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## Outcrop Lithostratigraphy and Petrophysics of the Middle Devonian Marcellus Shale in West Virginia and Adjacent States

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**Outcrop Lithostratigraphy and Petrophysics of the Middle Devonian Marcellus Shale in  
West Virginia and Adjacent States**

Margaret E. Walker-Milani

**THESIS**

submitted to the  
College of Arts and Sciences  
at West Virginia University  
in partial fulfillment of the requirements  
for the degree of

Master of Science  
in Geology

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2011

## ABSTRACT

### Outcrop Lithostratigraphy and Petrophysics of the Middle Devonian Marcellus Shale in West Virginia and Adjacent States

Margaret E. Walker-Milani

A stratigraphic study of 15 partial outcrops of the Marcellus Shale in West Virginia, Pennsylvania, and Maryland has identified six distinct lithofacies. These include grey calcareous shale (Facies 1), limestone (Facies 2), black calcareous shale (Facies 3), black non-calcareous shale (Facies 4), grey non-calcareous shale (Facies 5) and K-bentonite (Facies 6). Packages of these facies have been organized into six vertically stacked units (A-F). Deposition of the facies resulted from the rise and fall of relative sea level, which in turn shifted the location of the thermocline and affected the amount of terrigenous sediment distributed from the eastern source. Facies 1 and 2 were deposited above the thermocline and just below wave base. Facies 3 and 5 were deposited both above and below the thermocline depending on seasonal mixing and storm events. Facies 4 was deposited under the thermocline in the deepest water (~60 meters). Facies 1 and 5 accumulated in response to increased sediment influx, whereas Facies 2, 3 and 4 accumulated at times of low sediment supply. A decrease in sediment supply corresponded to a rise in relative sea level that allowed for the storage of terrigenous sediment far landward and the deposition of carbonate and organic-rich sediment on the foreland ramp. The intimate stratigraphic relationship among the shale and limestone facies over time and space indicates a dynamic and complex shallow-water environment for the deposition of the Marcellus Shale, as opposed to the traditional deep-water, sediment starved and statically-anoxic model.

A spectral gamma-ray type log constructed for the Marcellus Shale in outcrop (Units A-F) shows a good correlation with the formation in the nearby subsurface. Moreover, the outcrop units can be identified in terms of the subsurface nomenclature: Units A-C correspond to the Union Springs Formation; Unit D, the Cherry Valley Member; and Units E-F, the Oatka Creek Formation. Correlations indicate that the Marcellus becomes increasingly enriched in black shale (Facies 4) westward, resulting in an increased thickness of organic-rich condensed section. On the other hand, limestone and calcareous shale become less abundant westward into the basin due to the reduced sediment supply and greater water depth.

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## INTRODUCTION

The Marcellus Shale of the Appalachian Basin has traditionally been regarded as the petroleum source rock for conventional Upper Devonian and Lower Mississippian reservoirs. Although the Marcellus has a history of gas production dating back to 1821, the recent rejuvenation of Marcellus exploration began in 2004 when Range Resources introduced two crucial drilling and treatment technologies: horizontal wells and slickwater fracture stimulation. Their initial reports announced remarkable success with these techniques in Pennsylvania, kicking off a new unconventional shale gas play in the Appalachian Basin. The core area of this play – where the formation exceeds 50 ft. thick, is thermally mature, and is generally understood to have the best gas potential—includes Pennsylvania, West Virginia and New York, a staggering 50,000 sq. mi.

To date, most sedimentary studies have focused on the subsurface near the Marcellus core area (Roen, 1984; Boswell, 1996; Harper, 1999; Milici and Swezey, 2006; Ettensohn, 2008; Wrightstone, 2009; Boyce, 2010) and on outcrops in New York and Pennsylvania (Engelder 2008; Lash, 2009). Very few detailed investigations have addressed the outcrops of West Virginia, though preliminary work suggests that the Marcellus shale in West Virginia has a significantly different character than that to the north and west (Woodward, 1943; Dennison, 1960).

The primary goal of this thesis is to describe and interpret the sedimentological and stratigraphic nature of the Marcellus Shale in the outcrop belt of West Virginia and adjacent states of Pennsylvania and Maryland. A secondary goal is to create a type log from outcrop

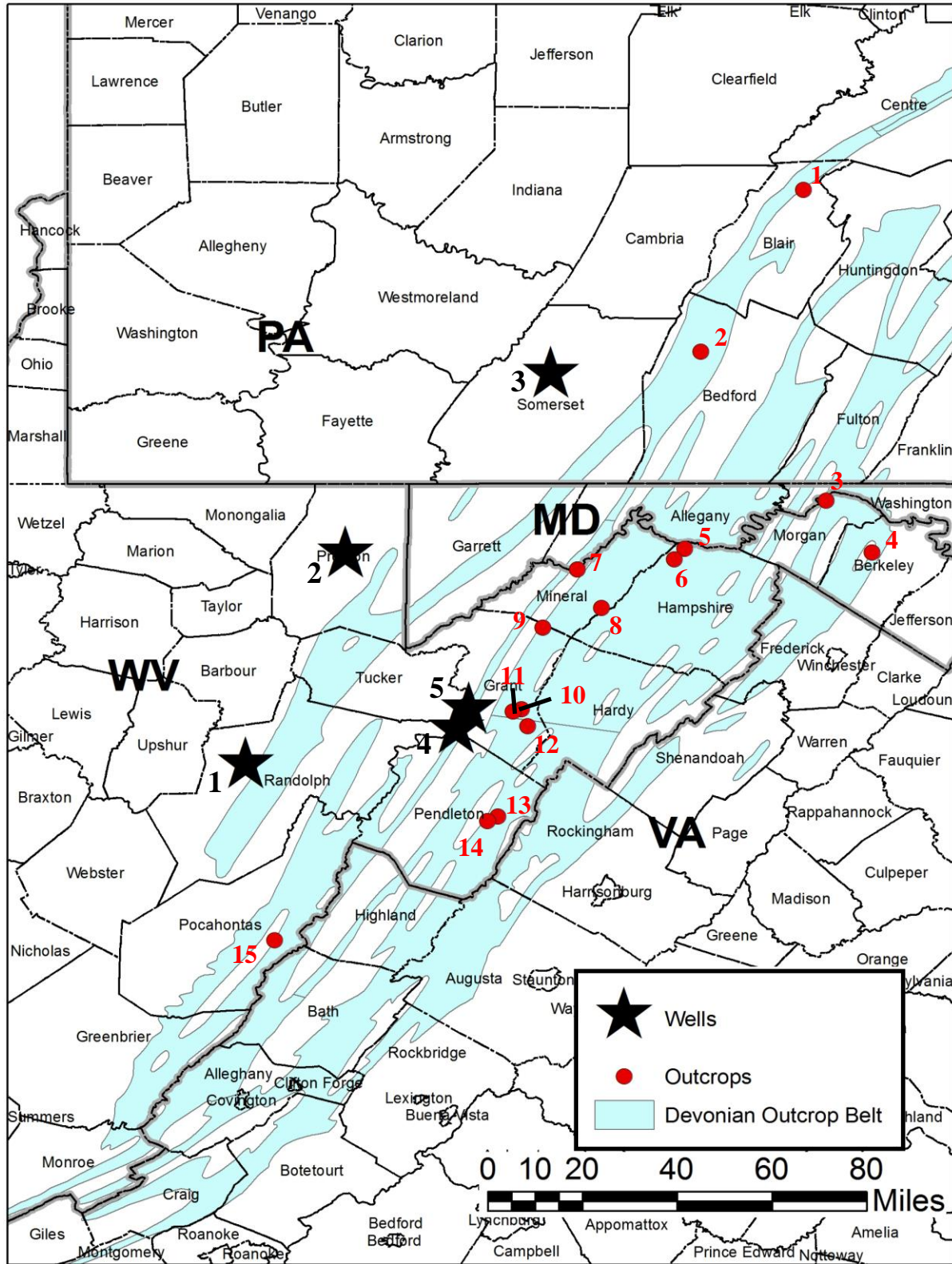
spectral gamma-ray data and correlate it to nearby well logs, so that these interpretations may be extended into the subsurface of the Appalachian Basin.

## **Purpose**

The purpose of this thesis is to better characterize the Marcellus Shale in terms of its sedimentological, stratigraphic and petrophysical properties within the outcrop belt of West Virginia and adjacent areas in Pennsylvanian and Maryland. Another purpose is to identify and describe the facies within the Marcellus and interpret them in terms of water depth, water chemistry, terrigenous input, organic content, and their temporal and spatial distribution. The spectral gamma-ray scintillometer was used to create an outcrop type log. The outcrop type log is used to correlate gamma-ray profiles to nearby well logs. The intent is to add further insight concerning the factors that control black shale deposition.

## **Study Area**

The study area (Fig. 1) consists of portions of West Virginia, Pennsylvania, and Maryland. It includes the majority of the eastern outcrop belt of West Virginia and includes one outcrop from western Maryland and two outcrops in south-central Pennsylvania (Table 1). The subsurface spectral gamma-ray well logs used for correlation are located in Randolph County (well #1), Preston County (well #2), and Grant County (well #4; well #5) in West Virginia and Somerset County (well #3) in Pennsylvania (Fig. 1).



**Figure 1.** Map of study area with outcrop and well locations. Well data was donated by petroleum companies, locations are approximate due to constraints on proprietary data.

<b>Number</b>	<b>Outcrop</b>	<b>Latitude</b>	<b>Longitude</b>
1	Tyrone, PA	40.648802	-78.269722
2	Bedford, PA	40.138302	-78.583749
3	Berkeley Springs, WV	39.669142	-78.200169
4	Tomahawk, WV	39.506425	-78.060651
5	Greenspring, WV	39.517384	-78.632605
6	Springfield, WV	39.483756	-78.664749
7	McCooles, MD	39.451803	-78.960822
8	Burlington, WV	39.330279	-78.887382
9	Whip Gap, WV	39.269075	-79.066308
10	North Petersburg, WV	39.011781	-79.131689
11	West Petersburg, WV	39.003594	-79.156687
12	Hiser, WV	38.95794	-79.112806
13	South Branch of the Potomac, WV	38.674019	-79.203486
14	Oak Flat, WV	38.658471	-79.23475
15	Frost, WV	38.2833	-79.885224

**Table 1.** Names and locations (latitude and longitude) of studied Marcellus Shale outcrops. See corresponding outcrop number on study area map (Fig. 1).

## Methods

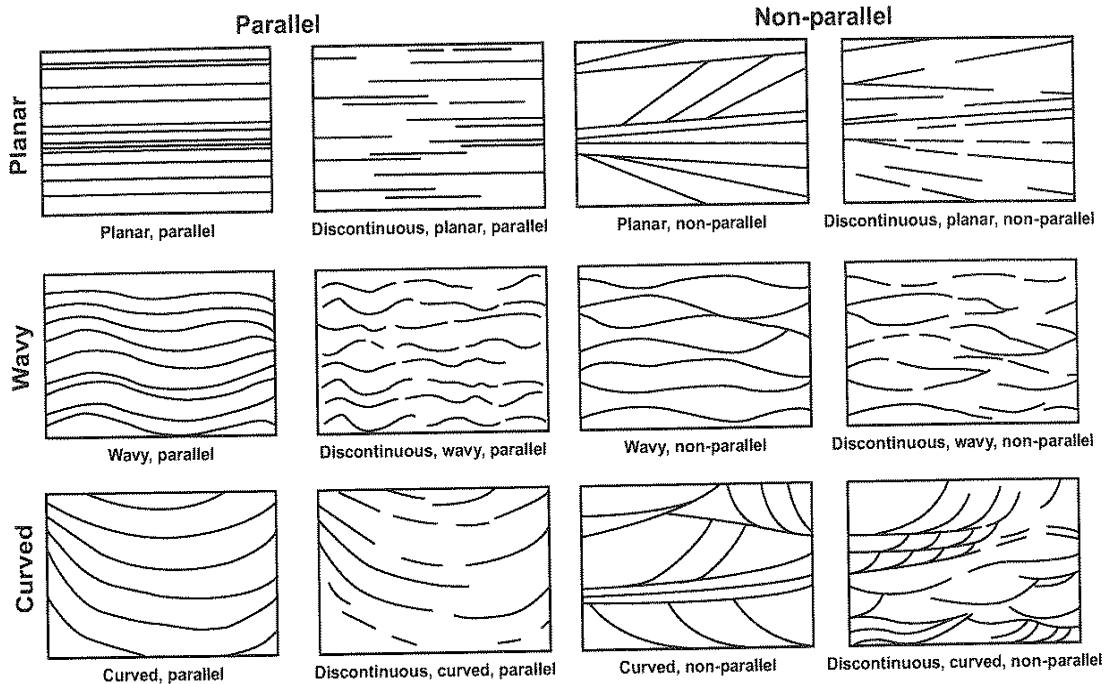
Fifteen partial Marcellus Shale outcrops in West Virginia, Pennsylvania and Maryland (Table 1; Fig.1) were measured and described in detail. Descriptions of lithofacies are based on field observations (see appendix) and include: rock type, color (fresh and weathered), grain size, visible minerals, parting thickness and geometry, bedding or parting surface, sedimentary structures, nodules, fossil content, color of shale when powdered and luster of shale streak. Parting thickness was based on Potter's (Potter et al., 1980) scheme for shale in outcrop (Fig. 2). Parting geometry was based on descriptive terms of Campbell (1967) (Fig. 3). The shale texture was determined by the luster and the color of the powder when the shale is scratched (Lazar et al., 2010) (Table 2). Bedding thickness for limestone and bentonite was classified using the scheme of Campbell (1967) (Fig. 4). Lithologic data were entered into SedLog® to create stratigraphic columns for each outcrop (Fig. 5). Columns were correlated and then combined into a composite section for the Marcellus Shale for the study area.

Thickness	Stratification		Parting	Composition
30 cm	Thin	Bedding	Slabby	<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> <p>↓ Clay and organic content</p> </div> <div style="text-align: center;"> <p>↑ sand, silt and carbonate content</p> </div> </div>
3 cm	Very thin			
10 mm	Thick	Flaggy		
5 mm	Medium	Platy		
1 mm	Thin	Fissile		
0.5 mm	Very thin	Papery		

**Figure 2.** Stratification and parting scheme used for description of shale lithofacies (Potter et al.,1980).

Rock type =>	Siltstone	Claystone	Siliceous Mudstone
<i>.Attributes</i>			
Grain Size:			
Median	>2/3 silt	Clay >2/3	2/3>clay>1/3
Range	.0625-.004mm	Silt to Clay	.0625-.004mm
Color: Powder	White, Light	Brown, Dark	Intermediate, Light to Dark
Luster: Scratch	Dull	Waxy	Mid-lustrous, Dull to Waxy

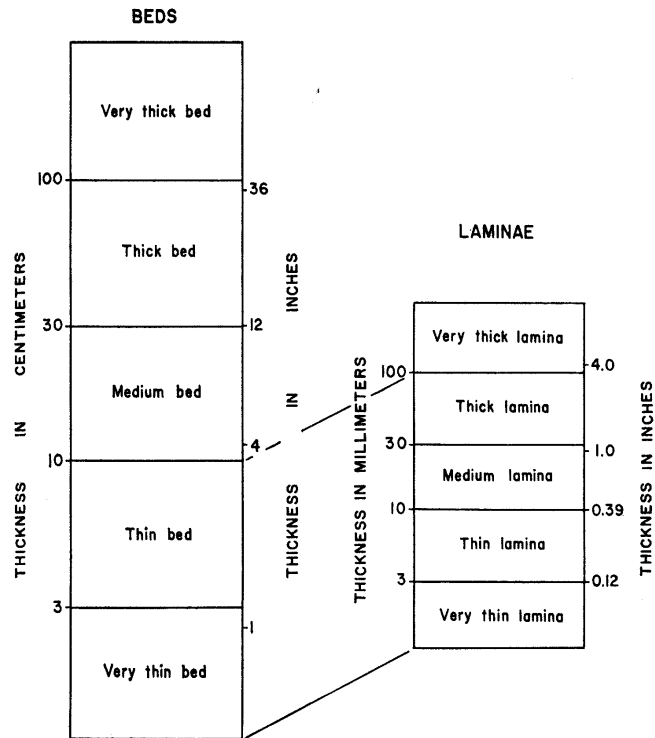
**Table 2.** Luster and color of rock when powdered based on field characteristics of lithofacies modified after (Lazar et al., 2010).



**Figure 3.** Descriptive terms for lamina continuity, shape and geometry (Lazar et al., 2010; modified after Campbell, 1967).

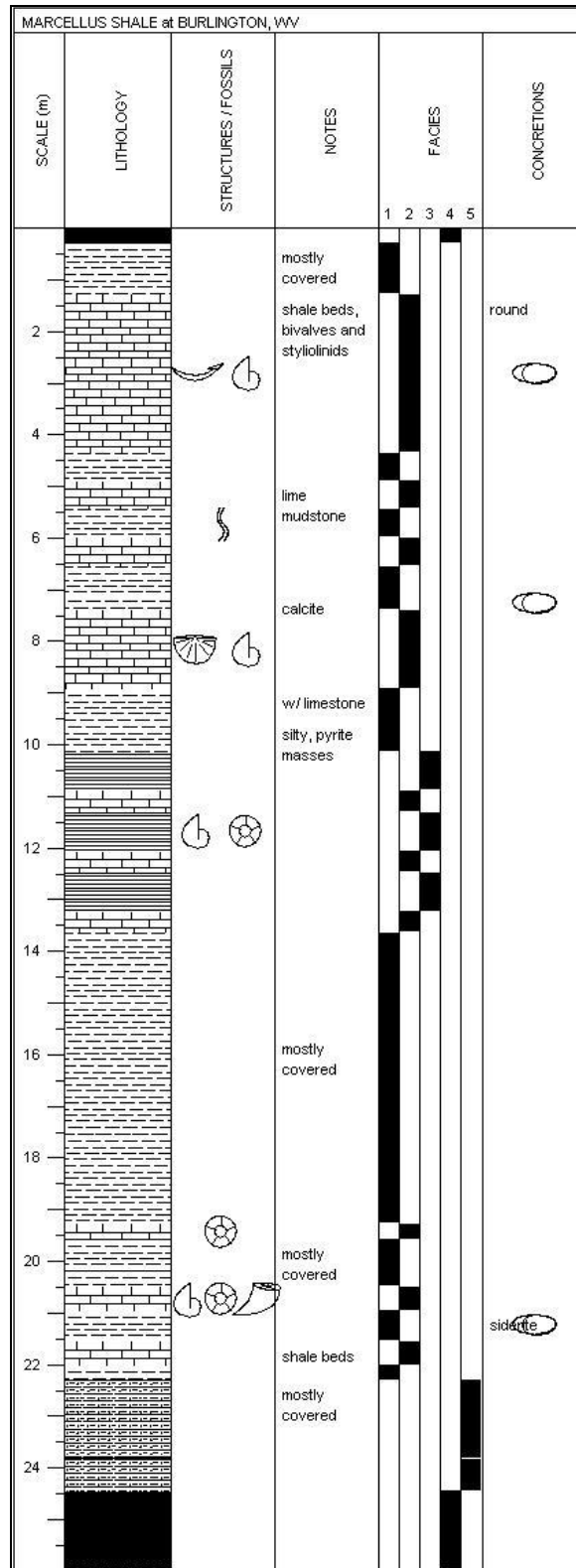


A spectral gamma-ray scintillometer, Radiation Solutions model RS230, was utilized on the outcrops. A spectral gamma-ray scintillometer is a hand-held tool that measures the radiation emitted during the decay of three of the most common elements contributing to naturally-occurring radioactivity: thorium, uranium and potassium. In the water column, reduced uranium ( $U^{+4}$ ) is relatively immobile and is thus



**Figure 4.** Laminae and bed thickness scheme (adapted from Ingram, 1953; after Campbell, 1967).

deposited along with organic material under anoxic conditions (Nielsen et al., 1987). Increased uranium concentrations are, therefore, typically associated with enriched total organic carbon (Swanson, 1960; Schmoker, 1981). Thorium concentrations in the Marcellus Shale are believed to be linked to clay concentrations, most notably illite (Boyce, 2010). Gamma-ray data were collected at 1.0 foot intervals along the outcrop. Effort was made to clear each outcrop of weathered material and, where possible, to place the detector at a consistent position against the outcrop to insure a constant rock volume was sampled for each reading (Lazar et al., 2010). The spectral gamma-ray data were downloaded to RS-Analyst® and imported into Microsoft Excel® and Petra® to create spectral gamma-ray profiles (Fig. 5). Conversions of gamma-ray data from parts per million (ppm) to standard American Petroleum Institute (API) units were based on (Korsbech, 2002).



**Figure 5.** An example of a Sedlog® outcrop stratigraphic column for the Marcellus Shale at Burlington, WV.

A gamma-ray type log was compiled from spectral gamma-ray outcrop profiles and used to correlate the Marcellus Shale into the subsurface.

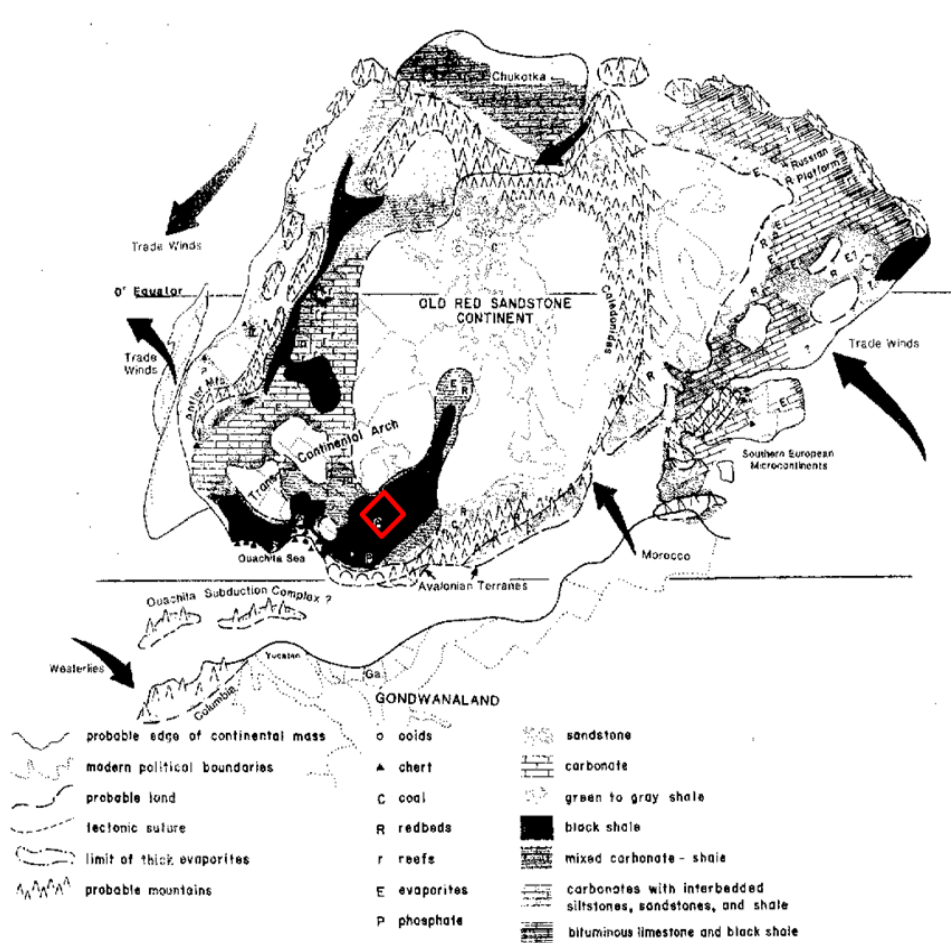
Representative rock samples from several outcrops were collected and analyzed by X-ray diffraction (XRD) and thermogravimetric analyses (TGA) to determine the bulk shale mineralogy and total organic carbon (TOC) of each sample.

Field descriptions, stratigraphic columns, XRD and TOC analysis, and spectral gamma-ray outcrop data provided the basis for identification of lithofacies and interpretation of depositional environments (Fig. 11-13).

## GEOLOGIC SETTING

### Regional Overview

The Middle Devonian marks the arrival of the Acadian orogen and its first influence as a clastic source in the Appalachian region (Ettensohn and Barron, 1981; Faill, 1985). The Acadian orogeny resulted from the collision between the Avalonia terrane and Laurentia to form the Laurussian continent (Fig. 6) (Faill, 1997; Ettensohn, 1987). Tectonic loading stemming from this orogenic event as well as the eustatic Eifelian-Givetian sea level rise created a shallow epicontinental sea in the foreland basin adjacent to the Acadian mountains (Werne et al., 2002).



**Figure 6.** Paleogeography of Old Red Sandstone Continent (Laurussia) during Devonian time modified from Ettensohn (1998). The study area is outlined in red.

The central Appalachian foreland basin is an asymmetrical, northeast-trending trough bounded on the south and east by the Acadian highlands, on the west by the Cincinnati arch, and on the north by the Old Red Sandstone continent (Ettensohn and Barron, 1981; Gao et al., 2000). This geometry resulted in restricted marine circulation within the Appalachian Basin during Middle Devonian time. A paleogeographic reconstruction of the Middle Devonian (Fig. 7) depicts present-day West Virginia, Pennsylvania and parts of New York, Virginia, Maryland and Ohio as a nearly-enclosed epicontinental sea (Woodrow, 1985; Blakey, 2011).

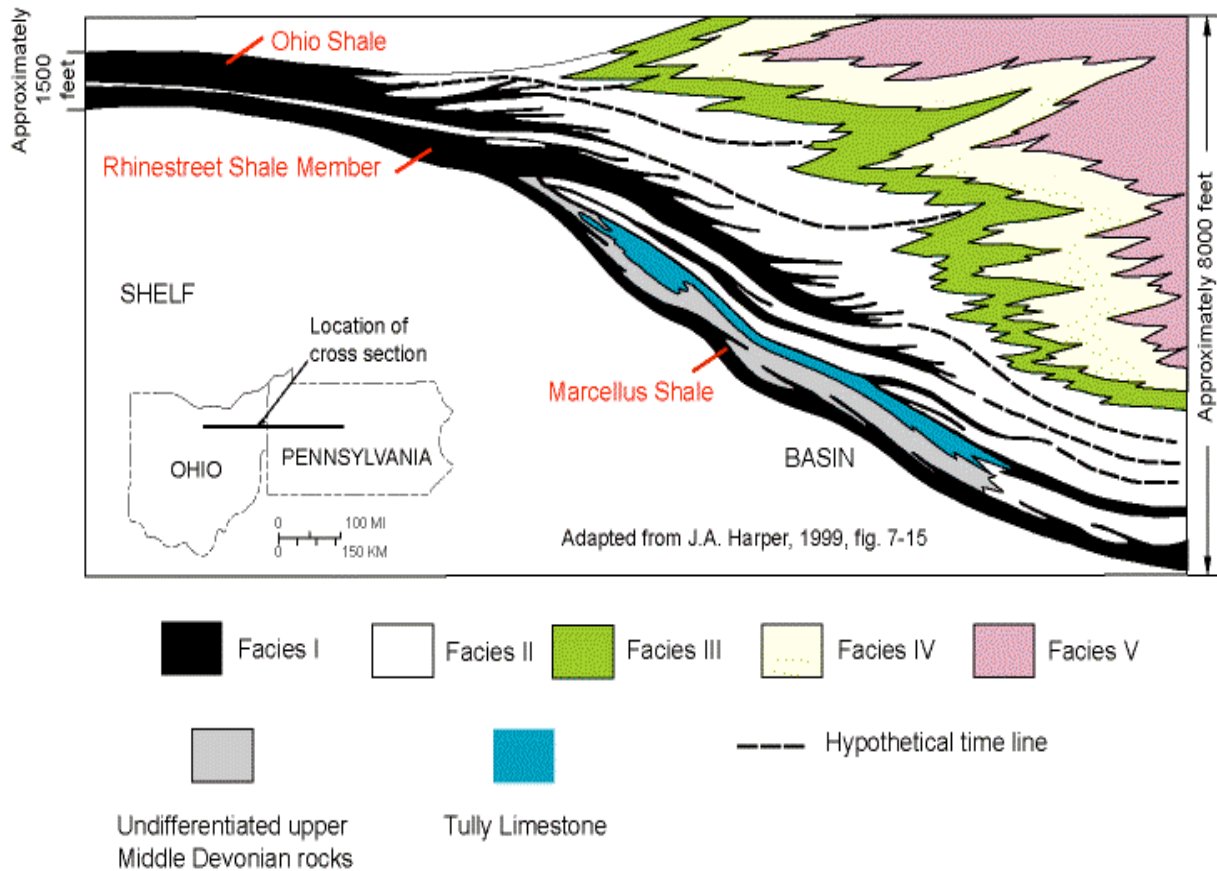


**Figure 7.** Middle Devonian paleogeographic reconstruction (385 Ma). Appalachian Basin indicated modified after Blakey (2011).

During Devonian time, the central Appalachian Basin was situated near the equator. Exact placement of the equator during this time is still debated, but most agree that Laurussia was an equatorial landmass located approximately 15-30 degrees south (Heckel and Witzke, 1979; Ziegler et al., 1979; Ettensohn and Baron, 1981). The central Appalachian Basin was located in the humid equatorial belt and subject to the easterly trade winds (Ettensohn and Baron, 1981). The Acadian highlands may have blocked the easterly trade winds carrying moisture from the adjacent ocean (Fig. 7), creating a rainshadow effect on the western side of the highlands (Ettensohn and Baron, 1981; Woodrow, 1985). The resulting paleoclimate experienced during the early part of the middle Devonian (Eifelian) may have been arid to semi-arid with the occurrence of large seasonal storms (Woodrow, 1985; Werne et al., 2002). Along with the influence of basin geometry and paleoclimate, other large-scale factors influencing the sedimentation of black shale in the Appalachian Basin were: active tectonism, subsidence and eustatic sea level rise.

The Acadian clastic wedge consists of two deltaic complexes including the Middle to Upper Devonian Catskill delta and the Late Devonian to Early Mississippian Price-Rockwell delta (Ettensohn, 1985; Boswell, 1996). The Catskill delta reaches its maximum thickness of 12,000 feet in eastern Pennsylvania and thins westward across the basin to nearly 400 feet (De Witt et al., 1975; Milici and Swezey, 2006). The Catskill delta complex is dominated by prograding sediments shed into the basin from the Acadian mountains to the east (Fig. 8). These sediments are grouped into five time-transgressive magnafacies (Harper, 1999). Facies I consists of “dark gray to black, somewhat calcareous, pyritic, sparsely fossiliferous mud” (Harper, 1999). This facies is interpreted as basinal muds deposited under anoxic conditions. Within the clastic wedge, seven transgressive black shale units (Facies I) were deposited extensively across the

basin and interfinger with coarser, lighter sediments (Facies II-V). These seven black shale tongues of the Catskill delta include the Marcellus (lowermost), Harrell, Geneseo, Middlesex, Rhinestreet, Huron and the Lower Mississippian Sunbury Shale (Dennison, 1985; De Witt et al., 1993; Harper, 1999; Milici and Swezey, 2006).



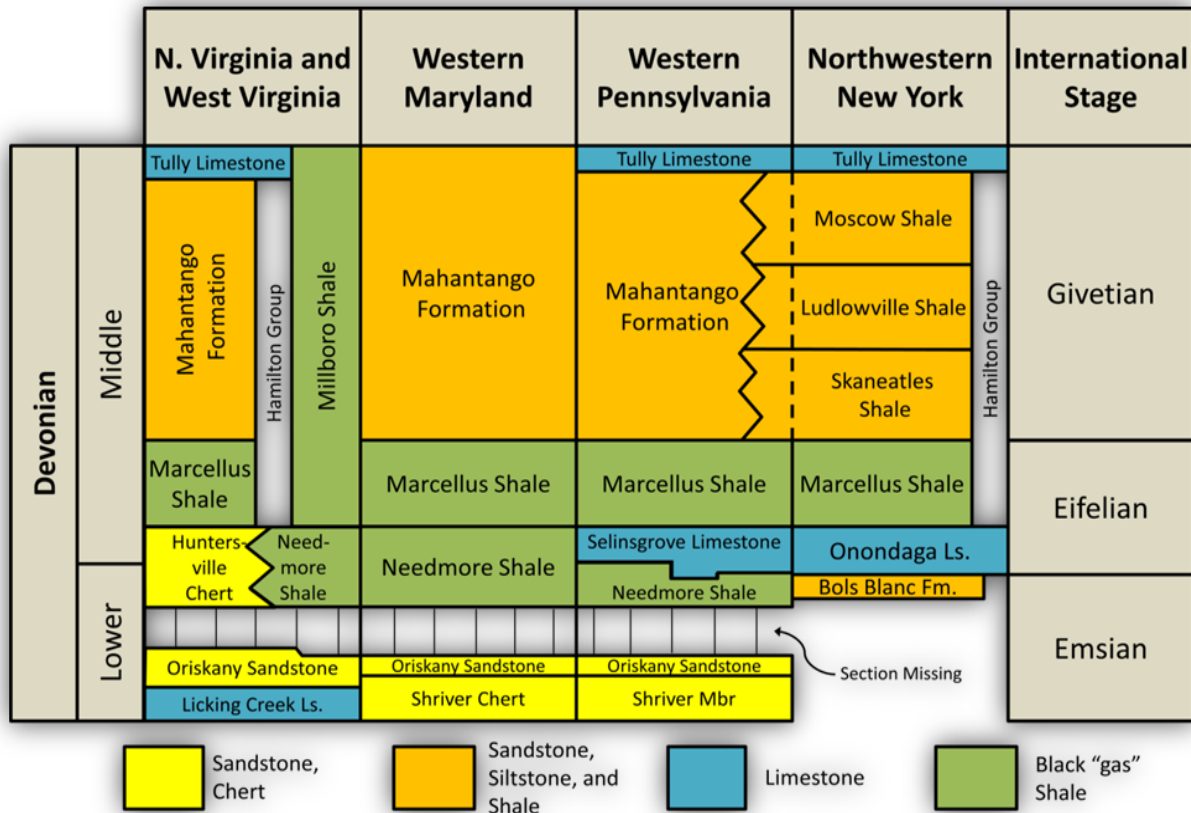
**Figure 8.** Regional facies model for the Acadian clastic wedge in the Appalachian Basin. Facies I: dark colored, organic-rich, basinal shales. Facies II: interbedded subfissile shales, fine- to coarse-grained, very thinly bedded siltstones and rare fine-grained sandstones. Facies III: marine clastic rocks that vary extensively in color and texture (fossiliferous). Facies IV: Interbedded multicolored mudrocks, shales, thin to thick-bedded siltstones, sandstones and conglomerates. Facies V: Red, green, or gray, non marine detrital rocks from Harper (1999).

## **Stratigraphy**

Comprised of the older Marcellus Shale and the younger Mahantango Formation, the Middle Devonian Hamilton Group was deposited in the Appalachian Basin in Pennsylvania, West Virginia, and parts of Maryland, New York, Virginia, and Ohio (Willard, 1935; Woodward, 1943) (Fig. 7). The Hamilton Group, deposited roughly 385 Ma, belongs to the Eifelian and Givetian stages of the Middle Devonian (Fig. 9).

The Hamilton Group increases in thickness and complexity from southwest to the northeast (Harper, 2008). It ranges in thickness from approximately 50 feet in western West Virginia to roughly 1700 feet in southwestern Pennsylvania (Woodward, 1943). Throughout the Appalachian Basin, the Marcellus Shale ranges from thickness of zero feet in Ohio, to roughly 800 feet in eastern reaches of the basin (Harper, 1999). Woodward (1943) suggests a maximum thickness of roughly 250-300 feet in the eastern panhandle of West Virginia, however, these thickness values are overestimated due to faulting and deformation. Regional mapping suggests a maximum thickness of ~200 feet in West Virginia (Wrightstone, 2009; VanMeter, 2011, personal communication).





**Figure 9.** Appalachian Basin regional stratigraphy modified from Milici and Swezey (2006).

As a whole, the Marcellus Shale is frequently described as homogenous carbonaceous black shale, containing locally-abundant pyrite, carbonate concretions, and very few fossils (Ettensohn and Baron, 1981; Harper, 1999). The Marcellus Shale of West Virginia has previously been described as black fissile carbonaceous shale that weathers grey. Several beds of calcareous shale and black limestone, and one or more zones of concretions (varying in composition, abundance and character) have also been recognized (Woodward, 1943; Dennison, 1960). The Marcellus shale has been reported to maintain this same character from east-central Pennsylvania to as far south as Bluefield, Virginia (Woodward, 1943).

The Marcellus Shale of western New York has been elevated to subgroup status and contains two distinct formations, the Union Springs and the Oatka Creek (Ver Straeten, 2007). The Union Springs is a highly organic, calcareous mudstone containing skeletal lags (Sageman et al., 2003). The overlying Oatka Creek Formation consists of several members including the Cherry Valley, Hurley and Berne members (Fig. 10) (Engelder and Lash, 2011). Directly overlying the Oatka Creek Formation in western New York are the dark shales and fossiliferous limestone beds of the Hurley Member (Engelder and Lash, 2011). The Cherry Valley Member of western New York is a bedded to nodular limestone that contains thin to thick black shale interbeds (Ver Straeten, 2007). The Cherry Valley Limestone, also called the Purcell Member, is recognized as calcareous shale in southern Pennsylvania and nodular limestone and shale in West Virginia and Virginia (Ver Straeten, 2007). The overlying Berne Member is a dark grey to black shale (Engelder and Lash, 2011).

central and western New York and eastern Ohio			eastern New York			central and eastern Pennsylvania		
Marcellus Subgroup	Oatka Creek Formation	Berne Member	Marcellus Subgroup	Mount Marion Formation	Solsville and Pecksport members	Marcellus Formation	Dalmatia (Fisher Ridge) Member	
		Cherry Valley Member Hurley Member			Berne Member			Purcell (Turkey Ridge) Member
Union Springs Formation	Bakoven Member		Union Springs Formation	Stony Hollow Member Bakoven Member			Shamokin Member	

**Figure 10.** Marcellus stratigraphy in New York modified from Engelder and Lash (2011).

Throughout most of the Appalachian Basin, the Marcellus Shale lies conformably upon Lower Devonian strata including the Onondaga Limestone, Huntersville Chert, and the Needmore Shale. These three facies interfinger laterally with one another and represent a western carbonate facies, a central basin siliceous facies, and an eastern clastic facies, respectively (Dennison, 1960; Basan et al., 1980; Sherrard and Heald, 1984).

The Tioga K-bentonite was deposited as seven distinct units across the basin during Onondaga through Marcellus time. The Tioga ash zones consist of micaceous tuff layers (middle coarse zone) and yellow to grey-brown, laminated, micaceous shale, and are thought to have originated from a volcano near Fredericksburg, Virginia (Dennison and Textoris, 1977; Harper, 1999; Ver Straeten, 2004).

Nearing the end of the Middle Devonian, coarse clastic sediments of the Mahantango Formation were shed into the basin. The Mahantango Formation, a large deltaic wedge, lies conformably above the Marcellus throughout the basin, and to the east it consists of grey to dark grey-black shale, siltstone, limestone and fine-grained sandstone (Ettensohn and Baron, 1981; Ver Straeten, 2007; Harper, 2008).

## PREVIOUS STUDIES OF BLACK SHALE

Two fundamental schools of thought attempt to explain the organic richness observed in black shale. The preservation school (Demaison and Moore, 1980; Ettensohn, 1981) requires the presence of a permanently-stratified water column (pycnocline). Under these conditions anoxic bottom waters can persist and allow for enhanced preservation of organic material in basin sediments. On the other hand, the production school (Pedersen and Calvert, 1990) argues that high concentrations of organic matter in black shale are a result of enhanced primary productivity in the surface water. Under enhanced productivity, the presence of anoxia is explained as a result of organic enrichment of bottom sediments rather than the cause.

Most depositional models for black shale combine both increased productivity and preservation of organic matter. These models for black shale deposition embrace multiple factors to explain productivity and preservation. They consider the effects of sediment rate, local tectonism, relative sea level, paleoclimate and biogeochemical cycling in the creation of black shale (Ettensohn and Barron, 1981; Werne et al., 2002; Sageman et al., 2003).

Ettensohn's (1985) depositional model called upon a deep-water environment for the deposition of black shale. His tectono-stratigraphic model emphasized active tectonism, which led to rapid subsidence and a deepening of the foreland basin. Oceanic upwelling of nutrient-rich water resulted in high biologic productivity and subsequent accumulation of organic material in a deep-water basin below a permanent pycnocline. Sediment starvation due to the rain shadow effect from the Acadian mountains allowed for the preservation of the organic matter. The presence of a permanent pycnocline explains the preservation of organic matter, and implies a deep, stagnant basin for these circumstances to persist. Algeo and Schekler (1998)

recognized the possible impact of Middle Devonian land plants on the deposition of black shale. The large increase in deep-rooted land plants in the Middle Devonian allowed for increased chemical weathering and nutrient runoff into the sea, as well as decreased erosion. These effects allowed for nutrients, but not clastic sediments, to enter the Appalachian Basin and create algal blooms. These factors resulted in the preservation of organic material in the basin (Algeo and Schekler, 1998).

Schwietering's (1977, 1981) depositional model favored the shallow to moderately-deep environment for the deposition of black shale. They proposed that black shale was deposited on the shallow epicontinental sea shelf along the western margin of the Appalachian Basin. Evidence for the deposition of black muds on a shallow shelf include: the westward thinning of the Hamilton group onto the paleo-shore of the Cincinnati Arch and the deposition of black shale as the first transgressive unit on top of an erosional unconformity. Both features indicate a shallow shelf rather than a deep basinal black shale deposit (Schwietering, 1977; Schwietering and Erwin, 1981). Sediment starvation of the western margin resulted from the basin center acting as a sediment trap for the clastic source to the east. This allowed black organic-rich sediment to accumulate on the shallow shelf. Streams entering the ocean from the stable western craton carried fresh water into the more saline sea water creating a stratified water column (halocline) on the shallow epicontinental sea shelf (Schwietering, 1977; Smith and Leone, 2010).

An alternative model relating to the deposition of the Marcellus Shale in New York envisions a shallow-water basin subjected to occasional storm activity that allowed for more oxygenated surface waters to mix with anoxic bottom waters (Sageman et al., 2003). Mixing led to seasonal oxic/anoxic oscillations, resulting in a seasonal thermocline rather than a permanent pycnocline. Nutrient-rich bottom waters brought to the surface by mixing resulted in high levels

of primary productivity in the surface water, thus increasing the potential delivery of organic matter to the sea floor. The seasonally anoxic basin, coupled with the effects of sediment starvation and relative sea level rise, resulted in the formation of the Oatka Creek Formation of the Marcellus Shale (Werne et al., 2002; Sageman et al., 2003).

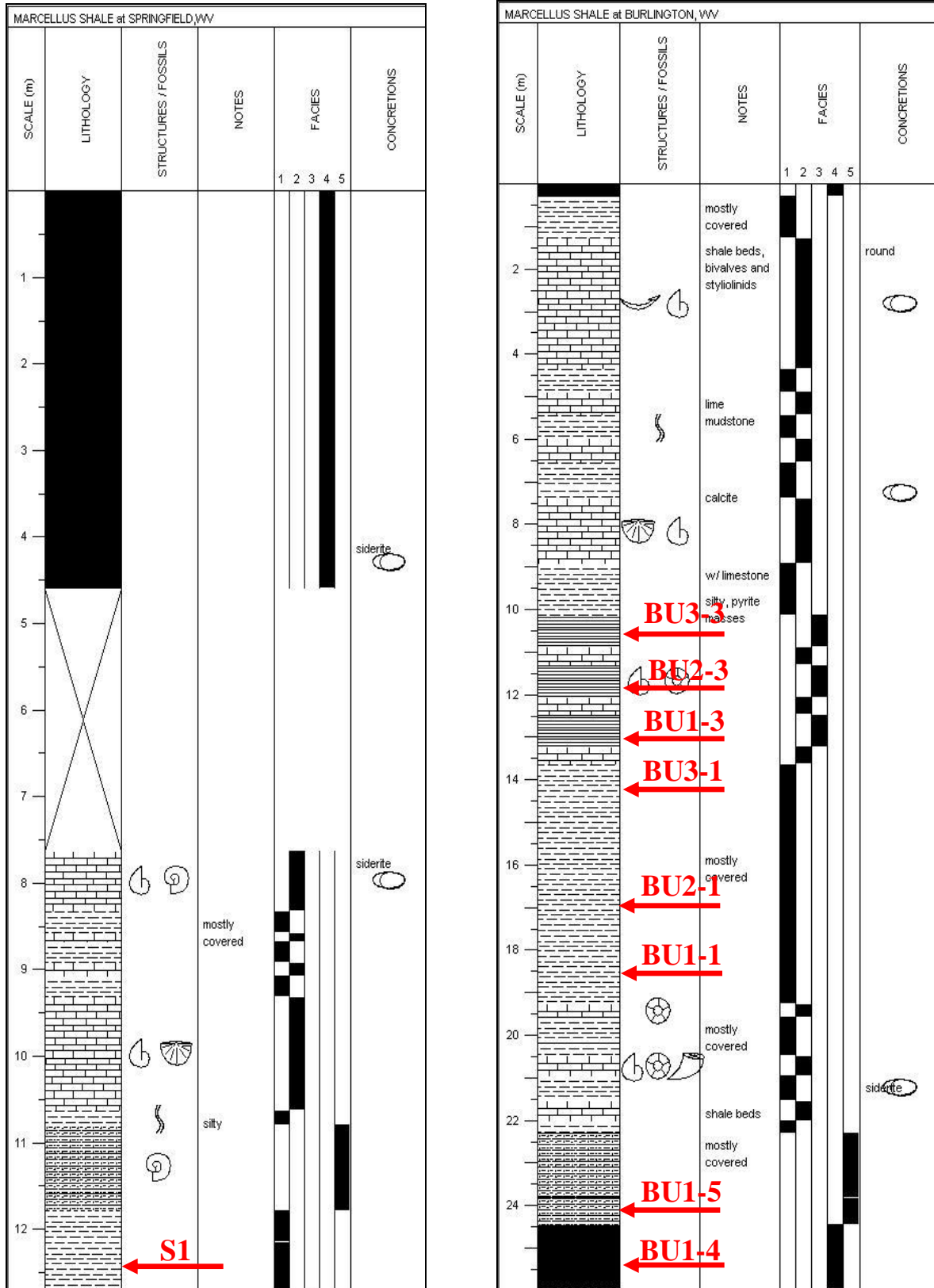
Whereas many models associate the deposition of organic-rich black shale with the depth of the basin, facies and fauna changes within the Marcellus Shale may be due to factors independent of depth. These include changes in circulation, nutrient supply of the water column, sedimentation rates, and substrate stability (McCollum, 1988). Some authors speculated that water depth was not at all a critical factor in the deposition of black shale as long as there were high primary productivity and anoxic bottom waters (Provo, 1978; McCollum, 1988).

## FACIES ANALYSIS

A total of 15 partial Marcellus Shale outcrops were studied and six lithofacies were identified. The six lithofacies include: 1) grey calcareous shale; 2) limestone; 3) black calcareous shale; 4) black non-calcareous shale; 5) grey non-calcareous shale; and 6) K-bentonite. Samples from several outcrops (Fig. 11-13) were analyzed for quartz, illite, kaolinite, calcite and organic matter using X-ray diffraction and TGA analysis. Quartz ranges from 24-75%, illite 12-47%, kaolinite 0-12%, calcite 0-47%, and organic carbon 4-14.5% for the shale lithofacies (Table 3).

Location	Sample No.	Facies	Quartz	Clay	Kaolinite	Calcite	Moisture	TOC
Burlington	BU1-1	1	38.6	42.9	1.6	8.3	1	7.5
Burlington	BU2-1	1	35.3	39.3	1.4	15.7	1.3	7
Burlington	BU3-1	1	24.4	20.4	0.2	47.5	1	6.5
Springfield	S1-1	1	34	41.3	0.4	17.3	0.7	6.5
Burlington	BU1-3	3	44.2	41.8	0.1	6	1.5	6.5
Burlington	BU2-3	3	38.7	42	0.2	10.1	1.5	7.5
Burlington	BU3-3	3	37.8	39.1	0.1	14	1	8
Burlington	BU1-4	4	48.5	42	-	-	1.5	8
Petersburg N.	P1-4	4	42.9	48.6	-	-	1.5	7
Whip Gap	WG1-4	4	55.1	28.9	-	-	1.5	14.5
Whip Gap	WG2-4	4	52.9	38.6	-	-	1	7.5
Whip Gap	WG3-4	4	74.9	12.1	-	-	2	11
Burlington	BU1-5	5	52	42	-	-	1	5
Greenspring	GS1-5	5	43.2	40.5	11.6	-	0.7	4
Greenspring	GS2-5	5	42.5	47.3	5	-	0.7	4.5
Greenspring	GS3-5	5	47.6	43.4	2.5	-	1	5.5

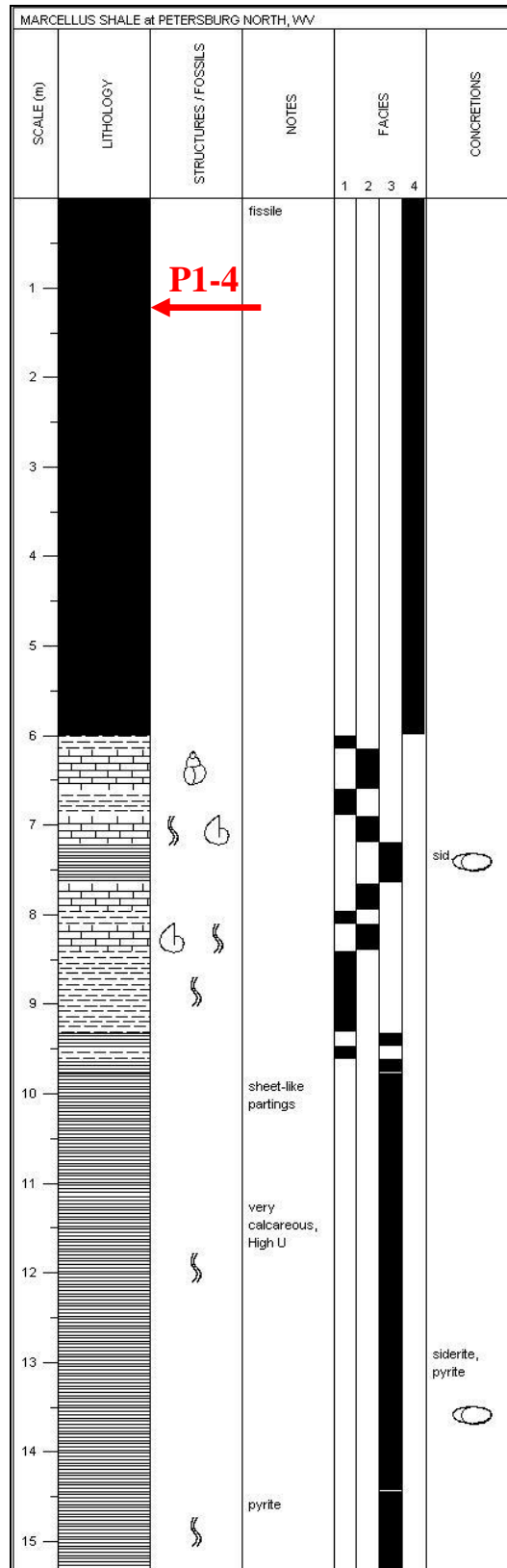
**Table 3.** X-ray diffraction and TOC data (weight percent).



**Figure 11.** XRD and TGA sample locations at Springfield and Burlington outcrops are labeled and shown with red arrows. See table 3 for sample information.







**Figure 13.** XRD and TGA sample location at Peterburg North outcrop is labeled and shown with a red arrow. See table 3 for sample information.

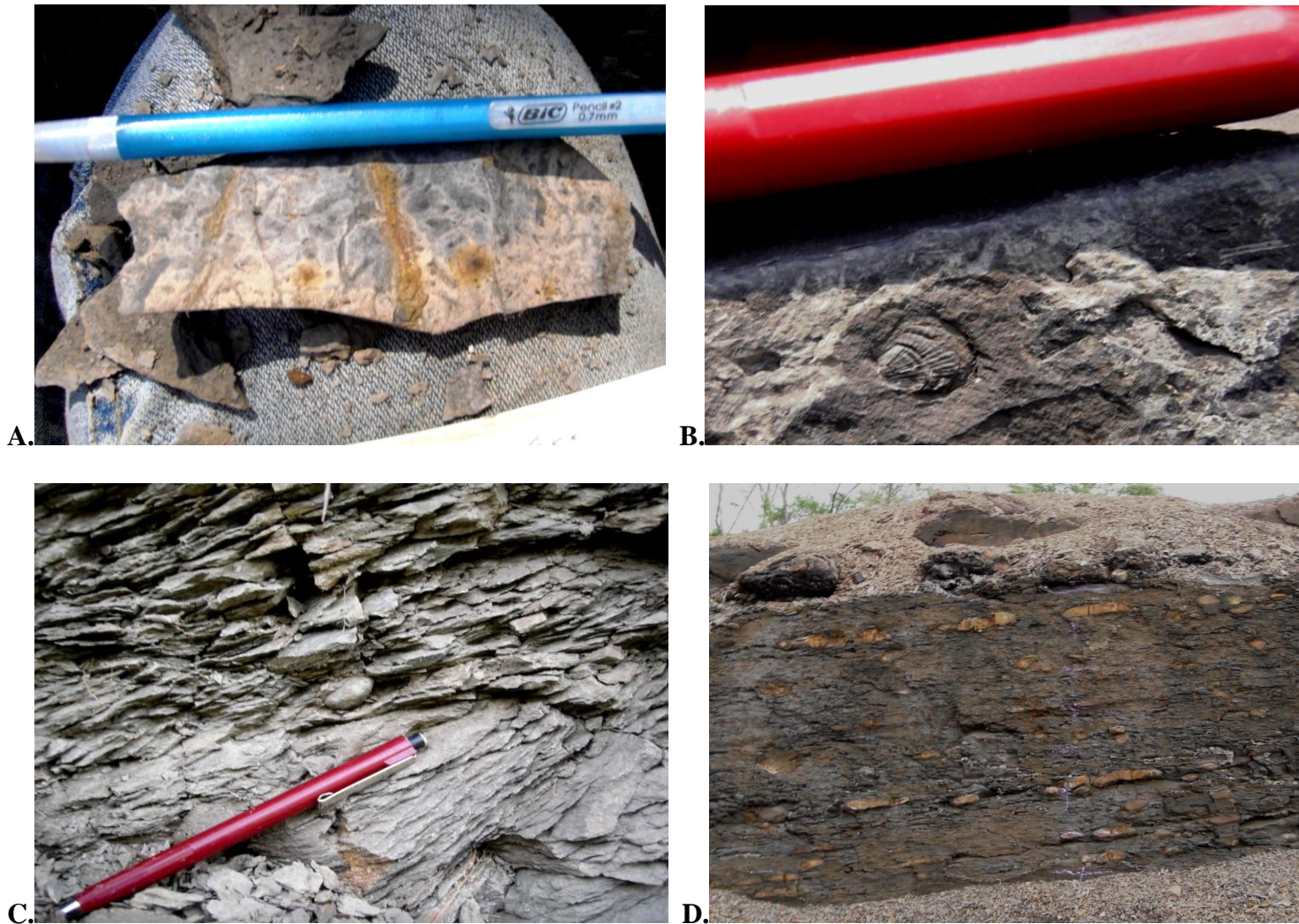
## **Facies Descriptions**

### ***Facies 1***

Facies 1 is grey calcareous shale, occasionally slightly calcareous (Table. 4). XRD analysis established a range of 8.3-47.5% calcite, with the remaining constituents consisting of clastic sediment; clay, silt, and organic matter. The average TOC is 6.8% for representative samples of Facies 1. The shale weathers brown, white or maroon. Shale partings are usually platy and exhibit wavy and discontinuous geometry. Parting surfaces are often bumpy and irregular. Bioturbation is common including horizontal, vertical and unoriented burrows. Body fossils are occasional, but when present include articulate and linguloid brachiopods, crinoids, ostracods, and oxidized and/or replaced shell debris. Nodules of siderite and calcite, as well as masses of pyrite and incipient nodules, occur throughout the rock (Fig. 14). An incipient nodule is the initial or beginning stage of a nodule, not completely formed into a distinct mass, but markedly different from the surrounding shale. Incipient nodules typically exhibit an oxidation halo. The rock's texture varies from medium to coarse mudstone (silty mudstone) based on its scratch and luster (Table 4).

**Table 4.** Sedimentary Characteristics of Facies 1, Grey Calcareous Shale

<b>Color fresh</b>	Medium-dark grey, brown
<b>Color weathered</b>	Brown, white, maroon
<b>Grain size</b>	Silt sized grains
<b>Parting thickness</b>	Platy to flaggy, also papery to fissile where associated with Facies 2
<b>Parting geometry</b>	Mostly continuous, wavy, parallel
<b>Parting surface</b>	Irregular, bumpy
<b>Nodules</b>	Calcite, pyrite, siderite, incipient
<b>Body fossils</b>	Brachiopods (including linguloids), crinoids, ostracods, unidentified shell debris, pyritized or replaced fossil debris
<b>Trace fossils</b>	Common bioturbation, unoriented, vertical, and horizontal burrows
<b>Color when powdered</b>	Light to intermediate, tan to medium brown
<b>Luster of streak</b>	Intermediate



**Figure 14.** Outcrop photographs of Facies 1, grey calcareous shale. **A.** Oak flat outcrop: horizontal and vertical oxidized burrows on bedding plane (15-cm pencil for scale). **B.** Tyrone outcrop: Small fossil brachiopod imprint (15-cm pencil for scale). **C.** Burlington outcrop: platy to flaggy grey calcareous shale with small nodule (15-cm pencil for scale). **D.** Petersburg West outcrop: grey calcareous shale with bedded siderite nodules of various size and shape (section ~ 9 feet in height).

## ***Facies 2***

Facies 2 is medium-grey to black limestone that weathers grey to brown (Table 5). The limestone beds are frequently micritic or argillaceous and are interbedded with both black and grey calcareous shale beds (Facies 1 & 3). Limestone beds are thinly-laminated to thickly-bedded and exhibit tabular, lenticular (most common), or nodular geometry (Fig. 15). The nodular geometry is produced by soft sediment compaction between beds of shale. The fossil assemblage – consisting of crinoids, brachiopods, rugose corals, tabulate corals, bivalves, styliolinids, gastropods, and bactritid and goniatite cephalopods – exhibits a moderate to moderately-low diversity although the density can be high. The limestone frequently contains trace fossils (burrow, tracks and trails).

**Table 5.** Sedimentary Characteristics of Facies 2, Limestone.

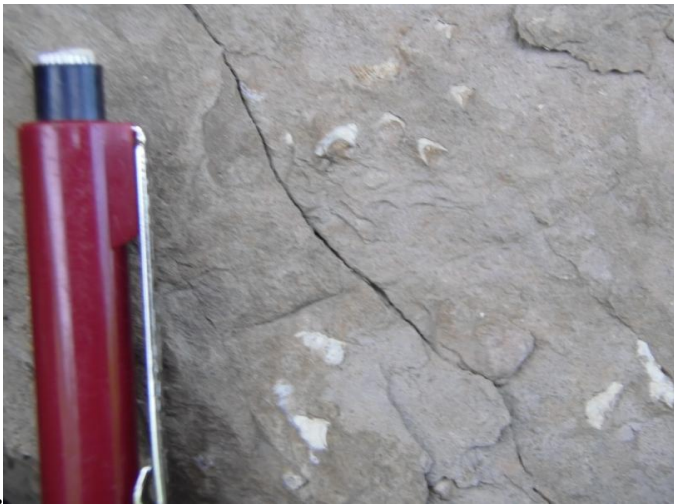
<b>Color fresh</b>	Medium to dark grey, very dark grey, black
<b>Color weathered</b>	Light grey, grey, brown, red staining
<b>Bedding thickness</b>	Very thinly to medium bedded, very thinly to thinly bedded, medium to thickly bedded, thinly laminated to thinly bedded
<b>Bed geometry</b>	Beds thin or pinch out, lenticular, nodular or continuous beds
<b>Bedding surfaces</b>	Irregular, bumpy
<b>Nodules</b>	Calcareous concretions
<b>Body fossils</b>	Crinoids, brachiopods, rugose and tabulate corals, bivalves, styliolinids, gastropods, bactritid and goniatite cephalopods
<b>Trace fossils</b>	Bioturbation, burrows, tracks and trails



A.



B.



C.



D.

**Figure 15.** Outcrop photographs of Facies 2, limestone. **A.** Burlington outcrop: limestone bed (~ 1 ft.) containing large calcareous concretions. **B.** Burlington outcrop: rugose coral. **C.** Burlington outcrop: brachiopod and crinoids stem debris on limestone bed (pencil for scale). **D.** Bedford outcrop: lenticular limestone beds (28-cm. hammer for scale).

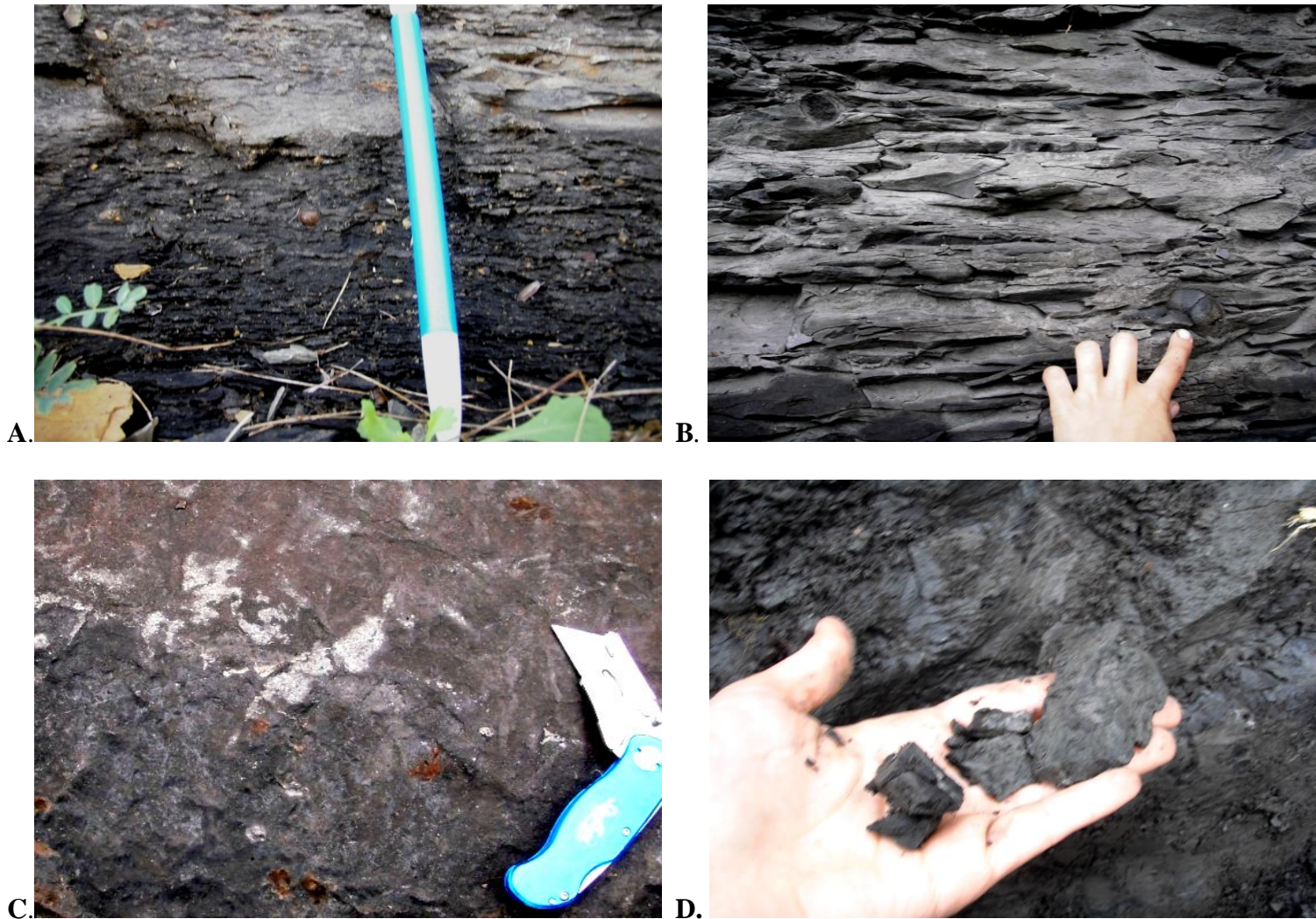
### ***Facies 3***

Facies 3 is black to dark-grey calcareous shale and is frequently interbedded with Facies 2 (Table 6). XRD and TGA analysis established a range of 6.0-17.3% calcite and an average of 7.3 % TOC. The quartz and clay content in Facies 3 is roughly 10 % less than spatially-equivalent rocks of Facies 5. Shale partings are commonly papery to fissile and platy. Partings are wavy and discontinuous; however, parting surfaces are commonly smooth and regular unless bioturbation is present (Fig. 16). Fossil debris of brachiopods and crinoids, surface traces, shallow burrows, and terrestrial plant debris are present, but rare. Siderite, calcite, and pyrite nodules do occur, but are rare. The rocks texture varies from a medium to fine-grained mudstone (Table 6).

**Table 6. Sedimentary Characteristics of Facies 3, Black Calcareous Shale.**

<b>Color fresh</b>	Black to dark grey
<b>Color weathered</b>	Orange, white, red, yellow
<b>Grain size</b>	Clay to silt
<b>Parting thickness</b>	Papery to fissile, platy
<b>Parting geometry</b>	Discontinuous, curved, wavy
<b>Parting surface</b>	Regular, irregularities associated with fossil debris
<b>Nodules</b>	Siderite, calcite and pyrite
<b>Body fossils</b>	Fossil debris, terrestrial plant debris
<b>Trace fossils</b>	Surface traces, shallow burrows
<b>Color when powdered</b>	Light to dark
<b>Luster of streak</b>	Intermediate





**Figure 16.** Outcrop photographs of Facies 3, black calcareous shale. **A.** Oakflat outcrop: calcareous black papery shale with small round siderite nodules (15-cm pencil for scale). **B.** Petersburg North outcrop: black calcareous shale with round calcareous nodules. **C.** Bedford outcrop: unoriented shallow burrows on bedding plane (12-cm knife for scale). **D.** Petersburg North outcrop: platy black calcareous shale with discontinuous partings.

#### ***Facies 4***

Facies 4 is black to dark-grey, occasionally chocolate-brown non-calcareous shale (Table 7). Orange and white weathering rinds are common. TGA analysis established an average of 9.6% TOC for this facies. Similar to Facies 3, shale partings are typically papery to fissile and occasionally platy. In Facies 4, however, partings are most always parallel and continuous, and parting surfaces are smooth and regular (Fig. 17). Horizontal lamination is common and small pyrite lenses and laminae are present in fresh samples. The shale is typically brittle and breaks into regular sheets or fragments, though it may also weather papery or break into conchoidal fragments that lack distinctive partings. Nodules are common and diverse in size, shape and composition. These include round, oblong, and spherical nodules of pyrite, calcite, and nodules of undetermined composition. Incipient nodules with oxidation halos are also common. Rare fossils include styliolinids, goniatite ammonoids, and replaced fossil debris. Woodward (1943) identified the following genera in black shale of the Marcellus in West Virginia: *Styliolina* (zooplankton of uncertain affinity), *Bacrites* (cephalopod), *Buchiola* (bivalve), and the brachiopods *Ambocoelia*, *Leiorhyncus*, *Lingula*, *Petrocrania*, and *Strophalosia*. The texture of the rock is a claystone (Table 7). The shale is often extremely structurally-deformed: faulted, drag-folded, and slickensided.

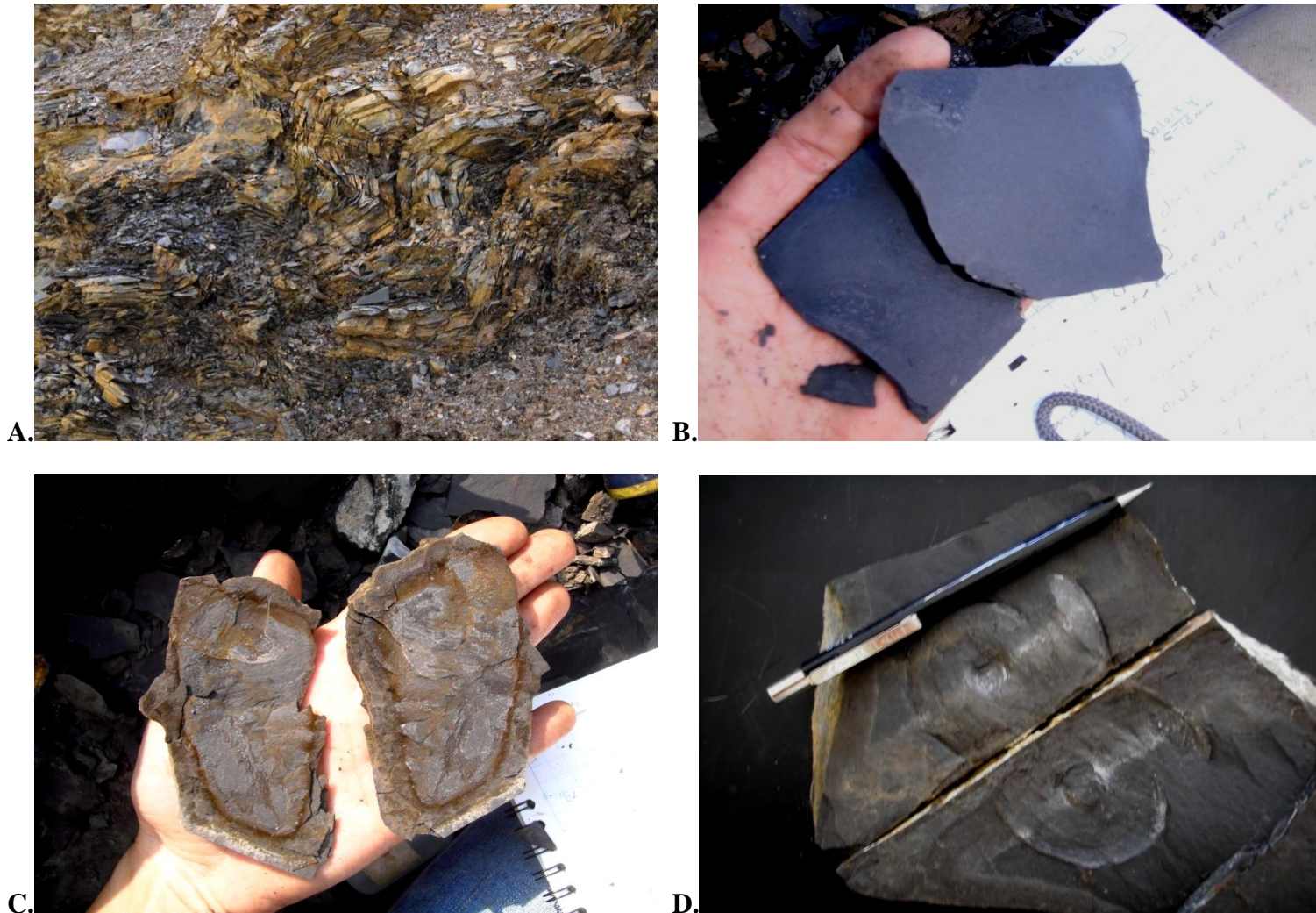
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**Table 7. Sedimentary Characteristics of Facies 4, Black Non-calcareous Shale.**

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<b>Color fresh</b>	Black, black to dark grey, brown.
<b>Color weathered</b>	Orange, white, yellow, maroon to red, brown to tan
<b>Grain size</b>	Clay
<b>Parting thickness</b>	Papery to fissile, platy, or destroyed by deformation
<b>Parting geometry</b>	Continuous, parallel, discontinuous, chonchodial, soft and flaky
<b>Parting surface</b>	Regular, flat, smooth, slightly irregular, wavy, ridges
<b>Nodules</b>	Incipient, pyrite, calcite nodules, and concretions
<b>Body fossils</b>	Styliolinids, goniatite ammonoids, rare replaced and undetermined fossil debris
<b>Color when powdered</b>	Dark brown, medium brown, black
<b>Luster of streak</b>	Waxy, very waxy, intermediate

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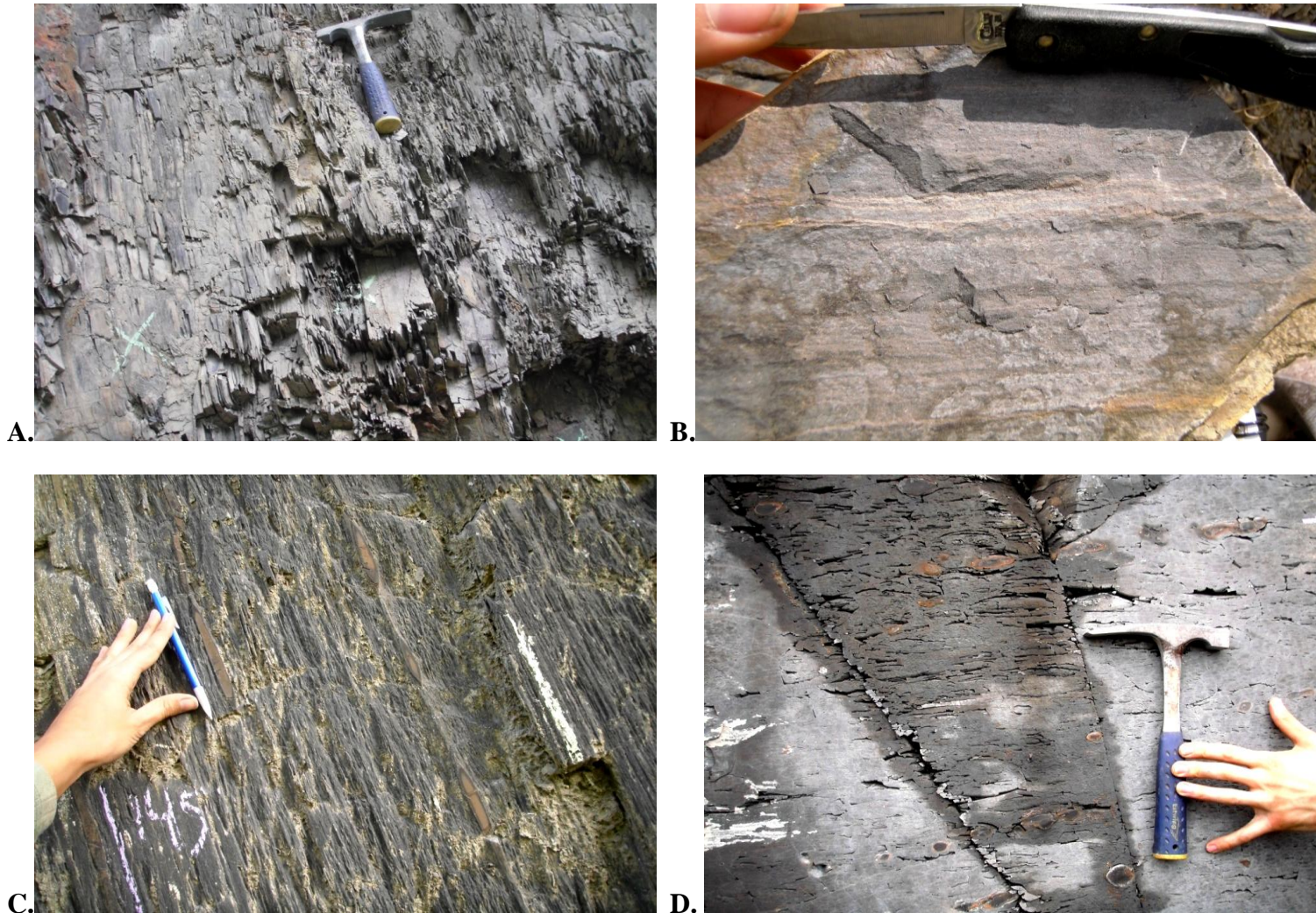
**Figure 17.** Outcrop photographs of Facies 4, black non-calcareous shale. **A.** Oakflat outcrop: highly deformed black shale with red and orange weathering (section ~ 6-8 feet). **B.** Petersburg North outcrop: sooty, black, fissile shale with parallel continuous parting and regular parting surface. **C.** Tyrone outcrop: incipient nodule with red to orange weathering halo. **D.** Tyrone outcrop: goniatite ammonoid imprint in pyritic black shale (15-cm pencil for scale).

## ***Facies 5***

Facies 5 is a dark to light-grey non-calcareous shale that weathers orange to red (Table 8). TGA analysis determined an average of 4.7% TOC for this facies. This shale is often silty and has platy and occasionally flaggy partings (Fig. 2). Parting geometry is typically discontinuous and parting surfaces are commonly irregular, bumpy, or wavy. Nodules are common and frequently aligned along bedding planes. Nodule composition includes siderite, calcite, pyrite, and undetermined minerals. Bioturbation is present, but rare. Body fossils are rare and include cephalopods and locally abundant brachiopods with low diversity. The rock's texture is a silty mudstone or siltstone (Table 8).

**Table 8. Sedimentary Characteristics of Facies 5, Grey Non-calcareous Shale.**

<b>Color fresh</b>	Dark grey, medium grey, light grey
<b>Color weathered</b>	Orange, red to maroon, white, tan to grey
<b>Grain size</b>	Clay to silt
<b>Parting thickness</b>	Platy (1-5mm), platy to flaggy (1-10mm), no distinctive partings
<b>Parting geometry</b>	Discontinuous
<b>Parting surface</b>	Slightly irregular, irregular, wavy, bumpy
<b>Nodules</b>	Siderite, calcite, pyrite and large calcareous concretions (often concentrated along bedding planes)
<b>Body fossils</b>	Small brachiopods, cephalopods, shell fragments
<b>Trace fossils</b>	Bioturbation
<b>Color when powdered</b>	Light, tan to brown
<b>Luster of streak</b>	Dull, occasionally intermediate



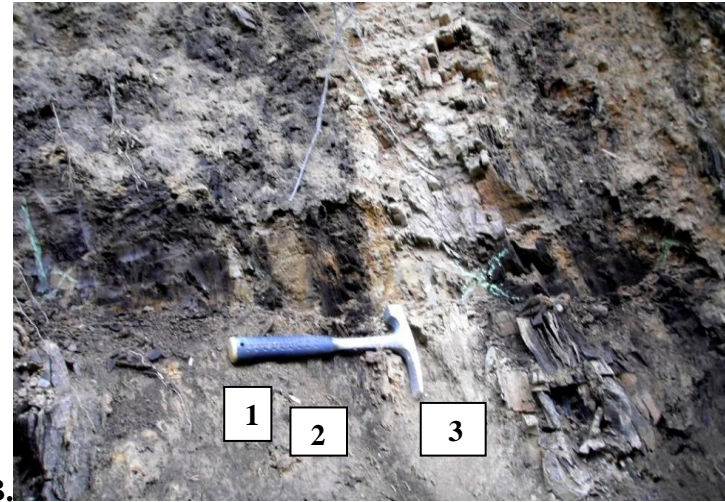
**Figure 18.** Outcrop photographs of Facies 5, grey non-calcareous shale. **A.** Greenspring outcrop: platy to flaggy grey shale (28-cm hammer for scale). **B.** Berkeley Springs outcrop: silty grey shale with wavy silt laminae (8-cm. knife for scale). **C.** Berkeley Springs outcrop: grey shale with flattened siderite nodules along bedding surface (15-cm pencil for scale). **D.** Petersburg West outcrop: grey shale that lacks distinctive partings and contains round siderite nodules (28-cm hammer for scale).

## ***Facies 6***

Facies 6 is a K- bentonite (Table 9), an altered volcanic ash that is designated the Tioga Bentonite (Dennison and Textoris, 1970; Ver Straeten, 2007). These bentonites are tan to grey and typically weather to tan clay. Sand-sized mica flakes are common. Bentonite beds range from 3-15 cm in thickness and can be graded or reworked by burrowers. Outcrops in our study area contain between one and three K-bentonite beds over a stratigraphic interval of 2-5 meters at the base of the Marcellus.

**Table 9. Sedimentary Characteristics of Facies 6, K-bentonite.**

<b>Color fresh</b>	Tan, brown, light brown, light to dark grey
<b>Color weathered</b>	Tan, brown, and grey clay
<b>Grain size</b>	Clay to coarse sand
<b>Visible Minerals</b>	Mica, pyrite
<b>Bed thickness</b>	Very thin to medium bedded (2.5-16 cm)
<b>Sedimentary structures</b>	Graded bedding, biogenically reworked

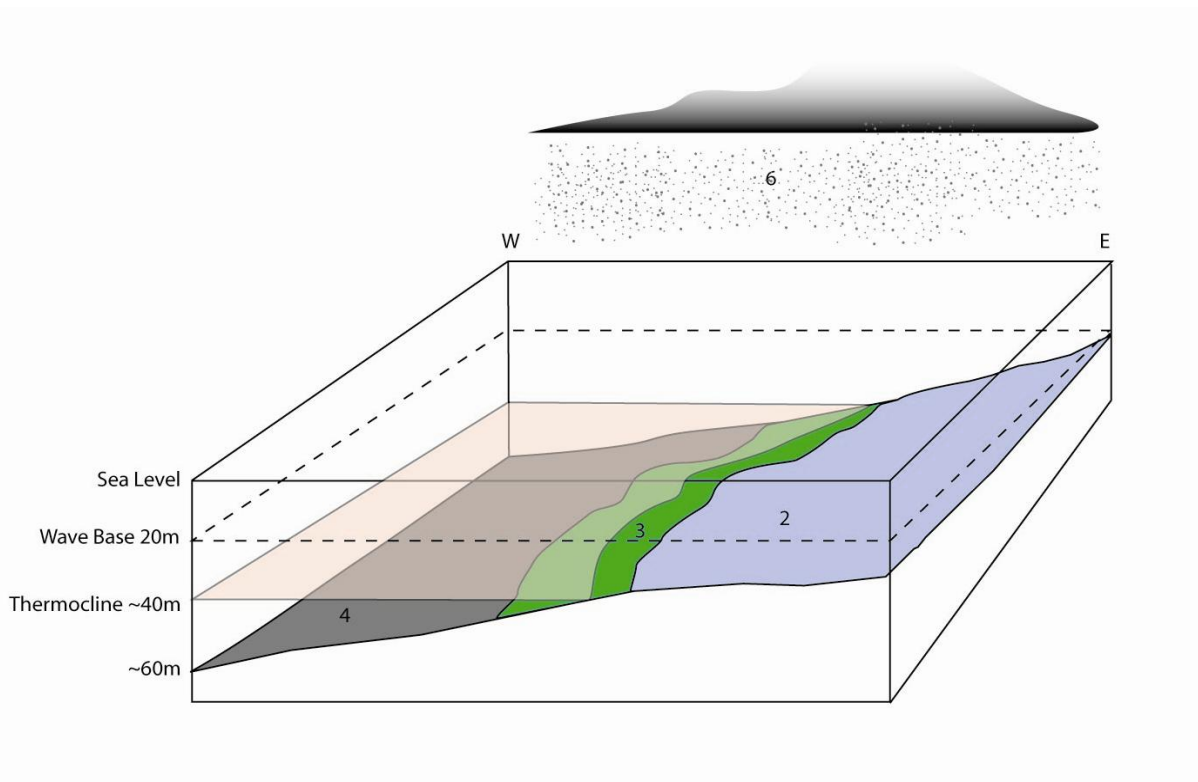


**Figure 19.** Outcrop photographs of Facies 6, Tioga K-bentonite. **A.** Bedford outcrop: grey to tan micaceous bentonite (~2 inches). **B.** Whip gap outcrop: three vertical bentonite beds ranging from 1-6 inches interbedded with black papery shale. **C.** Tomahawk outcrop: brown to tan graded micaceous bentonite.

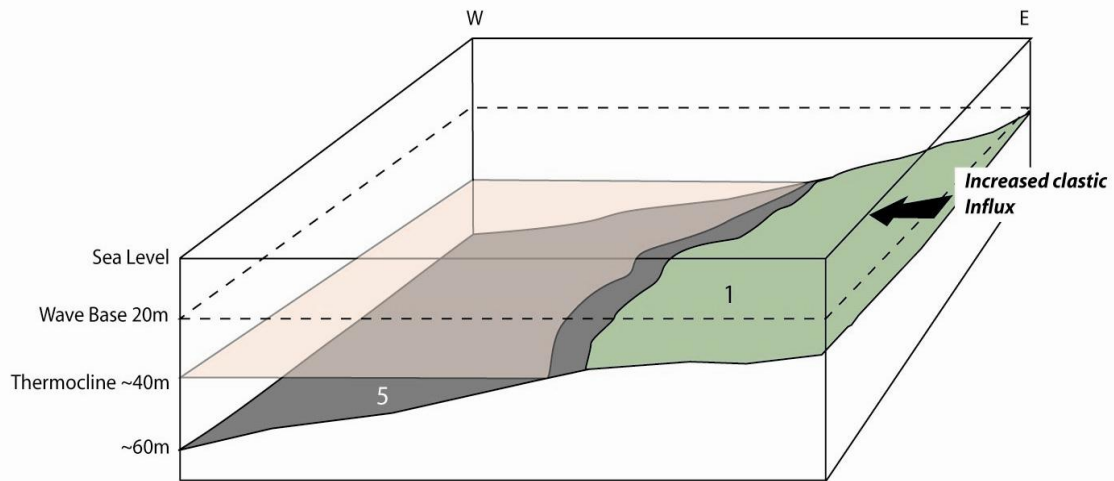


## Facies Interpretations

Facies 1 through 6 were deposited below wave base in a partially-enclosed epicontinental sea adjacent to the Appalachian highlands to the east. The epicontinental sea was relatively shallow and sediment input, water chemistry, and stratification were dynamic rather than stagnant. Sea level fluctuations, clastic influx, and shifts in the location of the thermocline resulted in the deposition of a number of facies including both calcareous and non-calcareous argillaceous mudstone, organic-rich facies, and limestone (Figs. 20; 21).



**Figure 20.** Generalized Marcellus Shale facies model depicting periods of low clastic sediment influx. The model includes Facies 2 (limestone), Facies 3 (black calcareous shale), Facies 4 (black non-calcareous shale) and Facies 6 (Tioga K-bentonite).



**Figure 21.** Generalized Marcellus Shale facies model depicting periods of increased clastic influx. The model includes the more proximal Facies 1 (grey calcareous shale) and more distal Facies 5 (grey non-calcareous shale).

The grey calcareous shale (Facies 1) was deposited on a low-energy ramp in relatively shallow water above the thermocline. Clastic sediment input was moderate, and the clastics mixed with biogenic lime sediment that formed in-situ on the seafloor. The assemblage of benthonic fauna, including brachiopods, crinoids, ostracods, and gastropods, indicates that bottom waters were oxygenated and the water salinity was normal marine. Common vertical and horizontal burrows show that the sediment was also oxic to suboxic.

The limestone (Facies 2) was deposited on a low-energy ramp during a time of low terrigenous sediment input. The presence of rugose and tabulate corals indicates that the limestone was deposited in relatively shallow water within the photic zone. The water salinity must have been normal marine throughout the water column to support the diverse faunal assemblage of corals, crinoids, brachiopods, bivalves, gastropods, and cephalopods as well as vertical and horizontal burrowers. Many limestone beds are lenticular and pinch out laterally into

calcareous shale of Facies 1 and 3. This distribution suggests that the lime sediment mostly accumulated as pods on an otherwise muddy (shaley) seafloor.

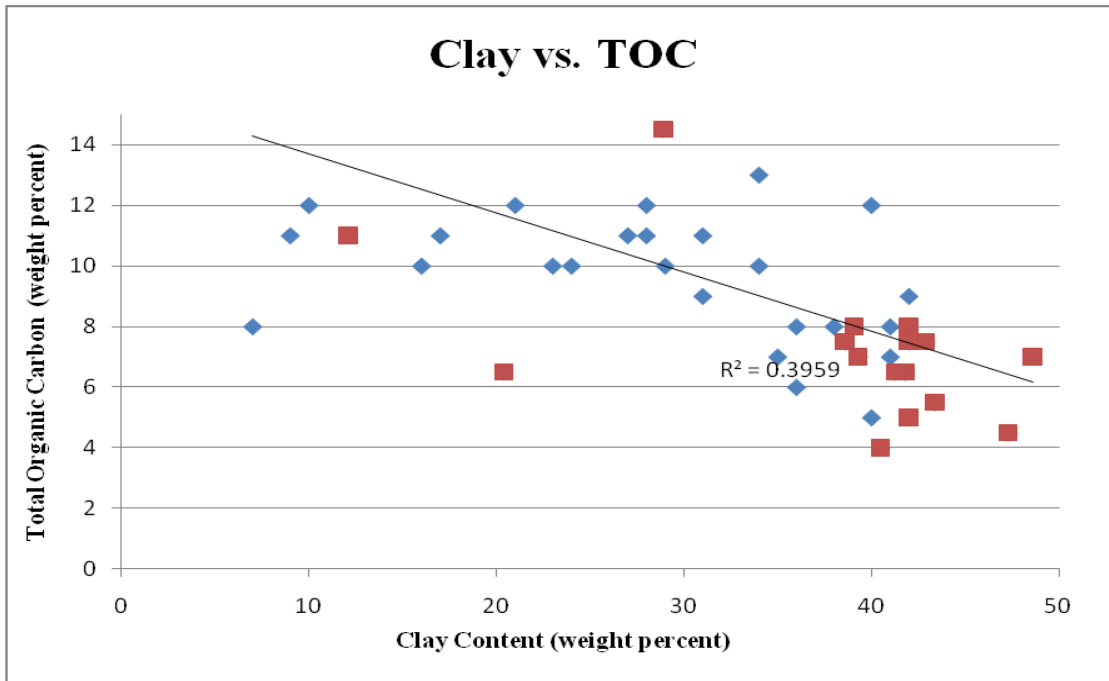
The black calcareous shale (Facies 3) was deposited on the relatively shallow ramp near the depth of the thermocline (~40 meters). The shallow, restricted nature of the epicontinental sea, high temperatures associated with the Devonian greenhouse climate, and overall low fresh-water input likely resulted in a dynamic thermocline rather than a permanent halocline or pycnocline (Tyson and Pearson, 1991). The calcite in Facies 3 may have been formed in-situ or sourced from the adjacent lime mud environment. This black calcareous shale is typically interbedded with or grades laterally into Facies 2; therefore, it probably formed in an adjoining environment on the shallow ramp, although water was slightly deeper. Facies 3 was deposited typically below the thermocline, allowing for better preservation of accumulated organic matter.

The content of terrigenous sediment in Facies 3 indicates that clastic input from the eastern highlands was reduced. Diminished clastic sediment input allowed for organic matter to accumulate below the thermocline with minimal dilution. Although terrigenous clastic input was relatively low, concentrations of quartz in Facies 3 ranges from 37 to 44 percent. This quartz content may be a result of eolian or diagenetic processes (Schieber et al., 2000; Werne et al., 2002; Sageman et al., 2003). The thermocline persisted during the deposition of Facies 3; however, large storms and seasonal mixing occasionally disrupted the thermocline and allowed oxygen to temporarily mix in the water column. During these times, some benthic organisms and burrowers could survive.

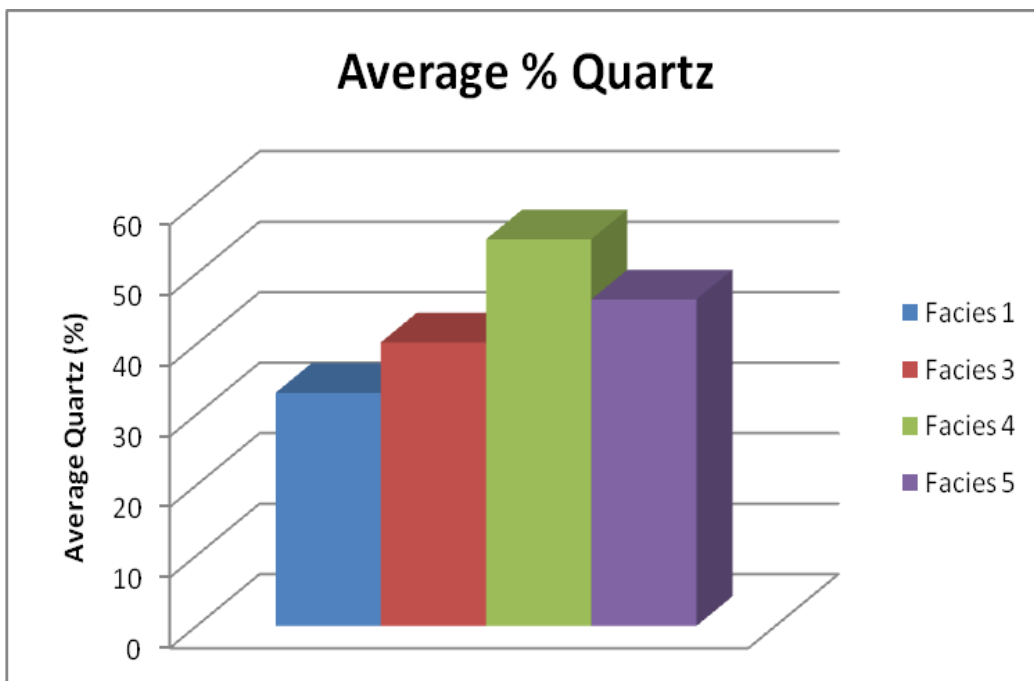
Black non-calcareous shale (Facies 4) was deposited during a time of regional sea level rise. Facies 4 sediments accumulated below the thermocline where the bottom water and

sediment were anoxic. Sea level rise caused flooding of the eastern landmass and subsequent storage of clastic sediment landward, resulting in the low clay content found in Facies 4. Low clastic sediment input allowed for the deposition of organic matter without dilution. This relationship is illustrated by the graph of clay content vs. total organic carbon derived from the XRD and TGA analyses (Fig. 22). Although terrigenous sediment input was low, Facies 4 has a significant amount of quartz (43-75%) as illustrated by Fig. 23. Much of this quartz may have been sourced from wind-blown eolian silt (Werne et al., 2002; Sageman et al., 2003) or diagenetic processes (Schieber et al., 2000). Wind-blown nutrients may have been brought into the basin, creating algal blooms that resulted in a high accumulation of organic matter (Sageman et al., 2003; Wrightstone, 2010). In addition to lower terrigenous sediment input, increased primary productivity in the water column may have played a role in the increased total organic carbon in Facies 4 (Pederson and Calvert, 1990).

Although bottom waters were persistently anoxic, surface waters were oxic, which allowed for planktonic and nektonic organisms, such as styliolinids and goniatite ammonoids, to survive. Burrows and bioturbation are absent and bedding planes are smooth and continuous, indicating a depositional environment where infaunal organisms could not survive.



**Figure 22.** TGA total organic carbon analysis plotted against clay content from XRD analysis. This graph shows the outcrop data in red and subsurface data (Boyce, 2010) in blue.



**Figure 23.** Graph illustrating the average quartz percentages for Facies 1, 3, 4 and 5.

Grey non-calcareous shale (Facies 5) was deposited during times of increased terrigenous clastic input. Silt-sized quartz and mica are common. During increased sediment input, Facies 5 was deposited in place of Facies 3 and 4 both above and below the thermocline. However, the overall lack of bioturbation and low abundance of fauna indicates that Facies 5 was typically deposited below the thermocline. During times of seasonal mixing, burrowers and small brachiopods temporarily inhabited the sea floor.

Volcanic eruptions during the Early to Middle Devonian deposited Facies 6, Tioga K-bentonite, across the basin. In my study, as many as three K-bentonites are found in the Marcellus section enclosed in black shale (Facies 4) as well as black calcareous shale (Facies 3) and limestone (Facies 2). Although some bentonites may have been reworked by burrowers or seasonal storms, ashes generally settled through the water column during the deposition of black shale (Facies 4) without disruption, producing a graded bed. The location of the source volcano is hypothesized to be in central Virginia (Dennison and Textoris, 1970; Ver Staeten, 2004).

## STRATIGRAPHIC PATTERNS

A composite graphic column (Fig. 24) was created based on correlations of 15 partial Marcellus Shale sections (Fig. 25-39) using key beds and combining the average thicknesses of the associated lithofacies. Each outcrop figure contains a vertical distribution of facies, fossil content, sedimentary features, concretions, and outcrop notes as well as a total gamma-ray curve, spectral gamma-ray curve (K, Th, U), and informal stratigraphic units. Six stratigraphic units (A-F) are recognized within the Marcellus Shale.

### **Unit A**

Unit A is the lowermost unit within the Marcellus Shale and has an average thickness of 5.5 meters. This is a transgressional unit overlying the Needmore Shale. Unit A consists of black calcareous shale of Facies 3, limestone of Facies 2, and beds of Facies 1, grey calcareous shale. Facies 6, the Tioga Bentonite, is also found within this unit. Interbedding of Facies 2 and 3 was caused by slight fluctuations of sea level, and the occasional occurrence of Facies 1 can be tied to increased sediment input during slight progradation of the shoreline. During deposition of Unit A the water increased to a depth between fair-weather wave base (~20 meters) to near the position of the thermocline (~40 meters) (Tyson and Pearson, 1991).

### **Unit B**

Unit B has an average thickness of 7.0 meters. This unit consists entirely of Facies 4, non-calcareous black shale, plus several K-bentonite beds (Facies 6) and represents a continuing sea level rise from the underlying Unit A. During the deposition of Unit B water depth was on the order of 60 meters, where the bottom water was generally anoxic and near the maximum depth of seasonal mixing. Maximum effective anoxia on modern shelves occurs mostly in water

less than 60 meters deep and the maximum depth of winter mixing in the semi-enclosed Black Sea is less than 60 meters (Tyson and Pearson, 1991; Kara et al., 2009).

### **Unit C**

Unit C consists of grey non-calcareous shale (Facies 5) and black non-calcareous shale (Facies 4) and has an average thickness of 4.0 meters. The lower contact of Unit C is gradational: Facies 4 decreases while Facies 5 becomes more abundant. This change corresponds with a decrease in total gamma-ray values from Unit B up through Unit C, most notably in the concentration of uranium. These vertical changes suggest that a greater amount of detrital quartz silt and mica had entered the sea and diluted the organic material. The increased influx of clastics is tied to the progradation of the eastern shoreline into the foreland basin.

### **Unit D**

Unit D typically contains interbedded rocks of grey calcareous shale (Facies 1) and very thin to thickly-bedded limestone (Facies 2). The average thickness of this unit is 8.0 meters, yet this unit can be as thin as 2.0 meters or as thick as 20 meters. Black calcareous shale (Facies 3) is also present but is minor. This unit was deposited during a time of regional sea level fall, when water depth shallowed to near wave base (~20 meters) and only rarely exceeded the depth of the thermocline (~40 meters) during the deposition of Facies 3. Interbedding of Facies 1 and 2 represents fluctuations in sediment supply. The limestones of this unit are notably more argillaceous than the limestones of Unit A. This unit has a wide range of character over the study area. Some limestone and shale packages exhibit repeating coarsening-upward cycles, where calcareous shale passes vertically into thin argillaceous limestone and thicker fossiliferous limestone (Fig. 25). Other beds used for correlation of Unit D contain large calcite concretions or



abundant brachiopods. Limestone and interbedded shale of this unit are most often fossiliferous and display a relatively diverse fossil assemblage, including well oxygenated, normal salinity, shallow-water fossils such as rugose corals and crinoids. The change from Unit D to Unit E is relatively abrupt from calcareous shales to non-calcareous black shale.

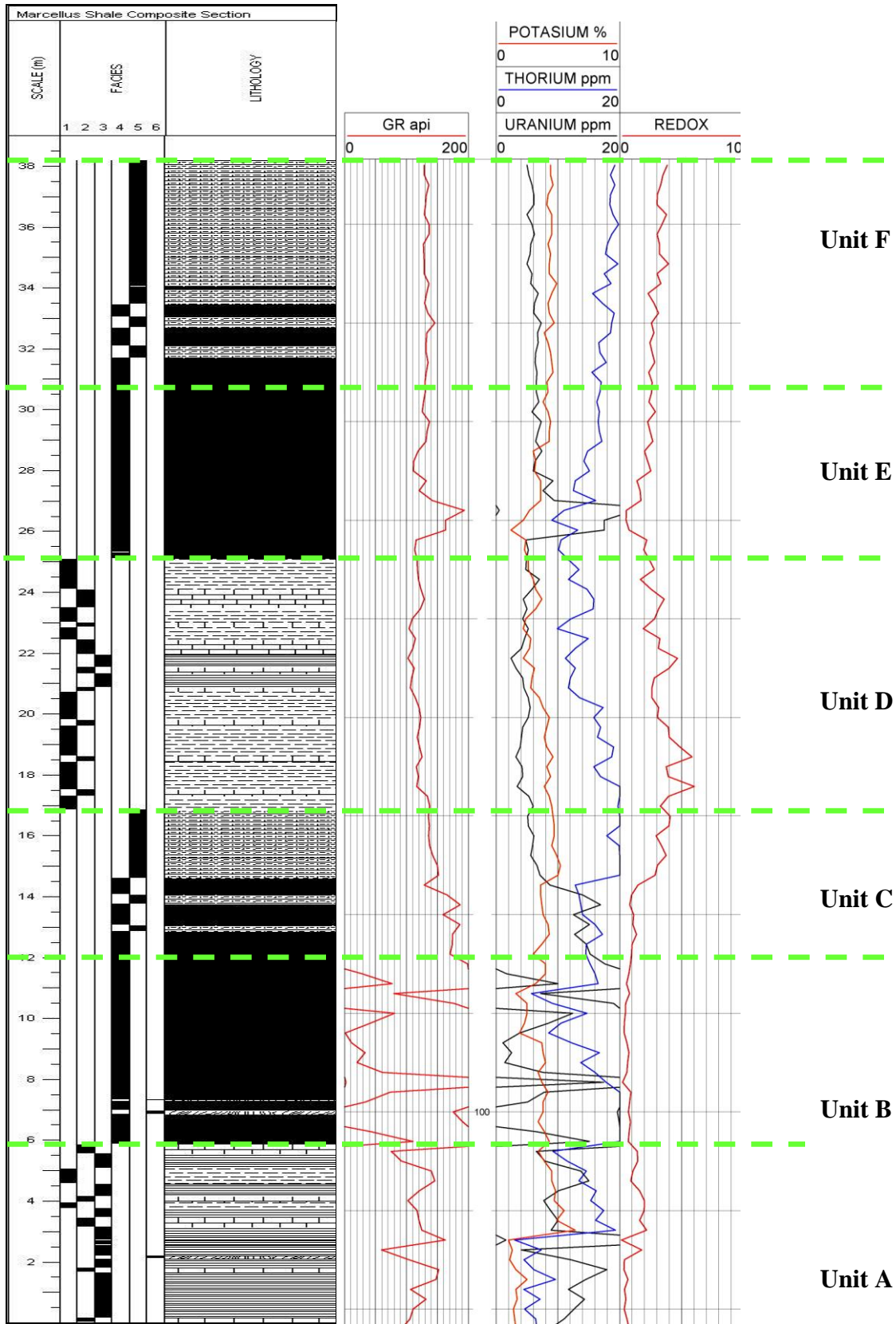
### **Unit E**

Unit E, the upper black shale, has an average thickness of 6.4 meters. This unit is comprised of only Facies 4, non-calcareous black shale. This unit represents a relative rise in sea level to 60 meters, well below the thermocline and near the maximum depth of winter mixing of the water column. Low clay contents in Facies 4 is a result of storage of clastic sediment on the flooded eastern landmass.

### **Unit F**

Unit F has an average thickness of 6.6 meters. This unit consists mostly of Facies 5, grey non-calcareous shale, and occasional interbeds of Facies 4. During deposition of this unit, progradation of the eastern shoreline produced an increase of clastics entering the basin. Interbedding between Facies 4 and 5 was likely caused by discontinuous progradation of the shoreline and intermittent supply of terrigenous silt. The contact with the overlying sandstone and siltstone beds of the Mahantango Formation is sharp.

Units A and B were deposited during a regional sea level rise while Unit D was deposited during a regional fall in sea level. Unit C and Unit F were deposited during progradation of the eastern landmass which deposited clastic sediments into deeper water. After deposition of Unit F the advance of the Mahantango clastic wedge ended Marcellus shale deposition in the Appalachian Basin.



**Figure 24.** Composite stratigraphic column and type log for Marcellus Shale in West Virginia.

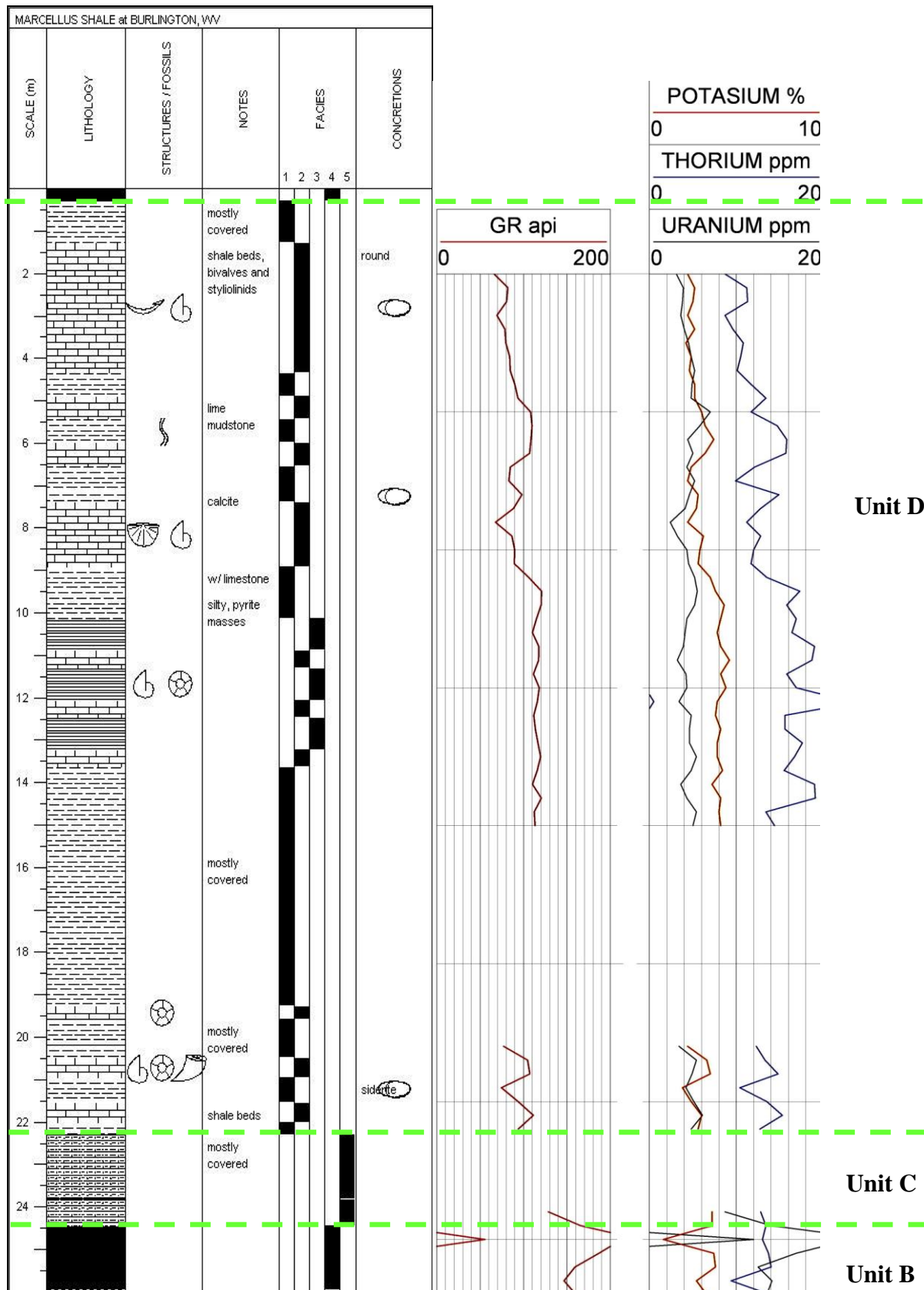


Figure 25. Burlington, WV stratigraphic column and spectral gamma-ray curve.

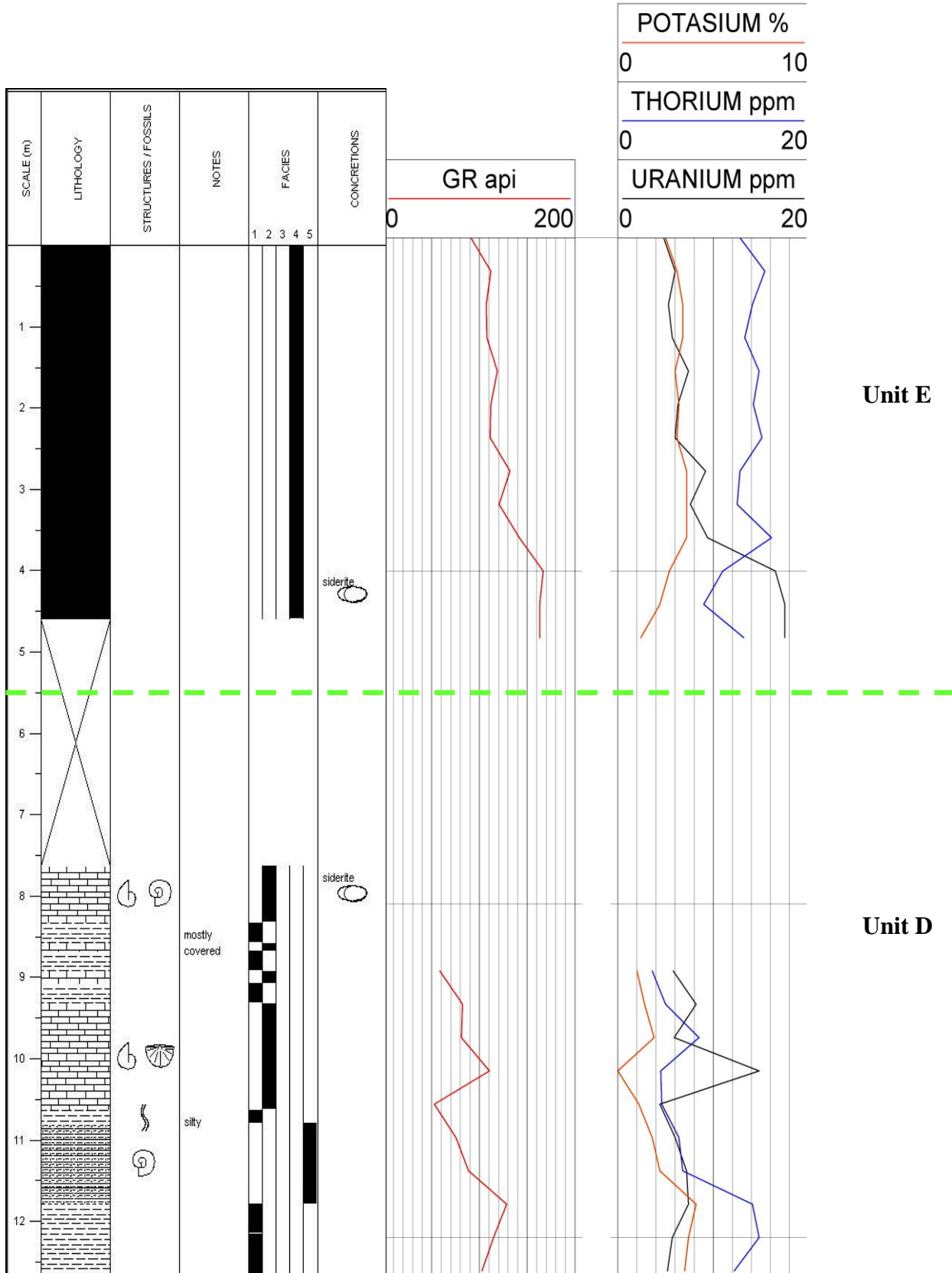


Figure 26. Springfield, WV stratigraphic column and spectral gamma-ray curve.

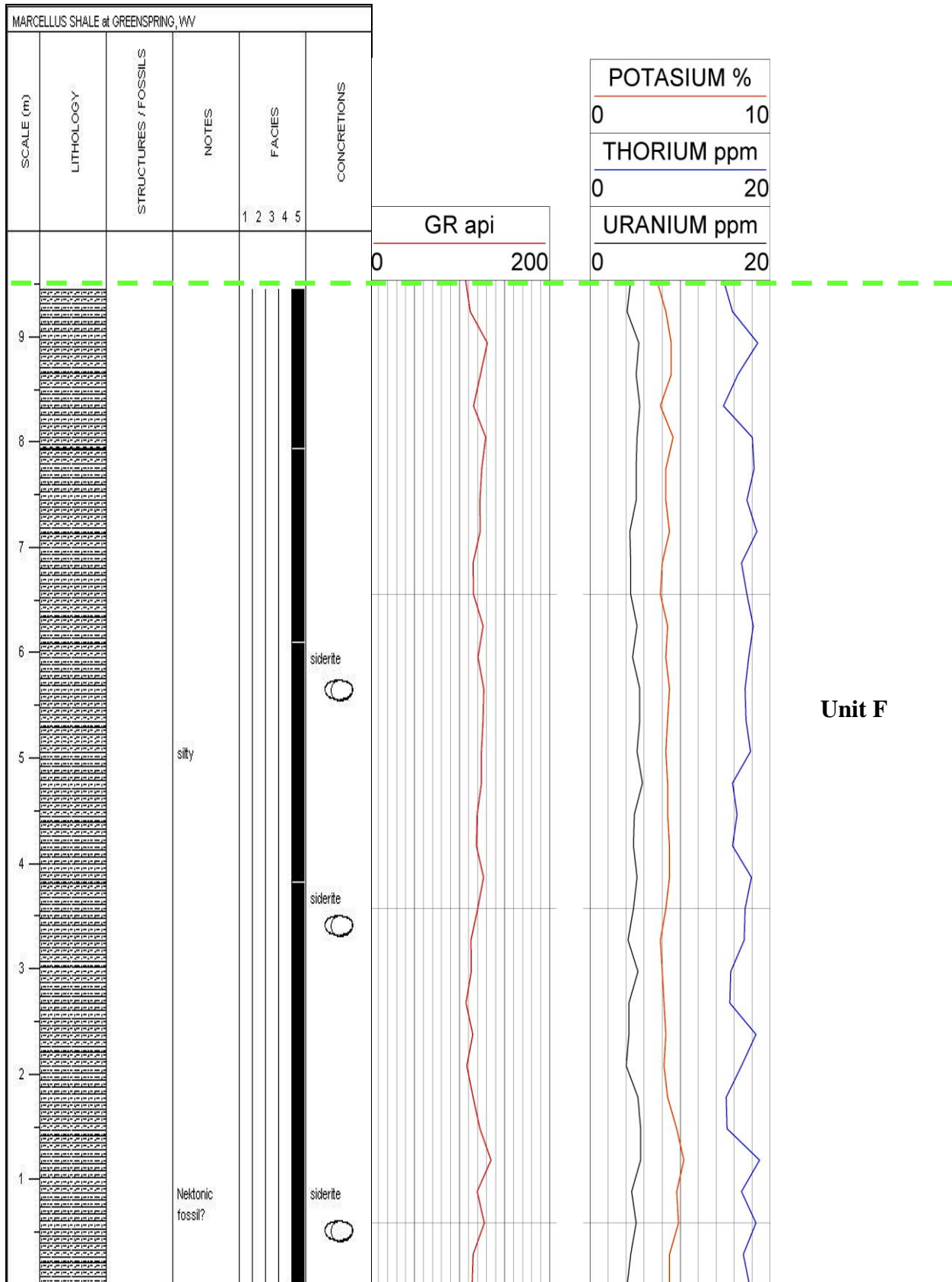


Figure 27. Greenspring, WV stratigraphic column and spectral gamma-ray curve.

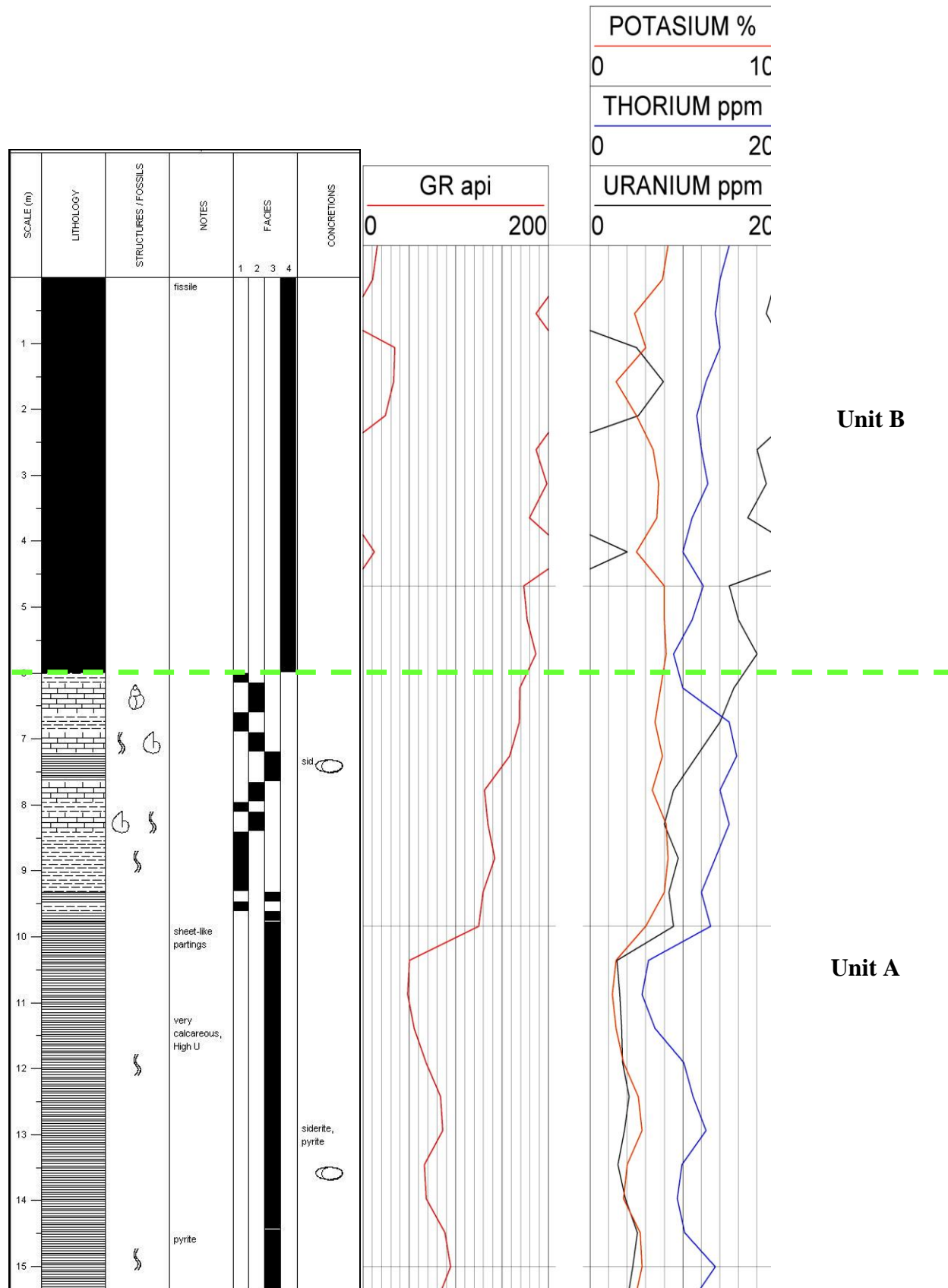


Figure 28. Petersburg North, WV stratigraphic column and spectral gamma-ray curve.

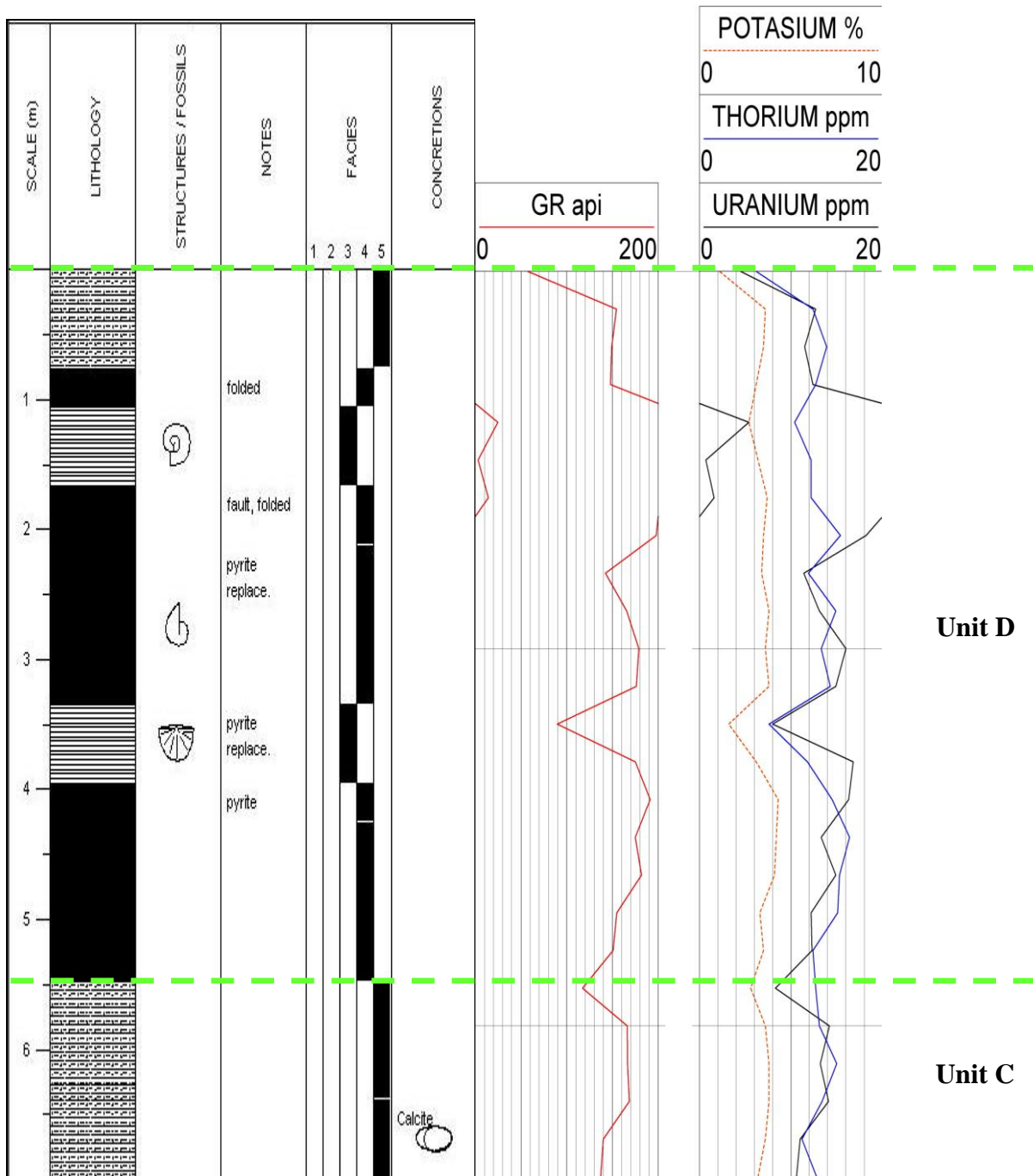


Figure 29. Tyrone, PA stratigraphic column and spectral gamma-ray curve.

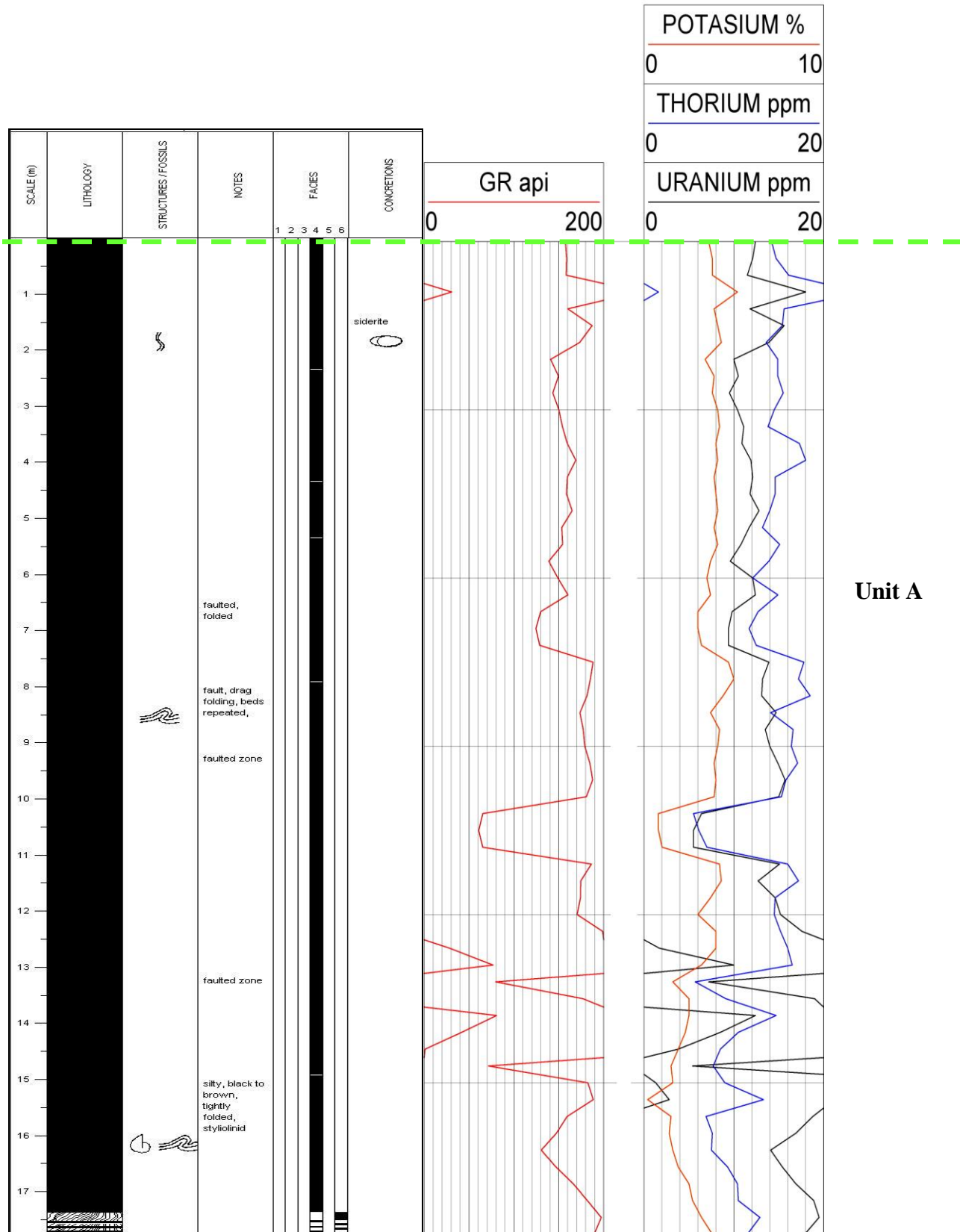


Figure 30. Whip Gap, WV stratigraphic column and spectral gamma-ray curve.



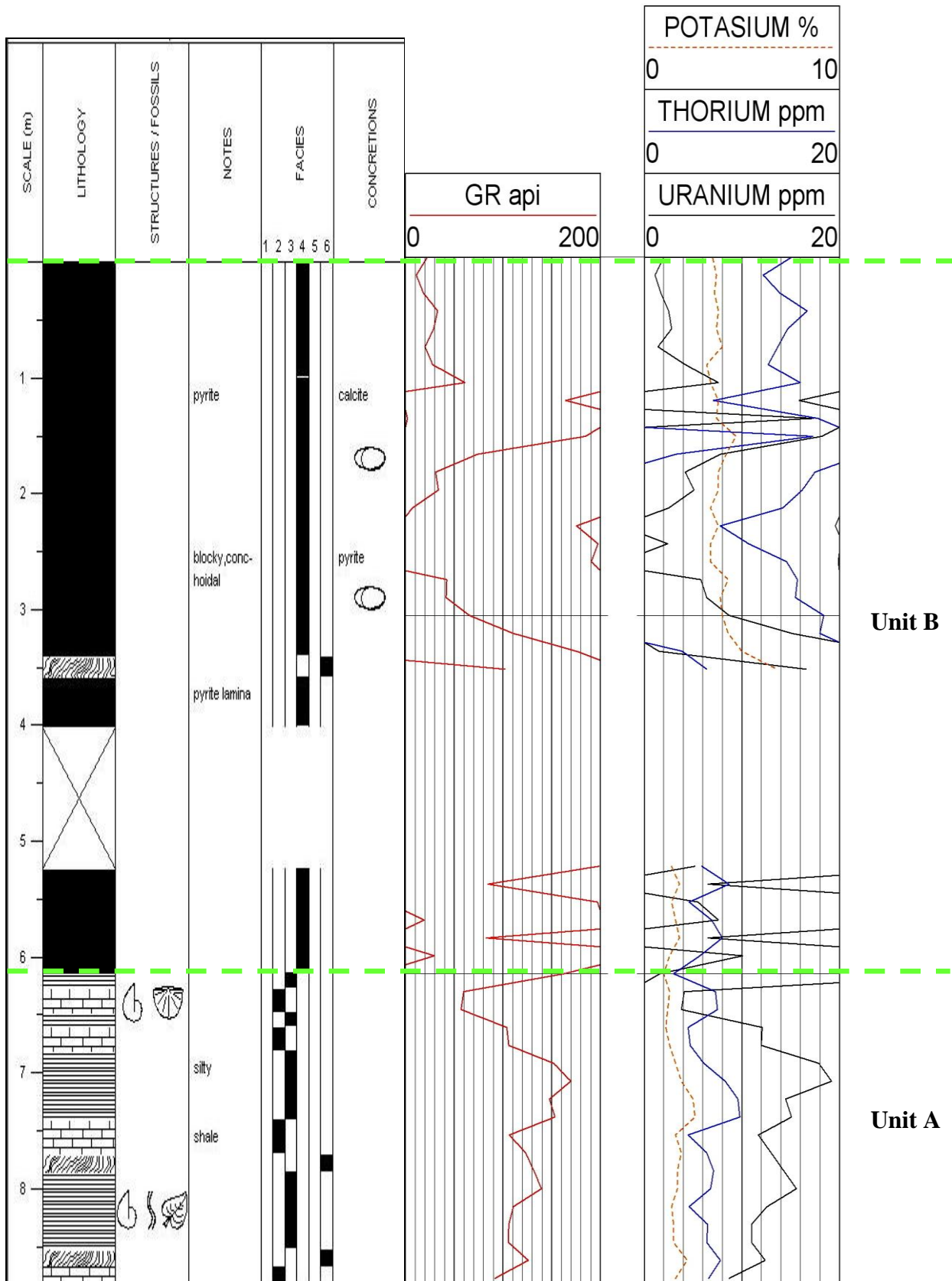
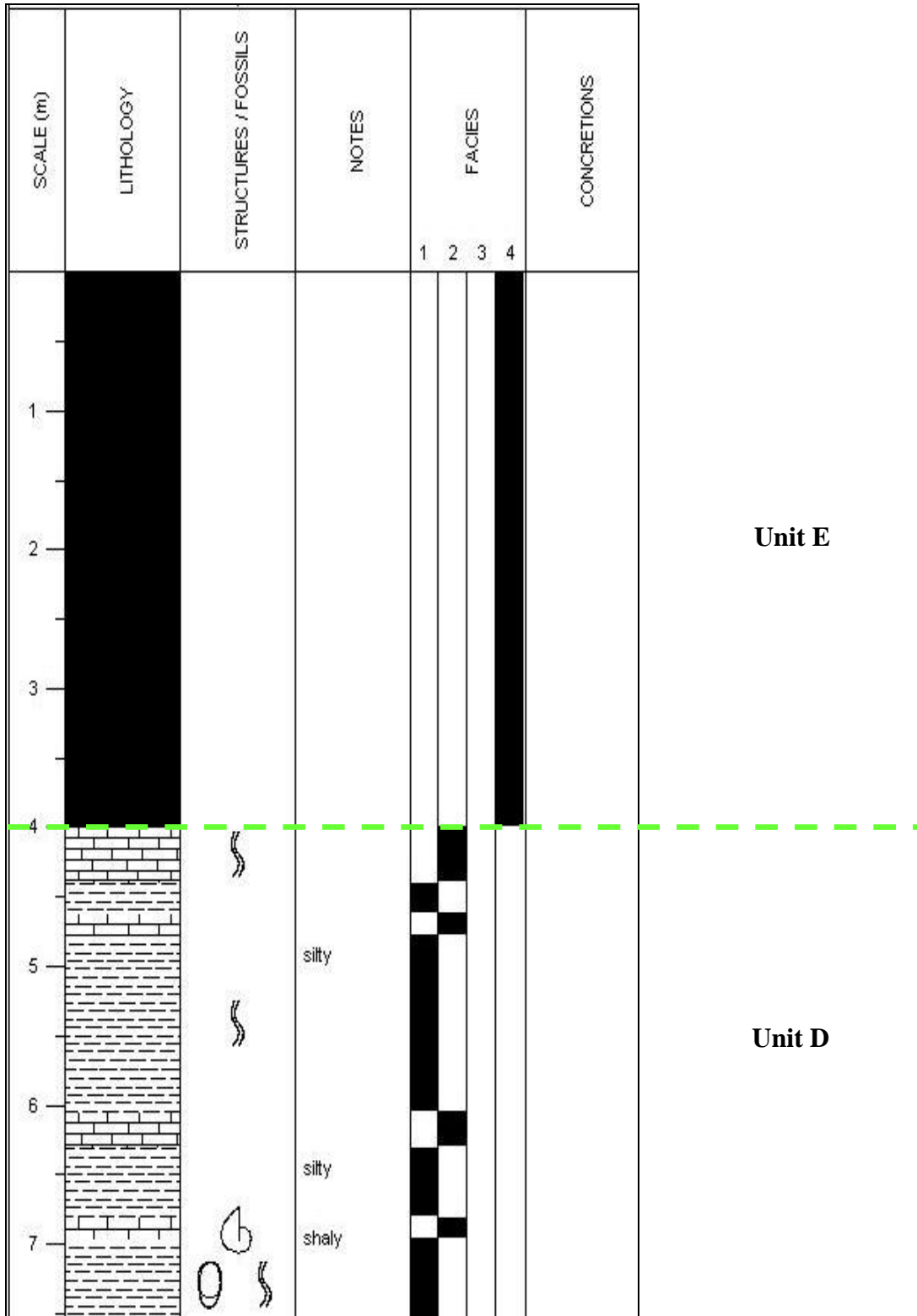


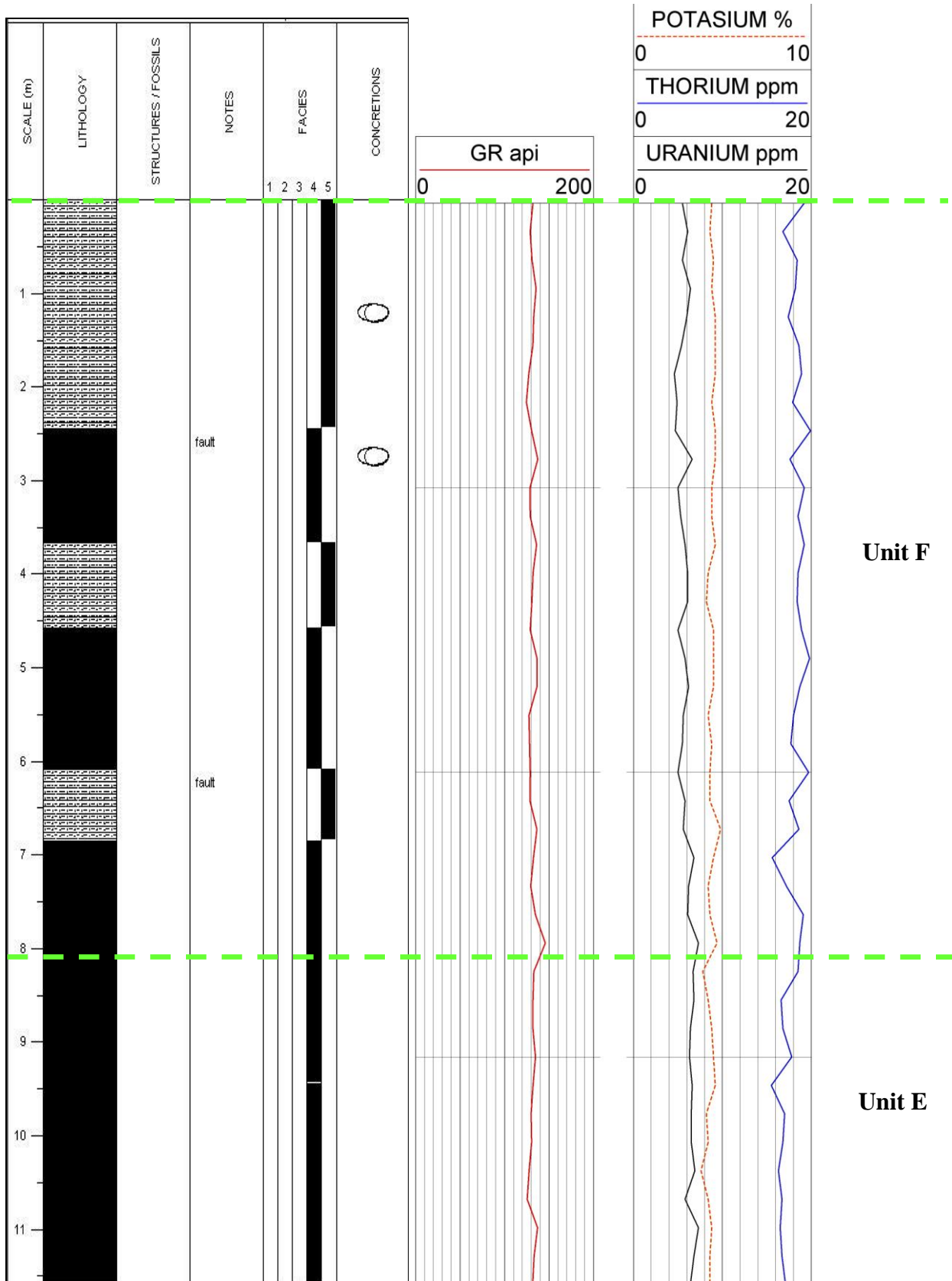
Figure 31. Bedford, PA stratigraphic column and spectral gamma-ray curve.



**Unit E**

**Unit D**

**Figure 32.** Hiser, WV stratigraphic column. Spectral gamma-ray was not used at this location,



**Figure 33.** South Branch of the Potomac, WV stratigraphic column and spectral gamma-ray curve.

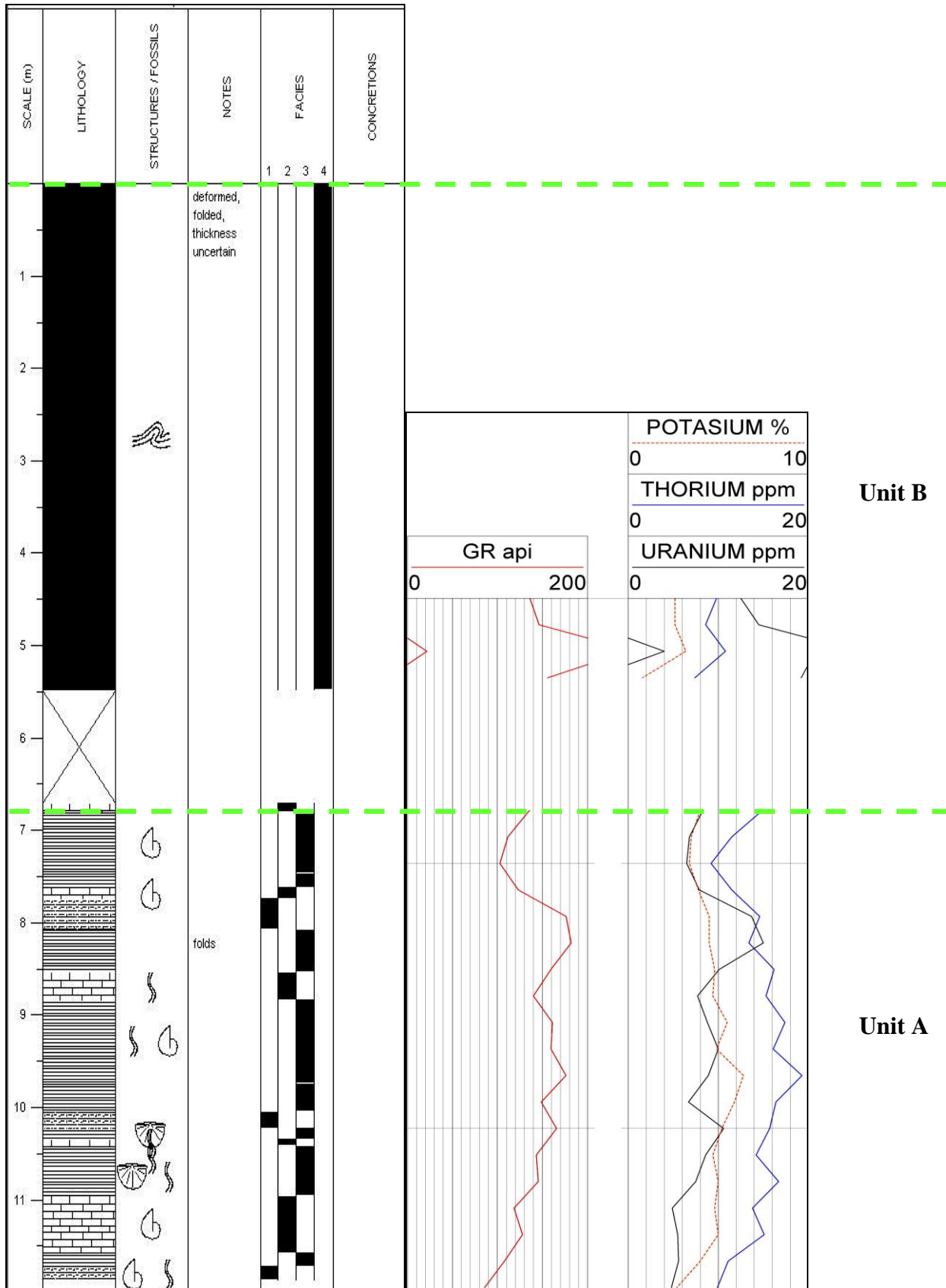


Figure 34. Oak Flat, WV stratigraphic column and spectral gamma-ray curve.

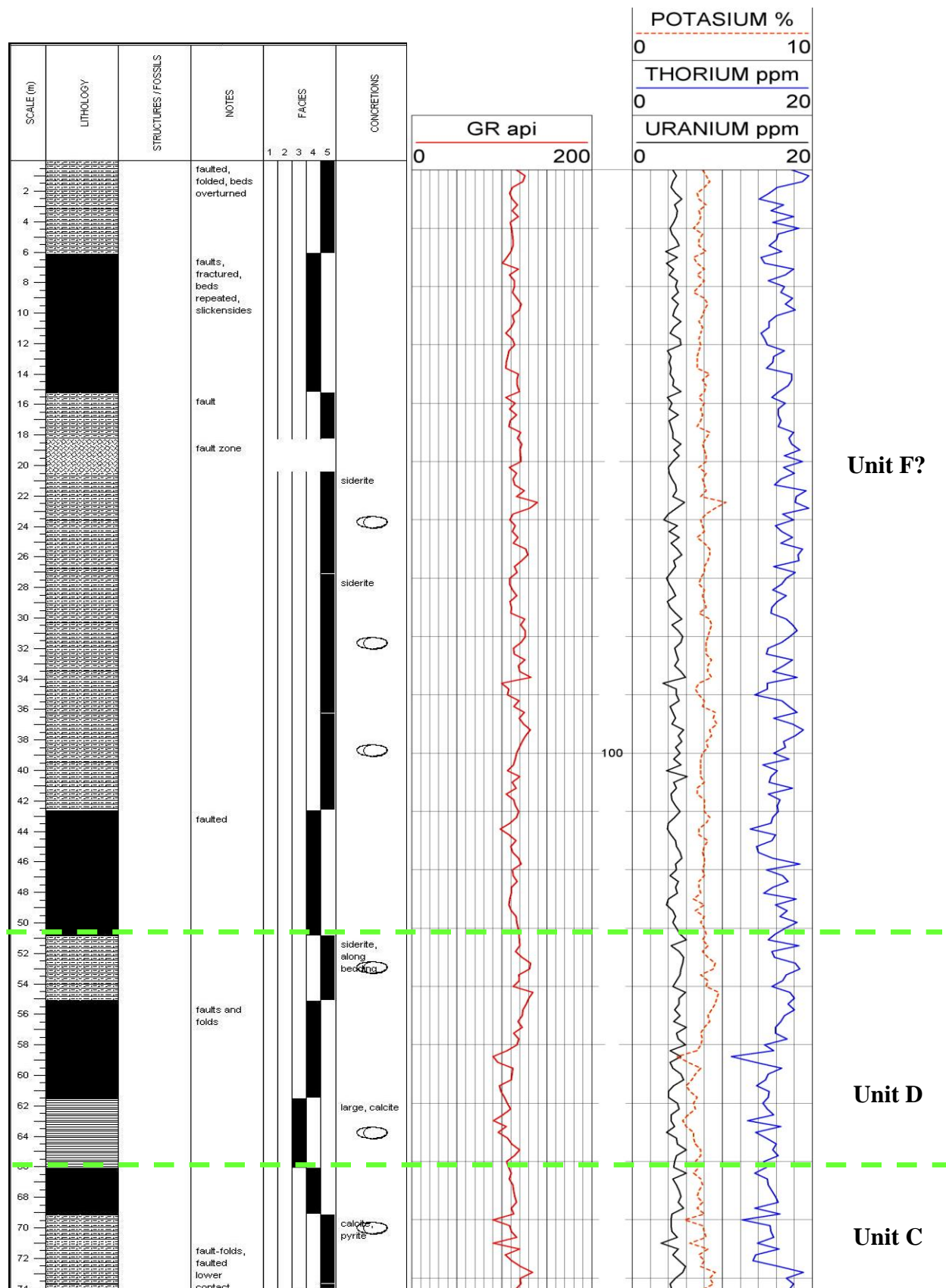


Figure 35. Berkeley Springs, WV stratigraphic column and spectral gamma-ray curve.

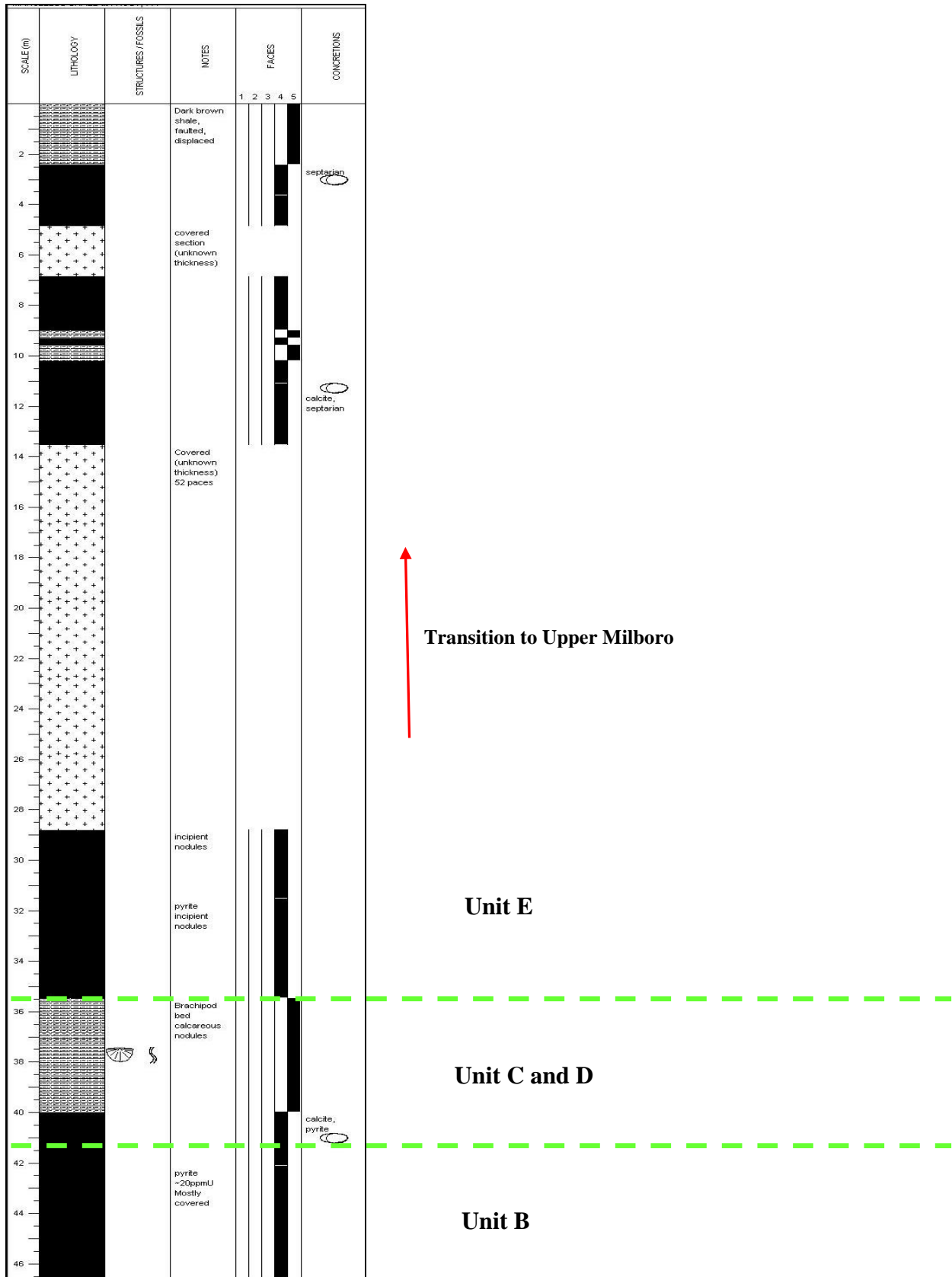


Figure 36. Frost, WV stratigraphic column. Spectral gamma-ray was not used at this location.

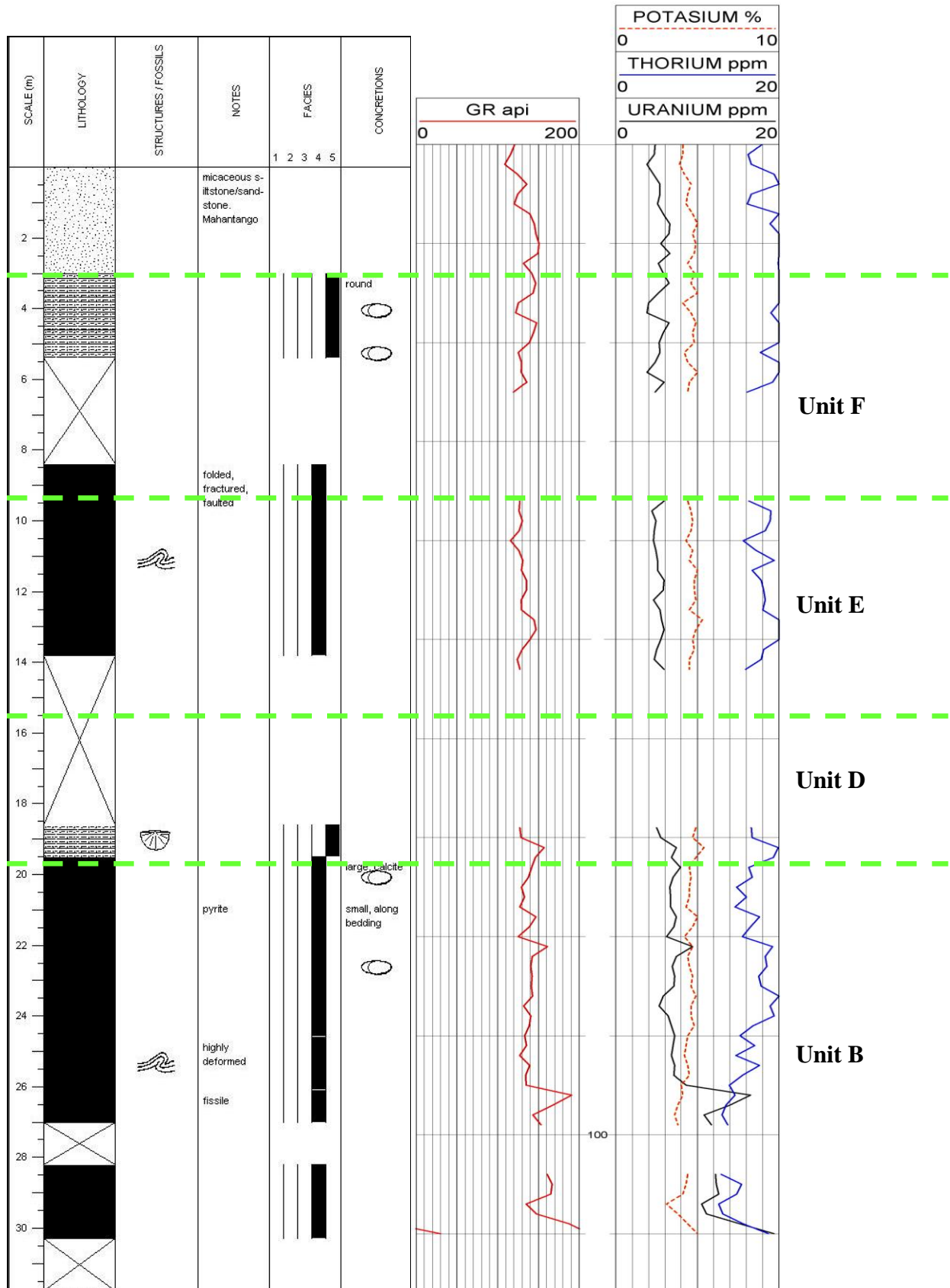


Figure 37. McCoolle, MD stratigraphic column and spectral gamma-ray curve.

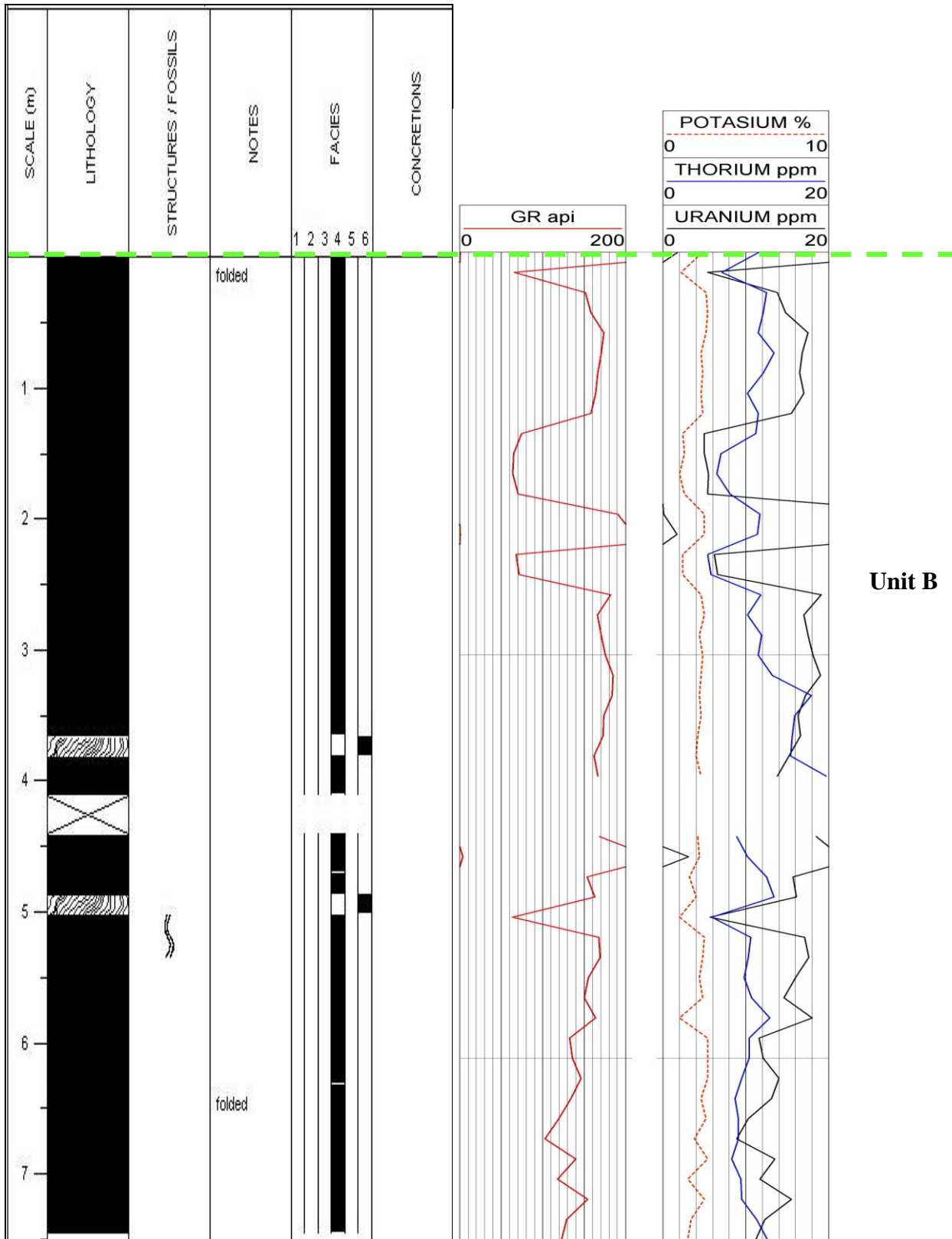


Figure 38. Tomahawk, WV stratigraphic column and spectral gamma-ray curve.



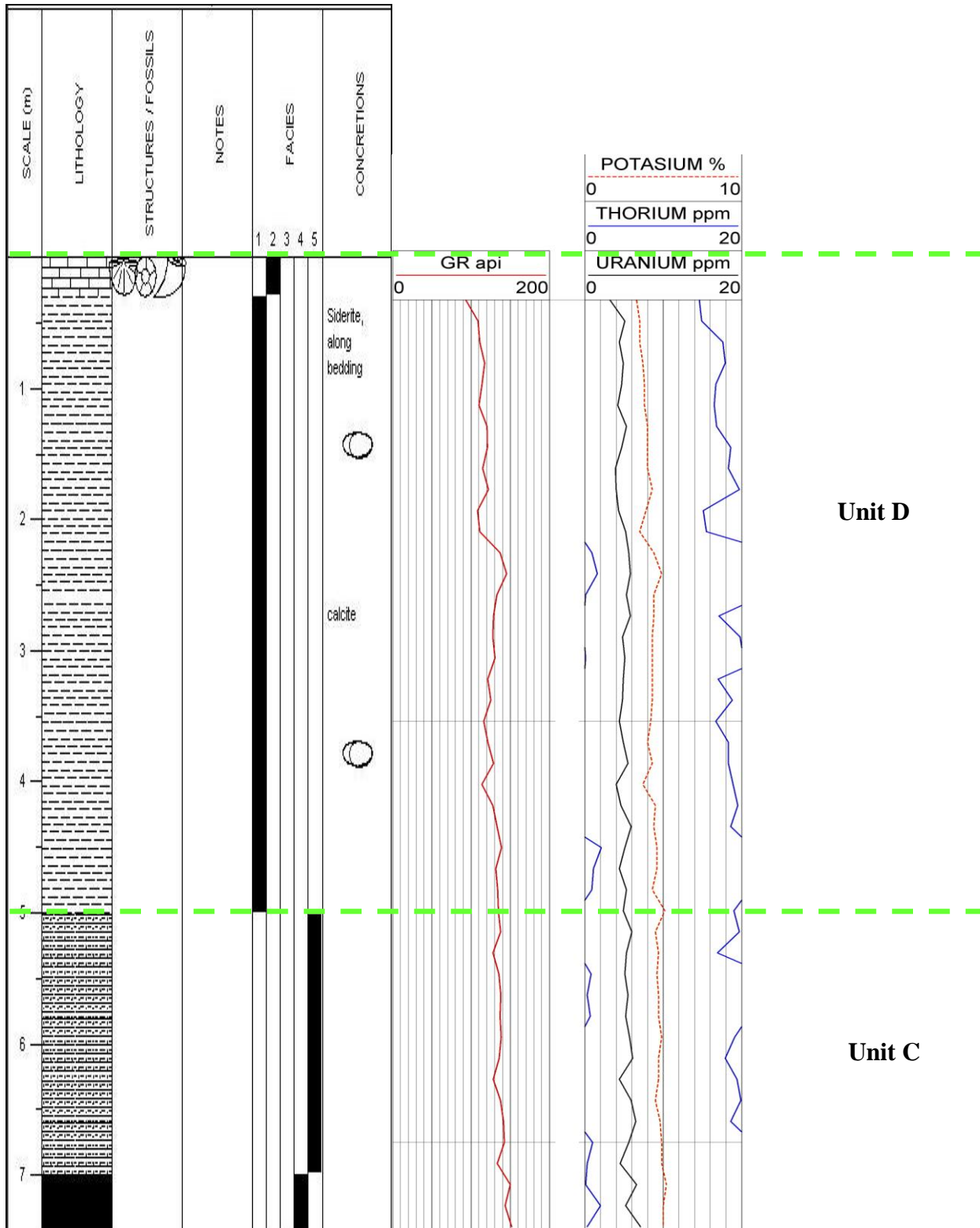


Figure 39. Petersburg West, WV stratigraphic column and spectral gamma-ray curve.

## GAMMA-RAY CORRELATIONS

Gamma-ray and spectral gamma-ray logs were created from scintillometer data collected at 15 partial outcrops (Fig. 25-39) and a gamma-ray type log was compiled for the composite section of the Marcellus Shale in the study area (Fig. 24). The spectral gamma-ray data for each outcrop was converted to API units using the following parameters: uranium ppm \* 6.69, thorium ppm \* 2.54, and potassium % \* 10.54 (Korsbech, 2002). The outcrop spectral gamma-ray API units were then summed to create a total gamma-ray curve (U + Th + K) for each outcrop (track 1). Individual concentrations of radioactive elements including uranium (ppm), thorium (ppm) and potassium (%) are displayed in track 2. The Th/U ratio (track 3) is used as a relative measure of redox conditions during deposition. Uranium is insoluble under reducing conditions and soluble under oxidizing conditions whereas thorium <sup>4+</sup> is insoluble under both reducing and oxidizing conditions. Therefore, comparing the relative amount of thorium to uranium (Th/U ratio) results in a relative measure of redox potential for the depositional environment (Adams and Weaver, 1958). A Th/U ratio values of two or less indicates deposition under anoxic conditions whereas values of seven or greater indicates deposition under oxic conditions (Adams and Weaver, 1958). Values between 2 and 7 indicate suboxic to dyoxic conditions. The composite type log was then used to compare and correlate each outcrop unit of the Marcellus Shale to nearby subsurface wells in the Appalachian Basin (Fig. 1).

### Unit A

The type log for Unit A in outcrop has total gamma-ray values that range between 60-162 API units (Fig. 24). Though uranium concentrations can be as low as 4.1 ppm, there are peaks at 15, 18 and 22 ppm. The higher uranium values are associated with black calcareous

shale (Facies 3), whereas the lower values are typically associated with limestone (Facies 2) and grey calcareous shale (Facies 1). The type log shows an abrupt increase in potassium and thorium concentrations in the middle of the unit. Gamma-ray character and thicknesses change considerably from the outcrop to the subsurface, even between wells spaced 7 miles apart (Fig. 41). Nevertheless, the total subsurface gamma-ray values and uranium concentrations are comparable to the type log and allow for correlation of Unit A into the subsurface. The gamma-ray profile for the upper contact of this unit is gradational.

The Unit A type log and subsurface logs have similar gamma-ray values; however, the thicknesses and log shape change. Thickness changes can be attributed to sediment supply and shifts in the thermocline. These result in varying development of Facies 1, 2 and 3. The overall increase in potassium (K) and thorium (Th) in the type log is related to increased abundance of clastic sediment in Facies 1 towards the top of the unit. Th/U ratio values of roughly two correspond with the increase in Th and K in the middle of the unit and suggest a period of slightly less anoxic deposition. The easternmost well (Fig. 40-3) shows similar high redox values indicating deposition under more oxic conditions. However, wells further into the basin (Fig. 40-1; Fig. 40-2) have redox numbers that represent deposition under anoxic conditions. Therefore, westward, the Marcellus exhibits decreased development of limestone (Facies 2) and grey calcareous shale (Facies 1) and increased development of black calcareous shale (Facies 3) and black non-calcareous shale (Facies 4).

## **Unit B**

The type log for Unit B in outcrop has total gamma-ray values that range between 170-602 API units, although readings are most often greater than 200 API. These elevated gamma-

ray values are related to increased uranium and thorium concentrations. Outcrop uranium concentrations average 30 ppm and are as high as 77 ppm, whereas thorium values reach a maximum of 42 ppm. The higher gamma-ray values of Unit B correspond well with nearby subsurface well logs where total gamma-ray values reach 662 API, uranium 77 ppm, and thorium 24 ppm. In both the outcrop type log and subsurface well logs, the maximum thorium and uranium values occur together in the base of Unit B (Fig. 40). The average thickness of Unit B in outcrop is roughly 23 feet. Unit B thickness remains similar from outcrop to subsurface; however, high gamma zones (>200 API) within the unit become thicker westward into the basin. The contact with the overlying unit is gradational (Fig. 40).

The elevated uranium is associated with an increase in organic matter in the rock (Swanson, 1960; Schmoker, 1981). The very high organic content in Unit B creates a rapid increase in the total gamma-ray profile that can be traced into the subsurface. The increased thorium concentrations seen at the base of this unit indicate an increased clay content and may be related to the presence of K-bentonites. The Th/U ratio values are less than one in the outcrop type log and indicate that Unit B was deposited under consistently anoxic conditions, although small fluctuations existed. The Th/U ratio in subsurface wells indicates deposition under similar consistently anoxic conditions; however, redox values do not fluctuate. Increased thickness of high gamma-ray zones in the subsurface may be associated with deposition in deeper water (~60 meters) or greater primary productivity in the surface water coupled with diminished clastic influx due to increased distance from the eastern source. Even during periods of low clastic influx, the proximal facies contain more clastics than their distal equivalents.

## Unit C

The type log for Unit C in outcrop has total gamma-ray values that range between 133-186 API units. Uranium values decrease considerably from the underlying unit with an average concentration of 7.7 ppm and a maximum of 16.5 ppm. Unit C is identified in the type log by an overall decrease in total gamma-ray values from the underlying unit (Fig. 40). Total gamma-ray values in the subsurface likewise decrease from the extremely high values observed in Unit B, although gamma-ray values for Unit C are greater in the subsurface (~250 API units). Unit C thickness in the subsurface varies but generally thins westward. Unit C is thickest in the northeasternmost well in the study area (Fig. 40-3) which is consistent with the proximity to the terrigenous source to the northeast (Fig. 1) (Ettensohn and Baron, 1981). The upper contact is gradational in the type log and subsurface wells (Fig. 40).

The type log for Unit C changes in character from the outcrop to the subsurface. The increase in thickness and uranium concentrations in the subsurface can be attributed to the deposition of a more condensed organic-rich section westward into the basin. The type log of Unit C indicates deposition during periods of increased clastic influx; therefore Unit C, in more proximal areas, is dominated by clastic Facies 5, whereas in more distal wells (Fig. 40-1; Fig. 40-2) Facies 4 dominates. The facies change laterally because, even during periods of increased clastic influx, little terrigenous clastic sediment reaches the more distal locations in the basin. The Th/U ratio for the type log indicates an upsection change from anoxic (<2) to suboxic (~4) conditions. In the subsurface the same trend is recognized; however redox values (< 2) suggest that anoxic conditions persisted throughout Unit C. Unit C redox values in the most basinward wells (Fig. 40-1; Fig 40-2) are significantly less than one, and indicate more anoxic conditions farther west into the basin, resulting in increased preservation of accumulated organic matter.

## Unit D

The type log for Unit D in outcrop has total gamma-ray values that range between 106-128 API units. As a whole, the gamma-ray profile for this unit is distinctively lower than the surrounding stratigraphic units. Uranium values for this unit are characteristically low, averaging 4.3 ppm. Uranium values can be as low as 2.4 ppm and as high as 7 ppm. Lower uranium concentrations are related to clean limestones beds of Facies 2 and grey calcareous shale of Facies 1. Although uranium concentrations decrease abruptly from the underlying unit, the gamma-ray profile of the basal contact tends to be gradational. In the outcrop type log the gamma-ray profile exhibits an overall coarsening-upwards trend in the gamma-ray, while the Th/U ratio values ( $>2-6$ ) indicate deposition under a generally oxic environment (Fig. 24). This unit holds similar character in the subsurface, though the cleaning-upward trend on the gamma-ray log is not well defined. Subsurface Th/U ratio values ( $>2-6$ ) in nearby wells indicate that Unit D was deposited under generally oxic conditions becoming more anoxic basinward ( $< 2$ ) (Fig. 40). Typically, Unit D thins from an average thickness of 30 feet at the outcrop to 15 feet westward into the subsurface. Several adjacent wells in Grant County, West Virginia (Fig. 41-4; Fig. 41-5) show a thickened section; this increase is associated with thrust faulting within the section.

The gradational nature of Unit D is due to a steady fall in relative sea level. The relatively low gamma-ray values and uranium concentrations are related to the increased deposition of carbonate facies above the thermocline. Under normal marine conditions and an oxygenated water column, any organic material that accumulated would be degraded rather than preserved. Thorium values are typically low and indicate a decrease in clastic clay deposition. The decrease

in thickness from the type log to the subsurface is due to less developed carbonate facies in more distal parts of the basin.

## **Unit E**

The type log for the black shale of Unit E in outcrop has total gamma-ray values that range between 112-196 API units. The gamma-ray profile clearly increases from the underlying unit due to increased levels of uranium. Concentrations of uranium in the type log can be as high as 20.5 ppm but average only 9 ppm. The type log for Unit E has a notably lower gamma-ray signature than the lower black shale of Unit B, and these concentrations decrease substantially up through Unit E. The thickness of high gamma-ray shale in the Unit E type log is relatively thin (~ 6 feet). In adjacent Grant County wells (Fig. 41-4; Fig. 41-5), Unit E has a thicker zone of high gamma-ray values but comparable uranium concentrations. Wells farther away from the outcrop belt, however, exhibit a thicker black shale section with considerably higher uranium concentrations (50 ppm). The sharp basal contact of Unit E correlates well with subsurface logs. The upper contact of this unit is gradational.

Similar to Unit B, Unit E shows a characteristic increase in organic content at the base of the unit that can be correlated to subsurface well logs. The enriched uranium zone of Unit B increases in thickness west into the subsurface, indicating a thickened section of increased organic matter (Fig. 40). Additionally, the subsurface wells exhibit an overall lower Th/U ratio values ( $< 1$ ) indicating increasingly anoxic conditions westward into the basin (Fig. 40). This lateral change is associated with longer periods of deposition under the thermocline, less dilution by terrigenous clastics, and possibly higher primary productivity in the surface water.

## Unit F

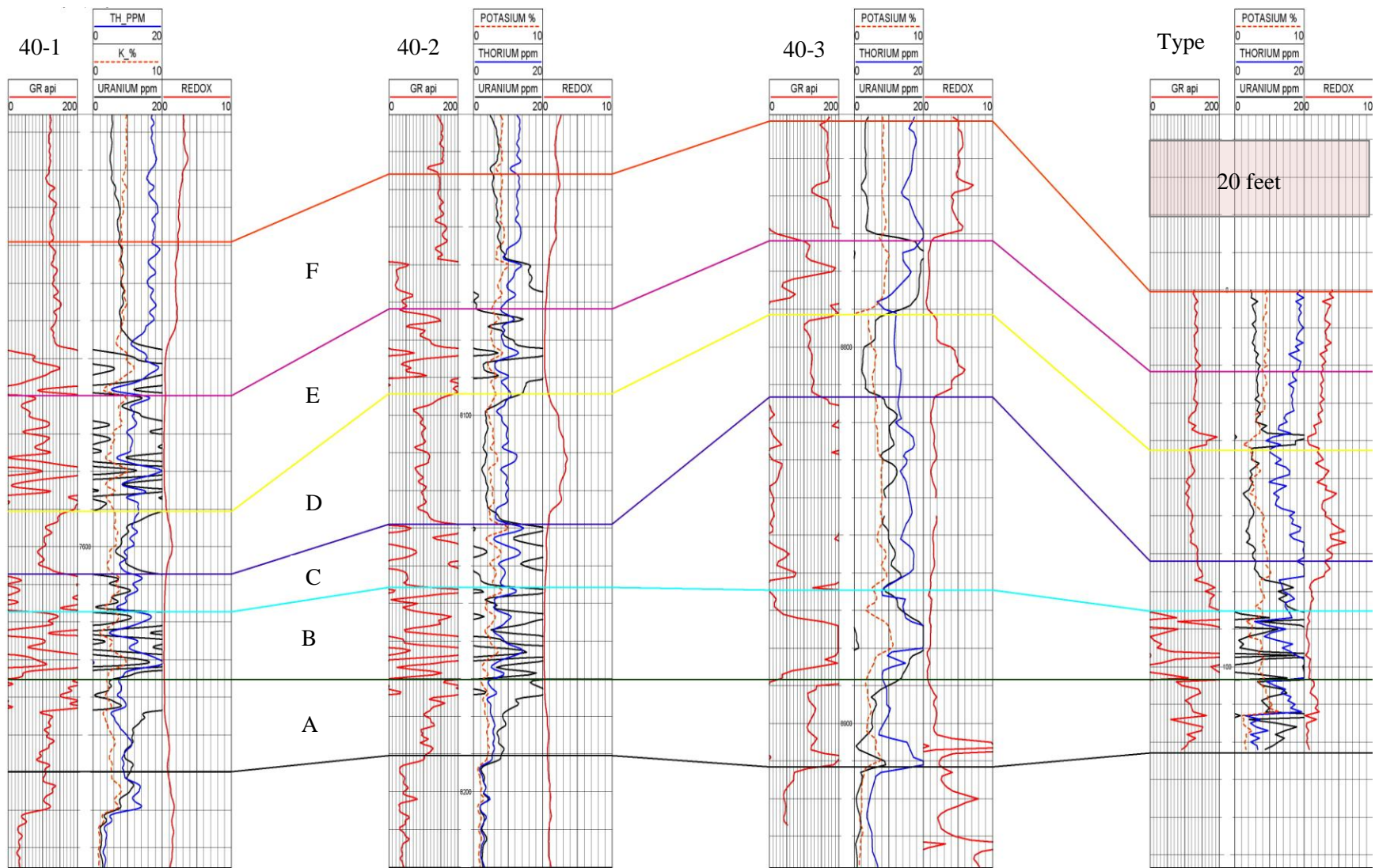
The type log for Unit F in outcrop has total gamma-ray values that range between 128-145 API units and a average uranium concentration of 5.6 ppm. The type log shows a constant decrease in total gamma-ray and uranium values upward through Unit F. As the uranium value declines, both thorium and potassium values gradually increase, indicating an increase in clastics. Nearby well logs show a similar trend in decreasing uranium and total gamma-ray response as well as a gradual increase in thorium and potassium at the top of the unit (Fig. 41). The subsurface gamma-ray character for Unit F varies, but it typically contains zones of high uranium at the base that are absent in the type log.

The decrease of uranium and increase in thorium and potassium associated with the type log for Unit F indicates dilution of organic material by clastics during the time of deposition. A gradual increase of thorium in Unit F can be attributed to increased clastic clay. Although the subsurface gamma-ray log indicates increased organic matter westward (*i.e.* higher uranium concentrations), the Th/U ratios both in the outcrop and subsurface still represent deposition under increasingly oxic conditions up the stratigraphic section (Fig. 40). Unit E marks the start of the large scale progradation that deposited the coarser clastic sediments of the Mahantango Formation.

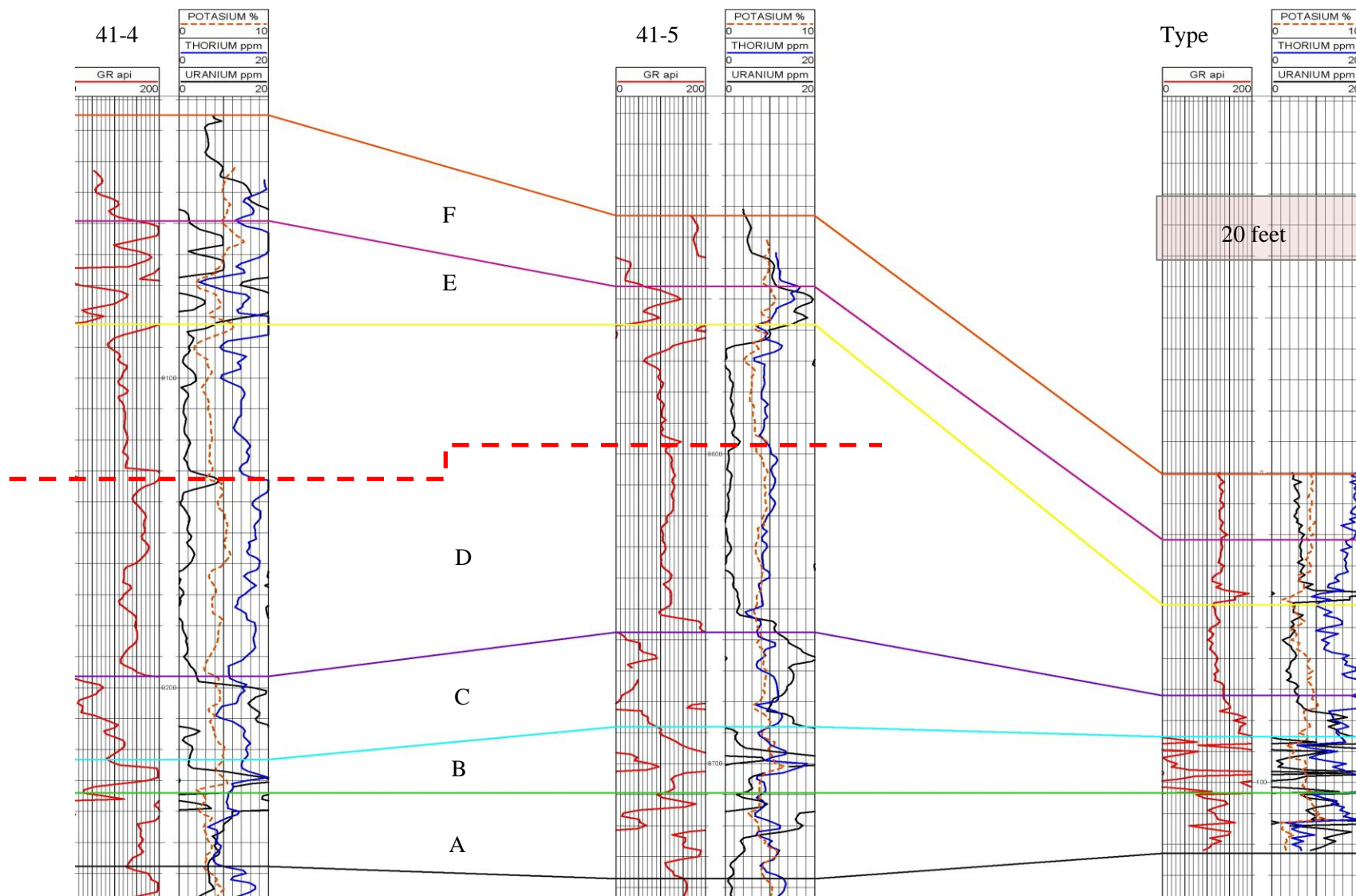
Spectral data, total gamma-ray (API units), and Th/U ratios from the outcrop type section provide useful tools for correlation from the outcrop belt westward to the subsurface well logs. The type log represents a more proximal facies assemblage while the subsurface logs represent a more basinward position. With respect to subsurface terminology for the Marcellus



Shale, Units A-C correlate to the Union Springs Formation, Unit D the Cherry Valley Member, and Units E-F the Oatka Creek Formation (Ver Straeten et al., 1994).



**Figure 40.** Stratigraphic units A through F in the Marcellus Shale type log (far right) are correlated with three subsurface wells (40-1, 40-2, 40-3). Total gamma-ray in API units is shown in track 1, concentrations of individual components are displayed in track 2 (i.e., potassium in percent, uranium in ppm, and thorium in ppm). The Th/U ratio indicating redox conditions is displayed in track 3. Correlations are based on log responses and are tied to units defined in the outcrop. For well locations see study area Figure 1.



**Figure 41.** Units (A-F) of the Marcellus Shale type log (far right) are correlated with two adjacent wells in Grant County West Virginia (41-4; 41-5). A thrust fault, interpreted with the dashed red line, more than doubles the thickness of Unit D in the subsurface. For well locations see study area Figure 1.

## CONCLUSIONS

The Marcellus Shale outcrops in the study area consist of six interbedded lithofacies (Facies 1-6). Facies deposition is primarily based on terrigenous sediment supply and shifts in the location of the thermocline, which is dependent on sea level:

- Facies 1 is light to dark grey, commonly bioturbated, calcareous shale. It was deposited in a foreland ramp environment below wave base (~20 meters) but above the thermocline (~40 meters) under normal marine conditions with a moderate supply of terrigenous clastic sediment.
- Facies 2 is dark grey to black, micritic, occasionally fossiliferous or argillaceous limestone. It was deposited in a foreland ramp environment below wave base and above the thermocline. It commonly formed in pods on a muddy shelf, resulting in a facies mosaic. The fossil assemblage indicates a normal marine, well-oxygenated water column, with low terrigenous input.
- Facies 3 is dark grey to black calcareous shale. It contains rare bioturbation, benthonic organisms, and fossil debris. It was typically deposited below the thermocline during times of decreased clastic influx. The bottom water was mostly oxygen-depleted, although seasonal mixing and large storms occasionally disrupted the thermocline and resulted in mixing of oxygen-rich surface water.
- Facies 4 is black to dark grey and occasionally chocolate-brown, non-calcareous shale with rare nektonic fossils. It was deposited during periods of low terrigenous clastic input in oxygen-depleted bottom-water, well below the thermocline. Water depth was roughly

60 meters, deeper than seasonal mixing depths, but within the depth of maximum effective anoxia in modern seas.

- Facies 5 is light to dark grey, silty, non-calcareous shale. It was typically deposited below the thermocline in place of Facies 3 and 4 during times of increased clastic influx. The water was mostly anoxic, though intermittent storm and seasonal mixing events allowed for deposition in more oxic conditions.
- Facies 6 the Tioga K-bentonite is tan, brown to grey, and composed of clay to sands sized grains of mica. Up to three bentonite ash beds, which were sourced from a volcano in Central Virginia, are identified at the base of the formation.

These lithofacies are stacked vertically into Units A through F, which can be identified in terms of subsurface stratigraphic terminology. The dominant facies in Units A-C, which represent the Union Springs Formation, include black calcareous shale (Facies 3), black non-calcareous shale (Facies 4), and grey non-calcareous shale (Facies 5). The dominant facies in Unit D, which represents the Cherry Valley Member, include limestone (Facies 2) and grey calcareous shale (Facies 1). The dominant facies in Units E-F, which represent the Oatka Creek Formation, include black non-calcareous shale (Facies 4) and grey non-calcareous shale (Facies 5).

The use of a handheld spectral gamma-ray tool to create an outcrop type log allows for stratigraphic correlations from the outcrop belt to the nearby subsurface. Concentrations of radioactive elements in similar facies are approximately the same in the outcrop as in the subsurface. As a result, outcrop Units A-F can be readily identified in the subsurface. Basinward,

these units exhibit an overall decrease in thickness of clastic-dominated (Facies 5) and carbonate (Facies 1 and 2) lithofacies as well as an increase in organic-rich (Facies 4) lithofacies. These lateral changes correspond with the greater distance from the terrigenous source and deposition in increasingly deep water beneath the thermocline.

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# **APPENDIX-OUTCROP DESCRIPTIONS**

## BURLINGTON WV, OUTCROP

**Location:** .9 miles East of  
**Burlington, WV on Rt. 50/220**  
**Latitude/Longitude:**  
**39.330279/-78.887382**

### **Unit Number: 1**

Unit Thickness: 3 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: dark grey to black  
Color Weathered: orange, white  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, (1-2mm)  
Parting Geometry: parallel, continuous, and broken by deformation  
Bedding Planes: regular, smooth  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: dark brown  
Luster of Streak: very waxy  
Other: locally deformed, parting weather in irregular shapes

### **Unit Number: 2**

Unit Thickness: 2 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: dark grey to black  
Color Weathered: orange  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, (1-2mm)  
Parting Geometry: parallel, continuous  
Bedding Planes: regular, relatively smooth  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: chocolate brown - black  
Luster of Streak: waxy  
Other: very similar to unit 1, partings break in angular shards, parting bedsets ~3 inches

### **Unit Number: 3**

Unit Thickness: 2 feet  
Facies Number: 5  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: orange, white  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: fissile (<1mm)  
Parting Geometry: discontinuous  
Bedding Planes: irregular  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: brown  
Luster of Streak: waxy  
Other: weathers in very small irregular fragments ~1 inch

### **Unit Number: 4**

Unit Thickness: 5 foot  
Facies Number: N/A  
Rock Type: covered interval  
Interbeds: N/A  
Color Fresh: N/A  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: N/A  
Fossil Content: N/A  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: very soft, probably same as unit 3

### **Unit Number: 5**

Unit Thickness: 1 foot  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: N/A  
Color Weathered: brown  
Grain Size: silty  
Visible Minerals: N/A  
Parting Thickness: platy- flaggy (2mm-10mm)

Parting Geometry: discontinuous  
Bedding Planes: irregular  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: light brown, tan  
Luster of Streak: semi-waxy  
Other: none

### **Unit Number: 6**

Unit Thickness: 1.5 feet  
Facies Number: 2 and 1  
Rock Type: Limestone  
Interbeds: calcareous shale  
Color Fresh: dark grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: small shiny grains (calcite)  
Parting Thickness: interbeds: platy (1-2mm)  
Parting Geometry: interbeds: discontinuous  
Bedding Planes: N/A  
Sedimentary Structures: calcareous nodules  
Fossil Content: none  
Color When Powdered: interbeds: brown, tan  
Luster of Streak: interbeds: semi waxy  
Other: limestone ranges from very thinly bedded (1-3cm) to medium bedded (16 cm), limestone consist of large calcareous concretions ~ 10cm in width, limestone appear to thin

### **Unit Number: 7**

Unit Thickness: 1.5 feet  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: fissile (.5-1mm) platy (1-5mm)  
Parting Geometry: fissile: flakey, parallel, platy: irregular

Bedding Planes: N/A  
Sedimentary Structures: nodules  
Fossil Content: none  
Color When Powdered: fissile shale: tan, platy shale: light  
Luster of Streak: fissile shale: peels, platy shale: powdery  
Other: fissile shale directly overlies limestone bed with nodules and grades upwards to party shale, nodules non-calcareous ~ 1 inch and form along bedding planes

**Unit Number: 8**

Unit Thickness: .5 feet  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: grey- brown  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: papery, (< .5mm)  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: partings break off in soft, papery pieces

**Unit Number: 9**

Unit Thickness: .5 feet  
Facies Number: 2 and 1  
Rock Type: limestone  
Interbeds: calcareous shale  
Color Fresh: N/A  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: possible skeletal debris, orange, red oxidized  
Color When Powdered: tan  
Luster of Streak: semi waxy  
Other: limestone is very thinly bedded (.5-1 inch)

**Unit Number: 10**

Unit Thickness: 1 foot  
Facies Number: 2  
Rock Type: limestone  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: calcite  
Parting Thickness: none  
Parting Geometry: none  
Bedding Planes: N/A  
Sedimentary Structures: nodules  
Fossil Content: crinoid stems, rugose corals  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: fossils replaced with crystalline calcite

**Unit Number: 11**

Unit Thickness: 1 foot  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: brown to grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, (2-5mm)  
Parting Geometry: discontinuous  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: tan to brown  
Luster of Streak: mid-luster to waxy  
Other: shale draped over Unit 10

**Unit Number: 12**

Unit Thickness: 2 feet  
Facies Number: covered interval  
Rock Type: N/A  
Interbeds: N/A  
Color Fresh: N/A  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A

Sedimentary Structures: N/A  
Fossil Content: N/A  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: probably soft shale

**Unit Number: 13**

Unit Thickness: 1 foot  
Facies Number: 2  
Rock Type: limestone  
Interbeds: none  
Color Fresh: grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: crystalline calcite  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: N/A  
Fossil Content: crinoids stems common  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: fossils are becoming more abundant than previous limestone units, randomly distributed

**Unit Number: 14**

Unit Thickness: 12 feet  
Facies Number: N/A  
Rock Type: covered section  
Interbeds: N/A  
Color Fresh: N/A  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: N/A  
Fossil Content: N/A  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: soft shale similar to units 11 and 12

**Unit Number: 15**

Unit Thickness: 4 feet  
Facies Number: 1  
Rock Type: slightly calcareous shale  
Interbeds: none  
Color Fresh: grey

Color Weathered: tan, green  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, (2-5mm)  
Parting Geometry: parallel  
Bedding Planes: regular, smooth  
Sedimentary Structures: horizontal laminations  
Fossil Content: none  
Color When Powdered: light brown  
Luster of Streak: semi-waxy  
Other: shale very slightly calcareous, breaks into small ~1-2 inch pieces, some bed set ~2-3 cm

**Unit Number: 16**

Unit Thickness: 4 feet  
Facies Number: 1 and 2  
Rock Type: calcareous shale  
Interbeds: argillaceous limestone  
Color Fresh: grey, interbeds: grey to dark grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, (1-5mm)  
Parting Geometry: discontinuous  
Bedding Planes: N/A  
Sedimentary Structures: interbeds: concretions  
Fossil Content: none  
Color When Powdered: light brown, interbeds: white to light tan  
Luster of Streak: semi-waxy, interbeds: dull  
Other: more competent shale than unit 15, interbeds: very thin to thinly bedded argillaceous limestone ~ 2-4cm

**Unit Number: 17**

Unit Thickness: 10 feet  
Facies Number: 3 and 2  
Rock Type: calcareous shale  
Interbeds: argillaceous limestone  
Color Fresh: grey to black, interbeds: dark grey

Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: papery to fissile ~ .1- 1mm  
Parting Geometry: continuous  
Bedding Planes: regular, smooth  
Sedimentary Structures: Fossil Content: interbeds: crinoid stems, fossil debris  
Color When Powdered: tan  
Luster of Streak: semi-waxy  
Other: fossils found on bedding planes, shale breaks in soft sheets, interbeds: argillaceous limestone ~ .5-1inch in thickness

**Unit Number: 18**

Unit Thickness: 1 foot  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: N/A  
Color Fresh: grey  
Color Weathered: N/A  
Grain Size: possible silt sized grains  
Visible Minerals: pyrite in nodules  
Parting Thickness: platy ~2mm  
Parting Geometry: discontinuous  
Bedding Planes: N/A  
Sedimentary Structures: pyrite nodules  
Fossil Content: none  
Color When Powdered: tan  
Luster of Streak: semi- waxy  
Other: possibly silty, pyrite nodules could be replaced shell debris

**Unit Number: 19**

Unit Thickness: 1 foot  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: grey  
Color Weathered: N/A  
Grain Size: silt sized grains  
Visible Minerals: pyrite in nodules  
Parting Thickness: platy, ~ 5mm  
Parting Geometry: N/A  
Bedding Planes: N/A

Sedimentary Structures: pyrite nodules  
Fossil Content: none  
Color When Powdered: tan  
Luster of Streak: semi- waxy  
Other: thicker partings, more silt sized grains than unit 18, pyrite concretions possibly replaced shell debris

**Unit Number: 20**

Unit Thickness: 2 feet  
Facies Number: 1 and 2  
Rock Type: limestone  
Interbeds: calcareous shale  
Color Fresh: dark grey, interbeds: grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: calcite  
Parting Thickness: platy  
Parting Geometry: discontinuous  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: limestone range from thinly laminated ~ 1cm to thinly bedded ~ 3cm; shale is usually more thinly laminated directly overlying limestone bodies

**Unit Number: 21**

Unit Thickness: 5 feet  
Facies Number: 1 and 2  
Rock Type: limestone  
Interbeds: calcareous shale  
Color Fresh: interbeds: grey  
Color Weathered: interbeds: brown  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: no distinct partings, bioturbated  
Parting Geometry: N/A  
Bedding Planes: irregular  
Sedimentary Structures: limestone beds are made of nodules, lenticular shaped limestone bodies, interbeds: burrows  
Fossil Content: small brachiopods



Color When Powdered:  
interbeds: brown  
Luster of Streak: interbeds:  
waxy  
Other: limestone beds are much  
larger than in Unit 20 ~.8-1.5  
feet, interbeds: calcareous shale  
also contains more carbonate  
rich beds ~ 2- 3cm, burrows  
filled with lighter color mud  
from above or below

**Unit Number: 22**

Unit Thickness: 1 foot  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: grey  
Color Weathered: brown, white  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: slabby ~ 10  
mm  
Parting Geometry:  
discontinuous  
Bedding Planes: irregular  
Sedimentary Structures:  
flattened, calcareous, and oblong  
concretions, burrows  
Fossil Content: none  
Color When Powdered: brown  
Luster of Streak: waxy  
Other: concretion has especially  
high specific gravity for size,  
shale is only slightly calcareous,  
and shale contains red/orange  
oxidized burrows

**Unit Number: 23**

Unit Thickness: 9 feet  
Facies Number: 1 and 2  
Rock Type: calcareous shale  
Interbeds: limestone  
Color Fresh: grey to dark grey  
interbeds: very dark grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: interbeds:  
calcite  
Parting Thickness: papery to  
platy  
Parting Geometry:  
discontinuous  
Bedding Planes: irregular

Sedimentary Structures:  
bioturbated  
Fossil Content: none  
Color When Powdered: tan  
Luster of Streak: semi- waxy  
Other: interbeds: limestone is  
very thinly bedded ~2-3cm, red  
to orange oxidized burrows in  
shale, shale begins to get darker  
towards Unit 24

**Unit Number: 24**

Unit Thickness: 10 feet  
Facies Number: 2  
Rock Type: argillaceous  
limestone  
Interbeds: none  
Color Fresh: black  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: irregular  
Sedimentary Structures: siderite  
nodules, possible oxidized  
burrows  
Fossil Content: bivalve,  
styliolinids  
Color When Powdered: brown  
Luster of Streak: dull  
Other: limestone is very thinly  
bedded, nodules very heavy,  
slightly calcareous, oval shaped  
range from .4-.7 feet in size

**Unit Number: 25**

Unit Thickness: 2 feet  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: brown  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures:  
calcareous nodules  
Fossil Content: some shell  
debris  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: partially covered

## SPRINGFIELD WV, OUTCROP

**Location:** 3 miles Northeast of  
Springfield, WV on Co. Rt.1  
**Latitude/**  
**Longitude:**39.483756/-  
78.664749

### **Unit Number: 1**

Unit Thickness: 92 cm  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: grey  
Color Weathered: brown  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: thick partings  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: first bed along railroad tracks

### **Unit Number: 2**

Unit Thickness: 45 cm  
Facies Number: 5  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: laminated  
Fossil Content: styliolinid, possible small ammonoid  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: contact with underlying unit appears to be gradational

### **Unit Number: 3**

Unit Thickness: 16 cm  
Facies Number: 1  
Rock Type: calcareous shale

(silty)  
Interbeds: none  
Color Fresh: grey  
Color Weathered: brown  
Grain Size: possibly silt sized grains  
Visible Minerals: none  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: extensively burrowed  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: contact with underlying unit appears to be gradational

### **Unit Number: 4**

Unit Thickness: 130 cm  
Facies Number: 2 and 1  
Rock Type: limestone, grainstone  
Interbeds: calcareous shale  
Color Fresh: black to dark grey  
Color Weathered: N/A  
Grain Size: pebble like grains in base of limestone bed  
Visible Minerals: none  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: ambeocela, brachiopods  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: limestone ~ 10-22cm with thin interbeds of shale, three limestone beds: (19cm, 14cm, 8cm), middle limestone bed contains unknown brown stick like features

### **Unit Number: 5**

Unit Thickness: 100 cm  
Facies Number: 1 and 2  
Rock Type: Covered section, limestone  
Interbeds: calcareous shale  
Color Fresh: N/A  
Color Weathered: N/A

Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: N/A  
Fossil Content: N/A  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: N/A

### **Unit Number: 6**

Unit Thickness: 70 cm  
Facies Number: 2  
Rock Type: limestone, three beds  
Interbeds: none  
Color Fresh: N/A  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: calcite  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: abundant siderite molds  
Fossil Content: re-crystallized cephalopod, calcite-filled structures, shell debris  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: limestone bodies are possibly wedge shaped, two generations of vertical fractures backfilled with calcite

### **Unit Number: 7**

Unit Thickness: 303 cm  
Facies Number: 5  
Rock Type: non-calcareous shale, mostly covered  
Interbeds: none  
Color Fresh: grey  
Color Weathered: brown  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: laminated  
Fossil Content: none  
Color When Powdered: N/A

Luster of Streak: N/A  
Other: low density, platy

**Unit Number: 8**

Unit Thickness: 60 cm  
Facies Number: 4  
Rock Type: non-calcareous  
Interbeds: none  
Color Fresh: black  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures:  
laminated, siderite concretions  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: shiny and deformed  
around siderite concretions

**Unit Number: 9**

Unit Thickness: 400 cm  
Facies Number: 4  
Rock Type: non-calcareous  
Interbeds: none  
Color Fresh: black  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, 1-  
4mm  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures:  
laminated  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: minor deformation,  
possible limestone lense one  
meter above this unit

## GREENSPRING WV, OUTCROP

**Location:** 1.4 miles Southwest of Greenspring, WV on Co. Rt. 1

**Latitude/Longitude:**  
39.517384/-78.632605

### **Unit Number: 1**

Unit Thickness: 10.25 feet  
Facies Number: 5  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: medium to dark grey  
Color Weathered: orange, maroon  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy to slabby, 2-10mm  
Parting Geometry: discontinuous  
Bedding Planes: N/A  
Sedimentary Structures: bedded nodules, horizontal laminae  
Fossil Content: part of unknown crustacean (Nektonic).  
Color When Powdered: light tan  
Luster of Streak: dull  
Other: black and red weathering around nodules, oblong shaped ~2 inches-1 foot

### **Unit Number: 2**

Unit Thickness: 1.08 feet  
Facies Number: 5  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: yellow, red  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, (2-3mm)  
Parting Geometry: non- parallel, discontinuous  
Bedding Planes: irregular, bumpy  
Sedimentary Structures: horizontal bioturbation  
Fossil Content: none

Color When Powdered: tan  
Luster of Streak: dull  
Other: Iridescent stains and white crystal precipitate on bedding surfaces.

### **Unit Number: 3**

Unit Thickness: 3.42 feet  
Facies Number: 5  
Rock Type: non- calcareous shale  
Interbeds: none  
Color Fresh: light-dark grey  
Color Weathered: orange, red  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, ~1mm  
Parting Geometry: discontinuous  
Bedding Planes: N/A  
Sedimentary Structures: nodules  
Fossil Content: None  
Color When Powdered: light grey  
Luster of Streak: intermediate luster  
Other: nodules randomly distributed, shale beds draped overtop

### **Unit Number: 4**

Unit Thickness: 1.42 feet  
Facies Number: 5  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: light- dark grey  
Color Weathered: orange, red, white  
Grain Size: N/A  
Visible Minerals: unknown silt sized grains  
Parting Thickness: platy to flaggy (1mm-5mm)  
Parting Geometry: discontinuous  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: tan  
Luster of Streak: dull

Other: grey shale is silty, distinct contact between facies 3 and 4

### **Unit Number: 5**

Unit Thickness: 3 feet  
Facies Number: 5 and 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: grey to black  
Color Weathered: white, grey  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, (1-5mm)  
Parting Geometry: discontinuous  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: tan-grey  
Luster of Streak: semi waxy, mid luster  
Other: very similar to Unit 4, weathers into irregular, discontinuous chips

### **Unit Number: 6**

Unit Thickness: 3 feet  
Facies Number: 5  
Rock Type: non-calcareous shale  
Interbeds: bedded siderite  
Color Fresh: dark grey  
Color Weathered: orange, red  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy ~ 5mm, interbeds: < 5mm  
Parting Geometry: sheet like,  
Bedding Planes: irregular  
Sedimentary Structures: 7ft long bedded siderite nodules  
Fossil Content: none  
Color When Powdered: light  
Luster of Streak: dull, interbeds: semi-waxy  
Other: lense shaped interbeds range from 1- 5 inches

**Unit Number: 7**

Unit Thickness: 6 feet

Facies Number: 5

Rock Type: dark grey to black  
non-calcareous shale

Interbeds: none

Color Fresh: grey- black

Color Weathered: white, yellow

Grain Size: may contain silt  
sized grains

Visible Minerals: N/A

Parting Thickness: platy, (2 -  
5mm)

Parting Geometry:  
discontinuous

Bedding Planes: irregular, wavy

Sedimentary Structures: none

Fossil Content: none

Color When Powdered: tan

Luster of Streak: semi waxy

Other: beds weathered into 1  
inch lense-like features, gritty

**Unit Number: 8**

Unit Thickness: 5 feet

Facies Number: 5

Rock Type: Light non-  
calcareous shale

Interbeds: none

Color Fresh: light to dark grey

Color Weathered: N/A

Grain Size: may contain silt  
sized grains

Visible Minerals: N/A

Parting Thickness: platy to  
flaggy (5-10mm)

Parting Geometry:  
discontinuous

Bedding Planes: N/A

Sedimentary Structures: none

Fossil Content: none

Color When Powdered: white

Luster of Streak: dull

Other: lense like features larger  
(1-5 inches), partings are found  
in .5-1 foot bedsets, gritty

## PETERSBURG NORTH WV, OUTCROP

**Location:** 1.5 miles North of Petersburg, WV on Rt. 42  
**Latitude/Longitude:** 39.011781/-79.131689

### **Unit Number: 1**

Unit Thickness: 2.5 feet  
Facies Number: 3  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: calcite  
Parting Thickness: no distinct partings  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: possible bioturbation  
Fossil Content: possible calcite replaced fossils  
Color When Powdered: tan, white  
Luster of Streak: dull  
Other: calcite veins, shale is crumble and smudges fingers

### **Unit Number: 2**

Unit Thickness: .5 feet  
Facies Number: 3  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: black to grey  
Color Weathered: tan  
Grain Size: N/A  
Visible Minerals: calcite  
Parting Thickness: fissile to platy, .5-3mm  
Parting Geometry: slightly irregular (shell debris), wavy  
Bedding Planes: bumpy  
Sedimentary Structures: N/A  
Fossil Content: possible shell debris  
Color When Powdered: tan  
Luster of Streak: intermediate  
Other: small calcite filled veins

### **Unit Number: 3**

Unit Thickness: 5.5 feet  
Facies Number: 3

Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: dark grey to black  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: concretion: calcite and pyrite  
Parting Thickness: N/A  
Parting Geometry: discontinuous  
Bedding Planes: irregular  
Sedimentary Structures: bedded concretions, randomly distributed concretions  
Fossil Content: none  
Color When Powdered: light tan  
Luster of Streak: dull  
Other: oval concretions are heavy and contain visible crystals of pyrite and calcite ~ 1-4 inches and are only slightly calcareous, one concretions ~ 1ft with shale draped over the top, base of unit shale breaks blocky and grades into more platy partings at the top of section

### **Unit Number: 4**

Unit Thickness:  
Facies Number: 3  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: black, brown, dark grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: semi-regular  
Sedimentary Structures: small reddish nodule  
Fossil Content: none  
Color When Powdered: medium brown  
Luster of Streak: medium waxy, peels  
Other: very calcareous, partings thinner than Unit 3, shale is crumbly and partings bedding surfaces are more regular than Unit 3

### **Unit Number: 5**

Unit Thickness: 5 feet  
Facies Number: 1  
Rock Type: calcareous shale/mudstone  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: tan to white  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy to flaggy ~ > 5mm  
Parting Geometry: non-parallel, discontinuous  
Bedding Planes: very irregular  
Sedimentary Structures: possible bioturbation,  
Fossil Content: none  
Color When Powdered: light brown to tan  
Luster of Streak: dull- slightly waxy  
Other: breaks in irregulars chunks, little to no obvious partings

### **Unit Number: 6**

Unit Thickness: 1 foot  
Facies Number: 3  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, ~ 2-3mm  
Parting Geometry: irregular  
Bedding Planes: irregular  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: dark brown, peels  
Luster of Streak: waxy  
Other: shale is soft and crumbly, breaks in angular pieces, leaves black smudges on hands

### **Unit Number: 7**

Unit Thickness: .5 feet  
Facies Number: 1  
Rock Type: calcareous shale

Interbeds: none  
Color Fresh: dark grey  
Color Weathered: brown, tan, green  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, 2-4mm  
Parting Geometry: continuous, parallel  
Bedding Planes: irregular surface  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: tan  
Luster of Streak: dull-intermediate  
Other: obvious change in parting size from Unit 6

**Unit Number: 8**

Unit Thickness: .3 feet  
Facies Number: 3  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, ~ 2-3 mm  
Parting Geometry: platy,  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: brown, peels  
Luster of Streak: waxy  
Other: same as Unit 6

**Unit Number: 9**

Unit Thickness: 2.7 feet  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: grey  
Color Weathered: none  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, ~1-2mm  
Parting Geometry: N/A  
Bedding Planes: semi-regular  
Sedimentary Structures: possible insipient nodules

Fossil Content: none  
Color When Powdered: tan  
Luster of Streak: medium waxy  
Other: same as Unit 7, breaks in larger sheets than Unit 6 and 8

**Unit Number: 10**

Unit Thickness: .5 feet  
Facies Number: 3  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: black to brown  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: brown, peels  
Luster of Streak: waxy  
Other: second measured section, continuous with lower section

**Unit Number: 11**

Unit Thickness: 1 foot  
Facies Number: 2 and 1  
Rock Type: argillaceous Limestone  
Interbeds: calcareous shale  
Color Fresh: dark grey  
Color Weathered: tan  
Grain Size: N/A  
Visible Minerals: calcite  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: interbeds: very bumpy  
Sedimentary Structures: interbeds: bioturbation  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: limestone appears to be continuous, very thin layer calcareous shale separate limestone beds, limestone beds ~ .33 and .66 feet

**Unit Number: 12**

Unit Thickness: .5 feet  
Facies Number: 1  
Rock Type: calcareous shale

Interbeds: none  
Color Fresh: grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, ~ 4-5 mm  
Parting Geometry: discontinuous  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: tan  
Luster of Streak: dull to intermediate  
Other: none

**Unit Number: 13**

Unit Thickness: 1 foot  
Facies Number: 2  
Rock Type: argillaceous limestone  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: possible scour  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: base of limestone bed is curved, scoured into underlying shale

**Unit Number: 14**

Unit Thickness: 1.5 feet  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: tan  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, ~ 5mm  
Parting Geometry: discontinuous  
Bedding Planes: irregular  
Sedimentary Structures: red, orange nodules, bioturbation  
Fossil Content: none

Color When Powdered: brown, peels  
Luster of Streak: waxy  
Other: none

**Unit Number: 15**

Unit Thickness: 1 foot  
Facies Number: 2  
Rock Type: limestone  
Interbeds: none  
Color Fresh: grey to dark grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: calcite  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: possible bioturbation, reddish nodules  
Fossil Content: possible oxidized fossils  
Color When Powdered: tan  
Luster of Streak: dull  
Other: round bumps possible calcite replaced fossil debris

**Unit Number: 16**

Unit Thickness: .5 feet  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: grey  
Color Weathered: grey, tan, yellow  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, ~ 2-3 mm  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: medium brown  
Luster of Streak: intermediate  
Other: none

**Unit Number: 17**

Unit Thickness: .5 feet  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: grey to dark grey  
Color Weathered: N/A

Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: fissile to platy, ~1-2mm  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: brown, peels  
Luster of Streak: waxy  
Other: thinner partings than underlying Unit 16

**Unit Number: 18**

Unit Thickness: 1.5 feet  
Facies Number: 2  
Rock Type: limestone  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: tan  
Grain Size: N/A  
Visible Minerals: calcite  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: gastropod mold, calcite replaced fossils  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: limestone body thickness changes laterally, very competent, calcite filled veins

**Unit Number: 19**

Unit Thickness: .5 feet  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, 2-3 mm  
Parting Geometry: N/A  
Bedding Planes: irregular  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: none

**Unit Number: 20**

Unit Thickness: 4 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black to dark grey  
Color Weathered: orange, red, yellow, white  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: fissile to platy, ~.5-1mm  
Parting Geometry: parallel, continuous  
Bedding Planes: regular- semi regular  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: dark brown  
Luster of Streak: very waxy  
Other: some slightly waxy features on bedding planes

**Unit Number: 21**

Unit Thickness: 16 feet  
Facies Number: 4  
Rock Type: non- calcareous shale  
Interbeds: none  
Color Fresh: black to dark grey  
Color Weathered: tan to orange  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy-flaggy, 2-10mm (un-weathered)  
Parting Geometry: N/A  
Bedding Planes: mostly regular  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: dark brown  
Luster of Streak: waxy, peels  
Other: parting not distinctive on lower un-weathered portion of outcrop, shale breaks in very blocky irregular shards, upper 6 feet of unit is more weathered and has slightly more platy partings (2-5 mm), XRD samples taken a 14 feet



## TYRONE PA, OUTCROP

**Location:** Tyrone, PA Auto Salvage

**Latitude/Longitude:** 40° 38' 55.28"/ 78° 16' 11.78"

Notes: Outcrop is measured in two separate sections. Beds are both dipping nearly vertically and upper portion of outcrop cannot be accessed from the ground.

### **Unit Number: 1**

Unit Thickness: 2 feet

Facies Number: 5

Rock Type: non-calcareous shale

Interbeds: none

Color Fresh: dark grey

Color Weathered: orange

Grain Size: N/A

Visible Minerals: none

Parting Thickness: platy, 3-4mm

Parting Geometry: N/A

Bedding Planes: irregular, wavy

Sedimentary Structures: large calcareous concretions

Fossil Content: none

Color When Powdered: medium to dark brown

Luster of Streak: semi-waxy

Other: concretions in section are large, not enough section is exposed see entire concretions, concretions found in float nearby are calcareous, oval shaped and measure up to 5 feet in length.

### **Unit Number: 2**

Unit Thickness: 4 feet

Facies Number: 5

Rock Type: non-calcareous shale

Interbeds: none

Color Fresh: dark grey

Color Weathered: nodules weather orange

Grain Size: N/A

Visible Minerals: none

Parting Thickness: platy, 1-4mm

Parting Geometry: N/A

Bedding Planes: semi-regular

Sedimentary Structures: slightly calcareous pseudo nodules

Fossil Content: none

Color When Powdered: dark brown

Luster of Streak: waxy

Other: un-weathered shale does not break into partings and contains internal laminations

### **Unit Number: 3**

Unit Thickness: 4 feet

Facies Number: 5

Rock Type: non-calcareous shale

Interbeds: none

Color Fresh: very dark grey

Color Weathered: white, orange, nodules have iridescent brown, maroon and white stains

Grain Size: N/A

Visible Minerals: calcite in veins

Parting Thickness: fissile to platy, .5-2mm

Parting Geometry: discontinuous

Bedding Planes: irregular, wavy, nodules

Sedimentary Structures: incipient nodules, oval shaped lumps on surface

Fossil Content: none

Color When Powdered: dark brown

Luster of Streak: waxy

Other: shale breaks into small chips, oxidizing halos around incipient nodules, small calcite filled veins present

### **Unit Number: 4**

Unit Thickness: 1 foot

Facies Number: 4

Rock Type: non-calcareous shale

Interbeds: none

Color Fresh: black

Color Weathered: N/A

Grain Size: N/A

Visible Minerals: pyrite

Parting Thickness: fissile to platy, .5-2mm

Parting Geometry: continuous

Bedding Planes: regular

Sedimentary Structures: insipient nodules

Fossil Content: none

Color When Powdered: N/A

Luster of Streak: N/A

Other: shale is brittle

### **Unit Number: 5**

Unit Thickness: 2 feet

Facies Number: 3

Rock Type: calcareous shale

Interbeds: none

Color Fresh: dark grey to black

Color Weathered: white, orange

Grain Size: N/A

Visible Minerals: pyrite

Parting Thickness: no apparent parting

Parting Geometry: N/A

Bedding Planes: N/A

Sedimentary Structures: pyrite nodules or replaced shell debris, internal laminations

Fossil Content: small brachiopods

Color When Powdered: dark brown

Luster of Streak: waxy

Other: some shale is only slightly calcareous

### **Unit Number: 6**

Unit Thickness: 4 feet

Facies Number: 4

Rock Type: non-calcareous shale

Interbeds: none

Color Fresh: black

Color Weathered: white, orange

Grain Size: N/A

Visible Minerals: pyrite

Parting Thickness: platy, 2-4mm

Parting Geometry: N/A

Bedding Planes: mostly regular

Sedimentary Structures: pyrite nodules or replaced shell debris  
Fossil Content: calcareous bumps  
Color When Powdered: medium to dark brown  
Luster of Streak: semi-waxy  
Other: pyrite is seen in nodule like forms on bedding partings, some large pyrite cubes  
**Unit Number: 7**  
Unit Thickness: 1.5 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: white, yellow bubbly precipitate on surface  
Grain Size: N/A  
Visible Minerals: calcite in healed veins  
Parting Thickness: papery, mostly destroyed  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: dark brown  
Luster of Streak: waxy  
Other: fault gauge present, beds are very deformed, shale is sooty and coaly, uranium ~ 25ppm  
  
**Unit Number: 8**  
Unit Thickness: 2 feet  
Facies Number: 3  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: yellow  
Grain Size: N/A  
Visible Minerals: pyrite  
Parting Thickness: no distinctive partings  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: pyrite nodules or replaced fossil debris  
Fossil Content: replaced fossil debris  
Color When Powdered: medium brown

Luster of Streak: semi-waxy  
Other: some shale is only slightly calcareous

**Unit Number: 9**  
Unit Thickness: 1 foot  
Facies Number: 4  
Rock Type: non-calcareous  
Interbeds: none  
Color Fresh: black  
Color Weathered:  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: papery to fissile ~ .5-1mm  
Parting Geometry: N/A  
Bedding Planes: regular, flat  
Sedimentary Structures: none  
Fossil Content: two large ammonoids  
Color When Powdered: medium brown  
Luster of Streak: semi-waxy  
Other: very deformed, very similar to unit 7

**Unit Number: 10**  
Unit Thickness: 2.5 feet  
Facies Number: 5  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: brown, maroon, and iridescent staining  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, 1-3mm  
Parting Geometry: wavy  
Bedding Planes: irregular, ridges  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: brown  
Luster of Streak: waxy  
Other: none

## WHIP GAP WV, OUTCROP

**Location:** 5.1 miles Southwest of Antioch, WV on Co. Rt. 7 (Whip Gap, Knobly Road)

**Latitude/Longitude:**  
39.269075/-79.066308

### **Unit Number: 1**

Unit Thickness: 3 feet  
Facies Number: Needmore Shale  
Rock Type: non calcareous mudstone  
Interbeds: none  
Color Fresh: brown, tan,  
Color Weathered: green, tan clay  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: some platy, 2-4mm  
Parting Geometry: non parallel, discontinuous  
Bedding Planes: irregular  
Sedimentary Structures: bioturbation  
Fossil Content: brachiopods, trilobites  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: none

### **Unit Number: 2**

Unit Thickness: 6 feet  
Facies Number: N/A  
Rock Type: covered section  
Interbeds: N/A  
Color Fresh: N/A  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: N/A  
Fossil Content: N/A  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: covered section consists of Needmore/Marcellus contact and possible bentonites beds.

### **Unit Number: 3**

Unit Thickness: 2 feet

Facies Number: 4 and 6  
Rock Type: non- calcareous black shale  
Interbeds: bentonite  
Color Fresh: black, interbeds: tan  
Color Weathered: N/A,  
interbeds: tan to brown clay  
Grain Size: interbeds: sand sized grains  
Visible Minerals: interbeds: mica  
Parting Thickness: papery ~ < .5mm  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: N/A  
Fossil Content: none  
Color When Powdered: black  
Luster of Streak: waxy to semi-waxy  
Other: interbeds: 3 bentonite beds ranging up to ~ .5 feet, some black shale is coaly and crumbles instead of parting, black shale is sooty and smudges fingers

### **Unit Number: 4**

Unit Thickness: 8 feet  
Facies Number: 4  
Rock Type: non -calcareous shale  
Interbeds: none  
Color Fresh: black/brown  
Color Weathered: N/A  
Grain Size: some tan silt sized grains  
Visible Minerals: tan grains  
Parting Thickness: fissile to platy ~ 4mm and less  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: internal discontinuous laminations  
Fossil Content: styliolinid, bryozoans (coquina?)  
Color When Powdered: dark brown  
Luster of Streak: waxy  
Other: thinly bedded shale with internal platy partings ~3-4mm, unit contains an anomalous

brown bed of very low density homogenous material, shale breaks blocky, locally deformed 2 feet repeat

### **Unit Number: 5**

Unit Thickness: 6 feet  
Facies Number: 4  
Rock Type: non -calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: tan, white  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy ~ 2mm  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: brown-black  
Luster of Streak: N/A  
Other: deformed fault zone 22-26 feet , some beds ~ 2-3cm are more massive, coaly and scratch black, some beds ~ 2cm have internal partings ~ 2-3mm and have lighter powder

### **Unit Number: 6**

Unit Thickness: 4 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: tan, white, green  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, 2-4mm  
Parting Geometry: not parallel  
Bedding Planes: relatively smooth  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: brown  
Luster of Streak: waxy  
Other: Fault between 25-26 feet, possible at of section, thicker bedsets ~ 8-10 cm with internal partings ~2 -4mm

**Unit Number: 7**

Unit Thickness: 10 feet  
 Facies Number: 4  
 Rock Type: non-calcareous shale  
 Interbeds: none  
 Color Fresh: black  
 Color Weathered: red, orange, white  
 Grain Size: N/A  
 Visible Minerals: none  
 Parting Thickness: platy, 2-3mm  
 Parting Geometry: discontinuous  
 Bedding Planes: relatively smooth  
 Sedimentary Structures: none  
 Fossil Content: none  
 Color When Powdered: dark brown to black  
 Luster of Streak: waxy  
 Other: fault between 32-33 feet, shale breaks jagged and sharp, 38-42 feet deformed by drag fold fault possibly repeated section

**Unit Number: 8**

Unit Thickness: 5 feet  
 Facies Number: 4  
 Rock Type: non-calcareous shale  
 Interbeds: none  
 Color Fresh: black  
 Color Weathered: grey, white, yellow  
 Grain Size: N/A  
 Visible Minerals: none  
 Parting Thickness: platy, ~ 2mm  
 Parting Geometry: deformed  
 Bedding Planes: deformed  
 Sedimentary Structures: none  
 Fossil Content: none  
 Color When Powdered: medium brown  
 Luster of Streak: semi-waxy  
 Other: fault between 42-43 feet, fault gauge deformed bedding partings, some shale shows bedding 3cm with ~ 2mm internal partings

**Unit Number: 9**

Unit Thickness: 10 feet  
 Facies Number: 4  
 Rock Type: non-calcareous shale  
 Interbeds: none  
 Color Fresh: black  
 Color Weathered: white, yellow  
 Grain Size: N/A  
 Visible Minerals: none  
 Parting Thickness: platy, 1 – 3mm  
 Parting Geometry: continuous  
 Bedding Planes: irregular, curved  
 Sedimentary Structures: nodules  
 Fossil Content: none  
 Color When Powdered: dark brown  
 Luster of Streak: semi-waxy  
 Other: shale breaks into irregular discontinuous pieces, oval nodules create discontinuity.

**Unit Number: 10**

Unit Thickness: 11 feet  
 Facies Number: 4  
 Rock Type: non-calcareous shale  
 Interbeds: none  
 Color Fresh: black  
 Color Weathered: N.A  
 Grain Size: N/A  
 Visible Minerals: none  
 Parting Thickness: fissile to platy, .5-2mm  
 Parting Geometry: discontinuous, non-parallel  
 Bedding Planes: irregular, curved, but smooth  
 Sedimentary Structures: possible horizontal bioturbation, soft red nodule- like feature possibly siderite  
 Fossil Content: none  
 Color When Powdered: brown to black  
 Luster of Streak: waxy, come off in peels  
 Other: brown and black marks may indicate horizontal bioturbation on bedding planes

## BEDFORD PA, OUTCROP

**Location: 10.9 miles  
Northwest of Bedford, PA on  
PA-56/US 220 (PJ's  
Contracting Services)  
Latitude/Longitude:  
40.138302/-78.583749**

### **Unit Number: 1**

Unit Thickness: .75 feet  
Facies Number: 2  
Rock Type: Limestone  
Interbeds: None  
Color Fresh: dark grey  
Color Weathered: light grey  
Grain Size: N/A  
Visible Minerals: mica,  
crystalline calcite  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: None  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: Mica (Biotite present in  
vertical vein)

### **Unit Number: 2**

Unit Thickness: 2.67 feet  
Facies Number: 3  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: black to dark grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: platy ~1mm,  
locally papery partings ~.5 mm  
Parting Geometry: non parallel,  
wavy, discontinuous  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: rare brown shell  
fragments  
Color When Powdered: white  
Luster of Streak: dull  
Other: none

### **Unit Number: 3**

Unit Thickness: .083 feet  
Facies Number: 6  
Rock Type: micaceous  
claystone, bentonite

Interbeds: none  
Color Fresh: very light grey to  
brown  
Color Weathered: tan  
Grain Size: fine sand  
Visible Minerals: micas  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: off -  
white  
Luster of Streak: shiny, waxy  
Other: Unit weathers to tan clay

### **Unit Number: 4**

Unit Thickness: 1 foot  
Facies Number: 2  
Rock Type: limestone  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: light grey  
Grain Size: N/A  
Visible Minerals: crystalline  
calcite  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: scour  
base  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: scours into underlying  
Unit 2: papery shale ~.5mm  
partings

### **Unit Number: 5**

Unit Thickness: 1.08 feet  
Facies Number: 6  
Rock Type: bentonite  
Interbeds: None  
Color Fresh: brown  
Color Weathered: off –white to  
tan  
Grain Size: very fine to coarse  
sand sized mica grains  
Visible Minerals: mica, pyrite  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none

Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: sharp contact with  
underlying unit

### **Unit Number: 6**

Unit Thickness: .75 feet  
Facies Number: 3  
Rock Type: calcareous shale  
Interbeds: None  
Color Fresh: dark grey to black  
Color Weathered: red, orange  
Grain Size: occasional silt sized  
grains  
Visible Minerals: N/A  
Parting Thickness: Platy ~1-  
5mm  
Parting Geometry:  
discontinuous  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: dark  
Luster of Streak: semi- waxy  
Other: beds ~1inch of internal  
platy partings

### **Unit Number: 7**

Unit Thickness: 2.25 feet  
Facies Number: 2, 3 and 4  
Rock Type: Limestone  
Interbeds: dark grey to black  
calcareous to non-calcareous  
shale  
Color Fresh: N/A  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: Calcite  
Parting Thickness: interbeds:  
papery to fissile (.5mm-1mm)  
Parting Geometry: interbeds:  
parallel  
Bedding Planes: interbeds:  
regular  
Sedimentary Structures:  
lenticular limestone bodies.  
Fossil Content: some  
fragmented shell debris  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: beds of limestone range  
from 1-5 inches in width and ~ 3

feet in length. Shale at top of unit is in 1 inch books and grades from calcareous to non-calcareous shale.

**Unit Number: 8**

Unit Thickness: 2 feet  
Facies Number: 4 and 5  
Rock Type: non-calcareous shale  
Interbeds: non-calcareous shale (silty)  
Color Fresh: black, interbeds: dark grey  
Color Weathered: yellow, orange  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: papery to fissile (.5-1mm)  
Parting Geometry: parallel  
Bedding Planes: regular, flat  
Sedimentary Structures: concretion ~ 1ft in length  
Fossil Content: none  
Color when powdered: interbeds: light  
Luster of Streak: interbeds: dull  
Other: black non-calcareous shale comes in ~1 inch books.

**Unit Number: 9**

Unit Thickness: .59 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: yellow, orange  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: papery (.5mm or less)  
Parting Geometry: parallel, discontinuous  
Bedding Planes: regular  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: none

**Unit Number: 10**

Unit Thickness: 3- 5 feet estimated  
Facies Number: N/A  
Rock Type: covered section  
Interbeds: N/A  
Color Fresh: N/A  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: N/A  
Fossil Content: N/A  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: N/A

**Unit Number: 11**

Unit Thickness: 1.33 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: white  
Grain Size: N/A  
Visible Minerals: pyrite  
Parting Thickness: N/A  
Parting Geometry: blocky  
Bedding Planes: regular  
Sedimentary Structures: horizontal laminations, pyrite laminations  
Fossil Content: none  
Color When Powdered: dark brown  
Luster of Streak: waxy  
Other: white weathering on bedding planes; no horizontal bedding partings observed, breaks in blocky shapes.

**Unit Number: 12**

Unit Thickness: .67 feet  
Facies Number: 6  
Rock Type: bentonite  
Interbeds: none  
Color Fresh: tan to grey  
Color Weathered: tan clay  
Grain Size: clay- very fine sand (whole range)  
Visible Minerals: mica, pyrite  
Parting Thickness: N/A

Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: graded  
Fossil Content: None  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: graded from brown claystone to micaceous sandstone. (zircon age data on this unit.)

**Unit Number: 13**

Unit Thickness: 1.33 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: pyrite  
Parting Thickness: platy, ~ 1mm  
Parting Geometry: N/A  
Bedding Planes: semi- irregular  
Sedimentary Structures: pyrite nodules, fine laminations.  
Fossil Content: none  
Color When Powdered: brown  
luster of Streak: waxy  
Other: pyrite nodules ~5mm, black shale comes in 1-4 inch competent packages.

**Unit Number: 14**

Unit Thickness: 9.84 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: yellow, orange, white  
Grain Size: N/A  
Visible Minerals: pyrite  
Parting Thickness: platy, ~ 1mm  
Parting Geometry: parallel, discontinuous  
Bedding Planes: regular  
Sedimentary Structures: carbonate concretions (6 inches- 1 foot), internal laminations  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A

Other: 1 inch books with  
internal laminations, breaks in  
angular fragments.

## HISER WV, OUTCROP

**Location: 3.3 miles Southeast of Petersburg, WV on Co. Rt. 9**

**Latitude/Longitude: 38.957940/-79.112806**

### **Unit Number: 1**

Unit Thickness: 66 cm  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: grey  
Color Weathered: N/A  
Grain Size: silt sized grains  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: irregular, bumpy  
Sedimentary Structures: bioturbated  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: none

### **Unit Number: 2**

Unit Thickness: 15 cm  
Facies Number: 2  
Rock Type: limestone, marl  
Interbeds: none  
Color Fresh: N/A  
Color Weathered: brown  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: irregular bumpy  
Sedimentary Structures: none  
Fossil Content: one shell found  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: brown, shaley, slightly fossiliferous limestone

### **Unit Number: 3**

Unit Thickness: 50 cm  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: grey  
Color Weathered: N/A

Grain Size: silty  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: N/A

### **Unit Number: 4**

Unit Thickness: 26 cm  
Facies Number: 2  
Rock Type: limestone  
Interbeds: none  
Color Fresh: very dark grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: limestone is micritic

### **Unit Number: 5**

Unit Thickness: 126 cm  
Facies Number: 1  
Rock Type: calcareous shale, marl  
Interbeds: none  
Color Fresh: grey  
Color Weathered: N/A  
Grain Size: silty  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: irregular, bumpy  
Sedimentary Structures: vertical burrows  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: none

### **Unit Number: 6**

Unit Thickness: 12 cm

Facies Number: 2  
Rock Type: limestone  
Interbeds: none

Color Fresh: N/A  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: none

### **Unit Number: 7**

Unit Thickness: 22 cm  
Facies Number: 1  
Rock Type: calcareous shale, marl  
Interbeds: none  
Color Fresh: grey  
Color Weathered: brown  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: none

### **Unit Number: 8**

Unit Thickness: 27-40 cm  
Facies Number: 2  
Rock Type: limestone  
Interbeds: none  
Color Fresh: N/A  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: tracks and trails  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A



Other: limestone body thins

**Unit Number: 9**

Unit Thickness: N/A

Facies Number: 4

Rock Type: non-calcareous  
shale

Interbeds: none

Color Fresh: black

Color Weathered: orange

Grain Size: N/A

Visible Minerals: none

Parting Thickness: fissile

Parting Geometry: N/A

Bedding Planes: N/A

Sedimentary Structures:  
laminated

Fossil Content: none

Color When Powdered: N/A

Luster of Streak: N/A

Other: orange oxidizing halos

## SOUTH BRANCH OF THE POTAMAC WV, OUTCROP

**Location:** 1.9 miles South of  
Fort Seybert, WV on Co.  
Rt.34 (South Branch)  
**Latitude/Longitude:**38.674019/  
-79.203486

**Unit Number: 1**  
Unit Thickness: 7 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: very black  
Color Weathered: orange, white, and maroon to brown staining  
Grain Size: N/A  
Visible Minerals: quartz  
Parting Thickness: no distinctive partings  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: dark brown  
Luster of Streak: waxy  
Other: shale breaks into irregular pieces 1-3cm, beds are deformed ~45 degrees, vertical fractures cut section, quartz filled veins

**Unit Number: 2**  
Unit Thickness: 4 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: orange, maroon to brown  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, 1-3mm  
Parting Geometry: N/A  
Bedding Planes: slightly irregular, smooth ridges on bedding surfaces  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: dark

brown  
Luster of Streak: semi waxy  
Other: none  
**Unit Number: 3**  
Unit Thickness: 4.5 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black to dark grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: fissile to platy, ~ < 1mm  
Parting Geometry: parallel, continuous  
Bedding Planes: regular, nearly smooth  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: medium brown  
Luster of Streak: semi-waxy  
Other: shale breaks into fissile sheets, shale partings are in competent books, small fault after this unit

**Unit Number: 4**  
Unit Thickness: 2.5 feet  
Facies Number: 5  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: medium grey  
Color Weathered: orange, red  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, 1-5mm  
Parting Geometry: N/A  
Bedding Planes: mostly regular, some wavy ridges on surface  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: light brown  
Luster of Streak: dull  
Other: small fault directly before this unit

**Unit Number: 5**  
Unit Thickness: 5 feet  
Facies Number: 4  
Rock Type: non-calcareous  
Interbeds: none  
Color Fresh: black to dark grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, 2-3mm  
Parting Geometry: discontinuous  
Bedding Planes: slightly bumpy and irregular, ridges  
Sedimentary Structures: small nodules on bedding planes  
Fossil Content: none  
Color When Powdered: medium brown  
Luster of Streak: semi-waxy  
Other: nodules are raised bumps on bedding planes (incipient)

**Unit Number: 6**  
Unit Thickness: 3 feet  
Facies Number: 5  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: medium grey  
Color Weathered: grey  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy to flaggy, 2-10mm  
Parting Geometry: discontinuous  
Bedding Planes: irregular  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: tan to light brown  
Luster of Streak: intermediate  
Other: partings less distinctive than underlying unit

**Unit Number: 7**  
Unit Thickness: 2 feet  
Facies Number: 4  
Rock Type: non-calcareous shale

Interbeds: none  
Color Fresh: dark grey to black  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, 1-2mm  
Parting Geometry: discontinuous  
Bedding Planes: regular, some ridges  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: medium brown  
Luster of Streak: semi-waxy  
Other: shale is brittle

**Unit Number: 8**

Unit Thickness: 2 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: dark grey to black  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: fissile to platy, .5-1mm  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: concretion, ~ 4 inches  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: first .3 feet of unit is crumbly fault gauge, bedding is destroyed and a white to tan weathering on surface, shale is soft and flaky

**Unit Number: 9**

Unit Thickness: 8 feet  
Facies Number: 4 and 5  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: grey to black  
Color Weathered: light grey, white, orange, and maroon  
Grain Size: N/A  
Visible Minerals: concretion: calcite and pyrite

Parting Thickness: fissile to platy, .5-2mm  
Parting Geometry: discontinuous  
Bedding Planes: mostly regular, some ridges  
Sedimentary Structures: large concretion ~ 2 feet  
Fossil Content: none  
Color When Powdered: medium brown  
Luster of Streak: semi-waxy  
Other: concretions are oval shaped and formed along bedding planes, Concretions contain calcite and pyrite

## OAK FLAT WV, OUTCROP

**Location:** 1.4 miles West of  
**Oak Flat, WV on U.S. 33**  
**Latitude/Longitude:**38.658471/  
-79.234750

### **Unit Number: 1**

Unit Thickness: 2 feet  
Facies Number: 2  
Rock Type: argillaceous  
limestone  
Interbeds: none  
Color Fresh: dark to medium  
grey  
Color Weathered: off white  
Grain Size: silt, clay sized grains  
Visible Minerals: calcite  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: black fossil  
fragments, the underlying  
calcareous shale contains  
chondrites and trilobite  
fragments  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: calcite filled veins, some  
more clay rich partings in  
limestone

### **Unit Number: 2**

Unit Thickness: .5 feet  
Facies Number: 2  
Rock Type: argillaceous  
limestone  
Interbeds: none  
Color Fresh: medium to dark  
grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, ~  
5mm  
Parting Geometry:  
discontinuous, wavy  
Bedding Planes: irregular,  
bumpy  
Sedimentary Structures: none  
Fossil Content: oxidized and  
replaced fossil debris  
Color When Powdered: light  
brown to grey

Luster of Streak: dull  
Other: none  
**Unit Number: 3**  
Unit Thickness: .5 feet  
Facies Number: 3  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: dark grey to black  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy to  
flaggy, 5-10mm  
Parting Geometry:  
discontinuous  
Bedding Planes: irregular  
Sedimentary Structures:  
burrows  
Fossil Content: small black  
fossils, possible linguloid  
Color When Powdered: medium  
brown  
Luster of Streak: semi-waxy  
Other: none

### **Unit Number: 4**

Unit Thickness: 1 foot  
Facies Number: 1 and 2  
Rock Type: calcareous shale  
Interbeds: argillaceous  
limestone  
Color Fresh: grey, interbeds:  
dark grey  
Color Weathered: interbeds: red  
stains  
Grain Size: limestone: silt sized  
grains  
Visible Minerals: interbeds:  
calcite  
Parting Thickness: partings not  
distinctive  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures:  
interbed: burrows  
Fossil Content: none  
Color When Powdered: medium  
brown, interbeds: light  
Luster of Streak: semi waxy,  
interbeds: dull  
Other: upper .2 feet of unit is  
very dark grey bioturbated  
limestone bed

### **Unit Number: 5**

Unit Thickness: .4 feet  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, ~ 1-  
3mm  
Parting Geometry: N/A  
Bedding Planes: irregular,  
bumpy  
Sedimentary Structures: none  
Fossil Content: rare shell  
debris, brachiopods  
Color When Powdered: light  
brown  
Luster of Streak: semi-waxy  
Other: none

### **Unit Number: 6**

Unit Thickness: .6 feet  
Facies Number: 3  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: black to dark grey  
Color Weathered: white, orange  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, ~2-  
3mm  
Parting Geometry: N/A  
Bedding Planes: moderately  
irregular  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: slightly to moderately  
calcareous on fresh surface

### **Unit Number: 7**

Unit Thickness: 1 foot  
Facies Number: 3  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: black to dark grey  
Color Weathered: yellow,  
white, orange  
Grain Size: N/A  
Visible Minerals: none

Parting Thickness: papery to fissile, ~ .1mm or less  
Parting Geometry: parallel  
Bedding Planes: regular, flat  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: fresh surface is very calcareous, shale in books ~1 – 6 inches, some grey shale with platy parting ~ 3-5mm.

**Unit Number: 8**

Unit Thickness: 2 feet  
Facies Number: 3  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: grey to blue, white  
Grain Size: none  
Visible Minerals: none  
Parting Thickness: platy to flaggy, ~2-10mm  
Parting Geometry: wavy, discontinuous  
Bedding Planes: irregular, bumpy  
Sedimentary Structures: oxidized burrows, nodules  
Fossil Content: none  
Color When Powdered: brown, peels  
Luster of Streak: semi-waxy  
Other: burrows have red orange weathering, nodules are flat, oval shaped and have high specific gravity, last foot of unit has no distinctive parting thickness and may be bioturbated: has a dull streak and white powder.

**Unit Number: 9**

Unit Thickness: 2 feet  
Facies Number: 3  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: N/A  
Grain Size: sand sized  
Visible Minerals: calcite  
Parting Thickness: flaggy, ~ 10mm, or no distinctive partings

Parting Geometry: N/A  
Bedding Planes: irregular  
Sedimentary Structures: oxidized horizontal and vertical burrows, nodules  
Fossil Content: some black shell debris  
Color When Powdered: light  
Luster of Streak: dull  
Other: nodules are flat, oval shaped and have high specific gravity, upper foot of unit is very weathered and crumbly, breaks into nodule like pieces

**Unit Number: 10**

Unit Thickness: 1.5 feet  
Facies Number: 3  
Rock Type: calcareous shale  
Interbeds: N/A  
Color Fresh: black  
Color Weathered: white and orange crust on surface  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, 1-2mm  
Parting Geometry: deformed  
Bedding Planes: deformed  
Sedimentary Structures: small siderite concretions  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: beds deformed, very black and coally

**Unit Number: 11**

Unit Thickness: 1.1 feet  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: medium to dark grey  
Color Weathered: light grey  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, 2-5mm  
Parting Geometry: non-parallel  
Bedding Planes: irregular, bumpy  
Sedimentary Structures: oxidized burrows  
Fossil Content: none

Color When Powdered: medium blue to grey  
Luster of Streak: semi-waxy  
Other: partings become thinner towards top of unit ~ 2mm

**Unit Number: 12**

Unit Thickness: .4 feet  
Facies Number: 2  
Rock Type: limestone  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: N/A  
Grain Size: sand sized  
Visible Minerals: calcite  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: N/A  
Fossil Content: fossil debris  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: limestone bed pinches out

**Unit Number: 13**

Unit Thickness: .5 feet  
Facies Number: 3  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: black to dark grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy to flaggy, 3-10mm  
Parting Geometry: discontinuous  
Bedding Planes: irregular  
Sedimentary Structures: N/A  
Fossil Content: possible fossil debris  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: N/A

**Unit Number: 14**

Unit Thickness: 2.5 feet  
Facies Number: 3  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none

Parting Thickness: platy, 1-5mm  
Parting Geometry: not parallel  
Bedding Planes: irregular, bumpy  
Sedimentary Structures: none  
Fossil Content: possible fossil debris  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: some more competent, very thin, micritic limestone beds in this section

folded, parting and bedding characteristics have been mostly destroyed, stratigraphic order and thickness is unknown due to high degree of deformation

**Unit Number: 15**

Unit Thickness: 4 feet  
Facies Number: N/A  
Rock Type: Covered section  
Interbeds: N/A  
Color Fresh: N/A  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: N/A  
Fossil Content: N/A  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: estimated 4 feet, lies between previous unit and deformed black shale

**Unit Number: 16**

Unit Thickness: estimated ~18 feet of shale  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: yellow, white, orange  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, 2-3m  
Parting Geometry: continuous  
Bedding Planes: flat, regular  
Sedimentary Structures:  
Fossil Content: none  
Color When Powdered: dark  
Luster of Streak: semi-waxy  
Other: repeated section, shale is highly deformed and kink

## BERKELEY SPRINGS WV, OUTCROP

**Location:** U.S. Silica Quarry  
3.3 miles North of Berkeley Springs, WV on U.S. Rt. 522  
**Latitude/Longitude:** 39.669142/-78.200169

Notes: Both Oriskany/Needmore and Needmore/ Marcellus contacts are exposed. Beds of the Marcellus change dip rapidly throughout section ~ 45- 90 degrees. Very hot (high uranium) black shale from base of Marcellus seem to be missing. Large fault is found at base of section near the Needmore/Marcellus contact. Upper section of Marcellus/ Mahantango is extremely folded and faulted. Large recumbent fold and high displacement thrust faults have made it difficult to determine true stratigraphic order of beds measured. Lower portion of sections seems to be in correct stratigraphic order.

### **Unit Number: 1**

Unit Thickness: ~ 40 feet  
Facies Number: N/A  
Rock Type: Needmore shale, non-calcareous  
Interbeds: calcareous shale, argillaceous limestone  
Color Fresh: medium grey to blue  
Color Weathered: light grey, buff, tan, white  
Grain Size: N/A  
Visible Minerals: calcite  
Parting Thickness: not distinctive  
Parting Geometry: discontinuous  
Bedding Planes: irregular, wavy  
Sedimentary Structures: burrows  
Fossil Content: brachiopods, trilobites, cephalopods  
Color When Powdered: light tan to white  
Luster of Streak: dull

Other: burrows filled with darker mud from below, fault plane observed between Needmore shale and Marcellus shale, contact looks abrupt

### **Unit Number: 2**

Unit Thickness: 1 foot  
Facies Number: 4  
Rock Type: non-calcareous  
Interbeds: none  
Color Fresh: dark grey to black  
Color Weathered: grey, orange, and red  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: papery, ~ .5 mm  
Parting Geometry: discontinuous, soft and flaky  
Bedding Planes: mostly flat and regular  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: light to medium grey  
Luster of Streak: semi -waxy  
Other: this unit is the along the Needmore/Marcellus contact, movement along contact, shale is flaky and soft

### **Unit Number: 3**

Unit Thickness: 9 feet  
Facies Number: 5  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: medium to dark grey  
Color Weathered: tan, orange  
Grain Size: N/A  
Visible Minerals: calcite in fault gauge, small unknown crystals on bedding planes  
Parting Thickness: papery to fissile, .5-1mm  
Parting Geometry: N/A  
Bedding Planes: regular to slightly irregular  
Sedimentary Structures: nodule  
Fossil Content: none  
Color When Powdered: N/A

Luster of Streak: N/A

Other: 4- 5 feet of fault gauge, fault gauge has calcite filled veins, beds deformed and locally change dip

### **Unit Number: 4**

Unit Thickness: 6 feet  
Facies Number: 5  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: grey, nodules weather tan  
Grain Size: N/A  
Visible Minerals: nodule: calcite and pyrite  
Parting Thickness: papery to fissile, ~ .5-1mm  
Parting Geometry: discontinuous  
Bedding Planes: irregular  
Sedimentary Structures: concretions and nodules  
Fossil Content: small shell fragments in concretions  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: small calcareous nodule is very black and contains euhedral pyrite cubes, large dark grey concretions are very calcareous, oval shaped, contain small white shell fragments and are ~ 1-2 feet in length, flaky grey shale directly above large concretions.

### **Unit Number: 5**

Unit Thickness: 10 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: dark grey to black  
Color Weathered: orange, red, white, yellow  
Grain Size: N/A  
Visible Minerals: unknown mineral on parting surfaces  
Parting Thickness: platy, 1-2mm

Parting Geometry: N/A  
Bedding Planes: regular, flat  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: light to medium brown  
Luster of Streak: dull  
Other: precipitate crystals on bedding planes, crystals have pearly luster and basal cleavage, thin veins of white and yellow weathering on partings surfaces

**Unit Number: 6**

Unit Thickness: 15 feet  
Facies Number: 3 and 4  
Rock Type: non-calcareous to slightly calcareous  
Interbeds: none  
Color Fresh: dark grey to black  
Color Weathered: grey  
Grain Size: N/A  
Visible Minerals: calcite  
Parting Thickness: papery to fissile, ~ .5mm  
Parting Geometry: discontinuous  
Bedding Planes: relatively regular  
Sedimentary Structures: large calcareous concretions  
Fossil Content: none  
Color When Powdered: light to medium brown  
Luster of Streak: dull  
Other: Two distinctive beds of large oval shaped nodules ~ 1-5 feet in length, shale is more calcareous near concretions, and concretions contain numerous large and small calcite filled veins

**Unit Number: 7**

Unit Thickness: 21 feet  
Facies Number: 4  
Rock Type: non-calcareous  
Interbeds: none  
Color Fresh: dark grey to black  
Color Weathered: orange, maroon, tan  
Grain Size: N/A  
Visible Minerals: quartz in healed fractures and veins

Parting Thickness: 1) platy, ~ 2mm or 2) papery to fissile, .5-1mm  
Parting Geometry: 1) continuous or 2) discontinuous  
Bedding Planes: 1) regular or 2) irregular  
Sedimentary Structures: dark grey, round, calcareous concretions  
Fossil Content: none  
Color When Powdered: light to medium brown  
Luster of Streak: dull  
Other: the shale throughout this unit alternates between two parting styles ( 1 and 2), unit contains faults and folds and large cross cutting quartz veins, concretions found in lower 2 feet of unit

**Unit Number: 8**

Unit Thickness: 14 feet  
Facies Number: 5  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: N/A  
Grain Size: silt sized grains  
Visible Minerals: quartz in healed veins  
Parting Thickness: platy, 2-5mm  
Parting Geometry: discontinuous  
Bedding Planes: N/A  
Sedimentary Structures: bedded nodules (siderite?)  
Fossil Content: none  
Color When Powdered: light  
Luster of Streak: dull  
Other: nodules are non-calcareous to slightly calcareous on fresh surface, dark grey and flattened, some layers of concretions form thin beds, unit contains fault gauge and quartz filled veins

**Unit Number: 9**

Unit Thickness: 27 feet  
Facies Number: 5  
Rock Type: non-calcareous shale (silty)

Interbeds: none  
Color Fresh: dark grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: quartz in healed fractures  
Parting Thickness: platy, 1-2mm  
Parting Geometry: N/A  
Bedding Planes: regular to slightly irregular  
Sedimentary Structures: bedded calcareous nodules (siderite?)  
Fossil Content: none  
Color When Powdered: light, tan  
Luster of Streak: dull  
Other: first two feet of unit are fault gauge, fault gauge has quartz filled veins and orange weathering, nodules form beds that can be traced through the outcrop, grey non-calcareous shale is interbedded with calcareous nodule beds ~ 5mm to 2 inch thick

**Unit Number: 10**

Unit Thickness: 4 feet  
Facies Number: 5 and 1  
Rock Type: non-calcareous shale (silty)  
Interbeds: calcareous mudstone or bedded calcareous nodules  
Color Fresh: medium to dark grey, interbeds: light grey  
Color Weathered: interbeds: tan  
Grain Size: silty sized grains  
Visible Minerals: N/A  
Parting Thickness: platy to flaggy, ~ 1-10mm or no distinctive partings  
Parting Geometry: discontinuous  
Bedding Planes: slightly irregular  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: light brown  
Luster of Streak: dull  
Other: interbeds only fizz when fresh surface is tested could be bedded nodules



**Unit Number: 11**

Unit Thickness: 10 feet  
 Facies Number: 5  
 Rock Type: non-calcareous shale  
 Interbeds: none  
 Color Fresh: dark grey  
 Color Weathered: white residue, tan, orange  
 Grain Size: N/A  
 Visible Minerals: none  
 Parting Thickness: platy, 2-5mm  
 Parting Geometry: discontinuous  
 Bedding Planes: slightly irregular  
 Sedimentary Structures: black, bedded, calcareous nodules  
 Fossil Content: none  
 Color When Powdered: tan  
 Luster of Streak: dull  
 Other: same as unit 9, bedded coalesced nodules are slightly to very calcareous and can be traced a crossed outcrop

**Unit Number: 12**

Unit Thickness: 16 feet  
 Facies Number: 5  
 Rock Type: non-calcareous shale  
 Interbed: non-calcareous shale (2 feet)  
 Color Fresh: dark grey  
 Color Weathered: orange, tan  
 Grain Size: N/A  
 Visible Minerals: none  
 Parting Thickness: platy, interbed: fissile to platy ~ 1mm  
 Parting Geometry: discontinuous, wavy, interbed: continuous  
 Bedding Planes: semi-irregular, interbed: regular  
 Sedimentary Structures: none  
 Fossil Content: none  
 Color When Powdered: blue to tan, interbed: medium brown  
 Luster of Streak: intermediate, interbed: dull  
 Other: interbed is dark grey, has thinner partings and is brittle

**Unit Number: 12**

Unit Thickness: 30 feet  
 Facies Number: 5  
 Rock Type: non-calcareous shale  
 Interbeds: none  
 Color Fresh: medium to dark grey  
 Color Weathered: grey to tan, nodules weather orange and black  
 Grain Size: N/A  
 Visible Minerals: none  
 Parting Thickness: platy, 1-3mm  
 Parting Geometry: continuous  
 Bedding Planes: mostly regular, some ridges on surface  
 Sedimentary Structures: bedded calcareous nodules, 1-6 inches  
 Fossil Content: none  
 Color When Powdered: light tan  
 Luster of Streak: dull  
 Other: calcite filled veins, calcareous nodules are darker than surrounding shale, shale layers are draped over nodules, and last ten feet of unit contain bedsets of partings and fewer bedded nodules

**Unit Number: 14**

Unit Thickness: 22 feet  
 Facies Number: 5  
 Rock Type: non-calcareous shale (silty)  
 Interbeds: none  
 Color Fresh: medium to dark grey  
 Color Weathered: N/A  
 Grain Size: silty sized grains  
 Visible Minerals: N/A  
 Parting Thickness: platy, 2-5mm  
 Parting Geometry: discontinuous  
 Bedding Planes: irregular  
 Sedimentary Structures: wavy laminations  
 Fossil Content: none  
 Color When Powdered: tan  
 Luster of Streak: dull  
 Other: visible bedsets

**Unit Number: 15**

Unit Thickness: 7 feet  
 Facies Number: N/A  
 Rock Type: fault gauge  
 Interbeds: N/A  
 Color Fresh: N/A  
 Color Weathered: N/A  
 Grain Size: N/A  
 Visible Minerals: N/A  
 Parting Thickness: no distinctive partings  
 Parting Geometry: deformed  
 Bedding Planes: deformed  
 Sedimentary Structures: N/A  
 Fossil Content: N/A  
 Color When Powdered: N/A  
 Luster of Streak: N/A  
 Other: beds change dip very quickly and contain many healed quartz veins; fault through section has caused deformation and displacement

**Unit Number: 16**

Unit Thickness: 13 feet  
 Facies Number: 5  
 Rock Type: non-calcareous shale  
 Interbeds: none  
 Color Fresh: dark grey  
 Color Weathered: N/A  
 Grain Size: N/A  
 Visible Minerals: none  
 Parting Thickness: platy to flaggy, 2-10mm  
 Parting Geometry: discontinuous  
 Bedding Planes: irregular  
 Sedimentary Structures: none  
 Fossil Content: none  
 Color When Powdered: tan  
 Luster of Streak: dull  
 Other: large fault between this unit and unit 15.

**Unit Number: 17**

Unit Thickness: 10-30 feet  
 Facies Number: 4  
 Rock Type: non-calcareous shale  
 Interbeds: none  
 Color Fresh: black, nodule: light grey  
 Color Weathered: maroon, orange, yellow

Grain Size: N/A  
Visible Minerals: pyrite  
Parting Thickness: papery to  
fissile, .5-2mm  
Parting Geometry:  
Bedding Planes: mostly regular,  
deformed  
Sedimentary Structures: non-  
calcareous pyrite nodule  
Fossil Content: none  
Color When Powdered: medium  
brown  
Luster of Streak: waxy  
Other: very deformed unit is 10  
feet at top of the outcrop and 30  
feet at the base were the section  
is measured, repeated section,  
beds locally change dip rapidly,  
unit is highly fractured, slick n  
slides and iridescent stain  
present on parting surfaces,  
pyrite fill in veins and present in  
small nodule

**Unit Number: 18**

Unit Thickness: ~ 20-30 feet  
Facies Number: 5  
Rock Type: non-calcareous  
shale  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, 1-  
5mm  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: light  
Luster of Streak: dull  
Other: large fault between unit  
17 and unit 18. This section is a  
large recumbent fold; section is  
doubled and may not be in  
stratigraphic order

## FROST WV, OUTCROP

**Location: 1.1 miles Northwest of Frost, WV on Co. Rt. 13 (Quarry Measured Section 1)**

**Latitude/**

**Longitude: 38.28330/-79.885224**

Unmeasured section notes: Needmore and Marcellus contact is covered. The first distinctive Marcellus exposure consists of Facies 4, non-calcareous black shale with high uranium reading (~ 20 ppm). The shale partings are platy and discontinuous (~ 1-2mm) and parting surfaces are mostly regular and smooth. Shale weathers orange to maroon and small traces of pyrite are seen on bedding planes. Large calcareous concretion ~ 4 feet in size is found in this section. Up section ~15 feet from first measured section, Facies 5, non-calcareous medium grey shale contains several thin beds of abundant brachiopod fossils of a single species. Shale also contains mud filled or red oxidized burrow. The bedding partings are platy 5mm and parting surfaces are bumpy and irregular. The shale streak is very waxy and the powder color is medium to dark brown. Up section: calcareous nodules are found in float and protruding from covered section between brachiopod shale and beginning of first measured section.

### **Unit Number: 1 Quarry Measured Section 1**

Unit Thickness: 9 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: very black  
Color Weathered: orange and maroon, yellow weathering on parting surfaces

Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: papery to platy, .5-2mm  
Parting Geometry: discontinuous, wavy  
Bedding Planes: slightly irregular, wavy  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: dark brown to black  
Luster of Streak: very waxy  
Other: partings may be deformed by faulting; unweathered sections have less distinct parting

### **Unit Number: 2 Quarry Measured Section 1**

Unit Thickness: 4 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: very black  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: pyrite associated with nodules  
Parting Thickness: fissile-platy, ~.5-1mm,  
Parting Geometry: discontinuous, nodules  
Bedding Planes: irregular, nodules  
Sedimentary Structures: incipient nodules on bedding planes  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: oxidizing halo around incipient nodules, partings are irregular and thicker due to prevalence of nodule features ~ 5-10mm, bed sets ~ .5 – 1 inch with internal partings, incipient nodules are heavy and flat and formed on bedding planes

### **Unit Number: 3 Quarry Measured Section 1**

Unit Thickness: 9 feet  
Facies Number: 4  
Rock Type: non-calcareous  
Interbeds: none  
Color Fresh: black  
Color Weathered: grey, orange, and maroon  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: fissile to platy, ~.5-1mm  
Parting Geometry: discontinuous, nodules  
Bedding Planes: regular, some wavy around nodules  
Sedimentary Structures: incipient nodules  
Fossil Content: none  
Color When Powdered: medium to dark brown  
Luster of Streak: semi-waxy  
Other: partings near nodules are larger and less regular, oxidized halos around nodules, yellow weathering on bedding planes

### **Measured Section 2 Notes:**

This section is significantly up-section from measured section 1 (~ 52 paces). Measured sections 2 and 3 hold a character unlike that of the Marcellus Shale in my study area. Therefore the transition zone from the lower Milboro (true Marcellus shale) and the Upper Milboro (overlying shale members) is within this covered interval.

### **Unit Number: 1 Quarry Measured Section 2 (Upper Milboro)**

Unit Thickness: 7 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: maroon, tan, orange, white  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, 1-4mm

Parting Geometry: continuous, non-parallel  
Bedding Planes: wavy, ridges  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: black  
Luster of Streak: waxy  
Other:

**Unit Number: 2 Quarry  
Measured Section 2**

Unit Thickness: 1 foot  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered:  
Grain Size: N/A  
Visible Minerals: non  
Parting Thickness: platy, ~1-4mm  
Parting Geometry: mostly continuous, non-parallel  
Bedding Planes: irregular  
Sedimentary Structures: septarian concretions  
Fossil Content: none  
Color When Powdered: medium brown  
Luster of Streak: intermediate  
Other: concretions are septarian and formed along bedding planes, range from 1-3 feet in width, calcite and unknown black mineral in veins.

**Unit Number: 3 Quarry  
Measured Section 2**

Unit Thickness: 3 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: grey, green, orange  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, 1-4mm  
Parting Geometry: N/A  
Bedding Planes: semi-irregular  
Sedimentary Structures: incipient nodules  
Fossil Content: none

Color When Powdered: N/A  
Luster of Streak: N/A  
Other: none

**Unit Number: 4 Quarry  
Measured Section 2**

Unit Thickness: 2 feet  
Facies Number: 5  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: medium grey  
Color Weathered: grey, tan  
Grain Size: silt and clay  
Visible Minerals: none  
Parting Thickness: platy to flaggy, 2-10mm  
Parting Geometry: discontinuous  
Bedding Planes: irregular  
Sedimentary Structures:  
Fossil Content: none  
Color When Powdered: dark brown  
Luster of Streak: waxy  
Other: this unit is more susceptible to weathering than surrounding units,

**Unit Number: 5 Quarry  
Measured Section 2**

Unit Thickness: 1 foot  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: yellow, maroon  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: irregular, ridges  
Sedimentary Structures: incipient nodules  
Fossil Content: none  
Color When Powdered: black  
Luster of Streak: waxy  
Other: partings are distorted by deformation

**Unit Number: 6 Quarry  
Measured Section 2**

Unit Thickness: 1 foot

Facies Number: 5  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: dark grey  
Color Weathered: green, grey, orange  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, ~2-5mm  
Parting Geometry: discontinuous  
Bedding Planes: irregular  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: light brown  
Luster of Streak: waxy  
Other: none

**Unit Number: 7 Quarry  
Measured Section 2**

Unit Thickness: 7 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: white, yellow, maroon  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, ~1-3mm  
Parting Geometry: continuous, non-parallel  
Bedding Planes: semi-irregular, ridges  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: dark brown  
Luster of Streak: intermediate  
Other: shale is in bedsets ~4-8 inches each

**Unit Number: 1 Quarry  
Measured Section 3 (Upper Milboro)**

Unit Thickness: 4 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none

Color Fresh: dark grey to black  
Color Weathered: buff to grey, white efflorescence >sp  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: papery to platy, <.5-1mm  
Parting Geometry: N/A  
Bedding Planes: regular  
Sedimentary Structures: large calcareous concretions at base of unit ~ 3 feet  
Fossil Content: none  
Color When Powdered: medium brown  
Luster of Streak: semi-waxy  
Other: partings come in books of varying in size, white precipitate on shale surface

**Unit Number: 2 Quarry  
Measured Section 3**

Unit Thickness: 2 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, 1-2mm  
Parting Geometry: discontinuous, nodules  
Bedding Planes: mostly regular, ridges and wavy features associated with nodules  
Sedimentary Structures: incipient nodules  
Fossil Content: none  
Color When Powdered: light to medium brown  
Luster of Streak: semi-waxy  
Other: oxidized halo around nodules

**Unit Number: 3 Quarry  
Measured Section 3**

Unit Thickness: 3  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: dark grey to black

Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: papery to fissile, .5-1mm  
Parting Geometry: discontinuous  
Bedding Planes: mostly regular  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: brown  
Luster of Streak: semi-waxy  
Other: faults in section, may be repeated

**Unit Number: 4 Quarry  
Measured Section 3**

Unit Thickness: 4 feet  
Facies Number: 4  
Rock Type: non-calcareous  
Interbeds: none  
Color Fresh: chocolate brown, dark grey to black  
Color Weathered: brown  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: fissile to platy, .5-2mm  
Parting Geometry: N/A  
Bedding Planes: relatively smooth  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: dark brown, peels  
Luster of Streak: waxy  
Other: brown shale breaks blocky in up to ~ 5mm partings; section has localized folds and deformation

**Unit Number: 5 Quarry  
Measured Section 3**

Unit Thickness: 3 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: dark grey to brown  
Color Weathered: brown  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: platy, ~ 2mm

Parting Geometry: some discontinuous  
Bedding Planes: semi-regular  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: medium brown  
Luster of Streak: semi-waxy  
Other: section has multiple small scale faults offsetting section

## McCOOLE MD, OUTCROP

**Location:** 3 miles Northeast of Keyser, WV on 21<sup>st</sup> St. Bridge Road (SW)

**Latitude/Longitude:**  
39.451803/78.960822

Notes: The Needmore/Marcellus contact is covered. The Needmore shale consists of dark grey, green and blue calcareous mudstone with both vertical and horizontal burrows. Body fossils such as brachiopods, cephalopods and gastropods are found in light grey mudstone. Needmore transitions very quickly to the darker more fissile shale of the Marcellus.

### **Unit Number: 1**

Unit Thickness: 7 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: red, orange, and maroon  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: partings destroyed by deformation  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: brown  
Luster of Streak: semi-waxy  
Other: fault at 5 feet, multiple small faults and fold in unit, highly fractured, shale is coaly and shiny

### **Unit Number: 2**

Unit Thickness: 4 feet  
Facies Number: N/A  
Rock Type: Covered Section  
Interbeds: N/A  
Color Fresh: N/A  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: N/A

Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: N/A  
Fossil Content: N/A  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: N/A

### **Unit Number: 3**

Unit Thickness: 9 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: red, orange, and maroon  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: parting no distinctive, destroyed by deformation  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: N/A  
Fossil Content: N/A  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: same as unit 1, highly deformed, fault gauge common

### **Unit Number: 4**

Unit Thickness: 17 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: dark grey to black  
Color Weathered: white efflorescence, red, orange, concretions weather yellow to light brown  
Grain Size: N/A  
Visible Minerals: pyrite in concretions  
Parting Thickness: platy, 1-2mm  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: non calcareous and calcareous, pyritic concretions

Fossil Content: none  
Color When Powdered: medium brown  
Luster of Streak: intermediate  
Other: shale breaks in to very small shards, some incipient nodule like features on parting surface, small displacement faults cut through unit

### **Unit Number: 5**

Unit Thickness: 3 feet  
Facies Number: 5  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: medium to dark grey  
Color Weathered: maroon  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: incipient nodules, with maroon weathering halos  
Fossil Content: brachiopod molds, lingula  
Color When Powdered: brown  
Luster of Streak: dull  
Other: some bedding planes have abundant brachiopod shells that seem to be the same species

### **Unit Number: 6**

Unit Thickness: 16 feet  
Facies Number: N/A  
Rock Type: Covered Section  
Interbeds: N/A  
Color Fresh: N/A  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: N/A  
Fossil Content: N/A  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: N/A

**Unit Number: 7**

Unit Thickness: 18 feet  
 Facies Number: 4  
 Rock Type: non-calcareous shale  
 Interbeds: none  
 Color Fresh: dark grey to black  
 Color Weathered: white, maroon, orange  
 Grain Size: N/A  
 Visible Minerals: none  
 Parting Thickness: platy, ~2mm  
 Parting Geometry: N/A  
 Bedding Planes: irregular, incipient nodules, ridges  
 Sedimentary Structures: incipient nodules  
 Fossil Content: none  
 Color When Powdered: brown to tan  
 Luster of Streak: waxy  
 Other: fault gauge and folded beds present, books of partings present

**Unit Number: 8**

Unit Thickness: 10 feet  
 Facies Number: N/A  
 Rock Type: Covered Section  
 Interbeds: N/A  
 Color Fresh: N/A  
 Color Weathered: N/A  
 Grain Size: N/A  
 Visible Minerals: N/A  
 Parting Thickness: N/A  
 Parting Geometry: N/A  
 Bedding Planes: N/A  
 Sedimentary Structures: N/A  
 Fossil Content: N/A  
 Color When Powdered: N/A  
 Luster of Streak: N/A  
 Other: N/A

**Unit Number: 9**

Unit Thickness: 5 feet  
 Facies Number: 5  
 Rock Type: non-calcareous shale  
 Interbeds: none  
 Color Fresh: dark grey  
 Color Weathered: orange  
 Grain Size: N/A  
 Visible Minerals: none  
 Parting Thickness: platy, 1-2mm  
 Parting Geometry:

Bedding Planes: irregular  
 Sedimentary Structures: non-calcareous nodules  
 Fossil Content: none  
 Color When Powdered: tan  
 Luster of Streak: dull  
 Other: nodules are grey, round and ~ 1 inch in diameter

**Unit Number: 10**

Unit Thickness: 7 feet  
 Facies Number: 5  
 Rock Type: non-calcareous shale  
 Interbeds: none  
 Color Fresh: dark grey  
 Color Weathered: N/A  
 Grain Size: N/A  
 Visible Minerals: none  
 Parting Thickness: no distinct partings, 1 -2 inch beds  
 Parting Geometry: N/A  
 Bedding Planes: N/A  
 Sedimentary Structures: bedded nodules  
 Fossil Content: unknown black and round imprints on parting surfaces, possible ammonoids or crinoids  
 Color When Powdered: tan to grey  
 Luster of Streak: dull  
 Other: nodules are dark grey, oblong and ~ 3 inches in length

**Unit Number: 11**

Unit Thickness: not measured  
 Facies Number: Mahantango Formation  
 Rock Type: non-calcareous shale  
 Interbeds: micaceous siltstone and fine sandstone  
 Color Fresh: grey to black  
 Color Weathered: brown, grey  
 Grain Size: silt to fine sand sized grains  
 Visible Minerals: micas  
 Parting Thickness: platy, (2-4mm)  
 Parting Geometry: discontinuous, wavy  
 Bedding Planes: irregular  
 Sedimentary Structures: non-calcareous bedded nodules,

calcareous nodules, cross bedding  
 Fossil Content: none  
 Color When Powdered: N/A  
 Luster of Streak: N/A  
 Other: interbeds of cross-bedded sandstone ~ 4 inches thick

## TOMAHAWK WV, OUTCROP

**Location:** 2 miles Southwest of Tomahawk, WV on Co. Rt. 7-4

**Latitude/Longitude:**  
39.506425/-78.060651

### **Unit Number: 1**

Unit Thickness: 1 foot  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: some papery to fissile <.5-1mm  
Parting Geometry: some parallel  
Bedding Planes: regular  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: dark brown  
Luster of Streak: waxy  
Other: shale is sooty and smudges fingers, some shale has distinct papery partings and others are coaly and lack distinctive partings

### **Unit Number: 2**

Unit Thickness: 1 foot  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black  
Color Weathered: some red to orange weathering  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: fissile, .5mm  
Parting Geometry: mostly parallel  
Bedding Planes: regular to slightly irregular, bumpy  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: dark brown  
Luster of Streak: waxy, peels

Other: fissile partings come in packages ~ 1 – 5mm

### **Unit Number: 3**

Unit Thickness: 2 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black to brown  
Color Weathered: brown  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: papery, < .5 mm  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: medium brown  
Luster of Streak: waxy  
Other: locally drag folded, may have repeated beds, breaks into very soft, papery, polygons

### **Unit Number: 4**

Unit Thickness: 3 feet  
Facies Number: 4  
Rock Type: papery non-calcareous shale  
Interbeds: fissile non-calcareous shale  
Color Fresh: black, interbeds: dark grey to black  
Color Weathered: dark grey, orange  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: papery, <.5 mm, interbeds: fissile~ 1mm  
Parting Geometry: mostly parallel  
Bedding Planes: mostly regular  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: black to grey  
Luster of Streak: waxy  
Other: locally drag-folded, deformation has destroyed parting

### **Unit Number: 5**

Unit Thickness: 2 feet  
Facies Number: 4 and 6  
Rock Type: non-calcareous shale  
Interbeds: bentonite, ~4 inches  
Color Fresh: very black, interbed: brown to tan  
Color Weathered: red, interbed: white to grey clay  
Grain Size: interbed: coarse sand to clay size  
Visible Minerals: interbed: mica  
Parting Thickness: platy, 2-5mm, some internal laminations  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: hardground: bioturbation, interbed: graded  
Fossil Content: none  
Color When Powdered: grey to brown, interbeds: brown  
Luster of Streak: waxy, interbed: waxy  
Other: black shale below bentonite is very hard and has no distinct partings, possibly a bioturbated subjacent hardground

### **Unit Number: 6**

Unit Thickness: 1 foot  
Facies Number: 4 and 6  
Rock Type: non-calcareous shale  
Interbeds: bentonite, ~ 3inches  
Color Fresh: black to dark grey  
Color Weathered: white to dark grey  
Grain Size: N/A  
Visible Minerals: interbed: mica  
Parting Thickness: papery to platy, <.5 – 2mm  
Parting Geometry: parallel, continuous  
Bedding Planes: regular  
Sedimentary Structures: internal laminations  
Fossil Content: none  
Color When Powdered: black  
Luster of Streak: medium waxy



Other: black shale has very flat fissile partings, shale breaks off in brittle sheets up to 1 foot in size.

**Unit Number: 7**

Unit Thickness: 1 foot  
Facies Number: N/A  
Rock Type: covered section  
Interbeds: N/A  
Color Fresh: N/A  
Color Weathered: N/A  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: N/A  
Fossil Content: N/A  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: section covered by tree roots and soil

**Unit Number: 8**

Unit Thickness: 4 feet  
Facies Number: 4 and 6  
Rock Type: non-calcareous shale  
Interbeds: bentonite, ~ .5 feet  
Color Fresh: black, interbeds: grey  
Color Weathered: interbed: grey to tan clay  
Grain Size: interbed: sand sized  
Visible Minerals: interbed: mica  
Parting Thickness: papery to fissile, < .5 mm -1 mm  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: one  
Fossil Content: none  
Color When Powdered: dark brown to black  
Luster of Streak: waxy  
Other: upper 2 feet of unit is papery black shale

**Unit Number: 9**

Unit Thickness: 6 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: black

Color Weathered: grey, white, orange

Grain Size: N/A

Visible Minerals: none

Parting Thickness: fissile to platy, 1- 2mm

Parting Geometry: parallel, sheets

Bedding Planes: regular

Sedimentary Structures: none

Fossil Content: none

Color When Powdered: black

Luster of Streak: semi-waxy

Other: some papery partings, shale is in books ~ 1- 10 mm with internal partings 1-2mm

**Unit Number: 10**

Unit Thickness: 3.5 feet

Facies Number: 4

Rock Type: non-calcareous shale

Interbeds: none

Color Fresh: black

Color Weathered: white, orange

Grain Size: N/A

Visible Minerals: none

Parting Thickness: platy, 1- 5mm

Parting Geometry: N/A

Bedding Planes: slightly irregular

Sedimentary Structures: none

Fossil Content: none

Color When Powdered: N/A

Luster of Streak: N/A

Other: locally folded, some partings come in books 1- 2cm

## PETERSBURG WEST WV, OUTCROP

**Location:** 2.2 miles West of Petersburg, WV on Rt. 28/55  
**Latitude/Longitude:** 39.003594/-79.156687

### **Unit Number: 1**

Unit Thickness: 1.5 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: dark grey to black  
Color Weathered: orange, white  
Grain Size: N/A  
Visible Minerals: none  
Parting Thickness: papery to platy, < .5-2 mm  
Parting Geometry: discontinuous  
Bedding Planes: slightly irregular  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: medium brown  
Luster of Streak: semi- waxy, powdery  
Other: shale becomes more papery at top .5 feet of this unit

### **Unit Number: 2**

Unit Thickness: 6.5 feet  
Facies Number: 4  
Rock Type: non-calcareous shale  
Interbeds: none  
Color Fresh: dark grey- black  
Color Weathered: white, orange, light grey  
Grain Size: N/A  
Visible Minerals: N/A  
Parting Thickness: fissile to platy, .5- 2mm  
Parting Geometry: non-parallel  
Bedding Planes: irregular, curved  
Sedimentary Structures: none  
Fossil Content: none  
Color When Powdered: tan  
Luster of Streak: dull- semi waxy  
Other: breaks into irregular pieces

### **Unit Number: 3**

Unit Thickness: 8 feet  
Facies Number: 5 to 1  
Rock Type: grey non-calcareous to slightly calcareous shale  
Interbeds: calcareous nodule beds  
Color Fresh: grey  
Color Weathered: white, white residue  
Grain Size: none  
Visible Minerals: none  
Parting Thickness: no distinctive partings  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: bedded nodules  
Fossil Content: none  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: nodules are dark grey, calcareous, oval, 1-2 inches in diameter, and are found in beds roughly .5 – 1 foot apart. Shale breaks into blocks controlled by jointing not parting.

### **Unit Number: 4**

Unit Thickness: 7.5 feet  
Facies Number: 1  
Rock Type: calcareous shale  
Interbeds: none  
Color Fresh: grey  
Color Weathered: nodules: orange, red, yellow  
Grain Size: none  
Visible Minerals: none  
Parting Thickness: platy, 2-3mm  
Parting Geometry: non-parallel, discontinuous  
Bedding Planes: none  
Sedimentary Structures: bedded nodules, siderite  
Fossil Content: nodules contain fossils  
Color When Powdered: white to grey  
Luster of Streak: dull  
Other: nodules are bigger than unit 3 (~5-6 inches in diameter),

bedded nodules every ~.5 foot, nodules are slightly calcareous and very flattened, shale beds draped over nodules.

### **Unit Number: 5**

Unit Thickness: 1 foot  
Facies Number: 2  
Rock Type: Limestone  
Interbeds: none  
Color Fresh: Dark grey  
Color Weathered: light grey  
Grain Size: N/A  
Visible Minerals: calcite  
Parting Thickness: N/A  
Parting Geometry: N/A  
Bedding Planes: N/A  
Sedimentary Structures: bioturbation, siderite  
Fossil Content: large and small brachiopods, crinoids columnals, and cephalopods  
Color When Powdered: N/A  
Luster of Streak: N/A  
Other: large brachiopods are flattened