DAY 1
ROAD LOG

Miles		
Int.	**Cum.**	**Description**
0.0	0.0	Leave parking lot at Ramada Inn, Washington, PA and depart for field Stops. See Figure 1.
0.3	0.3	STOP SIGN. Turn left onto W. Chestnut Street/US 40W.
0.4	0.7	Turn right onto ramp, then merge onto I-70W, toward Wheeling.
0.6	1.3	Lower Washington limestone on right.
4.2	5.5	Cross pipeline.
6.3	11.8	To left in median is an outcrop of Washington coal complex.
3.7	15.5	Enter West Virginia (Ohio County).
0.9	16.4	New Rest Area and Information Center to right.

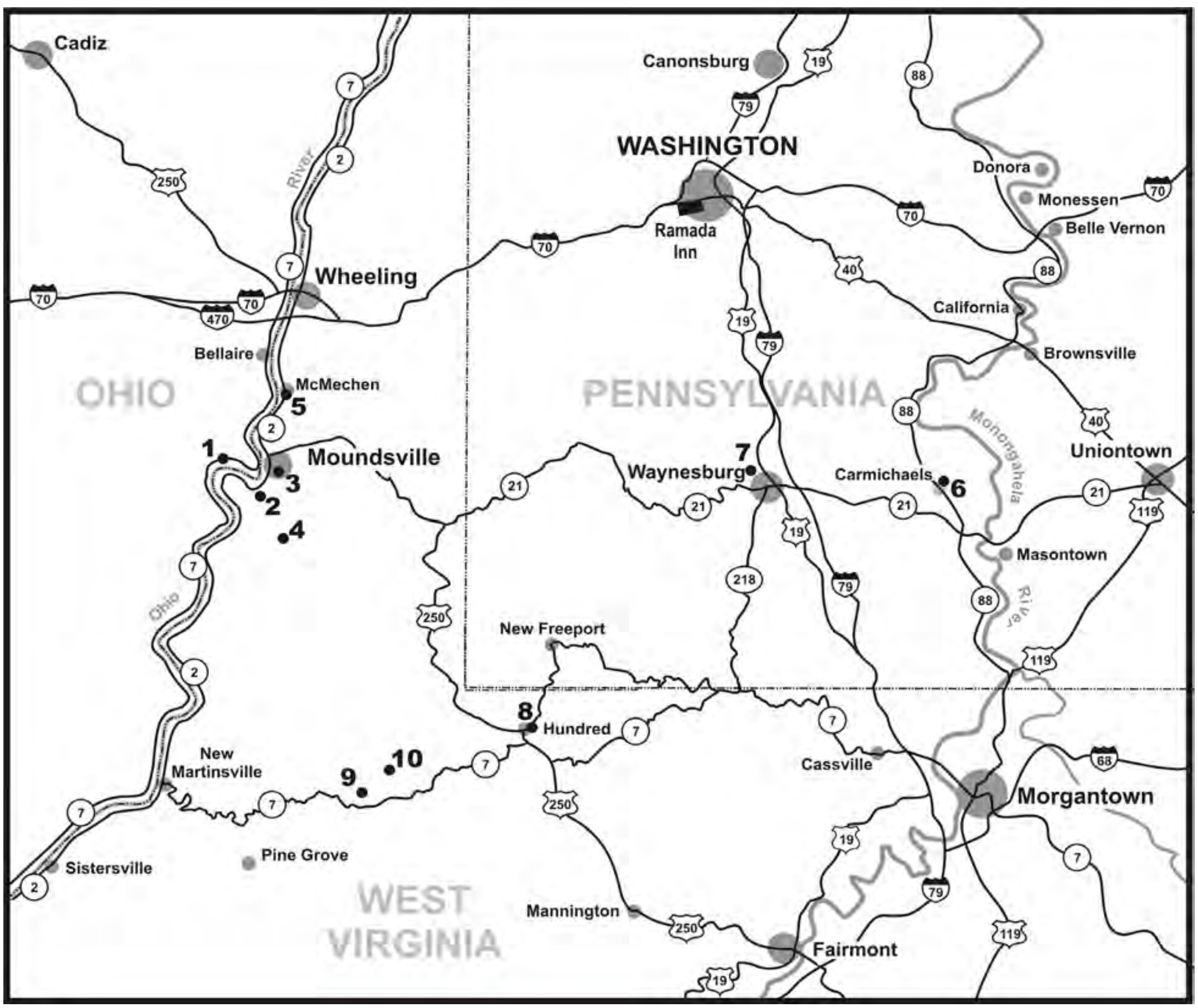

Figure 1. Location of the Ramada Inn (FC headquarters) in Washington, PA, and the 10 field Stops on the 76th Annual Field Conference of Pennsylvania Geologists.

3.6 20.0 Cabela's ahead on right.

0.7 20.7 Washington coal complex on right.

0.3 21.0 Waynesburg A coal in shallow cut on right.

0.8 21.8 Top of Benwood limestone on right.

0.9 22.7 Benwood limestone to right.

2.3 25.0 At Exit 5A, bear left onto I-470W.

2.0 27.0 Washington coal and Lower Washington limestone in cut on right near end of entrance ramp.

1.2 28.2 Benwood limestone in roadcut on right.

0.3 28.5 I-470W arches over southern part of Wheeling, WV, home of WWVA—the "late night" radio station once beloved by many "old timers" from far to the east. Wheeling has a fascinating history (see Fetherling, 2008). The first settler was Ebenezer Zane, who laid claim to land along the Ohio River here in 1769 and established a settlement called Zanesburg the following year. Fort Henry—built there in 1774—became a magnet for marauding Indians, Tories, and British Rangers during the Revolutionary War, withstanding sieges in 1777 and 1782. The first was immortalized by "McColloch's Leap" and the second by the exploits of Betty Zane (1759-1823) and Lewis Wetzel (1763-1808) (Figure 2; see Day 2 Road Log, mile 83.1). The former was a maternal ancestress of Zane Grey (1872-1939), noted author of westerns, and the inspiration for his first published novel, *Betty Zane* (1903).

Wheeling was a 19th-century transportation "mecca", being the temporary terminus of both the National Road (now US 40) and the Baltimore & Ohio (B&O) Railroad. Located about 1 mi north of the I-470 Ohio-River crossing and about 0.2 mi south of the I-70 crossing stands the Wheeling Suspension Bridge, built by Charles Ellet, Jr., in 1846-1849. This was the first long-span suspension bridge in the United States, and was for many years the longest clear-span bridge in the world (Figure 3). Today, it is the country's oldest such bridge in continuous use.

0.4 28.9 Cross Ohio River and enter Ohio (Belmont County).

0.3 29.2 Take Exit 6 to OH 7S; outcrop of Redstone limestone on left.

0.3 29.5 Proceed to STOP SIGN (outcrop of Pittsburgh coal on left); then turn right on OH 7S toward Bellaire.

1.7 31.2 Entering Bellaire, OH. Bellaire has been an important industrial center for more than a century, its glass-making earning it the title of "Glass City" beginning in 1870. Among these concerns were Belmont Glass Work, Bellaire Window Glass Company, the Bellaire Bottle Company, and, biggest of all, Imperial Glass Company. The demise of the latter in 1984 ended Bellaire's glassmaking era (Anonymous, 2011b).

Dominating the view from OH 7S are two prominent railroad bridges (Figure 4): the cantilevered-through-truss Bellaire/Interstate Bridge (1926) in the north and the Parker-through-truss Bellaire Railroad/Belmont Bridge (1905) just downriver (Anonymous, 2011d and e). The former (now abandoned and threatened with demolition) appeared in the 1991 Anthony-Hopkins film classic *The Silence of the Lambs* and the latter was featured in

Figure 2. Wetzel's Cave. Lewis Wetzel is reputed to have used this cave as a hiding place on various occasions in his personal war against the Indians. It is located on a steep hillside above Wheeling Creek near the west portal of the old B&O Railroad's Hempfield Tunnel (also called Tunnel Green). The cave reputedly has a length of 163 feet (see Fueg and Fueg, 1975, for a scaled map). Its narrow opening occurs in a calcareous sandstone beneath a a more resistant sandstone cap, probably situated in the upper Conemaugh Group. The cave figures rather prominently in Zane Grey's early frontier novels. In *The Spirit of the Border* (1906), he narrates how Wetzel initially discovered the cave by accident as he was being "hotly pursued by Shawnee"; it subsequently became his "safest" retreat. In *Betty Zane* (1903) Wetzel bushwhacks and scalps a Huron who had been using the cave as a shelter, having been led there by his recognition that the "chug-a-lug, chug-a-lug, chug-a lug" resounding through the woods was not made by a big turkey, as his less wily compatriots believed.

		the rousing conclusion of the 2010 Denzel-Washington film *Unstoppable* (Anonymous, 2011b).
2.3	33.5	Benwood limestone on right.
3.0	36.5	Benwood limestone on right.
2.7	39.2	Bridge to Moundsville, WV, ahead.
1.1	40.3	Dilles Bottom off to left. Note "BIG Cut" ahead on OH 7 (STOP 1).
0.4	40.7	Good view of "BIG Cut" ahead to left.
1.0	41.7	North end of "BIG Cut."
0.9	42.6	Pull off to left. Disembark.
		STOP 1: THE "BIG CUT" — STRATIGRAPHY OF THE PENNSYLVANIAN–PERMIAN TRANSITION
		See p. 259 for STOP Description.

Leave STOP 1. Turn around and return north on OH 7.

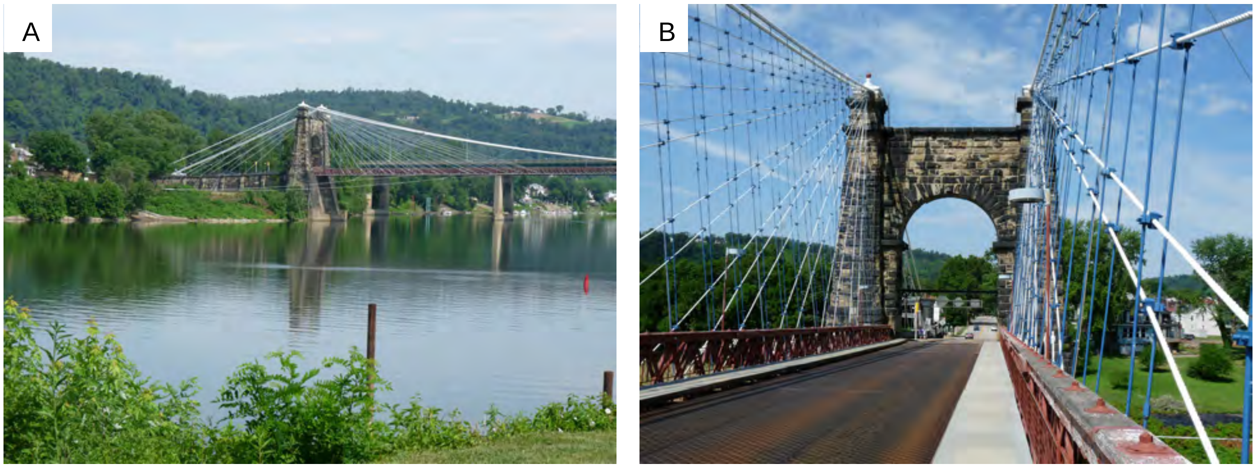

Figure 3. A—View of Ellet's Wheeling Suspension Bridge looking west across the main channel of the Ohio River toward Wheeling Island. The bridge has a structure length of 1,307 ft (398 m) and a span length of 1,010 ft (308 m). On 17 May 1854, a violent wind storm took down the main span, much of it falling into the Ohio River. The bridge was rebuilt and strengthened in the 1860s and early 1870s. The bridge had manor repairs in 1956, 1982, and 1999, but its original towers and cables are still in service (Prince, 2005; Fetherling, 2008; Kemp, 2011). B—West tower and cables of the Wheeling Suspension Bridge on Wheeling Island. The auxiliary, diagonal stay-cables (like thoses on the Brooklyn Bridge) were added by Washington Roebling in 1871-72 to further stabilize the structure and prevent another "Galloping Gertie" episode as had occurred nearly two decades earlier (Kemp, 2011).

1.2	43.8	Sewickley coal in "old" cut on left.
0.5	44.3	Enter Mead Township.
2.3	46.6	Bear right onto exit ramp leading to OH 872.
0.3	46.9	STOP SIGN. Turn right onto OH 872E/Ferry Landing Road.
0.3	47.2	Ohio-Edison coal-fired power plant on right.
0.2	47.4	Cross Ohio River into West Virginia (Marshall County).
0.2	47.6	Enter Moundsville, WV. Turn right on WV 2.
0.9	48.5	Turn left on WV 2Alt.
0.1	48.6	Turn left on Roberts Ridge Road.
0.1	48.7	Pull over at driveway on right. Disembark. (Buses will proceed ahead 0.5 mi to top of hill, and we will walk to reboard them there. Coffee and donuts will be served at second hairpin turn.) **STOP 2: ROBERTS RIDGE ROAD SECTION — STRATIGRAPHIC AND PALEONTOLOGIC FEATURES OF THE WAYNESBURG AND WASHINGTON FORMATIONS** See p. 264 for STOP Description.
0.5	49.2	Leave STOP 2, proceeding ahead on Roberts Ridge Road.
0.7	49.9	Turn right onto Lindsey Lane.
1.7	51.6	Y-intersection of Lindsey Lane and WV-2 Alt; turn left onto WV-2Alt.
0.9	52.5	Ledges on right are probably sandstone above Washington coal.
0.5	53.0	STOP SIGN. Turn right onto WV-2N.
0.1	53.1	To left is a good view of "BIG Cut" at STOP 1 across river in Ohio.
1.0	54.1	Benwood limestone on right.

Figure 4. Old postcard view of Bellaire, OH, looking east across the Ohio River from above mile 31.2. The Bellaire/Interstate Bridge is on the left and the Bellaire Railroad/Belmont Bridge is downstream on the right.

1.5 55.6 Enter Moundsville, WV.

1.0 56.6 Turn right on 8th Street.

0.2 56.8 STOP SIGN. Turn right onto Jefferson Avenue in front of the former West Virginia State Penitentiary (Figure 5). The prison here was founded in 1866 and built of wood. Construction of the present stone gothic structure began in 1867 and continued into the 1870's. Among the interesting aspects of the prison's history are the following: A school and library were completed in 1900; from 13 April to 14 June 1919, Eugene V. Debs, Socialist presidential candidate in numerous Federal elections, was held here for violating the Espionage Act of 1917; in 1921 a prison coal mine located a mile away was opened; a major expansion involving considerable new construction was completed in 1959; in the 1960's the prison reached a maximum population of about 2000 inmates; the last execution (by electric chair) took place in 1965; on 7 November 1979 fifteen prisoners escaped, including murderer Ronald Turney Williams, who was captured 18 months later and is still in West Virginia custody; and on 1 January 1986 a major prison riot took place. Later that same year the West Virginia Supreme Court ruled that the 5x7-ft cells constituted cruel and unusual punishment. The prison was decommissioned in the 1990's, and the last remaining prisoners were transferred to a correctional facility in Fayette County, West Virginia.

Figure 5. The former West Virginia State Penitentiary at mile 56.8 in Moundsville.

In literature, the native Davis Grubb (1919-1980) set his 1953 novel *The Night of the Hunter* in Moundsville, with the prison having a prominent role. (The novel was adapted for a movie staring Robert Mitchum and Shelley Winters in 1955). And (like the Bellaire bridges at mile 30.8), the penitentiary itself was featured in the adaptation of Grubb's 1969 novel *Fool's Parade* into a 1971 film starring James Stewart and George Kennedy (Anonymous, 2011c).

0.1 56.9 Turn right into parking lot. Disembark. The Historical Marker near the parking lot at the entrance to the museum here reads:

GRAVE CREEK MOUND. This world-famous burial mound was built by the Adena people sometime before the Christian Era. The mound was originally 69 feet high, 295 feet [error, see below] in diameter, and was encircled by a moat. There were many mounds in the area—hence the city's name: Moundsville. In 1838, the Grave Creek Mound was tunneled into and two log tombs with several burials and grave offerings were found.

STOP 3 AND LUNCH: GRAVE CREEK MOUND STATE PARK, MOUNDSVILLE, WV

See p. 281 for STOP Description.

Leave STOP 3, turning right on Jefferson Avenue.

0.3 57.2 STOP SIGN. Turn left on 12th Street.

0.9 58.1 Turn right on Big Grave Creek Road.

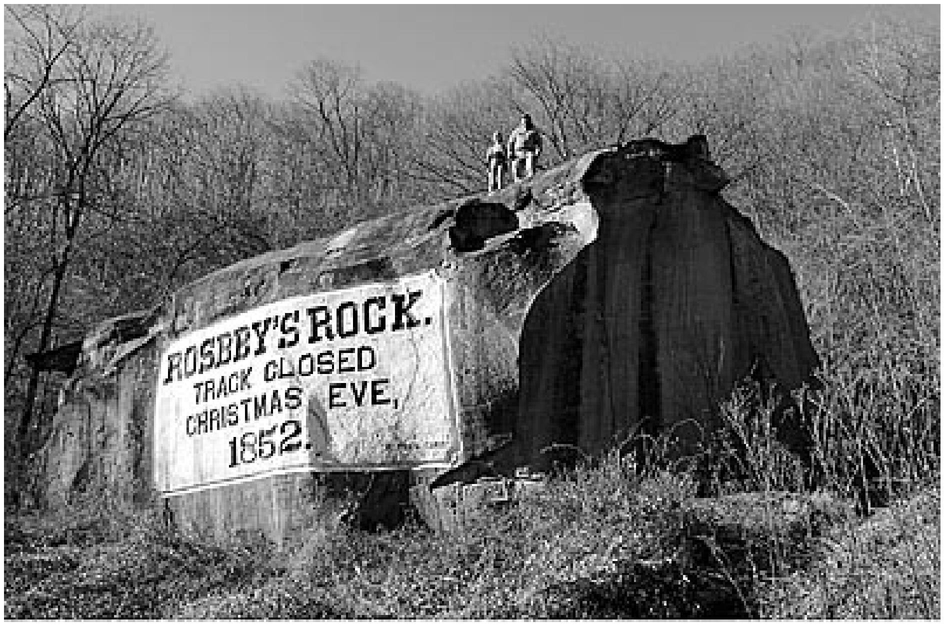

Figure 6. Rosby's Rock near mile 64.1 (photo by Carl E. Feathers.) The rock is a block of Upper Marietta, or higher Washington Group, sandstone, that has moved downslope to the level of the old railroad grade (Cross and Schemel, 1956, p. 12).

0.2 58.3 Northern Regional Jail Correction Facility (a local prison, not the successor to the State Penitentiary opposite STOP 3) on right. Continue on following Grave Creek Road (along eponymous creek) for next 5+ miles.

5.8 64.1 Road to left leads to Rosbys Rock village across creek. Geologically, Rosby's Rock is a huge (900 yds^3, 64 ft long and 20 feet thick) block of sandstone near the village that vaguely resembles a locomotive, on which a prominent carved inscription reads "ROSBBY'S (*sic*) ROCK. TRACK CLOSED CHRISTMAS EVE, 1852" (Figure 6). This commemorates the fact that the last spike completing the Baltimore & Ohio Railroad was driven here on 24 December 1852. The B&O was the first rail line linking the Atlantic Coast with the Ohio River Valley. (It joined Baltimore and Wheeling.) The line was heavily used for both passenger and freight service for over 100 years, the passenger service ending in 1957 and freight service in 1972-73. The line was abandoned and removal of the tracks and bridges began in 1974. The halcyon days of the village of Rosbys Rock are now long past.

0.4 64.5 Turn into pull-off to left. Disembark.

STOP 4: ROSBY'S ROCK SECTION — WASHINGTON COAL COMPLEX,PALEOSOL, AND LIMESTONE

See p. 290 for STOP Description.

Leave STOP 4, turning around and returning back along Grave Creek Road.

6.7 71.2 Turn left onto Fork Ridge Road and continue onto 12th Street.

1.1 72.3 Turn right onto Lafayette Avenue/Wheeling Avenue (WV-2N).

2.8 75.1 Historical Marker to right reads:

HARRIET B. JONES (b. 3 June 1856; d. 28 June 1943). Born 3 June 1856. In 1885 was first licensed woman physician in state; opened private practice then hospital in Wheeling, 1892. Jones was active in temperance and women's suffrage; and promoted establishment of state sanitariums in Terra Alta & Denmar, industrial school for girls in Salem and the Children's home in Elkins. Elected in 1924 to represent Marshall County in House. Died 28 June 1943.

0.4	75.5	Benwood limestone behind fence on right. Good view of Bellaire, OH, across Ohio River to left.
1.7	77.2	Turn right on 21st Street in McMechem, then turn left immediately on Marshall Street.
0.2	77.4	Turn left on unmarked street.
0.1	77.5	STOP SIGN. Turn left and then proceed into Municipal Pool parking lot.

STOP 5: McMECHEN LANDSLIDE, McMECHEN, WV

See p. 300 for STOP Description.

Leave STOP 5.

0.1	77.6	STOP SIGN. Turn right, then immediately right on Marshall Street.
0.2	77.8	Turn right onto "entrance street," then right on WV-2.
1.0	78.8	Benwood limestone to right and left.
0.3	79.1	Consol mine-mouth power plant on left; road passes directly under conveyor belt from mine.
1.5	80.6	Enter Ohio County.
0.9	81.5	Bear right onto 26th Street, following signs for I-470E.
0.3	81.8	Bear right onto ramp for I-470E.
0.4	82.2	Merge onto I-470E.
1.5	83.7	Waynesburg coal complex exposure on right, containing broken fragments of *Lingula* shells in thick shale parting.
3.2	86.9	Merge onto I-70E.
7.5	94,4	Cabella Drive. Continue ahead on I-70E.
4.6	99.0	Enter Pennsylvania.
4.4	103.4	Pennsylvania Welcome Center on right.
5.3	108.7	Right lane of I-70E closed because of small landslide in fill (affecting mainly shoulder).
4.1	112.8	To the right is CONSOL Energy Park (completed 2002), home of the Washington Wild Things, a professional baseball team. Affiliated with the Frontier League (which has no ties to Major League Baseball), the Wild Things play such teams as the Lake Erie Crushers, the Rockford Riverhawks, the Joliet Slammers, and the Traverse City Beach Bums.
0.4	113.2	Bear right at Exit 15, then merge with Chestnut Street/US-40E.
0.6	113.8	Turn right onto road to Ramada Inn.
0.3	114.1	Parking lot at Ramada Inn. **END OF DAY 1 FIELD TRIP**.

Many thanks to Margaret Brennan, Wheeling Area Historical Society, for providing historical information on the City of Wheeling, WV.

DAY 2
ROAD LOG

Miles		
Int.	**Cum.**	**Description**
0.0	0.0	Leave parking lot at Ramada Inn, Washington, PA.
0.3	0.3	STOP SIGN. Turn left onto W. Chestnut Street/US-40W.
0.4	0.7	Turn right onto ramp, then merge onto I-70E.
1.7	2.4	Enter South Strabane Township.
3.8	6.2	Bear right onto exit ramp, then merge with I-70S.
11.7	17.9	Enter Greene County. According to Tom Whitfield, students from West Virginia University traditionally painted a "Greene County Line" here on the southbound lane of I-70.
7.4	25.3	Bear off onto ramp at Exit 14 - Waynesburg, leading to PA-21.
0.2	25.5	TRAFFIC LIGHT. Turn left onto Roy E. Furman Highway (PA-21E).
0.4	25.9	TRAFFIC LIGHT. Road to left leads to State Correctional Institution.
1.5	27.4	Enter Jefferson Township.
6.7	34.1	Continue straight into Carmichaels on West George Street, where PA-21 bears off to right.
1.4	35.5	TRAFFIC LIGHT at Vine Street. Continue straight.
0.1	35.6	"Roundabout"—bear around to left onto Market Street.
0.2	35.8	Greene Academy—1790-1810 on right. The Greene Academy has been on the National Register of Listed Properties since 1976. The older part of the building was constructed of native fieldstone (Mather Sandstone) in 1791 as an Episcopal Church on land owned by James Carmichaels. In 1810, church trustees offered the community use of their building as a school and an addition of brick was constructed. By Act of Legislature in 1820, and with a State grant of $2,000, plus public subscriptions, it was a leading academy west of the mountains until 1860. Arguably its most important achievement was as a pioneer in co-education – it had a Female Department as early as 1837, the first such department in Pennsylvania (Carmichaels Area Chamber of Commerce, 2011). It was considered THE educational center of Greene County until Waynesburg College was founded in 1849. It finally closed in 1893 when the Carmichaels Borough School was built. After that, it went through several changes - first as a GAR post, then as three apartments, and lastly and currently as the community center and headquarters of the Greene County Council on the Arts. Greene Academy is open to the public by appointment. Tours may be arranged by calling 724-966-2731 or 724-627-3204.
0.1	35.9	Turn right onto McCann Lane into Laurel Point Cemetery.
0.1	36.0	Bear left onto gravel road through gate.
0.1	36.1	Turn left into Laurel Point Falls Park. Consol-Energy donated land for this park to Carmichaels borough.

STOP 6: LAUREL POINT FALLS PARK — CASSVILLE SHALE AND CARMICHAELS FORMATION

See p. 305 for STOP Description.

		Leave STOP 6. Turn around and return to "Roundabout" via Market Street.
0.4	36.5	Note old stone house on right built of native sandstone.
0.1	36.6	"Roundabout"—bear right onto W. George Street.
1.5	38.1	Continue straight on PA-21W.
0.7	38.8	Upper Devonian Venango-sand gas well on right.
1.1	39.9	Another gas well tapping the Venango sand on right.
0.3	40.2	Village of Khedive.
0.5	40.7	Enter Jefferson Township.
1.5	42.2	Bronze plaque on boulder to right reads: *SITE OF FIRST COURT HELD IN CREENE COUNTY 1797. Greene County Historical Society 1928.*
4.4	46.6	Go under I-70 overpass, continuing straight on PA-21W.
1.0	47.6	TRAFFIC LIGHT. Turn right onto Mount Morris Road (PA-21/US-19).
0.5	48.1	Enter borough of Waynesburg on High Street.
0.8	48.9	County Courthouse on left with PHMC Historical Marker which reads: *GREENE COUNTY. Formed February 9, 1796 from Washington County. Named for Gen. Nathanael Greene. Waynesburg, the county seat, named for Gen. Anthony Wayne, was incorporated in 1816. Site of Waynesburg College, founded 1849. Near [town of] Ten Mile is the birthplace of Gov. Edward Martin.*
0.5	49.4	Turn right on Tollgate Run Road.
0.1	49.5	Pull off on right side of road. Disembark.

STOP 7: WAYNESBURG LANDSCAPE AND CONSTRUCTION COMPANY QUARRY — WASHINGTON FORMATION AND JOLLYTOWN COAL (OF STEVENSON)

See p. 317 for STOP Description.

		Leave STOP 7, continuing straight ahead on Tollgate Road.
1.0	50.5	Turn right onto right onto US-19S (Washington Road)
1.3	51.8	US-19S splits. Bear right, continuing on WV-19S (S. Richhill Street).
0.3	52.1	Waynesburg University (founded 1849) to left beyond park.
0.1	52.2	Turn left onto Strawberry Street and head east.
0.2	52.4	Turn right onto N. Morgan Street.
13.1	65.5	Continue straight onto PA-218S (Smith Creek Road), entering Monongalia County, West Virginia, at Blacksville. Turn right onto Number Eight Hollow Road; then, at STOP SIGN, immediately right on WV-7 (Washington Street).

Figure 7. Civil War statue honoring Pvt. Jesse Taylor, Co. F, 7th West Virginia Regiment. Looking east down SR 3006 in Jollytown at mile 73.0.

Figure 8. Unmarked headstone in black slave cemetery on the old Garrison Plantation at mile 74.2. This stone has since vanished. Other, smaller markers were found nearby in their original positions. One of these is visible just to the right of the large tree in the forefront.

1.7	67.2	Turn right onto Delta Road 48 (Smith Road).
0.2	67.4	Reenter Pennsylvania (Wayne Township, Greene County). Road name changes to Toms Run Road (SR 3009).
0.9	68.3	Village of Brave.
0.8	69.1	Reenter West Virginia. Road name changes to Wana Shamrock Road (County Road 12). Continue ahead.
0.5	69.6	Enter back into Pennsylvania. Continue ahead on Toms Run Road (SR 3009).
0.5	70.1	Pass under iron railroad trestle.
0.4	70.5	Bear left at fork onto Dunkard Creek Road/Jollytown Road (SR 3012) toward village of Jollytown. The road cuts for several miles ahead are part of I. C. White's section of the Dunkard Group along the creek of that name.
1.6	72.1	STOP SIGN. Continue straight on Jollytown Road (SR 3006).
0.7	72.8	Village of Jollytown. First settled about 1790 and named after Titus Jolly, who purchased land here in about 1835.
0.2	73.0	The Civil War statue and cannons to left (Figure 7) honor a local soldier and reads: *JESSE TAYLOR, Pvt. Co .F 7th Reg't. W. Va. Inf'y. Aged 21 yrs. & 1 mon. First soldier killed from Greene Co., Pa. in the War of the Rebellion at Romney, W. Va., Oct. 26, 1861. Erected to his memory by his comrades.*
0.3	73.3	To left is road to village of Hero, where Taylor is buried. (Hero is named for Taylor). Bear right at fork to stay on Jollytown Road (now SR 3008).
0.2	73.5	Probable Marcellus gas well site to right.
0.6	74.1	Cross Bloody (formerly, Nigger) Run.
0.1	74.2	To right in woods at top bank are the remnants of a black slave cemetery (Figure 8), once part of the Garrison Plantation (see ahead).

1.0 75.2 Passing active oil well. This well is in the Hixonbaugh (Cappo Run) field, discovered in 1908, and producing from the Gordon and Fourth sands of the Venango Group (Upper Devonian). The Gordon is equivalent to the Venango Third sand of Venango County. The Fourth is equivalent to the Knox Third or Knox Fourth sand of Venango County (J. Harper, pers. comm., 27 July 2011).

0.1 75.3 At intersection of Shough Ridge Road and Jollytown Road, turn right on Jollytown Road. A secondary road off to the left leads to the old, brick Garrison Plantation House, visible in the distance. The plantation master was apparently Leonard Garrison (1750?-1819), a veteran of the Revolutionary War. Certainly one reason for Garrison maintaining "plantation slaves" in this part of Pennsylvania (possibly well into the early 19th century) is the proximity to the slave state of Virginia, only about a mile to the south. Although "An Act for the Gradual Elimination of Slavery" became law in 1780, slavery was not "officially" abolished in the Commonwealth until passage of the 13th Amendment in 1865 (Anonymous, 2011a; Harper, 2011).

2.2 77.5 To left at sharp bend is Pleasant Hill Methodist Church and Cemetery, dedicated 1905.

0.2 77.7 On bank to left is the Nineveh coal and limestone (Greene Formation) crops out. David White collected *Callipteris* (plant) here in 1902.
See Description on p.--.

0.8 78.5 Enter Freeport Township, continue on PA-18S.

0.1 78.6 STOP SIGN. Turn left on PA-18S toward Hundred, West Virginia.

1.0 79.6 Village of New Freeport.

0.1 79.7 Bear left to stay on PA-18S.

2.5 82.2 Village of Garrison—named for Leonard Garrison, the plantation owner.

0.9 83.1 Enter Wetzel County, West Virginia. The county is named for Lewis Wetzel (1763-1808), frontier Indian-fighter and -hater, whose exploits, both real and fictional, were vividly set into print by Zane Grey in his early novels *Betty Zane* (1903), *The Spirit of the Border (1906),* and *The Last Trail* (1909). He is presumably buried in McCreary Cemetery, Marshall County, West Virginia (Fueg and Fueg, 1975).

3.1 86.2 In cut to right is the Upper Washington limestone, with the Jollytown coal (of I. C. White) above it.

STOP 8 AND LUNCH: HUNDRED MUNICIPAL PARK — UPPER WASHINGTON LIMESTONE AND JOLLYTOWN COAL (OF I. C. WHITE)

There will be discussion of the outcrop and a chance to examine it close up.

0.1 86.3 Enter village of Hundred.

0.2 86.5 STOP SIGN. Turn left on WV-250S. Historical Marker to left here reads:

HUNDRED. Henry Church, who died in 1860 at the age of 109, was familiarly know as "Old Hundred" and town was named for him. He was a soldier in the British Army under Cornwallis and was captured by American troops under Gen. Lafayette.

0.5	87.0	Cut to left exposes sandstones and shales of the lower Greene Formation.
0.1	87.1	Turn right on WV-7W.
2.4	89.5	TRAFFIC LIGHT. To right is Wetzel County Long Drain Elementary School. Cross Long Drain (creek).
2.0	91.5	To left at intersection of WV-7 with Windy Hill Road, a massive sandstone bed, ~20 ft thick and well up in the Greene Formation, crops out.
2.5	94.0	Village of Knob Fork.
1.2	95.2	Village of Uniontown.
4.6	99.8	To left are two active oil wells in the Pine Grove-Camp Run field—producing from the Gordon and Gordon Stray sands (middle Venango Group) (John Harper, pers. comm., 28 July 2011).
1.6	101.4	Turn right on Great House Hill Road.
0.5	101.9	Pull off on right side of road. Disembark.

STOP 9: GREATHOUSE HILL ROAD CUT — MIDDLE AND UPPER ROCKPORT LIMESTONE (UPPER GREENE FORMATION)

See p. 321 for STOP Description.

Leave STOP 9, continuing up road to top of hill.

2.0	103.9	Pull off on right side of road across from barn. Disembark.

STOP 10: PHIL MEYER FARM — GEOMORPHOLOGY OF THE DUNKARD BASIN

See p. 326 for STOP Description.

Leave STOP 10—turn around and head back down Great House Hill Road.

2.5	106.4	STOP SIGN. Turn right on WV-7W.
16.4	122.8	Enter New Martinsville. You have now left the "boondocks" and have entered the highly industrialized Ohio River Valley.
0.2	123.0	STOP SIGN. Turn right onto WV-2N/WV-7W (3rd Street).
0.6	123.6	Business district of New Martinsville, county seat of Wetzel County.
1.4	125.0	Slight left onto WV-2N.
5.2	130.2	Enter Marshall County.
1.3	131.5	On left (and locally on right) for the next 10 miles is an almost continuous line of industrial and power plants, including Bayer Chemical, Pittsburgh Plate Glass, and Consol Energy.
11.1	142.6	New cuts in Benwood limestone to right.
6.3	148.9	Enter Moundsville.
0.4	149.3	Turn left onto S. 12th St in Moundsville onto WV-2 Spur.
0.4	149.7	Cross bridge over Ohio River and enter Ohio.
0.3	150.0	Continue straight onto OH-872W and turn right to merge onto OH-7N.
10.1	160.1	Turn left onto ramp to I-470E.

0.1	160.2	Keep right at fork and merge onto I-470E. Cross back over Ohio River and reenter West Virginia.
4.3	164.5	Merge onto I-70E.
9.0	173.5	Enter Pennsylvania.
14.8	188.3	Bear right at Exit 15, merging onto Chestnut Street-US40E.
0.6	188.9	Turn right at road to Ramada Inn.
0.3	189.2	Parking lot at Ramada Inn. **END OF DAY 2 FIELD TRIP**. Have a safe trip home!

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STOP 1: THE "BIG CUT": STRATIGRAPHY OF THE PENNSYLVANIAN-PERMIAN TRANSITION

Leader – Nick Fedorko

The impressive road cut at Stop 1 was created about 8 to 10 years ago as part of the widening of Ohio Rt. 7. The cut is about 1.6 km (1 mi) long and about 146 m (480 ft) high at the highest point. Geologically, it extends from just above the Sewickley coal bed in the Monongahela Group (concealed here but exposed updip at the base of the older cut just to the north) to very near the top of the Washington Formation of the Dunkard Group, exposing about 55 m (180 ft) of Monongahela Group and 91 m (300 ft) of Dunkard Group strata (Figure 1).

Figure 1. View of a portion of the roadcut along OH Rt. 7 at Stop 1 from across the Ohio River in WV. Photo by Vik Skema.

Although this cut has not been measured and described in detail by the field trip leaders—except for the Washington coal bed, the various benches have all been traversed, the rocks examined, and the stratigraphy worked out. The length of the cut provides an excellent opportunity to observe lateral changes in deposition at almost every bed level.

The nonmarine, lacustrine limestone beds interbedded with shale and mudstone visible at road level and above comprise the Benwood Limestone. Such limestone sequences first appear in the underlying Allegheny Formation and extend to the top of the Dunkard Group. These

Fedorko, Nick, 2011, Stop 1: Extensive roadcut on OH Rt. 7 between Dilles bottom and Powhattan Point, Belmont County, Ohio, *in* Harper, J. A., ed., Geology of the Pennsylvanian-Permian in the Dunkard basin. Guidebook, 76th Annual Field Conference of Pennsylvania Geologist, Washington, PA. p. 259-263.

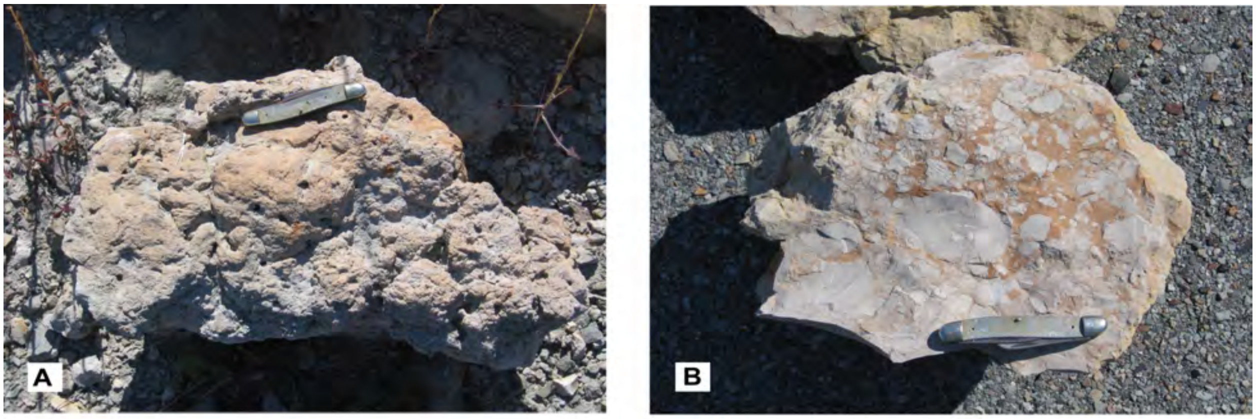

Figure 2. Stop 1, Benwood limestone subaerial exposure and desiccation features. Similar features can be observed in the Dunkard Group limestones. A – Nodular fabric. B – brecciated/ nodular fabric. C – Desiccation cracks on the top of a limestone bed exposed on a roadcut bench surface. Photos by Nick Fedorko.

limestones are especially prominent in the interval of the Monongahela Group from the base of the Pittsburgh to the base of the Uniontown coal beds (Pittsburgh Formation of Berryhill and Swanson , 1962), reaching the zenith of thickness in the Benwood Limestone as exhibited at this stop. The Benwood, like most of these units, exhibits many features indicative of frequent subaerial exposure in a shallow water depositional environment such as desiccation mud cracks, brecciation, and nodularization (Figure 2). Some of the green mudstone interbeds in the Benwood Limestone contain fossils of large fish inferring periods of deeper water (Figure 3).

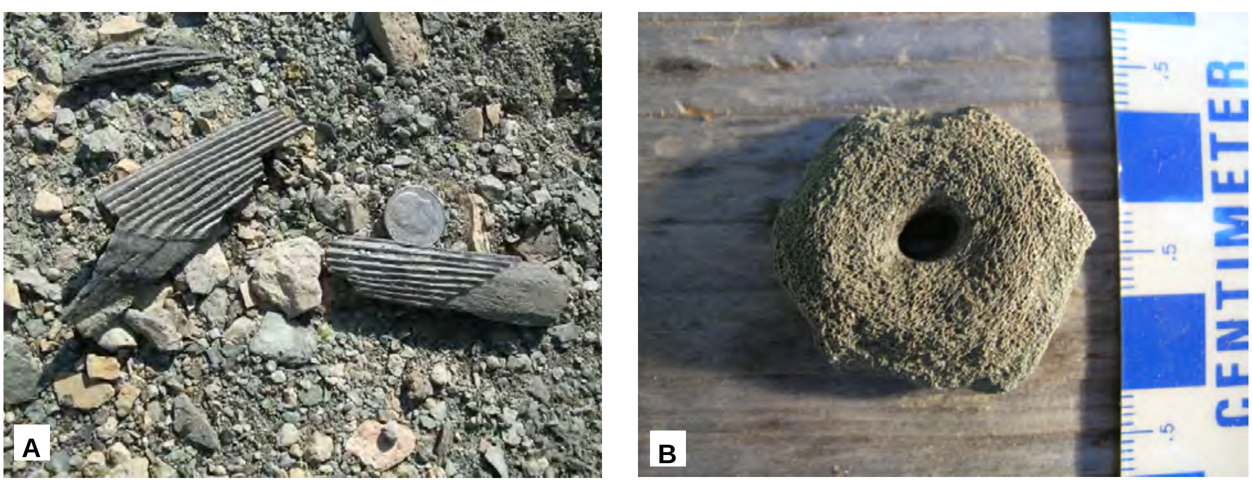

Figure 3. A – Large fragments of shark fin spines from Benwood limestone in road cut along OH Rt. 7 at Stop 1. B – Large boney vertebra from fish bone bed in Benwood Limestone at road cut along OH Rt. 7. Collected by Ed Fry, Geological Consultant.

Figure 4. The Mannington sandstone as seen up on the roadcut looking from the north end, showing the sand-filled channel and flanking sand deposits. Photo by Vik Skema.

The other bed prominently seen high in the cut is the Mannington Sandstone above the Waynesburg A coal bed (Figures 1 and 4). The cut intersects the channel system obliquely and the length of the cut provides an excellent opportunity to observe both the channel proper and the interfingering of the sand with the sediments of the flanking flood plain as the unit prograded (Figure 5). A thick-bedded, elongated belt of fluvially deposited sandstone occupies the same stratigraphic position in northeastern Washington County, Ohio where it is named the Leith Sandstone (Martin, 1998). Other thick deposits of the Mannington Sandstone are found in the subsurface in eastern Marshall County, West Virginia and in the southern part of the Dunkard Basin in West Virginia (see Cross Section A-A' on disk in this volume).

The Washington coal bed is the thickest exposed in the entire cut. The black shale roof is underlain by interbedded black shale and impure coal, typical for this coal (Figure 6). The *lingula* fossils have been found in the parting of the coal in this cut (see descriptions for Stops 2 and 4 for more details).

The strata above the Washington coal bed are difficult to access due to fewer benches and high, steep cut faces. What has been observed are the red beds between the Jollytown coal of Stevenson (1876) and the top of the Washington Formation which are fairly consistent basin-

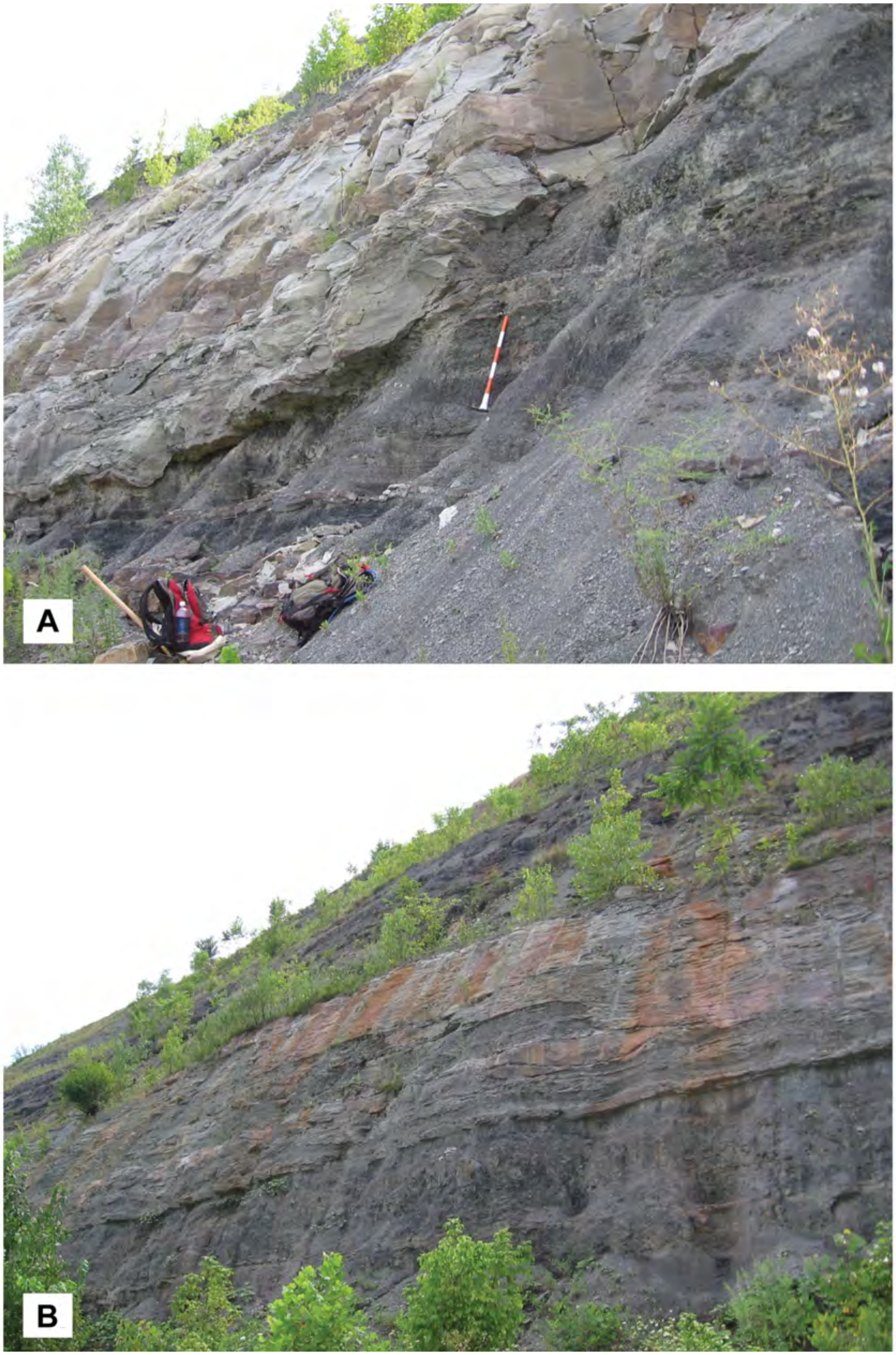

Figure 5. Stop 1, the Mannington Sandstone. A – Channel cut bank. Mattock for scale with 6 -inch alternating bands. B- Channel margin showing interfingering with flood plain deposits. Photos by Nick Fedorko.

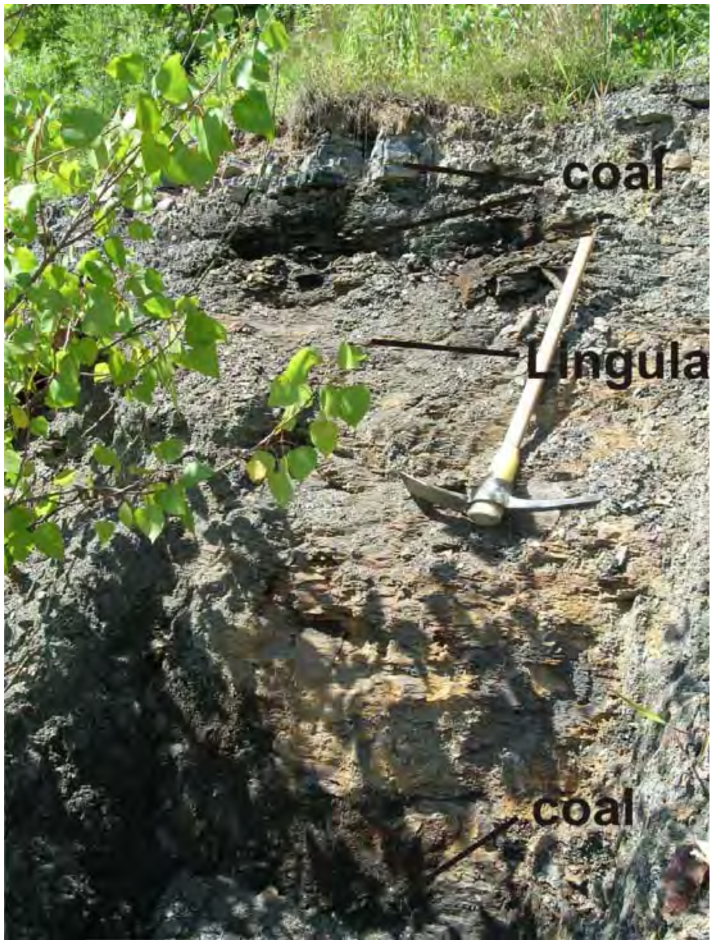

Figure 6. Washington coal exposed in the road cut on OH Rt. 7 at Stop 1. Mattock for scale is 3 feet long. Photo by Vik Skema.

wide (Figure 1 and see Cross Section A-A' on disk). The Jollytown coal of Stevenson (1876) was observed along a side road that starts at the level of Ohio Rt.7 at the north end of the cut, ascends a small stream valley, and leads to the top of the cut.

Our next stop at Roberts Ridge Road on the West Virginia side of the Ohio River about 4.3 km (2.7 mi) east-northeast of here will provide an opportunity to closely examine the Dunkard Group rocks from the Waynesburg coal to about 12 m (40 ft) above the Jollytown coal of Stevenson (1876).

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STOP 2: ROBERTS RIDGE ROAD SECTION—STRATIGRAPHIC AND PALEONTOLOGIC FEATURES OF THE WAYNESBURG AND WASHINGTON FORMATIONS

Leaders – Vik Skema and Bill DiMichele

INTRODUCTION

Roberts Ridge Road traverses the steep wall of the Ohio River Valley just south of Moundsville, WV, revealing 300 ft (91 m) of nearly continuous exposure of the lower Dunkard Group (Figure 1). Road cuts along the twisting, winding road provide an excellent opportunity to examine the Waynesburg Formation and most of the Washington Formation in great detail (Figures 2 and 3). The Waynesburg and Washington coals are the two predominant coals in the Dunkard and define the base of the two lower-most formations named after the coals (Berryhill and Swanson, 1962; Edmunds, 1999). These coals are often split by siliciclastic fluvial deposits in this part of the basin. One of these splits, the 7 ft (2 m) thick clay shale parting in the Washington coal complex, contains a thin layer of *Lingula* brachiopod fossils. This marks the last known Paleozoic marine transgression into the Appalachian basin and the only indisputable evidence of sea water incursion in 1,750 ft (533 m) of strata from just above the Ames marine limestone of the Conemaugh Group to the top of Dunkard Group strata. The section here is fine grained and does not have prominent sandstone. Limestones are present throughout the lower half of the section exposed along Roberts Ridge Road and often in close proximity to the coals, occurring both below and above coals. A noticeable change occurs in the section here and throughout the northern region of the Dunkard basin, beginning in the lower to middle part of

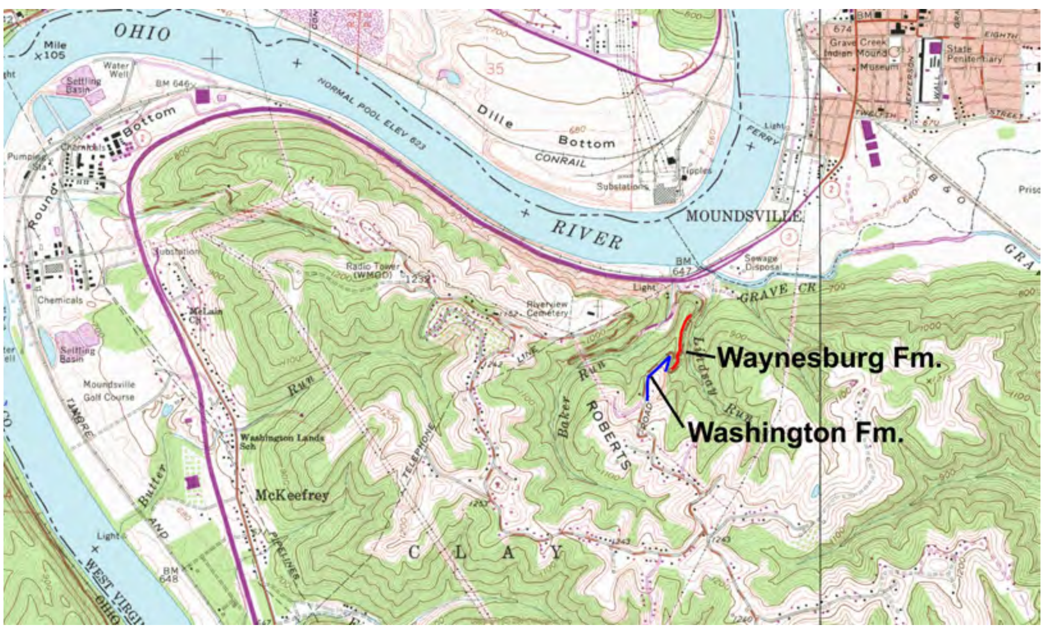

Figure 1. Location of Stop 2 along Roberts Ridge Road, south of Moundsville, WV. Colored lines indicate road cut exposures of Waynesburg Formation and all but the upper-most Washington Formation.

Skema, V. and DiMichele, W. A., 2011, Stop 2: Roberts Ridge Road section—stratigraphic and paleontologic features of the Waynesburg and Washington formations, *in* Harper, J. A., ed., Geology of the Pennsylvanian-Permian in the Dunkard basin. Guidebook, 76th Annual Field Conference of Pennsylvania Geologists, Washington, PA, p. 264-280.

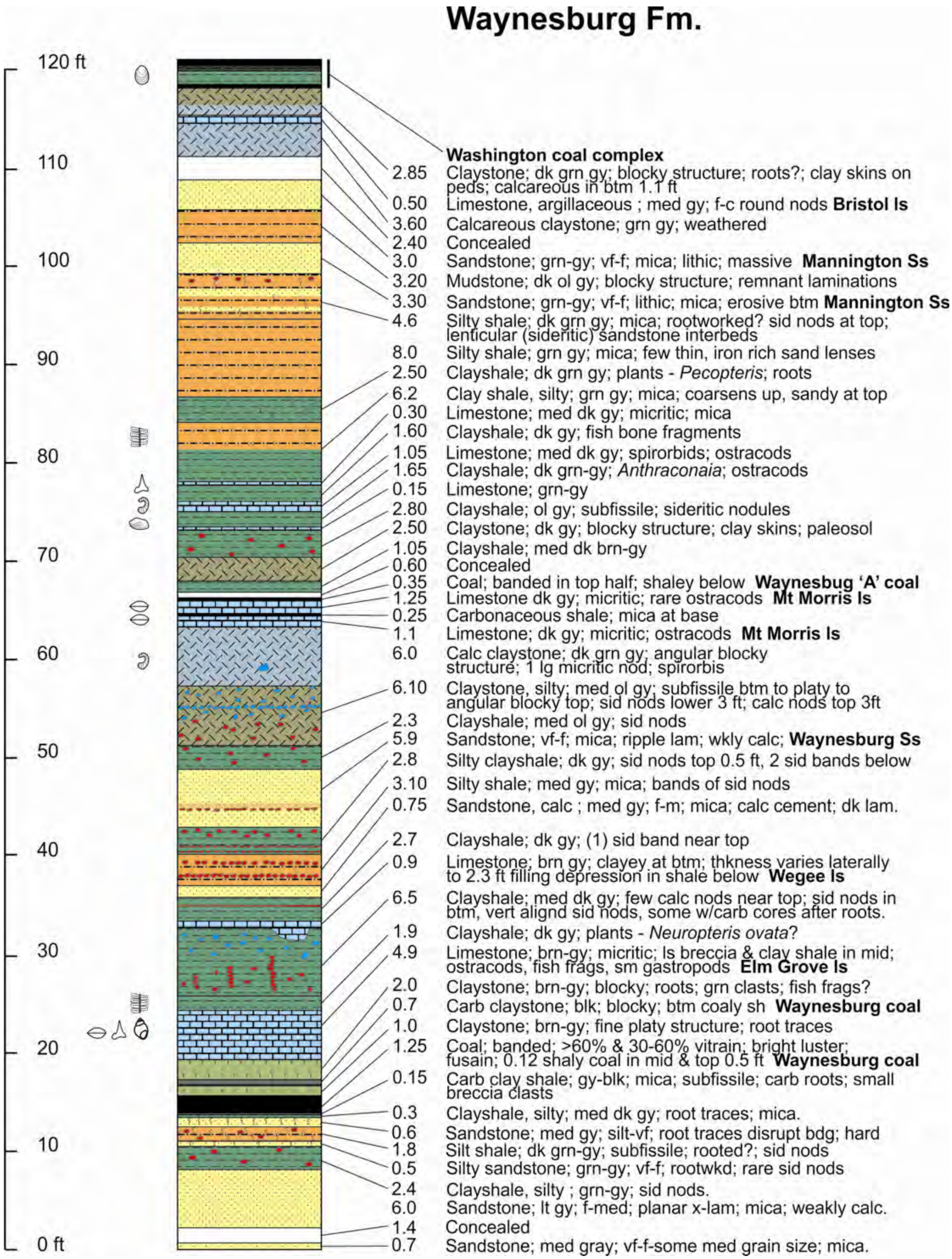

Figure 2. Graphic log of measured section of the Waynesburg Formation. Measured and described by Vik Skema and Nick Fedorko.

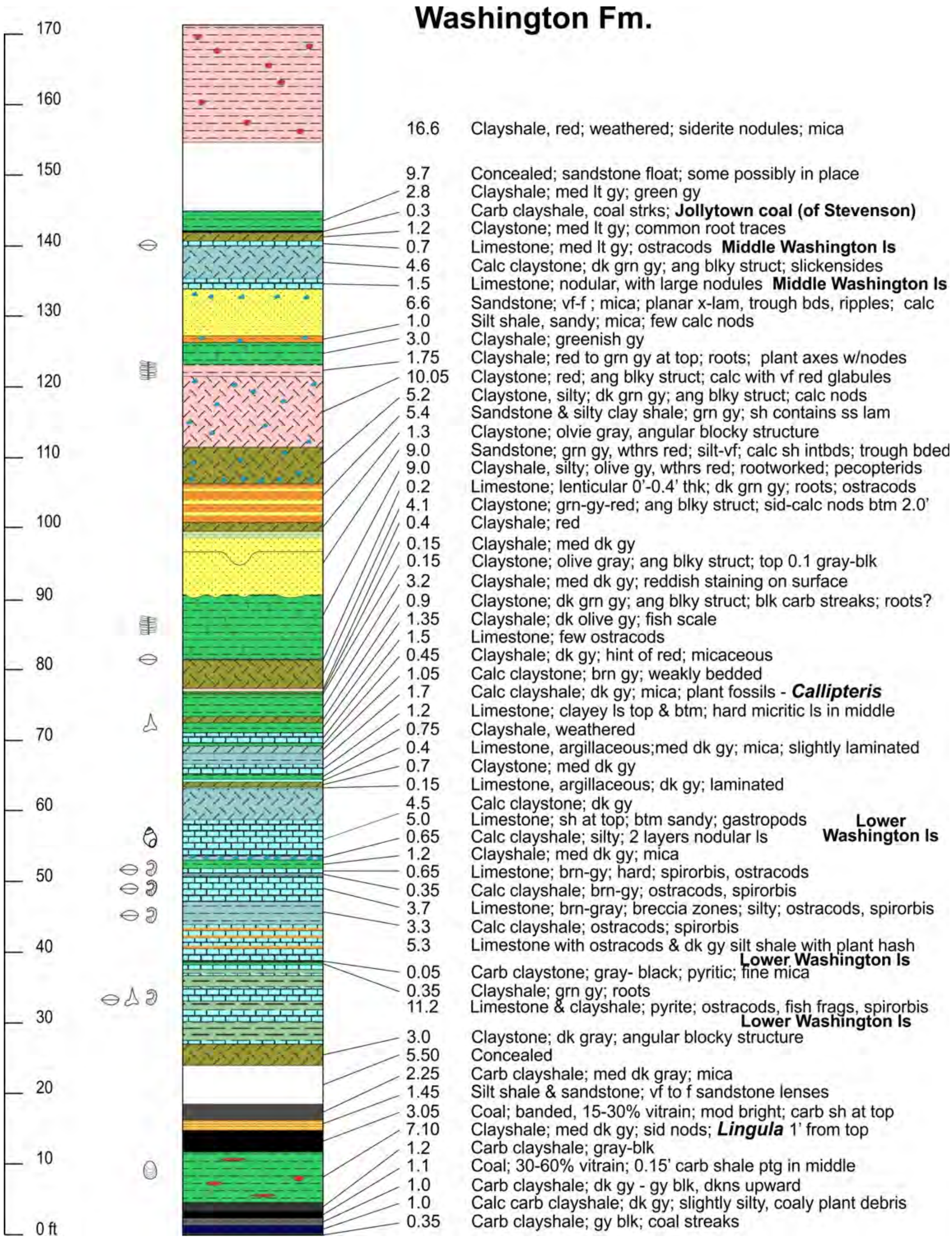

Figure 3. Graphic log of measured section of the Washington Formation. Measured and described by Vik Skema and Nick Fedorko.

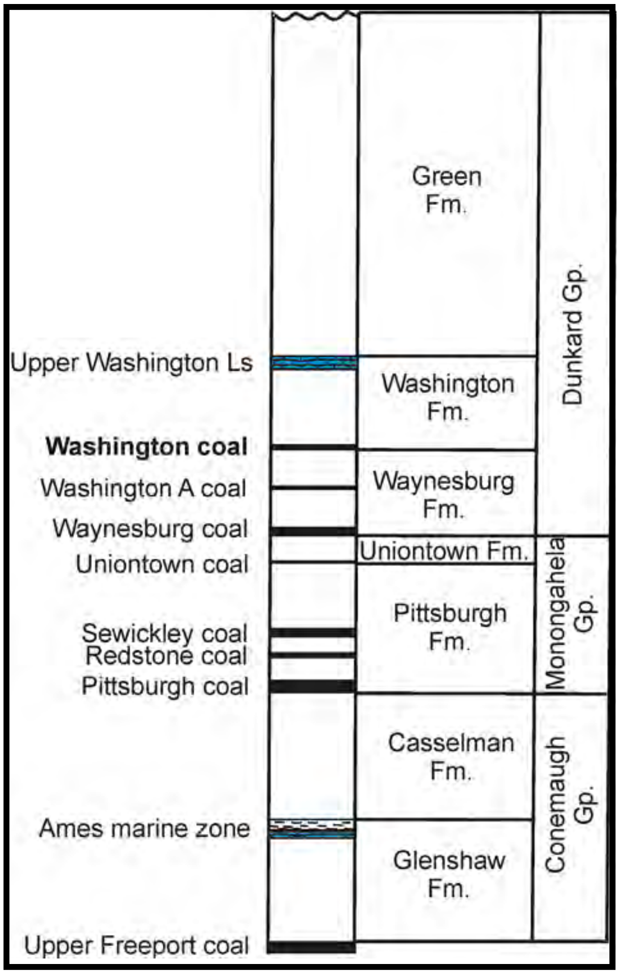

Figure 4. Stratigraphic column showing major coals and a few other key beds of the Upper Pennsylvanian and Lower Permian.

the Washington Formation: 1) varying degrees of red coloration appear; 2) coal beds become much thinner and often degrade to carbonaceous shales; 3) concretionary carbonate mineralogy becomes nearly exclusively calcareous, unlike in the Waynesburg Formation below, where both sideritic and calcareous concretions are common; and 4) the character of the plant assemblages changes subtly but significantly with the first appearance of callipterids, a type of seed-producing plant common in the Permian (but known as early as late Middle Pennsylvanian), though the background flora remains much the same as in the Waynesburg Formation.

COALS

The distribution of coal beds in the Dunkard Group is similar to that of the Monongahela Group below (Figure 4). Coals are thicker, better developed, and more widespread in the lower part of both groups, and become much thinner, clay-rich, and discontinuous upward. The lowest three coals of the Dunkard Group, the Waynesburg, Washington, and locally, marginally thick Waynesburg A, are the best developed. The Waynesburg coal and, to a greater degree, the Washington coal have relatively high ash and sulfur content and are split into coal complexes containing multiple benches of coal separated by thick partings. They are economically much inferior to the Pittsburgh, Sewickley, and locally thick Redstone coals of the lower Monongahela Group. The Washington coal complex is the last of the thick coals. Coals above are all thin, many are no more than a very thin concentrated accumulation of carbonaceous material in gray clay.

The Waynesburg coal near the base of the Roberts Ridge Road section is split into two benches of coal separated by 1 ft (0.3 m) of light brownish gray claystone that contains subvertical root traces. There is very little coal here. Only the bottom bench contains coal, which is a little more than 1 ft (0.3 m) of banded coal split by a thin shaley parting. The top bench is dull coaly shale with thin vitrain bands. The thick parting separating the two benches appears to be widespread eastward. In places along the eastern outcrop belt, where the Waynesburg coal is thick enough to mine, it also contains two main benches of coal separated by 1ft (0.3 m) of claystone, but locally is split into three benches, having a third thinner bench of coal at the top. The multi-benched character of the Waynesburg coal changes abruptly across the Ohio River in Belmont County, OH. The thin upper bench seen at Roberts Ridge disappears, leaving a single bed of coal everywhere that varies in thickness from less than 14 in

(36 cm) to a maximum of 60 in (152 cm) (Berryhill, 1963). Thick coal is limited to a narrow north-south oriented pod of greater than 42 in (107 cm) in the north-central part of the county. This single bed of Waynesburg coal can be traced from Belmont County northeastward through the Wheeling area and into the northern-most end of the basin in Pennsylvania.

Here at Stop 2 the Waynesburg coal is characteristically underlain by 14 ft (4.3 m) of subfissile shale and sandstone, and there is no paleosol or nonmarine limestone evident in that interval. The section below the sandstone under the Waynesburg coal is covered by colluvium, but where this section is exposed, the Little Waynesburg coal horizon is positioned 4 to 18 ft (1.2 to 5.5 m) below the Waynesburg coal throughout the northern region, and is always similarly separated from the Waynesburg by bedded shale and sandstone. The Little Waynesburg coal bed is often impure, thin, and in places laterally grades into carbonaceous shale. It is usually underlain by the nonmarine “Waynesburg” limestone. The strata between coal benches of the Waynesburg coal and the intervening strata between the Waynesburg coal and the Little Waynesburg coal are relatively undisturbed. There is very little evidence of pedogenesis or bioturbation, with the exception of root traces commonly found in the Waynesburg coal parting and to a lesser degree in the shale underlying the coal. It could be argued that the Little Waynesburg coal, the Waynesburg coal, and all intervening strata are part of a single coal complex deposited in a planar peat swamp that was periodically flooded from an adjacent river system. This coal complex could be considered to be a single coal sequence at the base of a cyclothem (see discussion of depositional environment in Cecil et al., 2011, and discussion of stratigraphy in Fedorko and Skema, 2011). The U.S. Geological Survey did detailed quadrangle mapping in the 1960s in 16 quadrangles in southwestern Pennsylvania, thoroughly examining much of the northern portion of the Dunkard Group strata. The general geologic section for the map of the Midway quadrangle in the northern end of the basin (Figure 5, taken from Roen, 1973) provides a good example of the character of the Waynesburg coal complex.

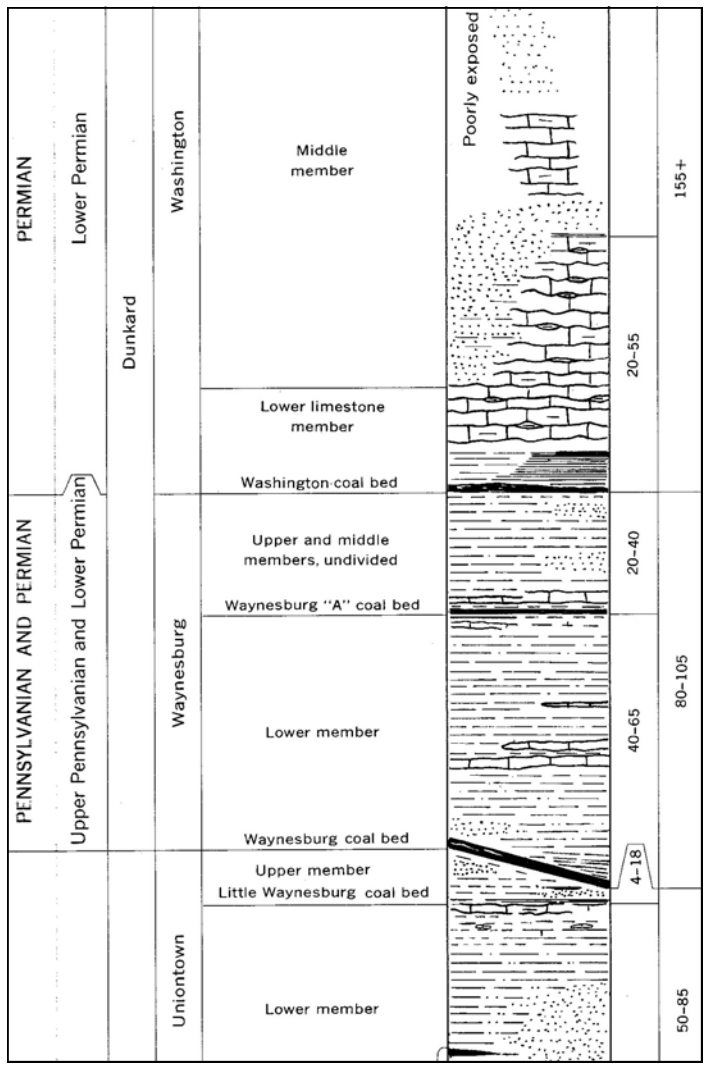

Figure 5. Generalized Stratigraphic Section from geologic map of the Midway Quadrangle in Washington County, PA (from Roen, 1973) illustrating the character of the split between the Waynesburg and Little Waynesburg coals.

Other major coals in the Monongahela Group, and the

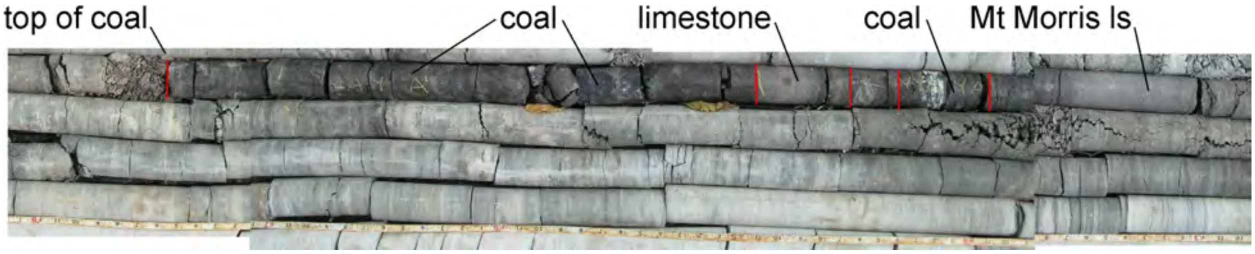

Figure 6. Limestone parting in Waynesburg A coal from core recovered from Foundation Coal Co. drill hole in the Holbrook Quadrangle of Greene County, PA.

Washington coal of the Dunkard Group, share this characteristic of extensive splitting and could be considered to be coal complexes. In Central Greene County the Sewickley coal is split into two benches separated by 15 ft (4.6 m) or more of sandstone and or sandy shale. The Washington coal has a clay shale split here at Stop 2, but to the southeast the split becomes silty, and farther east in Greene County, PA and parts of Washington County the coal splits into 3 to 4 coal horizons separated by silt shale and/or sandstone by a maximum of 36 ft (11 m) (see Stop 4 description). In all instances, this complex of split coals is bounded by a well developed paleosol beneath it, which in turn is underlain by a nonmarine limestone. It seems that distance between coal seams within the complex and the coarseness of intervening sediments are the only criteria for stratigraphic identification. At Roberts Ridge, in the big cut across the Ohio River (Stop 1), and at Rosbys Rock (Stop 4), the two coals are separated by 8.3 to 10 ft (2.5 to 3 m) of shale, and have been identified as splits of the Washington coal. Where the split exceeds 10 ft (3 m), and especially if the contained sediment becomes sandy, the lower coal has been identifyed as the Little Washington coal, representing an earlier occurrence of peat deposition. The character of the surrounding strata, the paleosol and limestone, seems to be disregarded in the processes of stratigraphic identification.

The Waynesburg A coal at Roberts Ridge is only 0.35 ft (0.1 m) thick. In Greene and Washington County, PA, where it crops out on the eastern side of the basin, it is 1 to 3 ft (0.3 to 0.9 m) thick, and has been mined there in surface mines along with the thicker Waynesburg coal. The Waynesburg A typically is thin or absent in nearby Belmont County, OH. However, in the southeastern corner of the county, across the Ohio River and only 8 mi (13 km) to the southwest of Stop 2, the coal averages 28 in (71 cm) thick; in one locale it is uniformly 40 in (102 cm) thick and attains a maximum thickness of 55 in (140 cm) (Berryhill, 1963). Regionally, the Waynesburg A coal is very closely associated with limestone. It often sits directly on the Mount Morris limestone, as it does here at Roberts Ridge. It also can have limestone directly above it and, in places, relatively thick limestone partings within the coal. Berryhill (1963) reported a 10 in (25 cm) thick limestone parting in the coal in the same area of southwest Belmont Count where it is thickest. A similar limestone parting 0.7 ft (0.5 m) thick was seen by the author in core recovered from a coal exploration drill hole near Holbrook, Greene County, PA (Foundation Coal Co. hole drilled in 2008, Figure 6). The Waynesburg coal and closely overlying Elm Grove limestone at Roberts Ridge is another example of the close association of coal with limestone in the lower part of the Dunkard Group.

SANDSTONES

The road cuts along Roberts Ridge Road contain multiple, relatively thin sandstone beds that are generally very fine to fine grained, silty, micaceous, and have a combined thickness of

Figure 7. This 9 ft (2.7 m) thick sandstone in the middle Washington Formation is the thickest sandstone unit in the exposures along Roberts Ridge Road. It consists of two beds of sandstone and has a wavy, erosive bottom.

Figure 8. Upper bed of 9 ft (2.7 m) thick sandstone unit cuts down through lower bed and into underlying reddish shale along a narrow channel. Both units are rootworked, with bedding in the shale being extensively affected.

36 ft (11 m) (Figures 2 and 3). Grain size is slightly coarser in a very few sandstones, which contain some medium size grains: 1) in portions of the sandstone below the Waynesburg coal at the base of the section; and 2) in a thin calcareous sandstone just above the Wegee limestone. The thickest individual sandstone is only 9 feet (2.7 M) thick and is situated in the middle of the Washington Formation just above the thick sequence of limestones at the bottom of the formation. It is trough bedded, very fine grained, micaceous, greenish gray (with red mottling on weathered surfaces), silty sandstone that has a wavy, erosive bottom (Figure 7). This sandstone consists of two nested fluvial channels, with the upper one having a narrow, conspicuous, down-cutting segment (Figure 8), but otherwise being flat bottomed (Figure 7). Most of the other, thinner sandstones in these road cuts are planar bedded, silty, occasionally contain ripple marks and laminations, and their beds are often disturbed by varying degrees of root penetration. Similar thin, fine grained sandstone are typical in this area and in the northern part of the basin. They may be the products of flood plain deposition adjacent to fluvial systems, and possibly also of deltas prograding into lacustrine standing-water systems deposited as river mouth bars (Cecil et al., 2011, and Stop 9 description). Thick, coarse sandstone deposits associated with fluvial channels of major river systems are not nearly as plentiful.

The thickest sandstone deposit in the Dunkard Group is found near the base of the Waynesburg Formation. This sandstone, commonly referred to as the Waynesburg sandstone, is best developed in several elongated, north–south oriented belts. Geologists who work in this part of the section in Pennsylvania are usually most familiar with the sandstone along its outcrop on the northeastern edge of the basin, where it is conspicuously thick and positioned directly above minable Waynesburg coal. This approximately 10 mi (16 km) wide belt of thick Waynesburg sandstone (also referred as the Mather Sandstone Lentil, Martin, 1998) can be traced from southwest of Morgantown, WV to southeastern Washington County, PA (Figure

9). It attains a maximum thickness of 100 ft (30.5 m) (Figure 10). Its geometry, bed forms, thickness, composition, and other features indicate deposition in a major north-flowing fluvial channel system. The coarse grain size of sandstone within this belt is exceptional when compared with the majority of normally fine grained sandstones encountered in the basin. Other belts of thick sandstone, coeval to the Waynesburg sandstone have been reported, especially in the southern part of the basin where thick, blocky sandstones having elongated belt forms are prevalent at about the same horizon. Foremost of these, because it has been extensively studied, is the Hockingport Sandstone Lentil in the southwestern part of the basin in Ohio (Martin, 1998). The Waynesburg sandstone is also well developed in western Belmont County, OH, to the west of Stop 2 where it is moderately thick, having a maximum thickness of 40 ft (12 m) (Berryhill, 1963). Drill hole data show another thick deposit of Waynesburg sandstone in eastern Marshall County, WV, approximately 16 mi (26 km) to the southeast of Stop 2 (see Fedorko Cross Section, 2011). This stratigraphic interval is very different along Roberts Ridge Road. The Waynesburg sandstone here consists of two relatively thin beds of micaceous, very fine to fine grained, ripple laminated sandstones (Figure 11). The thinner bottom bed fines upward and is very shaley at the top and contains a band of siderite nodules. The Waynesburg sandstone here is well above the Waynesburg coal and separated from it by shale and several lacustrine limestones, the Elm Grove and the Wegee.

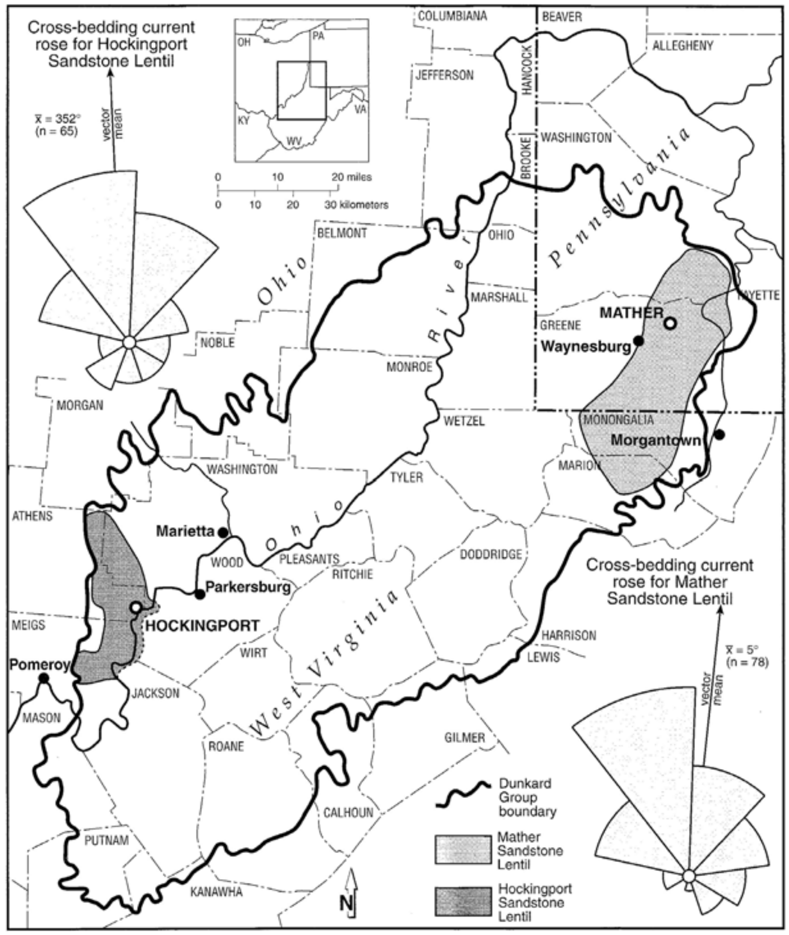

Figure 9. Map showing aerial distribution of two of the major thick-sandstone fluvial channel belts in the Dunkard Basin, with rose diagrams giving current direction. The trend in the thickest sandstone of the Mather Lentil is north-northeast, and that of the Hockingport Lentil is north-northwest (from Martin, 1998, p. 2, fig. 1).

The average sandstone composition for the Dunkard Group, as determined by Martin and Lorenz (1972) by combining compositional data of their own with those from various other studies, includes 63.5% quartz, 3.1% feldspar, 5.5% detrital mica (including both biotite and muscovite), and approximately 21% matrix, with rock fragments (pelitic sedimentary and micaceous metamorphic at 3.5%; and metaquartzite grains at about 7%) exceeding feldspar content (Martin, 1998). This composition plots as lithic greywacke or "dirty" lithic arenite on a QFL classification diagram. Megascopic examination of the sandstones on Roberts Ridge Road

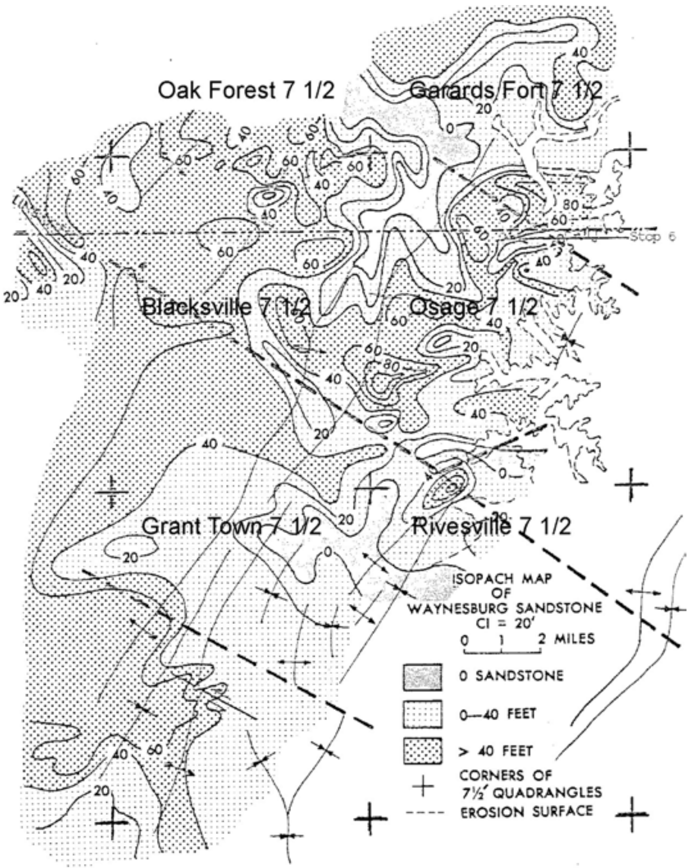

Figure 10. Isopach map of Waynesburg sandstone thickness in Mather Lentil northwest of Morgantown, WV. Thickness in the lentil is typically >40 ft (>12 m) and attains maximum thickness of 100 ft (31 m) (from Donaldson et al., 1979, p. 70, fig. 55)

certainly bears out the characterization of the typical Dunkard Group sandstone as being "dirty". The Dunkard Group sandstones, when compared to sandstones in the older, Middle Pennsylvanian, show noticeably less mineralogical maturation. Chemically unstable minerals such as biotite and feldspar are essentially not present in the older Pottsville and lower Allegheny Group sandstones, whereas in the Dunkard Group sandstones biotite is conspicuously present and plagioclase and orthoclase feldspars are noticeable. The difference probably reflects minimal chemical weathering in response to climatic dryness and to a lesser extent increasingly closer proximity to an expanding source area.

LIMESTONES

Limestones are a major component of Dunkard Group strata, but only in the northern to northwestern portion of the basin (Figure 12). Stratigraphically, limestones are concentrated in the Washington Formation, but appreciably increase in the Waynesburg Formation to the northwest. The extreme northern end of the basin contains the most limestone (see Figure 12 in Fedorko and Skema, 2011). There, continuous limestone units >30 ft (>9 m) thick are common and comprise most of the Washington Formation. Stratigraphically younger limestones are much thinner, but those in the middle to upper Greene Formation appear to be widespread, extending much farther south than the older, thicker Washington and Waynesburg Formation limestones. Individual beds of limestone range in thickness from a small fraction of 1 ft (0.3 m) to slightly more than 3 ft (0.9 m) and average about 1 ft (0.3 m). They are usually combined into thicker units of 2 to 25 individual beds that are separated by thin beds of claystone or shale. In the

Figure 11. Waynesburg sandstone ledge along Roberts Ridge Road. Wegee limestone at bottom in foreground.

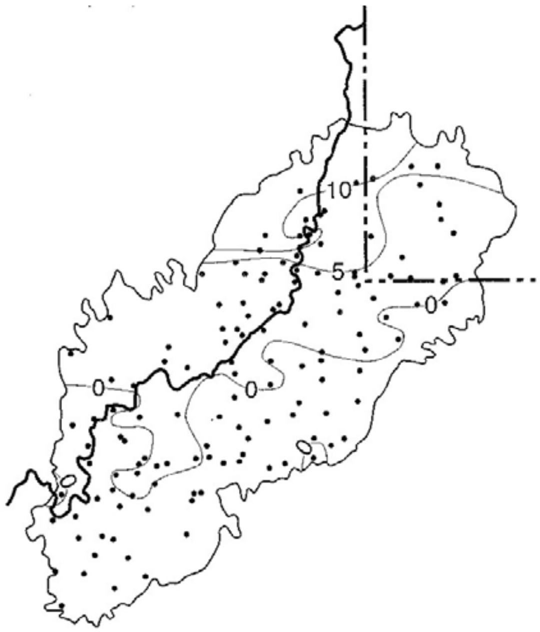

Figure 12. Contoured lithofacies-distribution map showing number of limestones per 60 meters (from Martin, 1998, p. 8)

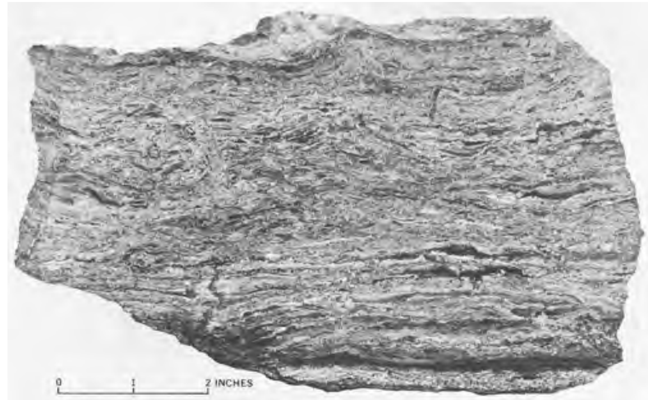

Figure 13. Laminated limestone containing irregular lenses probably formed by algae mats (from Berryhill et al., p. 12, fig. 9).

Figure 14. Interlaminated calcareous carbonaceous shale composed of irregular laminations of limestone formed by growth of algal mats and shale laminae containing abundant coaly plant material. This sample was collected from transitional zone between a thin limestone and a coaly shale in the Lower Washington Limestone Member of the Washington Formation at Browns Bridge, east of Blacksville, WV.

northern end of the basin these units are as much as 70 ft (21 m) thick (Berryhill et al., 1971). The limestones are mostly micritic, carbonate-mud rich wackestones that contain abundant nonmarine ostracodes, along with lesser amounts of a limited suite of other fossils. These include spirorbid worm tubes, very small gastropods, the fresh-water bivalve *Anthraconaia*, and fragmented vertebrate remains (mostly fish, but also occasionally amphibians). Algal material is also preserved in these limestones and associated rocks (Figures 13 and 14). They also often contain carbonate peloids that are suggestive of being bacterially formed in the photic zone of shallow water (Montanez, 2011). Trace to moderate amounts of siliciclastic clay and silt sized particles of mostly biotite mica are also present. They are laminated to varying degrees (Figure 15). However, desiccation features often disrupt bedding. Desiccation cracks, breccias, and conglomerate indicative of sub-aerial exposure and pedogenic processes can be found in nearly every limestone unit. In the thicker limestone units of the north, upper portions of individual beds are often conglomeratic (Figure 16). As the beds thin to the south and upward in the section, desiccation features become more pervasive with many beds being entirely affected.

A limited sampling and thin section analysis of the easily accessible major limestones representative of the entire Dunkard Group provided a sense of their changing character through time. These included samples from the Elm Grove, Mount Morris, and Lower Washington

Figure 15. Irregular laminations of ostracode-rich limestone. Large fish tooth near top of photo (from Berryhill et al., p. 13, fig. 10).

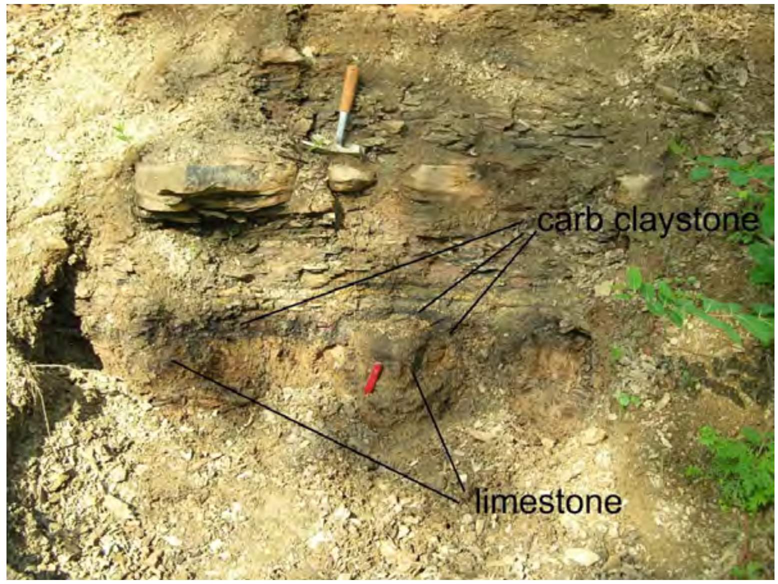

Figure 16. Sketch showing typical sequence of breccia conglomerate deposition in limestone beds of the Dunkard Group (from Berryhill et al., p. 15, fig. 13). Laminated micritic limestone (1) is desiccated and eroded; the product of this process, limestone breccia conglomerate in a silty micritic matrix (2), is deposited on the original bed; additional sub-aerial exposure forms desiccation cracks, which fill with more breccia conglomerate (3). The irregular shaped carbonaceous claystone may have formed during a wetter interlude of plant growth within this sequence of desiccation events. Some of these carbonaceous layers developed into thin, clay rich coals, especially in the Lower Washington and Mount Morris limestones.

limestones on Roberts Ridge Road. These three were somewhat laminated, containing ostracod shell layers, and peloidal, indicating deposition in relatively shallow water. The middle to upper Greene Formation limestones examined were muddier, appeared to be generally more laminated, contained more articulated ostracode shells, had fewer bacterially formed peloids, all attributable to possibly deeper water. Yet, the limestones also showed evidence of increased vadose zone diagenesis, indicating increased time of burial above the water table (Montanez, UC Davis, personal commun., 2011). Montanez attributed this to possibly wider fluctuation of water table level resulting from greater fluctuations between wet and dry extremes. The southward lobe of the zero line in the southern part of the basin on the map showing distribution and quantity of limestones (Figure 12) is strictly due to the presence of middle to upper Greene Formation limestones. There are no limestones in the Washington or Waynesburg Formation that far south. This apparently much greater extent of limestones, ones having possible deeper water characteristics, in the upper part of Dunkard Group strata is additional evidence suggesting a climatic shift to wetter extreme in the ongoing wet dry cycle.

Limestones are plentiful in the Roberts Ridge Road exposures. All of the Waynesburg Formation limestones can be seen here. The lower Washington Formation contains much limestone. Only the middle member of the Washington Formation lacks the limestone typically found to the north. There is an excellent exposure of the Elm Grove limestone just above the Waynesburg coal. It is composed of three beds, as it is in its type section at Elm Grove, WV. Its total thickness is 5 ft (1.5 m). The lower bed is 1.5 ft (0.5 m) thick and massive except for a thin

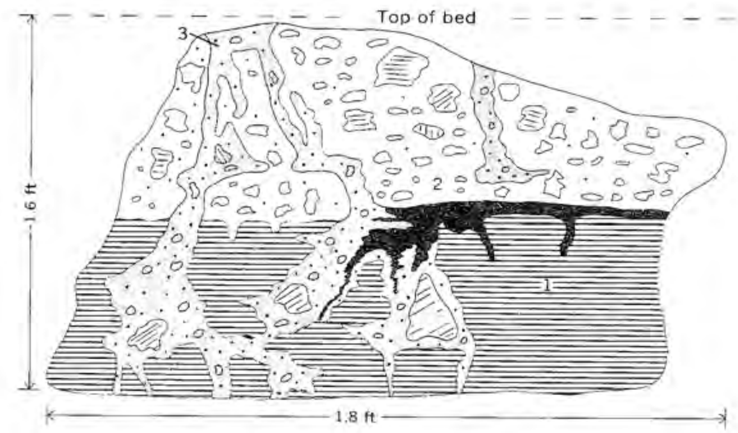

Figure 17. Irregular shaped coaly carbonaceous claystone in the Upper Rockport limestone sequence of the Greene Formation. The exposure is at Stop 9 along Greathouse road near Wileyville, WV.

laminated basal portion. The middle bed is 0.55 ft (0.17 m) thick, interbedded with calcareous clay shale, and contains abundant fossils, including fish scales and teeth, ostracodes, high spired gastropods, spirorbid worm tubes, and possible bivalve shell fragments. Both lower and middle beds contain micritic peloids. The upper bed is 2.4 ft (0.7 m) thick and laminated. It contains thin silty laminae and weathers bluish gray (Berryhill, 1963). Unlike the lower two beds that weather rapidly, the upper bed is resistant and forms a distinctive ledge. Ostracodes are common in the upper bed.

The Mount Morris limestone directly under the thin Waynesburg A coal is 2.6 ft (0.8 m) thick on Roberts Ridge Road and includes a thin black carbonaceous shale parting near its middle. The limestone above the parting also contains numerous brownish black laminations; some are wavy. Carbonaceous, clay rich laminae and irregular shaped lenses are not uncommon in the limestones of the Dunkard Group (Figure 16 and 17). Some grade locally into thicker, shaley coals. This seems to occur particularly more often in the Mount Morris limestone directly below the Waynesburg A coal and also in the upper part of the Lower Washington limestone. Ostracodes are present throughout the limestone.

There is single bed of very nodular limestone in the middle of the Washington Formation positioned 6.5 ft (1.9 m) below the Jollytown coal (of Stevenson; see Fedorko and Skema, 2011, fig. 12). It contains abundant micritic peloids. The matrix is micaceous with both biotite and muscovite present, and appears to be slightly gritty with possibly fine silt size quartz. Sparry calcite fills cracks and small voids. A few have oval to thin crescent shape, and look vaguely like shell material, but are too cryptic to be identified with any confidence. Fractured surfaces contain what appears to be vadose zone mineralization, small patches of calcite with dripstone texture. A dark yellowish orange secondary mineralization deposited in a network of spidery lines and connected, irregular shaped blebs saturate much of the rock (Figure 18). This limestone is probably the extensively desiccated thin edge of the much thicker deposit of Middle Washington limestone found to the northeast in Pennsylvania (see Fedorko and Skema, 2011, fig. 12).

There is a pronounced stratigraphic change in the distribution of concretionary

Figure 18. Extensively desiccated nodular limestone at the Middle Washington limestone horizon 6.5 ft (2 m) below the Jollytown coal (of Stevenson).

Figure 19. Vertical alignment of siderite nodules in the shale below the Wegee limestone in the lower part of the Waynesburg Formation suggestive of concretionary accumulation along a root system.

carbonates at Roberts Ridge Road. Both siderite nodules and calcareous concretions are common in the Waynesburg Formation and in the thick clay shale parting of the Washington coal at the base of the Washington Formation (Figures 1 and 2). Concretions above the Washington coal are nearly entirely calcareous except for a few siderite nodules in the red shale at the very top of the exposures. The lower half of the shale below the Wegee limestone in the Waynesburg Formation has an interesting vertical arrangement of siderite nodules that appear to have developed along a set of deep roots, some as much as 3 ft (0.9 m) long (Figure 19).

LINGULA BRACHIOPODS IN THE WASHINGTON COAL COMPLEX

One of the more interesting features of the Roberts Ridge Road exposures is the presence of small linguloid brachiopods in a thin layer of the 7 ft (2 m) thick clay shale parting of the Washington coal complex (Figure 20). Stauffer and Schroyer (1920) were the first to describe the fossil in their report on the Dunkard Series of Ohio. They found the fossil in "the black shales associated with the Washington coal" at one locality near Crabapple, in southern Belmont County, OH and named it *Lingula permiana.* Berryhill did a more systematic search for the fossil while mapping Belmont County, and he reported finding it at 17 other locations (Berryhill, 1963). He also found the bivalve *Myalina* with the *Lingula* in a few of the collecting locations. None have been found here at the Roberts RidgeRoad site. Berryhill reports that the linguloid fossils in Belmont County are found only in clay shale and in the siderite nodules associated with the shale. This appears to be the case on the West Virginia side of the Ohio River also. They are absent from the Washington coal parting where it coarsens to a silt shale 5 mi (8 km) to the southeast of this location at Rosbys Rock (Stop 4). Linguloid shells were found in a road cut exposure of the Washington coal along the eastbound lanes of I-470 in West Virginia

Figure 20. *Lingula* shells from a thin zone near the top of the clay shale parting in the Washington coal at Roberts Ridge.

east of the Exit 2 entrance ramp. The shells there were broken and possibly transported to this locale, implying that this site was at the eastern or northern limit. *Lingula* fossils have not been found anywhere in Pennsylvania. The multi-benched Washington coal complex becomes a single, thin coal southward in the Dunkard Basin, no more than a coaly shale in places, and no linguloid fossils or any other brackish water fossils have ever been found south of the Moundsville to New Martinsville area (Cross and Schemel, 1956) . It appears that *Lingula* may have lived in an embayment in the area of what is now the Ohio River. Its eastern margin would have been somewhere in the northern panhandle, and its southern terminus somewhere between New Martinsville and Moundsville. Western and northern limits have not been determined. But considering the apparent northward flow of rivers at this time, this may have been the landward end of an estuary opening to the sea located some distance to the north or northwest.

The *Lingula* fossils mark the last Paleozoic marine transgression into the Appalachians and are the only evidence of nearby marine conditions since a previous series of transgressions that occurred in the lower half of the Conemaugh Group of the Missourian (Kasimovian) Stage, approximately 7 My earlier (Edmunds, 1996). There are a few brief mentions in the literature (mostly guidebooks) of the possibility of other brackish-water fossils being found at other stratigraphic horizons of the Dunkard and Monongahela groups (Cross et al., 1950; Arkle, 1959; Cross, 1975; Martin, 1998). These horizons include the shale above the Jollytown coal and the shales above the Washington coal in the Washington Formation; the Elm Grove limestone in the Waynesburg Formation; and a shale below the Uniontown coal near the top of the Monongahela Group. An attempt was made to confirm these identifications, and only fresh water fossils were found in each case. In one example, the guidebook for a 1950 field trip reports finding orbiculoid brachiopods directly above the Jollytown coal (of Stevenson) in a road cut near Powhatan Point, OH in southernmost Belmont County (Cross et al., 1950, p. 65). Only conchostracans (bivalve crustaceans) were found in an examination of the exposure. Tasch (1975) reported finding *Gabonestheria belmontella* at the same horizon in central Belmont County, OH. Crushed shells of *Gabonestheria*, with their prominent nipple-type spine on top of the shell, could be easily misidentified as Orbiculoidea, and this may be what happened. The *Lingula* bearing shale in the parting of the Washington coal and the Elm Grove limestone on Roberts Ridge Road were examined for the possible presence of conodonts and other microfossils. None were found in the Washington coal complex, and the Elm Grove limestone yielded only fish teeth and scales (Skema et al., 2011).

FOSSIL PLANTS

Fossil plants were found at two levels above the Washington coal in the section exposed on Robert's Ridge Road.

1. Wetland flora: A typical Dunkard wetland flora was found in buff siltstone immediately above the Lower (-Middle combined?) Washington limestone (Figure 21). The plants in this flora, preserved as ghostly impressions, are predominantly tree fern foliage of the genus *Pecopteris* sp., with small numbers of specimens attributable to the pteridosperm *Neuropteris* sp., ground-cover sphenopsid *Sphenophyllum* sp., and facultative pteridosperm vine *Pseudomariopteris* sp. The rocks in which these plants occur appear to have been pedogenically overprinted, destroying much of the bedding and contained fossil plant remains.

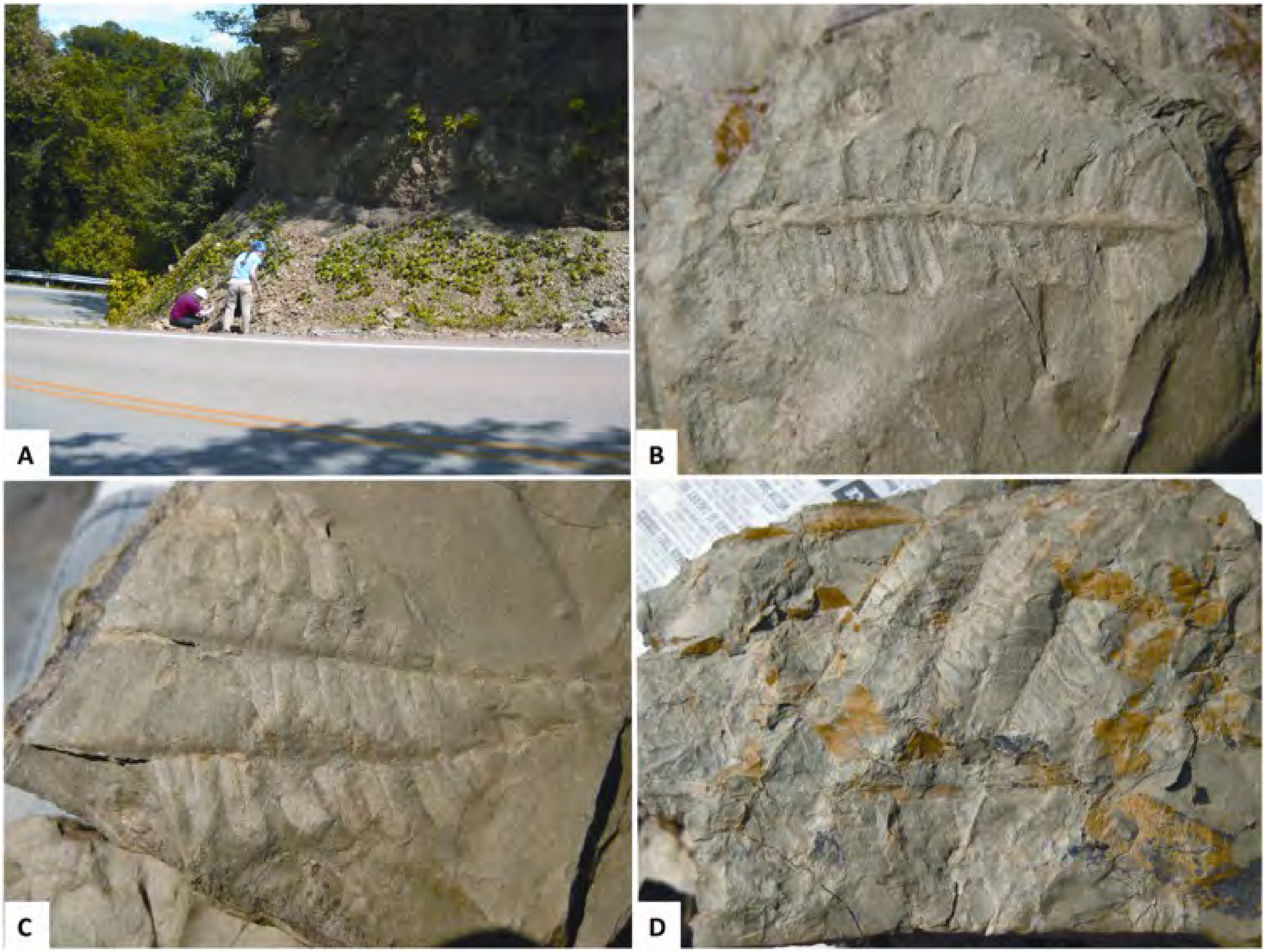

Figure 21. Plant collecting site on Robert's Ridge Road and examples of wetland flora from middle of Washington Formation. A. Location of plant collections. Poorly fissile, buff siltstone makes up most of the bank and spoils. Callipterid-bearing parting in Lower-Middle Washington Limestone is near the foot of the person to the left. B. *Pecopteris* tree fern foliage. C. *Neuropteris* sp., pteridosperm foliage. D. *Neuropteris* sp. pteridosperm foliage.

2. Seasonally-dry flora: In the uppermost part of the Lower (-Middle combined?) Washington Limestone, approximately 44 ft (13 m) above the top of the Washington coal, fossil plant material was found in a clastic interbed near the top of the limestone interval. In the upper part, miciritic limestone, carbonate rich mudstone, and mudstone are interbedded. Fragmentary plant material was identified in only one of these interbeds (visible primarily in the drainage ditch). The plant material identified in the field was very fragmentary and field identifications included the tree fern *Pecopteris* (which may be the most widespread and abundant Dunkard Group plant fossil), cordaitalean strap-like leaves, and callipterid foliage of the *Lodevia oxydata* or *Autunia naumannii* type.

The discovery of callipterid foliage at the Robert's Ridge Road site, in close association with nonmarine limestone, is consistent with the occurrence of these plants at some other sites, particularly the Brown's Bridge locality in Monongalia County, WV. At that location, well preserved callipterid foliage attributable to *Autunia conferta* and *Lodevia oxydata* (see DiMichele et al., 2011) occur in dark shales that also contain a fauna typical of nonmarine limestones (Tibert, 2011). This occurrence also reflects the known preferences of callipterid plants for seasonally-dry habitat conditions, which is consistent with proximity to settings in which nonmarine carbonates were being precipitated.

Search of clastic beds within the Washington limestones at this and other locations has failed to produce recognizable plant material of any kind, although organic debris is not uncommon in such clastic beds.

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STOP 3 AND LUNCH: GRAVE CREEK MOUND STATE PARK, MOUNDSVILLE, WV

Leaders: Jon Inners, Heather Cline, and Andrea Keller.

> *Grave Creek Mound is the pre-eminent archeological monument in West Virginia and the largest conical earth mound in the New World.*
>
> Hemmings, 1984, p. 3

Grave Creek Mound State Park consists of the historic topographic mound, the Delf Nonona Museum, and the surrounding grounds, all within the city of Moundsville (Figure 1). The Grave Creek Mound is the most prominent of a group of mounds and earthworks that once existed in the Grave Creek area in the decades preceding and following the American Revolution, and is apparently the only feature among the entire complex that survives (Figure 2). Most of these structures appear to have been built during the heyday of the Adena Culture of the Early Woodland Tradition ~2,300 to 2,100 years BP, but some may date from a later time.

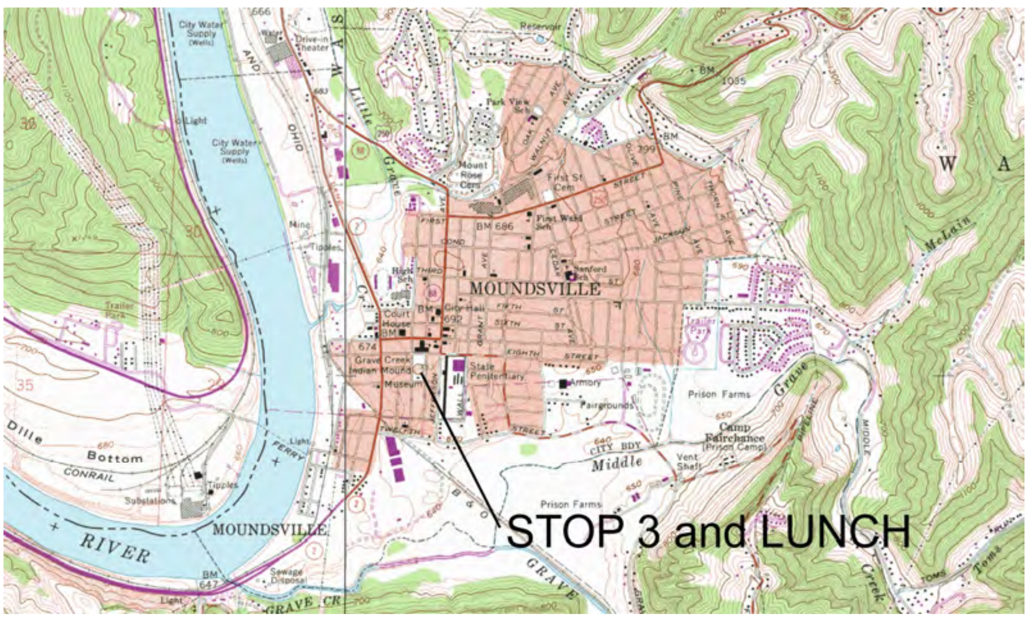

Figure 1. Location map for STOP 3 at Moundsville, WV.

ADENA CULTURE

The Adena homeland closely corresponded to the watershed of the Ohio River between Louisville, KY, and Pittsburgh, PA, and included significant parts of the states of Indiana, Ohio, Pennsylvania, West Virginia, and Kentucky. The Adena people had a relatively uniform tradition of building conical mounds of earth and stone. They were primarily hunters, gatherers, and collectors, but they appear to have cultivated, or selectively "encouraged", some

Inners, J. D., Cline, H., and Keller, A., 2011, Stop 3 and lunch: Grave Creek Mound State Park, Moundsville, WV, *in* Harper, J. A., ed., Geology of the Pennsylvanian-Permian in the Dunkard basin. Guidebook, 76th Annual Field Conference of Pennsylvania Geologists, Washington, PA, p. 281-289.

Figure 2. The Grave Creek Mound as it appears today. Trees have apparently been growing on the mound ever since its "abandonment" by the Adena people.

Figure 3. View north from the top of the mound, with the Moundsville Bottom, or Grave Creek Flats, of the Ohio River Valley in the near background, and the bordering hills underlain by Monongehela and Dunkard clastic rocks in the far background.

native plants, including sunflowers, goosefoot, beans, squash, and tobacco (Woodward and McDonald, 2001).

The northern part of the Adena cultural area lies north of the late Wisconsinan terminal moraine and possesses numerous ice-contact glacial features, including mound-like glacial kames. This area, and lands farther to the north extending into Michigan, had been the home of people of the immediately preceding late Archaic Glacial Kame Culture, who had utilized the easily dug, sand-and-gravel kames for the burial of their dead (Woodward and McDonald, 2001, p. 20-22). The building of artificial burial mounds by the Early Woodland Adena Indians is a logical step forward from this late Archaic practice of interment in natural "mounds," particularly in areas to the south beyond the late Wisconsinan glacial border.

GEOLOGY

The geomorphology and surficial geology of the State Park area and their relationship to the Grave Creek Mound are well described in Hemmings (1984, p. 5, 8; see Figure 3):

> Moundsville Bottom, known historically as the Grave Creek Flats, was the physical and cultural arena of the remarkable Adena climax in the Upper Ohio Valley. This large bottom, some 2,000 acres in extent, is hemmed in by rugged hills of Monongahela and Dunkard sandstones, limestone, shale, and coal (Hennen, 1909; Carlston and Graef, 1956). A series of Quaternary alluvial terraces extends about 3.5 miles along the river and 1.5 miles eastward. The alluvial fill exceeds 100 feet in thickness, and was emplaced as glacio-fluvial and fluvial deposits within a prominent abandoned meander. Little Grave, Middle Grave, and Grave Creek drain Moundsville Bottom and have deposited additional localized terrace sediments.
>
> A generalized geological map of this region distinguishes four terraces or sets of terraces, referred to as Lower, Intermediate, Upper, and Highest Terraces (Cross and Schemel, 1956). The last mentioned, high elevation, very old terrace

deposits are not known to occur at Moundsville. The Upper Terrace surface, 80 or more feet above normal river stage, was the site of Adena earthwork construction, and conferred definite advantages for such activity. This surface, for example has never been overflowed in historic times. The absence of flood risk was clearly known to Adena builders at Grave Creek, as it was to their counterparts elsewhere in the Central and Upper Ohio Valley. Furthermore, Upper Terrace areas giving only a slight advantage in favored building sites. Grave Creek Mound occupies one such site near the inner edge of an Upper Terrace surface.

…[T]he Wheeling Series of sandy and silty loams characterize the Upper Terraces (Caine, et. al., 1909; Beverage and Patton, 1960). The Wheeling soils are easily dug, provide good drainage, and have low susceptibility to slippage, all properties of some importance to earth construction.

CONSTRUCTION

Building of the Grave Creek Mound took place in successive stages from about 300 BC to 100 BC (2300 to 2100 BP), as indicated by multiple burials at different levels with the structure. The mound was originally ~69 ft (21 m) high, ~240 ft (73 m) in diameter, and surrounded by a waterless "moat" ~40 ft (12 m) wide, 4 to 5 ft (1.2 to 1.5 m) deep, and 910 ft (277 m) in length when measured at the midline. It appears to have been constructed in two major phases, the beginning of each phase being marked by an important burial (Figure 4; but see below). The moat was constructed during the second phase, and the earth that was removed from the moat was placed on the mound. When enlargement stopped, the feature comprised an estimated 57,000 tons, or some 3 million basket loads of earth (Hemmings, 1984; Woodward and McDonald, 2001; Anonymous, 2011).

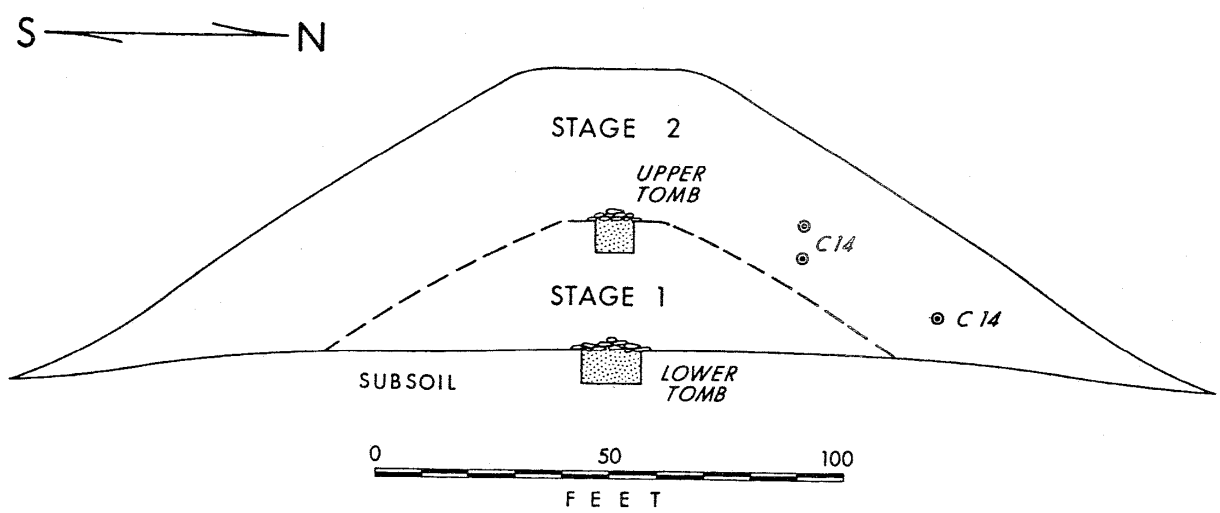

Figure 4. Structural details of the Grave Creek Mound obtained from historical accounts. The slopes of the first stage mound (dashed lines) are hypothetical (Hemmings, 1984, Fig. 15). The 1975-76 excavations raised some doubts as to the authenticity of this simple "two-stage" construction.

INITIAL EXCAVATIONS AND SCHOOLCRAFT'S INVESTIGATION

Joseph Tomlinson purchased the land upon which the Grave Creek Mound is situated early in the 1770s. Over the next 50 years, Tomlinson left the mound undisturbed despite recurrent suggestions that he excavate it, or at least allow others to do so. On September 10, 1803, Meriwether Lewis, on his way down the Ohio with William Clark at the beginning of their historic expedition west, splendidly described (in his idiosyncratic grammar and spelling) the still virgin mound as follows (University of Nebraska, Lincoln, 2011):

> last evening I landed on the east side of R. and went on shore to view a remarkable artificial mound of earth called by the people in this neighbourhood the Indian grave.—
>
> This remarkable mound of earth stands on the east bank of the Ohio 12 miles below Wheeling and about 700 paces from the river, as the land is not cleard the mound is not visible from the river—this mound gives name to two small creeks called little and big grave creek which passing about a half a mile on each side of it & fall into ohio about a mile distant from each other the small creek is above, the mound stands on the most elivated ground of a large bottom containing about 4000 acres of land the bottom is bounded from N. E. to S. W. by a high range of hills which seem to discribe a simecircle around it of which the river is the dimater, the hills being more distant from the mound than the river, near the mound to the N. stands a small town lately laid out called Elizabeth-town there are but about six or seven dwelling houses in it as yet, in this town there are several mounds of the same kind of the large one but not near as large, in various parts of this bottom the traces of old intrenchments are to be seen tho' they are so imperfect that they cannot be traced in such manner as to make any complete figure; for this enquire I had not leasure. I shall therefore content myself by giving a discription of the large mound and offering some conjectures with regard to the probable purposes for which they were intended by their founders; who ever they may have been.—
>
> the mound is nearly a regular cone 310 yards in circumpherence at it's base & 65 feet high terminating in a blont point whose diameter is 30 feet, this point is concave being depressed about five feet in the center, arround the base runs a ditch 60 feet in width which is broken or intesected by a ledge of earth raised as high as the outer bank of the ditch on the N. W. side, this bank is about 30 feet wide and appers to have formed the enterence to fortifyed mound— near the summet of this mound grows a white oak tree whose girth is 13 ½ feet, from the aged appeance of this tree I think it's age might resonably calculated at 300 years, the whole mound is covered with large timber, sugar tree, hickory, poplar, red and white oak &c— I was informed that in removing the earth of a part of one of those lesser mounds that stands in the town the skeletons of two men were found and some brass beads were found among the earth near these bones, my informant told me the beads were sent to Mr. Peals museum in Philadelphia where he believed they now were.—

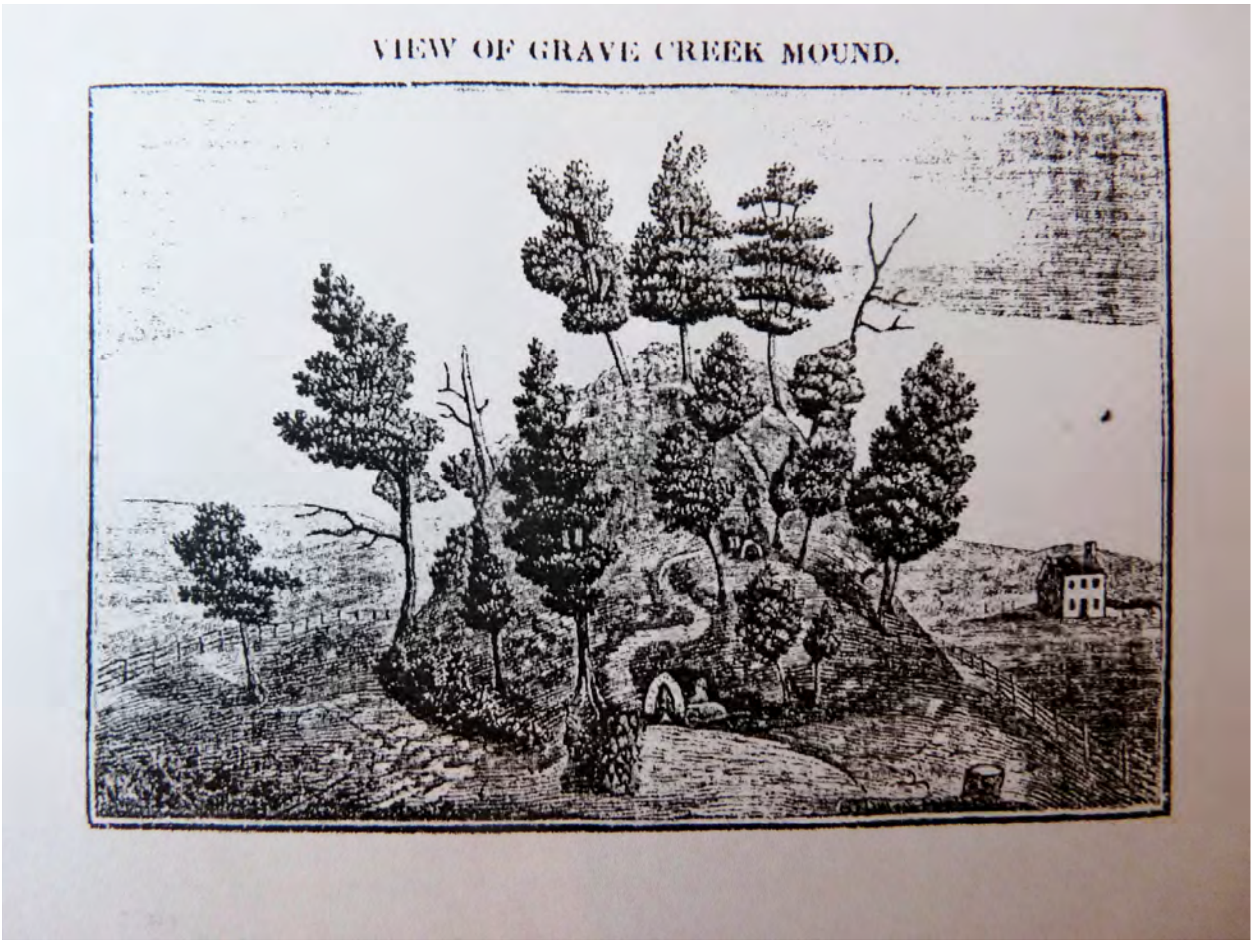

Figure 5. Drawing from the first news report of the Grave Creek Mound from the *Cincinnati Chronicle* in 1839.

Tomlinson died in 1826, and his son Jesse continued his father's protection of the mound for a dozen more years. Then, in 1838, he gave in to pressure to explore the site. Jesse's nephew Abelard Tomlinson was placed in charge of exploration, which got underway in March. The excavation—the earliest recorded investigation of an Adena Mound, consisted of cutting a tunnel, from about 4 ft (1.4 m) above the base toward the center, exposing a log tomb 111 ft (34 m) into the structure. Another horizontal tunnel into the mound at 34 ft (10 m) above the base, brought to light a second log tomb. A vertical shaft down from the top through the upper tomb to the lower was also excavated. The lower tomb contained skeletons of two adults, a male and a female. The upper tomb contained a single skeleton. Burial goods were found in both tombs. Abelard Tomlinson's excavations appear to have obliterated the "ditch" described by Meriwether Lewis (Figure 5; Woodward and McDonald, 2001, 267-268).

The Grave Creek Stone was reportedly found in the upper tomb. This "Runic Stone"—like numerous other strange stones, tablets, and alleged bodies "discovered" in the 19^{th} century (especially between 1830 and 1860)—fed debates as to whether "Europeans" reached America, and actually explored deep into the mid-continent, long before Columbus. The debate goes on today! (Woodward and McDonald, 2001, p. 268; McCullough, 2011).

After the mound was excavated, a museum was set up inside, where the lower log tomb had been found. Construction of the museum required that the chamber be enlarged, during

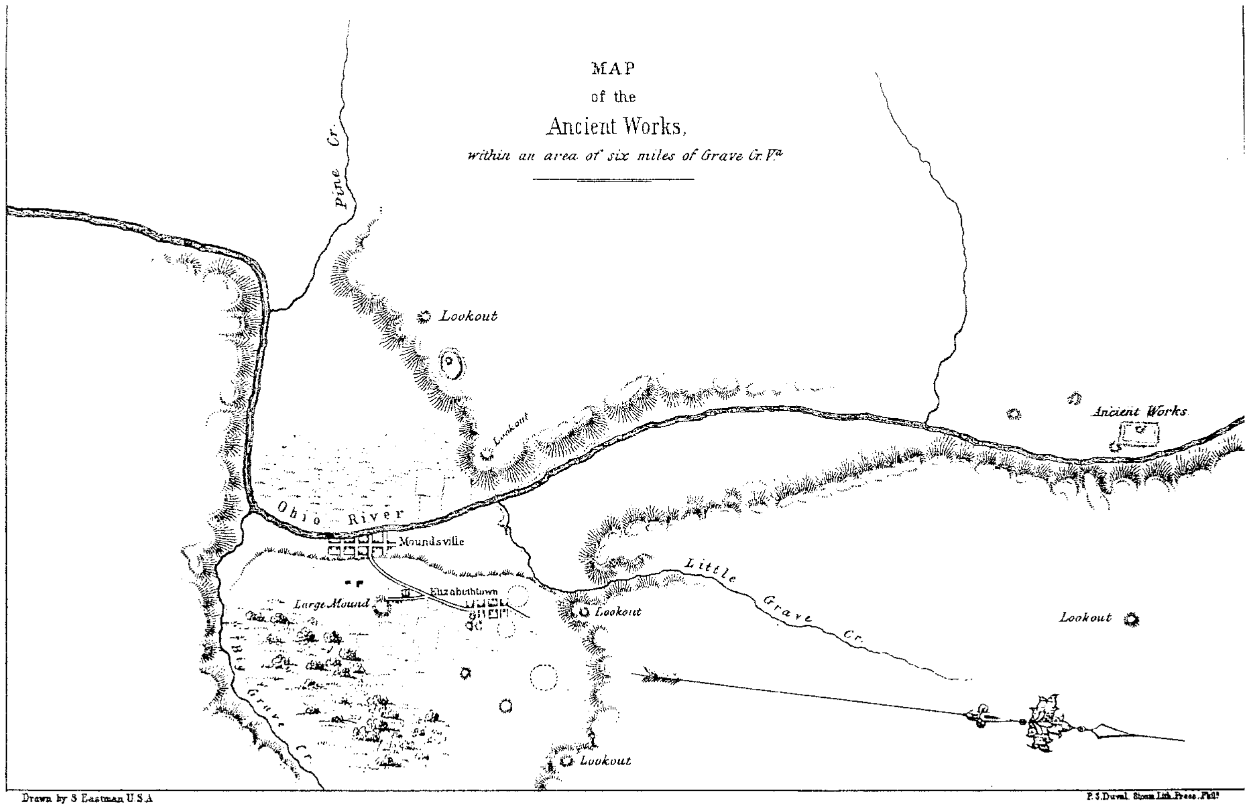

Figure 6. Mounds and earthworks in the vicinity of Moundsville, as depicted by in H. R. Schoolcraft (1851). The "large mound" is the Grave Creek Mound. Although no scale is given, the use of an accurate base map is indicated. Schoolcraft's records were obtained in 1853 and redrawn by Seth Eastman. This map constitutes the only reliable historic rendering of the Grave Creek earthwork complex. (See Hemmings, 1984, Fig. 4; Woodward and McDonald, 2001, Fig. 115).

which an additional 10 skeletons were found, all reportedly in a sitting position. Some time after this a 3-story observatory was built on the summit of the mound. The museum opened in 1839, and closed in about 1846.

In August 1843 Henry Rowe Schoolcraft (1793-1864), pioneer of American Indian ethnology, visited the Grave Creek Mound. His unscaled map of the site, published in 1851, is the only authoritative graphic record of the Grave Creek mound and its vicinity—drawn up before serious alterations to the site—that is known to exist (Figure 6; Hemmings, 1984, p. 10). Schoolcraft gives a vivid, though by modern accounts flawed, interpretation of the construction of the mound (Schoolcraft and Drake, 1884, p. 110):

> The opening of the great tumulus of Grave Creek, in Western Virginia, in 1838, revealed the mode which brought structures of earth of this capacity within the means of the semi-industrial tribes. It was evident that the lowermost of the two ancient vaults discovered was of vastly the more ancient era. It appeared conclusively that the structure was the result of comparatively trivial sepulchral labors during an immense period, one age and tribe having added to another the results of its easily accomplished and slowly accumulating toils. It also appeared that a mound-like natural hillock had been selected as the place of its first interment. By the original surface-line of the sod, disclosed by the lower gallery, it was further shown that the first interment was in a vault some six feet below

> the sod-line, over which earth was heaped—probably by carrying it up in leather bags from the surrounding plain. The personage interred—judging from his ornaments, and from the attention bestowed in excavating a square vault, lining it with timber and covering it with stones—was a patriarch or ruler of rank. Accumulations of irregular artificial strata of yellow and black sand, with a carbonaceous appearance and alkaline and acidulous properties, denoted the rise of the structure through the slow process of the incineration or natural decay of human bodies. So great was the epoch devoted to these sepulchral labors that the bones had undergone entire decay, and every osseous vestige had submitted to decomposition and become blended with the earth.

"ALTERATIONS"

Over the decades ensuing after 1838, the mound was subjected to various desecrations, including a saloon replacing the summit observatory; an artillery emplacement on the summit at the time of John Hunt Morgan's Civil-War raid into Kentucky, Indiana, and Ohio (July 1863); and, later, a dancing platform on the summit. On 4^{th} of Julys after the war, cannons were also hauled to the top and discharged (Woodward and McDonald, 2001, p. 268-269).

PROTECTION AND MODERN INVESTIGATIONS

In 1909 the State of West Virginia purchased the mound, placing it under the jurisdiction of the Penitentiary Board of the adjacent prison. The mound was cleaned up and once more made symmetrical, a process that in part required hauling earth to fill in the now concave summit. A spiraling stone walkway was built from the base to the top of the mound, and in 1915 a stone building for selling souvenirs made by prisoners was constructed on the south side of the mound. The building was enlarged in 1950, and a museum operated by the West Virginia Archeological Society was established. The museum opened in 1952 and continued in use until the Delf Norona Museum was built and opened to the public in December 1978 (Woodward and McDonald, p. 269-270).

In 1975-1976 the West Virginia Geological and Economic Survey carried out a two-phase field investigation of the Grave Creek Mound, followed by extensive laboratory analysis (Figure 7). This was the first really systematic archeological work at the site since it was penetrated by tunnels in 1838 (Hemmings, 1984). Some important results of this study were:

1. Rediscovery of the moat
2. Core drilling was used to study the mound content and structure as a means of avoiding excavation. Thirteen drill holes were emplaced, avoiding the disturbed core and north slope
3. A key stratigraphic zone was isolated and identified as moat fill for a late stage of the mound construction. A radiocarbon date of 200 BC obtained for 3 combined samples from this zone is presumed to pertain both to building of the moat and to a late, but not terminal, stage of construction
4. It appears that an hypothesis of "continuous building" is considered more probably than a "two-stage" hypothesis from 1838 accounts (see above)

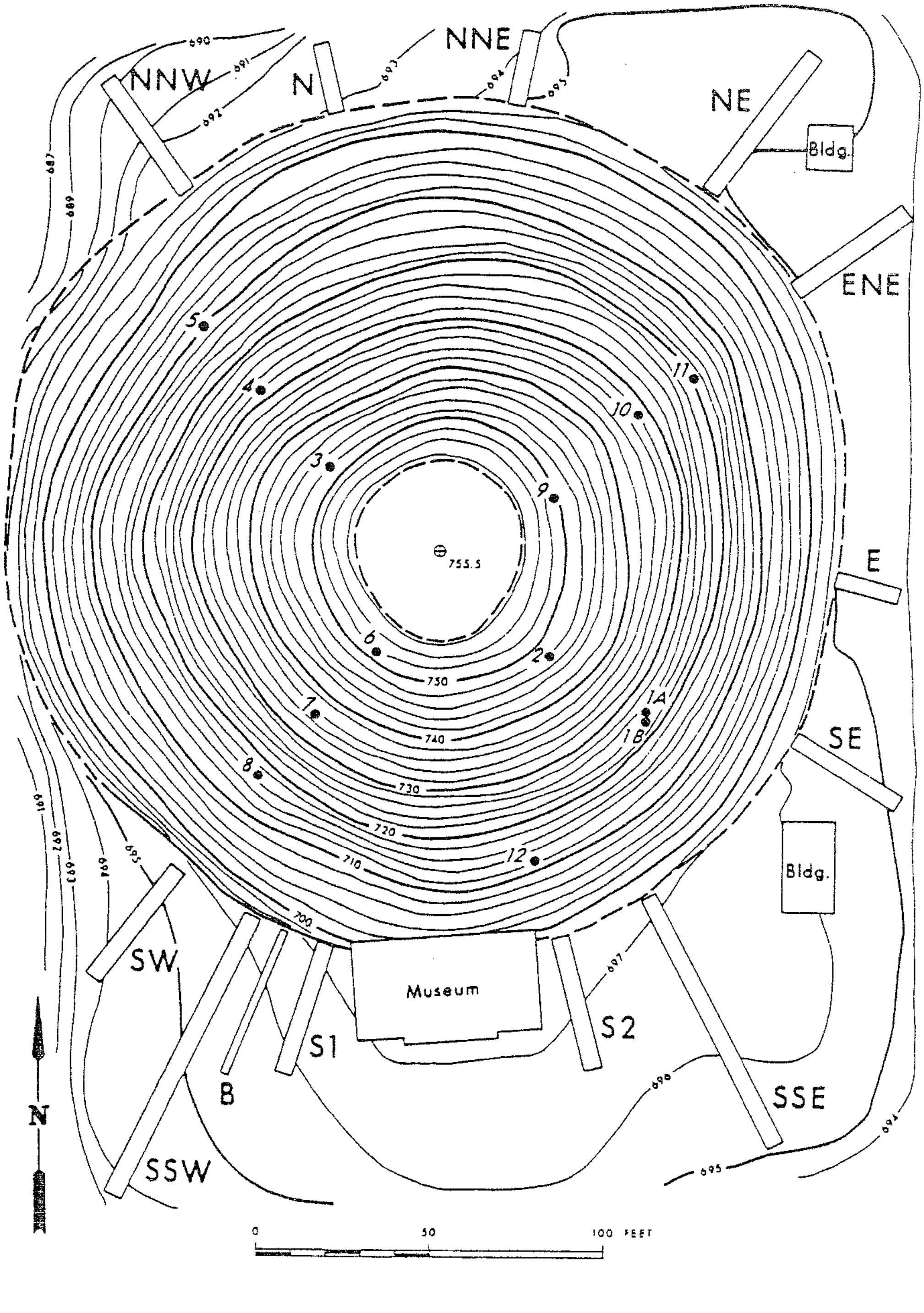

Figure 7. Topographic map of the Grave Creek Mound with locations of exploratory trenches and drill holes (Hemmings, 1984, Fig. 5).

After the completion of this study, Hemmings (1984, p. 4) concluded that “[a]fter millennia of prehistory and centuries of historical settlement, curious probing, and engulfment by civilization, Grave Creek Mound nevertheless stands little changed, a powerful monument to Adena architects and builders in the Ohio Valley.”

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STOP 4: ROSBY'S ROCK SECTION – WASHINGTON COAL COMPLEX, PALEOSOL, AND LIMESTONE

Leaders – Blaine Cecil and Vik Skema

A road cut just east of the village of Rosbys Rocks, WV (Figure 1) offers another good look at the Washington coal complex and a considerably better, less weathered, exposure of the underlying well developed paleosol than what we were able to see at Roberts Ridge. The Washington coal complex is somewhat similar to the exposure at Stop 2, except there are subtle, but significant differences. Here, the thick parting separating the two coals is 10 ft (3 m) thick, somewhat thicker than at Roberts Ridge. It is much siltier and contains thin sandstone beds near its top. The section directly under the lower coal is thicker and the character of individual beds within it are more discernable. There are no *Lingula* fossils in the Washington coal parting at Rosbys Rock (Figure 2).

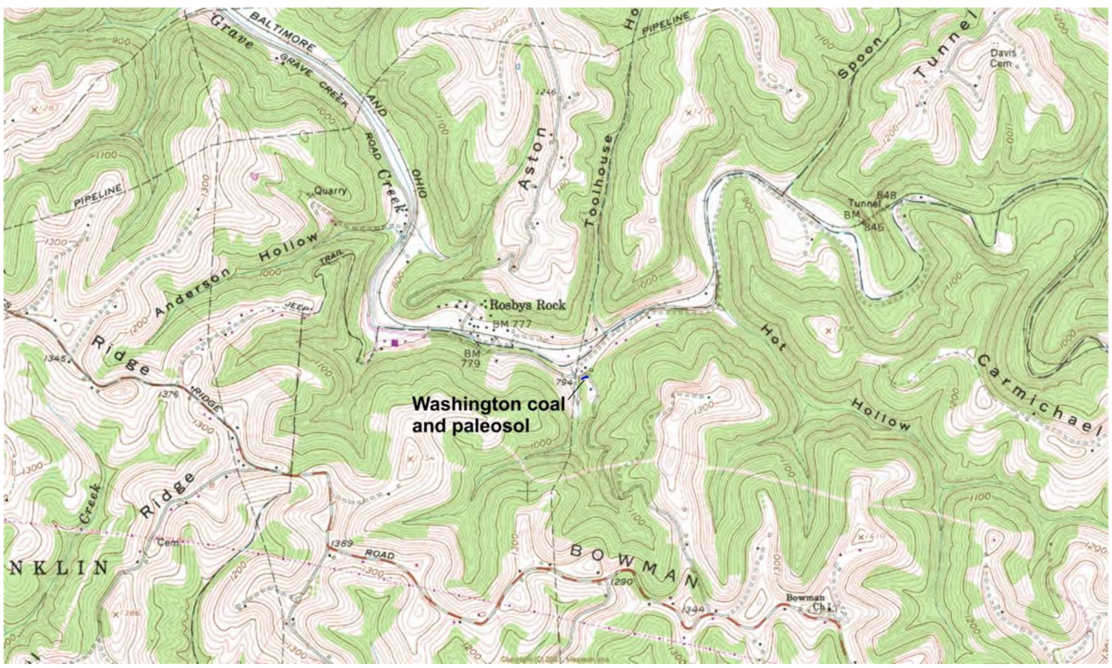

Figure 1. Location of Stop 4 along Grave Creek Road, just east of the village of Rosbys Rock, WV. The Washington coal and underclay are exposed in the cut.

The Washington coal and the distinctly colored, underlying claystone, especially in combination, are two of the most widespread and recognizable beds in the Dunkard Basin (White, 1891, 1903; Grimsley, 1910; Hennen, 1911; Cross, 1956; Collins and Smith, 1977). The Washington coal is a thick multi-benched coal complex throughout the northeastern part of the basin. It remains remarkably persistent as it thins and becomes a single bed southwestward. Even in Putnam County, WV at the southern end of the basin, where most of the Washington, Waynesburg, and Monongahela Group coals are absent or not much more than thin accumulations of carbonaceous material, the Washington coal horizon is reported to be persistently recognizable as a 6 to18 in (15 to 46 cm) thick dark shale mixed with black shale or

Cecil, C. B. and Skema, V., 2011, Stop 4: Rosby's Rock section – Washington coal complex, paleosol, and limestone, *in* Harper, J. A., ed., Geology of the Pennsylvanian-Permian in the Dunkard basin. Guidebook, 76th Annual Field Conference of Pennsylvania Geologists, Washington, PA, p. 290-299.

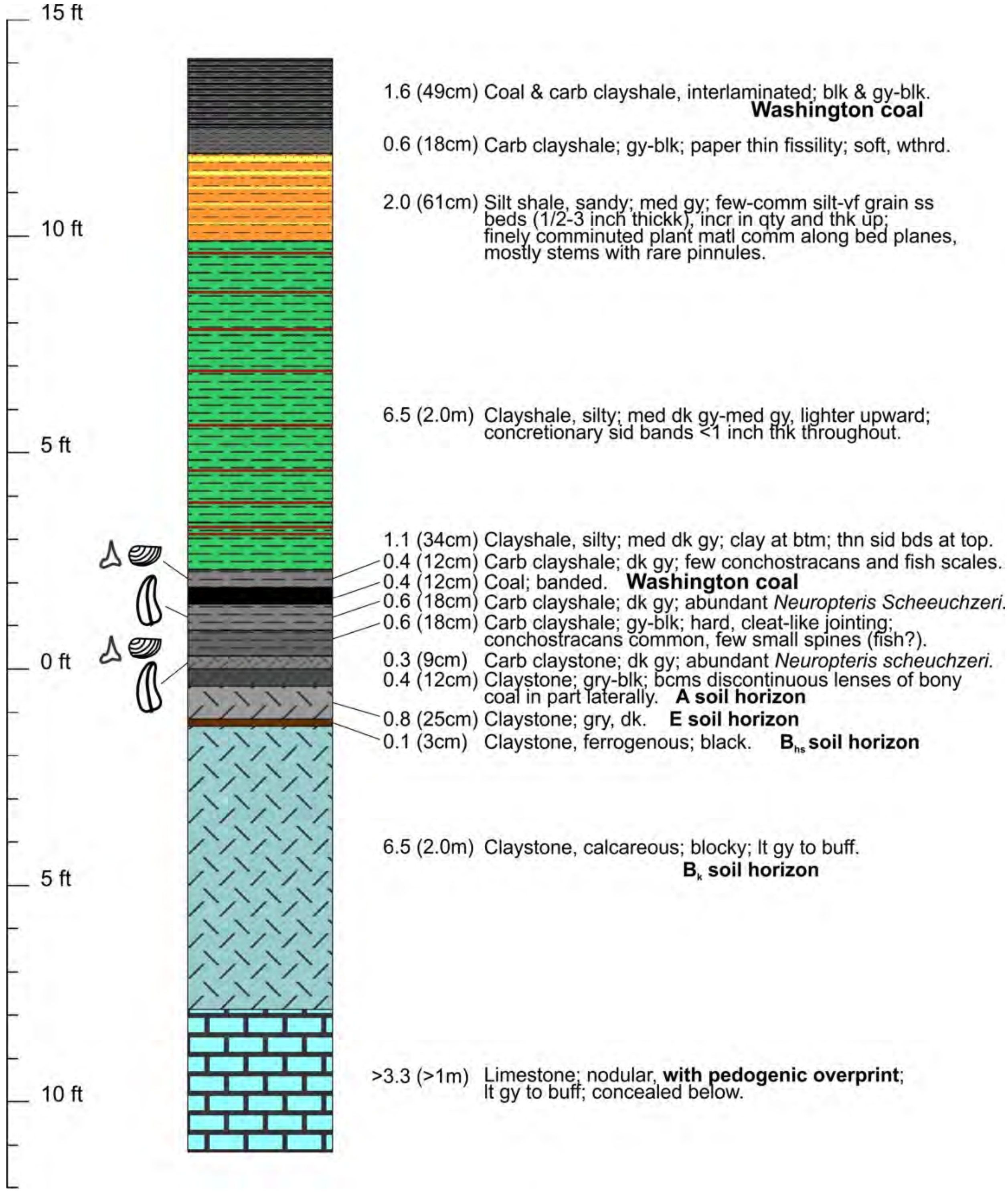

Figure 2. Graphic log of measured section of the Washington coal and underclay at Rosbys Rock. Measured and described by Blaine Cecil and Vik Skema (primary thickness values are in feet and tenths of feet).

Figure 3. Paleosol under Washington coal at Rosbys Rock. Note thin carbonaceous claystone (A soil horizon) underlain by gleyed, lighter gray claystone (E soil horizon) near top. The hard, blocky carbonaceous clay shale at the top contains conchostracans.

Figure 4. The Washington coal underclay horizon exposed in the big road cut along Route 7 in Ohio (Stop 1). The gleyed zone (E soil horizon) near the top of the paleosol stands out because of its light gray color.

occasionally with slate-like carbonaceous shale and coal (Krebbs, 1911). Krebbs reported that one of the coal interbeds rarely attained a thickness of 1 ft (0.3 m) and was mined (on a very limited basis and long ago). I. C. White (1891) went as far as to call the Washington coal "…. more persistent than any other coal of the Permo-Carboniferous Series". The underclay of the Washington coal is a light olive gray to yellowish gray, non-bedded, impure claystone. The upper part of this well developed paleosol has a thin zone of gleyed, light gray claystone that is often wet plastic clay (Figure 3 and 4; see detailed discussion of this paleosol by Cecil below). Iron staining of the upper exposed surface of this underclay is common. It is probably the thickest and best developed paleosol throughout all but the northeastern end of the basin in the lower half of the Dunkard. In the northeast it thins to a few tenths of a ft (a few cm) thickness and is underlain by the Bristol limestone. Whether they call it "fire clay shale", "underclay", "clay shale", or simply "clay", geologists who have mapped in this part of the section have all agreed that it is unique and an excellent stratigraphic marker bed.

The thick shale splitting the Washington coal at Rosbys Rock contains coarser material than the equivalent shale at Roberts Ridge and in the big road cut along Route 7 in Ohio. The entire parting, except for 0.4 ft (0.12 m) at the bottom, is siltier, and the upper 2.0 ft (0.6 m) contains thin, very fine grained sandstone beds. This is the beginning of an eastward trend of increasing sandstone content and overall thickening of the coal complex. To the east, the complex splits into three separate coals, locally four coals, with sandstone and sandy silt shale interbeds between each (Figure 5). The boundaries of the coal complex are herein defined by the base of the bottom coal and the top of the uppermost coal. The complex thickens to 30 to 40 ft (9 to 12 m) over appreciably large areas in Greene and Washington Counties of Pennsylvania. This definition includes the Little Washington coal and the Waynesburg B coal as part of the

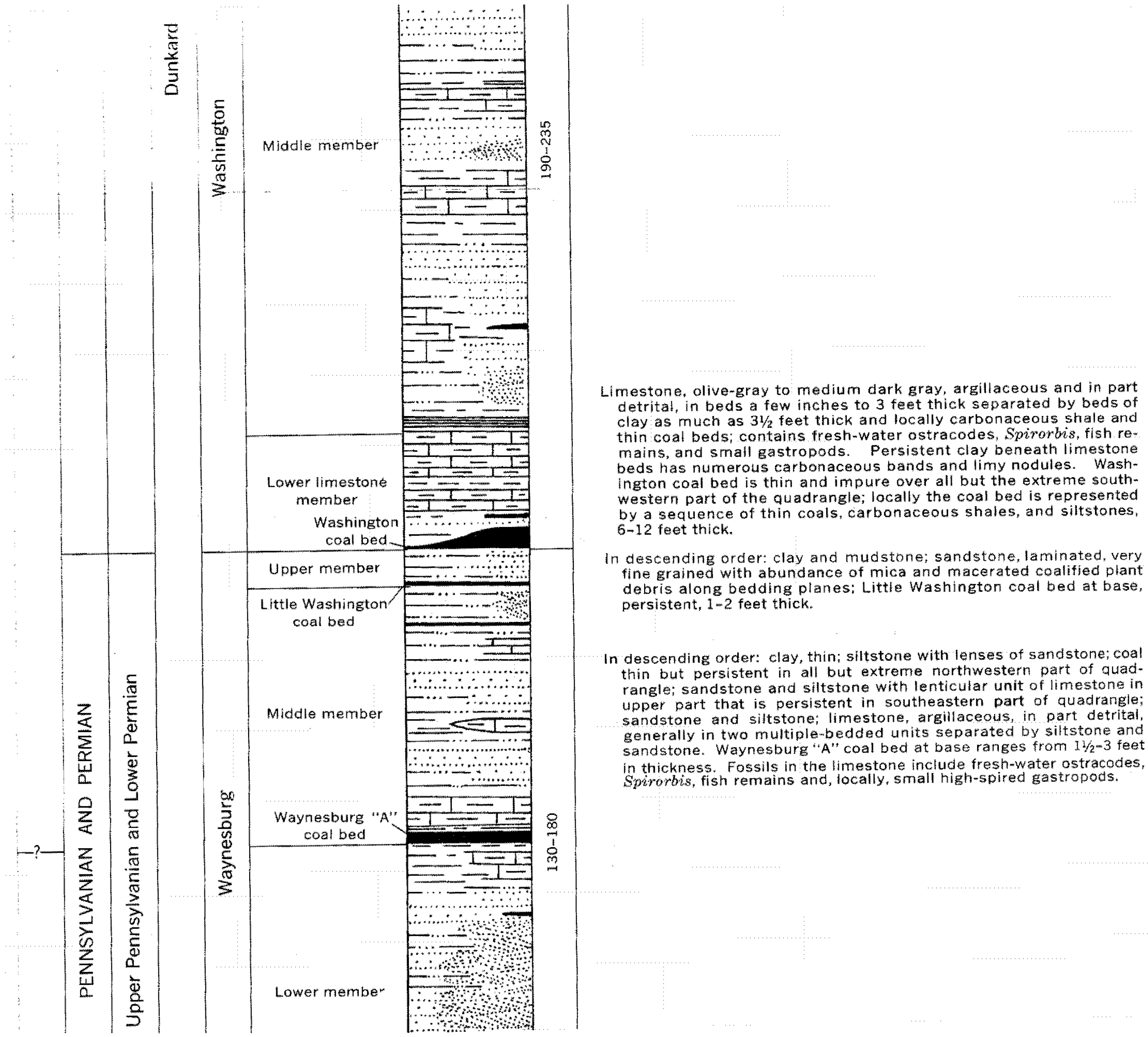

Figure 5. The general section included with the USGS General Quadrangle Map of the Ellsworth Quadrangle in Washington County (Berryhill and Schweinfurth, 1964) illustrates well the character of the Washington coal complex in areas where it is most split up and thickest. It contains four coals here separated by silty shale and sandstone. The coals in these settings have been identified as the Washington, Little Washington, and Waynesburg B and assigned to separate members. In areas where the splits consist of shale and are thinner the entire complex is considered to be the Washington coal. The paleosol and Bristol limestone usually underlay the coal complex in both settings.

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complex in the areas where thickness of the complex is greatly expanded (see description for Stop 2 for more explanation). An isopach map showing the thickness of total sandstone within the complex illustrates this eastward trend (Figure 6). The isopach map also suggests that the sandstone is possibly distributed into north-south oriented belts, similar to the orientation of the thick fluvial channel belt of the Waynesburg sandstone (Mather Sandstone Lentil above the Waynesburg coal, see Stop 2 discussion). The data used to construct this preliminary isopach map was derived primarily from coal company drill hole logs from Pennsylvania, some of which were drillers logs. More data and more detailed data are needed to definitely establish the validity of a sandstone trend. A line of section using several drill hole logs from the Daniels Run area in the Ellsworth quadrangle in south-central Washington County illustrates the change

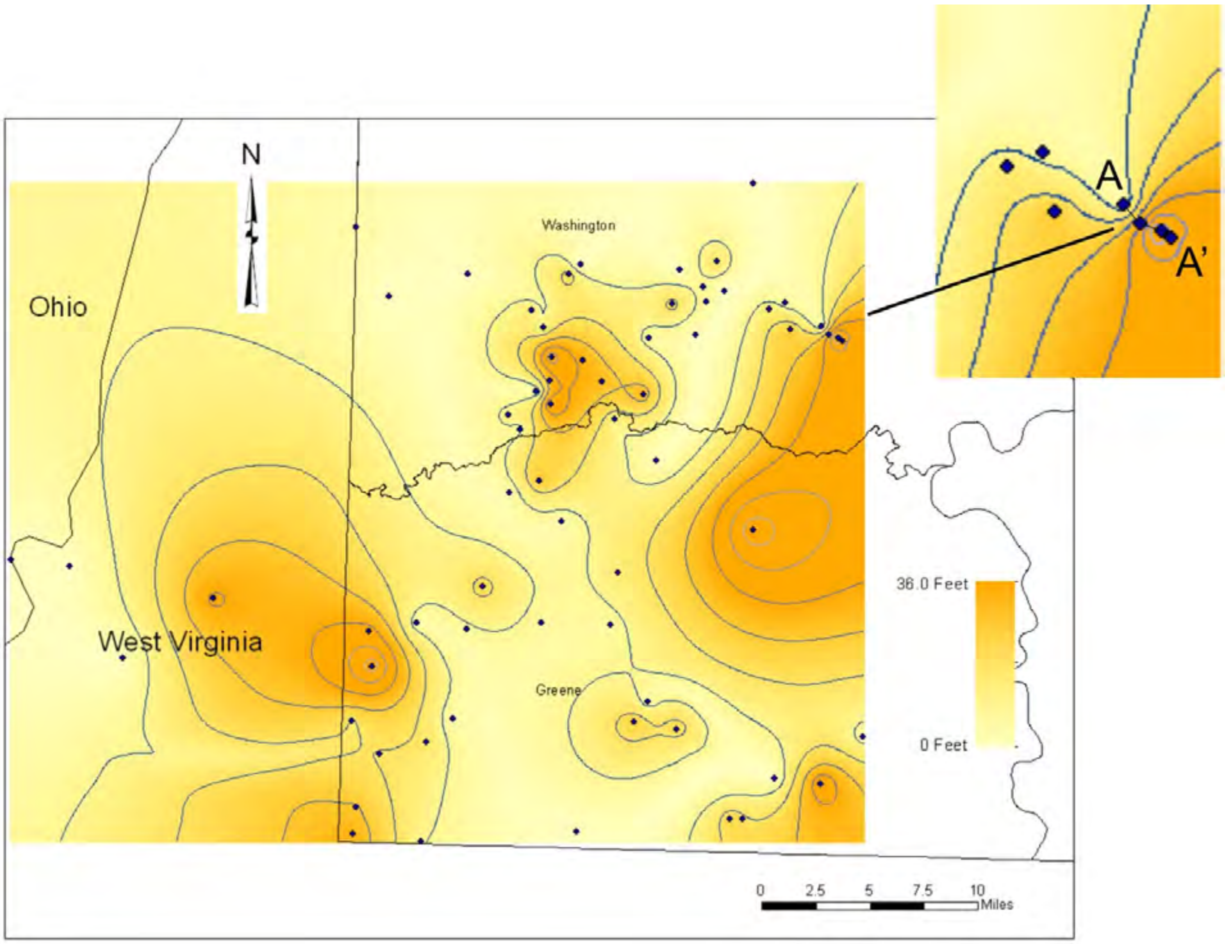

Figure 6. An isopach map showing the total thickness of sandstone within the Washington coal complex in Greene and Washington County, Pennsylvania, and adjacent portion of the northern panhandle of West Virginia, and nearby Ohio. The three farthest west data point are Rosbys Rock, Roberts Ridge Road, and the big road cut at Stop 1 in Ohio.

in sand content and thickness of the Washington coal complex between one of the sandstone belts and an adjacent area containing finer grained strata (Figure 7). There appears to be a correspondence of thicker sandstone accumulation in the coal complex with thicker sandstone in the underlying Mannington sandstone and the Waynesburg sandstone farther below. This section suggests the possibility that the course of the river system in which the thick sandstone of the Mather Lentil was deposited (see discussion for Stop 2) persisted for a long time in about the same area, depositing the thickest sandstone of the Mannington horizon and eventually affecting the peat swamp of the Washington coal horizon. Another, parallel, thick fluvial channel deposit of the Waynesburg coal along the western border of Pennsylvania also shows stacking of thick sandstones in the Waynesburg and Mannington horizons, and within the Washington coal complex (Figure 6 and drill hole 10 in the cross section by Fedorko and Skema, 2011).

The *Lingula* in the Washington coal parting at Roberts Ridge and in Ohio are always in clay rich shale at the top of the parting within 1 or 2 ft (0.3 or 0.6 m) of the upper coal bench. None have been found in the coarser facies at Rosbys Rock or eastward. Instead, conchostracans are present and are usually in the finer shale component of the generally coarser

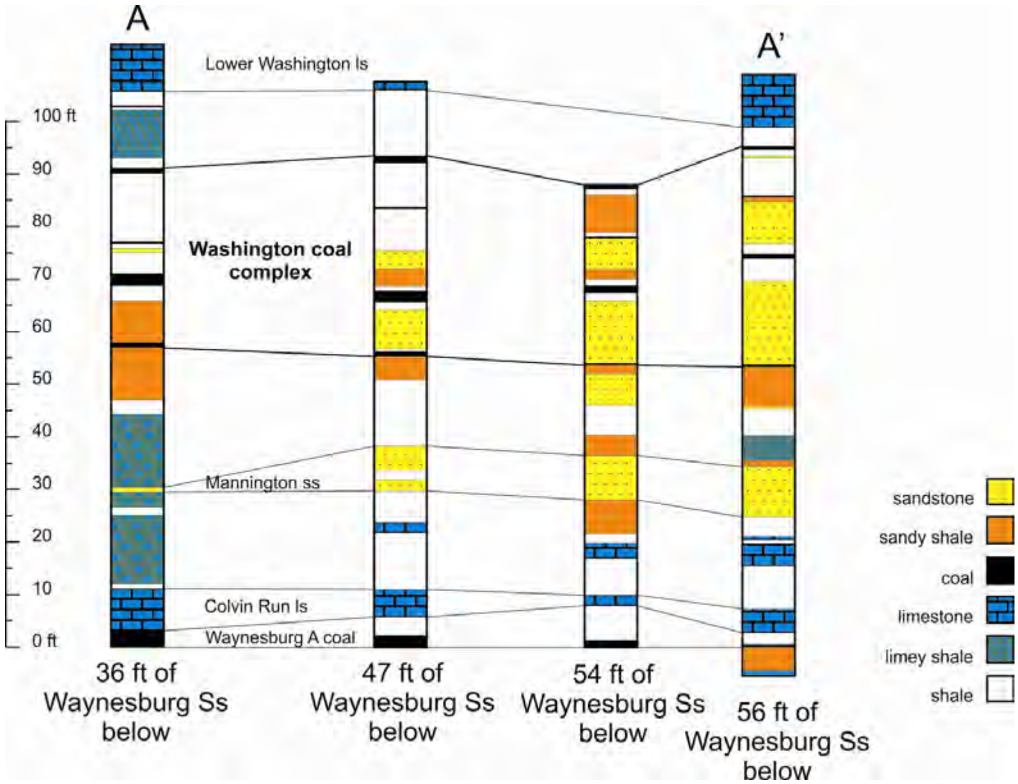

Figure 7. Cross section of the Washington coal complex at Daniels Run in south-central Washington County illustrates the change in character of the complex between areas of thick sandstone and thin sandstone. Areas with thick sandstone splits appear to correspond with areas of thicker Mannington and Waynesburg sandstones.

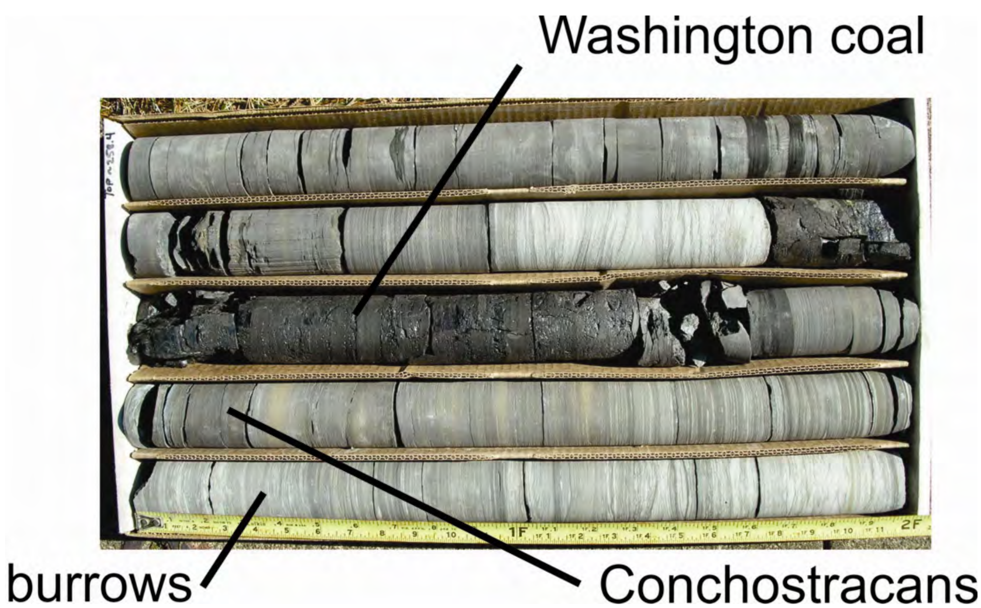

Figure 8. Core recovered from a hole drilled by Alliance Coal at their Tunnel Ridge Mine contained conchostracans just below the Washington coal, at about the same horizon Lingula was found in Belmont County, Ohio. The sandy shale just below this horizon contained burrows that are often seen in association with the conchostracans horizon.

parting. Portions of sandy siltstone beds of the complex often contain burrows, which may be attributable to conchostracan activity (Figure 8). Here at Rosbys Rock a few fish scales were found along with conchostracans in the thin dark shale directly above the lower coal (Figure 9). The conspicuous hard carbonaceous clay shale bed below the lower of the split pair of coals also contains abundant conchostracans, possibly more than one species, and a few small spines that appear to be possibly from fish (Figure 10). Some of the conchostracans appear to be *Gabonestheria*, characterized by a nipple-like spine at the top of the umbonal portion of one of the valves. Tasch (1975) reported finding them in the dark roof shales of the Washington coal near Mannington, WV and named them *Gabonestheria manningtona*. An abundance of similar fossils were found at the same horizon in the dark shale overlying the Washington coal at the big road cut along Route 7 in Ohio (Figure 11). Tasch (1975) places great importance on the presence of these fossils. He cites reports of collection of the same fossil from the Permian of “French Equatorial Africa”, “USSR”, and the Wellington Formation of Kansas. Much turmoil has wiped the USSR off world maps since Tasch published his paper, and the countries in the federation of French Equatorial Africa went their separate ways even before publication of the paper, but the Wellington Shale of Kansas remains part of the Leonardian Series of the Permian even after the great chronostratigraphic upheaval brought on by conodont dating (Sawin and others, 2008). Tasch concludes that Dunkard strata from the Washington coal and higher are Early Permian since *Gabonestheria manningtona* and two other species of conchostracans found in this part of the Dunkard are unknown in the Carboniferous anywhere in the world.

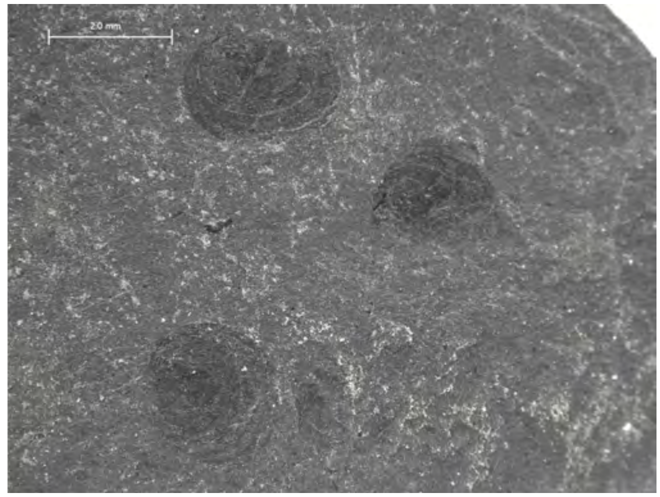

Figure 9. Conchostracans found in the dark shale directly above the lower of the two split coals at Rosbys Rock.

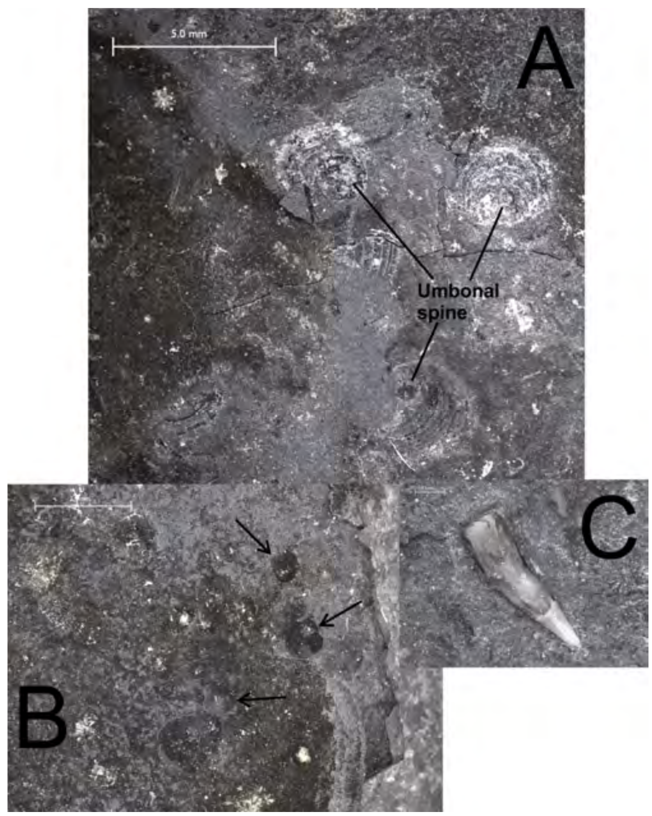

Figure 10. Conchostracans and other fossils found in the hard carbonaceous shale below the lower split of Washington coal at Rosbys Rock. A – Conchostracans that may be *Gabonestheria manningtona* with characteristic nipple like spines centered in the umbo region of the valve. B – A possibly different species of conchostracans (or possibly broken off umbo portions of *Gabonestheria* shells). Arrows point out these fossils. C – A small spine that may have come from a fish.

THE WASHINGTON COAL UNDERCLAY

Figure 11. An example of a conchostracan (possibly *Gabonestheria manningtona*) that was found in the dark shale above the Washington coal in the big road cut at Stop 1 in Ohio.

As with virtually all coal beds in the Appalachian basin, the base of the Washington coal complex is underlain by underclay (seat earth). As discussed above (Skema), the underclay associated with the Washington coal complex is extremely wide spread and has been noted in many places throughout the Dunkard basin. At Rosby's Rock, WV, the strata considered to be part of the underclay sequence are composed of a series of four (4) units (units 2 through 5, Figure 2 and Table 1) totaling more than 6.6 ft (2 m) in thickness. Individual units within the underclay are distinguishable at this stop by their color, composition, and texture (Figure 3).

The basal 5 in (12 cm) of the Washington coal complex and the underclay beneath the coal at this stop exhibit characteristics of paleosol horizons indicative of at least three phases of soil formation (pedogenesis). The uppermost soil, which includes the basal 5 in (12 cm) of coal and 0.8 to 1.2 in (2 to 3 cm) of underlying plant fossil-bearing mudstone, is interpreted as a Histosol complex that formed under peraquic soil moisture conditions (water logged) (see Cecil et al., 2011 and Keys to Soil Taxonomy, Soil Survey Staff, 1992, pages 34-37 for definitions of soil moisture). The lower two soils (underclay), developed prior to the onset of mineral- and peat-

Table 1. Pedogenic underclay characteristics and paleoclimate interpretations.

Unit #	Lithology	Color	Thickness	Soil horizon	Paleo- climate
	Coaly shale (carb clayshale) w/ conchostracans	Black	18 cm (0.6 ft)	Histosol	Humid
	Mudstone w/plant fossils (carb clayshale w/ *Neuropteris*)	Dark gray	9 cm (0.3 ft)	Histosol	Humid
1	Claystone	Gray-black	12 cm (0.4 ft)	A	Moist sub-humid
2	Claystone	Gray, dark	25 cm (0.8 ft)	E	Moist sub-humid
3	Claystone	Black, ferruginous	2-3 cm (0.1 ft)	Bhs	Moist sub-humid
4	Blocky claystone	Lt gray to buff, calcareous	2 m (6.5 ft)	Bk	Dry sub-humid to semiarid
5	Nodular limestone	Lt gray to buff	> 1 m (>3.3 ft)	Limestone w/ pedogenic overprint	Dry sub-humid to semiarid
	Concealed				

swamp conditions (Histosols), are the predominant focus of paleosol discussions at this stop.

Underclay paleosol characteristics indicate that pedogenesis was not genetically linked to subsequent peraquic conditions that prevailed during Histosol formation (peat-and clastic-swamp conditions). Ustic soil moisture (mostly dry) is indicated for the first phase of pedogenesis of the mineral paleosols (paleosol 1) by accumulation of calcium carbonate in a >6.6 ft (>2 m) thick Bk horizon. Ustic soil moisture appears to have resulted from a dry-subhumid to semi-arid climate (rainfall regimes are defined in Cecil et al., 2011). The subsequent phase of pedogenesis (paleosol 2) appears to have developed under aquic soil moisture conditions that were superimposed on the original paleosol by an increase in rainfall and a moist-sub-humid climate. The relatively wetter climate led to the aquic soil moisture regime and the development of an A and E horizon. The A and E horizon developed in response to gleying, leaching of calcium carbonate, and reduction and illuviation of iron into a new B horizon (unit 3). Finally, ever increasing rainfall and a humid climate led to peraquic soil moisture (permanent water logging) and the onset of Histosol formation.

Underclay paleosols, such as the sequence beneath the Washington coal complex at Rosby's Rock, have important geologic implications. First, they are indicative of a basin-scale unconformity and a protracted period of non-deposition and pedogenesis. During pedogenesis of the lower paleosol (1), the paleoclimate was so dry that streams were small, perhaps ephemeral. Fluvial sediment transport and deposition was minimal, or whatever fluvial sediment load there may have been bypassed the basin. The dry-subhumid paleoclimate led to precipitation of calcium carbonate throughout the paleosol profile. Yet there was sufficient rainfall to transform the pre-existing sediment into a soil, destroying any bedding as paleosol peds developed. The pedogenic overprint was both intense enough and long enough, as to have caused partial dissolution and nodularization of a pre-existing limestone bed at a depth of over 6.6 ft (2 m) (Table 1 unit 5). Capillary action within the paleosol appears to have been the predominant source of dissolved carbonate, which moved up into the overlying soil where it was precipitated during the dry season to form a Bk horizon under an aridic to ustic soil moisture regime.

In contrast, pedogenesis of the upper paleosol (2) was driven by a paleoclimate that graded from moist-suhumid to humid climatic conditions. The progressive climate change went from the dry-subhumid climate condition to a moist subhumid condition, and finally to a humid climate and the peraquic conditions that led to Histosol formation and the onset of peat formation. The moist-subhumid condition resulted in gleying of the top of the pre-existing calcic paleosol accompanied by leaching of calcium carbonate and iron with illuvial iron being deposited in a ferruginous BS horizon. The climate change also must have brought about a change in soil Eh and pH from alkaline conditions during the formation of soil 1 to acidic conditions that caused the gleying and translocation of iron during formation of soil 2.

The stop at Rosby's Rock illustrates the profound control paleoclimate had on the origin of underclays and coal. Although rainfall and soil moisture regimes can only be inferred qualitatively, the sequence of precipitation of soil carbonate followed by gleying and leaching of carbonate and iron represents a clear indication of rather extreme changes in soil moisture and soil chemistry. The absence of root structures and any visible trace of organic matter in the lower paleosol (1) indicate that climatic conditions were so dry during pedogenesis that plants were either absent or very sparse on the landscape. In contrast, plants must have blanketed the landscape as humid conditions developed during the formation of soil 2. Organic-rich A and B horizons in soil 2 provide unequivocal evidence for a rather dense flora on the landscape prior to permanent water logging and the onset of swampy conditions.

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STOP 5: McMECHEN LANDSLIDE, McMECHEN, WV

Leaders – Dick Gray and Helen Delano

At this stop we will gather by the buses for a brief discussion of landslides in the field trip area, and then those who wish can disperse in small groups to walk through the landslide area of the town and observe features that may be relict from the 1970s and/or may represent continuing slow movement.

STABILIZATION OF A COLLUVIAL SLOPE

Landslide movements in March 1975 affected a significant portion of McMechan, W.V. (Figure 1). Subsequent investigation revealed the movements were due to reactivation of a colluvial slide mass. In addition to the economic restraints normal to most engineering projects, development of a stabilization scheme required consideration of social impacts. Excavation of the upper portion of the colluvial mass to reduce driving forces was restricted by the community's interest in minimizing relocation of undamaged homes. Drainage measures were limited to public streets. The adopted stabilization design was a compromise between technical measures and socio-economic considerations and resulted in a calculated factor of safety of 1.0 for the worst post-construction case.

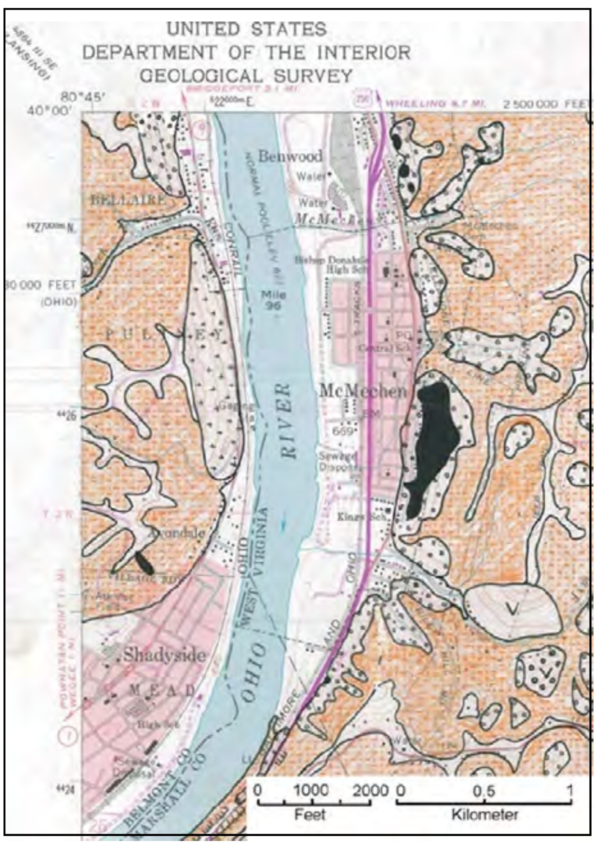

Figure 1. Portion of the USGS Moundsville quadrangle landslide map (Hackman et. al., 1978) . Black = Active or recently active Landslide. Small circles = Old landslide. White area with V = Colluvial slope. Small circles with V = Colluvial slope with landslides. Stipple pattern colored orange = Soil and rock susceptible to landsliding.

TOPOGRAPHY

The lower portion of the town occupies a terrace 15 m (49 ft) above the river and the adjacent hillside rises to a height of 160 m (525 ft) above the river. Prior to the 1930s, the town occupied only the river terrace. In the 1930s and 1940s three streets were constructed parallel to the contours on the lower portion of the hillside.

GEOLOGY AND SLOPE DEVELOPMENT

The hillside above McMechen consists of flat-lying, interbedded claystone, shale, limestone, and sandstone of Pennsylvanian and Permian age. Weathering and mass wasting produce a silty-clayey colluvial soil containing

Gray, R. E. and Delano, H. L., 2011, Stop 5: McMechen landslide, McMechen, WV, *in* Harper, J. A., ed., Geology of the Pennsylvanian-Permian in the Dunkard basin. Guidebook, 76th Annual Field Conference of Pennsylvania Geologists, Washington, PA, p. 300-304

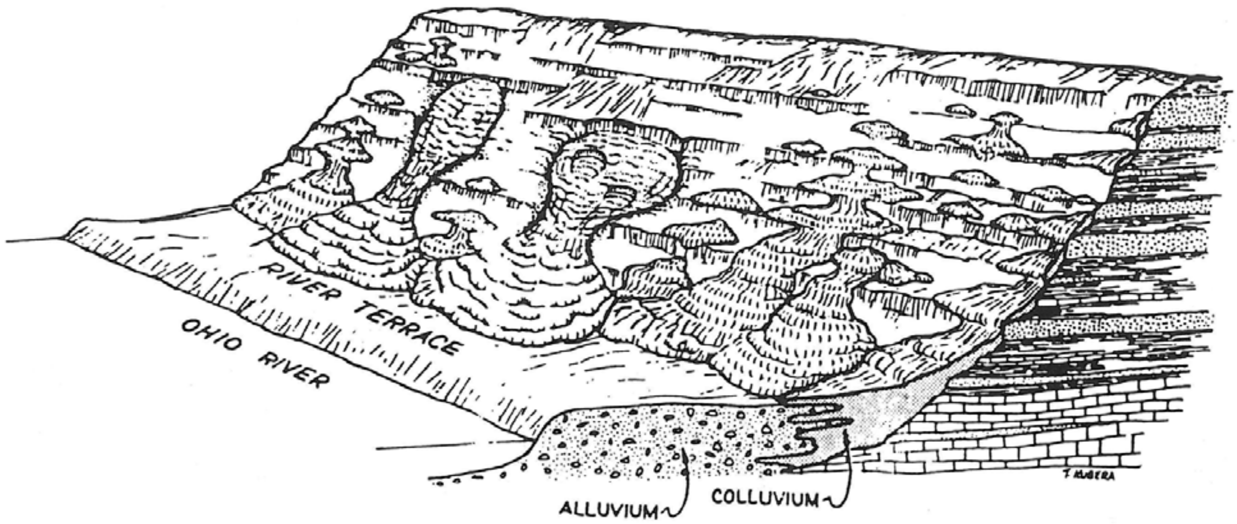

Figure 2. Schematic of colluvial slope development (from Gray & Gardner, 1977).

pebble size to large fragments of the more resistant rock types. Colluvial soils are generally stiff to hard and individual samples have relatively high shear strengths. However, creep or sliding processes (or both) during slope development has generally reduced the shear strength along movement surfaces to residual or near-residual levels (Gray et al., 1979)

In the upper two-thirds of the slope, rock outcrops at several levels, and the colluvial cover are discontinuous. The lower third of the slope is covered by a large complex colluvial mass (Figure 2). At the base of the slope, the colluvium interfingers with the alluvium of the river terrace. Slope angles of the colluvial mass vary from a maximum of 30 degrees in its upper portions to 8 to 11 degrees at its toe. Gray and Gardner (1977) discussed in detail the processes of colluvial slope development at McMechen.

LANDSLIDING

In March 1975, landslide movements damaged 56 of 120 homes located on the colluvial mass. Based on property damage and slide scarps, the movements were primarily in the upper, steeper portions of the colluvial mass. The most severe damage was in concentrated areas just below swales that extended upslope from the main colluvial mass. The area exhibiting movements had dimensions of 1,000 m (3,281 ft) along the hillside and 200 m (656 ft) across the slope. This colluvial mass had a maximum depth of 13 m (43 ft) and a volume of approximately 1.5 x 106 m^3 (139 yd^3). Figure 3 shows a section through the slide area (from Gray et al., 1980).

Although the slide area was developed in the 1930s and 1940s, few problems occurred until 1975. The movements in 1975 are attributed to increased precipitation. Figure 4 shows precipitation data at McMechen from 1945 to 1978 in terms of deviation from the normal. Precipitation was generally well below normal for 12 years prior to 1974. In 1974, precipitation was well above normal for six straight months (April – September) culminating in September with the third highest monthly precipitation (11.7 cm) (4.6 in) since 1945. Precipitation was slightly below normal in October and November. From December 1974 through March 1975, when extensive landsliding was reported, precipitation was again above normal.

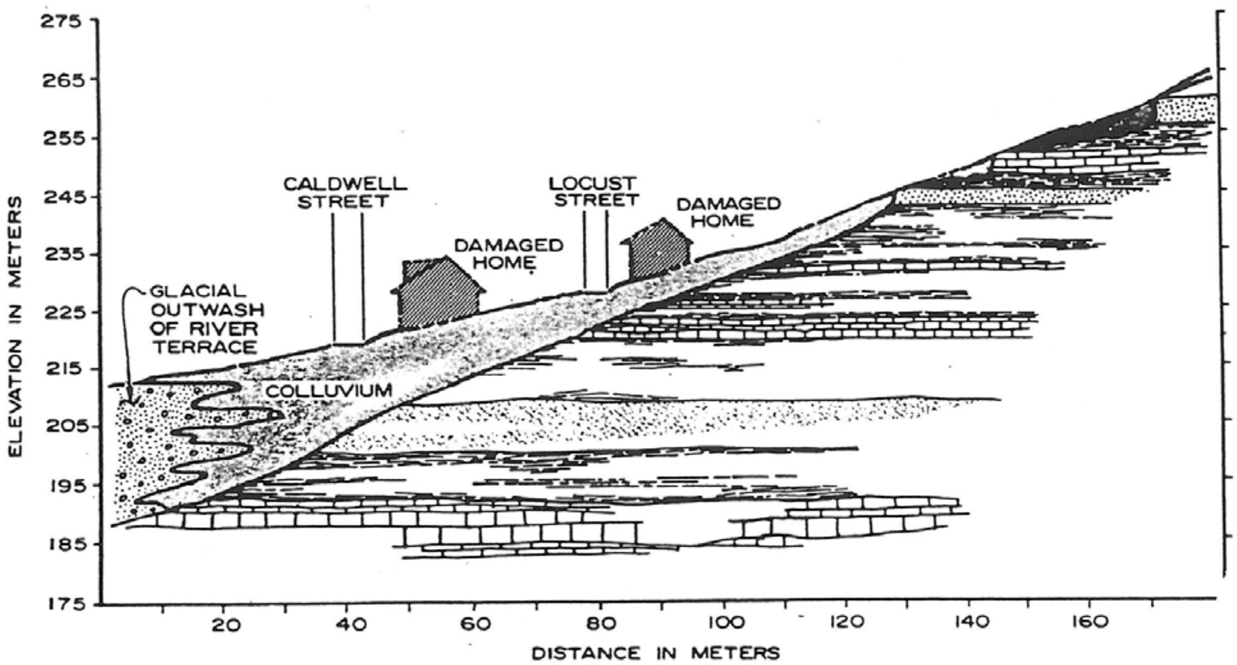

Figure 3. Section showing lower third of the hillslope (from Gray et al., 1980).

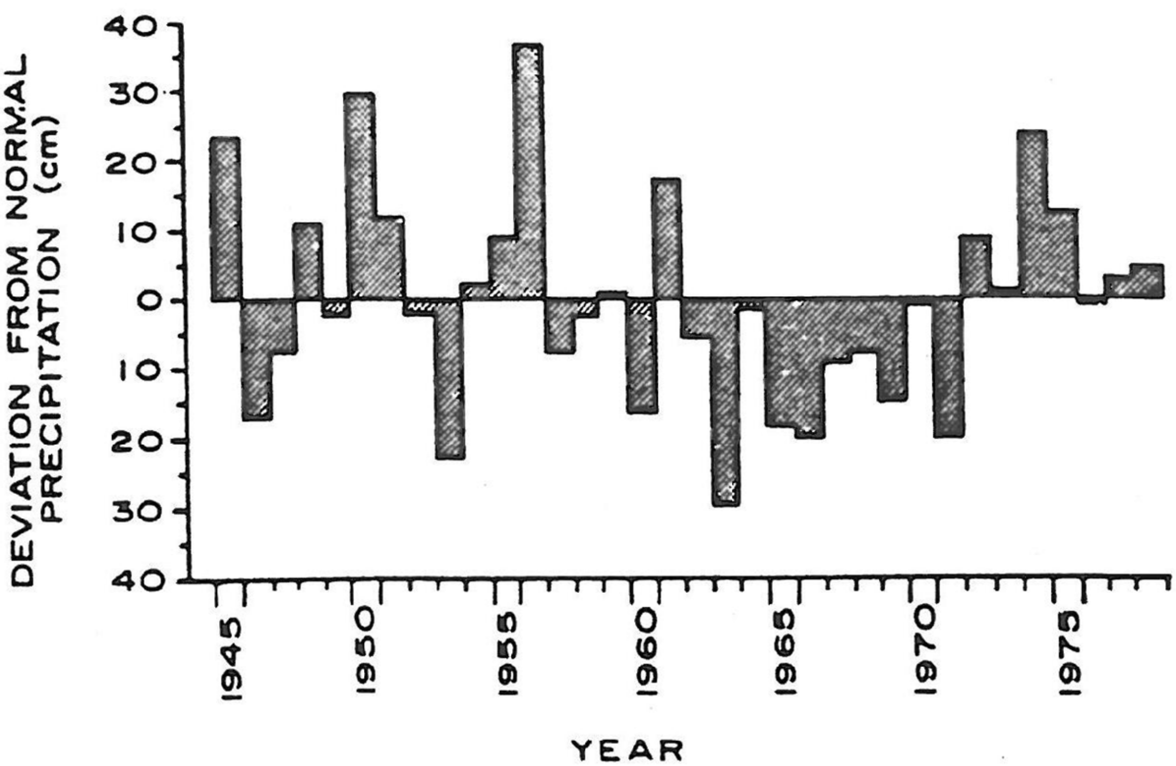

Figure 4. Yearly deviation from normal precipitation (from Gray et al., 1980).

TESTING AND ANALYSIS

Direct shear testing of the colluvium produced initial (peak) strength values of Ø = 27 degrees and cohesion = 0, and residual strength values of $Ø_r$ = 15 degrees and cohesion = 0. Residual friction angles of 14-18 degrees were obtained by back calculation, which corresponded well with the lab obtained values.

STABILIZATION MEASURES

Slope stabilization studies were predicated on preventing additional damaging movements and minimizing disruption of the community. Preliminary study in 1975 indicated that a combination of excavation of the upper portion of the colluvial mass to reduce driving forces, and subsurface drains, was most suitable. A factor of safety of 1.4 was selected for design of the stabilized slope.

Additional subsurface information, detailed topography and laboratory tests were obtained prior to final design of the stabilization scheme in 1977. It was found that a factor of safety of 1.4 could not be obtained without an excavation that would remove many houses. This was unacceptable from a social – political standpoint and it was decided to accept minimum factors of safety of 1.1 against deep sliding and 1.0 against shallow (less than 3 m [9.8 ft]) sliding. A typical section showing the planned excavation at the top of the colluvial mass is shown in Figure 5.

Volumes to be excavated uphill of the soil bench at Locust Street were 210,245 m^3 (275,000 yd^3)of soil and 9,175 m^3 (12,000 yd^3) of rock. Estimated cost of this excavation in 1977 dollars was $1,000,000. Total estimated construction cost for the proposed fix in 1977 dollars was $2,750,000.

CLOSING

This landslide was one of a few individual features noted as landslides of special interest on the USGS Landslide Map of the Conterminous United States (Radbruch-Hall et al., 1982).

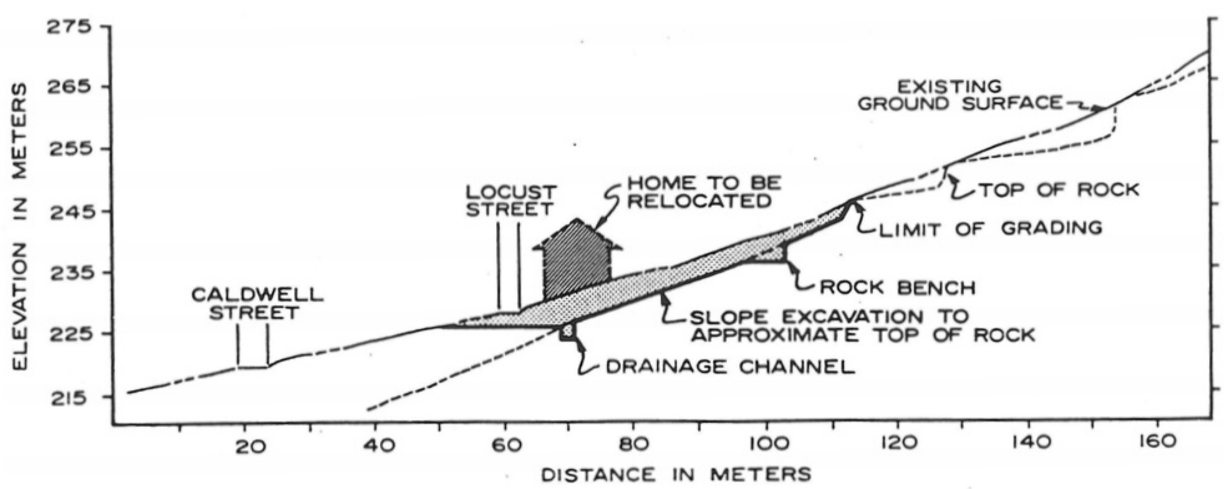

Figure 5. Section showing excavation stabilization scheme (from Gray et al., 1980).

Figure 6. Leaning wall near south end of active landslide area in McMechan. Photo by Francis Ashland, U.S. Geological Survey.

Lessing et al. (1976) also discuss this site as one of the very rare situations where Federal Flood Insurance provided coverage for landslide damages. We have not been able to find more information on this beyond Lessing's brief mention.

As you walk through the landslide area, look for features that might have occurred as the result of 1970s slope movement and those that might represent continuing slow movement (e.g., Figure 6).

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STOP 6: LAUREL POINT FALLS PARK – CASSVILLE SHALE AND CARMICHAELS FORMATION

Leaders: John Harper, Steve Kite, and Mitch Blake

INTRODUCTION

Welcome to Carmichaels Borough (Figure 1). The borough was settled in 1768, laid out by Major James Carmichael, and incorporated from Cumberland Township in 1855. The first post office in Carmichaels began operating in 1822 (Anonymous, 2011).

James Carmichaels was a scout under Colonel Henry Enochs of the Second Battalion, Washington County Militia and, according to local history, was originally awarded a tract of land on Tenmile Creek in what is now the borough of Jefferson. He is supposed to have traded that tract with one Thomas Hughes for Hughes' land on Muddy Creek. Carmichaels died in 1796 (Leckey, 1977).

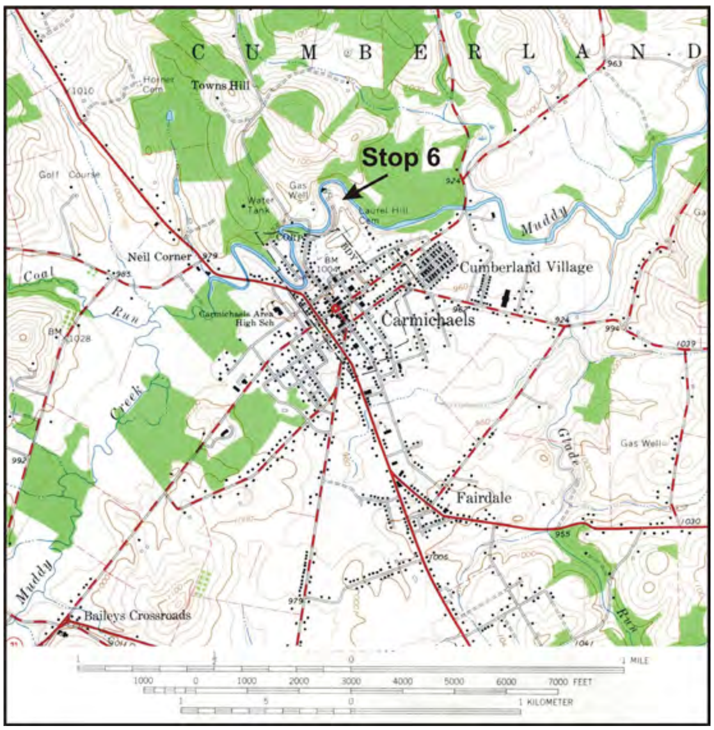


Figure 1. Map of the Carmichaels Borough area, showing the location of Stop 6 (Laurel Point Falls Park).

Among the borough's claims to fame are the Greene Academy (see p. ___), the Carmichaels Covered Bridge over Muddy Creek, the annual Covered Bridge Festival, the Bituminous Coal Show/Festival, and unfortunately, one of the worst coal-mining disasters in Pennsylvania history. Two gas and coal-dust explosions occurred within minutes of each other on December 6, 1962 in the Frosty Run shaft of Robena No. 3 mine, operated by U.S. Steel Corp. beneath Carmichaels. Thirty-seven men died 207 m (680 ft) below ground as a result of the first explosion; two other men were knocked down but not injured by the force of the second explosion. The remaining 133 miners in the mine that night escaped without mishap (Beitler, 2008; United States Mine Rescue Association, 2011).

Our stop at Laurel Point Falls Park (Figure 1) is an opportunity for conferees to examine the basal Dunkard rocks, collect some nice plant fossils, and learn about the Pleistocene Carmichaels Formation. The lower beds of the Waynesburg Formation, including the fossiliferous Cassville Shale, are exposed on both sides of Muddy Creek, which can be accessed via a series of trails descending the steep cliffs from near the picnic shelter in the park. Descent along the trail at the fence will allow you to arrive at Muddy Creek just downstream of Laurel Point Falls, a small but prominent waterfall

Harper, J. A., Kite, J. S., and Blake, B.M., Jr 2011, Stop 6: Laurel Point Falls Park—Cassville Shale and Carmichaels Formation, in Harper, J.A., ed., Geology of the Pennsylvanian-Permian in the Dunkard basin. Guidebook, 76th Annual Field Conference of Pennsylvania Geologists, Washington, PA, p. 305-316.

Figure 2. Photograph of Laurel Point Falls on Muddy Creek in Carmichaels, Greene County, PA. The falls is formed on a resistant lower layer of Mather Sandstone (Waynesburg sandstone of earlier authors).

near the bridge that carries Market Street across the creek (Figure 2).

We will also learn about the Carmichaels Formation, the Pleistocene lacustrine sediments found as terrace deposits in abandoned meanders of the preglacial Monongahela River. Carmichaels is the type locality.

WARNING: Use caution descending the paths into the deep Muddy Creek gully. The hill is steep and covered with tangling vegetation, including poison ivy, and rocks capable of causing serious injury. Some of the worn paths are better than others, but be certain to watch the path and your feet on the way down and while exploring the creek banks.

WAYNESBURG FORMATION

Waynesburg Coal

The Waynesburg coal traditionally had been considered to be the top of the Monongahela Formation. Berryhill and Swanson (1962), however, revised the stratigraphy of the Dunkard Group to include the Waynesburg coal at the base, and named all of the rocks from the base of the Waynesburg coal to the base of the Washington coal Waynesburg Formation (see Fedorko and Skema, 2011).

The Waynesburg is the most promi-nent coal bed in Greene County (Campbell, 1902; Stone, 1932a). It typically varies in thickness from 1.5 to 2.7 m (5 to 9 ft), includes many thin or a few thick shale partings (Figure 3), and often contains some pyrite (Stone, 1932a). Fontaine and White (1880) found that the shale partings varied greatly over a short distance, suddenly thickening from 13 or 15 cm (5 or 6 in) up to 1.8 m (6 ft) or more. The coal crops out in the valleys of the larger creeks in eastern Greene County, as well as in Wheeling Creek near the western boundary with West Virginia. Although there are places in the county where the coal is very thin, or even absent, it typically disappears only where it is cut out by the overly-ing Mather Sandstone (Waynesburg sandstone of Stevenson, 1876 and most later

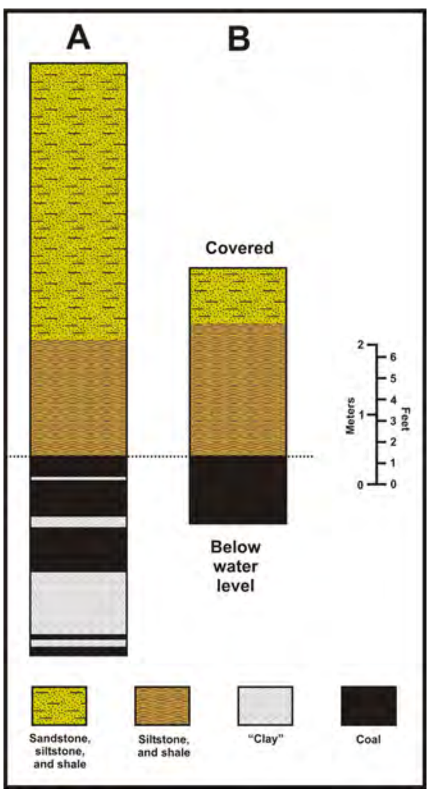


Figure 3. Stratigraphic sections of the lower Waynesburg Formation along Muddy Creek. A – Composite based on Stevenson (1876, p. 57). Notice the number of "clay" partings in the coal. B – Section measured by Harper on the north side of Muddy Creek opposite the most easily accessed fossil collecting site.

authors). As a resource, it has been most important in Greene County and adjacent parts of West Virginia where, historically, it was mined at many small country banks for local use. Stevenson (1876) found numerous such coal banks along Muddy Creek from Carmichaels to about 1. 6 km (1 mi) from its mouth in the Monongahela River.

Cassville Shale

The Cassville Shale (type locality – Cassville, Monongalia County, WV) forms the "roof" of the Waynesburg coal seam. It attains a thickness of up to 3.7 m (12 ft) in parts of Greene County (Stevenson, 1876; Stone, 1932a), although in the exposures at this stop, it is only about 1.2 to 1.5 m (3 to 5 ft) thick (Figure 3). It is, perhaps, best known as the unit containing the most abundant and diverse plant fossils in the Dunkard Group (see below). At Carmichaels, these usually are found within 0.6 m (2 ft) of the top of the coal. The shale disintegrates readily upon exposure to the elements, and so is difficult to obtain and preserve good specimens. Historically, the best material in the Carmichaels area was found in spoil piles associated with coal mining in the Muddy Creek valley.

Mather Sandstone Lentil

Where the Cassville Shale is absent, the overlying sandstone lies directly on top of, and sometimes cuts out, the Waynesburg coal. Stevenson (1876) originally named this Waynesburg sandstone, but Martin and Henninger (1969) renamed it the Mather Sandstone Lentil (also, see discussion and reply by Roen et al., 1970). This is the most conspicuous sandstone in Greene County, ranging from 12 to 21 m (40 to 70 ft) thick. It is coarse grained, light gray to light tan, and can be thin bedded or massive (Stone, 1932b). There are usually two nearly equal sections of sandstone separated by shale and/or fissile siltstone. The lower of the two is most often massive and forms cliffs and waterfalls where exposed, such as Laurel Point Falls (Figure 2). In some places, however, it tends to be soft and easily eroded, producing large cavities and honeycomb weathering patterns (Stevenson, 1876). The upper section of the sandstone typically is cross-bedded and flaggy. Although not exactly the best building stone in Greene County, it has been used in numerous localities for foundations, road metal, and even dimension stone. Good examples of the latter include several buildings in Waynesburg (Stone, 1932b) and the abutments of the two bridges at Carmichaels, including the famous 1889 Carmichaels Covered Bridge on Old Town Road (Stone, 1932a; Anonymous, 2011). The older section of the Greene Academy in Carmichaels probably is built from Mather Sandstone as well. Several quarries existed in the early 1900s in the vicinity that supplied much of the building stone and aggregate used in the town. At one time Cumberland Township operated a quarry on the bank of Muddy Creek where the Mather Sandstone is 12 m (40 ft) thick. Stone (1932a) reported that the rock was blasted down and hauled away without the need for crushing because it broke into chunks less than 0.3 m (1 ft) in diameter. At Stop 6, the Mather is mostly covered along the slopes of Muddy Creek (Figure 3), but where exposed is very hard and resistant. It forms the 3.4-m (11-ft) high Laurel Point Falls (Figure 2), and also forms a broad overhang of the Waynesburg coal and Cassville Shale just upstream from where the trail descends to the creek (Figure 4). Where the sandstone forms the bed of Muddy Creek just before the falls, it exhibits small potholes ranging in shape from circular to highly irregular (Figure 5).

Figure 4. Photograph of overhang of Mather Sandstone above the Cassville Shale a few meters east of Laurel Point Falls.

Plant Fossils

Many different varieties of plant fossils have been documented from the Cassville Shales, particularly in West Virginia near the type lo-cality of the formation, and at West Union in Doddridge County, WV (Fontaine and White (1880; D. White, 1913; Darrah, 1969). Stevenson (1876, p.59), in discussing the Cassville Shale at Carmichaels, wrote:

> The best locality for making collections is on Muddy creek, near Carmichaels, in Greene county, where, for almost half a mile, the shale and coal are finely exposed along the stream, and the very numerous openings give ready access to the roof. Mr. White [I. C. White, Stevenson's field assistant], who has given some attention to the study of fossil plants, has made out the following partial list of genera occur-ring at this locality and its vicinity:—*Neuropteris, Pecopteris, Alelhopteris, Sphenopteris, Anotopteris*?, *Goniopteris?, Sphenophyllum, Annularia, Pinnularia,* and *Hymenophyllites.*

Stevenson (1876, p. 131) also reported that a 6-ft long stem of *Calamodendron* (*Calamites* stem) that had been found in the roof of a coal mine along the bank of Muddy Creek near Carmichaels.

Fontaine and White (1880) described 104 genera and species of plants from the Cassville at numerous localities in southwestern Pennsylvania, northern West Virginia, and western Maryland. D. White (1913) added 5 more. Of these, 81 species were obtained from Cassville itself, 41 from West Union, 8 from Carmichaels, and 13 from various other localities in West Virginia and Maryland (Fontaine and White, 1880; D. White, 1913). The flora Fontaine and

Figure 5. Small potholes in the bed of Muddy Creek at Laurel Point Falls. A – Small circular pothole reminiscent of a drill hole. B – Somewhat larger, irregularly shaped pothole.

White (1880) found at Carmichaels included (their identifications):
Darrah (1969) collected 225 specimens from the Cassville Shale at Carmichaels, which he identified as:

Rhacophyllum lactuca (Sternberg)
Rhacophyllum speciocissimum Schimper
Pecopteris merianiopteroides Fontaine & White
Pecopteris pluckeneti Brongiart
Pecopteris pteroides Brongiart
Pecopteris miltoni Artis
Pecopteris arborescens (Schlotheim)
Sphenophyllum filiculmis Lesquereaux

He found the most common forms included *Macroneuropteris scheuchzeri,* the two species of *Neuropteris,* and *Pecopteris arborescens*. He thought this established the Carmichaels flora as

*Macroneuropteris scheuchzeri (*Hoffman)
Neuropteris auriculata Brongniart
Neuropteris ovata Hoffman
Pecopteris arborescens (Schlotheim)
Nemejcopteris (Pecopteris) feminaeformis (Schlotheim)
Pecopteris germari (Weiss)
Pecopteris stellataini
Callipteridium sp.
Annularia cf. stellataini
Callipteridium sp.
Annularia cf. stellata Schlotheim

being closer to the flora from West Union than to that from Cassville.

Hoskins et al. (1983), based on limited collecting over 20 years, found the genera *Sphenophyllum*, *Neuropteris*, *Odontopteris, Sigillaria,* and *Stigmaria* from the Cassville at Carmichaels, but didn't attempt to identify them to species. My own quick collections while researching this stop included very commonly occurring *Macroneuropteris scheuchzeri* and *Sphenophyllum* sp. The avid collector should be able to find more than a few forms. The shale has been hacked at and broken from the bank walls by many collectors over the years, and has collapsed from undercutting in some places. This provides much easily collected material.

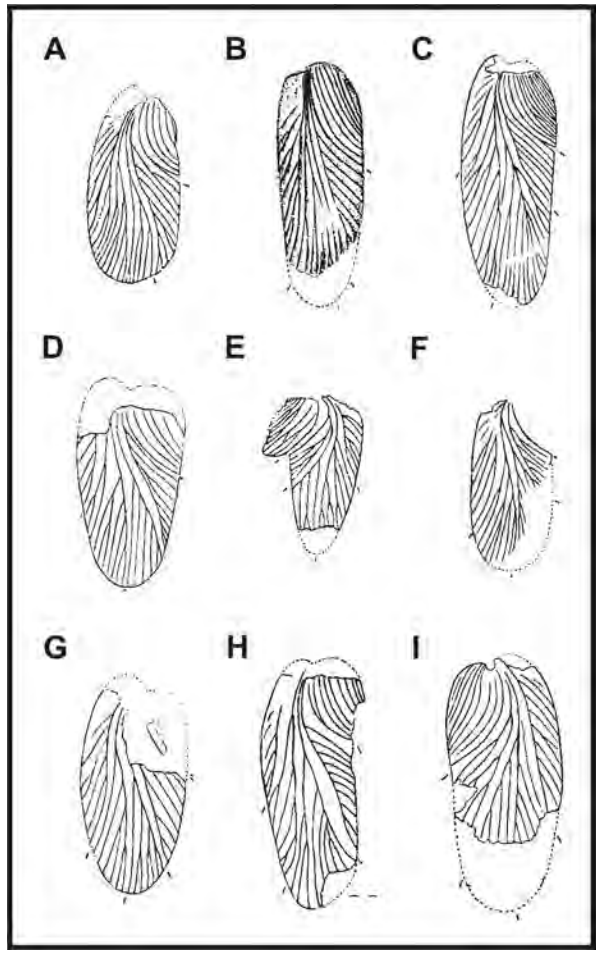
BE AWARE: The shale breaks very easily, so that good fossils can be lost if you are not cautious about carefully collecting, wrapping, and preserving your finds. It is highly recommended that collectors bring plenty of newspaper or paper towels, collecting bags (plastic zipper bags are ideal, and you can write on them with a permanent marking pen like a Sharpie), and one or more boxes. Try not to pile too much shale into a bag or box. The better you take care of your specimens the more valuable they will be to you. If you do happen to find some good identifiable specimens, we will have some high-powered expertise on the field trip who should be able to tell you what you found.

Invertebrate Fossils

The Cassville Shale is also well known for its fossil insect fauna (Scudder, 1895), although these elusive fossils are much more difficult to find and identify. No fossil insects have been described or officially reported from Carmichaels, but it wouldn't surprise me to learn that many wing impressions from this locality occur in private collections, and possibly even in local area university collections. Anyone collecting plant fossils from the Cassville should be on the lookout for insects. Don't be fooled – they might look like tiny plant leaflets, but the veination is significantly different.

Cassville insects all belong to the Order Blattoidea – the cockroaches (Figure 6). Non-

Figure 6. Representative fossil cockroach wings from the Cassville shale (reproduced from Scudder, 1895). A – *Amblyblatta lata* (Scudder). B – *Amoeboblatta permanenta* (Scudder). C – *Apempherus complexinervis* (Scudder). D – *Bradyblatta sagittaria* (Scudder). E – *Exochoblatta hastate* (Scudder). F – *Penetoblatta virginiensis* (Scudder). G – *Petrablattina ovata* (Scudder). H – *Spiloblattina aperta* (Scudder). I – *Symphyoblatta debilis* (Scudder). All drawings X2.



blattoids occur in some Pennsylvanian formations, but none are known from the Cassville Shale. Scudder (1895) and Handlirsch (1906) originally described the Cassville insects, but more recent revision has reduced the number of species considered valid (Durden, 1969).

In addition to insects, the Cassville Shale also is known to contain at least one other invertebrate fossil. Scott (1971) documented two specimens of the eurypterid, *Adelophthalmus mansfieldi* (C. E. Hall) (Figure 7), from a 3-m (10-ft) thick section of the Cassville Shale in a road cut about 7.2 km (4.5 mi) east of Waynesburg, PA. Hall (1877) originally described *A. mansfieldi* from the shale below the Darlington coal of the Allegheny Formation near Cannelton, Beaver County, Pennsylvania. As with insects, nothing of this sort has been recorded from Carmichaels, but avid collectors should keep a close eye on their finds.

CARMICHAELS FORMATION

The Monongahela River between Greene and Fayette counties flows in a steep-walled channel that is about 46 m (150 ft) deeper than the surrounding country side. The river did not always occupy that particular channel, however. At one time, before Pleistocene glaciation occurred to the north, the ancestral Monongahela (Pittsburgh River of Stout et al., 1943) wound in a far more circuitous route than the present day river (Figure 8), and at a substantially higher elevation. At some point since the first glacier advanced into northwestern Pennsylvania and blocked the predominantly northwestward

Figure 7. *Adelophthalmus mansfieldi* (C. E. Hall). From Hall (1884), pl. IV, fig.2.

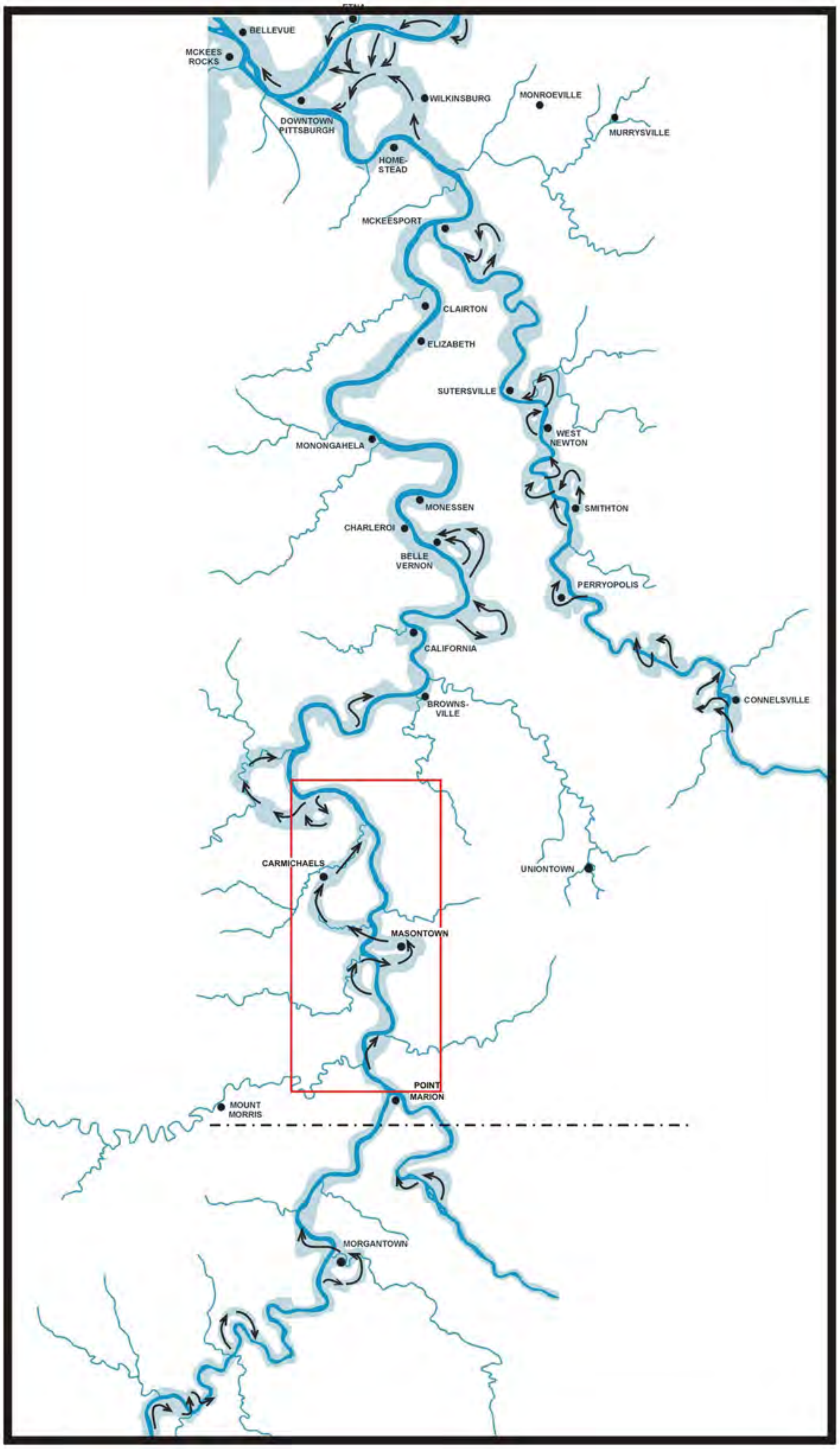


Figure 8 The modern Monongahela River drainage, including larger tributaries in darker blue, with approximate traces of abandoned pre-glacial meanders (terraces) in lighter blue. Town names for orientation. Arrows indicate directions of flow. The red rectangle indicates the area shown in Figure 9.

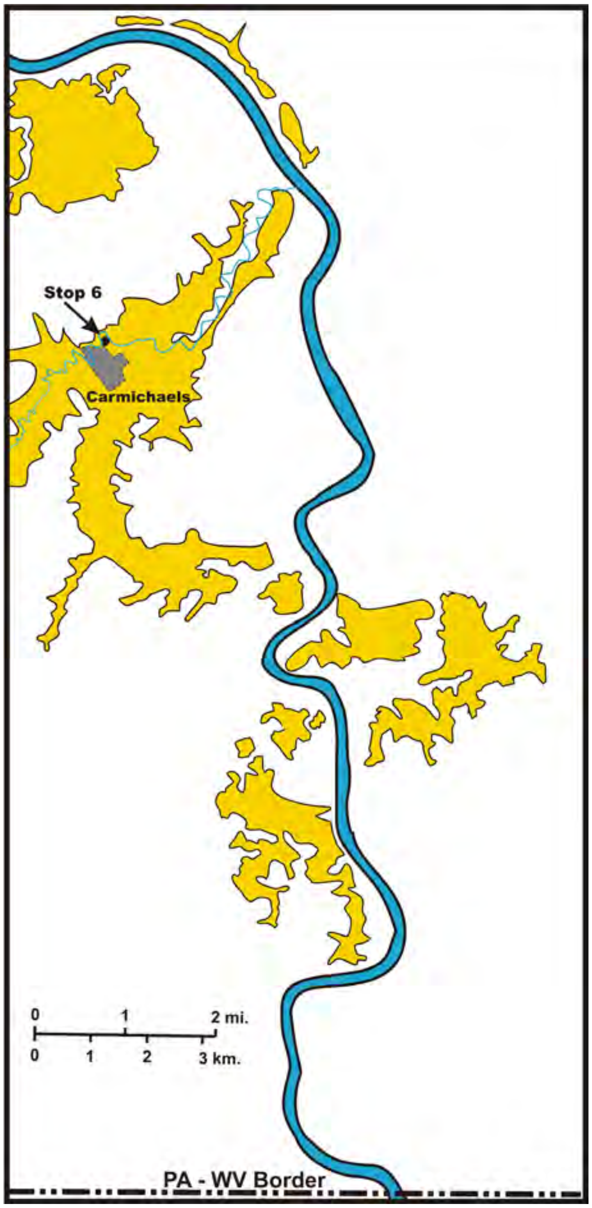


Figure 9. Extent of the existing Carmichaels Formation at Carmichaels (redrawn from Campbell, 1902).

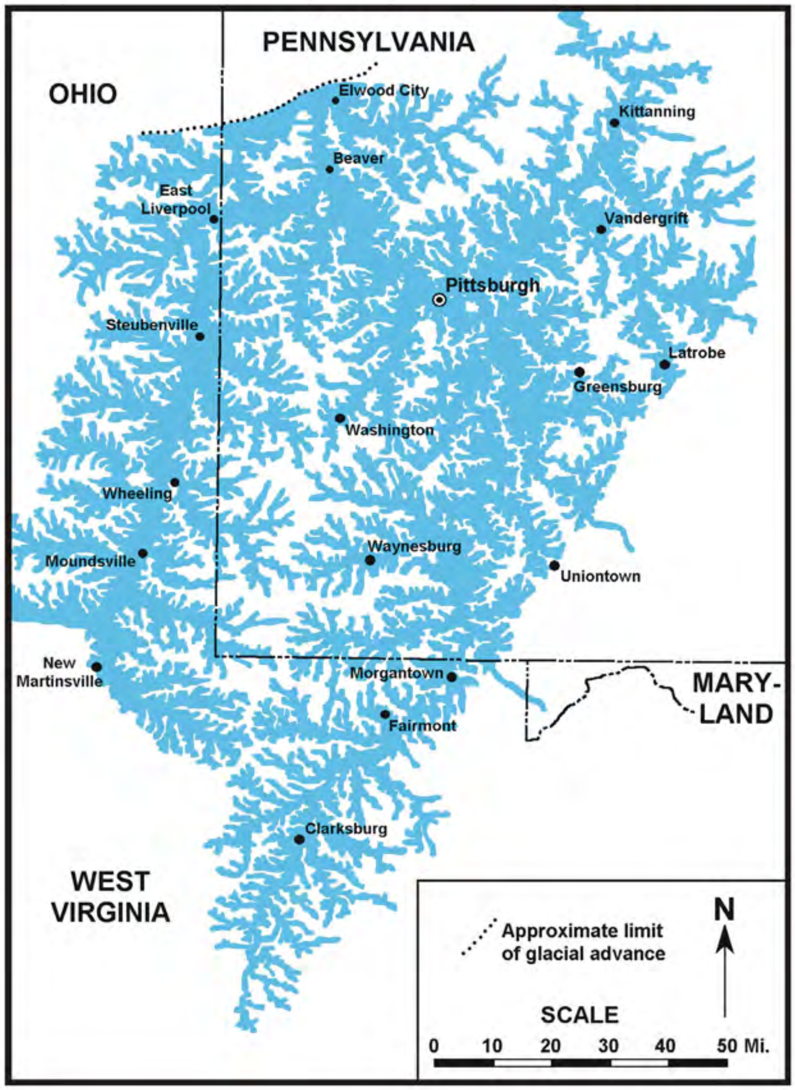
drainage, most of the meanders were abandoned and the current channel was cut, leaving numerous old channel segments high-and-dry. One of the more prominent of these abandoned meanders occurs at Carmichaels (Figure 9), although it is difficult to recognize from ground level. Other than the broad, flat topography atypical of southwestern Pennsylvania, the town of Carmichaels would not seem to be much different than any other small community in Greene County. The flatness of the topography, of course, would have attracted many settlers and businesses, and excavation of basements would have exposed an extensive deposit of unconsolidated sediment resembling that found in the floodplain of the Monongahela. Today, we call such a flat area above the river a terrace.

White (1896) was probably the first to recognize that there actually are several terraces, containing varying thicknesses of clay, sand, and gravel, at various levels in the valleys of the Monongahela, Allegheny, and Ohio rivers and their tributaries. He suggested that these were deposited during the Pleistocene in a vast lake-like reservoir that he called Lake Monongahela. He suggested that the north-flowing river system had been blocked by advancing glacial ice, impounding the river waters, and raising the level of Lake Monongahela to an elevation of 335 m (1,100 ft).

Much of what is currently known about Lake Monongahela comes from studies of the terrace remnants located near the present Monongahela River channel in northern West Virginia and southwestern Pennsylvania (Wright 1890; White, 1896; Leverett, 1934; Gillespie and Clendening 1968; Morgan, 1994), and near the lower Allegheny channel north and east of Pittsburgh (Marine, 1997). Modern reconstructions of Lake Monongahela (Figure 10) indicate that the lake's boundaries extended into the upper Ohio and the lower Allegheny drainages as well as throughout the Monongahela drainage (Gillespie and Clendening, 1968; Morgan, 1994; Marine, 1997; Marine and Donahue, 2000).

As the ponded water in Lake Monongahela rose, it eventually overtopped drainage divides, and the water spilling over them eroded cols in the divides and formed new drainage channels paralleling the ice margin. Because these outlets were now at lower elevations, ponding during the next glacial advance never reached the level of the first ponding. Subsequent pondings occurred at progressively lower elevations as the outlets were eroded and the river channels became entrenched. And as each ponding occurred, newly formed lacustrine

Figure 10. Reconstruction of the possible configuration of Lake Monongahela based on the 335 m (1,100 ft) maximum lake elevation (modified from Marine, 1997).



sediment was deposited in the lake bottom and sides.

Because the Monongahela River system was impounded several times, leaving different lacustrine remnants at different elevations (Leverett, 1934; Fullerton, 1986; Jacobson, 1987), there are complications. Depositional events from repeated glacial advances and retreats have overprinted each other stratigraphically, making it difficult to decipher the drift boundaries of individual glacial events (Marine and Donahue, 2000).

Campbell (1902) named these Lake Monongahela lacustrine deposits found throughout northern West Virginia and southwestern Pennsylvania Carmichaels Formation for deposits preserved in the abandoned meander channel at Carmichaels (Figure 9). The name is often used for all Pleistocene terrace deposits, even though many of the sediments in the Allegheny-Ohio drainage are distinctly different glacial outwash deposits.

Unfortunately, we probably will not see any exposures of the Carmichaels. As Donahue and Kirchner (1998) indicated, one of the more frustrating aspects of doing field work on the Carmichaels is the lack of good exposures. Rare exceptions include building excavations, road construction, and dug but unfilled grave sites. Carmichaels deposits typically consist of clay, silt, and sand, generally ranging in color from

Figure 11. Photograph of Carmichaels Formation at Speers, Washington County. Notice the red coloration and the large range of clast size.

Table 1. Terrace levels of the Monongahela River near Morgantown, West Virginia (after White, 1896)

Terrace	M (Ft) Above River Level	M (Ft) Above Sea Level
First	9-12 (30-40)	~253 (~830)
Second	23-24 (75-80)	~267 (~875)
Third	38-53 (125-175)	280-296 (920-970)
Fourth	~61 (~200)	305 (1,000)
Fifth	84-91 (275-300)	320-335 (1,050-1,100)

reddish-orange to tan, and containing subangular to well-rounded, cobbles and boulders of local bedrock, typically sandstone (Marine, 1997; Donahue and Kirchner, 1998; Marine and Donahue, 2000) (Figure 11). The clays tend to be highly plastic (Carmichaels clay was used in the early pottery industry in western Pennsylvania). Donahue and Kirchner (1998) speculated that the red clays might be derived from soils developed during the interglacial intervals. Carmichaels Formation deposits occur on the upper two terrace levels (Jacobson et al., 1988).

White (1896; also Jacobson, et al., 1988; Morgan, 1996; Marine, 1997) recognized that Carmichaels Formation terraces within the Monongahela drainage can be grouped by elevation above sea level into three distinct levels representing three different glacial damming events (Table 1): 1) ~320-335 m (~1,050-1,100 ft) representing one pre-Illinoian stage of glaciation; 2) ~ 305 m (~1,000 ft) representing a second pre-Illinoian stage of glaciation; and 3) ~280-296 m (~920-970 ft) representing Illinoian glaciation. These elevations represent the upper limits of Lake Monongahela deposition. The glacial ages are based primarily on correlation with outwash gravel trains and drift, and on remanent paleomagnetism measurements at widely scattered localities (Marine, 1997). Two lower terraces, occuring at 253 m (~830 ft) and 267 m (~875 ft) (Table 1) represent Wisconsinan glaciation (White, 1896; Marine, 1997), and are not composed of Carmichaels Formation sediment. Marine (1997) could find no geomorphic evidence of lake-cut terraces or discernible paleoshorelines, at least in the lower Allegheny drainage. In most cases the lacustrine silts and clays associated with Lake Monongahela rest directly on bedrock, suggesting that Lake Monongahela did not form the high terraces themselves, but modified pre-existing river terrace remnants by mantling them with lacustrine clays and silts. Also, the time duration of the ponded waters in the lower Allegheny and Monongahela valleys was not sufficient to cut terraces in the local bedrock.

Campbell (1902) indicated that the rock floor of the meander channel at Carmichaels lies at an altitude of 280 m (920 ft), indicating that the type Carmichaels Formation is probably Illinoian in age. The deposit is as much as 18 to 21 m (60 to 70 ft) deep, and extends up the sides of the valley about 49 m (160 ft) above the floor of the meander. The bottom of the channel contains well-rounded boulders, and the material deposited upon this layer shows no regularity of deposition. As Campbell (1902) pointed out, at times the waters must have been still because of the abundance of clay; at other times there were fairly strong currents that brought sand and coarse material, including boulders, into the deposit. One can occasionally find wood and other organic debris in the matrix, such as a log that was reported to have been found in the clay about 12 m (40 ft) from the surface (Campbell, 1902).

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STOP 7: THRALL CONTRACTING COMPANY QUARRY – WASHINGTON FORMATION AND JOLLYTOWN COAL (OF STEVENSON)
Leader—Vik Skema

The highwall of the Thrall Contracting Quarry along Toll Gate Road west of Waynesburg, Pennsylvania (Figure 1) exposes approximately 50 ft (15 m) of the middle part of the Washington Formation, including the Jollytown coal (of Stevenson) at the top of the cut (Figure 2). The limestone that is usually found closely below this coal is missing at the quarry. There are limestone nodules in a siltstone 14 ft (4 m) below the coal, and a thin lag deposit of limestone nodules in a 3 ft (0.9 m) sandstone directly under the siltstone. The siltstone contains several layers of horizontally aligned limestone nodules. This is about the same stratigraphic horizon as the peloidal limestone in the Roberts Ridge Road section, which was also directly on sandstone (see discussion for Stop 2). These aligned limestone nodules at Thralls Quarry could be remnants clasts of hard micritic limestone that had nearly completely deteriorated from extensive sub-aerial exposure.

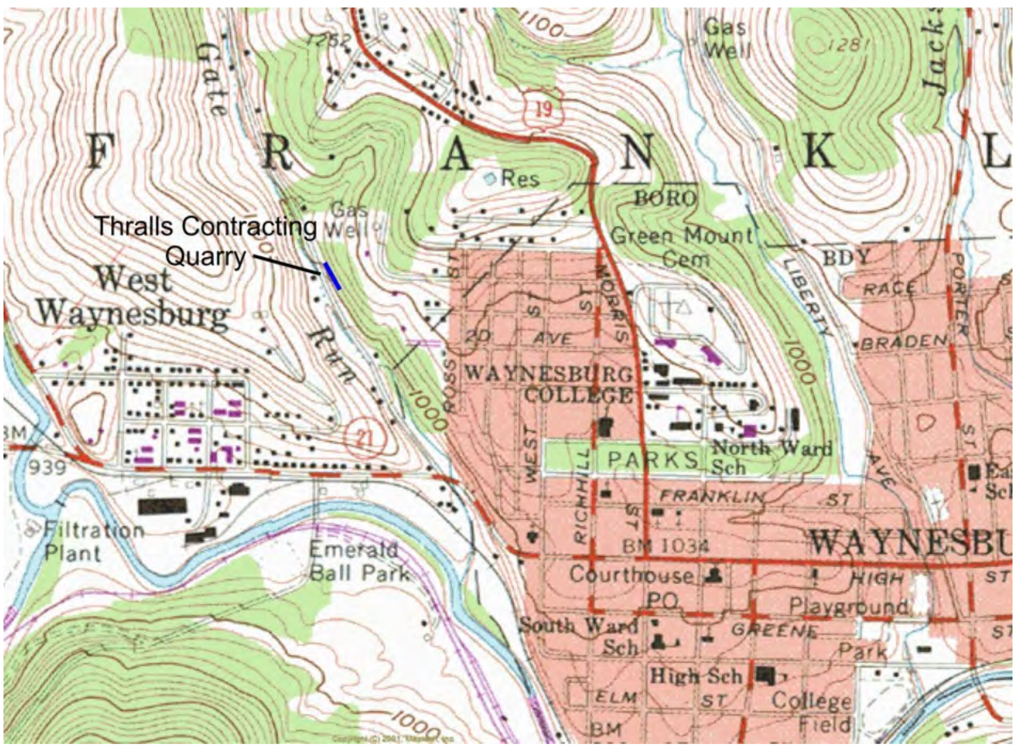

Figure 1. Location of Thralls Contracting quarry along Toll Gate Road, west of Waynesburg, Pennsylvania.

There is a well developed vertisol paleosol 6 ft (1.8 m) below the sandstone (Figure 3). It consists of two beds. The upper 2.4 ft (0.7 m) is greenish gray with some red mottling. It has a blocky soil structure and all traces of bedding planes have been destroyed. It contains abundant, irregular shaped limestone nodules of varying sizes. Size appears to increase upward, and the largest are about 2¾ X 4½ in (70 x 120 mm) in size (Figure 4). They are composed of hard

Skema, V., 2011, Stop 7: Thrall Contracting Company quarry – Washington Formation and Jollytown coal (of Stevenson), *in* Harper, J. A., ed., Geology of the Pennsylvanian-Permian in the Dunkard basin. Guidebook, 76th Annual Field Conference of Pennsylvania Geologists, Washington, PA, p. 317-320.

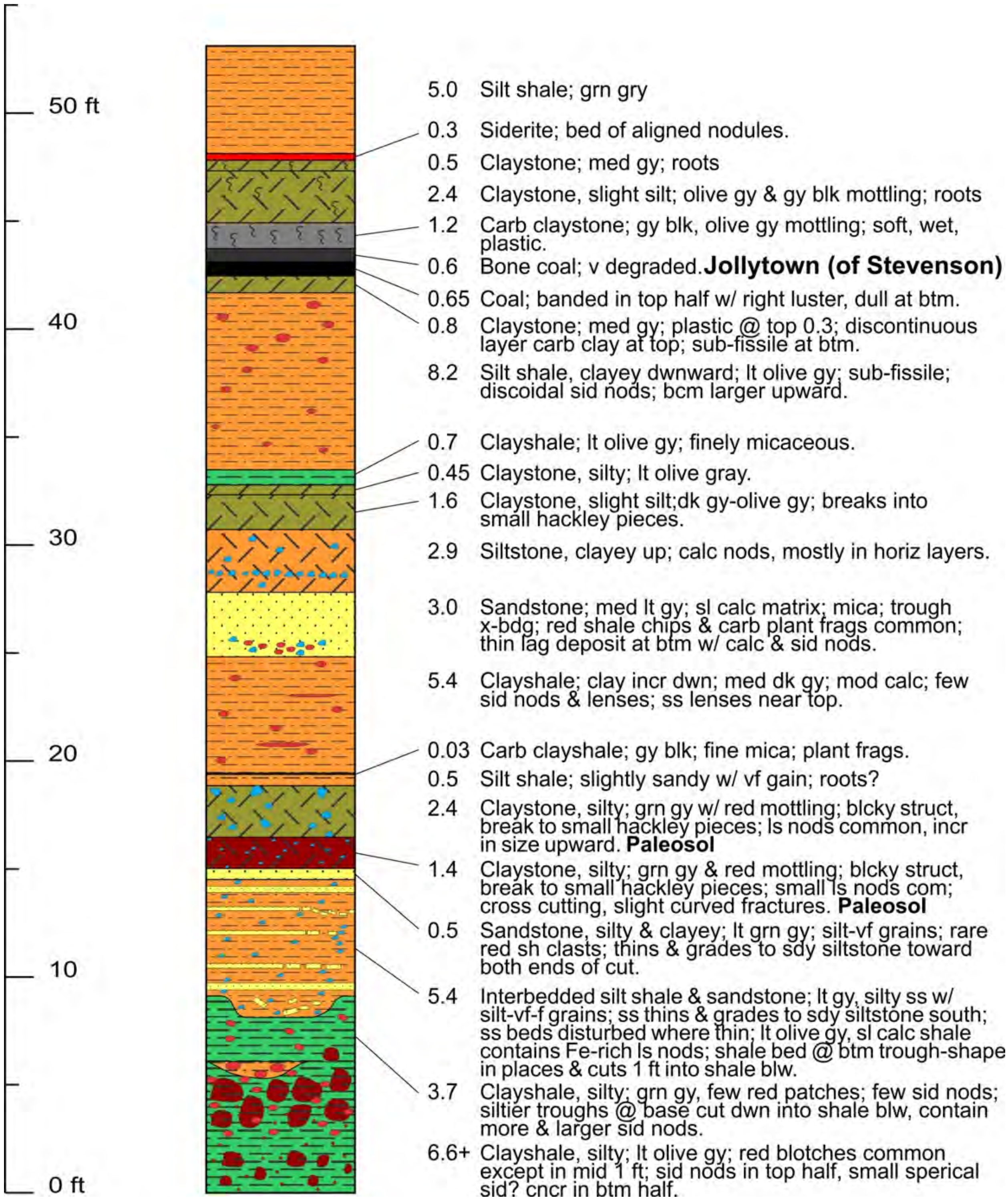

Figure 2. Graphic log of measured section at Thralls Contracting quarry. Measured and described by Vik Skema.

Figure 3. Well developed paleosol containing limestone nodules exposed at Thralls quarry.

Figure 4. Large limestone in upper part of paleosol.

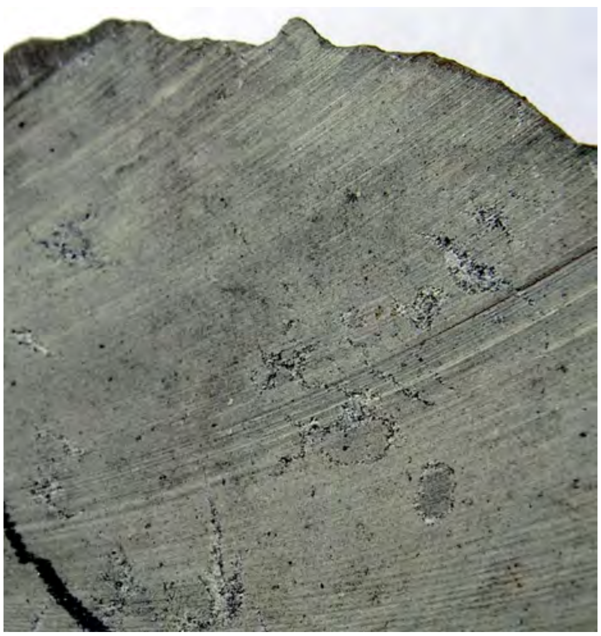

Figure 5. Limestone nodules in upper part of paleosol are composed of hard micritic limestone and contain thin fractures filled with finely crystalline sparry calcite. Some of these are circular.

Figure 6. The outer surfaces of the limestone nodules have small secondary sub-spherical concretions

micritic limestone and contain thin fractures filled with finely crystalline sparry calcite. Some of these fractures are circular; a few are perfect circles (Figure 5). A few of these circles contain slightly darker colored material. The outer surfaces of the nodules have small secondary sub-spherical concretions and patches of dripstone-like calcite (Figure 6). The lower bed of the paleosol is 1.4 ft (0.4 m) thick and is also mottled red and greenish gray, but with noticeably more red. It contains cross cutting fractures that are oblique and slightly curved. It also contains calcareous concretions, but these are all small, and there are no large nodules as in the upper bed (Figure 7). The wide size range of the limestone nodules in the upper bed, and the upward increase in their size suggests the possibility that they may be altered remnant limestone clasts of the parent material and not strictly products of pedogenesis. The more uniformly sized calcareous concretions of the lower bed appear to be pedogenic glaebules.

The relatively long horizontal extent of the strata in the highwall of Thralls Contracting quarry allows a good look at lateral changes in the unit directly below the paleosol that contains 5.9 ft (1.7 m)of interbedded sandstone and silt shale. The sandstone beds have silt to very fine grain size and contain clay and abundant mica. They appear to be somewhat sideritic. The upper most bed is thickest (0.5 ft [0.15 m]), but thins and grades into siltstone toward both ends of the quarry wall. All of the other beds below are thicker and cleaner on the north end and thin to the south as they grade into siltstone. All of the sandstone beds become discontinuous as they thin, and take on a somewhat broken and jumbled appearance (Figure 8). A few individual pieces of sandstone become rounded as the bed breaks apart. Some of these have flow roll features (Figure 9). These features probably resulted from deformation during compaction of thin, only partially lithified sandstone beds into softer mud interbeds. The silt shale interbeds contain iron-rich, calcareous sub-spherical nodules. Some of these are stacked vertically. The bottom of the interbedded sandstone and silt shale unit is unconformable and has shallow troughs that cut into the underlying shale. They are composed of slightly sandy silt shale and contain an abundance of the same calcareous nodules that were scattered throughout the silt shale interbeds in the unit. There are also some pieces of the broken apart sandstone in these troughs.

The bottom of the section is greenish gray silty clay shale (fissile to sub-fissile mudstone) that contains relatively large blotches of red coloration. The upper half of this shaley section contains discoidal siderite nodules. The size of these varies, and some are large. The bottom half has unusually small (0.1 to 0.4 in [3-10 mm]) and spherical concretions that are probably also siderite.

Figure 7. Lower part of Paleosol is mottled red and green and contains small calcareous concretions.

Figure 8. Interbedded sandstone and silt shale unit under paleosol changes laterally at Thralls quarry. Sandstone beds thin and grade into sandy siltstone. As they thin they become somewhat broken apart and jumbled from compactional deformation.

Figure 9. Flow roll features in a few of the broken apart sandstone beds suggests that they were only partly lithified during compactional deformation.

STOP 9: GREATHOUSE HILL ROAD CUT – MIDDLE AND UPPER ROCKPORT LIMESTONE (UPPER GREENE FORMATION)

Leader – Blaine Cecil

The strata exposed at this stop on Greathouse Hill Road, Wetzel Co., WV (Figure 1) occur near the middle part of the nearly 183 m (600 ft) thick Greene Formation (see Fedorko and Skema, 2011). The strata here appear to have been deposited within the Dunkard lacustrine basin as opposed to the alluvial plain environment, which occurs further to the south. This stop illustrates many key features related to autocyclic and allocyclic conditions during deposition of the Greene Formation as well as many other parts of the Dunkard Group. The lithology's

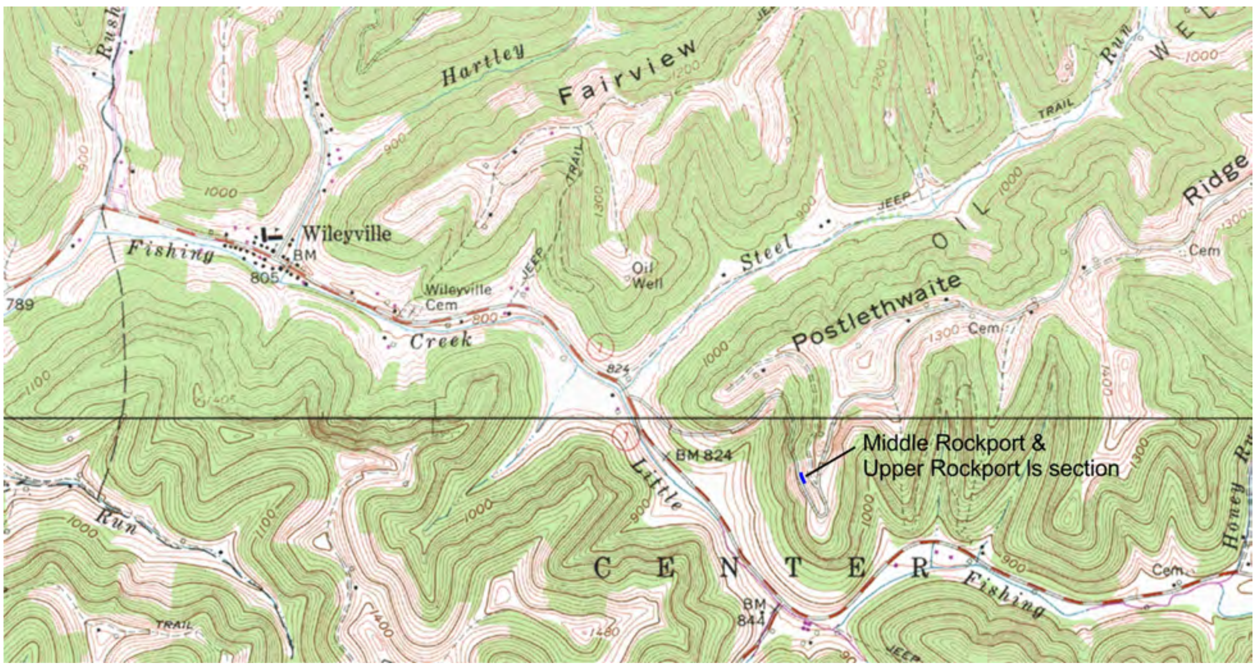

Figure 1. Location of exposure of the Middle Rockport to Upper Rockport limestone section on Greathouse Hill Road near Wileyville, WV.

associated with the Middle Rockport Limestone are of specific interest in ascending order: **a)** basal mudstone (≥2 m [≥6.6 ft] petrocalcic paleosol), **b)** limestone (nonmarine, Middle Rockport Limestone), **c)** thin shale bed, and **d)** "flat bottom" sandstone (Figures 2 and 3).

A discussion of units **a** through **d** follows:

a) The mudstone at the base of the exposure is a well-developed petro-calcic paleo-Vertisol. This paleosol provides definitive information about the paleo-water table, soil moisture, the nature of pedogenesis, and the ambient paleoclimate. The pedogenic features contained within the 2 m (6.6 ft) paleosol, such as the blocky peds and cross-cutting fractures indicate that the paleosol was subjected to seasonal

Cecil, C. B., 2011, Stop 9: Greathouse Hill Road cut—middle and upper Rockport limestone (upper Greene Formation), *in* Harper, J. A., ed., Geology of the Pennsylvanian-Permian in the Dunkard basin. Guidebook, 76th Annual Field Conference of Pennsylvania Geologists, Washington, PA, p. 321-325.

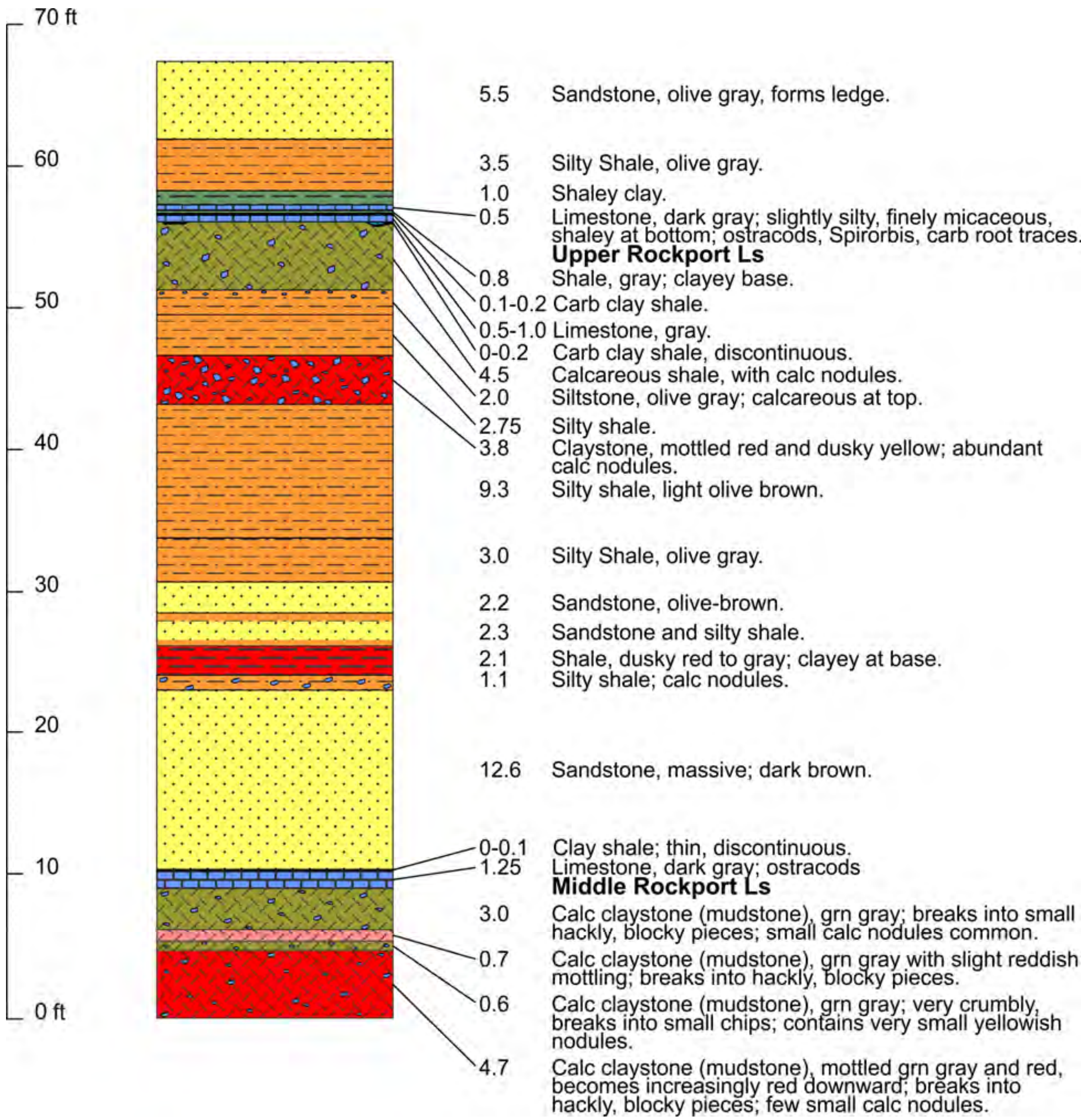

Figure 2. Graphic log of measured section of the Middle Rockport limestone and underclay, Upper Rockport limestone, and associated rocks at exposure on Greathouse Hill Road near Wileyville, WV. Lower Rockport and underclay section measured and described by Blaine Cecil and Vik Skema. The remainder of the section is a modification of section of Auriel Cross (in Cross and Schemel, 1956). Primary thickness values are in feet and tenths of feet.

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rainfall, but it was rarely if ever water logged during pedogenesis. However, the red-green mottling indicates that there was sufficient soil moisture for part of the year to cause partial reduction of iron. The water table must have been at least two meters below the paleosol surface, even in the lacustrine basin. The dark red zone beneath the mottled horizon is probably the relatively unaltered C or R horizon (Figure 4). The highly calcareous nature of the paleosol is indicative of a general ustic soil

Figure 3. Middle Rockport limestone and underclay.

Figure 4. Lower portion of paleosol under Middle Rockport limestone. Limestone is concealed, but sandstone bed that overlies it can be seen at top of photo.

moisture regime where evaporation always removed soil moisture absorbed from precipitation, a process that causes calcium carbonate accumulation. Thus, pedogenesis resulted in the addition of calcium carbonate to the entire soil profile with minimal to no leaching (weathering) of primary minerals. Formation of such soils occurs in dry-subhumid to semiarid climates. Unlike the paleosol complex discussed at Stop 4, the paleosol here does not exhibit visible evidence for an increase in precipitation during the later stages of pedogenesis.

b) At Stop 9, 10 to15 cm 4 to 6 in) of nonmarine limestone unconformably overlies the calcic-paleosol. This limestone appears to be regional in extent, having been correlated with an equivalent limestone described near Rockport, WV about 97 km (60 mi) southwest of Stop 9 (see Fedorko and Skema, 2011). Unlike most nonmarine limestones in Pennsylvanian and Dunkard strata, the limestone here does not contain discernable subaerial exposure features. The limestone above the calcic paleosol records an allocyclcle-driven rise in the water table and a switch from pedogenesis and a subsurface ground water table to lacustrine conditions and carbonate deposition. There is no compelling field evidence to indicate the cause of water table rise. Hypothetically, however, water table rise may have been driven by either the rapid development of a pluvial period, or a far-distant sea level high stand that ponded drainage from the Dunkard basin thereby creating lacustrine conditions in the topographically lowest portion of the basin. If the latter case were the actual mechanism, then both the Middle and Upper Rockport limestones would have been deposited contemporaneously with an open marine, high stand limestone, as might be found in the Western Interior basin of Kansas. Ponding of drainage by repeated sea level rise appears to have contributed to the Pleistocene/Holocene stratigraphy of bottom sediments in the Gulf of Carpentaria basin, Northern Australia (Edgar et al., 2003).

c) The stratigraphy at the previous stop (Stop 8) included the Upper Washington Limestone overlain by the thin Jolleytown underclay and coal. In turn, the coal bed horizon is overlain by a dark gray shale (interpreted as lacustrine prodelta mud by

Cecil), which is comformably overlain by a "flat bottom" sandstone. This stratigraphic succession is common in many Dunkard cycles. For whatever reason, here at Stop 9, the underclay, coal, dark gray shale succession is missing and the Middle Rockport Limestone is overlain by a very thin shale that occupies the stratigraphic position of the coal and dark gray shale exposed at Stop 8.

d) The thin shale is overlain by flat bottom sandstone, interpreted here, as elsewhere by Cecil, as a distributary mouth bar. Such mouth bars formed as deltas prograded into standing-water systems. The stratigraphic succession above the calcic paleosol indicates that lacustrine conditions developed but remained shallow during deposition of the nonmarine limestones. Subsequent deepening was accompanied by deltaic progradation, at least through deposition of flat-bottom sandstones. The top of the flat bottom sands is often incised by channel-form sandstones that were the result of incision by distributary progradation (see Cecil et al., 2011). Overlying channel-form sandstones and shales, that appear to be flood plane deposits, were the result of autocyclic alluvial plane progradation. Subsequent water level fall and subareal exposure caused pedogenesis to begin again at the top of the cycle. There is no conclusive evidence to suggest that erosional bases of channel-form sandstones, not only here but also throughout the Dunkard, were ever the result of fluvial incision induced by sea level fall.

If, in fact, the limestones beds, such as the Middle and Upper Rockport exposed at this stop, are regional in extent, then they are marker beds that are likely the result of allocyclic processes. These allocyclic processes may have included 1) a sea level high stand that ponded Dunkard basin drainage, and 2) a relatively dry climatic regime. The high stand ponding and the dry climate resulted in regional-scale alkaline lakes, and carbonate deposition. In addition, if lacustrine deepening following limestone deposition, as indicated by the overlying shales and flat-bottom sandstones, then an allocyclic control on lake level rise is indicated. Thus, the unconformities at the surface of the paleosols that underlie the limestones may represent cycle boundaries. The limestone-shale-flat bottom sandstone succession may then denote the early part of the subsequent sedimentary cycle. The heterogeneity of intervening strata may be the result of autocyclic deposition in mixed alluvial plain and deltaic-lacustrine environments (see Cecil et al., 2011 and Cecil, 2003, for a discussion of autocyclic and allocyclic processes).

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HARPER'S GEOLOGICAL DICTIONARY

CRYSTALLOGRAPHY - [L. Crystallum, crystal; graphicus, to write or record] The procedure a bride-to-be performs at the local department stores to inform wedding guests which pattern of glassware she has chosen to match her very best dinnerware (see SINOLOGY, the study of china).

STOP 10: PHIL MYERS FARM—GEOMORPHOLOGY OF THE DUNKARD BASIN

Leader: Bill Sevon

We are now at Phil Myers farm where we can look over the landscape that comprises the area of this field conference (Figure 1). We arrived by travelling up Greathouse Road to the hilltop. The road from the hill base to the top illustrates a typical aspect of the area – the outcrops are along the roads. You will see no outcrops from this view point. What you will see is typical scenery.

Figure 1. Topographic map of the stop area centers on Phil Myers farm. Map is part of the Wileyville 1;24,000-scale topographic map. Note the NSTA tributary pattern. Red lines delineate valleys.

Greathouse Road brought us to the curvy crest of Postlethwaite Ridge. The crest of this ridge is free of woodland vegetation and you can see the smooth curvature of the narrow ridge crest (Figure 2). This is typical of the Greene and Washington county area. The bedrock is Greene Formation the typical bedrock throughout most of the area traversed on this trip. The slopes are covered with woodland vegetation that obscures whatever geology that may be there.

Looking in either direction at the ridge crest, one obtains an excellent view of what most upland surfaces in the area are like: smooth surfaced, narrow, and nicely rounded with no upland flat. Looking to the west one gets a good view of the existence of the noses of several slopes separated by tributaries flowing into Steel Run that in turn joins Little Fishing Creek. More ridge crests are in the background. Despite the total woodland vegetation, the overall aspect of upland crest, tributary valleys, and sloping noses coming down from the upland top is

Sevon, W. D., 2011, Stop 10: Phil Myers farm, *in* Harper, J. A., ed., Geology of the Pennsylvanian-Permian in the Dunkard basin. Guidebook, 76th Annual Field Conference of Pennsylvania Geologist, Washington, PA. p. 326-328.

Figure 2. Typical ridge-top farm land in the Dunkard Basin along smoothly curving, narrow crests.

Figure 3. The view to the west of the Phil Myer Farm provides a good example of the north side tributary asymmetry so prevalent in the Dunkard Basin. The sloping noses in the valley wall along Steel Run are separated by relatively large tributaries that enter the valley from the north to northwest.

clearly visible. One feature of these tributaries and all the tributaries in this area is their north side tributary asymmetry (NSTA) (Figures 1 and 3). There are a few, very short tributaries that enter the NE-SW trending larger streams from the southeast, but the large tributaries enter from the north or northwest. This suggests that either the bedrock has a small south dip or the streams prefer to erode northward following the concept of Lattman (1954), or there is some other unknown explanation.

One factor not discussed in the paper is that of folds. There are several anticlines and synclines in the Greene and Washington counties area that have a NE-SW orientation. These folds lack of obvious surface expression that is not surprising because structural relief on these folds ranges from 5 to 135 ft (1.5 to 41 m) and averages 50 ft (15 m). Thus, with fold axis separation of about 3.5 mi (5.6 km) and irregular axial traces, such folds are less than easily discernible.

Figure 1 shows not only the local topography, it shows topography that is essentially identical to that shown in Sevon (this guidebook, figs. 4, 5, and 6). This area in West Virginia shows that the topography typical of the Waynesburg Hills Section extends beyond the borders of Pennsylvania, into West Virginia. Despite the apparent similarity of the topography throughout the section and beyond, much needs to be learned about the origin of the topography. That investigation would necessitate closer attention to the lithologic variability and the probable effects of small structural variations. It would not be a simple investigation, it would be challenging, and in the end, not only beneficial to geological science, but a reward to the studier.

REFERENCE

Lattman, L. H., 1954, The one-sided development of tributaries in tilted sedimentary rocks in the eastern Allegheny Plateau of West Virginia: Papers of the Michigan Academy of Science, Arts and Letters, v. 39, p. 361-365.

HARPER'S GEOLOGICAL DICTIONARY

NAPPE - a large thrust sheet in a temporary state of suspended tectonic activity.

PENNSYLVANIA GEOLOGICAL SURVEY
EST. 1836

PITTSBURGH GEOLOGICAL SOCIETY
1945