Mbr. Wide variability in the Si/Al concentration is observed in the most basal portion of the Union Springs Mbr. with respect to the upper section. A similar trend is observed in the Ti/Al concentrations, with values near to or greater than the GSM value of 0.045 (Sageman et al., 2003). Elevated Si/Al values also correspond to the bentonite layers observed in the cores, for example, at approximately 800′ depth, Figure 6; 922′ depth, Figure 7. At times, elevated Si/Al values are associated with decreases in Fe_T/Al and Ti/Al, but correlate with increased TOC/P_{total} concentrations, mostly observed in the Lower Union Springs Mbr. (i.e., approximately 910 ft depth in the Bald Eagle core, 795 ft depth in the Erb core).

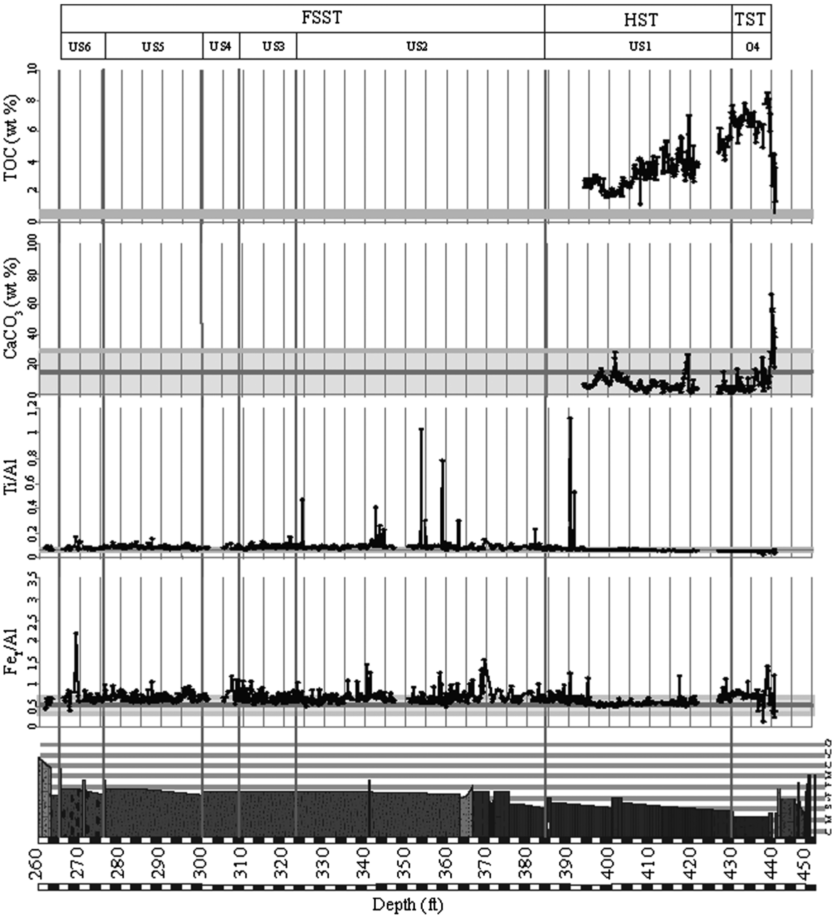

Figure 6. Ti/Al, Fe/Al ratios, and $CaCO_3$ and TOC wt% values are plotted versus depth for the Union Springs Mbr. for the Bilger core, Central Pennsylvania. Data from 260′ to approximately 395′ depth were collected by XRF analysis. Chemical data were correlated with the seven parasequences O4 and US1–US6 and sequence stratigraphic interpretation of a TST, HSST, and FSST (modified after Kohl et al., 2014). Gray-shaded areas represent the GMS values of 0.045 and 0.5 for Ti/Al and Fe/Al concentrations, respectively, and 13.6 and 0.5 wt% for $CaCO_3$ and TOC.

Ti/Al and Si/Al values may be interpreted to reflect changes in the delivery of detrital sediments to the basin (Sageman et al., 2003). Lower Ti/Al ratios may indicate deposition of sediments in a lower energy environment and therefore may represent a period in which there was a smaller fraction of clastic flux because Ti is associated with somewhat coarser material as it is brought into the system by silt-sized heavy minerals (Spears and Kanaris-Sotiriou, 1976; Piper and Calvert, 2009). Although minor amounts of Si to the marine environment can be derived from hydrothermal sources, pore waters, and seafloor weathering, the major source of dissolved silica is from continental runoff (Calvert, 1983). Biogenic silica also plays an active role in marine biogeochemical cycles derived primarily from planktonic organisms (Ozkan et al., 2014) or benthic silica sponges. Silica can also be derived from volcanic glass.

Although increases in the Si concentration (and Si/Al) may reflect an increase in clastic flux (Sageman et al., 2003) or an increase in relative abundance of detrital quartz resulting from current winnowing, the higher Si/Al that occurs independently from increases in Ti/Al and Fe/Al values suggests increasing contributions of biogenic silica as a result of an increase in productivity in surface waters (Calvert and Pedersen, 2007; Ozkan et al., 2014). This trend appears most obvious in the lower Union Springs Mbr., although it is not as well developed in the most distal Snow Shoe core. Thin-section analyses from the Lower Union Springs Mbr. of the Kenny Erb core confirm the presence of authigenic silica cements and pore fillings, possibly derived from highly soluble biogenic opal. Opal is more highly soluble than quartz and pore-water dissolved silica concentrations will increase quartz saturation, leading to precipitation of quartz cements in mudstones. It is interesting that the possible evidence for a biogenic silica source in the lower part of the Union Springs Mbr. occurs in concert with highest TOC, Mo, U, and TOC/P_{total} values indicating possible higher productivity and euxinic conditions in that interval.

The $CaCO_3$ concentrations range between 0 and 20 wt% and generally increase up section with respect to the lower Union Springs Mbr. (Figures 6–9). Elevated values occur within the thin, fossil-fragment-rich, beds

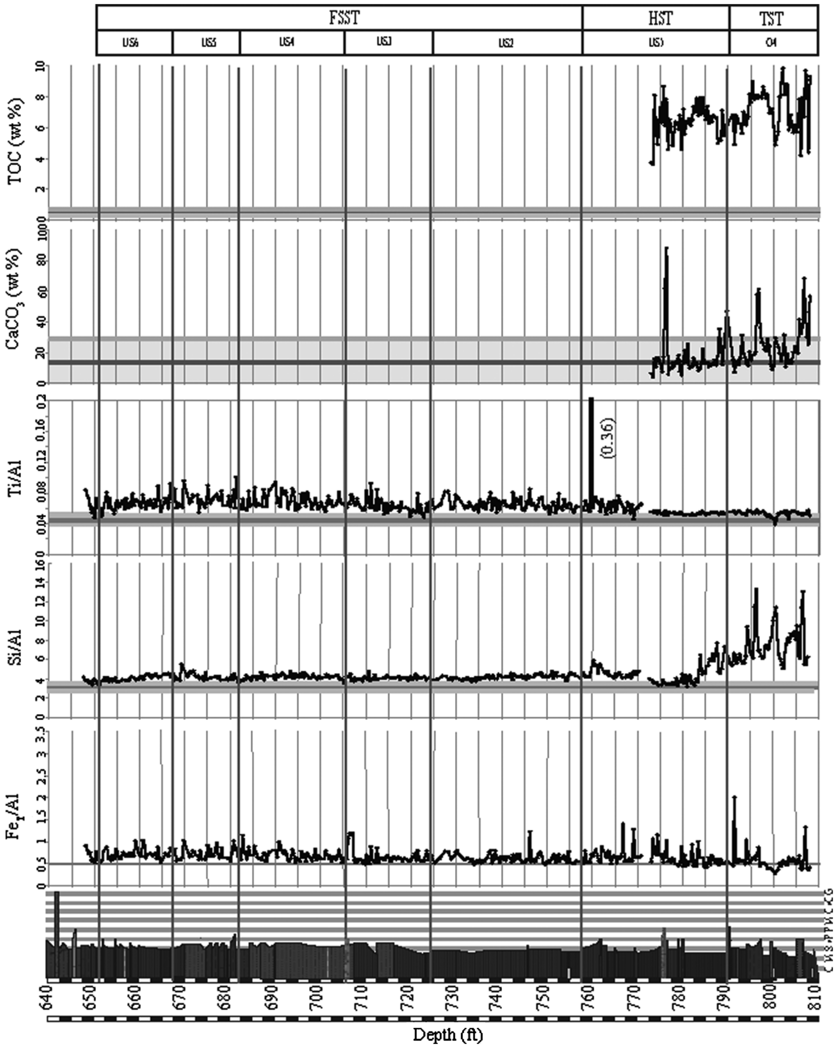

Figure 7. Ti/Al, Fe/Al, and Si/Al ratios, and $CaCO_3$ and TOC (wt% values) are plotted versus depth for the Union Springs Mbr. for the Kenny Erb core, Central Pennsylvania. Data from 647′ to approximately 775′ depth were collected by XRF analysis. Chemical data were correlated with the seven parasequences O4 and US1–US6 and correlating sequence stratigraphic interpretation; TST, HSST, and FSST (modified after Kohl et al., 2014). The gray-shaded areas represent the GMS values of 0.045 and 0.5 for Ti/Al and Fe/Al concentrations, respectively, and 13.6 and 0.5 wt% for $CaCO_3$ and TOC. The Fe/Al values range around the MSG value, as may be expected given the proximal location of the core. The spikes in Fe/Al tend to correlate with decreases in the $CaCO_3$ values, as may be expected from an increased clastic input up section.

or concretions that are also enriched in Mn and Fe, located near the top of parasequences. Variability in $CaCO_3$ concentration also increases in the top of the upper Union Springs Mbr. in the Bald Eagle core. Even though $CaCO_3$ concentrations may reflect productivity (Calvert and Pedersen, 2007), the formation of carbonate could also reflect decreases in clastic sediment input that is associated with parasequence tops and overlying marine flooding surfaces.

Interpretation

Redox proxies suggest that the Union Springs Mbr. was deposited predominantly under anoxic to euxinic bottom water conditions. Elevated U and Mo concentrations suggest that the sediment pore waters and a portion of the water column were anoxic, and they were probably euxinic when Mo is significantly enriched during deposition of the lower Union Springs Mbr., in concert with the lack of bioturbation and fine lamination of the cores. The bottom water anoxic/euxinic conditions suggest that the lower Union Springs Mbr. was most likely deposited under a stratified water column, in which the water column was deep enough to prevent wind mixing to the bottom sediments at least 100 m (330 ft depth of fair-weather wave base) deep in the central part of the basin (Kohl et al., 2014)

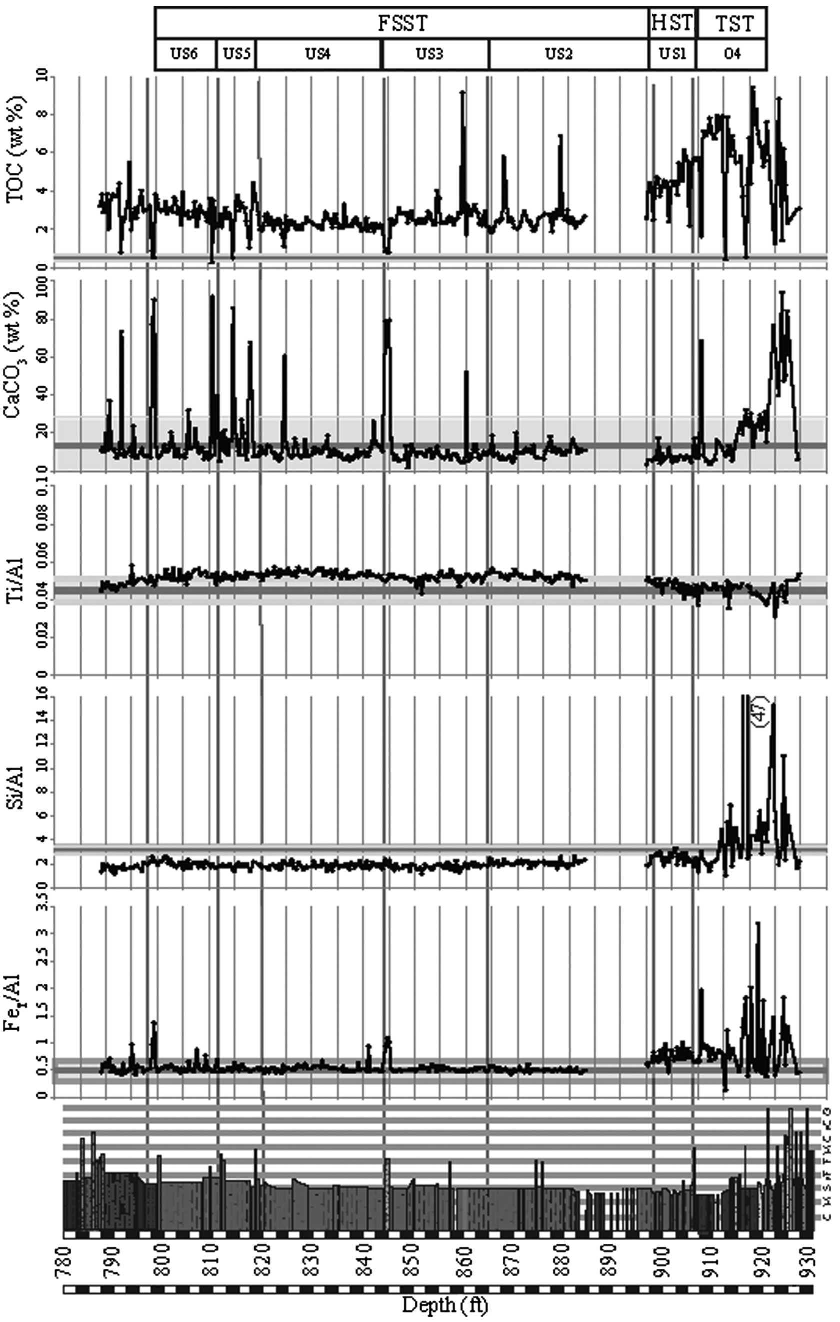

Figure 8. Ti/Al, Fe/Al and Si/Al ratios, and $CaCO_3$ and TOC (wt% values) are plotted versus depth for the Union Springs Mbr. for the Bald Eagle core, Central Pennsylvania. Chemical data were correlated with the seven parasequences O4 and US1–US6 and correlating sequence stratigraphic interpretation; TST, HSST, and FSST (modified after Kohl et al., 2014). Gray-shaded areas represent the GMS values of 0.045 and 0.5 for Ti/Al and Fe/Al concentrations, respectively, and 13.6 and 0.5 wt% for $CaCO_3$ and TOC.

The lack of oxygen to the bottom waters increased the likelihood of preservation of organic matter. Productivity appears to be high in the surface waters, as suggested by elevated TOC/P_{total} values, indicating that there was efficient cycling of P back to the surface waters, and that high fluvial input of nutrients was not necessary to maintain high productivity at that time. Furthermore, upwelling of nutrients may have been enhanced in that the basin was located with the trade wind belt in the southern hemisphere at the time of Marcellus Shale deposition (Scotese and McKerrow, 1990; Werne et al., 2002). Additionally, inshore sediment trapping limited the clastic dilution of organic C and the lowermost Union Springs Mbr. most likely represents the most condensed interval (high Fe_T/Al values not associated with clastic flux).

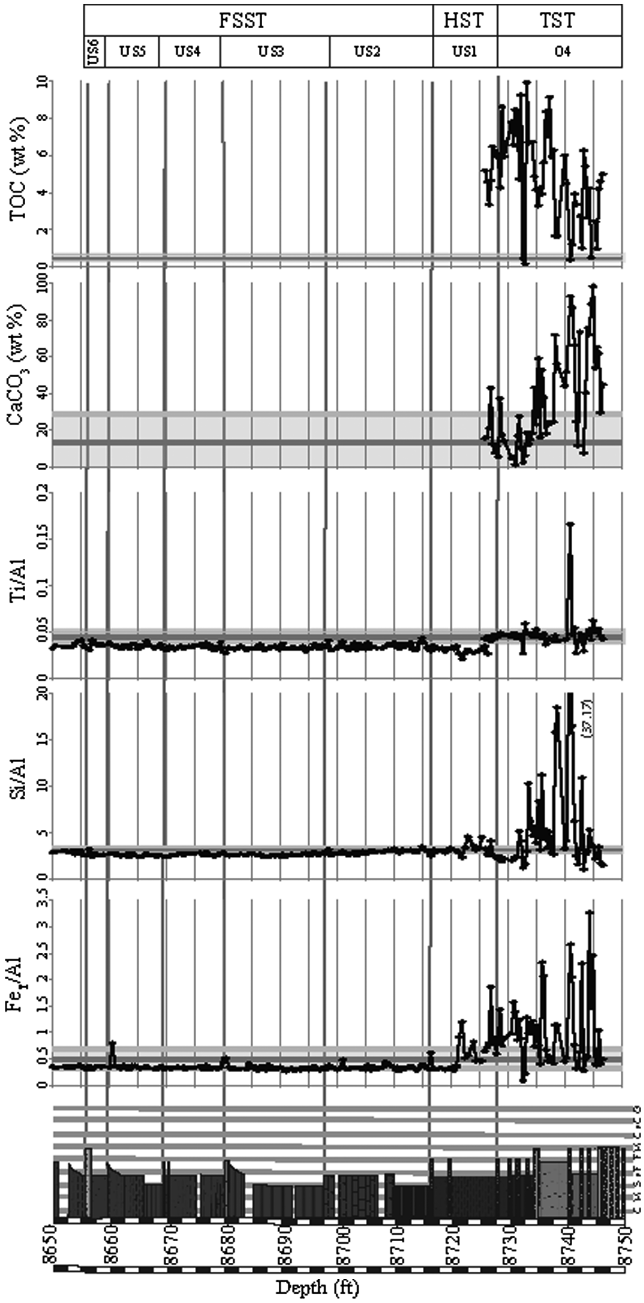

Figure 9. Ti/Al, Fe/Al and Si/Al ratios, and $CaCO_3$ and TOC) (wt% values) are plotted versus depth for the Union Springs Mbr. for the Snow Shoe core, Central Pennsylvania. Data from 8650 ft to approximately 8725 ft depth were collected by XRF analysis and was provided by EnerPlus Resources (Chevron). Chemical data were correlated with the seven parasequences O4 and US1–US6 and correlating sequence stratigraphic interpretation; TST, HSST, and FSST (modified after Kohl et al., 2014). Gray-shaded areas represent the GMS values of 0.045 and 0.5 for Ti/Al and Fe/Al concentrations, respectively, and 13.6 and 0.5 wt% for $CaCO_3$ and TOC.

As deposition of the Union Springs Mbr. continued, there was a shift to more frequent oscillations between anoxic and dysoxic conditions as indicated by decreasing concentrations of U and Mo, and increasing Mn. A decrease in relative sea level in the upper Union Springs Mbr. would have decreased the volume of water in the basin, making mixing events more effective, and this allowed oxygen to penetrate intermittently to the bottom sediments. The recycling of P to surface waters would become less efficient as anoxia diminished, and surface productivity would have decreased. Both feedbacks would have decreased the concentration of organic C in the sediments. In addition, dilution of organic C by clastic sediment likely increased on the basis of the increasing sand/silt layers in the upper Union Springs Mbr. of more proximal sites (Bilger, Kenny Erb). Anoxia/euxinia appears to have been punctuated by periods in which oxygen was able to penetrate to bottom waters, as suggested by the elevated Mn and Ba concentrations. Dysoxic events also appear to correlate with periods in which the clastic fraction increases, suggesting that there are smaller scale base level changes, or parasequences within the Union Springs Mbr.

The geochemical data support the independent sequence stratigraphic interpretation of six parasequences within the Union Springs Mbr., and an additional parasequence that spans the transition of the underlying Onondaga Formation to the lower Union Springs Mbr. (PS-O4, PS-US1–PS-US6 after Kohl et al., 2014). In the northwest part of the basin, the top of PS-O4 is marked by a sharp flooding surface and transition to the organic-C-rich mudrocks; however, in the central part of the basin, the Onondaga Formation grades into the Union Springs Mbr (Kohl et al., 2014), as supported by the chemical data from the Snow Shoe core and represents the transgressive systems tract (TST). TSTs are characterized by low rates of clastic sediment input to basins.

PS-US1 represents the high-stand systems tract (HSST), the base of which is interpreted as the maximum marine flooding surface, which corresponds to the highest U, Mo, TOC, and highest inferred surface-water productivity values. It also encompasses the interval of highest Si/Al ratios, which most likely reflects the initial preservation of biogenic silica in the sediments. In all cores, there appears to be a dramatic shift in the geochemical indicators at the top of PS-US1. The overlying parasequences (PS-US2–PS-US6) compose the interpreted falling stage systems tract (FSST), leading to a forced regression, increased sediment supply to the basin (progradation of shorelines and deltas) and deposition of the upper Union Springs Mbr. in shallower water.

Although it has been argued that tectonics was the main force for observed changes in stratigraphy and chemistry (Ettensohn, 1985a, 1985b; ver Straeten and Brett, 2000), relative base level changes may have been driven by several different factors. Eustacy and climate are the most likely causes of relative sea level changes in the Middle Devonian Appalachian Basin and not thrust-load-induced tectonics (Brett et al., 2011; Kohl et al., 2014) for the interval of the Union Springs Mbr., which represents a third-order sequence deposited over approximately three million years (Kohl et al., 2014). A revised Middle Devonian sea-level curve and correlated Appalachian Basin sequences are similar to sequences in the Michigan and Illinois Basins, suggesting that base-level changes were not confined to our area of study (Brett et al., 2011). Changes in relative sea level can be seen across the basin as opposed to just the foredeep located closest to the Acadian mountain range.

Conclusion

The Union Springs Mbr. does not appear to have been deposited under dominantly oxic conditions, in keeping with the presence of fine (millimeter-scale) laminations and the lack of bioturbation and articulated benthic body fossils in that unit. Redox sensitive ele-

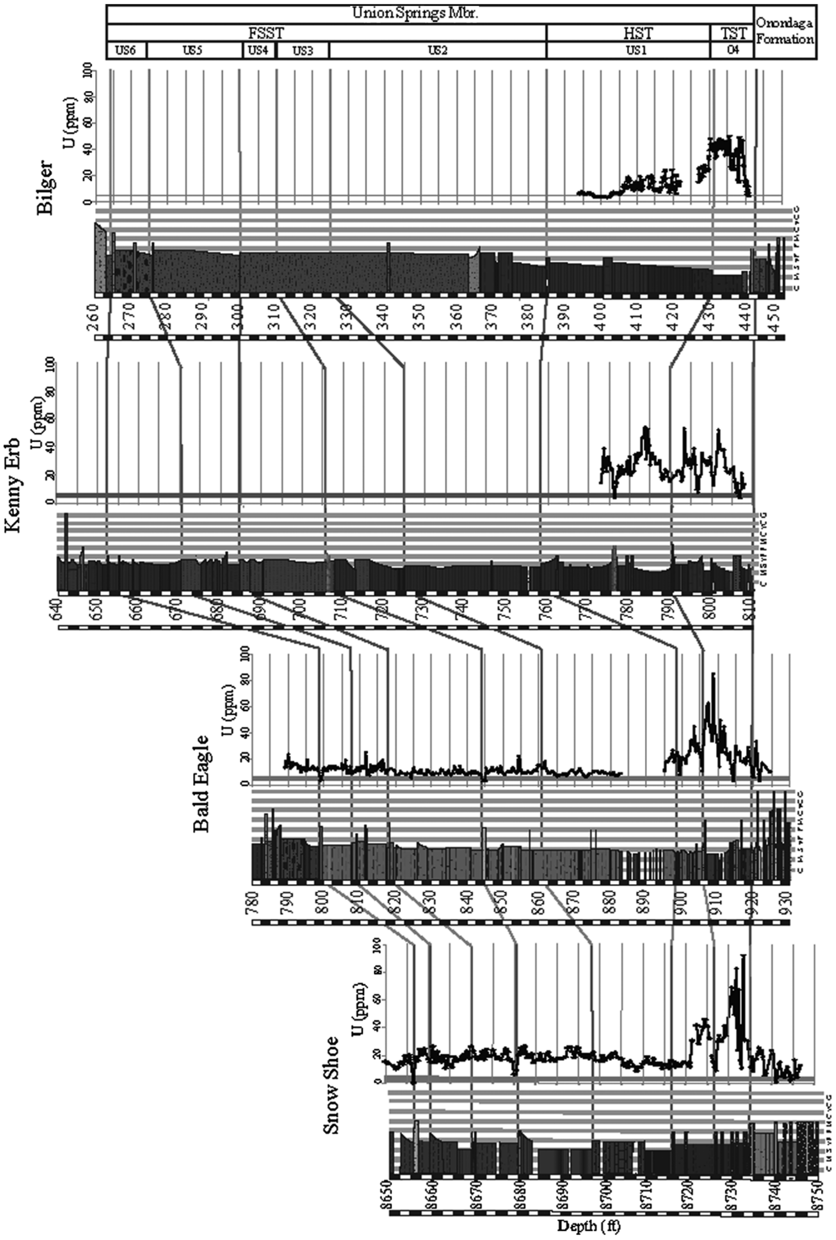

Figure 10. Transect of U concentrations in ppm from more proximal to more distal in the basin (right to left on the page), and correlated stratigraphy and parasequences; O4 and US1–US6 and correlating sequence stratigraphic interpretation; TST, HSST, and FSST (modified after Kohl et al., 2014). U concentrations are greatest in the Lower Union Springs Mbr. and decrease up section. Concentrations generally increase from more proximal to more distal in the basin.

ments further suggest that the Union Spring Mbr. was most likely deposited under deeper water conditions with a trend upward toward shallower and somewhat more oxic conditions. Appalachian Basin water masses were predominantly anoxic and most likely euxinic over the course of Union Springs Mbr. source rock deposition, as suggested by the observed correlation between U and Mo. Anoxia/euxinia was periodically interrupted by dysoxia, mainly in the most proximal sites, whereas stratified conditions appear to be interrupted less in the deepest portion of the basin.

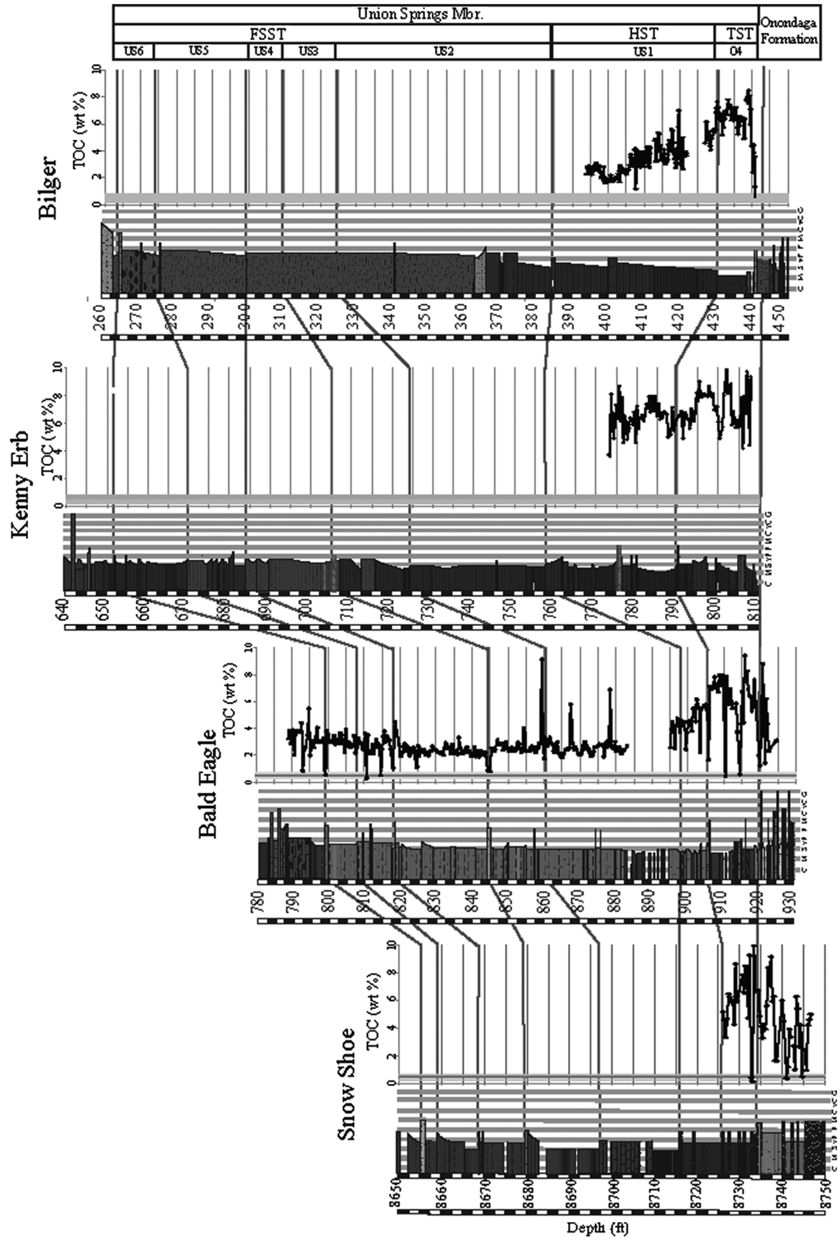

Figure 11. Transect of TOC concentrations in wt% from more proximal to more distal in the basin (right to left on page) and correlated stratigraphy and parasequences; O4, US1–US6, and correlating sequence stratigraphic interpretation; TST, HSST, and FSST (modified after Kohl et al., 2014). TOC concentrations are greatest in the Lower Union Springs Mbr. and decrease up section.

As deposition of the Union Springs Mbr. continued, a greater influx of clastic material occurred, suggesting a drop in relative sea level and/or progradation of deltaic sediments from the uplands to the east. Seven parasequences are observed in the geochemical data and are supported by previous lithologic and sequence stratigraphic interpretations that the Union Springs Mbr. of the Marcellus Formation and the underlying Onondaga Formation represent a third-order depositional sequence. The basal Union Springs Mbr. was deposited during the TST and HSST, whereas the upper Union Springs Mbr. represents the FSST.

Even though these smaller scale base-level changes (parasequences) may have been the result of several factors, such as climate fluctuations or tectonic subsidence, the interpretations are consistent with deposition of the Union Springs Mbr. under a predominantly stratified water column, particularly in the deepest portion of the basin. Sites more proximal to the ancient shoreline were influenced by changes in the location of rivers and shifting delta lobes. Changes in the relative sea level appear to have been the dominant control on depositional conditions, in which a drop in relative sea level would allow for oxygen to more easily reach sediments. Given the interpreted relative water depths of at least 100 m (330 ft) and the prevailing euxinic bottom water conditions, seasonal mixing would have rarely penetrated to the sediments during deposition of the basal Union Springs Mbr.

Acknowledgments

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Appendix A

Bulk geochemical results

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. 10

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
261.54			5.87		2.48	433.77		0.44		
261.71			6.98		3.10	422.60		0.57		
261.88			4.86		3.20	357.42		0.39		
262.04			4.28		2.52	471.25		0.40		
262.21			5.18		2.78	489.74		0.45		
262.38			4.89		3.30	622.32		0.31		
262.55			4.32		2.22	662.79		0.33		
262.71			6.35		3.64	643.29		0.49		
262.88			6.53		3.90	562.24		0.57	13.58	
263.05			6.60		4.47	376.78		0.40	32.25	
263.22			7.33		4.80	238.78		0.44	30.31	
265.91			1.92		2.38	778.71		0.19		
266.24			7.44		5.10	283.51		0.49	21.26	
266.41			7.52		4.64	332.10		0.51	20.34	
266.57			8.01		4.78	349.79		0.50	26.81	
267.08			6.35		4.47	327.97		0.48		
267.24			5.02		4.27	269.26		0.47	24.83	
267.41			3.62		1.71	1345.81		0.26	26.74	
267.58			4.76		1.81	1121.21		0.28		
268.58			5.65		4.61	234.40		0.44	24.22	
268.92			4.89		3.97	295.44		0.43	29.40	
269.45			1.13		2.47	979.83		0.19		
269.62			5.80		4.25	237.86		0.44	18.17	
269.79			7.53		4.55	255.37		0.47	15.29	
270.96			8.02		4.79	573.20		1.01	29.31	
271.13			7.80		4.88	306.04		0.57	27.63	
271.63			4.94		4.18	332.69		0.43	37.44	
271.79			5.17		3.73	301.47		0.37	29.09	
271.96			7.35		4.54	300.16		0.47	27.73	
272.13			6.81		4.67	287.47		0.47	32.94	
272.30			5.63		4.23	307.84		0.45	27.51	
272.46			6.30		4.34	305.78		0.46	30.04	
272.63			6.15		4.71	296.78		0.50	37.07	
272.80			6.72		4.17	386.03		0.42	25.89	
272.97			7.65		5.34	361.15		0.46	22.05	
273.13			7.30		4.80	363.39		0.52	14.53	
273.30			7.78		4.46	320.39		0.51	15.09	
273.47			6.71		4.12	441.88		0.49	14.37	
273.64			7.83		4.35	430.33		0.48	16.94	
273.80			6.15		4.03	506.84		0.43	25.48	
273.97			7.76		4.96	333.06		0.52	20.15	
274.14			7.30		4.91	347.64		0.51	20.69	
274.30			6.10		4.73	306.01		0.46	18.37	

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
274.64			7.35		4.56	314.92		0.51	25.19	
274.81			7.21		5.16	306.99		0.55	29.46	
274.97			5.49		3.70	437.75		0.39	21.73	
275.31			6.34		4.34	370.36		0.52	24.64	
275.48			7.04		4.63	408.46		0.51	21.47	
275.64			7.17		4.26	370.30		0.58	16.13	
275.81			6.95		4.49	417.74		0.49	22.04	
275.98			2.58		1.73	518.44		0.23		
276.14			4.40		4.31	416.54		0.43	27.50	
276.31			5.13		4.38	517.25		0.49	28.81	
276.48			5.83		4.10	492.00		0.48	29.73	
276.65			6.05		4.40	360.91		0.56	26.10	
276.81			5.97		4.06	326.59		0.47	16.88	
276.98			6.77		4.27	258.58		0.56		
277.36			6.93		4.44	269.38		0.57	14.71	
277.53			5.82		3.79	343.71		0.48	15.98	
277.70			6.01		3.76	398.80		0.52	12.33	
277.86			4.83		3.43	388.77		0.44	18.40	
278.03			4.95		3.71	405.49		0.43	26.27	
278.20			2.62		2.53	1300.64		0.31		
278.37			4.84		3.76	643.64		0.44	18.88	
278.53			5.84		4.45	319.97		0.48	20.33	
278.70			5.15		3.33	294.89		0.41	20.13	
278.87			4.18		3.15	348.54		0.39	14.39	
279.04			6.56		4.48	303.88		0.52	26.29	
279.20			6.21		4.53	250.95		0.51	20.03	
279.37			6.38		4.68	353.08		0.50	20.49	
279.54			6.17		4.42	220.15		0.49	19.28	
279.70			4.65		3.87	363.96		0.45	21.75	
279.87			5.58		3.99	266.80		0.48	26.82	
280.04			4.84		3.39	362.29		0.43	18.08	
280.21			3.27		2.85	645.39		0.33	17.53	
280.37			4.95		3.93	311.18		0.45	18.61	
280.54			7.29		4.45	316.59		0.56	13.25	
280.71			7.30		4.44	385.03		0.52	14.11	
280.88			4.77		3.92	377.08		0.43	19.95	
281.04			4.58		3.61	325.17		0.48	13.53	
281.21			5.68		3.51	370.13		0.47		
281.38			3.67		2.63	423.69		0.33		
281.55			7.11		4.31	335.79		0.53	21.91	
281.71			5.54		3.63	318.04		0.50	14.96	
281.88			6.89		4.41	306.51		0.58	22.43	
282.05			6.23		4.21	391.34		0.59	15.94	
282.21			6.17		3.99	448.75		0.57	14.13	
282.55			7.14		4.36	370.32		0.56	14.37	
282.72			6.94		4.01	454.30		0.60		
282.88			5.51		4.34	337.31		0.59	21.14	
283.05			5.35		3.81	405.84		0.49	13.73	
283.22			7.29		4.17	440.30		0.63		

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
283.39			4.81		3.80	427.71		0.48	16.81	
283.89			5.61		3.59	503.10		0.50	18.19	
284.05			3.91		3.34	345.79		0.48	24.32	
284.22			5.44		3.67	344.96		0.50	23.82	
284.39			6.03		3.73	359.86		0.52	19.03	
284.56			6.84		3.97	367.81		0.49	19.94	
284.78			5.65		3.45	418.59		0.45	12.53	
284.95			6.52		3.73	286.88		0.53	20.55	
285.11			4.46		3.37	370.43		0.42	16.49	
285.28			5.51		3.45	291.18		0.49	21.63	
285.45			6.82		3.96	316.33		0.54	22.64	
285.62			7.33		4.24	283.50		0.60	23.07	
285.78			5.61		3.99	275.12		0.46	18.87	
285.95			7.06		4.29	326.61		0.51	23.66	
286.12			6.76		4.07	341.10		0.55	16.04	
286.29			5.07		3.44	304.86		0.43		
286.45			6.79		4.43	225.52		0.56	14.97	
286.62			7.46		4.53	416.44		0.58	22.19	
286.79			3.82		3.31	332.87		0.44	21.61	
286.96			6.28		4.26	369.98		0.54	24.03	
287.12			5.74		3.21	335.19		0.55	15.61	
287.29			6.63		3.77	323.22		0.54	18.76	
287.46			6.83		3.97	383.18		0.56	19.47	
287.62			5.20		3.61	408.44		0.44	16.97	
287.79			3.45		3.65	356.86		0.52	29.29	
288.13			7.57		4.56	307.30		0.54	21.09	
288.29			7.05		4.14	229.43		0.56	18.59	
288.46			5.60		4.09	286.15		0.47	24.19	
288.63			5.29		3.45	367.48		0.43	15.43	
288.80			6.94		4.03	302.59		0.55	20.99	
288.96			7.07		4.08	318.45		0.55	29.38	
289.13			5.52		3.70	268.38		0.47	28.47	
289.30			5.72		4.44	338.86		0.49	32.74	
289.46			6.89		4.22	341.48		0.54	19.24	
289.97			6.10		4.04	312.11		0.54	14.74	
290.13			5.08		3.88	297.28		0.48	20.67	
290.30			5.41		4.04	287.41		0.50	22.14	
290.47			6.71		4.03	308.38		0.51	20.01	
290.64			6.40		3.94	380.54		0.49	22.66	
290.80			4.40		2.99	356.50		0.37	13.95	
290.97			4.31		3.43	251.88		0.43	28.41	
291.14			6.53		4.00	311.10		0.45	28.17	
291.31			7.49		4.70	345.26		0.55	28.24	
291.47			6.40		4.10	354.42		0.48	20.30	
291.64			7.40		4.53	332.88		0.56	22.76	
291.81			5.94		4.36	564.59		0.46	16.85	
291.97			5.37		3.84	593.20		0.40	17.63	
292.14			5.73		3.89	279.11		0.51	30.35	
292.31			5.96		3.60	349.22		0.39	25.78	

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
292.48			6.47		3.97	241.40		0.48	28.46	
292.64			6.08		4.13	243.24		0.49	23.64	
292.81			6.59		4.19	329.24		0.54	31.79	
293.19			7.53		4.28	384.42		0.51	30.75	
293.35			6.32		3.90	252.51		0.51	30.48	
293.52			6.65		3.90	311.66		0.51	42.39	
293.69			7.27		4.16	336.21		0.52	41.45	
293.85			6.71		3.82	258.53		0.49	27.23	
294.02			6.64		4.38	328.29		0.53	31.87	
294.19			5.58		4.36	325.34		0.49	24.70	
294.36			5.53		3.81	313.13		0.44	16.45	
294.52			6.18		3.86	255.69		0.44	25.58	
294.69			5.58		3.75	361.57		0.46	26.61	
294.86			7.09		4.42	299.69		0.56	28.29	
295.03			6.72		4.56	415.61		0.54	27.07	
295.19			4.70		3.26	344.52		0.42	21.02	
295.36			4.97		3.64	359.35		0.45	37.23	
295.53			5.83		4.41	340.19		0.49	40.26	
295.70			4.74		4.31	310.66		0.40	38.45	
295.86			5.92		4.23	347.64		0.48	41.20	
296.03			5.47		4.06	315.62		0.49	31.35	
296.20			4.45		3.55	297.76		0.50	22.83	
296.36			4.28		3.65	389.50		0.33	21.94	
296.53			4.60		3.97	326.72		0.51	35.37	
296.70			4.49		3.93	351.00		0.47	30.06	
296.87			5.44		5.14	334.01		0.47	32.24	
297.03			5.84		3.93	351.96		0.45	26.15	
297.20			5.72		3.91	348.18		0.42	16.75	
297.37			6.99		4.51	292.58		0.51	28.96	
297.54			5.68		4.24	252.22		0.46	35.78	
297.70			4.97		4.29	314.41		0.45	51.17	
297.87			8.53		5.01	353.86		0.52	35.04	
298.21			4.96		4.07	266.34		0.48	28.98	
298.37			6.37		4.06	390.86		0.47	16.55	
298.54			7.26		4.62	316.83		0.55	30.53	
298.71			7.66		4.67	314.38		0.53	41.82	
298.87			6.99		4.15	325.27		0.44	28.93	
299.04			6.13		3.64	316.03		0.40	23.43	
299.21			6.20		4.46	320.93		0.48	54.01	
299.38			6.54		4.05	207.75		0.49	33.97	
299.54			5.10		3.80	288.99		0.39	32.82	
300.60			6.68		4.35	295.99		0.47	21.37	
300.77			5.24		4.04	210.51		0.40	18.67	
300.94			5.79		3.82	323.48		0.45	24.32	
301.11			5.89		4.25	354.72		0.48	18.00	
301.44			6.45		3.95	272.83		0.45	23.98	
301.61			5.96		3.92	297.28		0.49	17.67	
305.17			5.28		3.97	320.08		0.50	28.95	

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
305.34			6.07		4.15	252.23		0.47	24.35	
305.84			6.80		4.09	316.12		0.51	17.20	
306.34			5.44		3.76	258.35		0.44	22.87	
307.04			4.51		3.73	308.86		0.47	30.62	
307.20			3.63		3.08	168.17		0.41	24.40	
308.04			4.16		4.93	383.63		0.29	20.70	
308.21			7.39		3.94	266.37		0.49	22.95	
308.38			5.68		3.90	306.17		0.44	20.90	
308.54			5.20		4.04	295.22		0.44	20.11	
308.71			4.27		4.72	152.96		0.42	22.40	
308.88			6.30		3.88	297.75		0.45	15.98	
309.04			2.24		1.52	1291.11		0.18		
309.21			3.29		3.54	467.24		0.33		
309.38			4.26		3.76	422.27		0.36	14.89	
309.55			5.92		4.08	291.84		0.50	33.22	
309.71			6.65		5.65	267.29		0.46	17.35	
309.88			5.41		3.74	247.51		0.41	29.14	
310.05			6.99		4.17	246.58		0.50	29.97	
310.22			6.62		7.10	251.11		0.44	14.46	
310.38			5.78		4.19	245.44		0.43	19.65	
310.55			6.57		3.82	297.42		0.45	12.54	
310.72			6.57		5.86	299.36		0.37	26.69	
310.89			6.21		3.98	269.78		0.45	15.74	
311.05			6.36		3.95	294.41		0.50	13.84	
311.22			4.93		3.87	385.59		0.36		
311.39			6.64		3.86	415.83		0.45		
311.55			6.54		3.95	443.32		0.50	11.48	
311.73			5.14		3.36	288.70		0.43	13.75	
311.90			4.11		3.54	473.09		0.38		
312.07			3.56		3.19	429.32		0.37	19.06	
312.23			2.85		3.02	499.99		0.32	17.57	
312.40			3.41		2.86	342.31		0.41	20.89	
312.57			5.54		3.51	284.17		0.53	20.10	
312.74			8.15		4.36	368.73		0.57	19.94	
312.90			7.34		3.84	368.80		0.50	17.67	
313.07			5.56		3.54	317.77		0.44	14.49	
313.24			6.18		3.74	309.33		0.50	13.87	
313.40			4.67		3.60	302.51		0.42	16.76	
313.57			5.44		3.73	381.82		0.52		
313.66			6.00		3.52	281.55		0.53		
313.83			5.73		3.81	380.28		0.47	14.27	
314.00			4.70		3.54	489.17		0.39		
314.16			5.17		3.58	296.65		0.49	21.36	
314.33			4.36		3.83	397.45		0.37		
314.50			5.21		3.42	322.37		0.51	13.69	
314.66			5.36		3.44	386.71		0.51	19.04	
314.83			6.05		3.65	322.30		0.48	15.28	
315.00			3.21		2.95	615.37		0.41		

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
315.17			6.83		3.74	345.02		0.49	13.34	
315.33			5.37		3.46	306.52		0.50	14.95	
315.50			4.61		3.26	351.42		0.49	20.26	
315.67			5.58		3.52	344.03		0.49	19.23	
315.84			6.49		3.88	315.80		0.50	16.30	
316.00			3.74		2.97	276.55		0.40	24.47	
316.67			6.28		3.69	362.31		0.49	12.52	
316.84			6.50		3.78	361.21		0.55	12.34	
317.01			6.96		4.12	288.21		0.53	18.48	
317.17			5.17		3.48	364.97		0.48	19.91	
317.34			4.96		3.50	394.86		0.48	14.24	
317.68			4.51		3.17	317.28		0.47	18.37	
317.84			6.05		3.50	379.13		0.51	16.13	
318.01			5.74		3.81	343.38		0.53	19.57	
318.18			7.82		4.20	286.79		0.56	17.58	
318.35			6.52		3.66	324.40		0.54	14.74	
318.68			4.70		3.32	235.26		0.39	20.18	
318.75			4.60		3.60	321.30		0.49	19.99	
318.92			5.68		3.39	349.88		0.52	22.55	
319.08			6.11		3.71	372.19		0.56	20.02	
319.25			5.43		3.50	387.25		0.48	17.33	
319.42			6.10		3.68	407.78		0.47	15.59	
319.59			5.07		3.87	511.53		0.47	17.64	
319.75			6.22		3.76	282.36		0.54	17.43	
319.92			5.88		3.58	415.57		0.53	17.73	
320.09			7.00		3.87	306.49		0.59	15.39	
320.26			4.48		3.42	496.16		0.47	20.97	
320.42			3.86		3.05	635.50		0.36	15.21	
320.59			5.24		3.64	319.31		0.49	18.95	
320.76			4.68		3.53	318.13		0.51	25.75	
320.92			6.98		3.90	417.42		0.54	18.27	
320.95			6.06		3.55	297.58		0.49	17.29	
321.09			5.96		3.95	317.67		0.43	26.50	
321.26			6.58		4.03	421.23		0.55	13.82	
321.43			4.34		3.45	318.23		0.50	20.45	
321.59			5.94		3.43	336.97		0.49	16.49	
321.76			4.98		3.59	384.58		0.83	20.70	
321.93			6.19		3.81	335.67		0.52	19.19	
322.09			6.01		3.63	312.10		0.53	17.15	
322.26			5.07		3.46	304.86		0.48	17.49	
322.43			7.03		4.09	312.36		0.57		
323.27			4.55		3.84	309.42		0.48		
323.43			7.72		4.49	370.32		0.53	21.64	
323.60			2.90		3.01	1057.06		0.26		
323.77			2.91		1.71	1336.02		0.30		
323.93			4.66		3.26	460.70		0.44	17.91	
324.10			5.87		3.82	342.18		0.51	19.71	
324.27			4.69		3.55	221.13		0.47	29.04	

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
324.44			4.44		3.26	243.60		0.48	20.29	
324.60			5.73		4.03	351.10		0.49	20.02	
324.77			4.38		3.61	304.79		2.04	17.81	
324.94			6.94		4.08	301.23		0.52	14.62	
325.11			5.77		3.79	276.09		0.45	17.62	
325.27			6.74		4.05	321.66		0.51	14.18	
325.44			6.60		3.63	290.77		0.51	11.71	
325.61			5.80		3.99	355.37		0.47	14.81	
325.61			4.66		2.22	1040.30		0.35		
325.82			6.60		3.73	385.58		0.52	12.37	
325.99			5.41		3.34	357.68		0.44	16.76	
326.15			4.94		3.18	391.35		0.41	18.19	
326.32			6.57		3.80	354.54		0.50	23.39	
326.49			6.03		3.90	234.48		0.48	23.03	
326.66			6.47		4.02	256.25		0.53	23.71	
326.82			6.69		4.09	321.67		0.52	19.69	
326.99			6.61		3.77	274.60		0.50	17.53	
327.16			6.15		5.31	296.66		0.45	19.67	
327.33			7.55		4.02	274.70		0.59	15.32	
327.49			7.75		4.98	299.60		0.61	16.80	
327.66			6.30		3.97	322.13		0.59	15.02	
327.83			6.41		3.71	249.32		0.49	15.12	
327.86			5.58		3.03	315.04		0.45	12.89	
327.96			7.56		4.31	374.98		0.57	13.69	
328.13			6.39		4.02	291.35		0.53	22.13	
328.30			7.09		4.14	256.36		0.52		
328.47			6.78		3.89	306.49		0.57		
328.63			6.21		3.78	304.07		0.53		
328.80			8.50		4.34	298.10		0.55		
328.97			4.79		4.18	563.14		0.41		
329.13			7.45		4.05	337.86		0.53		
329.30			6.31		3.88	383.09		0.54	19.70	
329.47			6.76		3.62	354.75		0.53	16.69	
329.64			5.20		3.35	294.83		0.51	22.68	
329.80			6.68		3.84	284.16		0.52	15.70	
329.97			5.08		3.52	433.29		0.43	15.27	
330.14			6.20		3.78	341.90		0.50	23.33	
330.31			5.47		3.67	313.35		0.49	25.44	
330.47			5.40		4.08	368.69		0.44	18.86	
331.48			5.42		4.08	270.99		0.48	22.80	
331.49			8.13		4.50	380.82		0.55	15.36	
331.67			7.03		4.60	344.84		0.47		
331.83			6.09		4.55	262.27		0.47	17.22	
332.00			5.73		4.29	310.66		0.52	15.20	
332.17			5.72		4.39	269.98		0.48	20.52	
332.34			7.93		4.80	356.82		0.57	16.94	
332.50			4.59		3.38	368.55		0.45	17.02	
332.67			6.15		3.91	309.61		0.60	17.32	

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
332.84			6.07		4.17	317.22		0.49	15.76	
333.00			6.16		4.08	303.95		0.49	14.78	
333.17			5.38		4.08	311.75		0.49	15.91	
333.34			6.98		4.19	319.70		0.56		
333.51			7.61		4.11	310.90		0.54		
333.54			6.82		4.20	295.81		0.51	15.09	
333.61			6.51		4.24	388.17		0.46		
333.78			6.04		3.79	320.71		0.46		
333.95			8.28		4.47	362.68		0.51		
334.11			6.97		4.39	332.33		0.53	15.55	
334.28			7.74		4.22	299.22		0.53	14.16	
334.45			6.39		3.97	325.05		0.50	15.80	
334.61			6.56		3.86	284.75		0.48	15.24	
334.78			5.83		3.97	273.65		0.51	15.33	
334.95			6.97		3.92	317.08		0.51	13.31	
335.12			4.98		3.50	246.37		0.45	17.63	
335.28			5.77		3.83	377.27		0.47	14.95	
335.45			4.83		3.54	348.42		0.45	16.01	
335.62			5.45		3.66	256.45		0.46	15.16	
335.79			5.29		4.02	309.33		0.44	16.50	
335.95			3.85		4.18	439.39		0.38	14.75	
336.12			4.48		3.55	303.31		0.44	20.94	
336.29			5.14		3.81	275.78		0.41	17.64	
336.46			5.48		3.74	326.11		0.49	16.92	
336.62			5.93		4.18	264.35		0.52	21.88	
336.79			6.16		3.93	219.61		0.52	17.31	
338.13			3.94		2.57	765.64		0.36	12.31	
338.13			6.78		4.17	329.72		0.59		
338.26			3.28		3.46	690.49		0.30		
338.43			6.89		4.27	336.04		0.60	12.42	
338.60			5.74		4.49	297.69		0.54		
338.77			6.88		4.29	359.47		0.56	12.85	
338.93			5.83		3.91	320.77		0.60	15.91	
339.10			5.15		4.03	509.12		0.37	11.26	
339.27			6.11		3.92	297.72		0.58	15.26	
339.44			6.33		4.00	349.22		0.59	15.01	
339.60			6.13		4.28	331.30		0.59	16.35	
339.77			5.35		3.64	365.57		0.53	17.20	
339.94			6.10		3.84	302.52		0.50	17.53	
340.10			5.41		3.66	281.23		0.56	15.45	
340.27			6.64		4.29	396.50		0.59	12.97	
340.30			5.93		4.24	447.79		0.53	13.27	
340.50			6.77		4.14	365.59		0.62	13.08	
340.67			3.57		5.22	868.20		0.25		
340.84			6.60		4.42	293.52		0.52	17.47	
341.34			5.87		3.91	332.78		0.51	21.04	
341.50			3.55		4.52	702.77		0.34		
341.67			4.94		3.74	290.33		0.52	17.25	

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
341.84			5.42		3.74	304.18		0.76	22.41	
342.01			5.92		4.13	349.56		0.61	19.80	
342.17			4.92		3.46	364.45		0.47	14.45	
342.34			5.06		3.76	327.87		0.56	20.87	
342.51			5.72		3.91	403.59		0.54	17.75	
342.68			5.27		3.74	346.76		0.55	15.53	
342.84			4.31		3.34	236.52		1.74	19.85	
343.01			5.54		3.63	266.30		0.51		
343.18			4.79		3.70	252.15		0.50	23.79	
343.35			5.72		4.10	324.42		0.57	24.17	
343.51			5.60		3.70	307.72		0.53	14.77	
343.68			5.33		3.57	307.85		0.53		
343.85			4.41		3.65	212.93		1.12	24.80	
344.01			5.15		3.86	260.42		0.50	25.94	
344.35			6.48		4.27	332.87		0.57	25.72	
344.52			5.86		4.15	308.28		0.54	27.68	
344.68			6.01		4.08	306.71		0.54	29.50	
344.85			5.33		4.31	328.02		1.18	27.07	
345.02			6.62		4.17	361.32		0.54	23.15	
345.02			7.08		4.22	308.13		0.54	18.91	
345.12			7.22		4.22	411.42		0.61	17.61	
345.29			6.36		4.30	300.84		0.58	17.24	
345.46			6.71		4.11	297.45		0.55	20.72	
345.62			6.01		3.76	371.72		0.52	17.38	
345.79			7.23		4.39	400.88		0.61	12.44	
346.29			6.75		4.38	290.17		0.58	13.18	
346.46			4.88		3.85	338.97		0.46	19.72	
346.63			6.41		4.05	343.17		0.56	15.49	
346.80			6.36		4.29	418.36		0.57	22.12	
346.96			7.01		4.20	404.54		0.55	19.95	
347.13			8.49		4.91	338.87		0.62	18.08	
347.30			7.33		4.52	326.41		0.57	18.51	
350.83			6.63		3.59	360.42		0.53	17.05	
351.16			5.57		3.68	432.76		0.50	12.01	
351.33			6.24		3.67	428.35		0.55	15.29	
351.50			5.81		3.85	629.06		0.56		
352.00			5.63		3.20	426.69		0.49	16.06	
352.17			4.13		3.82	863.51		0.30	13.07	
352.33			6.10		3.63	331.59		0.53	17.44	
352.50			5.94		3.88	415.34		0.55	22.45	
352.67			6.39		3.97	406.22		0.54	23.69	
353.00			7.40		4.32	369.63		0.60	18.79	
353.17			6.30		4.15	375.12		0.56	20.54	
353.34			5.72		3.99	325.65		0.52	14.05	
353.51			6.39		4.38	407.94		0.66	15.10	
353.67			6.39		3.98	311.40		0.55	17.82	
353.84			6.97		4.03	324.02		0.59		
354.01			3.70		2.99	226.89		3.82	15.47	

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
354.18			7.15		3.90	312.41		0.60	13.48	
354.34			6.64		3.61	340.55		0.63	17.16	
354.51			4.94		3.71	539.54		0.46	14.74	
354.68			4.67		3.51	611.09		0.39		
354.84			5.83		3.48	472.35		0.51	13.15	
355.01			5.62		3.45	295.25		1.66	19.93	
355.18			5.92		3.46	263.75		0.54	18.67	
355.35			6.83		3.95	298.57		0.49	15.43	
355.51			6.93		3.93	313.17		0.54	19.53	
355.68			6.60		3.60	228.02		0.49	15.47	
355.85			6.45		3.88	365.24		0.52	22.38	
356.02			5.03		3.49	406.35		0.46	19.30	
356.25			5.75		3.73	306.43		0.51	20.79	
356.41			6.88		3.94	298.37		0.55	20.27	
356.58			4.86		3.42	283.66		0.36		
356.75			6.13		3.67	341.24		0.55	16.26	
356.91			6.50		3.57	427.91		0.60	16.78	
357.08			5.83		5.45	634.16		0.51		
357.25			5.50		3.25	405.98		0.49	17.56	
357.42			5.48		3.53	270.12		0.53	15.41	
357.58			5.45		3.77	286.82		0.51	19.04	
357.75			5.53		3.49	294.71		0.51	18.27	
358.09			5.66		3.35	294.11		0.48	18.79	
358.42			5.59		3.38	248.20		0.54	20.99	
358.59			3.66		4.63	584.12		0.32		
358.88			6.25		3.44	328.78		0.56	15.05	
359.04			4.27		4.26	614.48		0.36		
359.21			5.05		2.99	267.41		3.94	15.48	
359.38			7.45		3.90	309.47		0.54	20.26	
359.54			5.77		3.21	284.76		0.55	15.85	
359.71			5.97		3.19	206.78		0.51	15.14	
359.88			5.73		3.72	304.16		0.52	24.73	
360.05			3.68		2.88	294.00		0.44	19.44	
360.21			7.23		3.37	307.14		0.41	14.51	
360.38			6.04		3.50	275.81		0.58	23.51	
360.55			5.74		3.94	349.42		0.52	22.09	
360.72			4.56		3.38	375.28		0.53	21.05	
360.88			5.76		3.28	327.39		0.50	19.58	
361.05			6.31		3.51	313.71		0.49	21.22	
361.22			5.12		4.42	351.85		0.48	22.41	
361.39			5.09		5.01	268.50		0.44	31.01	
361.55			4.44		3.37	396.64		0.42	22.70	
361.72			7.23		4.43	381.98		0.55	27.85	
361.89			6.52		5.46	374.91		0.50	39.76	
362.05			6.89		4.54	313.73		0.54	32.62	
362.22			7.48		4.83	275.53		0.52	30.54	
362.39			6.08		4.78	334.68		0.54	25.63	

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
362.72			7.98		5.19	325.64		0.57	33.28	
363.06			7.26		7.33	274.60		0.44	56.21	
363.23			6.95		4.73	334.95		2.05	35.82	
363.39			6.61		4.97	310.47		0.49	39.94	
363.56			8.20		4.89	359.58		0.55	26.60	
363.73			7.84		4.88	298.88		0.54	27.59	
364.08			7.70		4.78	323.24		0.55	24.42	
364.25			7.97		6.01	315.28		0.56	33.82	
364.42			7.43		5.33	364.86		0.54	34.81	
364.59			7.41		6.10	310.26		0.54	22.11	
364.75			6.55		4.85	350.04		0.54	27.37	
365.26			7.49		4.58	318.21		0.51	25.97	
365.42			7.39		4.16	348.73		0.51	17.39	
365.59			4.98		3.80	481.55		0.38	30.19	
365.76			5.55		3.90	470.32		0.48	32.76	
365.92			4.83		4.86	789.00		0.42	33.79	
366.09			5.57		4.40	308.75		0.49	27.69	
366.26			4.32		4.08	514.72		0.40	36.65	
366.43			4.14		4.23	769.83		0.40	20.37	
366.59			3.72		4.08	670.79		0.41	23.96	
367.18			7.62		5.60	349.61		0.56	28.60	
367.34			8.63		5.37	292.47		0.58	23.61	
367.51			8.15		4.98	307.87		0.56	26.59	
367.68			7.73		4.85	347.50		0.56	24.42	
367.85			8.00		4.98	381.37		0.53	27.48	
368.01			8.73		5.20	374.25		0.55	33.64	
368.18			7.10		4.92	266.92		0.57	38.17	
368.35			8.38		5.57	326.95		0.59	37.94	
368.52			7.28		4.88	251.72		0.56	37.84	
368.68			6.70		6.48	222.19		0.52	52.21	
368.85			5.17		6.82	245.43		0.39	62.29	
369.02			5.89		8.00	240.16		0.42	67.48	
369.19			5.59		5.35	295.10		0.44	42.28	
369.35			6.11		4.90	208.62		0.43	30.11	
371.19			5.24		8.24	465.85		0.77	68.30	
371.36			5.99		4.51	300.44		0.57	34.47	
371.53			7.82		4.61	383.42		0.61	24.66	
372.68			6.76		4.46	364.52		0.47	25.43	
373.52			4.61		4.02	328.97		0.49	37.13	
373.69			4.74		3.97	275.34		0.44	37.46	
374.02			6.12		4.15	344.07		0.47	47.40	
374.19			6.98		4.75	259.71		0.43	56.08	
374.41			7.80		4.69	361.84		0.48	39.63	
375.08			7.71		4.53	343.78		0.52	20.76	
376.08			7.04		4.63	365.23		0.53	32.05	
376.25			5.26		5.03	381.53		0.57	49.87	
376.42			7.11		4.46	366.74		0.55	28.78	

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
376.75			7.79		4.59	384.94		0.62	34.02	
376.92			8.14		5.04	333.76		0.58	34.08	
377.08			8.20		5.12	328.85		0.53	30.17	
377.25			8.86		5.07	434.54		0.55	26.56	
377.42			6.28		4.52	361.20		0.49	22.49	
377.59			6.86		4.58	361.56		0.55	29.45	
377.75			6.48		4.44	366.59		0.52	35.92	
377.92			7.85		4.42	416.00		0.51	26.22	
378.09			6.00		4.13	366.58		0.51	41.22	
378.26			5.79		3.86	362.86		0.45	35.92	
378.42			6.62		4.06	332.55		0.51	57.51	
379.37			5.86		4.18	249.83		0.47	50.14	
380.21			4.92		3.84	348.51		0.46	57.05	
380.54			5.33		4.14	283.21		0.41	55.40	
380.71			5.17		4.32	344.28		0.44	55.38	
380.88			5.91		4.81	360.83		0.44	46.76	
381.04			5.01		3.97	308.75		0.42	38.50	
381.21			5.09		4.08	425.10		0.53	45.20	
381.38			7.43		4.55	483.01		0.60	38.56	
381.73			6.11		3.96	450.50		0.50	41.55	
381.89			6.34		4.32	383.44		0.63	41.58	
382.06			6.48		4.31	389.13		1.46	34.57	
382.23			7.41		4.58	387.15		0.50	35.85	
382.39			6.76		4.33	303.24		0.51	46.42	
382.56			6.83		4.38	331.34		0.47	45.64	
382.73			6.56		4.51	336.54		0.50	51.92	
382.90			4.73		4.74	358.54		0.45	47.54	
383.06			5.65		4.29	360.64		0.62	54.48	
383.23			7.32		4.86	319.02		0.51	60.96	
383.40			7.37		4.36	359.48		0.51	68.20	
383.57			6.80		4.65	345.53		0.45	55.97	
383.73			6.25		4.16	336.31		0.49	70.40	
383.90			6.39		4.38	347.00		0.41	71.33	
384.07			6.15		4.52	314.95		0.51	76.19	
384.24			7.50		5.19	267.06		0.49	44.39	
384.40			7.84		4.63	318.78		0.46	35.53	
384.90			7.80		4.57	399.32		0.47	21.90	
385.07			5.45		3.50	392.41		0.49	28.91	
385.24			6.02		3.50	538.73		0.44	25.72	
385.41			6.50		3.81	453.25		0.43	28.59	
385.57			3.93		3.27	389.60		0.36	36.56	
385.74			5.00		4.14	321.01		0.39	56.96	
385.91			6.75		4.33	355.66		0.41	57.89	
386.08			5.38		4.17	373.93		0.43	49.46	
386.24			7.55		4.74	298.63		0.49	34.40	
386.41			7.54		4.44	352.02		0.45	37.74	
386.83			5.93		4.17	349.92		0.41	45.04	

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
386.99			5.58		4.17	253.14		0.50	25.33	
387.16			5.33		3.96	292.77		0.50	28.72	
387.33			6.36		4.24	356.14		0.45	32.77	
387.50			6.82		4.32	336.45		0.49	43.59	
387.66			4.62		3.84	305.30		0.37	43.01	
387.83			5.78		3.94	289.54		0.45	49.25	
388.00			6.17		4.02	318.82		0.45	44.61	
388.16			4.99		4.06	245.96		0.39	39.04	
388.33			7.13		5.02	252.49		0.47	27.59	
389.00			7.60		4.39	369.18		0.48	27.69	
389.17			6.08		5.93	360.30		0.43	29.13	
389.34			7.13		4.35	314.59		0.49	26.09	
389.50			7.26		4.12	379.65		0.48	21.28	
389.82			6.70		4.20	309.13		0.46	28.65	
389.99			5.66		3.97	346.23		0.39	31.02	
390.15			8.46		4.45	426.56		0.50	31.30	
390.32			7.15		4.04	439.41		0.47	37.96	
390.49			6.83		3.97	277.89		0.47	31.47	
390.66			3.71		4.67	303.26		4.17	37.34	
390.82			5.66		3.92	309.13		0.42	48.10	
390.99			6.83		4.11	334.65		0.42	41.36	
391.16			6.65		4.19	366.94		0.45	45.74	
391.32			6.00		4.26	290.99		0.43	42.43	
391.49			5.62		4.03	252.6		0.45	36.12	
391.66			5.23		3.73	268.4		2.75	34.00	
391.83			5.65		3.96	382.73		0.41	43.48	
391.99			6.46		4.10	248.49		0.42	41.35	
392.16			6.10		3.78	358.91		0.42	41.12	
392.33			7.23		4.05	419.14		0.41	41.46	
392.50			5.63		3.98	292.19		0.42	41.70	
392.66			6.99		4.20	306.54		0.40	33.90	
392.83			6.65		3.94	395.05		0.40	42.99	
393.00			7.25		4.04	403.24		0.49	30.80	
393.17			6.93		4.10	326.57		0.45	27.92	
393.33			5.83		3.70	309.04		0.46	32.28	
393.50			5.72		4.16	341.35		0.46	21.64	
393.67			6.06		4.15	245.11		0.49	24.28	
393.83			7.15		4.46	400.19		0.45	24.86	
394.00	2.26	7.25	6.55	933	3.97	230	0.03	0.4	27	6.39
394.17	2.71	6	7.01	998	3.9	230	0.03	0.43	33	7.4
394.33	2.85	6	6.95	985	3.69	210	0.03	0.42	35	7.57
394.50	2.7	5	7.13	1020	3.64	210	0.03	0.43	32	7.93
394.67	2.85	5.25	6.97	986	3.67	200	0.03	0.41	35	7.83
394.83	2.7	4.75	7.11	1010	3.77	200	0.03	0.42	31	7.61
395.00	2.38	4.25	6.71	941	7.66	200	0.03	0.41	32	6.92
395.17	2.44	5.35	7.19	979	3.97	220	0.03	0.43	28	6.56
395.33	2.62	5.5	7.19	989	3.84	220	0.03	0.44	26	6.39

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
395.50	2.24	4.75	7.03	977	4.77	220	0.03	0.42	27	6.01
395.67	2.48	6.25	7.14	1040	4.21	210	0.03	0.43	28	6.23
395.83	2.8	6.5	7.51	1050	3.97	220	0.03	0.44	28	6.65
396.00	2.63	6.25	7.27	1020	3.93	210	0.03	0.43	26	6.38
396.17	2.87	6.25	7.41	1070	3.92	210	0.04	0.43	26	6.61
396.33	2.6	6.5	7.68	1040	4.24	230	0.03	0.45	28	6.77
396.50	2.58	7.25	7.23	1060	4.05	230	0.04	0.43	29	7.05
396.67	3.09	9	7.22	1000	3.83	240	0.04	0.42	31	7.48
396.83	2.72	9.75	7.38	1020	3.92	240	0.04	0.44	28	7.04
397.00	2.86	10	7.17	992	3.71	240	0.04	0.42	28	6.79
397.17	2.71	12.75	7.15	994	3.63	270	0.04	0.42	27	6.89
397.33	2.61	11.25	7.19	993	3.9	240	0.04	0.42	24	6.21
397.50	2.84	10.5	7.27	992	3.4	260	0.04	0.43	21	5.81
397.67	2.89	12	7.05	971	3.29	250	0.04	0.41	21	5.89
397.83	2.41	14.75	6.96	954	3.49	290	0.06	0.4	17	5.07
398.00	2	12.75	7.42	978	4.32	300	0.04	0.44	18	4.47
398.17	2.07	17.5	6.78	914	3.53	320	0.11	0.4	15	4.84
398.33	2.01	15.25	6.97	916	3.57	310	0.05	0.42	15	4.23
398.50	2.03	12.25	7.4	972	4.17	310	0.04	0.44	21	4.78
398.67	2.82	12.5	7.11	925	3.91	310	0.04	0.44	11	4.18
398.83	1.75	11.25	7.48	980	3.84	320	0.04	0.47	10	4.11
399.00	1.81	9.75	7.74	1000	3.57	270	0.04	0.48	9	4.06
399.17	2	9.5	7.98	1040	3.78	290	0.04	0.48	9	4
399.33	1.59	11	8.01	1030	4.01	320	0.04	0.49	8	3.91
399.50	1.91	9.75	7.61	992	4.18	310	0.04	0.48	10	3.85
399.67	1.64	8.5	7.75	1030	4.16	300	0.04	0.5	11	3.91
399.83	1.7	8	8.02	1020	3.98	300	0.03	0.5	9	3.96
400.00	1.76	7.25	8.01	1010	4.01	290	0.03	0.5	12	4.2
400.17	1.71	7.75	7.81	1010	3.95	280	0.04	0.49	10	3.91
400.33	1.78	6.5	8.06	1050	4.21	270	0.03	0.5	12	4.01
400.50	1.85	8.5	7.85	1010	3.91	280	0.04	0.49	14	4.33
400.67	2.19	9.5	7.71	999	3.88	290	0.05	0.49	17	4.79
400.83	1.83	12.75	7.36	960	3.86	310	0.06	0.46	16	4.58
401.00	1.71	12	7.13	962	4	300	0.06	0.45	14	3.79
401.17	1.69	15.25	7.02	977	3.51	340	0.06	0.44	13	3.75
401.33	1.78	14.25	7.14	934	3.4	330	0.05	0.43	11	3.64
401.50	1.96	24.5	5.9	774	2.86	440	0.05	0.36	11	3.64
401.67	1.96	28.25	5.56	738	2.95	500	0.06	0.34	14	3.52
401.83	1.84	13.5	6.99	928	3.4	300	0.05	0.43	14	3.76
402.00	1.99	13	7.42	998	3.51	290	0.05	0.45	11	3.91
402.17	2.07	11	7.38	976	3.44	260	0.05	0.45	13	4.12
402.33	2.01	14.5	6.7	887	3.46	280	0.05	0.42	14	4.32
402.50	2.11	9.5	7.31	982	3.8	260	0.05	0.47	17	4.42
402.67	2.01	12.75	7.62	1040	5.07	300	0.06	0.54	24	5.24
402.83	2.28	12.25	6.99	966	4.15	280	0.05	0.51	21	5.17
403.00	2.48	14	6.82	902	3.52	290	0.05	0.42	24	6.07
403.17	1.68	10.25	7.15	943	3.8	250	0.05	0.44	30	6.69
403.33	2.91	8.75	7.15	950	3.63	240	0.04	0.44	32	7.17

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
403.50	2.74	9.75	7.17	967	3.72	250	0.05	0.44	34	7.67
403.67	2.39	9.25	6.71	934	3.88	240	0.03	0.42	32	6.65
403.83	2.47	10.25	7.04	953	3.85	240	0.04	0.52	28	6.82
404.17	2.62	9	7.33	975	4.08	260	0.04	0.44	37	7.05
404.33	2.55	8.75	7.15	939	3.69	240	0.04	0.45	32	7.02
404.50	2.37	11.75	6.87	889	3.83	260	0.04	0.45	30	6.77
404.67	2.37	8.25	7.12	906	3.91	240	0.05	0.42	31	6.66
404.83	2.44	6.75	7.19	927	4.06	240	0.03	0.46	34	6.83
405.00	2.24	6.75	7.37	958	4.13	220	0.03	0.46	32	6.39
405.17	2.32	8.25	7.39	1010	4.01	220	0.04	0.52	24	6.2
405.33	2.62	6.5	7.28	962	4.06	230	0.05	0.44	29	7.73
405.50	2.51	5.5	7.33	988	4.39	220	0.04	0.47	33	7.76
405.67	2.62	4.5	7.52	994	4.89	240	0.03	0.47	37	7.53
406.00	2.95	5.75	7.38	1000	3.98	250	0.03	0.46	38	8.25
406.17	3.53	5	7.64	1080	3.98	210	0.04	0.53	52	11.8
406.33	3.75	3.75	7.5	1040	3.91	200	0.03	0.46	60	13.1
406.50	3.46	3.75	7.56	1050	3.9	190	0.03	0.44	62	13.3
406.67	2.87	3.75	7.62	1070	3.94	180	0.05	0.46	47	12.6
406.83	3.22	2.75	7.28	1370	3.91	170	0.02	0.45	37	10.3
407.00	3.37	3.25	7.41	1490	3.69	180	0.03	0.46	43	11
407.17			7.7	1870	4.32	180	0.03	0.55	45	11
407.33	4.09	4.25	7.52	1530	3.79	180	0.03	0.47	44	11.9
407.50	4.19	6.5	7.53	1330	3.89	190	0.04	0.44	58	15.7
407.67	1.16	7.5	7.23	1070	3.77	200	0.04	0.43	66	19
407.83	3.97	9.25	7.21	1180	3.94	210	0.04	0.42	59	17.4
408.00	4.02	5.5	7.48	1070	3.9	220	0.04	0.43	58	17.7
408.17	3.09	4	7.12	1290	3.86	190	0.04	0.43	61	16.2
408.33	3.43	4.25	7.25	1260	3.75	180	0.03	0.46	42	11.7
408.50	3.82	5	7.58	1430	3.83	190	0.04	0.45	46	12.9
408.67	3.12	3.75	7.51	1090	3.87	190	0.04	0.43	57	13.2
408.83	2.78	3	7.41	1350	4.11	200	0.03	0.47	44	10.6
409.00	2.84	3.5	7.43	1160	4.27	180	0.03	0.46	37	9.58
409.17	2.9	3.25	7.34	1070	4.34	180	0.03	0.45	38	9.76
409.33	3.16	1.25	7.36	1050	3.8	180	0.03	0.44	33	9.15
409.50	3.9	4.75	7.49	1070	4.56	200	0.04	0.45	47	11
409.67	3.93	5	7.36	1030	4.07	190	0.03	0.43	63	14.3
409.83	3.89	5	7.45	1040	3.94	200	0.04	0.44	59	15.3
410.00	2.84	3.25	7.36	1040	4.05	200	0.03	0.45	63	14.6
410.17	3.72	4.5	6.6	936	4.46	160	0.03	0.41	42	11.9
410.33	3.84	5	7.34	1030	3.89	190	0.03	0.45	54	12.7
410.50	3.14	5.25	7.17	1000	3.89	200	0.03	0.43	58	12.3
410.67	3.71	8.5	6.71	935	3.77	200	0.03	0.42	43	9.97
410.83	4.31	9.75	6.56	920	3.86	220	0.04	0.4	55	11.7
411.00	3.82	9.75	6.56	950	3.66	210	0.13	0.4	63	19.5
411.17	2.8	5.85	6.34	925	3.66	230	0.07	0.38	59	15.2
411.33	2.82	6.03	6.63	932	3.81	200	0.04	0.39	42	9.17
411.50	2.76	5.78	6.53	912	3.56	190	0.04	0.4	44	9.65

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
411.67	3.8	5.6	6.59	936	3.72	190	0.04	0.4	41	9.9
411.83	4.26	8.05	6.76	959	3.59	170	0.03	0.39	67	12.5
412.00			6.63	934	3.69	200	0.04	0.37	81	16.8
413.00	4.77	6.13	6.91	975	3.93	190	0.04	0.38	94	19.3
413.17	4.87	9.13	6.47	915	3.78	190	0.04	0.35	95	18.9
413.33	3.2	1.45	7.3	1060	4.01	160	0.04	0.41	52	11.1
413.50	3.35	1.78	7.3	1080	3.96	170	0.04	0.42	53	11.3
413.67	3.94	3.58	7.15	1070	3.8	160	0.05	0.4	69	13.8
413.83	4.82	7.43	6.73	978	3.63	190	0.05	0.36	83	17.9
414.00	5.35	6.48	6.72	976	3.75	180	0.06	0.35	88	20
414.17	5.24	6.85	6.61	976	3.67	180	0.05	0.35	84	18.1
414.33	4.43	5.33	6.32	932	3.38	170	0.04	0.34	66	14.9
414.50	4.41	4.9	6.99	1030	3.72	170	0.05	0.39	70	15.9
414.67	3.31	3.63	6.92	1030	3.95	170	0.04	0.41	49	10.5
414.83	3.43	4.3	6.91	1190	3.55	180	0.04	0.4	52	9.2
415.00	3.4	3.38	6.98	1060	3.95	170	0.03	0.41	48	8.48
415.17	3.55	2.64	7.36	1230	3.85	160	0.03	0.42	51	9.23
415.33	3.56	3.05	7.33	1350	3.94	170	0.03	0.41	53	9.73
415.50	4.12	3.3	7.49	1280	3.91	170	0.03	0.4	56	9.87
415.67	3.74	5.45	7.1	1920	4.13	180	0.03	0.39	51	10.1
415.83	3.2	5.03	7.15	1340	4.41	190	0.04	0.4	41	9.09
416.00	3	4.05	7.37	1060	3.98	190	0.03	0.41	37	8.03
416.17	3.16	4.25	7.34	1040	3.72	180	0.03	0.41	37	7.94
416.33	3.49	4.18	7.29	1040	3.8	180	0.04	0.41	42	9
416.50	3.32	3.85	6.83	1000	3.7	160	0.03	0.38	39	9.21
416.67	3.71	3.88	7.32	1080	4.37	180	0.04	0.4	52	11.2
416.83	4.47	6.73	7.03	1030	3.64	190	0.05	0.37	67	14.9
417.00	4.79	6.78	7.01	1050	3.46	180	0.05	0.36	71	18.3
417.17	4.79	6.63	7.01	1100	3.53	170	0.05	0.38	71	19.1
417.33	4.43	4.93	6.42	1090	7.68	260	0.03	0.35	69	16.7
417.50	3.97	2.95	7.03	1360	3.65	160	0.03	0.37	107	23.5
417.67	5.61	3.73	6.95	1270	3.73	170	0.04	0.37	105	24.5
417.83	5.52	1.63	6.89	1090	3.58	180	0.03	0.37	77	18.1
418.00	4.57	6.43	6.81	1040	4.72	180	0.03	0.37	65	13.7
418.17	3.88	5.95	6.89	1030	3.52	190	0.03	0.36	68	12.2
418.33	3.41	7.75	6.86	1000	3.39	210	0.04	0.36	66	13
418.50	4.07	10.68	6.4	952	4.04	230	0.03	0.35	45	11
418.67	3.1	11.25	6.22	926	4.1	250	0.03	0.33	38	7.95
418.83	2.72	14.33	6.33	921	3.08	270	0.04	0.33	37	7.33
419.00	3.12	16.38	5.71	846	2.72	270	0.06	0.31	44	9.33
419.17	3.7	21.15	5.37	808	2.62	250	0.18	0.29	54	12
419.33	4.62	21.48	4.88	761	2.7	260	0.21	0.25	84	18.4
419.50	5.77	26.75	5.01	774	2.84	250	0.13	0.26	100	24.6
419.67	7	2.8	7.68	1200	4.27	160	0.05	0.41	66	14.6
419.83	4.21	2.8	7.82	1580	4.44	160	0.04	0.42	47	9.8
420.00	3.14	2.78	7.67	1310	4.5	150	0.04	0.42	48	10.9
420.17	3.12	1.88	7.59	1210	5.08	150	0.03	0.41	51	9.84

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
420.33	2.93	1.4	7.83	1180	4.32	140	0.03	0.42	43	9.01
420.50	2.87	1.38	7.34	1630	4.45	170	0.03	0.38	91	20.3
420.67	4.99	4.5	6.95	949	3.8	250	0.05	0.4	36	6.5
420.83	2.65	9.83	6.99	1350	4	170	0.03	0.39	63	14.6
421.00	3.59	4.65	7.21	2150	4.61	170	0.03	0.4	64	15.4
421.17	3.74	3.5	7.14	1940	5.08	160	0.03	0.39	62	15.1
421.33	3.62	3.33	7.08	4230	3.69	170	0.04	0.37	55	13.5
421.50	3.94	4.73	7.39	2560	3.97	150	0.04	0.39	53	12.5
421.67	3.63	3.43	7.3	7010	4.14	160	0.04	0.4	65	15.4
421.83	3.79	4.08	7.46	1110	4.29	170	0.03	0.38	82	15.3
422.00			7.66	1160	4.69	140	0.04	0.4	126	25.7
427.00	4.58	5.48	7.54	1100	4.94	130	0.03	0.4	113	21.3
427.17	6.17	1.88	7.64	1190	5.58	130	0.03	0.4	84	16.5
427.33	6.14	0.63	7.43	1080	4.59	160	0.04	0.38	78	18.5
427.50	4.8	0.83	7.68	1100	4.49	150	0.04	0.39	76	18.4
427.67	5.04	5.73	7.78	1200	4.94	150	0.04	0.4	79	20.1
427.83	5.09	4.63	7.81	1170	5.54	170	0.03	0.4	126	27.1
428.00	5.01	3.3	6.31	956	5.76	240	0.02	0.32	90	19.7
428.17	5.43	3.65	7.11	1060	5.78	200	0.03	0.36	80	22.5
428.33	4.38	15.38	7.67	1160	5.47	160	0.03	0.39	102	24.6
428.50	4.08	9.03	7.87	1190	5.01	160	0.03	0.4	117	28
428.67	5.07	3.7	6.92	1050	7.77	150	0.03	0.36	102	24.5
428.83	5.16	3.5	7.51	1230	5.8	140	0.02	0.38	109	23.7
429.00	4.94	4.35	7.45	1140	4.77	130	0.03	0.38	73	25.3
429.17	5.52	2.9	7.54	1140	4.78	160	0.04	0.38	81	23.8
429.33	5.61	2.9	7.63	1120	4.9	130	0.03	0.38	114	25.1
429.50	5.56	5.25	7.34	1080	4.65	160	0.03	0.36	140	32.6
429.67	5.41	2.18	8.01	1190	4.81	140	0.03	0.38	171	34.7
429.83	5.57	5.65	7.6	1120	5.65	130	0.03	0.37	185	39.6
430.00	7.2	0.83	7.74	1150	5.78	130	0.03	0.38	220	48.1
430.17	6.86	1.15	7.82	1170	6.2	140	0.03	0.39	204	44
430.33	7.67	1.08	7.58	1120	6.2	150	0.04	0.38	206	44.4
430.50	7.23	1.58	7.74	1150	5.54	150	0.03	0.39	175	41.6
430.67	6.91	4.5	7.84	1200	6.09	150	0.04	0.4	215	43.3
430.83	6.51	4.2	6.97	1200	5.42	110	0.03	0.34	179	40.9
431.00	6.78	2.63	7.53	1330	5.72	100	0.03	0.37	192	42.9
431.17	6.36	5.7	7.12	1190	5.65	130	0.03	0.36	170	38.7
431.33	6.77	3.3	5.61	977	4.41	200	0.03	0.28	145	33.5
431.50	6.27	5.48	7.21	1230	5.74	140	0.03	0.36	191	45
431.67	5.18	17.1	6.51	1110	5.64	170	0.03	0.33	157	35
431.83	6.64	5.2	6.7	1220	5.15	120	0.04	0.33	187	40.2
432.00	5.74	9.93	7.17	1340	5.4	80	0.04	0.36	201	44.5
432.17	6.33	6.55	6.98	1170	5.47	190	0.03	0.34	188	42.3
432.33	6.82	2.45	7.66	1320	6.14	130	0.04	0.38	201	46.1
432.50	6.4	11.35	7.52	1270	5.9	130	0.03	0.37	195	47.7
432.67	6.98	3.43	7.51	1280	5.97	120	0.03	0.37	193	44.9
432.83	6.85	3.98	7.59	1300	5.74	150	0.03	0.38	190	43.3

Table A-1. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bilger core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Mo (ppm)	U (ppm)
433.00	6.66	4.78	7.99	1260	5.25	150	0.03	0.38	218	41.9
433.17	6.67	5.88	7.98	1410	5.97	100	0.04	0.39	211	46.9
433.33	7.81	2.9	7.73	1200	5.28	160	0.03	0.38	196	40.4
433.50	7.12	1.75	7.71	1200	5.17	160	0.04	0.37	207	41.1
433.67	7.29	3.55	7.58	1150	5.48	150	0.05	0.37	208	43.8
433.83	7.39	2.98	7.54	1200	5.69	160	0.03	0.38	215	45.2
434.00	7.17	2.6	5.85	927	6.2	370	0.03	0.29	164	35.7
434.17	7.22	3.21	7.53	1260	5.7	120	0.03	0.37	198	44
434.33	6.28	10.98	7.63	1230	5.64	110	0.03	0.37	204	46
434.50	6.72	3.58	7.7	1310	5.52	120	0.04	0.38	202	44.2
434.67	7.1	2.08	6.96	1200	5.22	130	0.04	0.35	168	36.3
434.83	6.93	3.1	6.94	1270	5.1	90	0.04	0.34	189	40.3
435.00	6.26	4.83	7.43	1280	5.53	100	0.04	0.37	187	43.5
435.17	6.5	3.28	8.09	1280	5.41	120	0.04	0.42	179	40.3
435.33	6.56	3.45	7.52	1220	5.79	130	0.03	0.37	214	50.1
435.50	6.63	5.8	5.33	941	3.54	160	0.03	0.27	151	27
435.58	7.21	3.58	5.03	869	3.38	170	0.03	0.25	142	25.2
436.00	5.72	11.7	5.54	998	3.7	120	0.03	0.25	153	32.2
436.08	5.23	16.88	4.56	864	3.38	120	0.03	0.21	146	30.1
436.25	5.8	10.2	4.08	738	3.55	170	0.03	0.2	153	35
436.50	5.9	13.28	4.96	912	1.85	140	0.04	0.19	119	24.9
436.75	6.57	14.85	6.67	1160	4.58	100	0.03	0.33	171	36.9
437.00	6.5	6.4	6.06	1120	4.13	90	0.04	0.29	172	36.6
437.17	6.46	6.9	6.09	1130	3.9	90	0.04	0.28	170	37.6
437.33	6.33	7.15	6.07	1160	4.06	90	0.03	0.29	184	40
437.50	6.23	6.48	5.13	960	3.13	90	0.04	0.21	152	35
437.67	6.41	8.08	4.46	733	3.31	180	0.03	0.21	131	27.8
437.83	4.9	24.75	6.8	1020	3.48	180	0.05	0.37	71	16.9
438.00	6.4	8.03	13.6	2210	1.64	70	0.07	0.31	8	15.3
438.17		2.45	4.46	688	3.72	150	0.03	0.22	201	49.1
438.33	7.77	16.98	4.11	641	3.07	140	0.04	0.21	176	39.8
439.00	8.5	8.13	4.03	630	5.71	110	0.03	0.2	138	34.4
439.17	7.52	7.18	5.1	756	6.67	110	0.04	0.26	235	46.7
439.33	8.1	4.6	5.13	723	4.6	100	0.04	0.27	104	28.1
439.50	5.97	8.33	4.98	724	2.75	120	0.05	0.22	129	27
439.67	7.12	12.4	4.13	545	2.14	180	0.03	0.21	43	16.4
439.83	4.35	28.5	4.76	622	2.67	160	0.03	0.25	38	12.4
440.08	4.37	23.83	1.46	215	0.99	540	0.08	0.07	65	15
440.17	2.39	66.75	2.27	307	1.74	360	0.04	0.11	55	14.3
440.25	4.51	55.25	2.13	296	1.36	480	0.05	0.11	85	16.3
440.33		57.25	6.12	739	2.3	170	0.03	0.32	43	7.95
440.42	3.8	20.9	5.43	665	1.75	190	0.03	0.27	16	6.16
440.50	4.43	29	3.89	506	1.33	240	0.03	0.19	11	7.1
440.58	3.86	41.5	3.66	502	1.39	250	0.04	0.18	19	9.37
440.67	3.52	44.25	4.42	573	5.34	190	0.05	0.28	56	12.2
440.75	0.38	31	5.2	911	1.17	180	0.03	0.16	6	7.16
440.83	3.56	18.08	2.34	2190	0.88	270	0.02	0.09	7	4.9
440.92	1.33	38.25	2.95	2020	1.09	230	0.02	0.12	9	4.7

Table A-2. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 770.79 ft. depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Kenny Erb core.

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)
648.08			4.11		3.73	236.67		0.34	17.34	55.98	
648.41			5.87		4.76	267.65		0.45	22.85	31.46	
648.73			5.34		3.84	290.59		0.39	20.81	41.30	
649.06			5.72		4.30	241.65		0.36	21.82	39.56	
649.39			7.66		4.37	332.86		0.42	27.52	32.86	
649.72			7.58		4.56	292.74		0.45	28.03	39.19	
650.05			8.36		4.44	336.78		0.40	28.25	47.77	
650.37			5.71		4.42	315.25		0.42	22.62	48.64	
650.70			6.06		4.07	317.59		0.41	23.39	54.66	
651.03			2.70		1.36	1306.50		0.17	9.47		
651.36			7.27		4.22	390.08		0.44	26.18	28.07	
651.69			6.89		3.90	453.67		0.35	24.00	51.71	
652.02			6.83		5.27	328.91		0.42	25.85	48.10	
652.75			4.21		3.70	253.43		0.34	17.40	55.11	
653.08			7.23		4.36	377.70		0.44	27.52	37.62	
653.41			6.11		3.92	317.37		0.45	25.21	44.35	
653.74			7.24		4.13	361.25		0.43	27.10	58.45	
654.07			6.67		4.59	346.58		0.39	26.71	45.72	
654.39			8.18		4.92	436.10		0.44	30.71	51.37	
654.72			6.03		4.96	431.71		0.40	23.76	33.13	
655.05			5.90		4.56	321.07		0.41	24.12	40.40	
655.38			6.92		4.60	327.26		0.43	25.85	48.22	
655.71			7.35		4.45	330.25		0.47	27.75	39.83	
656.03			6.34		4.26	293.56		0.43	23.72	36.72	
656.36			5.73		4.31	359.78		0.41	21.79	42.61	
656.69			6.11		4.15	301.00		0.36	24.19	45.59	
657.02			6.28		4.45	318.20		0.46	24.51	33.19	
657.35			7.02		4.65	345.57		0.43	27.08	29.07	
657.76			5.57		4.09	365.06		0.38	21.74	31.63	
658.08			6.49		4.38	349.52		0.41	24.77	34.46	
658.41			5.62		4.21	384.94		0.44	23.09	48.55	
658.74			6.83		4.62	356.49		0.44	28.83	43.56	
659.07			6.09		6.19	384.20		0.44	25.29	31.92	
659.73			6.00		4.52	303.26		0.41	23.40	46.46	
660.05			6.84		4.76	344.18		0.44	27.38	43.36	
660.38			6.60		4.37	340.35		0.40	26.35	48.48	
660.70			5.64		5.80	298.18		0.44	24.15	35.36	
661.03			5.54		5.11	272.89		0.38	23.19	34.80	
661.36			7.13		4.46	307.04		0.43	28.33	53.85	
661.69			6.52		4.51	270.64		0.45	28.38	55.92	
662.02			6.30		4.50	350.85		0.40	27.90	35.98	
662.34			5.52		4.09	337.96		0.39	25.24	51.40	
662.75			6.58		4.47	406.16		0.44	27.94	42.81	
663.08			6.71		4.67	382.09		0.41	27.55	53.45	
663.41			5.88		4.27	345.31		0.42	26.05	49.02	
663.74			7.13		4.36	294.89		0.45	30.90	65.88	
664.07			4.42		3.86	281.51		0.40	20.18	48.50	

Table A-2. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 770.79 ft. depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Kenny Erb core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)
664.39			6.89		4.36	362.05		0.49	29.67	40.57	
664.72			7.04		3.68	300.87		0.40	29.28	48.47	
665.71			5.60		4.10	370.42		0.41	25.11	51.91	
666.36			6.73		4.48	303.78		0.40	30.39	38.12	
666.77			4.37		3.67	207.75		0.40	20.09	42.60	
667.02			5.35		4.29	378.82		0.39	24.02	45.34	
667.35			6.65		4.57	226.85		0.45	27.75	53.62	
667.76			4.74		3.96	322.38		0.40	21.62	51.71	
668.08			7.97		4.51	283.16		0.48	31.05	47.51	
668.33			7.12		4.28	346.46		0.45	30.36	39.49	
668.74			7.63		4.63	338.28		0.51	30.19	37.25	
669.07			7.01		4.08	331.62		0.44	28.32	46.77	
669.40			7.39		4.63	304.91		0.45	28.38	36.74	
669.72			3.94		4.05	464.03		0.38	21.71	36.61	
671.04			7.08		4.66	288.63		0.47	30.18	33.16	
671.36			6.46		4.30	372.09		0.44	29.21	29.85	
671.69			4.99		3.95	396.38		0.39	23.97	41.45	
672.02			4.90		3.80	288.83		0.37	22.84	50.59	
672.35			5.63		3.95	315.10		0.43	27.42	36.24	
672.76			6.31		4.37	308.07		0.49	27.71	30.55	
673.09			7.91		4.68	324.15		0.43	32.91	42.95	
673.41			5.47		4.34	359.48		0.39	23.75	44.30	
673.74			6.88		4.11	288.74		0.47	27.69	37.67	
674.40			7.12		4.26	333.60		0.44	29.99	45.48	
674.73			6.40		4.27	259.39		0.43	24.79	43.23	
675.05			4.33		3.99	392.84		0.39	20.30	74.24	
675.38			6.12		4.11	303.77		0.44	24.34	71.74	
675.71			7.52		6.17	269.13		0.50	30.40	39.06	
676.04			6.06		4.16	266.81		0.43	24.84	28.96	
676.37			6.51		4.43	424.88		0.48	26.88	43.01	
677.02			4.41		4.30	498.83		0.35	18.39	41.65	
677.35			5.94		4.20	415.03		0.43	25.59	44.83	
677.68			7.29		4.56	293.70		0.52	29.77	37.65	
678.09			4.66		4.03	393.68		0.39	20.18	48.19	
678.42			7.06		4.54	347.08		0.45	27.52	32.42	
679.40			7.19		4.41	379.68		0.46	28.50	40.20	
679.73			6.75		4.25	303.16		0.51	27.49	45.50	
680.06			7.75		4.35	286.87		0.48	30.19	39.43	
680.38			6.65		4.89	281.11		0.46	27.05	40.41	
680.79			4.45		4.51	364.33		0.37	19.80	40.16	
681.04			6.95		5.66	375.72		0.42	27.28	32.30	
681.37			4.58		3.84	294.53		0.46	20.91	60.83	
681.70			6.26		4.14	350.97		0.46	25.79	38.80	
682.35			7.13		4.15	295.31		0.42	25.99	38.42	
682.76			6.64		7.62	326.25		0.48	25.99	28.74	
683.09			7.34		5.44	351.94		0.44	28.12	25.02	
683.34			7.67		5.93	375.14		0.46	30.30	18.31	
683.66			8.25		4.92	377.56		0.47	32.10	25.16	
684.07			4.53		3.96	371.74		0.37	19.75	34.93	

Table A-2. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 770.79 ft. depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Kenny Erb core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)
684.40			7.28		5.03	445.69		0.46	30.02	36.94	
685.06			7.93		5.55	354.77		0.52	30.60	27.47	
685.39			4.91		4.39	272.48		0.43	20.51	32.81	
685.71			7.14		5.23	349.55		0.45	30.85	26.66	
686.04			6.99		4.46	315.69		0.44	29.08	28.72	
686.37			7.70		4.79	392.15		0.51	30.48	28.54	
686.70			7.01		4.15	305.65		0.45	30.13	25.64	
687.03			7.90		4.56	331.33		0.50	31.93	29.17	
687.35			5.34		3.94	325.79		0.45	25.03	35.2	
687.68			6.22		4.54	359.13		0.48	27.79	33.56	
688.01			7.72		4.22	292.47		0.48	30.05	32.33	
688.34			6.38		4.40	419.51		0.49	28.39	26.66	
688.75			4.97		3.88	260.15		0.42	21.26	30.63	
689.99			5.38		4.32	430.56		0.51	23.56	34.36	
690.40			6.59		4.26	277.03		0.44	26.13	33.32	
690.73			5.67		5.64	310.67		0.41	25.47	29.83	
691.06			5.77		5.27	615.89		0.36	24.38	29.23	
691.39			5.55		4.52	329.46		0.48	24.76	40.47	
691.71			5.28		3.87	319.74		0.42	23.20	43.45	
692.04			5.51		4.32	344.60		0.46	25.60	37.78	
692.37			5.62		4.05	357.99		0.46	25.22	41.66	
692.78			7.35		4.25	312.78		0.44	29.94	42.54	
693.03			7.88		4.43	346.73		0.52	33.23	32.10	
693.35			7.04		4.34	262.46		0.49	29.52	28.49	
693.76			4.81		3.93	340.23		0.41	22.96	32.02	
694.01			4.95		3.63	397.14		0.40	22.92	37.90	
694.41			8.06		4.20	324.76		0.46	32.75	28.02	
694.73			6.41		3.99	311.44		0.42	29.18	37.15	
695.06			8.16		4.76	366.46		0.48	35.08	26.50	
695.39			8.01		4.44	293.20		0.49	33.82	23.26	
695.72			5.19		4.04	288.50		0.41	23.28	31.05	
696.05			6.84		4.43	329.36		0.46	28.85	21.59	
696.37			5.61		4.01	282.59		0.45	25.98	41.80	
696.70			7.48		4.12	305.93		0.47	31.08	44.21	
697.03			4.98		3.67	299.32		0.40	23.00	43.62	
697.69			6.37		4.11	320.32		0.43	27.13	34.88	
698.01			7.99		4.50	299.84		0.47	32.59	27.22	
698.34			7.09		4.50	285.46		0.46	29.01	27.88	
698.75			5.31		4.38	391.09		0.39	23.89	34.17	
699.08			7.16		4.23	362.41		0.48	30.27	46.89	
699.41			7.23		4.88	360.41		0.43	30.13	35.62	
699.74			7.17		4.31	306.84		0.44	28.60	37.32	
700.06			6.59		4.12	316.04		0.45	28.22	38.81	
700.72			8.06		4.88	392.86		0.48	32.87	26.87	
701.05			7.79		6.17	324.68		0.44	32.40	28.00	
701.38			6.55		4.59	413.50		0.44	27.42	27.37	
701.70			5.95		4.07	325.07		0.45	26.69	33.51	
702.03			6.87		4.17	335.39		0.46	30.02	42.27	

Table A-2. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 770.79 ft. depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Kenny Erb core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)
702.36			7.29		3.97	331.14		0.51	30.09	37.99	
702.69			7.21		4.76	294.11		0.45	31.03	42.13	
703.34			6.85		4.01	348.06		0.45	29.09	37.04	
703.67			5.83		3.98	273.28		0.40	25.07	40.60	
704.00			4.57		3.73	403.86		0.37	20.35	41.54	
704.41			6.67		4.37	433.73		0.46	28.42	34.75	
704.74			7.86		4.11	430.06		0.53	31.38	30.50	
705.07			7.02		4.44	255.29		0.46	28.39	35.70	
705.39			7.50		4.07	339.24		0.50	29.64	31.70	
705.72			8.20		4.89	389.30		0.50	29.27	40.99	
706.05			3.03		3.25	4008.17		0.20	12.86	0.00	
706.38			2.72		3.21	3205.46		0.18	11.39	15.48	
706.71			2.73		3.16	3253.38		0.21	11.71	0.00	
707.03			2.74		3.29	3470.91		0.21	12.52	22.59	
707.36			6.86		3.88	380.93		0.46	25.93	44.75	
707.69			7.84		4.08	389.86		0.51	29.60	36.70	
708.02			7.02		4.27	383.67		0.51	28.75	38.78	
708.35			7.53		4.31	263.84		0.49	29.17	38.90	
708.76			7.45		4.49	309.60		0.46	29.53	36.67	
709.08			7.92		4.62	282.24		0.48	31.33	47.01	
709.42			8.12		4.25	319.46		0.46	32.41	43.05	
709.75			8.30		4.01	251.23		0.49	31.20	49.55	
710.08			5.10		3.59	308.26		0.42	21.56	51.50	
710.75			8.25		4.09	329.56		0.51	32.72	31.21	
711.08			4.32		3.85	263.36		0.40	20.75	37.20	
711.42			8.17		4.81	347.54		0.50	31.07	42.92	
711.75			8.00		4.35	316.55		0.50	31.33	50.26	
712.08			7.42		3.92	197.37		0.42	30.29	55.59	
712.42			4.43		3.80	217.38		0.38	19.75	51.87	
712.75			7.26		3.84	301.18		0.43	28.93	43.09	
713.08			6.84		4.12	288.02		0.47	27.30	38.48	
713.42			7.23		4.58	319.60		0.52	29.20	38.30	
714.07			8.08		4.64	325.60		0.43	32.99	48.52	
714.41			6.89		4.52	391.58		0.46	28.58	42.10	
714.74			7.33		5.04	432.55		0.40	29.83	30.93	
715.08			6.83		4.23	354.38		0.44	29.79	35.54	
715.41			7.87		4.29	348.06		0.45	33.10	38.34	
715.75			6.74		4.06	286.76		0.46	28.24	44.22	
716.08			7.00		4.56	292.82		0.43	28.69	35.02	
716.41			7.26		4.49	330.95		0.45	29.59	33.41	
716.75			7.47		4.47	375.73		0.46	31.17	36.86	
717.08			7.11		4.59	404.04		0.45	29.14	33.90	
717.42			7.39		4.63	426.68		0.42	30.74	39.76	
717.75			7.21		4.30	376.99		0.49	30.93	48.57	
718.09			7.40		4.15	336.93		0.45	29.24	42.55	
718.42			7.16		4.41	446.84		0.43	29.60	40.03	
718.76			6.83		4.14	321.51		0.42	27.86	45.41	
719.43			7.68		4.26	312.25		0.45	32.19	48.41	

Table A-2. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 770.79 ft. depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Kenny Erb core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)
719.76			8.19		4.64	357.48		0.41	31.79	50.91	
720.10			7.74		4.78	365.27		0.43	30.70	42.19	
720.43			7.61		5.08	454.67		0.44	32.23	41.46	
720.76			6.84		4.98	466.31		0.38	27.06	49.15	
721.10			8.01		4.58	342.30		0.44	33.09	53.95	
721.43			5.24		4.17	316.11		0.42	23.45	65.87	
721.77			7.86		4.57	405.29		0.43	31.53	49.73	
722.10			7.40		4.14	306.43		0.48	31.39	54.86	
722.44			7.73		4.36	297.65		0.41	31.68	63.80	
722.77			8.03		4.49	409.23		0.39	33.18	45.76	
723.44			6.80		5.42	459.05		0.45	28.76	46.03	
723.78			7.65		4.41	417.92		0.43	29.83	63.81	
724.11			5.97		3.81	414.53		0.41	24.17	82.85	
724.44			5.78		3.89	295.23		0.42	23.77	100.24	
725.11			7.98		4.11	352.05		0.48	31.25	46.64	
726.12			7.14		4.29	324.39		0.46	28.26	44.43	
726.45			6.91		4.46	315.14		0.45	27.66	40.72	
727.46			4.95		3.89	386.12		0.41	21.42	47.31	
728.12			5.09		3.96	333.68		0.42	22.00	46.50	
728.79			8.01		4.78	396.44		0.47	31.70	30.31	
729.13			7.73		4.98	362.25		0.46	31.59	33.84	
729.46			7.76		5.23	380.56		0.49	30.24	35.38	
729.80			5.28		3.99	296.78		0.41	21.92	38.47	
730.13			5.38		4.27	365.97		0.39	21.97	54.29	
730.47			5.98		4.32	340.39		0.44	24.63	47.62	
731.80			8.02		4.62	381.70		0.48	30.73	50.37	
732.14			7.66		4.71	404.45		0.49	30.86	46.17	
732.47			7.83		4.94	289.71		0.48	31.01	40.87	
732.81			7.19		4.36	334.96		0.49	29.99	55.17	
733.14			7.94		4.33	344.96		0.51	31.87	44.92	
733.48			7.63		4.53	292.77		0.48	30.48	53.75	
733.81			8.89		4.29	323.59		0.52	33.29	33.62	
734.15			7.86		4.11	246.37		0.49	31.87	42.17	
734.48			7.27		4.15	242.18		0.47	29.75	55.64	
734.82			8.50		4.54	327.20		0.47	31.93	56.30	
735.15			7.05		4.11	331.02		0.50	29.47	58.37	
735.48			7.38		3.81	317.04		0.46	28.81	63.37	
735.82			7.29		4.22	338.79		0.50	29.16	62.02	
736.15			7.44		4.10	341.37		0.45	31.00	54.12	
736.49			6.70		4.09	317.07		0.40	27.20	50.78	
736.82			6.92		4.38	283.15		0.47	28.59	52.02	
737.16			5.81		4.40	404.57		0.42	25.21	58.35	
737.49			4.73		3.77	298.41		0.38	20.80	59.98	
737.83			8.38		4.31	271.23		0.49	33.57	50.40	
738.16			7.15		4.10	249.36		0.47	29.08	44.13	
738.50			5.72		4.56	327.74		0.42	25.13	44.10	
738.83			7.76		5.03	327.17		0.43	31.22	45.03	
739.17			6.95		4.20	223.33		0.49	28.23	53.97	

Table A-2. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 770.79 ft. depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Kenny Erb core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)
739.50			8.11		4.25	378.26		0.47	32.55	38.49	
739.83			6.79		4.50	438.32		0.46	30.31	45.78	
740.17			6.72		4.16	317.80		0.45	29.14	43.28	
740.50			6.37		4.21	399.45		0.45	27.08	42.76	
740.84			7.44		4.25	324.04		0.47	31.03	38.17	
741.17			7.12		4.47	268.84		0.46	30.27	37.68	
741.51			7.33		4.86	450.80		0.46	30.88	38.06	
741.84			6.94		4.27	274.98		0.43	29.48	48.46	
742.18			7.72		4.18	292.41		0.48	32.19	50.98	
742.51			5.63		3.91	336.03		0.46	25.93	48.82	
742.85			7.60		4.34	259.07		0.46	29.76	52.80	
743.18			5.77		4.03	335.48		0.42	26.13	46.01	
743.51			6.90		4.24	332.36		0.48	29.67	38.86	
743.85			7.41		5.33	355.40		0.48	30.95	39.02	
744.18			7.15		4.16	347.05		0.53	30.54	39.28	
744.52			7.94		4.17	308.31		0.46	33.77	45.27	
744.85			7.38		3.96	307.55		0.42	32.10	54.02	
745.19			8.24		4.43	375.81		0.50	33.46	57.77	
745.52			5.82		3.51	354.89		0.40	25.20	39.87	
745.86			7.19		4.14	269.16		0.47	28.75	34.40	
746.19			6.52		8.02	387.53		0.56	28.68	37.41	
746.53			7.14		3.88	376.09		0.46	29.25	41.92	
746.86			6.23		3.74	335.05		0.42	26.21	56.18	
747.19			7.33		3.97	379.69		0.46	30.55	54.71	
747.53			7.02		3.95	305.05		0.41	29.71	65.37	
747.86			6.63		4.16	353.20		0.41	29.92	59.77	
748.20			5.77		4.15	413.30		0.41	26.02	42.30	
748.53			5.56		4.25	269.97		0.41	24.58	36.37	
748.87			5.62		3.75	302.05		0.42	25.88	37.58	
749.20			7.28		3.76	291.24		0.46	33.56	38.97	
749.54			7.85		3.80	310.72		0.47	33.24	55.54	
749.87			7.64		4.12	289.88		0.47	32.39	49.88	
750.21			6.68		3.71	279.43		0.42	29.05	63.21	
750.54			7.50		3.98	331.00		0.40	31.41	68.57	
750.87			6.80		3.94	434.45		0.38	28.86	64.93	
751.21			6.08		3.91	386.10		0.41	26.54	60.61	
751.54			5.47		3.89	319.43		0.37	26.08	66.67	
751.88			7.79		4.03	342.59		0.43	32.05	63.16	
752.21			7.37		4.15	331.90		0.43	31.59	57.45	
752.55			5.16		3.64	211.48		0.41	24.16	59.87	
752.72			7.08		3.90	410.01		0.44	30.34	58.09	
753.39			6.46		4.15	490.75		0.38	27.81	57.49	
753.72			6.38		4.27	412.44		0.46	27.35	69.47	
754.06			6.96		4.08	414.48		0.44	30.47	62.44	
754.39			7.09		3.77	393.59		0.43	29.62	51.30	
754.73			5.45		4.23	457.07		0.36	20.76	54.11	
755.06			6.97		3.65	398.80		0.46	29.78	44.98	
755.40			6.85		3.56	286.16		0.41	31.58	57.78	

Table A-2. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 770.79 ft. depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Kenny Erb core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)
755.73			7.03		3.52	268.52		0.39	32.57	49.46	
756.07			7.44		3.73	292.22		0.41	32.89	56.36	
756.40			6.51		3.67	318.11		0.41	29.70	60.59	
756.74			7.12		3.89	282.01		0.44	31.23	62.78	
757.74			7.07		3.96	329.13		0.43	29.15	84.22	
758.07			7.30		3.71	314.38		0.42	31.32	64.98	
758.41			6.19		4.88	256.43		0.43	29.07	49.33	
758.74			6.47		3.62	290.71		0.43	28.34	44.10	
759.08			7.59		4.03	242.14		0.43	32.05	36.61	
759.41			7.41		3.87	305.67		0.42	31.39	46.79	
759.75			1.05		0.74	1732.01		0.37	4.44		
760.08			5.61		3.74	258.26		0.34	26.54	95.21	
760.75			4.18		3.42	398.15		0.31	24.82	122.96	
761.09			5.02		3.38	344.92		0.34	26.78	114.43	
761.42			5.10		2.88	363.14		0.35	27.93	76.91	
761.76			5.71		3.00	432.44		0.32	26.08	60.55	
762.09			3.58		3.17	482.92		0.25	19.83	98.85	
763.09			4.77		3.05	433.45		0.25	22.42	107.55	
763.43			4.37		3.44	347.20		0.28	20.02	160.97	
763.76			4.13		3.19	456.88		0.28	19.98	96.33	
764.10			6.82		3.36	384.33		0.37	30.05	59.84	
764.43			7.10		4.38	259.87		0.48	30.79	33.76	
764.77			6.82		4.58	332.00		0.48	29.19	44.03	
765.10			7.40		4.82	291.49		0.41	30.43	55.16	
765.44			7.20		3.69	311.04		0.43	30.18	79.17	
765.77			5.11		3.34	191.93		0.39	23.29	80.33	
766.11			5.86		3.67	307.97		0.40	25.75	62.62	
766.44			6.00		3.91	247.70		0.40	28.16	66.33	
766.78			6.68		9.39	211.35		0.41	29.73	33.70	
767.11			7.21		4.01	367.46		0.39	29.70	50.20	
767.44			7.44		4.25	259.93		0.42	31.06	60.62	
767.78			6.81		3.84	301.99		0.46	28.13	43.69	
768.11			6.21		3.81	228.78		0.41	27.41	67.43	
768.45			7.16		3.92	261.89		0.38	29.96	70.53	
768.78			6.61		3.70	272.40		0.43	29.52	79.24	
769.12			7.99		10.27	270.19		0.37	32.95	68.40	
769.45			6.13		3.99	411.20		0.36	29.00	94.89	
769.79			6.08		3.92	309.78		0.37	28.87	66.12	
770.12			5.88		3.79	298.31		0.36	26.00	62.21	
770.46			5.71		3.67	313.69		0.36	27.65	50.03	
770.79			5.55		3.77	276.86		0.36	26.65	55.17	
773.04	3.50	6.38	7.36	1780	4.00	140	0.04	0.41	29.7	77	14.1
773.38	3.46	4.24	6.86	1740	7.33	120	0.04	0.38	27.2	105	24.1
773.71	6.79	16.12	6.28	1510	4.71	180	0.05	0.36	24.2	175	38.9
774.04	5.20	10.99	7.05	1710	4.99	140	0.07	0.38	25.3	110	26
774.38	4.08	16.78	6.39	1540	7.36	200	0.05	0.34	22.7	103	22.2
774.71	5.50	14.89	6.66	1570	4.60	170	0.07	0.38	24.5	118	33
775.04	6.36	12.86	7.06	2010	5.03	150	0.03	0.38	23.7	129	28.5

Table A-2. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 770.79 ft. depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Kenny Erb core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)
775.38	5.85	7.44	7.58	1890	5.10	130	0.04	0.41	25.8	116	23.6
775.71	7.17	17.18	6.92	1730	3.71	180	0.05	0.36	23.3	116	24.4
776.04	2.31	62.22	3.15	3680	2.29	270	0.49	0.18	12.4	34	10.8
776.38	0.93	88.16	0.97	3410	1.00	380	0.15	0.05	3.48	14	3.59
776.71	4.31	5.91	7.94	2030	4.45	120	0.03	0.41	27.8	63	14.4
777.04	5.90	9.54	7.57	2010	4.32	140	0.05	0.42	26.4	94	18.5
777.38	5.48	9.46	7.73	2020	4.09	160	0.03	0.42	26.3	99	26
777.71	4.17	13.45	7.41	1820	4.61	150	0.03	0.4	26	87	20.1
778.04	5.05	10.78	7.25	2010	4.41	170	0.04	0.4	26	99	26
778.38	5.55	12.59	7.40	1900	3.68	160	0.03	0.39	25.1	89	20.3
778.71	5.39	14.31	7.12	1800	3.46	170	0.04	0.38	25.5	100	23.9
779.04	4.83	18.26	6.84	1640	3.13	170	0.04	0.36	24.8	54	22.8
779.38	6.26	7.69	7.57	1880	3.87	150	0.03	0.42	26.9	116	29.7
779.71	4.34	5.19	7.21	1820	6.41	100	0.03	0.39	26.5	94	20.7
780.04	6.17	14.18	7.17	1810	3.17	180	0.07	0.37	25.4	169	33
780.38	4.40	21.09	5.61	1420	3.90	200	0.03	0.29	23.9	93	19.5
780.71	5.49	13.96	6.74	3410	3.06	180	0.03	0.35	26.2	97	22.1
781.04	4.67	25.75	5.88	2920	2.76	280	0.03	0.31	22.7	101	22.6
781.38	5.91	9.94	7.08	1860	3.84	130	0.03	0.37	27	139	34.2
781.71	5.53	10.14	6.51	1760	3.61	140	0.04	0.33	27.8	145	28.2
782.04	5.76	11.24	6.39	3960	5.96	130	0.04	0.34	24.7	151	35.5
782.38	6.16	16.29	6.94	1670	3.10	170	0.04	0.36	25.3	133	33.3
782.71	6.15	12.36	6.84	> 10,000	3.87	130	0.04	0.35	24.3	137	34.8
783.04	6.86	13.13	7.29	1790	3.26	130	0.05	0.38	25.7	160	46.5
783.38	6.24	8.18	6.48	1700	6.52	120	0.04	0.35	24.8	197	46.2
783.71	7.17	9.52	6.70	1690	4.29	110	0.04	0.35	27.9	181	53.8
784.04	6.01	12.56	5.71	1430	3.60	120	0.04	0.32	27.4	139	31.3
784.37	6.14	22.31	4.25	1100	2.68	140	0.18	0.24	26	113	52.6
784.71	6.08	13.31	5.77	1390	2.43	140	0.05	0.31	28.4	132	40.8
785.04	5.63	13.57	5.98	1540	2.99	120	0.04	0.31	26.9	108	27.2
785.38	6.38	13.43	5.90	1480	2.51	140	0.05	0.32	28	141	35.5
785.71	5.59	10.78	5.24	1360	3.34	100	0.04	0.28	29.1	139	31.2
786.04	5.93	11.50	5.41	1360	2.59	120	0.04	0.29	29.3	128	32.7
786.38	5.56	12.70	4.85	1210	3.32	100	0.04	0.27	28.8	149	27.6
786.71	5.95	12.43	4.87	1250	2.94	110	0.04	0.27	29	131	28
787.04	5.63	15.33	4.37	1050	2.47	130	0.04	0.24	28.6	140	27.5
787.38	5.85	11.82	4.86	1200	2.51	120	0.04	0.27	30.2	133	30.1
787.71	4.10	18.03	4.67	1110	2.84	120	0.03	0.25	28.3	114	18.1
788.04	3.41	35.55	3.65	943	1.73	210	0.12	0.19	23.4	61	16.6
788.38	3.91	24.15	4.93	1220	2.91	180	0.04	0.27	25.5	82	18.6
788.71	6.25	12.17	5.60	1290	2.79	120	0.04	0.31	28	121	23.3
789.04	4.18	23.40	5.09	1210	2.54	160	0.05	0.27	25.7	95	22.3
789.71	3.27	47.07	2.54	655	1.44	230	0.51	0.14	18.6	69	14.9
791.04	5.77	15.42	5.12	1110	2.31	120	0.03	0.29	28.7	113	19.6
791.38	4.56	8.24	4.78	1100	9.59	60	0.03	0.27	26	103	19.7
791.71	5.82	14.05	4.47	992	2.39	110	0.04	0.24	29.8	124	22.5
792.04	5.63	14.53	4.53	1080	2.38	110	0.04	0.25	29.7	107	22.6
792.38	5.53	12.08	4.74	1030	2.86	100	0.03	0.27	26.6	121	22

Table A-2. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 770.79 ft. depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Kenny Erb core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)
792.71	5.22	16.62	4.68	987	2.56	110	0.03	0.26	28.6	116	15.6
793.04	3.85	31.39	3.74	846	2.09	160	0.04	0.2	24.5	79	18.5
793.38	5.62	19.75	4.50	1060	2.52	130	0.03	0.24	26.3	120	52.9
793.71	5.69	16.51	4.98	1110	2.41	130	0.04	0.27	27.9	134	35.1
794.04	5.38	12.63	4.86	1070	5.06	100	0.03	0.25	27.4	143	28.1
794.38	5.94	11.58	4.67	1040	3.22	90	0.03	0.27	29.9	126	26.5
794.71	6.49	20.38	3.04	743	1.57	90	0.18	0.17	28.7	87	31.3
795.04	6.47	15.07	3.73	872	2.09	90	0.04	0.21	30	112	24.6
795.38	7.32	18.28	4.11	953	2.55	110	0.04	0.22	27.9	117	29.8
795.71	6.37	18.82	4.19	946	2.68	110	0.03	0.23	27.1	170	38.9
796.04	6.26	20.46	4.27	956	2.53	110	0.03	0.23	26.4	139	26.8
796.38	3.41	57.94	1.38	332	0.95	450	0.05	0.08	15.8	54	9.62
796.71	3.04	61.56	1.12	309	0.97	560	0.07	0.06	14.9	33	7.41
797.04	5.07	36.57	3.12	657	1.37	150	0.05	0.17	21.7	94	18.9
797.38	5.80	26.64	3.61	794	1.76	120	0.03	0.2	25.4	92	19.9
797.71	6.39	26.10	3.92	847	2.04	120	0.04	0.22	24.9	149	35.3
798.04	6.39	21.86	4.36	959	2.16	110	0.04	0.24	26.8	155	30.6
798.38	6.23	20.91	4.30	997	2.06	110	0.03	0.22	26.9	137	28.7
798.71	5.76	29.05	3.45	771	1.35	130	0.05	0.17	25.7	118	29.8
799.04	5.27	24.09	3.65	802	1.40	130	0.03	0.19	27.5	107	26.8
799.38	6.05	12.26	4.41	1030	1.75	90	0.04	0.22	31.3	118	28.6
799.71	6.56	8.89	4.20	1040	1.52	80	0.04	0.2	33.3	120	32.4
800.04	5.39	10.99	4.05	959	1.35	90	0.03	0.19	33.7	93	21.9
800.37	3.42	29.71	2.81	801	0.74	190	0.04	0.11	28.2	53	12.6
801.04	4.36	23.82	2.62	652	0.97	130	0.05	0.14	30	72	26
801.38	6.40	19.54	3.54	810	1.80	110	0.05	0.19	28.6	132	36
801.71	7.64	14.40	4.47	1020	1.98	110	0.07	0.25	28.9	148	51.8
802.04	7.92	19.41	4.33	943	2.43	120	0.05	0.24	26.2	169	38.3
802.38	5.55	31.59	4.01	875	2.19	150	0.04	0.22	22	155	37.9
802.71	7.35	10.86	5.60	1190	2.69	80	0.06	0.32	28.5	189	37.7
803.04	7.12	19.05	4.07	970	1.92	100	0.07	0.21	27.4	136	38
803.38	4.96	14.97	3.90	1070	2.50	80	0.04	0.18	30.1	89	25.2
803.71	5.95	12.73	3.81	906	2.11	80	0.04	0.21	31.3	101	22.5
804.04	5.24	14.18	3.95	940	2.18	90	0.04	0.22	31	95	21.2
804.38	4.54	20.14	3.32	788	2.06	100	0.05	0.19	28.9	87	21.1
804.71	4.69	24.13	3.37	785	1.91	110	0.05	0.19	28.4	92	23.7
805.04	4.55	20.16	3.40	788	1.71	110	0.04	0.19	30.2	104	23.3
805.38	4.90	19.59	3.66	870	1.94	110	0.04	0.20	29.7	92	25.4
805.71	4.57	41.50	2.28	455	1.54	190	0.03	0.12	21.7	67	14.9
806.04	2.83	32.48	3.76	812	1.48	130	0.03	0.20	24.1	20	7.42
806.38	5.03	36.66	3.55	759	1.30	130	0.04	0.18	21.7	69	13.8
806.71	2.13	68.28	1.12	326	0.66	530	0.09	0.06	12.8	20	4.6
807.04	5.17	46.66	0.57	341	0.76	600	0.33	0.03	7.46	19	3.36
807.38	6.31	30.50	4.21	868	1.64	130	0.04	0.23	23.1	113	20.9
807.71	3.26	25.42	4.69	931	1.68	110	0.02	0.27	25.9	43	10.7
808.04	4.03	56.78	2.39	473	1.00	200	0.04	0.12	15	110	13.5

Table A-3. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bald Eagle core.

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)	S (wt%)
789.04	3.23	10.59	8.96	> 10,000	4.11	230	0.04	0.4	11.9	56	13.4	3.5
789.38	3.83	12.40	6.31	> 10,000	3.87	210	0.03	0.31	12.5	78	18.6	N/A
789.71	2.89	10.04	6.87	> 10,000	3.78	170	0.03	0.32	10.5	58	14.1	5.46
790.04	3.29	19.85	5.29	> 10,000	3.32	220	0.04	0.25	9.84	60	23.7	N/A
790.38	3.86	10.99	7.7	> 10,000	4.29	200	0.03	0.38	14.9	80	17.7	4.35
790.71	2.04	37.03	7.92	> 10,000	5.64	200	0.03	0.37	14	74	13.3	N/A
791.04	3.51	11.59	8.54	8050	4.01	240	0.05	0.39	12.4	66	14.6	3.37
791.38	3.81	11.41	8.76	1700	5.02	230	0.04	0.42	15.9	82	17.1	N/A
791.71	3.81	11.33	8.97	1640	4.52	240	0.05	0.41	10.8	77	15.9	3.08
792.04	3.72	6.97	9.31	8440	4.1	230	0.04	0.42	15.2	68	16.8	N/A
792.38	3.85	7.94	9	4670	4.13	230	0.04	0.42	16	71	15.9	2.99
792.71	4.41	8.48	8.69	8050	4.27	210	0.04	0.42	14.6	77	15.5	N/A
793.04	0.82	73.19	8.46	> 10,000	3.54	210	0.03	0.41	13.4	59	12.9	3.45
793.38	2.37	8.87	6.88	> 10,000	4.26	190	0.04	0.33	13.5	45	14.9	N/A
793.71	2.58	7.88	9.3	2060	4.14	230	0.03	0.44	14.2	37	10.2	3.04
794.38	3.48	9.82	8.72	1880	4.27	230	0.03	0.43	14.4	69	13.9	3.27
794.71	5.47	12.27	8.82	1750	4.59	260	0.04	0.43	14.8	55	11.6	N/A
795.04	1.98	7.95	4.31	> 10,000	4.14	150	0.04	0.25	7.53	45	11	9.79
795.38	2.64	23.73	7.44	1520	4.3	390	0.04	0.36	12.8	57	19.7	N/A
795.71	3.10	6.82	8.58	1720	3.54	220	0.03	0.42	15.5	60	12.1	3.22
796.04	2.58	6.72	8.3	1510	4.89	210	0.03	0.42	16	54	12.2	4.77
797.04	4.05	11.89	8.15	1520	4.38	230	0.03	0.42	11.4	87	14.5	N/A
797.38	2.96	7.90	8.43	1620	3.89	210	0.03	0.43	18	62	11.7	3.18
798.04	3.02	8.11	8.58	1590	4.36	200	0.03	0.42	16.8	73	13.2	N/A
798.71	3.25	7.04	8.36	1460	4.46	200	0.03	0.44	18	70	9.37	3.41
799.04	0.89	77.45	1.79	450	1.74	2160	0.04	0.09	4.69	14	3.98	N/A
799.38	0.53	90.26	1.47	1790	2.01	2130	0.08	0.07	3.42	14	4.19	N/A
799.71	3.81	12.41	7.74	1360	4.34	240	0.03	0.39	17.1	77	11.5	N/A
800.04	3.61	7.29	7.57	1340	3.5	190	0.03	0.4	14.4	80	13.4	3.23
800.38	3.06	7.23	8.05	1370	4.08	180	0.02	0.42	17.9	68	12.2	N/A
800.71	2.96	8.59	7.93	1670	4.23	180	0.03	0.41	17.2	63	10.8	3.22
801.04	2.98	10.10	7.55	1320	4.06	190	0.02	0.39	17.1	60	11.1	N/A
801.38	3.07	13.66	7.24	1360	3.95	240	0.03	0.38	18.8	64	14.2	2.86
801.71	3.45	10.03	7.31	1300	4.23	210	0.03	0.41	19.1	70	14.3	N/A
802.04	2.82	10.68	7.41	1320	3.98	200	0.03	0.38	15.7	52	12.6	3.83
802.38	3.14	12.39	7.34	1300	4.1	220	0.03	0.39	17.9	54	14.3	N/A
802.71	3.08	20.27	7.08	1160	4.21	270	0.03	0.36	13.6	49	14.5	2.85
803.04	2.92	13.92	6.69	1210	3.64	240	0.02	0.38	14	52	12.3	N/A
803.38	3.65	7.55	8.12	1350	4.12	190	0.03	0.41	14.2	79	14.1	3.2
803.71	3.50	11.07	7.92	1270	4.33	210	0.02	0.4	13.8	60	12.7	N/A
804.04	2.87	11.43	7.97	1290	3.98	230	0.03	0.4	14.8	57	13.5	3.25
804.38	3.13	7.37	7.51	1360	3.42	200	0.03	0.42	16.2	69	12.9	N/A
804.71	2.24	8.52	8.34	1360	4.44	200	0.02	0.42	16.4	65	12.7	3.23
805.04	3.92	7.54	7.96	1360	3.68	200	0.04	0.42	12.6	82	16.4	N/A
805.38	2.77	7.03	8.22	1360	4.35	180	0.03	0.43	17.9	55	12.2	3.11
805.71	2.72	11.40	8.5	1340	4.02	230	0.04	0.41	14.4	52	13	N/A

Table A-3. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bald Eagle core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)	S (wt%)
806.04	2.93	32.14	6.12	1100	4.06	350	0.07	0.33	14.4	57	19.4	2.63
806.38	2.58	11.68	8.31	1370	4.34	210	0.03	0.43	13.5	47	9.17	N/A
807.04	2.71	12.76	7.4	1290	3.52	230	0.03	0.41	15.8	46	9.7	2.8
807.38	3.45	22.40	6.59	1100	3.99	320	0.06	0.37	13.4	42	14.1	N/A
807.71	2.19	13.84	6.95	1050	6.11	260	0.03	0.39	14.7	32	9.05	4.89
808.04	2.60	9.52	7.42	1270	4.04	220	0.04	0.42	12.8	38	9.74	N/A
808.38	3.25	10.72	8.09	1650	4.24	230	0.03	0.43	17.1	51	10.3	3.08
808.71	2.99	12.39	7.58	1240	3.75	240	0.03	0.41	14.7	49	11.3	N/A
809.04	2.85	6.37	8.63	1420	4.1	190	0.03	0.47	14.7	48	10.7	3.3
809.38	2.89	9.89	7.46	1500	5.71	220	0.03	0.41	16.7	48	14	N/A
809.71	2.44	6.72	8.98	1450	4.51	190	0.02	0.47	18	47	12.2	3.13
810.04	2.57	6.32	8.84	1420	4.76	180	0.02	0.46	17.9	44	11.2	N/A
810.38	3.62	7.88	8.84	1260	4.52	190	0.03	0.46	15.3	59	14.4	3.22
810.71	0.27	91.94	8.57	1350	4.05	180	0.02	0.46	17.2	60	13	N/A
811.04	3.52	8.26	8.21	1310	3.84	200	0.03	0.44	14.2	55	14.4	3.3
811.38	2.13	36.96	6.43	1020	3.71	460	0.06	0.31	10.7	37	13.1	N/A
811.71	2.15	39.65	5.31	1210	3.71	400	0.05	0.29	9.31	58	25.4	2.68
812.04	2.33	5.03	8.71	1430	4.04	190	0.03	0.45	16.2	40	8.12	N/A
812.38	2.79	19.59	7.77	1270	4.09	310	0.04	0.39	13.9	46	11.6	2.79
812.71	2.14	11.37	8.62	1400	4.39	240	0.03	0.45	16.7	31	7.83	N/A
813.04	2.72	21.48	7.02	1120	3.41	310	0.05	0.38	12.5	49	15.2	2.64
813.38	3.15	9.46	8.72	1270	4.36	230	0.03	0.45	16.7	61	11.8	N/A
813.71	2.59	8.27	8.74	1300	4.69	220	0.02	0.46	15.6	47	10.4	3.66
814.04	2.85	16.24	7.99	1210	4.38	260	0.03	0.41	16.1	50	14.8	N/A
814.38	2.52	16.18	6.9	1140	3.35	220	0.04	0.36	11.9	42	11.4	2.97
814.71	0.51	85.81	7.5	1160	3.64	280	0.03	0.38	11.7	49	12.7	N/A
815.04	2.47	26.88	6.99	1060	4.42	340	0.06	0.36	9.54	44	13.5	2.75
815.38	3.43	17.02	7.36	1190	4.23	240	0.03	0.4	13.9	60	16.4	N/A
815.71	3.77	10.65	8.28	2290	4.3	230	0.03	0.44	17.5	63	17.4	2.91
816.04	3.00	8.49	8.26	1270	4.05	220	0.02	0.44	15.1	45	11.2	N/A
816.38	3.40	26.76	7.24	1070	4.38	310	0.06	0.37	12.7	56	19.2	2.79
816.71	3.20	19.76	7.61	1200	4.28	300	0.06	0.4	15.3	43	16.3	N/A
817.04	3.14	8.22	8.4	1300	4.17	210	0.03	0.46	15.4	48	11.7	3.04
817.38	2.45	5.97	8.92	1410	4.68	190	0.03	0.46	18.1	37	8.96	N/A
818.04	1.06	67.51	7.74	1230	3.68	220	0.03	0.42	11.1	42	11.7	3.07
818.71	4.45	7.80	8.73	1580	4.44	190	0.03	0.47	19.1	52	12.7	3.08
819.71	2.77	8.11	8.95	1400	4.99	220	0.02	0.47	18.1	46	11.4	N/A
820.04	1.98	13.03	8.36	1410	4.14	230	0.05	0.45	15.7	30	8.11	2.85
820.38	1.94	9.51	9.94	1550	4.99	220	0.02	0.5	17	31	8.15	N/A
820.71	2.19	10.55	8.38	1370	3.73	220	0.03	0.45	14.8	32	8.29	3.01
821.04	2.68	8.92	8.72	1370	4.63	230	0.03	0.46	15.6	40	8.62	3.11
821.38	2.83	13.59	7.72	1270	3.85	270	0.04	0.43	12.2	46	10.8	N/A
821.71	2.29	13.01	8.24	1270	3.8	240	0.03	0.44	12.5	36	8.82	3.08
822.04	2.66	12.74	8.61	1250	4.65	230	0.03	0.47	16.2	37	9.09	N/A
822.38	2.25	9.74	8.58	1280	4.7	230	0.03	0.46	16.8	33	9.09	3.01
822.71	1.96	9.91	7.86	1200	4.28	200	0.02	0.45	14.9	30	8.72	N/A
823.04	2.46	6.79	8.63	1410	3.85	210	0.03	0.47	15.4	32	8.67	2.87
823.38	2.28	7.95	8.86	1360	4.46	230	0.03	0.46	14.3	33	9.43	N/A

Table A-3. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bald Eagle core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)	S (wt%)
823.71	2.56	5.45	8.21	1270	3.9	200	0.03	0.46	16	35	9.14	2.94
824.04	2.33	6.49	8.06	1220	3.53	190	0.02	0.43	12.6	34	8.55	N/A
824.38	1.75	21.05	4.39	6930	2.59	230	<0.01	0.24	9.98	20	5.65	3.09
824.71	1.10	60.52	8.74	1330	4.23	200	0.03	0.48	19	41	10.2	N/A
825.04	2.69	12.78	8.21	1210	4.33	260	0.03	0.44	16.3	45	13.5	2.8
825.38	1.98	11.35	8.3	1240	4.56	230	0.03	0.47	16.1	42	11.3	N/A
825.71	2.46	8.13	8.68	1320	4.57	210	0.03	0.48	16.8	35	10.1	2.95
826.04	2.27	7.24	8.65	1300	4.45	200	0.02	0.46	20.3	36	9.71	N/A
826.38	2.43	8.94	8.76	1350	4.7	240	0.03	0.47	18.3	36	9.04	2.95
826.71	2.38	16.94	7.63	2200	3.83	270	0.05	0.42	12.6	34	10.7	N/A
827.04	2.04	13.80	8.4	1150	4.6	260	0.04	0.44	13.4	41	12	2.77
827.38	2.07	8.13	8.23	1280	4.9	200	0.03	0.47	17.6	35	8.95	N/A
827.71	2.25	8.14	8.43	1340	4.63	200	0.03	0.47	15.7	34	8.86	2.85
828.04	2.00	7.13	8.5	1280	4.75	200	0.02	0.47	15.5	29	7.9	N/A
828.38	2.27	7.69	8.21	1290	4.43	200	0.03	0.45	12.8	32	7.97	2.93
828.71	2.34	16.68	7.43	1140	4.61	260	0.05	0.41	12.2	38	11.9	N/A
829.04	2.66	10.29	8.04	1170	4.72	230	0.03	0.45	14.4	45	11.2	2.84
829.38	2.47	7.70	8.48	1230	4.41	200	0.03	0.46	14.7	37	9.95	N/A
830.04	2.39	8.91	8.42	1220	4.56	210	0.02	0.45	15.2	34	8.56	2.71
830.38	2.30	12.35	8.1	1180	4.68	220	0.04	0.44	18.1	35	9.86	N/A
830.71	2.24	9.68	8.15	1180	4.57	220	0.03	0.45	14.2	33	8.43	2.73
831.38	2.14	11.33	7.93	1170	4.63	230	0.03	0.45	15.2	36	9.42	N/A
831.71	2.19	9.34	8.09	1160	4.38	220	0.03	0.45	14.2	39	9.28	2.72
832.04	2.01	10.15	7.77	1180	5.25	210	0.03	0.44	17.6	33	8.62	N/A
832.38	2.50	12.79	7.72	1120	4.26	250	0.03	0.41	14.6	38	9.41	2.51
832.71	2.92	11.60	7.97	1180	4.38	220	0.03	0.44	15.7	47	12.4	N/A
833.04	2.78	18.61	7.67	1060	4.41	240	0.05	0.41	10.8	40	11.9	2.66
833.38	2.52	7.64	8.18	1160	4.48	190	0.03	0.44	13.6	41	10.4	N/A
833.71	2.58	8.11	8.25	1220	4.34	200	0.02	0.46	15.9	34	8.9	2.58
834.04	2.13	10.81	8.16	1290	4.53	210	0.03	0.42	11.8	31	8.24	N/A
834.38	2.55	11.32	7.85	1160	4.17	220	0.02	0.43	16.2	35	9.96	2.24
834.71	2.81	8.59	7.85	1170	4.25	230	0.03	0.44	17.6	40	11.3	N/A
835.04	2.32	9.71	8.16	1210	4.21	200	0.03	0.44	16	34	8.95	2.38
835.38	2.11	7.88	8.27	1230	4.31	200	0.02	0.44	14.1	29	7.78	N/A
835.71	2.24	9.05	8.38	1280	4.31	200	0.03	0.43	15.6	33	8.61	2.49
836.04	2.09	6.54	8.3	1260	4.7	190	0.02	0.45	15.4	35	9.21	N/A
836.38	3.32	5.79	8.65	1240	4	180	0.04	0.46	15.8	49	14.2	2.51
836.71	2.56	6.78	8.28	1200	4.21	180	0.03	0.46	16.6	41	12.8	N/A
837.04	2.16	7.89	8.58	1280	4.18	170	0.03	0.44	15.9	35	9.93	2.6
837.38	2.20	5.51	8.88	1280	4.28	170	0.02	0.47	14.1	36	9.38	N/A
837.71	2.17	7.54	8.32	1200	4.12	160	0.03	0.44	17.6	35	8.94	2.77
838.04	2.31	6.45	8.68	1280	4.18	180	0.03	0.45	17.4	51	14.8	N/A
838.38	2.50	8.12	8.37	1200	4.05	200	0.03	0.44	14.3	36	10.3	2.43
838.71	2.60	11.74	7.97	1140	4.02	220	0.04	0.42	15.9	42	12	N/A
839.04	2.21	7.39	8.16	1820	5.16	180	0.02	0.44	16.1	42	10.3	3.76
839.38	2.32	8.08	8.43	1230	4.27	200	0.03	0.45	19.1	37	8.92	N/A
839.71	1.94	9.96	8.28	1190	4.31	200	0.03	0.45	14.7	30	8.07	2.58
840.04	1.99	9.80	8.43	1250	4.42	210	0.03	0.45	13.9	31	8.06	N/A

Table A-3. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bald Eagle core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)	S (wt%)
840.38	2.12	10.18	8.05	1190	4.22	200	0.03	0.43	15.5	34	8.88	2.55
840.71	2.59	7.44	8.38	1200	4.09	230	0.05	0.44	18.7	39	10.2	N/A
841.04	1.91	7.92	7.59	1590	7.09	180	0.03	0.42	12.2	34	8.54	6.35
841.38	2.18	11.89	8.33	1190	4.04	230	0.04	0.44	14.4	37	10.7	N/A
841.71	2.27	13.89	7.81	1120	3.87	210	0.04	0.42	16.9	41	9.68	2.6
842.04	1.89	26.09	7.91	1120	3.96	210	0.04	0.42	15.9	41	8.96	N/A
842.38	2.30	16.17	8.15	1130	4.27	260	0.04	0.43	15.4	42	10.7	2.39
842.71	2.28	14.21	8.04	1180	4.06	250	0.03	0.42	14.3	39	9.82	N/A
843.04	2.09	13.24	8.47	1170	4.25	230	0.03	0.45	17.2	36	9.19	2.44
843.38	2.26	12.25	8.31	1180	3.87	210	0.02	0.44	16.8	37	8.24	N/A
843.71	2.20	10.26	8.47	1240	4.12	210	0.03	0.43	13.7	37	8.55	2.49
844.38	0.87	78.81	2	1620	1.9	880	0.08	0.1	4.65	14	3.29	N/A
844.71	0.83	77.09	2.16	9250	2.36	970	0.09	0.11	4.04	14	3.57	1.09
845.04	0.79	79.43	2.05	611	2.07	1860	0.07	0.11	4.77	12	3.39	N/A
845.38	2.54	17.50	8.01	1150	4.26	280	0.06	0.42	13.8	47	13.2	2.55
845.71	2.52	9.48	8.58	1220	4.36	210	0.03	0.46	15.5	44	9.51	N/A
846.04	2.29	6.26	8.99	1250	4.23	180	0.03	0.47	13	43	9.74	2.68
846.38	2.41	8.39	9.13	1270	4.35	200	0.03	0.47	18.5	43	10.9	N/A
847.04	3.12	5.27	8.58	1220	4.37	170	0.03	0.45	13.8	56	14	2.83
847.38	2.85	6.02	8.77	1220	4.25	170	0.03	0.46	14.4	49	11	N/A
848.04	2.83	6.26	8.99	1280	4.42	180	0.03	0.47	17.2	51	12.5	N/A
848.38	2.88	13.29	8.23	1180	4.09	250	0.03	0.42	14.6	57	13.4	2.54
848.71	2.39	1.79	8.76	1290	4.41	170	0.02	0.45	16.6	43	9.71	N/A
849.04	2.76	7.96	8.58	1210	4.52	190	0.03	0.43	11.8	51	10.9	2.82
849.38	2.96	14.22	8.4	1160	4.19	240	0.06	0.42	16.7	53	14.5	N/A
849.71	2.52	11.59	8.2	1210	4.31	210	0.03	0.42	15.4	43	10.5	2.49
850.04	2.47	10.28	8.12	1200	3.91	190	0.03	0.41	14.8	41	9.21	N/A
850.38	2.29	8.00	8.38	1240	4.3	200	0.03	0.39	13.2	37	8.3	2.47
851.04	2.57	10.02	8.67	1230	4.55	220	0.03	0.45	14.9	48	10.1	N/A
851.38	2.33	9.41	8.35	1190	4.83	210	0.03	0.36	10.2	47	10.4	3.12
851.71	2.52	8.93	8.41	1230	4.4	200	0.04	0.43	13.7	48	10.7	N/A
852.04	2.36	7.74	8.67	1480	4.56	200	0.04	0.46	17.1	45	9.77	2.72
852.38	2.55	10.86	8.44	1220	4.55	220	0.04	0.43	14.8	47	11.1	N/A
852.71	2.94	10.02	9.09	1240	4.3	200	0.04	0.46	15.7	50	13.7	2.36
853.04	2.85	11.32	8.32	1150	4.53	220	0.04	0.44	14.8	49	13.1	N/A
853.38	2.50	6.89	8.83	1190	5.3	190	0.04	0.46	13.6	53	11	3.5
853.71	2.23	8.01	8.68	1140	4.92	200	0.04	0.45	14.1	44	9.43	N/A
854.04	2.28	10.42	8.65	1220	5	220	0.04	0.44	16.3	43	10.4	2.79
854.38	4.02	12.78	9.03	1150	4.28	230	0.05	0.45	17.2	69	22.2	N/A
854.71	3.63	8.98	8.23	1110	4.76	180	0.04	0.44	16.8	73	19.5	3.26
855.04	2.36	7.89	8.89	1290	4.45	200	0.04	0.49	17.7	42	11.3	N/A
855.38	2.34	7.62	8.54	4360	4.99	190	0.02	0.45	15.2	46	9.38	3.28
855.71	2.31	6.53	8.81	1210	4.57	190	0.02	0.46	14.5	45	8.86	N/A
856.04	2.34	7.43	9.05	1260	4.73	200	0.02	0.48	18.2	44	9.66	2.91
856.38	2.59	10.57	8.2	1180	4.45	190	0.01	0.44	17.6	45	9.4	N/A
856.71	2.67	8.53	8.97	1240	4.58	210	0.03	0.47	14.1	42	10.5	2.78
857.04	2.43	6.05	9.09	1300	4.69	200	0.03	0.51	17.7	45	10.3	N/A
857.38	2.60	8.66	8.66	1210	4.56	200	0.03	0.48	15.7	46	9.82	2.67

Table A-3. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bald Eagle core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)	S (wt%)
857.71	2.23	8.39	8.61	1130	4.44	210	0.02	0.45	12.3	40	8.88	N/A
858.04	2.50	8.76	8.31	1180	4.08	230	0.04	0.44	19.1	39	10.2	2.5
858.38	2.60	7.28	9.22	2740	4.35	200	0.03	0.47	15.7	43	10.5	N/A
858.71	2.88	5.71	8.71	3730	4.25	180	0.02	0.41	11.6	49	11.4	2.76
859.04	2.88	4.48	9.13	3630	4.33	180	0.03	0.48	16.1	51	11.7	N/A
859.38	9.15	4.93	9.04	2550	4.66	170	0.02	0.46	15.3	48	10.9	3.17
859.71	3.39	4.65	8.83	3500	4.2	180	0.05	0.46	18.4	62	15.1	N/A
860.04	1.73	52.12	8.45	2440	4.01	180	0.03	0.45	17	65	14.5	2.68
860.38	3.24	5.22	8.98	4270	4.33	180	0.04	0.48	15.2	57	15.2	N/A
861.04	2.72	6.89	8.88	3720	4.63	170	0.02	0.46	18	55	12.9	2.98
861.38	3.06	11.30	8.78	2390	4.29	210	0.03	0.44	18.9	56	13.3	N/A
861.71	3.31	14.17	8.39	4720	4.45	240	0.03	0.43	14.8	73	18.2	2.49
862.04	2.92	11.09	7.92	3800	4.09	190	0.03	0.42	16.1	57	12.3	N/A
862.38	2.83	6.98	8.67	1250	4.72	190	0.03	0.46	16.7	51	11.2	2.93
862.71	2.32	6.28	8.88	1440	4.78	190	0.03	0.46	15.4	41	9.26	N/A
863.04	2.22	8.40	8.76	3420	4.83	210	0.02	0.43	16.4	42	9.42	2.91
863.38	2.72	10.34	8.37	2570	4.56	220	0.03	0.43	16.1	43	10.1	N/A
863.71	2.96	8.59	9.1	2120	4.52	210	0.05	0.48	17.1	55	11.1	2.31
864.04	2.15	8.74	8.12	4090	3.75	210	0.02	0.44	14.9	44	9.77	N/A
864.38	2.16	10.27	7.62	1070	3.91	200	0.02	0.41	14.6	38	7.9	2.46
864.71	1.94	9.09	7.81	1080	4.53	180	0.02	0.43	19.2	41	8.43	N/A
865.04	1.84	18.89	7.26	1080	4.16	290	0.02	0.41	15.9	34	6.87	2.36
865.38	2.09	8.21	8.06	1160	4.5	200	0.03	0.44	16	34	7.07	N/A
866.04	2.44	9.43	8.07	1100	3.79	180	0.03	0.44	18.2	42	8.23	N/A
866.38	2.39	7.21	8.11	1130	4.43	180	0.03	0.44	14.8	41	8.39	2.81
866.71	2.54	6.04	8.65	1140	4.03	190	0.03	0.45	17.6	39	8.49	N/A
867.04	2.54	7.95	8.29	1110	4.19	190	0.03	0.44	15.6	43	8.93	1.85
867.38	5.80	6.50	8.69	1640	4.29	200	0.04	0.45	20.7	44	9.12	N/A
867.71	4.49	5.82	8.68	1200	4.61	200	0.04	0.46	17.6	35	7.77	2.81
868.04	2.86	6.71	8.89	1250	4.44	200	0.04	0.45	18.9	35	8.51	N/A
868.38	2.41	7.86	10.7	1540	5.06	230	0.03	0.56	21.6	37	9.22	2.46
868.71	2.61	6.21	8.39	1160	3.55	190	0.03	0.45	16.3	43	10.6	N/A
869.04	2.43	4.58	8.87	1180	4.2	180	0.03	0.47	17	45	11.3	2.56
869.38	2.13	778.36	8.54	1140	4.34	200	0.03	0.48	17.5	49	11.9	N/A
869.71	2.07	20.14	8.47	1200	4.1	180	0.03	0.46	18	40	10.4	N/A
870.04	2.05	9.53	8.31	1240	4.19	200	0.02	0.45	18.9	35	9.68	2.44
870.38	2.15	9.63	8.35	1160	4.68	190	0.03	0.44	16.9	37	8.62	N/A
870.71	2.39	9.60	7.82	1120	3.96	200	0.03	0.42	18.3	42	9.56	2.1
871.04	2.69	9.27	8.14	1110	3.93	200	0.03	0.42	16.3	46	10.6	N/A
871.38	2.97	10.58	8.32	1110	3.83	190	0.03	0.43	18.2	52	13.1	2.23
871.71	2.68	11.93	8.23	1110	3.91	200	0.04	0.43	18.2	52	11.5	N/A
872.04	2.44	9.94	7.96	1100	4.85	200	0.04	0.41	17.5	45	9.73	3.42
872.38	2.46	11.62	7.71	1100	3.5	230	0.04	0.4	12.7	39	8.31	N/A
872.71	2.21	9.39	8.06	1120	4.17	210	0.04	0.42	15.7	37	7.3	2.77
873.04	1.94	13.48	7.54	1020	3.8	210	0.03	0.38	16.4	30	5.98	N/A
873.38	1.95	7.32	7.48	1130	3.8	200	0.03	0.41	14	29	7.09	2.69
873.71	2.23	6.88	8.43	1150	4.46	200	0.03	0.44	16.5	31	7.67	N/A
874.04	2.57	6.86	7.95	1090	3.96	180	0.03	0.43	17.4	34	8.45	2.47

Table A-3. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bald Eagle core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)	S (wt%)
875.04	2.73	6.36	8.26	1110	3.98	180	0.04	0.43	18.2	43	9.87	N/A
875.38	2.83	10.40	7.7	1030	4	200	0.04	0.39	15.4	58	11	2.46
876.04	2.79	13.21	7.52	1020	3.81	210	0.04	0.39	14.8	60	10.8	N/A
876.38	2.71	18.22	7.69	1030	3.79	250	0.06	0.38	16.7	57	10.7	2.23
876.71	1.90	10.25	8.12	1020	3.87	210	0.05	0.4	15.8	48	9.6	N/A
877.04	2.88	12.34	7.7	1020	3.73	190	0.02	0.39	14.6	53	9.37	2.26
877.38	2.57	9.74	7.8	1050	3.98	190	0.03	0.41	16.9	48	10.5	N/A
877.71	3.07	9.68	7.82	1020	3.78	190	0.04	0.4	12.4	57	11	2.13
878.04	2.72	11.61	7.97	1050	3.93	200	0.03	0.41	16	46	10.2	N/A
878.38	6.89	10.34	7.71	1060	4.09	200	0.04	0.42	20.2	52	9.29	2.43
878.71	3.05	8.62	7.79	1040	3.87	190	0.03	0.42	15.1	52	9.53	N/A
879.04	2.54	8.35	8.14	1060	3.85	190	0.03	0.43	16.7	41	8.66	2.17
879.38	2.54	10.37	7.92	1050	3.8	200	0.03	0.42	14.9	43	9.3	N/A
879.71	3.01	9.95	7.83	1020	3.7	190	0.03	0.4	13.3	55	9.48	2.1
880.04	2.33	10.27	7.53	1010	4.12	200	0.04	0.4	14.6	48	8.47	N/A
880.38	2.36	14.13	7.18	973	3.63	210	0.05	0.37	14.1	47	8.23	2.07
880.71	2.61	16.88	7.22	1000	3.41	240	0.22	0.34	13.7	53	10.1	N/A
881.04	2.28	14.11	7.28	977	3.67	200	0.04	0.38	19.3	39	7.98	1.93
881.38	2.12	12.76	6.89	945	3.71	200	0.03	0.36	15.7	33	7.16	N/A
881.71	2.39	9.30	7.41	997	3.49	190	0.03	0.39	15.6	48	8.09	1.93
882.04	2.36	9.79	7.62	1030	3.45	190	0.04	0.39	17.2	38	7.73	N/A
882.38	2.41	11.48	7.58	998	3.47	190	0.03	0.38	16.9	45	8.82	1.9
883.04	2.67	10.78	7.53	1050	3.72	190	0.04	0.38	17.9	53	9.27	N/A
895.04	2.57	3.14	7.95	1080	4.92	140	0.02	0.4	15.1	37	10.9	3.97
895.38	3.95	5.54	7.74	1030	4.45	150	0.04	0.4	14.4	79	17.5	N/A
895.71	4.46	5.82	7.27	997	4.65	140	0.02	0.36	14.7	89	18.6	3.58
896.04	4.12	5.40	7.17	962	4.57	140	0.02	0.36	19.2	80	18.1	N/A
896.38	2.49	6.31	6.56	903	5.44	130	0.04	0.32	17.7	96	19.7	4.79
896.71	4.20	7.22	6.33	927	4.35	130	0.04	0.32	17.2	82	20.9	N/A
897.04	4.72	6.08	6.53	912	4.94	120	0.03	0.31	18.7	93	21.9	4.23
897.38	4.66	17.40	6.08	862	4.02	140	0.05	0.29	16.6	109	26.6	N/A
897.71	3.74	4.07	6.25	893	5.33	110	0.03	0.32	18.9	85	18.2	4.66
898.04	4.26	9.24	5.74	819	4.06	140	0.04	0.25	13.3	81	18.6	N/A
898.38	4.55	5.65	6.19	847	5.53	110	0.04	0.3	11.6	107	23.5	5.23
898.71	4.24	6.64	6.23	878	6.13	120	0.03	0.3	15.9	108	25.3	N/A
899.04	4.47	7.92	6.21	907	3.81	140	0.04	0.3	14.3	93	22	4.12
899.38	2.43	12.06	7.87	1020	3.61	200	0.04	0.4	17.2	44	8.22	N/A
899.71	3.67	7.46	6.44	1010	5.6	130	0.03	0.32	18.9	69	16.2	4.92
900.04	4.51	4.78	6.52	903	5.64	110	0.03	0.32	17.1	91	21.4	N/A
900.38	4.53	7.49	6.04	863	4.12	130	0.04	0.28	18.3	83	20.5	4.09
900.71	4.49	6.26	5.93	874	4.15	130	0.03	0.3	19.9	101	19.7	N/A
901.04	3.80	5.40	6.31	906	5.79	110	0.04	0.31	12.3	77	16.9	5.38
901.38	5.48	7.12	6	848	4.53	140	0.04	0.27	16.5	96	22.5	N/A
901.71	5.33	7.98	5.96	824	4.25	150	0.04	0.26	14.3	107	23.4	4.34
902.04	4.52	7.43	6	848	6.07	120	0.04	0.29	17.6	101	25.7	N/A
902.38	6.15	6.28	6.44	1200	4.57	120	0.03	0.26	12.5	128	33.8	3.87
902.71	5.80	7.98	6.54	908	4.85	140	0.03	0.31	18.8	129	34.6	N/A
903.04	5.56	7.42	6.71	954	6.05	130	0.03	0.32	16.5	129	30.7	5.51

Table A-3. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 393.83 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Bald Eagle core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)	S (wt%)
903.38	2.20	6.95	6.96	921	5.16	130	0.04	0.3	15	192	45	N/A
903.71	5.43	4.73	6.89	955	5.64	110	0.04	0.32	15.8	111	25.9	5.36
904.38	5.70	17.33	6.58	897	4.23	180	0.03	0.28	11.7	115	32.1	N/A
904.71	5.60	6.87	7.09	990	4.53	120	0.03	0.34	17.8	100	27.8	3.92
905.04	5.77	6.67	6.44	940	4.41	110	<0.01	0.24	8.54	97	24.4	N/A
905.38	5.41	15.71	6.23	876	4.09	160	0.03	0.29	15.4	94	20.7	3.36
905.71	1.64	68.40	1.59	585	3.13	470	0.12	0.07	4.8	20	11.1	N/A
906.04	7.13	8.32	7.21	906	6.48	130	0.05	0.35	17.1	130	39.1	6.03
906.71	6.95	5.36	7.47	1010	7.12	100	0.04	0.35	15.5	181	50	N/A
907.04	7.13	4.88	7.64	6700	6.56	110	0.05	0.35	14.5	187	60.6	6.43
907.38	7.82	3.43	7.5	4780	4.99	110	0.04	0.34	10.5	179	62.7	N/A
907.71	7.01	4.86	7.43	1010	6.66	110	0.03	0.34	15.4	151	45.4	6.48
908.38	6.74	6.14	7.17	958	5.07	140	0.05	0.35	16.1	168	34.1	N/A
908.71	7.97	16.21	5.72	881	4.65	160	0.03	0.26	13.9	183	85.4	4.55
909.04	7.21	14.74	4.05	613	3.47	110	0.04	0.19	12.3	152	45.4	N/A
909.71	7.93	12.47	3.64	592	2.97	90	0.03	0.17	17.7	155	35	3.1
910.38	0.43	7.90	13.7	1790	1.75	140	0.16	0.58	14.5	11	14.5	N/A
910.71	7.88	8.42	3.8	580	4.69	70	0.04	0.19	20.8	169	49.6	4.99
911.04	6.63	13.31	4.22	704	3.04	80	0.03	0.15	15.6	115	29.4	N/A
911.38	5.83	12.21	3.1	536	2.41	70	0.02	0.15	21.4	95	25.3	2.56
911.71	6.91	5.32	7.41	1000	6.69	120	0.02	0.34	13.8	164	45.1	N/A
912.38	5.49	15.52	3.34	566	2.22	120	0.03	0.16	16.9	93	23.9	N/A
913.04	5.52	22.83	3.68	697	1.72	110	0.04	0.17	12.4	56	19.5	2.03
913.38	5.85	25.63	4	672	2.35	120	0.03	0.19	10.3	100	24.7	N/A
913.71	3.72	19.56	3.9	646	5	90	0.02	0.19	14.1	44	12.7	5.36
914.38	0.55	32.38	0.17	400	0.31	90	0.17	<0.01	7.99	10	3.22	N/A
914.71	4.34	25.12	5.68	858	2.25	120	0.03	0.27	13.9	91	19	1.92
915.04	6.77	23.63	4.48	647	2.87	110	0.04	0.21	12.4	172	29.8	N/A
915.38	4.40	30.20	2.97	1470	6	90	0.06	0.13	13	118	23.4	6.81
915.71	9.43	12.54	3.02	470	2.14	70	0.04	0.13	13.3	129	23.5	N/A
916.04	7.53	17.40	2.98	466	1.66	80	0.04	0.13	13	144	25.8	1.78
916.38	8.27	24.31	2.96	505	1.43	90	0.05	0.13	11.8	84	18.7	N/A
916.71	6.96	23.34	2.6	1440	8.28	70	0.04	0.11	12.3	123	18.2	9.57
917.04	6.48	29.44	1.87	385	0.97	100	0.03	0.08	12	92	17.9	N/A
917.38	6.35	21.65	3.17	459	1.42	90	0.04	0.13	9.09	131	20.7	1.34
917.71	5.29	25.78	2.25	363	4	150	0.03	0.09	12.2	77	16.4	N/A
918.04	5.59	31.24	2.28	340	1.01	120	0.04	0.09	11.9	87	18.6	0.89
918.38	7.63	15.49	4.82	659	1.85	80	0.05	0.18	18.6	175	29.2	N/A
919.71	1.97	76.48	0.41	104	0.6	230	0.02	0.02	6.27	25	6.63	0.43
920.04	1.25	63.63	1.61	370	0.64	290	0.02	0.05	8.97	10	5.98	N/A
920.71	8.83	39.87	3.9	3850	2.32	120	0.08	0.17	7.63	199	33.3	2.57
921.38	1.42	94.17	0.42	80.9	0.49	260	0.04	0.02	1.43	23	8.66	N/A
921.71	6.20	47.47	0.24	506	0.44	360	0.02	0.01	2.65	18	3.44	0.11
922.04	4.31	50.27	3.86	456	2.3	120	0.03	0.15	8.98	36	12	N/A
922.38	2.32	84.27	0.6	109	0.78	240	0.04	0.03	3.66	110	17.2	0.57
924.38	3.07	5.98	8.24	1090	3.67	170	0.03	0.42	13.8	42	10.3	N/A
924.71	3.11	5.96	8	1110	3.71	160	0.03	0.43	17.8	47	10.5	2.21

Table A-4. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 8726.04 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Snow Shoe core.

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)	S (wt%)
8650.0			11.45	1349.08	4.01	222.13		0.37	32.76	32.16	15.53	3.41
8650.5			11.24	1384.46	3.66	239.59		0.40	32.60	30.44	14.32	3.31
8652.0			9.63	1417.69	3.44	153.18		0.33	29.41	35.91	12.13	3.21
8652.5			11.24	1359.24	3.66	143.16		0.39	33.23	40.54	10.08	3.19
8653.0			10.39	1460.96	3.71	155.09		0.36	29.95	42.19	11.47	3.07
8653.5			10.38	1475.21	3.64	161.87		0.36	31.48	51.79	14.67	3.25
8654.0			9.69	1319.10	3.41	173.42		0.37	25.74	62.87	13.46	3.47
8654.5			9.61	1359.45	3.63			0.38	29.35	39.09	19.52	3.64
8655.0			10.10	1539.90	3.76	85.32		0.42	30.69	33.30	15.54	3.15
8655.5			12.45	1510.13	4.13			0.44	31.77	45.37	20.18	3.97
8656.0			12.89	1671.46	3.90	81.44		0.42	33.72	37.46	14.22	3.67
8656.5			1.70	1568.84	0.62	552.45		0.05	5.46	5.46	0.00	0.72
8657.0			12.95	955.66	3.90	67.52		0.48	31.17	40.60	17.29	3.70
8657.0			12.55	1568.21	3.81			0.52	30.72	40.36	18.83	3.94
8657.5			10.84	1593.25	3.86	170.34		0.41	29.58	30.41	16.19	3.48
8658.0			10.75	1654.03	3.87	307.58		0.38	27.59	51.78	24.42	3.49
8658.5			11.79	1604.08	4.06	226.66		0.44	30.35	47.20	20.77	4.38
8659.0			11.26	1679.03	3.99	221.27		0.40	29.34	46.29	24.87	3.52
8660.0			11.22	1299.52	3.87			0.43	30.37	48.36	17.56	3.45
8660.5			7.39	904.50	5.88	128.91		0.27	20.40	35.29	15.52	8.35
8661.0			10.62	1163.31	4.00	260.10		0.36	27.71	41.91	26.54	4.04
8661.5			12.25	1421.14	4.20	132.93		0.43	32.52	30.52	14.92	3.62
8662.0			12.62	1522.51	4.02	258.21		0.40	31.32	36.87	22.96	3.70
8662.5			13.02	1651.16	4.62	99.82		0.44	33.15	38.34	16.48	4.46
8662.5			12.52	1601.66	4.67	114.50		0.45	32.54	36.63	18.33	4.38
8663.0			11.92	1535.80	3.90	173.09		0.42	31.12	34.02	15.48	3.36
8663.5			14.02	1493.52	4.16	176.09		0.45	33.14	43.18	20.05	3.42
8664.0			11.14	1645.52	4.13	165.42		0.41	30.49	23.69	10.93	3.48
8664.5			11.16	1643.50	4.16	184.75		0.41	28.42	36.23	19.40	3.30
8665.0			13.68	1467.27	4.54	184.54		0.44	32.74	31.36	13.49	4.02
8665.5			13.30	1679.73	4.23	181.76		0.44	32.30	26.30	11.59	3.60
8666.0			13.30	1554.48	4.54	144.38		0.48	32.84	25.39	19.03	3.38
8666.5			11.18	1542.84	4.03	108.32		0.45	30.52	26.48	15.82	3.45
8667.0			12.87	1468.41	4.19	141.07		0.46	33.06	32.91	16.95	3.64
8668.0			13.87	1472.45	4.22	136.84		0.45	34.36	28.71	19.70	3.64
8668.0			12.70	1556.08	4.02	122.21		0.43	32.91	27.00	16.66	3.45
8668.5			12.76	1502.96	4.02	225.15		0.43	31.58	26.33	20.94	3.34
8669.0			12.49	1469.92	4.50	142.65		0.46	31.78	34.74	23.11	3.55
8669.5			13.76	1382.72	4.33	132.05		0.44	33.38	25.34	18.35	3.80
8670.0			12.03	1420.28	3.85	287.33		0.37	29.18	33.70	26.63	3.30
8670.5			13.56	1542.06	4.40	184.50		0.47	33.20	33.86	23.50	3.63
8671.0			12.64	1601.60	4.04	158.57		0.43	32.28	29.60	19.45	3.41
8671.5			12.97	1535.69	4.34	176.56		0.41	32.70	33.96	17.40	3.68
8672.0			12.28	1585.35	4.32	112.81		0.41	32.58	34.83	19.10	3.95
8672.5			11.46	1602.47	3.84	118.62		0.40	30.84	36.87	23.03	3.42
8673.0			13.13	1292.91	4.21	106.82		0.42	33.87	26.26	17.34	3.71

Table A-4. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 8726.04 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Snow Shoe core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)	S (wt%)
8673.0			13.00	1460.34	4.48			0.42	33.06	26.90	21.00	4.20
8673.5			11.81	1396.07	3.70	184.97		0.40	31.57	32.46	24.52	3.17
8674.0			12.50	1436.86	4.18	141.36		0.43	33.45	26.81	19.62	3.68
8674.5			12.04	1528.52	3.92	137.88		0.42	32.26	31.94	19.93	3.55
8675.0			12.24	1546.97	4.09	114.51		0.43	33.18	28.67	24.00	3.63
8676.0			11.44	1467.86	4.18	132.46		0.42	32.07	33.86	17.69	3.89
8676.5			13.02	1452.26	3.97	188.59		0.44	33.25	23.30	18.65	3.48
8677.0			9.73	1555.38	3.68	214.17		0.37	28.39	24.41	17.15	3.10
8677.5			12.23	1451.97	3.68	188.04		0.40	31.59	29.41	21.32	3.19
8678.0			12.57	1590.54	3.99	176.02		0.44	32.32	30.35	24.94	3.26
8678.5			12.33	1502.45	4.09	231.12		0.39	30.76	33.53	22.86	3.49
8678.5			12.78	1557.49	4.22	212.09		0.39	30.96	33.22	17.27	3.73
8679.0			12.48	1619.76	3.92	216.61		0.40	31.69	32.36	17.63	3.16
8679.5			10.19	1580.35	3.53	207.19		0.40	27.97	32.91	15.83	3.07
8680.0			3.13	1333.98	1.37	555.37		0.09	8.91	8.01	6.64	1.09
8680.5			3.48	2610.85	1.80	777.49		0.10	9.09	9.90	9.42	1.08
8681.0			12.19	1384.94	4.16	208.95		0.40	30.49	33.62	20.56	3.64
8681.5			13.08	1497.69	3.97	109.97		0.43	32.77	56.46	25.73	3.45
8682.0			13.73	1540.01	4.41	81.37		0.43	34.51	36.95	21.47	3.83
8682.5			12.72	1611.17	3.82	167.46		0.41	32.43	53.75	26.99	3.13
8683.0			12.60	1496.35	3.94	113.86		0.44	33.43	39.72	18.75	3.10
8684.0			13.63	1538.91	4.15	181.99		0.42	34.27	36.75	21.50	3.12
8684.0			13.43	1624.58	4.08	202.86		0.44	34.36	37.71	20.49	3.05
8684.5			12.00	1666.61	4.96	212.79		0.39	31.80	36.20	15.10	3.68
8685.0			12.06	1438.01	4.00	184.86		0.39	32.06	51.19	16.46	3.21
8685.5			12.02	1516.94	4.37	167.60		0.40	31.79	41.46	17.15	3.24
8686.0			12.67	1480.58	3.60	171.82		0.41	32.29	42.18	21.51	2.57
8686.5			11.42	1529.70	4.02	136.62		0.41	30.32	46.10	17.31	3.21
8687.0			13.93	1404.55	4.92	115.82		0.44	33.25	42.30	16.18	4.40
8687.5			13.05	1533.34	3.85	196.76		0.41	31.85	44.78	21.55	2.83
8688.0			13.48	1513.31	5.22	146.29		0.43	32.02	66.80	22.66	4.91
8688.5			13.22	1295.72	4.00	151.95		0.46	33.21	40.03	16.64	3.19
8689.0			13.09	1480.56	4.30	88.81		0.46	33.14	38.11	18.01	3.55
8689.0			13.96	1521.08	4.29	137.78		0.48	34.35	39.06	17.17	3.69
8689.5			12.87	1557.04	4.07	118.67		0.42	32.50	35.52	16.20	3.26
8690.0			13.95	1542.55	4.80	111.97		0.44	33.77	38.67	18.15	4.16
8690.5			12.36	1506.47	3.97	125.67		0.46	32.53	38.59	18.43	3.00
8691.0			14.45	1231.96	3.83	162.53		0.46	34.79	36.64	17.97	3.02
8692.0			13.09	1622.29	4.14	120.14		0.44	34.45	38.80	19.31	3.48
8692.5			13.49	1900.02	3.79	149.71		0.45	33.87	58.09	25.90	3.54
8693.0			13.92	1638.40	4.26	132.62		0.45	35.13	52.13	26.66	3.90
8693.5			13.93	1843.81	4.00	147.50		0.45	35.30	52.44	23.17	3.49
8694.0			12.09	1680.02	4.12	96.63		0.42	32.79	44.42	18.97	3.78
8694.5			10.49	1389.65	3.51	219.76		0.34	29.18	49.19	26.08	2.92
8694.5			11.51	1354.55	3.50	247.87		0.34	30.61	51.16	22.61	3.03
8695.0			12.70	1480.09	3.71	245.39		0.42	32.31	57.75	25.80	3.03
8695.5			13.19	1497.20	3.93	131.76		0.43	33.86	41.85	21.22	3.81
8696.0			11.03	1363.08	3.98	73.82		0.41	31.57	37.27	19.96	3.37

Table A-4. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 8726.04 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Snow Shoe core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)	S (wt%)
8696.5			12.48	1239.31	3.95	146.87		0.42	32.36	31.39	19.28	4.21
8697.0			12.78	1385.31	3.72	208.36		0.41	33.28	48.77	21.17	3.62
8697.5			11.38	1492.93	3.73	151.98		0.41	31.95	33.52	18.37	2.98
8698.0			13.12	1483.23	3.91	176.78		0.45	34.88	27.91	20.73	3.27
8698.5			9.75	1453.15	3.67	139.31		0.40	30.75	24.53	22.79	3.02
8699.0			13.38	1313.97	4.66	184.06		0.41	34.54	50.20	16.88	4.65
8700.0			12.78	1444.10	3.74	169.94		0.42	35.13	36.59	16.28	3.51
8700.5			12.09	1493.31	3.85	181.35		0.42	32.64	31.89	20.39	3.72
8701.0			9.98	1514.68	4.84	216.36		0.39	29.54	35.85	16.66	4.41
8701.5			12.13	1519.22	3.89	190.90		0.40	33.19	37.23	18.23	4.02
8702.0			13.70	1484.33	4.18	169.77		0.42	34.52	25.71	18.92	4.13
8702.5			11.87	1463.15	3.96	143.06		0.41	32.46	27.28	20.49	3.56
8702.5			12.03	1151.48	3.96	121.79		0.42	32.62	26.84	18.58	3.47
8703.0			10.83	1280.91	3.53	140.73		0.41	31.21	35.59	22.17	3.26
8703.5			13.92	1453.31	4.55	212.15		0.43	35.22	47.53	22.46	4.08
8704.0			11.77	1673.54	3.78	178.16		0.43	33.31	35.00	19.22	3.53
8704.5			10.87	1431.24	3.60	194.26		0.39	32.14	23.87	18.52	2.82
8705.0			13.21	1429.17	3.84	227.28		0.42	35.57	50.80	18.00	3.24
8705.5			10.12	1548.51	3.81	219.32		0.39	29.75	37.73	13.31	3.80
8706.0			11.30	1403.54	3.29	196.07		0.37	33.36	37.58	14.69	2.74
8706.5			11.46	1445.04	3.95	177.68		0.39	33.57	37.62	11.88	3.58
8707.0			11.30	1451.98	3.47	186.84		0.37	33.00	43.03	16.27	2.74
8708.0			10.88	1405.10	3.76	200.01		0.36	31.42	27.45	12.50	3.93
8708.5			10.60	1336.31	4.67	214.19		0.36	31.61	61.28	8.96	3.37
8709.0			9.97	1451.45	4.16	159.09		0.36	30.95	24.54	11.68	3.62
8709.5			10.43	1529.53	3.87	168.21		0.38	32.44	26.80	12.03	3.40
8710.0			10.03	1328.12	3.39	105.02		0.38	32.75	34.99	14.44	3.35
8710.5			12.23	1378.66	3.54	120.30		0.41	35.52	40.69	15.85	3.37
8710.5			11.60	1343.80	4.01	61.48		0.44	34.82	44.83	16.31	4.27
8711.0			12.63	1318.68	3.43	165.69		0.41	35.24	49.15	19.44	3.27
8711.5			10.80	1516.35	3.54	103.32		0.40	33.38	40.30	15.01	2.99
8712.0			10.75	1469.07	3.47	189.07		0.37	32.18	36.12	14.83	3.25
8712.5			10.16	1353.47	3.51	188.01		0.38	30.57	46.62	18.20	3.27
8713.0			9.95	1365.40	3.67	91.77		0.38	30.86	29.82	13.51	3.42
8713.5			11.52	1398.53	3.71	172.62		0.37	33.04	34.41	14.74	3.30
8714.0			11.94	1281.39	3.34	228.26		0.37	34.02	38.57	14.77	2.91
8714.5			9.88	1386.79	3.29	138.96		0.38	30.80	30.50	10.98	3.13
8715.0			8.05	1251.67	3.20	143.44		0.35	27.88	49.42	13.83	2.56
8716.0			11.24	1220.80	3.47	165.38		0.39	33.52	42.44	11.35	3.09
8716.0			11.34	1285.90	3.56	221.28		0.37	33.39	43.44	13.69	3.12
8716.5			12.25	1287.35	7.50	394.30		0.36	30.50	185.22	16.91	7.08
8717.0			10.11	1665.65	3.11	222.37		0.36	31.61	38.68	16.22	2.62
8717.5			11.62	1451.86	3.48	214.97		0.38	33.78	41.24	12.43	3.04
8718.0			11.33	1428.81	3.65	228.12		0.36	34.25	36.50	14.50	3.59
8718.5			10.91	1488.60	3.46	223.90		0.36	33.15	38.74	12.65	3.50
8719.0			11.63	1559.18	3.39	258.89		0.34	32.75	45.29	14.60	3.16
8719.5			10.19	1473.38	3.08	287.94		0.33	30.42	30.02	15.58	2.43
8720.0			9.83	1421.16	3.28	257.88		0.32	32.34	46.72	15.19	3.72

Table A-4. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 8726.04 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Snow Shoe core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)	S (wt%)
8720.5			11.70	1327.47	3.29	223.98		0.37	36.72	32.35	15.22	3.35
8721.0			11.29	1420.65	4.25	155.52		0.39	34.31	43.52	12.49	3.83
8721.0			11.66	1360.11	4.01	165.94		0.40	35.27	40.25	15.38	3.75
8721.5			8.80	1438.49	8.02			0.23	24.65	198.46	31.55	11.50
8722.0			12.01	1470.67	14.46			0.25	27.50	189.52		19.68
8722.5			9.06	1503.51	4.71	85.79		0.25	30.39	97.85	42.34	5.95
8723.0			7.96	1240.29	4.47			0.25	36.29	82.78	29.14	6.06
8724.0			9.13	1060.50	7.55			0.25	32.28	90.77	41.19	10.17
8724.5			10.33	1187.41	4.76			0.30	32.14	216.36	46.85	5.26
8725.0			10.84	1309.30	5.03			0.33	35.48	87.15	41.74	6.52
8725.5			7.54	1292.71	3.49	82.35		0.23	33.75	76.36	33.12	4.68
8726.04	5.19	15.80	5.12	1080.00	3.30	140.00	0.03	0.22	16.70	90.00	19.80	3.15
8726.38	4.59	16.35	4.64	1120.00	3.37	140.00	0.02	0.21	12.00	79.00	15.70	N/A
8726.71	3.35	21.07	4.89	1180.00	3.92	180.00	0.03	0.22	12.90	47.00	11.80	3.75
8727.04	4.64	43.24	2.71	868.00	5.04	260.00	0.13	0.11	11.00	34.00	9.17	N/A
8727.38	6.48	12.61	5.61	1260.00	4.42	140.00	0.02	0.26	14.30	148.00	29.90	4.25
8727.71	6.24	7.95	5.92	1310.00	5.31	100.00	0.03	0.28	14.20	131.00	34.90	N/A
8728.04	6.07	11.56	5.68	1270.00	3.38	110.00	0.03	0.25	13.50	109.00	30.90	3.39
8728.38	5.88	5.67	6.14	1360.00	5.54	100.00	0.04	0.28	13.10	126.00	30.20	N/A
8728.71	4.27	37.44	3.87	948.00	5.56	270.00	0.03	0.19	9.12	75.00	32.70	5.75
8729.04	8.64	17.66	5.96	1260.00	4.51	150.00	0.05	0.28	11.10	190.00	41.80	N/A
8729.38	5.94	14.43	6.52	1320.00	5.85	160.00	0.02	0.31	14.20	130.00	34.50	5.65
8730.71	7.82	4.91	7.36	1410.00	7.20	120.00	0.03	0.33	14.50	209.00	69.40	N/A
8731.04	6.56	5.68	6.34	1240.00	9.99	90.00	0.03	0.31	13.40	169.00	58.30	11.3
8731.38	8.48	1.32	6.09	1280.00	8.47	170.00	0.08	0.27	14.40	310.00	49.70	N/A
8731.71	8.41	17.05	4.80	1110.00	4.13	150.00	0.03	0.21	11.20	198.00	83.00	4.15
8732.04	4.73	27.73	2.35	611.00	2.91	190.00	0.02	0.11	12.00	86.00	24.10	N/A
8732.38	9.25	10.61	4.35	984.00	3.86	100.00	0.03	0.19	17.70	254.00	67.60	4.4
8732.71	0.44	2.53	13.30	3890.00	1.21	40.00	0.06	0.36	15.80	15.00	16.90	N/A
8733.04	0.17	6.24	10.80	2680.00	2.40	180.00	0.16	0.64	17.00	14.00	11.10	1.36
8733.38	9.92	18.89	3.66	916.00	4.69	120.00	0.05	0.18	10.80	312.00	92.60	N/A
8733.71	6.68	12.40	1.84	588.00	1.83	80.00	0.03	0.09	18.90	106.00	31.10	2.06
8734.04	6.70	15.23	2.25	599.00	2.25	100.00	0.03	0.11	14.00	114.00	31.50	N/A
8734.38	6.73	18.59	2.41	789.00	2.93	130.00	0.03	0.11	11.20	110.00	30.90	3.42
8734.71	4.88	43.24	1.77	505.00	1.30	200.00	0.03	0.08	9.99	78.00	24.80	N/A
8735.04	4.16	23.31	3.22	708.00	3.65	100.00	0.02	0.17	12.50	44.00	11.80	4.08
8735.38	3.30	59.06	0.87	354.00	0.65	340.00	0.09	0.04	7.26	76.00	19.60	N/A
8735.71	4.24	16.39	4.32	992.00	1.76	80.00	0.03	0.20	13.50	36.00	9.08	1.95
8736.04	3.93	52.70	0.92	379.00	2.14	200.00	0.05	0.04	10.30	53.00	17.50	N/A
8736.38	5.62	38.09	2.49	735.00	5.16	170.00	0.03	0.12	10.90	62.00	17.60	5.76
8736.71	8.37	18.32	2.19	482.00	1.47	70.00	0.04	0.08	11.50	136.00	21.10	N/A
8737.04	7.06	24.41	3.38	734.00	1.57	90.00	0.05	0.14	11.30	123.00	26.00	1.55
8737.38	9.15	23.76	2.56	579.00	1.41	90.00	0.04	0.11	13.00	119.00	21.60	N/A
8737.71	5.94	24.23	2.90	717.00	1.46	110.00	0.04	0.12	8.00	131.00	24.10	1.45
8738.04	6.27	24.71	3.87	988.00	1.61	110.00	0.04	0.16	10.20	81.00	19.10	N/A
8738.38	1.67	71.79	0.43	259.00	0.49	490.00	0.03	0.02	6.77	29.00	5.87	0.27
8738.71	1.65	56.10	0.50	238.00	0.57	370.00	0.03	0.02	9.22	36.00	7.41	N/A
8740.04	6.00	44.18	2.66	810.00	1.20	200.00	0.06	0.11	8.64	107.00	23.90	1.26

Table A-4. Data tabulation of geochemistry by XRF for the Upper Union Springs Mbr. (to 8726.04 ft depth) and sodium peroxide fusion of the Union Springs Mbr., Marcellus Formation, Snow Shoe core. (continued)

Depth (ft)	C_{org} (wt%)	$CaCO_3$ (wt%)	Al (wt%)	Ba (ppm)	Fe (wt%)	Mn (ppm)	P (wt%)	Ti (wt%)	Si (wt%)	Mo (ppm)	U (ppm)	S (wt%)
8740.38	4.50	51.80	1.63	491.00	0.86	300.00	0.04	0.07	6.69	110.00	21.40	N/A
8741.04	0.38	92.86	0.06	347.00	0.16	1780.00	0.05	<0.01	2.23	3.00	0.96	0.1
8741.38	1.21	86.81	0.21	609.00	0.43	570.00	0.03	0.01	3.46	17.00	4.53	N/A
8741.71	3.93	66.24	1.10	342.00	0.84	280.00	0.02	0.06	6.83	59.00	14.00	0.71
8742.04	3.38	24.78	5.88	1030.00	1.84	330.00	0.04	0.16	14.40	18.00	15.40	N/A
8742.38		11.80	10.50	806.00	3.49	200.00	0.08	0.42	16.40	7.00	5.25	2.08
8742.71	2.73	73.48	1.65	322.00	1.04	260.00	0.03	0.08	5.35	15.00	7.36	N/A
8743.04	1.02	89.81	0.23	194.00	0.53	650.00	0.01	0.01	2.50	7.00	4.63	0.24
8743.38	6.27	7.63	13.20	1020.00	3.66	190.00	0.08	0.39	13.30	33.00	9.33	N/A
8743.71	5.41	40.49	2.52	370.00	1.27	220.00	0.02	0.12	6.68	12.00	12.10	0.98
8744.04	2.66	75.68	1.51	311.00	0.83	350.00	0.02	0.07	4.50	13.00	8.02	N/A
8744.38	4.24	73.96	0.19	1830.00	0.62	800.00	0.01	<0.01	1.00	4.00	2.20	0.17
8744.71	0.52	88.60	0.72	152.00	1.05	950.00	0.03	0.03	2.63	4.00	6.16	N/A
8745.04		98.26	0.48	243.00	1.18	1120.00	<0.01	0.03	1.69	3.00	3.46	1.1
8745.38	2.46	53.87	3.51	396.00	1.41	330.00	0.12	0.18	7.55	5.00	17.10	N/A
8745.71	0.98	65.24	3.18	397.00	1.21	320.00	0.01	0.16	7.09	4.00	4.45	0.53
8746.04	4.21	61.80	0.75	164.00	0.78	830.00	0.02	0.04	2.59	4.00	4.85	N/A
8746.38	4.62	29.70	6.34	723.00	2.59	240.00	0.03	0.29	11.00	49.00	10.60	1.59
8746.71	5.01	45.16	4.99	409.00	2.51	210.00	0.05	0.21	7.27	24.00	13.30	N/A

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