UPPER DEVONIAN STRATA OF THE NORTHERN APPALACHIAN BASIN

Field Trip 1 – 27-29 July, 2023

Subcommission on Devonian Stratigraphy
Geneseo, New York

SDS 2023 - pre-meeting trip - Upper Devonian Marine Strata of the Northern Appalachian Basin

Day 1 – 27 July (Thursday)
0.0 0.0 Depart La Quinta Inn – W 150 Street, Cleveland Airport North – 8:00

4.5 4.5 Stop 1 – Morley Ford Dam, Valley Pkwy, Rocky River Reservation, Cleveland, Ohio. Chagrin and Cleveland members of the Ohio Shale (no hammers or collecting).

10.3 14.8 Stop 2 – North Quarry Picnic Area, Valley Pkwy, Wallace Lake, Berea, Ohio. D-C Boundary: Bedford, un-named unit, and Sunbury Member of the Orangeville Formation (no hammers or collecting).

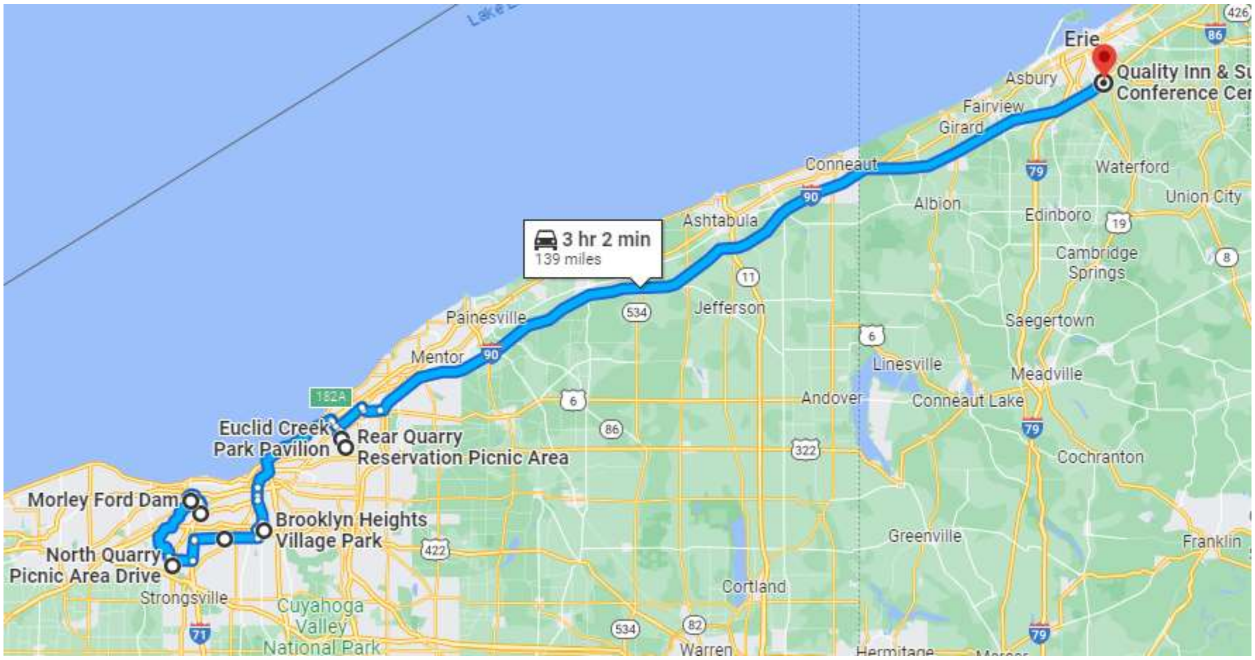
8.5 23.3 Stop 3 – Snow Road Picnic Area, Big Creek Pkwy, Parma Heights, Ohio. Red Bedford Formation (no hammers or collecting).

5.1 28.4 Stop 4 – Tuxedo Road, Brooklyn Heights Village Park, W 4th Street. Chagrin and base of Cleveland members with Skinners Run Bed (no hammers or collecting).

19.4 47.8 Stop 5a – Euclid Creek Park Pavilion / Welsh Woods Picnic Area, Euclid Creek Reservation, Euclid, Ohio. Chagrin and Cleveland members of Ohio Shale – cycles (no hammers or collecting).

1.7 47.5 Stop 5b – Rear Quarry Reservation Picnic Area, South Euclid, Ohio. Euclid Member of the Bedford Formation (no hammers or collecting).

91.5 139 End of field trip – Quality Inn – Perry Highway, Erie, Pennsylvania.



LATE FAMENNIAN TO BASAL MISSISSIPPIAN STRATIGRAPHY IN NORTHERN OHIO: REFERENCE SECTION FOR THE END-DEVONIAN SUCCESSION IN THE LAKE ERIE REGION

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INTRODUCTION

Today we present an overview of key Cleveland area end-Devonian stratigraphic units with the intent to relate them to major, global paleoclimatic disturbances now known to have adversely effected biosphere development at this time. Although the impact of the Frasnian-Famennian extinction crisis has become better known in recent decades, the closing zonal portion of the Devonian narrative, corresponding to the Hangenberg biocrisis interval, apparently witnessed at least one severe global "icehouse" event, a major ^{13}C excursion, and two extinction phases; the first effecting mainly the marine biosphere, and the second greatly diminishing terrestrial ecosystems (McGhee, 2013).

In reviewing standing literature relating to the Ohio Devonian back in 2008, I was struck by how the comparatively thin end-Devonian units in this region differed from lower, thicker divisions recording long-standing regressive, progradational advance of the Catskill delta complex. I was further struck by the upward disappearance of neritic taxa in the marine section and by the appearance of enigmatic deposits in the barren interval. Although our initial work on correlative strata started in northwest Pennsylvania, I have come to realize that sections were generally much more complete in Ohio, offering an ideal view of key biostratigraphic intervals and unit contacts needing formal study.

The key Devonian rock divisions we will see today are, in ascending order, the Chagrin Shale (Chagrin Member of Ohio Shale), the Cleveland Shale (Cleveland Member of Ohio Shale), the Bedford Shale (Bedford Formation), and the Berea Sandstone (Berea Formation). At Stop two, we will see the Orangeville Shale (Orangeville Formation) comprising the lowest described Mississippian (Tournaisian) division. We refer to the Orangeville as the lowest "described" Mississippian unit as a cautionary note, because, at STOP 2, we will also examine a thin, lower bed-scale division, which is currently un-named and which is yet to be biostratigraphically sampled.

Discoveries since our work started in 2008 are severalfold. First, the disconformity along the base of the Cleveland Shale, marked by channelized detrital pyrite accumulations (Skinners Run Bed), appears to be regionally diachronous and suggestive of southeastward temporal onlap over the post-Chagrin unconformity surface. Second, the lower, marine to marginal marine part of the Bedford Shale thickens eastward across the Cleveland metropolitan area with concurrent eastward loss of the upper Bedford red mudstone division across the Cuyahoga River Valley. The conspicuous eastward rise of a key sandstone marker bed, Euclid Member, in Bedford sections, further suggests that the lower Bedford records a pulse of westward progradation with associated clinoform development. Third, the disconformity marking the base of the Bedford becomes more prominent southeastward, such that it nearly oversteps the entire Cleveland Shale south of

Cleveland and completely does so in the adjacent subsurface. This lowstand event, essentially coeval to the occurrence of a three-ton granite lonestone near the top of the Cleveland Member in Kentucky, is now understood to mark the incursion of tidewater glaciers into the Devonian epicontinental sea (Ettensohn et al., 2020). Fourth, the succeeding Bedford Shale is notable for being largely barren of neritic, shelly taxa and for development of thick interval of enigmatic, microfractured, red-brown mudstone, which has been interpreted as either a terrestrial or offshore marine unit (see contrasting interpretations of Pepper et al., 1954 and Pashin and Ettensohn, 1995). If this unit is indeed an offshore deposit, it may yield zonally useful microtaxa for assessing the severity and timing of conditions during the Hangenberg biocrisis interval. Finally, the regionally prominent base-Berea disconformity is understood to be a major lowstand signal that correlates eastward and southeastward through intermediate units to coarse diamictite deposits of interred glacial origin in eastern Pennsylvania and Maryland (Brezinski et al., 2010).

Key questions remain to be addressed. Recognition by the present authors of a thin, un-named and undated, calcareous sandstone unit between the topmost Devonian Berea Sandstone and the basal Tournaisian Orangeville Shale, opens the possibility that the base of the Missisippian Subsystem may be at the base of the unnamed unit, not the Orangeville. New discovery of the western terminus of the base-Bedford unconformity in sections to the west of Cleveland expressed as depositional continuity from Cleveland Member into Bedford Member across central Ohio, opens the opportunity to establish precise zonal placement of the onset and development of Hangenberg biocrisis events in this part of the Appalachian Basin.

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DAY 1, STOP 1: CHAGRIN-CLEVELAND MEMBER CONTACT ALONG ROCKY RIVER IN ROCKY RIVER RESERVATION OF THE CLEVELAND METROPARKS

Time permitting, our field trip agenda today will include four to five stops in the Cleveland metropolitan area. Originally, we had hoped to arrange the stop order to examined sections in ascending geological order of age. However, the timing of traffic flow in the city demands that we proceed eastward across to through the day to best exit the city prior to the late afternoon rush hour. This means that we will see the Devonian-Carboniferous boundary at the next stop and lower units later.

Here at Stop 1, we view a particularly steep and striking, southwest-facing cliff section displaying the Chagrin-Cleveland Member contact along the Rocky River, south of Tyler Field and east of the Valley Parkway in the Rocky River Reservation of the Cleveland Metroparks (Fig. 1). This exposure is at Google coordinates 41.458456° N, -81.819431° W, on the Lakewood, Ohio 7.5' quadrangle. About 22 m (70 ft) of the Chagrin succession is visible in the lower part of the bank, which is succeeded by approximately 30 m (95 ft) of Cleveland Shale. Participants will disembark at the parking area bordering Valley Parkway south of the Morley Ford Dam and proceed on foot along the southwest side of the Rocky River to better view the cliff section across the river. COLLECTING OF ROCK AND FOSSIL MATERIAL IS STRICTLY FORBIDDEN.

The Chagrin Member is normally expressed as recessive weathering, often monotonous, grey-green mudstone in most Cleveland area sections to the east of this locality (see Stops 4 and 5a). However, at this place, it is anomalously silty, displaying a prominent succession of flaggy, turbiditic siltstone layers, closely resembling prodelta slope deposits ("Portage magnifacies" *sensu* Chadwick, 1935, and others) within the New York Devonian section (Fig. 1). These siltstone beds display numerous erosive sole mark features recording westward-directed turbiditic density flow events on paleoslope in a dysoxic, aggradational slope regime. Fossils are very rare in this facies, suggestive of high turbidity and dysoxic bottom conditions. This flaggy succession was identified as "Olmsted", rather than "Chagrin" by Lewis (1988) and Coogan et al. (1986) owing to its distinctive turbiditic character.

Why the Chagrin is so very turbiditic along the Rocky River is a bit of a mystery. It is generally understood that it represents a downslope facies relative to typical Chagrin Shale, because all of the Chagrin is known to pass westward into variegated black and gray shale deposits in counties to the west of Cleveland, as it transitions further downslope into the basinal Huron Member of the Ohio Shale. However, the relative absence of siltstone in presumed upslope Chagrin Shale deposits across most of the Cleveland metropolitan area poses a problem as to how the Rocky River Chagrin sections temporally connect eastward to equivalent facies in the shelf setting. This is a question that we will address in more detail at Stops 4 and 5 later today.

Figure 1. Chagrin Member-Cleveland Member succession along Rocky River; silty, turbiditic Chagrin succession capped by rhythmic black Cleveland deposits. Note strong pattern of apparent cyclicity of repeating resistant, organic-rich, black shale bands in the Cleveland succession (J. Hannibal - image).

As is most evident in this bank section at Stop 1, the Cleveland Member is characterized by distinctive rhythmic, decimeter-to-meter-scale, alternations of more resistant, organic-rich bands with recessive, less organic-rich intervals (Fig. 1). Vertical change in the spacing of this ribbing appears to correlate with changes in shale radioactivity; closely-spaced ribbing apparently denotes cyclic episodes of increased organic-matter accumulation, which can be traced regionally on logs.

Along the Rocky River, the overlying black Cleveland Member, expressed as distinctly rhythmic ("ribbed") black shale, conformably overlies the grey Chagrin succession as a maximally thick (34 m (> 105 ft)) succession of organic-rich, basinal deposits (Fig. 1). yielding a sparse, low diversity benthos of lingulid brachiopods and other small benthic invertebrates. However, the Cleveland Shale is best known for its vertebrate fauna, most notable for the large arthrodiran fish *Dunkleosteus terrelli* (Newberry, 1873) and articulated fossil sharks (Williams, 1990; Carr, 2010; Carr and Jackson, 2010; Fig. 2). Along the Rocky River, the Cleveland also contains flattened specimens of the cephalopod aptychi *Spathiocaris* (Frye and Feldmann, 1991).

The lower and middle parts of the Cleveland Shale are known to yield the key conodonts *Polygnathus experplexus* Sandberg and Ziegler, 1979, *Bispathodus aculeatus aculeatus* (Branson and Mehl, 1934a), and *Bi. aculeatus anteposicornis* Scott, 1960, indicative of the *aculeatus* Biozone (Zagger, 1993). This zonation is consistent with correlation with the global Dasberg transgression event (Becker and Hartenfels, 2008). House et al. (1986) found ammonoids in the uppermost Cleveland layers indicative of the *costatus* or *ultimus* conodont biozones. Similarly, Ettensohn et al. (2020) indicate that the topmost Cleveland Shale interval in Kentucky falls within the *ultimus* Biozone (lower part of former *Praesulcata* Zone) interval as well. Eames

(1968, 1974) recovered meiospores indicative of the "LN" polynomorph biozone within the topmost Cleveland interval, consistent with these other zonal calls. In light of heightened interest in the zonation of late Famennian strata since the work of Zagger and Eames, it is evident that a comprehensive reevaluation of the Cleveland-Bedford conodont-palynomorph record is in order. In particular, if deposition of the upper part of Cleveland Shale is coincident with the onset of the Hangenberg vertebrate extinction, the famous fish fauna, including *Dunkleosteus* and shark taxa, for which this unit is well known, should have an upper limit of stratigraphic occurrence within the Cleveland succession, coincident with upward appearance of *ultimus* Biozone conodonts and LN Biozone palynomorphs.

Figure 2. The most complete known skeletal reconstruction of *Dunkleosteus terrelli* (Newberry, 1873) from the Cleveland Shale, clearly showing plaster portions versus actual bone. Note that the cranium, dentary, and shoulder girdle are largely intact, CMNH 7054, used with permission from the Cleveland Museum of Natural History.

Although the Chagrin-Cleveland contact is conformable at Stop 1, it becomes notably disconformable eastward, beginning at Big Creek, near the Cleveland Zoo and along West Creek at Stop 4. Across the Cleveland metropolitan area and eastward to western Ashtabula and Trumbull counties, the erosional base of the Cleveland Shale is marked by a laterally discontinuous, channelized lag deposit of detrital pyrite in association with dispersed fish bone debris and plant fragments, which is informally named the Skinners Run pyrite bed (Baird et al., 2023). Baird et al. (2014); Blood et al. (2019), believing that the base-Cleveland contact is a major drowning surface, argued that the Cleveland black muds diachronously onlapped a regionally sloped submarine ramp during a major (Dasberg) transgression event. Basinward areas along the Rocky River were marked by continuous deposition from Chagrin into Cleveland time with a major episode of constructional silt influx recorded in latest Chagrin time. However, to the east (upslope) active erosional downcutting was removing the last vestiges of an end-Chagrin regression (pre-Dasberg lowstand event) to produce the downslope turbiditic wedge visible at Stop 1 (Fig. 1). According to this model, a small basal part of the turbiditic wedge is still visible below the base-Cleveland unconformity farther east at Big Creek, but is completely absent at West Creek (Stop 4) where older Chagrin strata are expressed as soft grey mudstone below a major surface of truncation, marked by the Skinners Run Bed. Hence, the Skinners Run bed and the regional surface on which it rests is believed to be regionally diachronous, becoming younger southeastward and older (basinward) to the northwest across the Cleveland area. Genesis of the distinctive Skinners Run lag deposit will be discussed further at Stop 4.

DAY 1, STOP 2: DEVONIAN-CARBONIFEROUS (D/C) BOUNDARY AT WALLACE LAKE, BEREA, OHIO

Section flooring small gully below storm sewer drain at south end of path leading west and south from footbridge over north-flowing outlet creek from Wallace Lake (site of former Berea Sandstone quarry) to the east branch of the Rocky River in the Berea Mill Stream Run Metropark (Google coordinates 41.364410º N, 81.858592º W, Berea, Ohio 7.5' Quadrangle). Bridge over outlet is accessed via short path northward from North Quarry parking lot on west side of Valley Parkway near the north end of Wallace Lake. This locality is within the Cleveland Metropark System ("Emerald necklace"); COLLECTING OF ROCK AND FOSSIL SAMPLES IS STRICTLY FORBIDDEN.

This section displays two important standing well established units in the literature, topmost beds of the latest Devonian Berea Sandstone, and the higher, basal Tournaisian Sunbury Member of the Orangeville Formation. We will first proceed south from the bridge, pointing out the Berea exposure along the lake edge, but will first stop first at the small stream where the base-Sunbury contact is exposed to discuss the Devonian/Carboniferous boundary. Following this stop, we will return to the Berea section to examine a thin, regionally persistent, unnamed and biozonally undated stratum, which caps the Berea and floors the Sunbury. This layer leaves open to question the actual position of the Devonian/Carboniferous boundary in northern Ohio. The Berea Sandstone has been quarried for dimension stone in Ohio for more than 200 years. It has been extensively quarried here at Berea, and, particularly, farther to the west where it has been locally exploited for dimension stone in very deep quarries. Berea that has been quarried is typically a gritty, cross-laminated to massive sandstone, such as is displayed in this abandoned quarry at the lake edge. However, much of the Berea, outside of "channel-like" belts of cross-bedded "quarrystone," is thinner-bedded and characterized by complex disturbed bedding, marked by load casts and diapiric slumps at multiple scales of magnitude (Wells et al., 1991; Pashin & Ettensohn, 1995). These disturbances have been attributed to diapiric sediment loading associated with rapid sediment influxes comparable to mudlump development on the modern Mississippi Delta (Pashin & Ettensohn, 1995), although Fakhari et al. (2022) argue that some, or much, of these disturbance features are of tectonic origin.

The Berea Sandstone connects eastward to the coarse, channelized Cussewago Sandstone and one thinner, higher sandstone (newly designated Stratton Creek Member) in northwest Pennsylvania (Baird et al., 2023). Still farther east, under western Pennsylvania, it correlates to the informal subsurface Murrysville sandstone complex. The Berea and its eastern correlatives are understood to be temporally linked to coarse sediment influxes associated with the Rockwell Formation and Spechty Kopf Formation diamictites and are the erosive product of glacial pulses now recognized in end-Devonian sections in central and eastern Pennsylvania and Maryland

(Sevon, 1979; Brezinski et al. 2010). As such, the Berea and Cussewago sandstones appear to be a possible lowstand event-correlative to the "Hangenberg sandstone" in the European and North African sections, most notably, the coarse Seiler Conglomerate of German sections (Becker et al., 2016; Kaiser et al., 2016). Marginally nonmarine Berea deposits lack a shelly fauna and have no conodont and ammonoid record. Berea palynomorphs yield LN biozone taxa (Eames, 1974; Coleman & Clayton, 1987).

Figure 3. Compact ledge of unnamed calcareous, burrowed, silty mudstone unit unconformably juxtaposed on friable, cross-bedded Berea Sandstone in Stop 2b exposure bordering Wallace Lake. Scale in decimeters (J. Hannibal – image).

At the small creek, about 6 meters (19.6 ft) of dark to near-black, fissile, basal Mississippian Sunbury Member of the Orangeville Formation are exposed in the falls face below the storm drain. The base of the Sunbury is displayed in the creek floor immediately below the cascade. A 0.0–1.0 cm-thick siltstone bed yielding widely dispersed fish bone fragments marks the basal layer of the Sunbury, corresponding to an erosive transgressive lag deposit flooring the dark shale. The Sunbury is known to be basal Tournaisian based on conodonts and meiospore content; *Siphonodella sulcata* has been recovered from the Sunbury in New York by Hass (1958). Coleman and Clayton (1987) and Pashin and Ettensohn (1995) report VI biozone meiospores in this unit in Kentucky. The Sunbury records a major episode of combined flexural crustal loading timed with eustatic transgression. It denotes culmination of southwestward, flexural foredeep basin migration during the end-phase of the Acadian Orogeny; it is understood to mark "tectophase IV" *sensu* Ettensohn et al., (2009), but is reinterpreted to represent "tectophase V" of Ver Straeten (2010).

Returning part way along the path to the Berea exposure seen earlier, we want to point out a compact, thin, 28-32 cm (11–12.5 in) layer of calcareous, muddy siltstone containing trace fossils that caps the Berea (Fig. 3). This layer rests unconformably on the Berea at this locality and at most other correlative sections eastward into western Ashtabula and Trumbull counties east of Cleveland. As such, it is a regionally thin, unnamed division between the Berea and the Sunbury-Orangeville succession that is positioned between the Devonian and the Mississippian systems. Given that this marine division has not yet been sampled for zonal content, this leaves the precise position of the Devonian/Carboniferous boundary open to question in this part of Ohio.

DAY 1, STOP 3: ENIGMATIC RED BEDFORD DEPOSITS IN BIG CREEK METROPARK RESERVATION, PARMA, OHIO

Field trip participants arrive via southward turn from Snow Road onto Big Creek Parkway, followed by the first left turn into a looped park road (Snow Road Loop) where we will park. Stop 3 is adjacent to a parking area bordering Big Creek opposite a west-facing exposure of brick red-colored, shaly mudstone that is visible from the parking lot (Fig. 4). Locality is at 41.402619º N, -81.756664º W, on the Lakewood 7.5' Quadrangle. Stop will involve brief discussion while participants view the exposure from the west side of the creek.

If any area stratigraphic division best illustrates potential connections between the regional stratigraphy and inferred global end-Devonian crisis events, the Bedford Formation is that unit (Figs. 4-7). Deposition of the Bedford is entirely within the Hangenberg biocrisis interval, and its depositional record, along with that of the succeeding Berea Sandstone, records severe paleoenvironmental deterioration that is only partly understood, but which might turn out to be process-specific.

Figure 4. Red Bedford section in cutbank of Big Creek where it is best observed at the Snow Road Loop viewing area at Day 1, Stop 3; scale in decimeters (from Baird et al., 2013, Baird et al., 2014).

The Bedford Formation west of the Cuyahoga River is a strongly heterolithic unit, displaying, in upward-respective order, a thin, basal, variably fossiliferous marine bed that disconformably caps the Cleveland Shale, followed by a thicker, succeeding gray, silty mudstone interval with sparse fauna and some bioturbation, which is succeeded by faunally barren strata comprising the middle parts of the Bedford. This barren interval commences with the Euclid Siltstone, followed by a fining-upward passage to grey-greenish shale which is conformably succeeded by a long interval of red to red-brownish mudstone (red Bedford facies) which is distinctly silt-poor and typically microfractured to varying degrees (Fig. 4). Proceeding southwestward from the Cleveland area to Columbus, Ohio, a still higher grey (marine) Bedford division, absent in northern Ohio, appears above the red Bedford interval, and the Bedford-Berea contact approaches apparent depositional continuity.

However, eastward and southward from Big Creek, the Bedford succession is regionally overstepped by the Berea Sandstone, such that the red Bedford interval is last observed at Columbia Run near Boston, Ohio and at Euclid Creek west of the Chagrin Valley (Baird et al. 2013, 2014; Baird et al., 2023; Fig. 5a, b). This process of eastward erosive overstep continues eastward into central Ashtabula and Trumbull counties of northeasternmost Ohio where both the Cleveland Shale and Bedford Formation are absent in sections and the Berea-equivalent Cussewago Sandstone rests disconformably upon the Chagrin Member (Fig. 6).

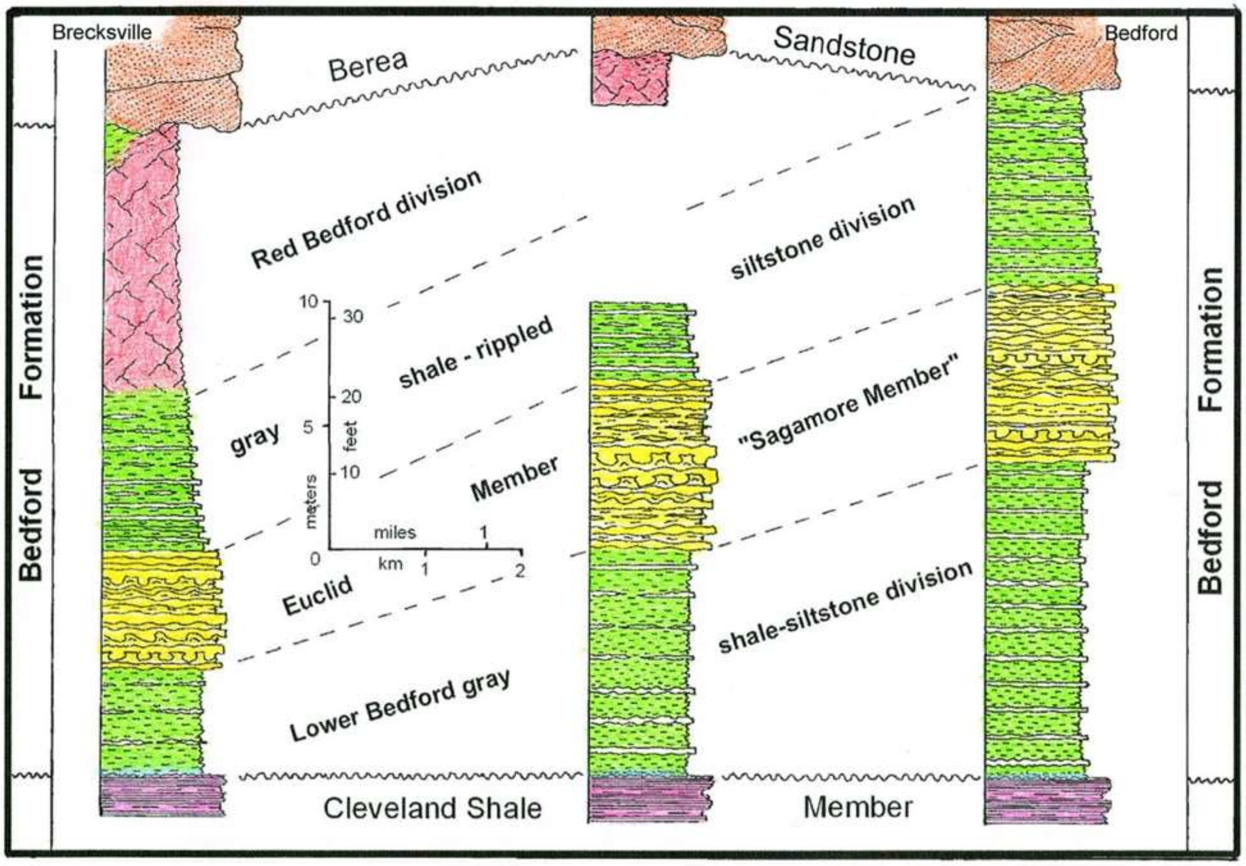


Figure 5a. East-west stratigraphic transect showing regional truncation of Bedford divisions across the Cuyahoga Valley.

The Stop 3 exposure is very distinctive and typical of the red Bedford interval. Aside from the color, it has very weakly developed bedding and a near absence of siltstone, which, in this section, is expressed as small, localized, deformed siltstone masses shaped like driftwood (Fig. 4). Bedding in the red mudstone is variably microfractured, which along with the deformed siltstone masses, indicates that this sediment has suffered pervasive and complex microdeformation. The soft, crumbly, splintery nature of the red mudstone imparts a distinctive "wall of mud" appearance to these sections (Fig. 4). Because the red mudstone is highly expandable, it disintegrates readily and weathers to slopes that are very slippery when wetted. Localized, 6-12 cm (2.5-5 in.) diameter, circular patches of greenish grey mudrock occur randomly distributed in the bank; these represent localized reduction spots, which are characteristic of red clastic rocks.

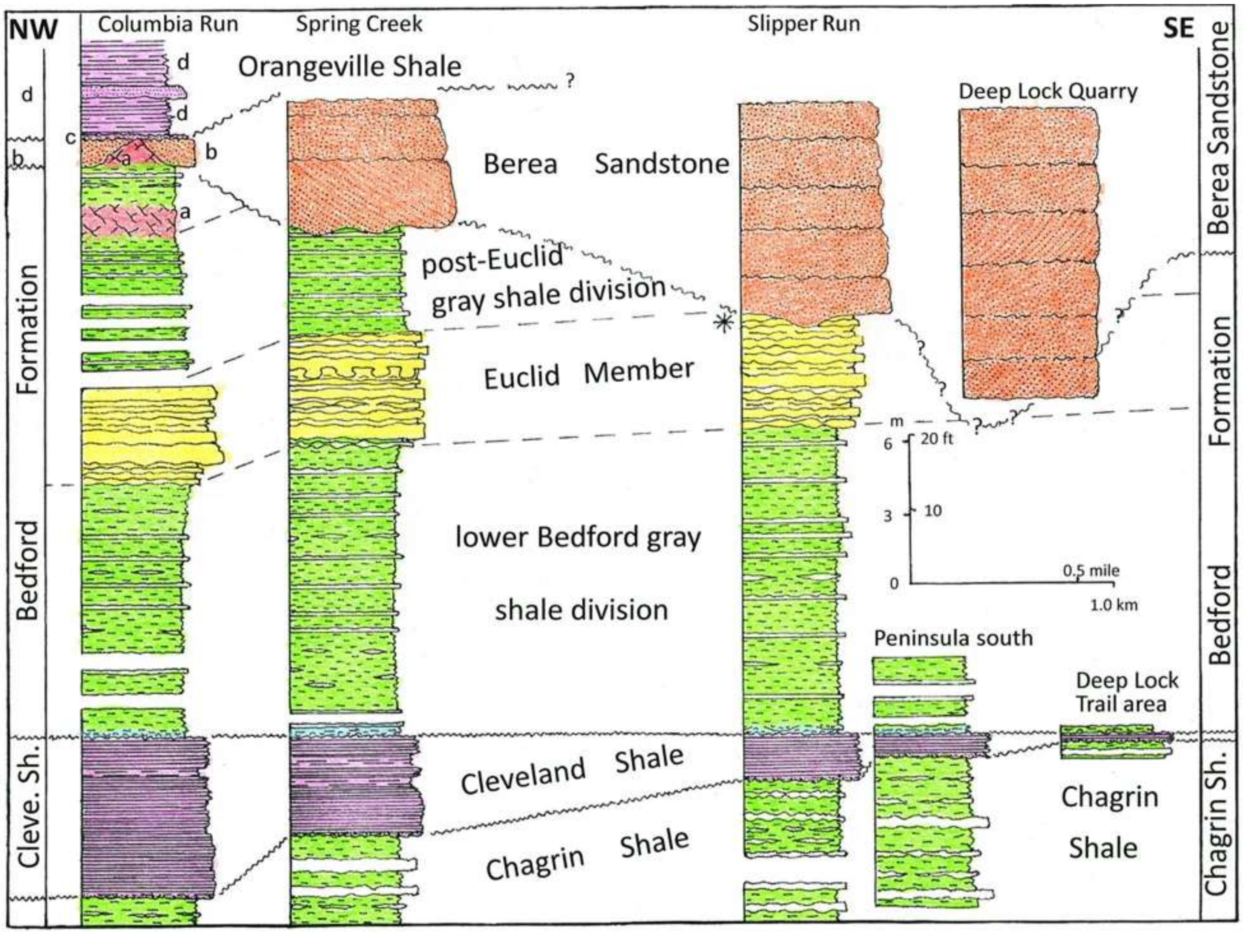


Figure 5b. North-south stratigraphic transect showing overstep of the Cleveland Member below the base-Bedford disconformity and higher overstep of middle Bedford units below the base-Berea disconformity.

The red Bedford division has been interpreted as a terrestrial, deltaic facies by Pepper et al. (1954) and this is consistent with interpretations of other red beds in the Acadian orogeny as well as Pennsylvanian red beds. However, more recently, the Bedford red beds have also been interpreted as a marine, offshore, prodelta slope-to-basin deposit (Lewis, 1988; Pashin and Ettensohn, 1995). Detailed comparison of the interval between the Euclid Siltstone and the red Bedford in northern Ohio, coupled with examination of the red Bedford-to-base-Berea interval near Columbus in south-central Ohio, illustrates that the two intervals show an opposing, mirror-image trend of sediment-fining as the red interval is approached (Fig. 7a, b). These trends, plus the near-absence of silt are somewhat supportive of the red Bedford deposit being of an offshore origin. Moreover, the red Bedford interval appears to lack development of fining-upward sequences, caliche zones, and root traces, typical of terrestrial units.

If the red Bedford is indeed an offshore marine deposit, it should theoretically yield some microfaunal remains that may have biozonal importance. So far, this easy to disaggregate mudstone has yielded no discernable macro- or microfauna, but our work has just begun. After all, the middle part of the Bedford Formation appears to be well within the greater Hangenberg biocrisis interval, so this peculiar deposit might provide valuable clues about end-Devonian biocrises that are unique to this area.

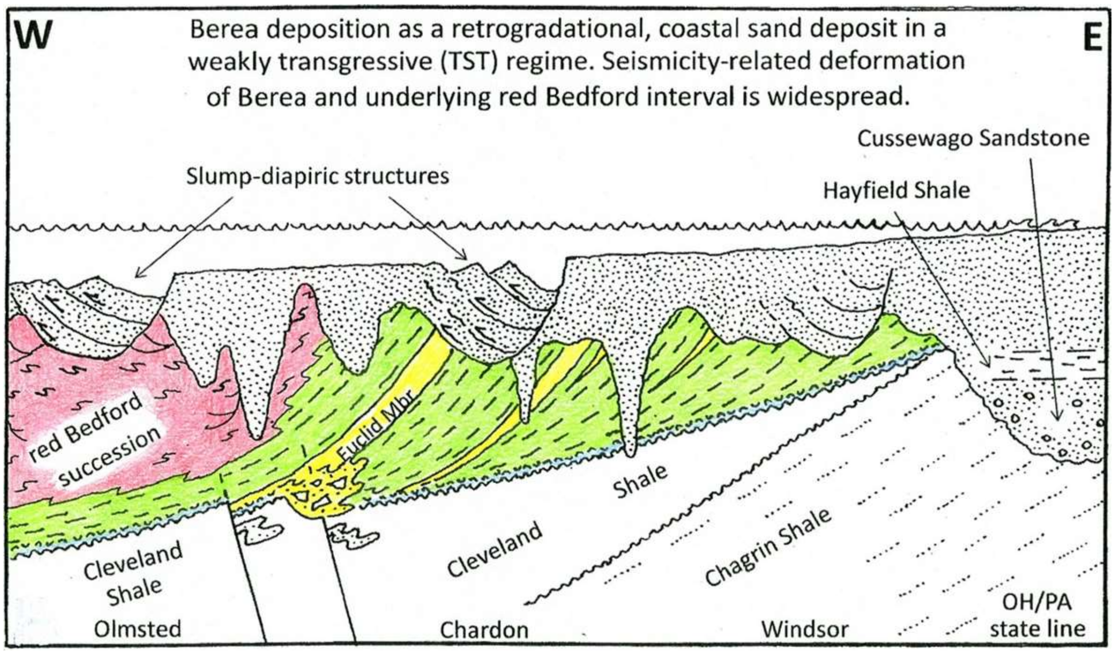


Figure 6. Inferred model of eastward regional beveling of the entire Cleveland Shale-Bedford Formation succession along transect from Rocky River eastward to the Ohio-Pennsylvania state line (from Blood et al., 2019).

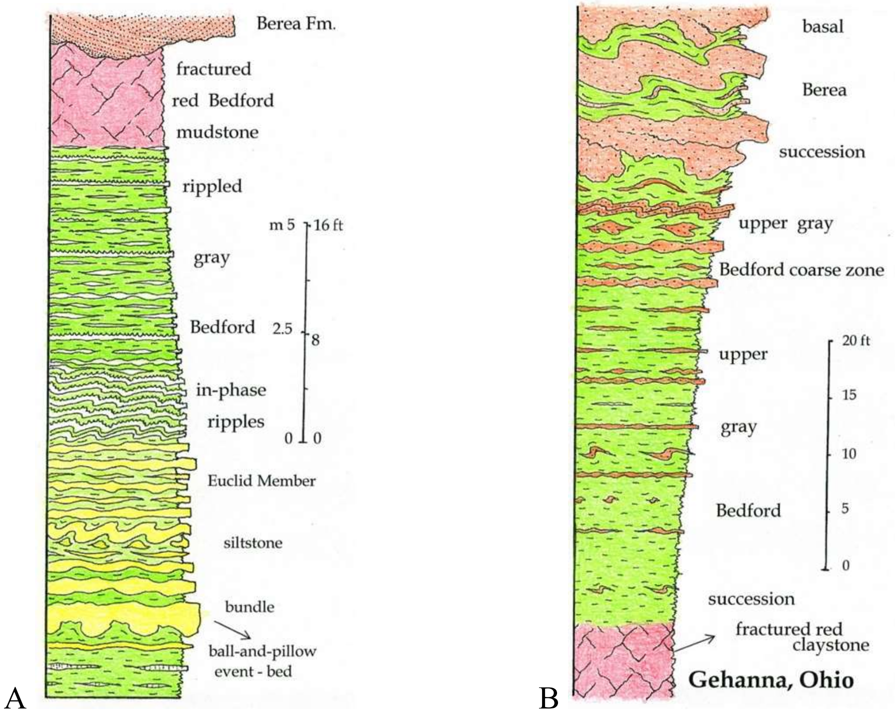


Figure 7. Deposition of red Bedford interval in stratigraphic context; **A**, spectral (gradational) upward decrease in silt influx from Euclid Sandstone into red Bedford in northern Ohio; **B**, spectral (gradational) increase in silt influx from red Bedford into lower Berea Sandstone interval in south-central Ohio reflecting opposing, mirror-image trends to nearly complete hiatus in silt supply to shelf or coast during red Bedford depositional event (from Blood et al. 2019).

DAY 1, STOP 4: UNCONFORMABLE CHAGRIN-CLEVELAND CONTACT ALONG WEST CREEK (SKINNERS RUN), BROOKLYN HEIGHTS VILLAGE PARK, BROOKLYN HEIGHTS, OHIO (TUXEDO PARK ON GOOGLE MAPS)

Enter Brooklyn Heights Village Park via Broadview Road, turning east on Tuxedo Avenue turning south on West 4th Street and descend to lower park level and dead-end parking lot bordering West Creek. Disembark and follow gravel park path to point of easy access to the creek edge near bankside exposures displaying the Chagrin Member-Cleveland Member contact on both sides of the creek west of the parking area. This section is at Google coordinates 41.412457º N, -81.683750º W, and is located on the Cleveland South 7.5' Quadrangle map. West Creek has classically been known to geologists as Skinners Run (Prosser, 1912, p. 74; Cushing *in* Cushing and others, 1931; Hlavin, 1976; Hannibal and Feldmann, 1983; Lewis, 1988). The name West Creek has become predominant in public usage over all of its reaches in recent decades and the portion of the stream south of West Ridgewood Drive in Parma has recently been integrated into the Cleveland Metroparks, ensuring the popularity of the name. West Creek, a tributary of the Cuyahoga River, passes through the Cleveland suburbs of Parma, Brooklyn Heights, and Seven Hills. Portions of the stream are parklands. The Chagrin and Cleveland Members are easily accessible along West Creek via the Brooklyn Heights Village Park. A paved hiking trail parallels the stream between the parking lot and a bridge which passes over a small NE-SW oriented tributary of the strata. The lower part of the section, including the Chagrin/Cleveland contact (Fig. 8), are accessible from trails that extend west and east from the Village Park.

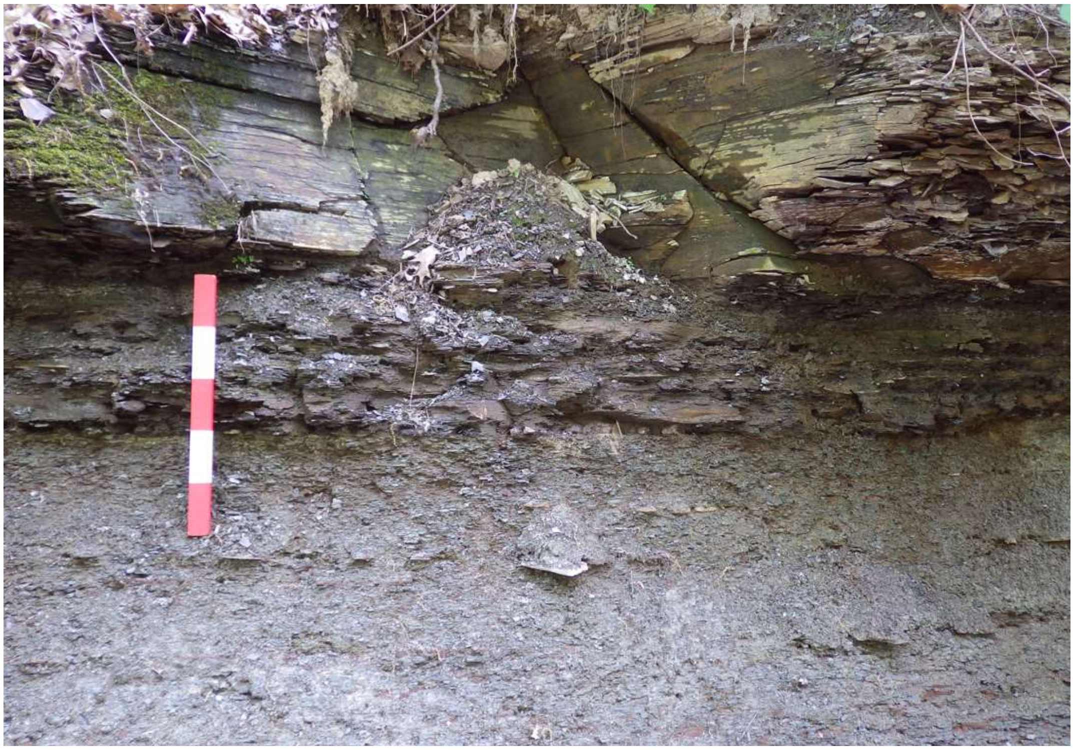


Figure 8. Chagrin Member capped disconformably by more resistant, black Cleveland Member along West Creek ("Skinner's Run") in the Brooklyn Heights Town Park; scale in decimeters (J. Hannibal).

The Chagrin Member, here a gray shale, is exposed in the stream immediately below the parking lot. Twelve m (39 ft) of gray Chagrin shale are exposed along West Creek below the contact with the Cleveland Member. The Chagrin Shale/Member is punctuated with siltstone beds the exterior of which are colored red when oxidized indicating iron, mainly siderite; brachiopods are also present. Trace fossils are relatively abundant in the unit. The "rooster-trail" ichnotaxon

Zoophycos is found in the siltier beds and three-dimensional arthropod traces belonging to the genus *Chagrinichnites* are found in the sideritic beds.

The Skinners Run pyrite bed (Hlavin, 1976), located at the base of the Cleveland Member, varies in thickness from about 0.5 to 20+ cm (1.4 to 7.0 inches) at this location. It can be seen in cross section in the rock wall along the creek upstream of the parking lot, but better exposures can be seen at the contact in the waterfall face just upstream of the small footbridge that crosses West Creek adjacent to a northerly flowing side tributary. This waterfall has dramatically recessed over the years, due to natural erosion; as recently as 1983, the Chagrin-Cleveland contact in the waterfall face was 0.19 miles 0.3 km downstream of the junction of the aforementioned side tributary, as mapped by Hannibal and Feldmann (1983). The Skinners Run pyrite bed is the only part of the Cleveland Member that has had its conodonts examined (Zagger and Banks, 1989; Zagger, 1995). The Skinners Run bed, varying in thickness here and elsewhere, is not always present at the Chagrin-Cleveland contact (Hlavin, 1976; Coogan and others, 1986); it is expressed as laterally separated lentils along the base-Cleveland contact. Owing to rapid, erosional bank recession, noted above, anomalously thick masses of this pyritic unit are frequently left as dense placer blocks on the floor of this creek.

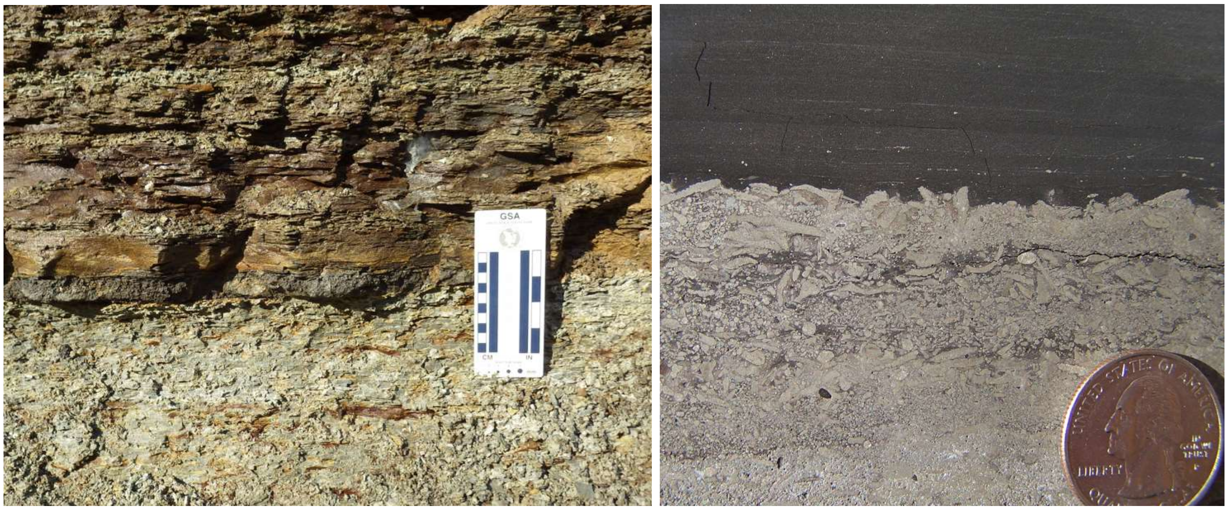


Figure 9. Discontinuity roofed by Cleveland Member along West Creek ("Skinner's Run") in the Brooklyn Heights Town Park; **(A)** Detrital pyritic lens concentration in bank sections along creek. At this locality and at others, it is expressed as laterally discontinuous lenses of detrital pyrite and insoluble phosphatic bioclasts along the contact; **(B)** Close-up view of thick, channelized, detrital pyrite lens that has been cut and polished. Note development of four discrete detrital pyrite accumulation events, separated by thin black shale bands; this indicates contemporaneity of detrital pyrite accumulation with the anoxic setting associated with the onlap of Cleveland Member black mud deposits. (Photo credit: Gordon Baird) in Blood et al. (2019).

The Skinners Run bed is clearly a diastemic lag deposit that regionally floors variably organic-rich deposits of the Cleveland Shale. As such, it is a transgressive lag marking a major drowning surface probably closely associated with the Dasberg transgression event (Becker and Hartenfels, 2008). Skinners Run lag lenses are principally composed of detrital (reworked) pyrite with subsidiary fractions of fossilized wood, fish bones, and conodonts (Fig. 9a, b), which were exhumed and current-transported in an oxygen-deficient basin setting. Pyritic grains typically include sand- and gravel-grade clasts with smooth, faceted, discrete boundaries, which occur sorted and concentrated in laterally separated lentils along the unconformity surface. Such pyrite was sourced from the underlying Chagrin Member where similar pyrite occurs *in situ* within the topmost beds of that unit. Skinners Run lenses are analogous to laterally separated lenses of detrital pyrite observed in the older Middle Devonian Leicester Pyrite Member, which floors a widespread disconformity along the base of the black Geneseo Formation across western New York (Baird and Brett, 1986).

Proof of physical pyrite exhumation by episodic erosive currents in a predominantly dysoxic to near-anoxic bottom regime along this and other contacts is shown by the presence of earlier fossilized fossil steinkerns and randomly reoriented pyritic, geopetal chamber fillings in reworked clasts. Skinner's Run bed pyritic clasts in lag lenses occur solely with insoluble reworked material such as waterworn fish bones, conodonts, plant debris, and occasional quartz pebbles, strongly suggesting that reworked Chagrin Member carbonate bioclasts such as brachiopods and molluscan debris were dissolved under predominantly reducing conditions (Baird and Brett, 1986, 1991; Baird et al., 2013; Fig. 9b).

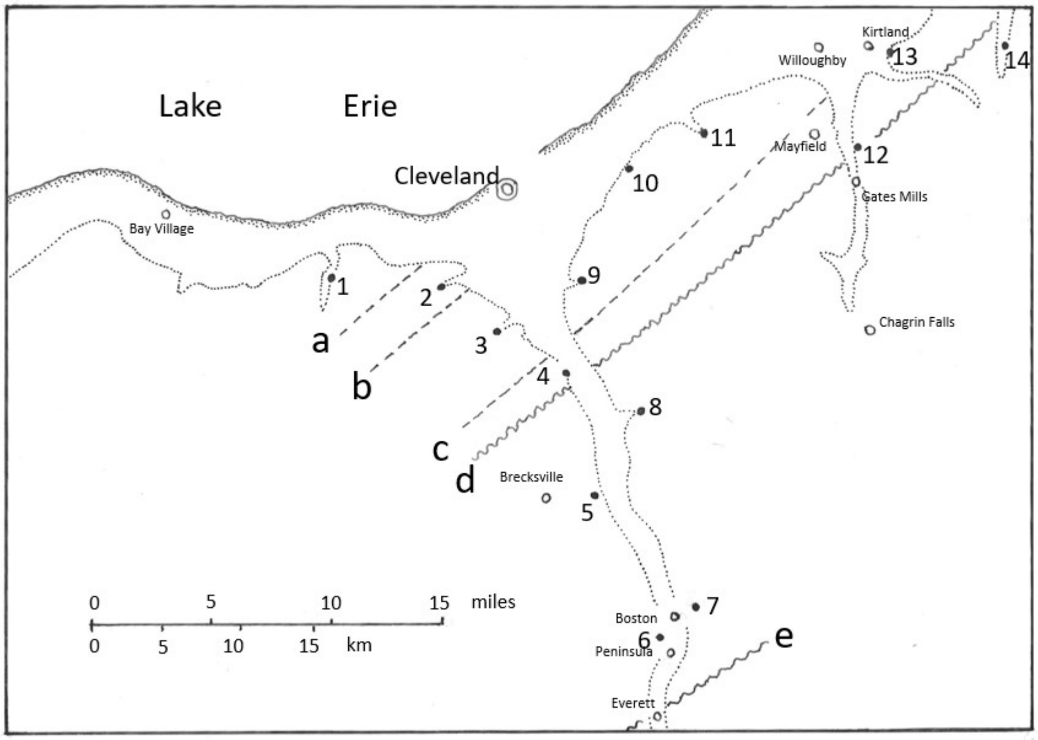


Figure 10. Inferred southeastward transgressive onlap of Cleveland member over regional sub-Cleveland erosion surface; Regional (spatial) map view of southeastward diachronous onlap of Cleveland Shale divisions onto a regional, sloped erosion surface: a, base of lowest (gray shale) division of Cleveland member, b, base of lower Cleveland member black shale interval, c, base of "Penitentiary Glen" interval of gray, silty shale, d, base of thick, upper Cleveland member division of black shale, e, southeastward Cleveland erosional limit below Bedford Formation. Numbers 1–14 denote key Cleveland member sections. From Blood et al. (2019).

The laterally separated detrital pyrite lenses along the unconformity surface are now best understood to be the outcrop expression of submarine erosive channels (furrows) on a regionally sloped seafloor. Downslope transport of coarse lag allochems was focused into these troughs, followed by post-burial dewatering and compaction of water-rich Chagrin and Cleveland sediments, which flattened original channel paleorelief to produce a "flat" unconformity contact. As mentioned earlier at Stop 1, the sub-Cleveland erosional contact is understood to record diachronous regional drowning of the erosion surface, such that oldest, downslope Cleveland Member strata conformably rest on topmost Chagrin strata at the Rocky River, and progressively younger Cleveland beds are observed to onlap the disconformity surface southeast across the

Cleveland metropolitan area (Figs. 10, 11). In the absence of conodont dating control, the best evidence for this onlap is apparent progressive southeastward loss of black, basal Cleveland strata, followed by sequential loss and pinch-out of a newly recognized, higher, non-black Cleveland Shale division, provisionally named the Penitentiary Glen beds interval (Baird et al., 2014; Baird et al., 2023, Figs. 10, 11). Proceeding southward up the Cuyahoga and Chagrin Valleys, the grey, flaggy Penitentiary Glen interval is observed to descend to the base-Cleveland disconformity before onlapping at extinction along the contact; this southward onlap process is understood to be the microscale expression of widespread, southeastward thinning of the Cleveland Member toward its depositional limit across Ohio. We will have a better view of the Penitentiary Glen division at Euclid Creek (Stop 5). This southeastward-younging of basal Cleveland strata is further supported by a similar trend of southeastward isopachous thinning of the Cleveland Shale overall across northern Ohio.

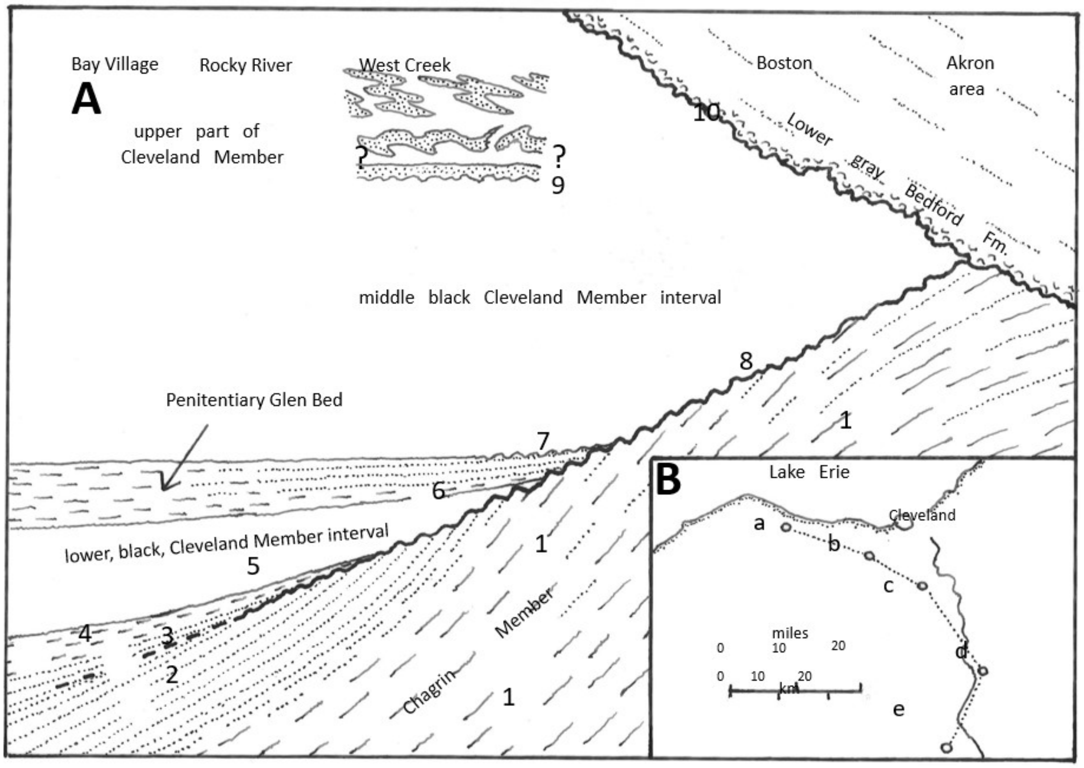


Figure 11. Vertical, northwest-southeast stratigraphic transect showing the onlap pattern displayed in Figure 3. Numbered units/events include: 1, gray, Chagrin member mudstone, 2, turbiditic fan deposits of uppermost progradational Chagrin succession; 3, basinward "toe" of discontinuity surface, 4, predominantly gray shale, deposits of lowest (unnamed) Cleveland member division, 5, lower Cleveland black shale interval, 6, silty, gray shale deposits of the informal "Penitentiary Glen bed", 7 – 8, onlapping upper Cleveland member black shale division, 9, seismically emplaced siltstone-sandstone masses within Cleveland Shale at West Creek and Rocky River, 10, base-Bedford Formation disconformity. Lettered localities (inset) include: a, Rocky River Metropark, both at and north of Lorain Road overpass bridge, b, exposures along Big Creek north of Big Creek Metropark, c, West Creek ("Skinner's Run) in Brooklyn Heights Town Park, d, Tinkers Creek in Bedford Glen Metropark, e, Slipper Run. From Blood et al., (2019).

DAY 1, STOPS 5 a-b: CHAGRIN-CLEVELAND SHALE SUCCESSION ALONG EUCLID CREEK IN THE EUCLID RESERVATION METROPARK, EUCLID, OHIO

One of the best locations, and certainly most accessible location, to view the Upper Devonian sequence in northeastern Ohio is the stretch of Euclid Creek within the Euclid Creek Reservation of the Cleveland Metroparks. Within the Reservation Euclid Creek flows near or alongside Euclid Creek Parkway, a meandering park road which allows easy access. At this location Euclid Creek is cut into, and is perpendicular to, the Portage Escarpment, resulting in a relatively steep stream gradient. Water level in the stream can be quite variable, however, both from place-to-place and seasonally. Treacherous waterfalls and plunge pools form due to development of small-scale structural features (commonly referred to as “pop-up” structures), such that water levels, normally quite shallow can locally exceed 1.5 m (5 ft) downstream from these structures. Water level can be quite shallow (a few centimeters/inches) along some stretches and relatively deep in other areas (greater than 1.5 m (5 ft).

Within the reservation, a 45+ m (148 ft) thick section of the Upper Devonian Chagrin Member is exposed along with the overlying Cleveland Member (18 m/59 ft), the Bedford Shale (29.6 m/97 ft), and the lower 10 m (32.8 ft) of the Berea Sandstone (Figs. 12, 13).

Day 1, Stop 5a: Chagrin-Cleveland Shale contact prominently displayed in high, southwest-facing cutbank of Euclid Creek adjacent to the Welsh Woods Park shelter and picnic area. Section is at Google coordinates 41.548636°N, -81.527994°W, on the East Cleveland 7.5’ Quadrangle. Participants will disembark to examine the steep outcrop from the west side of Euclid Creek.

The Welsh Woods Picnic area, located about 1.6 km (1.0 mi) south of the Highland Road entrance to the reservation, is a particularly advantageous place to examine the Chagrin Shale-Cleveland Shale succession. Euclid Creek is relatively broad and shallow at this location. The tall exposure on the eastern side of the creek encompasses the upper part of the Chagrin as well as the overlying Cleveland interval. Thin siltstone beds within of varying thickness can be seen in the Chagrin Shale down to stream level. The Chagrin-Cleveland contact is marked by an upward change from grey, recessive-weathering Chagrin deposits to slightly more resistant ribbed beds of the Cleveland succession about 2/3 of the way up the slope (Figs. 12, 13).

The Chagrin exposed in this area, like most of the section exposed in this reservation, is composed of gray to gray-green to gray-blue shale with interbedded cm-scale siltstone beds. The siltstones are mainly light gray in color, but some siltstone beds rich in iron carbonate siltstone, here and elsewhere in the section, have an external reddish brown exterior coloration due to the oxidation of siderite. Jointing, mainly in parallel sets, is also visible in the outcrop here.

Fossils are present in the Chagrin at Euclid Creek, but sparsely so (Fig. 14). The most common megafossils are trace fossils, many of which were illustrated in the chapter on ichnofossils (Hannibal, 1996) in *Fossils of Ohio* (Feldmann and Hackathorn, 1996). These include species of the ichnogenera *Chagrinichnites* and *Zoophycos*. *Chagrinichnites* is the most common of these and is found on the tops and bottoms of sideritic beds. This taxon has also been found *in situ* along the stream here. This ichnofossil is typical of the Chagrin at its type section along the Chagrin River to the east. There are also rare occurrences of body fossils in the Chagrin Member along Euclid Creek. These include brachiopods and sponges (Miklus and Hannibal, 2004). The brachiopod taxa are some of the same taxa as those described by Schwimmer and Feldman (1990) from two more prolific Chagrin Member localities (Brecksville and Brandywine Falls). The coelacanth *Chagrinia* was found at this location (Schaeffer, 1962).

Figure 12. Chagrin-Cleveland exposure at Welsh Woods vista (J. Hannibal).

Note that the Chagrin interval is distinctly shalier at this locality than at Stop 1, where the unit displayed numerous turbiditic layers imparting a distinctly flaggy appearance to the section. Why should downslope Chagrin deposits to the west be so much more dominated by influxes of silt relative to the mud-dominated, neritic Chagrin deposits in upslope shelf settings? One idea is that displacement along the Middleburgh Fault, adjacent to the present Rocky River trend, may have served to steepen the paleoslope during Famennian time and trigger numerous density flow events. An alternate model, favored by the present authors, is that the coarse, flaggy, upper Chagrin succession along the Rocky River is absent at Euclid Creek. Both here at Euclid Creek and at West Creek (Stop 4), a prominent regional disconformity is present at the base of the Cleveland Member, but is absent along the Rocky River where coarse Chagrin is present. What this suggests is that a significant erosional lowstand event preceded the Dasberg drowning event, generating a prograding, downslope clastic wedge at the basin margin that was timed with upslope sediment removal in shelf areas (Baird et al., 2014; Blood et al., 2019). Preliminary evidence for this falling-stage downcutting process is apparent complete southward overstep of the last portion of the top-Chagrin siltstone facies in sections near the Cleveland Zoo northwest of Stop 4.

Closer examination of the Cleveland Shale in the high bank face at STOP 5 shows the presence of a 4 m (13 feet)-thick, grey shale-flaggy siltstone unit that is developed above the base of the Cleveland succession (Fig. 12). This is the newly recognized Penitentiary Glen beds interval discussed earlier at Stop 4, which is understood to descend to the base-Cleveland disconformity and onlap to extinction southeast of the Euclid Creek section in the Chagrin Valley (Baird et al., 2014; see Stop 4, Figs. 10, 11).

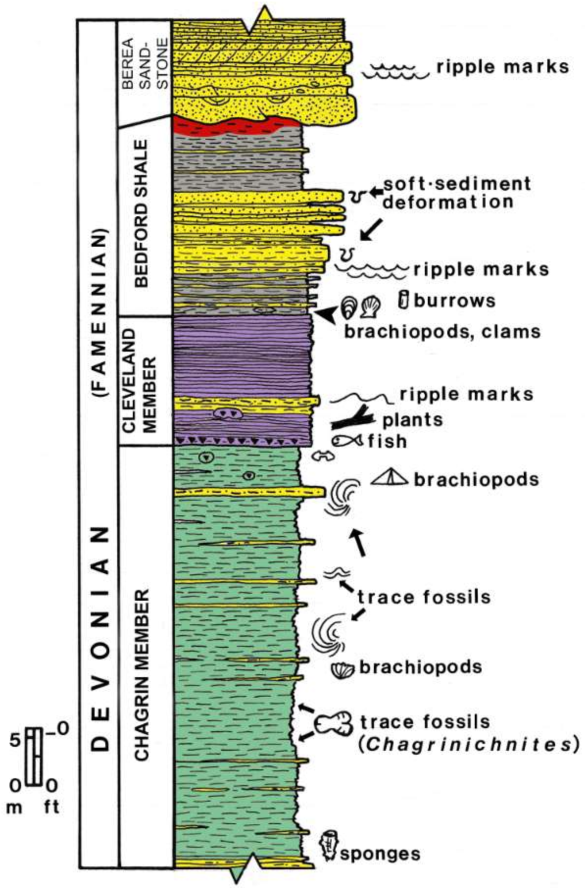


Figure 13. Schematic stratigraphic succession at Euclid Creek (J. Hannibal).

Time limits our viewing of intervening upstream sections of the topmost Chagrin Shale, Cleveland Shale, and basal Bedford Formation along Euclid Creek; we will depart the Welsh Woods area and, if time permits, proceed directly to the Kelley Picnic area, upstream within the park.

Figure 14. The hypichnial trace fossil Chagrinichnites from siltstone bed in Chagrin Member, Euclid Creek, scale in mm.

DAY 1, STOP 5b (Optional stop): Kelley Picnic area in the southern (upstream) part of the Euclid Reservation. Proceed southward along Metropark Drive for 1.0 km (0.63 mi). After passing below the Monticello Road overpass, turn left onto park road, which descends to bridge over Euclid Creek adjacent to parking lot for Kelley Picnic Area. Type exposure of the Euclid Siltstone Member adjacent to the bridge is at 41.536826ºN, -81.527994ºW on the East Cleveland 7.5' quadrangle.

Kelley Picnic Area, located just south of where Monticello Road passes over Euclid Creek Parkway, is a handy place to access trails that lead to views of the Bedford Formation. The picnic area and adjacent area were part of an extensive quarrying operation in the nineteenth and first part of the twentieth centuries.

This section represents the type section of the Euclid Member of the Bedford Formation. This is a locally prominent coarse unit within the lower-to-middle parts of the Bedford Formation. The rock unit quarried here is a fine-grained sandstone known in the building trade as Euclid bluestone. This was only one of a number of Euclid bluestone quarries, stretching from Independence west of the Cuyahoga River in an arcuate band towards the northeastern corner of Cuyahoga County.

The bridge over Euclid Creek that provides access to the picnic areas also is a good place to view a very large ball-and-pillow structure on the downstream side of Euclid Creek. A trail not far from the upstream side of the bridge leads to a fine view of Bedford deformational structures including a cross section of boudinage-like sandstone structures that resemble a string of huge wieners (Fig. 15). The Euclid is a lower, smaller-scale, depositional analog of sandy, deformed deposits characteristic of large parts of the younger Berea Sandstone. The deformed layering developed here is actually a preview of multi-scale disturbance events at many levels through the Euclid interval and within the higher red Bedford, culminating in widespread development of massive load casts and diapiric features within the lower Berea Sandstone (Wells et al., 1991; Pashin and Ettensohn, 1995; Fakhari et al., 2019).

Farther upstream, but not as accessible, the contact between the red Bedford and the overlying Berea Sandstone at this location is undulatory and marked by minor faulting. However, time constraints limit our presence to the "wiener exposure."

Figure 15. Load casts resembling a string of wieners in upper Euclid Member at Kelley Picnic area. Scale in decimeters (J. Hannibal).

DETAILED ROAD LOG FOR DAY 1

0 mi. Exit La Quinta Hotel parking lot; turn right (east) out of parking lot onto short road segment heading east.

0.1 mi. (0.1) Turn left (north) on W. 150th Street

0.9 mi. (1.0) West 150th becomes Warren Road after crossing Lorain Avenue (Rte. 10); continue north on Warren Road

0.4 mi. (1.4) Forked intersection of Warren and Munn Roads; turn left onto Munn Road and follow Munn NW.

0.5 mi. (1.9) Intersection of Munn Road and Rocky River Drive; turn right (north) onto Rocky River Drive (Rte. 237) northward and continue as the road curves left to the west.

0.4 mi. (2.3) Rocky River Drive becomes Riverside Drive. Continue westward on Riverside Drive.

0.3 mi. (2.6) Intersection of Riverside Drive with Hogsback Lane; turn left (SW) onto Hogsback Lane (note sign for Rocky River Reservation of the Cleveland Metroparks). Follow Hogsback Lane.

0.4 mi. (3.0) Intersection of Hogs' Back Lane (slight name change from Hogsback Lane) and Valley Parkway; turn left (SE) onto Valley Parkway and proceed up-valley.

1 mi. (4.0) Pass Tyler Field on your right.

0.2 mi (4.2) Bridge over Rocky River.

0.1 mi. (4.3) almost immediately after crossing bridge over Rocky River, turn into first parking area to your left, this is the SW end of Morely Ford Dam (STOP 1). (Careful; there is *no* sign along the parkway for the ford.)

Return to vehicles.

0 mi. (4.3) Turn left onto Valley Parkway and proceed south up-valley.

5.8 mi. (10.1) Pass intersection of Valley Parkway and Cedar Point Road. Continue on Valley Parkway. Note: just to the south, at 6.6 mi., you will encounter the first of several fords; these are closed in high water.

8.5 mi. (12.8) Pass sledding hill.

8.8 mi. (12.3) Pass Berea Falls parking area. Turn left where Valley Parkway ends, following Barrett Road south, following signs that say "Parkway continues." Continue south on Barrett Road which will again become the Valley Parkway after crossing Bagley Road.

8.9 mi. (13.2) Intersection of Nobottom Road with Barrett Rd. Keep on Barrett Rd, following signs for "Parkway continues."

9.2 mi. (13.5) Intersection of Barrett Road with West Bagley Road. Cross West Bagley (continuing south) onto Valley Parkway. South of West Bagley Road you will be leaving the Rocky River Reservation of the Cleveland Metroparks, and entering the adjacent Mill Stream Run Reservation of the Cleveland Metroparks. Continue south on Valley Parkway.

10 mi. (14.3) North Quarry sign. Turn right at sign into the parking lot for North Quarry and continue straight into parking lot. This lot leads to the northern part of Wallace Lake (a former quarry). Exit vehicles and proceed north on foot along stream draining Wallace Lake to small footbridge over stream. Continue south on west side of stream past north end of Wallace Lake to small gully fed by storm drain (STOP 2a).

Return northward along edge of Wallace Lake to examine low outcrop at edge of water-filled quarry (STOP 2b).

0 mi. (14.3) Return to vehicles and exit to Valley Parkway. Turn left onto Valley Parkway and continue north to intersection with West Bagley Road.

0.7 mi. (15) Turn right (east) onto West Bagley Road.

2.2 mi. West Bagley Road becomes East Bagley Road at the intersection of Bagley and Front Street. Note the Berea Sandstone buildings, including several belonging to Baldwin-Wallace University, near this intersection.

3.0 mi. (17.3) Intersection with I-71. Enter northbound I-71 and continue northward to Snow Road exit. [Construction will cause delays as traffic merges into fewer lanes.]

4.8 mi. (19.1) I-71 – Snow Road interchange. Exit right (eastbound) onto Snow Road.

5.1 mi. (19.4) Continue eastward on Snow Road.

8.1 mi. (22.4) Intersection of Hausermann Road with Snow Road. Turn right (south) just beyond this intersection, onto Big Creek Parkway. You are entering Big Creek Reservation of the Cleveland Metroparks; continue eastward for 0.1 mi.
8.2 mi. (22.5) Turn left into Snow Road Picnic Area along this access road. Pull into parking lot by first picnic area. Exit vehicles. Proceed on foot for 20 meters to bank of Creek (STOP 3).

0 mi. (22.5) Return to vehicles, exit parking area, and and turn right onto Big Creek Parkway. Continue on Parkway to Snow Road.
0.1 mi (22.6) Turn right (east) on Snow Road.
3.4 mi. (25.9) Intersection with Broadview Road. Turn left (north) onto Broadview Road. Note the Quarry District sign on the SE corner and the dark historic Berea Sandstone building (it is just above a quarry) along Broadview.
4.2 mi. (26.7) Intersection of Broadview Road and Tuxedo Ave.; turn right (east) onto Tuxedo. Follow Tuxedo east [construction prevents entry from Granger at this time].
4.9 mi. (27.4) Tuxedo Avenue will turn to the left; turn right here following West 4th Street south. Enter Brooklyn Heights Village Park and continue straight south into parking lot at the bottom of the hill, bordering West Creek.
5.2 mi. (27.7) Park and exit vehicles; proceed on foot via park trail to upstream bank exposure (STOP 4).

0 mi. (27.7) Return to vehicles, exit park uphill via West 4th Street straight onto Tuxedo Avenue to intersection of Tuxedo Avenue and Brookpark Road. [Tuxedo will be one way due to construction here.]
0.4 mi (28.1) At intersection of Tuxedo and Brookpark traffic light turn left (west) onto Brookpark Road. Continue on Brookpark westward.
1.0 mi (28.7) Intersection of Brookpark Road with I-176. Turn right to enter I-176.
About 4.5 mi. (32.2) I-176 gradually ends, merging into I-90; follow signs for 90E Cleveland, continue northward on I-90.
8.5 mi. (36.2) I-90 turns sharply to northeast by Lake Erie; continue northeast-ward.
16.4 mi. (44.1) Take the East 185 St. exit., turning left (south) onto E. 185 which will become Nottingham and then Dille Road as you proceed southeastward (some maps show these roads all as E. 185).
17.7 mi. (45.4) Dille Road will change to Highland Road at the intersection with Euclid Ave. Continue straight (southeast) on Highland Road into Euclid Metropark.
18.1 mi (45.8) Intersection of Highland Road with Euclid Creek Parkway; turn right (southwest) onto Euclid Creek Parkway, bordering Euclid Creek. Note sign for Euclid Creek Reservation of the Cleveland Metroparks. Continue on Euclid Creek Parkway.
19.3 mi (47) Turn left into Welsh Woods Picnic Area on your left. Pull into nearest available parking space. Exit vehicles and proceed on foot across picnic area to west edge of Euclid Creek below conspicuous, high shale cutbank (STOP 5a).

Return to vehicles and continue south on Euclid Creek Parkway.
20.2 mi (47.9) Turn left at intersection of Euclid Creek Parkway with access road to the Rear Quarry Reserved Picnic Area on the left. Enter Rear Quarry Reserved Picnic Area, cross short bridge over Euclid Creek and park in lot just beyond (STOP 5b).

0.0 mi. (47.9) Return to vehicles and exit Euclid Creek Reservation, turning right, (northward) on Valley Parkway.
2.1 mi. (50) Turn left (northwestward) from Valley Parkway onto Highland Road.
2.5 mi. (50.4) Turn right (northeast) from Highland Road onto Euclid Avenue (Rte. 20) and follow Euclid Ave eastward to intersection with I-90.
5.5 mi (53.4) Entrance ramp to I-90 eastbound; continue along I-90 northeastward to Erie, Pennsylvania.
84 m. (137.4) Turn right to Exit I-90 at State Street (PA Route 97) interchange in Erie, Pennsylvania. Almost immediately make a right turn to enter driveway for Quality Inn and Suites.
Exit vehicles at hotel. End of Day 1 field trip.

Alternative routing between Stops 4 and 5 to avoid getting split up on Interstates 176 and 90 in afternoon traffic [this route is fine but will take a bit less than an hour]

0 mi. Return to vehicles, exit park uphill (West 4th Street) to intersection of West 4th Street with Tuxedo Avenue. Continue in same direction (north) on Tuxedo (ignore confusing street signs.)

0.4 mi Traffic light at Intersection of Tuxedo Avenue and Granger Road (Rte. 17). Turn left (west) at traffic light (passing construction) onto Granger. (note: construction blocks entrance to the right.)

0.6 mi. Turn right (north) onto I 480. Continue on ramp and then eastward on I 480.

3.4 mi. I-480 continues eastward across the Cuyahoga River valley; continue east on I-480.

8.6 mi. Exit I-480 at Warrensville Center Road exit (Exit 25B); exit is on the right. Turn right (north) onto Warrensville Center Road; continue north on Warrensville Center to intersection with east-west Emory Road.

9.7 mi. Turn right (east) onto Emory Road; continue to intersection with north-south Richmond Road (Rte. 175).

About 11.7 mi. Turn left (north) onto Richmond Road; continue north on Richmond Rd. (Rte. 175) to intersection with Anderson Road.

18.4 mi. Turn left on Anderson Road (SW)

__mi Turn right on East Green a short bit.

19.7 mi. Turn right (north) onto Euclid Creek Parkway, entering the Euclid Creek Reservation of the Cleveland Metroparks.

19.9 mi. Continue on Euclid Creek Parkway passing Kelly Picnic Area

20.7 mi. Turn left into parking lot of Welsh Woods Picnic Area on the left. Pull into nearest available parking area. Exit vehicles and proceed on foot across picnic area to west edge of Euclid Creek below conspicuous, high shale cutbank (STOP 5a).

0 mi. Leave parking lot, turning right (north) on Euclid Creek Parkway until intersection with Highland Rd. Turn left (NW) onto Highland Road

__ mi. At intersection of Highland Rd. and Euclid Ave. (Rte. 20) Turn right (NE) onto Euclid Avenue and follow Euclid Ave to intersection with I-90.

____mi. Entrance ramp to I-90 eastbound; continue along I-90 northeastward to Erie, Pennsylvania.

___mi. I-90 intersection. Take I-90 East.

2.3 I-90 intersects I-271 at Willoughby, Ohio; continue east on I-90 toward Erie, PA.

57.8 Ohio-Pennsylvania state line.

79.8 Intersection of I-90 with I-79 southwest of Erie, PA. Continue northeast on I-90.

81.8 I-90 – Route 19 interchange south of Erie, PA. Continue northeast on I-90.

84.8 I-90 – State Street interchange at south edge of Erie, PA. Exit right to connect with PA Route 97.

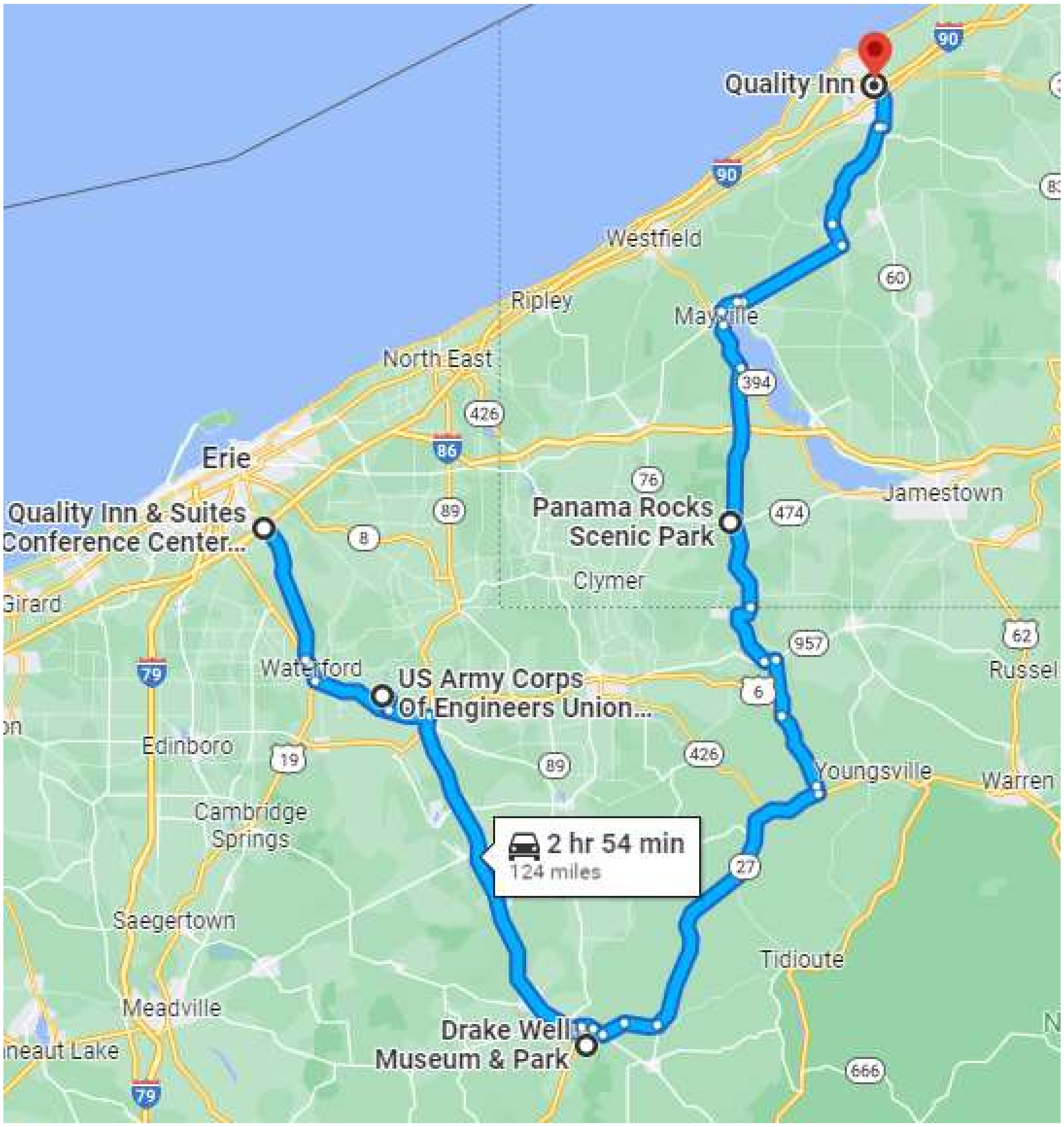
84.9 Turn right (south) onto Route 97, but make an immediate right turn into the entrance of the Quality Inn hotel.

Park and depart vehicles. End of Day 1 road log.

SDS 2023 - pre-meeting trip - Upper Devonian Marine Strata of the Northern Appalachian Basin

Day 2 – 28 July (Friday)

0.0	0.0	Quality Inn – Perry Highway, Erie, Pennsylvania. – 8:00
17.1	17.1	Stop 1 – US Corps of Army Engineers Union City Dam, Waterford, PA. Set GPS to 14700 Middleton Road, Waterford, PA, which will get you near the right place, and look for a left (west) turn to the dam site further up the road. Cross the dam to the parking lot.
27.2	44.3	Stop 2 – Drake Well Museum and Park, 202 Museum Lane, Titusville, PA -
46	90.3	Stop 3 – Panama Rocks Scenic Park, 11 Rock Hill Road, Panama, NY.
33.7	124	End of field trip – Quality Inn – Dunkirk, New York.



MIDDLE-LATE FAMENNIAN STRATIGRPHY IN THE "OIL LANDS REGION" OF NORTHWEST PENNSYLVANIA. DEVONIAN COASTAL-ESTUARINE SETTINGS ON THE GREAT CATSKILL DELTA

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INTRODUCTION

This second day of field stops brings us considerably closer to the inferred paleoshore of the Catskill Delta complex near to the time of its maximum westward progradational development (Harper and Laughrey, 1987). The sections we will view include a spectrum of near-shore deposits ranging from storm-influenced open shelf, to low energy, restricted, inner shelf or estuary, and to high-energy, bay mouth bar facies. Although we will not examine the classic, terrestrial red bed deposits of the Duncannon Member of the Catskill Formation today, owing to distance and time, we will encounter older red bed deposits in the classic Catskill front region on the last day of the SDS field trip.

The region reviewed in this section, includes the classic "Oil regions" district of northwest Pennsylvania and bordering regions of the southwest New York where oil exploration started in earnest and evolved from a stampede to a science (Harper, 2009). In the century following Colonel Drake's producing well south of Titusville, Pennsylvania, came early stepwise development of exploration concepts starting with the anticlinal theory, fracking, and the pioneering use of geophysical logs in delineating key pay sands and the construction of a spatial subsurface stratigraphy for locating targets. This drilling was first applied to the upper Devonian Famennian, subsurface Bradford and Venango sandstone divisions, particularly, the "Venango third sand" of earlier drillers, which we will examine under the unit name Panama Member at Stops 1 and 3. Early on, this work led to recognition of complex repeated episodes of coastal sand sequestration in the form of evolving barrier bar development followed by transgressive bar burial processes (see Dickey et al., 1943; Harper and Laughrey, 1987; Dodge, 1992; Hopkins, 1992).

Owing to the lack of long, continuous outcrops across most of the northwest Pennsylvania region and adjacent New York State, much of the stratigraphy is "provisional" and must be understood as a "work in progress". It is ironic that, in the region where subsurface exploration was born, study of the surface geology has remained limited owing to widespread forest cover and thick colluvial deposits. In spite of this, we were able to locate the eastern (upslope) equivalents of the Cleveland Member eastward to the Meadville and Oil Creek Valley meridians (Crawford County, PA). These deposits are expressed in the lower and middle parts of the provisional Drake Well Formation, the type section of which we will see at STOP 2. A discontinuity at the very base of this interval, flooring the newly designated Cora Clark Park Member, is distinctly marked by detrital pyrite, fish bones, and conodonts as the inferred upslope equivalent of the Skinner's Run Bed, which we saw at STOP4 yesterday.

At STOP 1 today, we will see the disconformable contact between the Chadakoin Formation and the overlying Panama Member of the Venango Formation in the Union City Dam spillway west of Union City, Erie County, PA. We will examine an atypical shale-dominated subfacies of the Ellicott Member in the uppermost Chadakoin Formation. Unlike typical Ellicott storm shelf deposits, characterized by numerous closely-spaced, siltstone and fine sandstone beds interspersed with numerous lenticular brachiopod-bryozoan coquinite lenses, the upper Ellicott at the Union City Dam spillway is a shale-dominated succession distinctive for widely-spaced siltstone beds, a brownish, gray color, as well as several levels of microfractured mudstone and load cast development. The abundance of trace fossils and low diversity of shelly taxa suggest that this deposit represents a somewhat restricted inner shelf setting of estuarine character. This unit appears to be the surface expression of the subsurface “pink beds” interval of Pennsylvania drillers, which is known to underlie the base of the Venango Formation (Hopkins, 1992).

The overlying Panama Member, though inaccessible in the high banks, can be examined in fallen blocks along the spillway floor. As noted above, it marks the basal division of the Venango Formation and corresponds to the historically important “third Venango sand” that triggered the exploration frenzy in the mid-1800s. The lower and middle parts of the unit are well sorted, clean, cross-bedded, white, quartzose sandstone, while the upper quarter portion is quartzose granule to pebble-grade conglomerate (orthoconglomerate). We will see enhanced development of this facies at STOP 3, which represents the acme of Panama Member development. The Panama Member marks a major lowstand erosion event, capping the regressive topmost Chadakoin succession (Baird et al., 2023). Sea level-fall led to base-level downcutting in landward areas with corresponding influxes of coarse sediment to the coastline. Subsequent transgression and coastal drowning led to synchronous up-valley sediment sequestration in estuaries and longshore reworking of residual coarse sediment lag fractions trapped along the coastline to become pay sands (Hopkins, 1992; Snedden and Dalrymple, 1999).

At STOP 2 we will examine the type section of a new provisional unit, the Drake Well Formation, which overlies the Venango Formation (Harper, 1998; Baird et al., 2009a; Baird et al., 2023). This unit, first recognized from gamma ray log profiles focused on the region around Oil Creek and Titusville by Harper (1998) is further supported by the rediscovery of key basal marker strata, first described by Caster (1934) through the work of Baird et al. (2009a). This work, coupled with identification of key conodonts, shows the Drake Well to be an upslope equivalent of the Cleveland Member in Ohio (Baird et al., 2009b).

Following lunch in the Drake Well Park and a tour of the Drake Well Museum, participants will be able to sample the type section exposure across from the museum entrance and parking area. This exposure is notable for the occurrence of several types of extinct articulated phyllocarid crustaceans, the unusual taxon *Titusvillia*, and other rare forms. These occur in amalgamated siltstone and fine sandstone strata, indicative of deposition on a storm-influenced open shelf.

At STOP 3 we examine one of the best-known “rock cities”, Panama Rocks, which is not only the type section of the Panama Member, but which is also a key area commercial attraction. At this place, the Panama reaches a maximum thickness of 18 meters and is essentially entirely composed of coarse, granule-to-pebble grade pebbles, essentially entirely composed of milky vein quartz. As such, this occurrence is the thickest of several well-known developments of locally thick Devonian orthoconglomerate in this region.

Along the park trail, participants will see numerous huge joint blocks of Panama, which have slowly moved downslope through mass-wasting over millennia. The vertical faces of the blocks show a complex tractional history of sediment transport with notable reversals of current flow in a high-energy current regime reflecting the action of storms and tides. Local development of this thick orthoconglomerte facies is best understood to mark the development of valley head barrier bars, timed with lowstand and early transgressive phases of eustatic change along the paleocoast (Hopkins, 1992; Snedden and Dalrymple, 1999; Smith and Jacobi, 2006). Two ideas relating to the origin of the distinctive discoidal quartz pebbles will also be discussed as well as a potential test of both models.

Given the uncertainties of correlation control, many questions remain regarding temporal relationships of known units to one another. Possible temporal connection of lower Drake Well Formation strata (*Bispathodus aculaetus* Zone) to the Oswayo Formation farther east in the Olean-Bradford area, still needs to be confirmed. Absence of conodont data from the marine Corry Sandstone, the highest Devonian unit in northwest Pennsylvania, currently represents a gap in our understanding of when and how the Devonian ends in the northwest Pennsylvania region. Given that the Venango Formation – Corry Formation succession straddles much of the Hangenberg temporal interval, future reexamination of the variably diverse macrofauna (brachiopods, bryozoans, molluscs) in these units should shed critical light on the impact of successive biocrises in neritic shelf settings.

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Trip starts at 8:00 AM from the parking lot of the Quality Inn in Erie, PA.

0.0	0.0	Exit hotel premises; turn right (southeast) onto PA Route 97 toward Waterford, PA.
8.7	8.7	Intersection of Route 97 and PA Route 19; turn left (south) onto PA routes 19/97 and proceed into and through

		Waterford, PA.
1.5	10.2	Route 97 splits off to left (east); bear left to stay on Route 97.
5.0	15.2	Turn left (north) onto Middleton Road.
0.8	16.0	Turn left (west) onto road to Union City Dam.
0.3	16.3	Road splits. Bear left to cross Union City Dam.
0.3	16.6	Parking lot at west end of Union City Dam. Depart from vehicles (**STOP 1**).

STOP 1: UPPER PART OF ELLICOTT MEMBER OF CHADAKOIN FORMATION, CAPPED BY PANAMA MEMBER OF THE VENANGO FORMATION, SPILLWAY SECTION AT UNION CITY DAM, WEST OF UNION CITY, ERIE COUNTY, PENNSYLVANIA

Continuous interval displaying the uppermost part of the Ellicott Member of the Chadakoin Formation unconformally overlain by the Panama Member of the basal Venango Formation in large spillway excavation linked to the Union city Dam along French Creek 5 km (3 mi) west of Union City, Erie County, Pennsylvania. This exposure is at coordinates 41.919141°N, 79.902523°W, and it is located on the southeastern part of the Waterford 7.5' Quadrangle. We will reach this section from east-west PA Route 97 via north-south Middleton Road for about 0.8 km (0.5 mi), followed by left turn onto westbound road, continuing 0.5 km (0.3 mi) over the Union City Dam to a public parking area at the west end of the dam. We will then disembark and continue on foot along descending gravel service road leading to the lower (east) end of the spillway cut. From there, we will proceed only a limited distance into the spillway cut. Collecting is encouraged; our discussion will partly focus on the assortment of loose blocks on the spillway floor and accessible Ellicott shale bank sections.

The Union City Dam spillway is perhaps one of the best places in Erie County Pennsylvania to take students to see impressive strata and to collect loose Late Devonian fossils. Permission must be obtained from the United States Army Corps of Engineers (A.C.E.) to take groups into the spillway. Because of safety concerns, hard hats and secure footwear are mandatory; the A.C.E. cut back the Panama sometime in order to stop automobile-sized blocks of the Panama Sandstone from falling into the spillway. It is important to avoid the rock walls and stay to the center when in the spillway. We thank the A.C.E. for permissions granted over the decades to bring groups of students in and for permission to collect loose fossils for educational use and visits by scientists.

Two key stratigraphic divisions are visible in the 30-m- (95 ft-) thick spillway succession (Fig. 1). The main, 25-m- (78-ft-) thick part of the section is the shale-dominated uppermost interval of the Chadakoin Formation. This is abruptly succeeded by an approximately 5-m- (15–17 -ft-) thick interval of Panama Sandstone, a massive, quartzose unit which is the lowest member division of a long succession of siltstone and sandstone unit comprising the Venango Formation in northwest Pennsylvania (Caster, 1934; Harper and Laughrey, 1987).

In neighboring New York State, the Chadakoin Formation is divided into a lower Dexterville Member and a higher, thicker division called the Ellicott Member (Tesmer, 1963; Baird and Lash, 1990). Based on comparison of facies and faunas, the present authors extend the term Ellicott into Erie County, Pennsylvania, which includes the Chadakoin succession developed in this spillway section (Baird and Lash, 1990; Baird et al., 2023, in press).

The Chadakoin Formation, which includes marine strata of upper middle Famennian age within the Conneaut Group, most closely approximates the zonal level of the *styriacus* conodont zone

(Over et al., 2009; Spalletta et al., 2017). This interval occurs within the *Cheiloceras* global ammonoid biozone and within the *Maeneceras* regional ammonoid zone (House and Kirchgasser, 2008). According to Richardson and Ahmed (1988) the Conneaut Group falls entirely within the *Synorisporites flexuosis* (Juschko, 1960*)-Grandispora cornuta* Higgs, 1975 palynomorph assemblage zone.

Figure 1. Union City Dam spillway section (loc. 8), 5.6 km (3.5 mi) west-northwest of Union City, Erie County, Pennsylvania (Waterford 7.5-minute quadrangle, section coordinates 41.91946°, -79.90290°), displaying brownish-weathering shale deposits on the topmost Ellicott Member (a) below the disconformable base of the coarse Panama Sandstone Member (b) of the Venango Formation. The brownish shale unit is suggestive of proximity to the inferred paleocoast and is particularly notable for diverse trace fossils, including xiphosuran resting traces. The top of the Panama Member is quartz pebble conglomerate at this locality. (D Over – image; from Baird et al., 2023, used with permission).

The Ellicott Member is a richly fossiliferous interval generally characterized by numerous, closely-spaced repetitions of grey-greenish shale partings of tabular to lenticular siltstone partings, interspersed with lenticular concentrations of closely-packed brachiopod, bivalve, bryozoan, and pelmatozoan debris (coquinites). Thicker siltstone and fine sandstone beds often display hummocky cross-stratification, and siltstone and shell-rich layers are often amalgamated. These deposits are understood to record oxygenated shelf conditions in a storm-influenced open shelf regime with conditions varying from outer shelf through mid-ramp to foreshore conditions (Snedden and Dalrymple, 1999; Smith and Jacobi, 2006). The Ellicott is understood to be an upslope, shoreward temporal equivalent of the mudstone-dominated, outer shelf Chagrin Shale succession as we observed in the Cleveland, Ohio area at Day One, stops 1, 4, and 5 (Fig. 2a, b).

However, the topmost Ellicott succession observed here at the Union City spillway is anomalously shaly with only widely dispersed, tabular siltstone layers and widely scattered, thin shell beds as compared with the underlying lower and middle Ellicott succession (Fig. 1). In particular, the shale in the spillway walls displays indistinct bedding, and it distinctly weathers to a chocolate, reddish brown color (Baird et al., 2013; Baird et al. 2023, in press). Moreover, this shale interval is notable for multiple levels of soft-sediment, load cast deformation and what appears to be extensive microfracturing at several levels. In the Sherman-Stedman area in western Chautauqua County, New York, essentially identical facies occur below the Panama Sandstone at sections flowing into French Creek (Baird and Lash, 1990). Because this shale was so very different from typical underlying tempestite-dominated deposits of the Ellicott Member, it was informally termed the “barren, cleaved shale” division of the Ellicott succession (Baird and Lash, 1990).

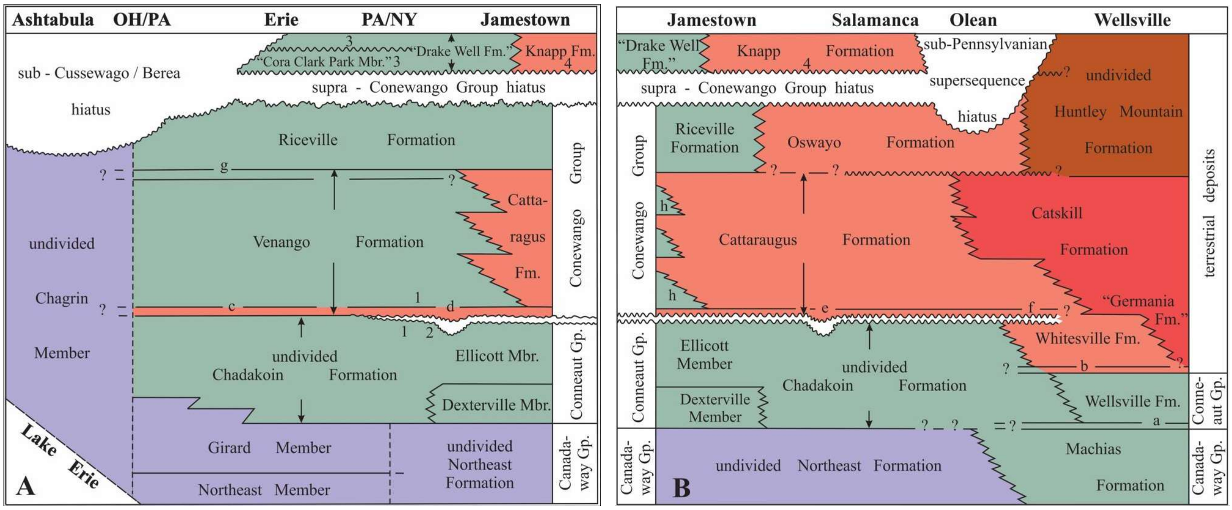

Figure 2. Provisional chronostratigraphic transects of Conneaut and Conewango Group succession from northeast Ohio, eastward to the Wellsville, New York, meridian; **A**, Conneaut–Conewango Group chronostratigraphy from the Ashtabula meridian in Ohio, eastward to the Jamestown, New York meridian; **B**, Jamestown, New York–Wellsville, New York transect for the same interval. Figure utilizes Rickard’s (1975) placement of the Cuba Formation as basal unit of Conneaut Group (see text). “Rawson formation” of Manspeizer (1963), not shown in figure, is coincident with the lower part of the Wellsville Formation (see text). Numbers denote key biostratigraphic references: 1, House (1962) – ammonoids; 2, Over et al. (2009) – conodonts; 3, House (1962) – ammonoids; 4, Baird et al. (2009 a, b) - conodonts. Lettered units include: a, Cuba Formation; b, Hinsdale Sandstone Formation; c, Panama Sandstone Member (distal sandstone phase); d, “Panama Rock City” orthoconglomerate occurrence (Panama Member); e, “Little Rock City” orthoconglomerate occurrence (Salamanca Member); f, Wolf Creek Member; g, Woodcock Member; h, Venango Formation (image created by G. Baird and modified by D. Jeffrey Over; from Baird et al., 2023, used with permission).

This topmost division of the Ellicott Member is also well known for the occurrence of unusual marine taxa and an unusually diverse suite of trace fossils. Trilobites, normally well represented in Lower and Middle Devonian deposits, are effectively regionally extinct in the Famennian of the northern Appalachian Basin. In their place is a rich arthropod record of phyllocarid crustaceans and early xiphosurans (Hannibal and Feldmann, 1983; McKenzie, 2009). In particular, the Union City site is famous for the occurrence of xiphosuran resting traces and the trace makers as well (Baird et al., 2009, 2013b; Fig. 3). Less commonly, body fossils of xiphosurans and phyllocarids can be recovered from shale exposures near the floor of the spillway.

The upward change from silty, tempestite-dominated facies of the typical underlying Ellicott succession, into this shale-dominated unit, appears to record an initial transgression event followed by a higher terrigenous pulse associated with pre-Panama sea-level-fall. Discovery by Baird of a quartz pebble-filled channel, 1.5 meters (5 ft) below the base of the Panama Sandstone, within the top-Chadakoin shale unit in a creek near Wattsburg, Erie County, Pennsylvania, suggests that this shale unit is closely linked to a significant regression event which culminated in sub-Panama erosion (Baird and Lash, 1990). We tentatively interpret the topmost Ellicott as recording low energy conditions in a restricted inner shelf or estuarine setting peripheral to the paleocoast. In light of the above, this topmost Ellicott Member division appears to be the western (distal) outcrop expression of the upper portion of the distinctive "pink rock" interval of drillers, separating the older, sandstone-bearing Bradford Group succession from the younger, sandstone-bearing Venango Group in the subsurface (Hopkins, 1992). This important and somewhat enigmatic, shale-dominated division has been long recognized in the subsurface throughout a large region under western Pennsylvania and West Virginia (Hopkins, 1992).

The Venango Formation, classically exposed in southeastern Erie and Crawford counties in Pennsylvania, is principally composed of a marine, subtidal shelf succession of thin shale layers, brachiopod-rich coquinoid beds and lenses, enclosed within a thick succession of stacked siltstone beds largely of apparent storm-bed (tempestitic) origin. However, it is also characterized by mappable beds and lenses of quartz-dominated, massive sandstone and nearly pure quartz conglomerate (orthoconglomerate) units at several levels. It is time-equivalent to the upper part of the thick, undivided Chagrin Member of the Ohio Shale in Ohio, which is represented by sparsely fossiliferous, shaly, down-ramp deposits across northern Ohio (Caster, 1934; Baird et al., 2009; Baird et al., 2013; Hannibal et al., 2012; Figs. 2a, b).

The regional base of the Conewango Group and Venango Formation is taken at the respective bases of the Panama Conglomerate Member and the equivalent Wolf Creek Conglomerate Member or to the lowest bright red shale beds in sections where the sandstone markers are poorly developed (Tesmer, 1963; Rickard, 1975; Figs. 2a, b). Carll (1883) designated the name Panama for an interval of conglomeratic sandstone with a type section at Panama, Chautauqua County, New York where it thickens greatly, forming a conspicuous "rock city," which we will see at Day two, Stop 3. The Panama and several higher conglomeratic sandstones within the Venango interval are observed to thicken into spatially linear to arcuate trends in the subsurface, understood to represent high-energy coastal barrier bar systems (Harper and Laughrey, 1987; Hopkins, 1992). Many of these linear trending bodies served as major "pay sands" during the long oil exploration history of this region. The Panama Member is the outcrop expression of the productive "third Venango sand" of driller's terminology (Carll, 1883; Caster, 1934). Both the Panama Member and the higher, similar conglomeratic sandstones locally thicken greatly, being expressed as variably well known "rock city" attractions, but these localized occurrences are difficult to correlate owing to the inferred complexities of the Devonian coast and poor surface outcrop control today. Depositional settings represented by the quartzose conglomeratic deposits of the Panama Member will be discussed at greater length at Day two, Stop 3.

At the Union City spillway, the base of the Panama is knife-sharp, marking the position of a low-stand disconformity. Though the clean, cross-bedded, quartz sandstone records a relatively shallow, high-energy setting, succeeding Venango strata mark an abrupt change to brachiopod and bryozoan-rich, lower-energy mudstone-dominated deposits, suggesting that the Panama Sandstone at this locality is part of a transgressive systems tract succession marking reestablishment to open subtidal shelf conditions following Panama deposition. At the top of the massive sandstone interval is a thin bed containing quartz pebbles in association with disarticulated valves of the brachiopod *Cyrtospirifer.* This may mark the base of the succeeding Venango division, informally known as the *Amity Shale* (see Chadwick, 1925); as such this bed may represent a transgressive lag deposit which caps the Panama Sandstone.

The Panama Member and succeeding Venango Member of the Conewango Group approximate the interval of the *styriacus* Zone (= former Lower *postera* Zone) through the *Bispathodus* *costatus* Zone (= former upper portion of the Middle *expansa* Zone; Kirchgasser et al., 1997; Over et al., 2009). This stratigraphic interval also roughly corresponds to the internationally recognized LL-LE miospore biozones (Avkhimovich *et al*., 2011). The Cattaraugus Formation corresponds to the *Vallatisporites pusillites* (Kedo) Dolby and Neves, 1970 (*sensu lato*)-*Apiculiretusispora fructicosa* Higgs, 1975 assemblage zone with rare appearances of "LL" zone taxa in its upper part (Richardson and Ahmed, 1988). The discovery of the ammonoid, *Sporadoceras milleri*, collected in the basal Venango Panama Member near Erie, Pennsylvania, suggests a correlation with the broad *Platyclymenia* Stufe (House and Kirchgasser, 2008).

Figure 3. Whitened specimen of complex *Protolimulus eriensis* (Williams, 1885) cubichnial ichnofossil, CMNH 8253, used with the permission of the Cleveland Museum of Natural History.

Key macrofaunal elements that participants are likely to find are the brachiopods *Cupulorostrum* (*Camarotoechia*) and *Cyrtospirifer*, which are common in one or more, thin, tabular shell beds low in the Ellicott section. Other frequent fossils are bivalves, ramose bryozoans, and pelmatozoan debris. Most notable are abundant and diverse trace fossils, particularly repichnial, cubichnial, and even fugichnial forms (Fig. 3). One of the interesting fossils found in the spillway is the horseshoe crab resting trace *Protolimulus* (Fig. 3). This is a resting trace linked to the horseshoe crab *Kasibelinurus randallii* which is also found locally. *Protolimulus* is not uncommon in the spillway and it is also found in other area localities developed in nearshore deposits (Babcock et al., 1995). Articulated phyllocarids as well as numerous ophiuroids have turned up at this locality. Of particular interest is the unusual asteroid trace *Asteriacites gugelhupf,* which is a common deep burrow, looking like a pentagonal German birthday cake (Seilacher, 2007). Fossil plants found here include a 1.5-m (5-foot) trunk section of a fossil lycopod (scale tree) and the holotype of the earliest structurally preserved lycopod strobilus *Bisporangiostrobus harrisoni* Chitaley and McGregor, 1988, which was found in the lowest of the exposed Ellicott beds. Occasional vertebrate findings include a large placoderm plate found in fall-down blocks of the Panama Sandstone; this specimen turned out to belong to the arthrodire genus *Dunkleosteus*, the giant arthrodiran fish of Cleveland Member fame (Carr and Jackson, 2008; Carr, 2010).

		Return to vehicles and retrace route back to intersection of routes 8 and 97 at Union City.
4.0	20.6	Turn right (south) onto Route 8 from Route 97 and proceed through Union City. PA Route 6 intersects Route 8 in the middle of town. Continue straight on Route 8.
0.8	21.4	Route 6 splits off of Route 8 at south edge of Union City. Bear left to stay southbound on Route 8.
8.4	29.8	Intersection of Route 8 with PA Route 77. Riceville, type locality of the Upper Devonian Formation is one mile southwest of this intersection. Continue south on Route 8.
3.6	33.4	Pass through hamlet of Centerville, PA and cross east branch of Oil Creek. Continue south on Route 8.
7.2	40.6	Pass through Hydetown, PA, which represents the southward terminus of the Kent ice advance, marking the limit of maximum ice cover in this region. Continue southeast on Route 8.
3.6	44.2	Intersection of Route 8 with PA Route 27 near west edge of Titusville, PA. Proceed eastward to middle of Titusville on routes 8/27.
0.4	44.6	Route 8 turns right, away from Route 27. Turn right (south) on Route 8. About 0.8 miles north of this intersection where Route 89 crosses Church Run, is the type locality of the enigmatic sponge or trace fossil *Titusvillia drakei* Caster, 1939.
0.3	44.9	Cross Oil Creek and take an immediate left onto East Bloss Street at the light. Proceed eastward on east Bloss Street for one mile.
1.0	45.9	Cross Oil Creek on one-lane bridge and take an immediate right (south) turn at the east end of the bridge.
0.2	46.1	Enter Drake Well Park. Park and depart vehicles. **STOP 2**. Drake Well Park and Museum. Type section of the Drake Well Formation.

DAY 2, STOP 2: TYPE SECTION OF PROVISIONAL DRAKE WELL FORMATION AND ADJACENT DRAKE WELL MUSEUM.

Type exposure of provisional Drake Well formation at northern railhead of Oil Creek Railroad line, opposite Drake Well Museum and park complex along Oil Creek, 1.6 km (1.0 mi) southeast of Titusville, Venango County, Pennsylvania. We will reach this locality via east (left) turn from Route 8 onto Bloss Street at the south edge of Titusville. Bloss Street changes to Allen Street southeastward to the bridge over Oil Creek. Upon crossing the bridge, turn south onto Museum Lane and continue 0.3 km (0.2 mi) to parking area for the Drake Well Museum and adjacent tourist railroad station. The parking area is at coordinates 41.611868°N, -79.656813°W on the northeast corner of the Titusville South 7.5' Quadrangle. This stop is in two parts; examination of the type section of the Drake Well formation adjacent to the railroad platform and later visit to the nearby Drake Well Museum, which celebrates Edwin L. Drake who demonstrated the feasibility of obtaining oil cheaply using salt well technology as well as the subsequent turbulent exploration history in this region. Participants will disembark and proceed a short distance northward past the railroad terminal and platform to an outcrop bordering the east side of the railroad track at google coordinates

41.613246°N, -79.656434°W, where trip leaders will discuss the evolution of the "Drake Well formation" concept as well as the significance of fossils found at this site. Light collecting is permitted here from loose, fall-down debris at the base of the rock face.
Drake Well Memorial Park has long been a point of historical interest as the birthplace of the petroleum industry. In conjunction with the Memorial Museum, the State of Pennsylvania has appointed the railroad cut near the park entrance as a site open for fossil collecting. The exposures continue along the south tracks as well as around the corner along Pine Creek.

Strata displayed in this bank are temporally younger than both the Chadakoin and Venango formations that we saw earlier at Day two, Stop 1. However, this exposure may be an eastern time-correlative of part of the Cleveland Shale that we saw on Day One. In an earlier Pennsylvania Field Conference guidebook, John Harper did a detailed write-up on the old railroad cut section opposite the entrance to the Drake Well Museum and proposed that this outcrop be the type section of his new Drake Well Formation (Harper, 1998). His division, based largely on subsurface log information, was a rediscovery of a marine interval equivalent to the lower Knapp succession of the Warren area. Kenneth Caster (1934) had reassigned the upper part of White's (1881) original "Riceville Member" into two divisions; a lower (Chagrin-equivalent) restricted Riceville entity, and higher lower Knapp-, and Bedford-equivalent division which he designated the Kushequa Member. As Caster's Kushequa type section in McKean County proved problematic, interest in the Kushequa concept waned, but the stratigraphy remained clouded over several decades. Eventually, Harper (1998) and Dodge (1992) came to recognize the nature and extent of earlier miscorrelations in subsurface logs followed by rediscovery of Caster's old regional, base-Kushequa ("Spirifer bed") marker by Baird in sections north of Titusville (Baird et al., 2009) allowing the base of the unit to be defined lithologically. Hence, the Drake Well Member concept presented here represents an approximate return to Caster's original Kushequa concept, but with a new name and new type section.

Deposition of the lower and middle parts of the Drake Well Formation appears to be largely timed with deposition of the Cleveland Shale in Ohio. The basal Drake Well stratum, ("Spirifer bed" of Caster, 1934), marks the appearance of key brachiopods that signal the presence of the "Knapp fauna" that was once thought to be Mississippian. Following its rediscovery by Baird, this bed was found to be a lag deposit yielding syringothyrid brachiopods in association with phosphatic debris and the key zonal conodonts *Bispathodus aculeatus aculeatus* (Branson and Mehl, 1934a) and *Polygnathus symmetricus*? Branson, 1934. indicative of the *aculeatus* conodont biozone and apparent equivalency to part of the Cleveland Shale (Baird et al., 2009). Observed dominance of the conodont *Bi. aculeatus anteposicornis* Scott, 1960 in topmost Drake Well strata, above the top of this section, suggest equivalency to the *costatus* biozone or higher (Baird et al., 2009).

A provisional, member-scale, basal Drake Well division, designated the *Cora Clark Park* member, displays a few thin black shale beds in association with diminutive, offshore trace fossils, thus preserving some Cleveland facies features in this area. In particular, the discontinuity flooring the "spirifer bed" and Cora Clark Park interval is locally rich in detrital pyrite, suggesting that it is the upslope equivalent of the Skinners Run pyrite bed observed at Day One, Stop 4. However, unlike the basinal, organic Cleveland Member succession in Ohio, the Drake Well Formation is generally expressed as a mid- to inner shelf neritic deposit. The Drake Well Formation is characterized by numerous stacked and amalgamated siltstone and sandstone beds, which accumulated in a storm-influenced shelf setting (Baird et al., 2009, 2013, 2023).

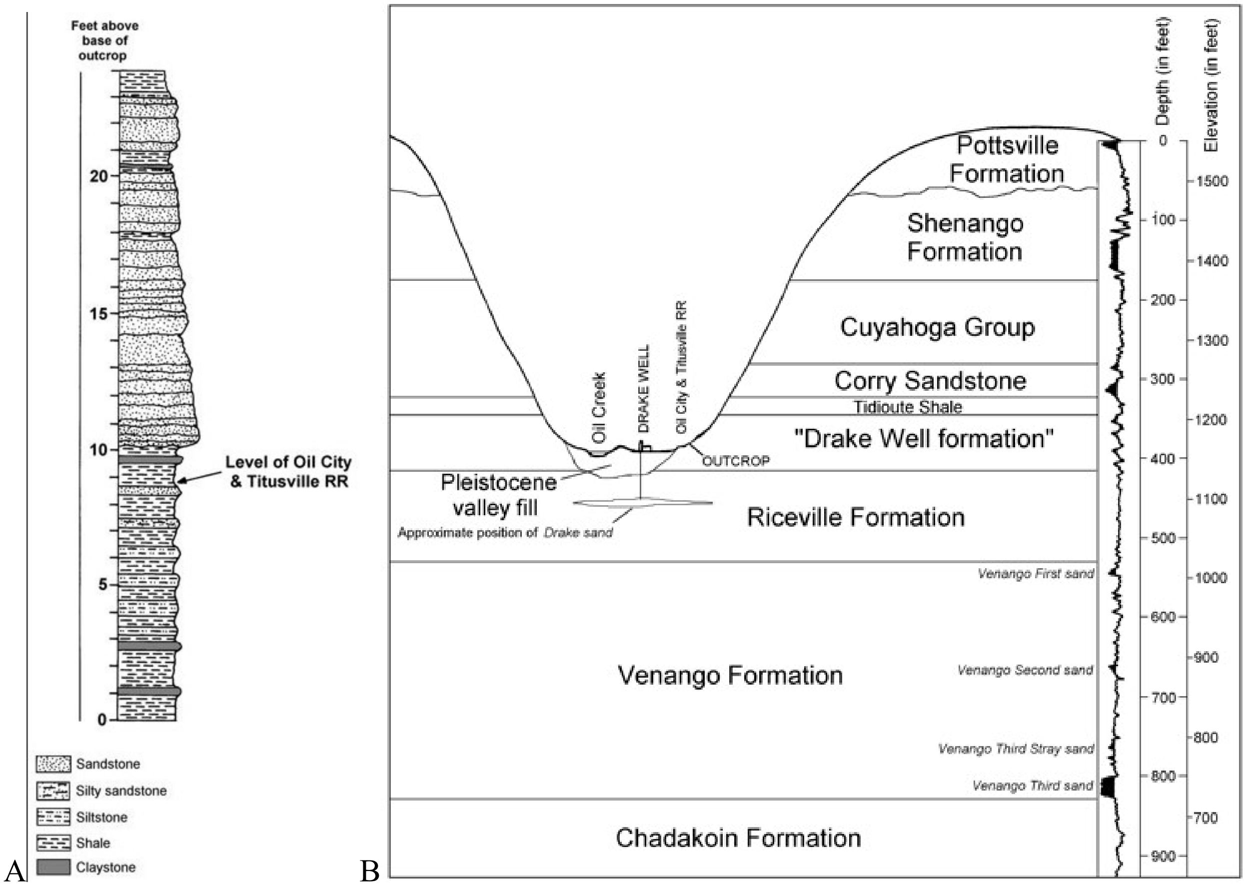

Figure 4. A. Schematic stratigraphic column of the Drake Well Formation near its type location by the site of the Drake Well. Note that the visible type Drake Well section that we will see at STOP 2 is only a subset of the entire unit and that neither the base or top of the Drake Well Formation can be seen here (from Harper, 1998, used with permission). **B**. Geologic cross-section of the Oil Creek Valley and Wildcat Hollow in the vicinity of STOP 2 showing the Drake Well Formation in stratigraphic and topographic context (from Harper, 2009, used with permission).

This railroad cut displays 7.5 m (24 ft) which is only a lower-middle subset of the 18 m (60 ft) total thickness of the Drake Well succession (Harper, 1998; Fig. 4). The lower 3.5 m (10 ft) of this outcrop (now partly covered) is predominantly shale with thin, tabular siltstone beds. The upper 4 meters consists of more resistant sandstone and siltstone beds which are distinctly rich in fossils (see below). Based on southward dip projection of the underlying "Spirifer bed" by Baird from the Centerville area, the actual Riceville-Drake Well boundary is presently believed to be at or slightly below the level of Oil Creek at the latitude of this railroad cut (Baird et al. 2009; Fig. 4).

The part of this cut closest to the train platform is the best exposure for collecting, and it continues to produce new and unusual fossils. Periodic rock falls provide slabs that can be split to expose fossils. Beds are variably fossiliferous, but most fossil material is comminuted to varying degrees. Important fossils observed in the lower-middle Drake Well succession include: the syringothyrid brachiopod *Sphenospira* (*Syringothyris*) *angulata* Simpson, 1890, the pentagonal echinoid *Hyattechinus*, localized concentrations of coleolid tubes, and articulated glass sponges. The main fossiliferous horizon is the 23 cm (9 in) sandstone unit approximately 13 ft (4 m) above the level of the tracks. It is particularly notable for several different genera of articulated phyllocarids, an early group of extinct crustaceans (Feldmann et al., 1992; Fig. 5a, b). This layer produces the largest numbers of phyllocarids, although phyllocarids are also found sparingly below this layer, some with the segmented abdomen attached (McKenzie, 2009a). It is significant that no trilobites are found in this section or in other Famennian northern Appalachian Basin sections; the prominence of crustaceans at multiple levels in this region may be an example of ecological replacement in the arthropod record. The “sponge” fossil, known as *Titusvillia drakei* Caster, 1939 is found frequently in the lighter colored sandstone beds below the arthropod-bearing layer (Fig. 6). It is possible, if not probable, that this taxon is actually the trace fossil *Armstrongia oryx* based on examination of numerous specimens (McKenzie, 2009b). Other trace fossil genera are exposed on loose slabs in the float. Careful examination of these fallen blocks will turn up numerous specimens of the inarticulate brachiopod *Lingula* as well as other shelled fauna.

Figure 5. A. Phyllocarid *Echinocaris randalli* Beecher 1902 from the Drake Well Formation, Titusville, Venango County, Pennsylvania, CMNH 8296, Scale bar = 5 mm long, used with permission of the Cleveland Museum of Natural History. **B.** *Pephricaris* from Cattaraugus County, New York (34 mm wide). Larger specimens of the genus are found in the Drake Well Formation (from McKenzie, 2009a, used with permission).

Figure 6. Typical “*Titusvillia*” (*Armstrongia oryx*) from the Drake Well Formation, Venango County, Pennsylvania. Specimen 6 cm long (collection of Scott C. McKenzie), from McKenzie, 2009a, used with permission (from McKenzie, 2009b, used with permission).

Upon completion of this field stop, participant will secure their specimens at vehicles and then proceed to the Drake Well Museum.

		Return to vehicles and retrace route back to intersection of route 8 and 27 near the west edge of Titusville, PA.
1.9	48.0	Bear right (northwestward) to stay on Route 8. Valley is the expression of the Tyrone-Mt. Union structural lineament.
23.6	71.6	Intersection of routes 8 and 97 in Union City; continue north on Route 8.
0.8	72.4	Exit Union City. Continue north on Route 8.
6.9	79.3	Intersection of Route 8 with PA Route 89 south of Wattsburg, PA. Continue north on routes 80/89 into Wattsburg.
5.5	84.8	Intersection of Route 8/89 with PA Route 474 in middle of Wattsburg, PA. Turn right (east) onto Route 474 and proceed toward Clymer, NY.
0.5	85.3	Exit village of Wattsburg.
9.2	94.5	Enter village of Clymer, NY. Continue east on Route 474.
0.9	95.4	Exit Clymer, NY; continue east on Route 474.
9.7	105.1	Intersection of Route 474 with Rock Hill Road at west edge of Panama, NY. Make sharp right turn onto Rock Hill Road and proceed up hill.
0.2	105.2	Driveway entrance to Panama Rocks Park concession at top of hill grade. Turn left into entrance and park vehicles (**STOP 3**).

DAY TWO, STOP 3: TYPE SECTION OF PANAMA CONGLOMERATE, BASAL MEMBER DIVISION OF VENANGO FORMATION AT PANAMA, NEW YORK

Classic "rock city" exposure of the type section of the Panama Member at Panama Rocks private concession park, 0.8 miles (1.2 km) west of Panama, Chautauqua County, New York at Google coordinates 42.072798^{o}N, -79.486082^{o}W, on the Panama, New York 7.5' Quadrangle. After checking with management, our group will proceed via proscribed path from the office and parking area into a maze-like boxwork of large joint blocks of quartz pebble conglomerate that have drifted downslope to varying degrees owing to mass wasting and weathering along joint faces. We will follow the main path, which loops around back to the parking area.

The regional base of the Conewango Group and Venango Formation is taken at the respective bases of the Panama Conglomerate Member and the equivalent Wolf Creek Conglomerate Member or to the lowest bright red shale beds in sections where the sandstone markers are poorly developed (Tesmer, 1963; Rickard, 1975). Carll (1880) designated the name Panama for an interval of conglomeratic sandstone with a type section at Panama, Chautauqua County (Panama, New York 7.5-minute quadrangle at 42.07320°, -79.48681°), where it reaches a maximum thickness of 21 m (69 ft) and is exposed as a prominent "rock city" exposure on a hillside. However, the Panama Member normally varies from 3.7 to 9.1 m (12 to 30 ft) in thickness regionally. The Panama Member is the outcrop expression of the productive "third Venango sand" unit of driller's terminology (Carll, 1880; Caster, 1934).

At "Panama Rock City" at Panama, New York, the Panama Member is anomalously thick and it is composed largely of cross-laminated, quartz pebble orthoconglomerate composed of ovoidal to discoidal-shaped, milky quartz pebbles (Tesmer, 1963; Baird and Lash, 1990; Smith and Jacobi, 2000). Where it is thinner, it is typically composed of hard, orthoquartzitic sandstone

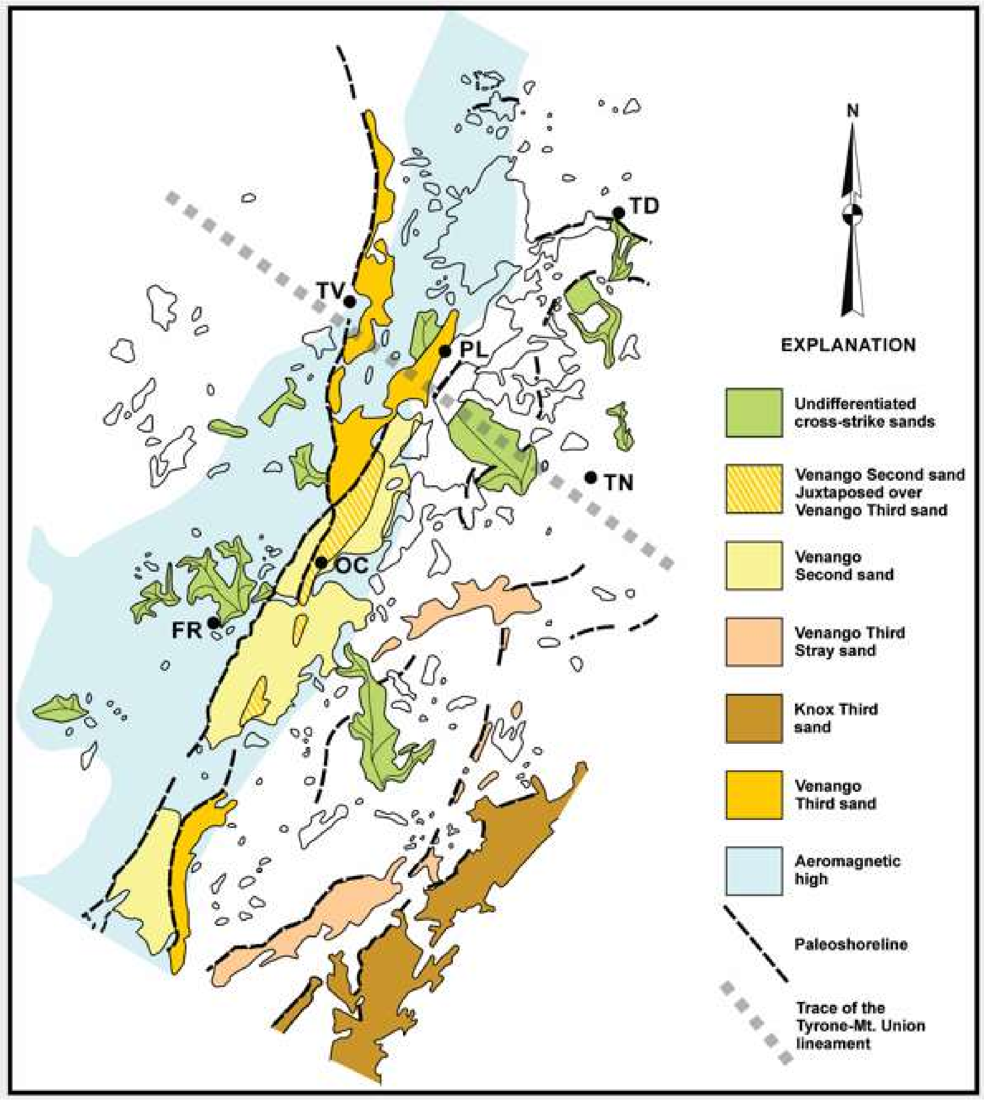

Figure 7. Spatial distribution of subsurface sandstone bodies at multiple superimposed levels within the Venango Formation succession within the classic oil and gas producing region of Venango County and adjacent region. Note the strong north-northeast-south-southwest linear trend of key linear sandstone units, which respectively mark the inferred successive shoreline positions of Hopkins (1992). These linear bodies are understood to represent preserved high energy, coastal bar-barrier features, which have long served as important target sands (see text). Sandstone units shown in green trend approximately normal to the strike of the barrier-bar sands; these may have originated as localized distributary mouth bar sands or tidal ebb deltas developed along the coastline. Superposition of the thick, multistory, Venango second and third sands is understood to have taken place within a shoaled, higher-energy belt of inferred structural origin that is indicated by development of a spatial aeromagnetic high (blue shaded area); persistence of this shoaled area over time as a coastal buttress led to repeated development of thick, clean sands in this area, critical for hydrocarbon sequestration. Heavy dashed lines denote the inferred seaward margin of respective beach-barrier trends of Hopkins (1992). Cross-strike sands are green. Other sandstone divisions (Red Valley and Venango first sands), as well as numerous other sand units of hybrid or uncertain origin, are uncolored. Line of gray square symbols denotes trace of regional Tyron-Mt. Union cross-fold structural lineament. Key towns (black circles) include: FR = Franklin, OC = Oil City, PL = Pleasantville, TD = Tidioute, TN = Tionesta, TV = Titusville. Image modified from Dickey et al., 1943; Hopkins, 1992, Baird et al., in press, used with permission.

with quartz pebble lenses and dispersed pebbles, often in association with sparse marine fossils. Generally, the Panama Member displays a sharp, unconformable basal contact over silty shale deposits of the topmost Ellicott Member of the Conneaut Group across parts of Erie County, Pennsylvania and in New York State (Baird and Lash, 1990). The high energy, pebbly facies, the localized, anomalous thicknesses of this unit, and the subjacent unconformity, suggest that deposition of the base-Conewango Group boundary marks a major regressive lowstand event.

The thick, orthoconglomeratic sandstone units are understood to record high-energy, wave-dominated, shallow offshore bar to marine shoreface conditions. According to Smith and Jacobi (2006), thick, localized orthoconglomerate occurrences such as the Panama Member and similar units are most likely the record of dominant wave- and tidal current-action along barrier bars at the seaward limits of coastal estuarine sediment systems (Fig. 7). As such, these high energy sandstone deposits often correspond to the "pay sands" that supported historic oilfield development in this region. Some of these coarse units are envisioned to have accumulated seaward of incised valley systems, timed with marine transgression, coastal ravinement, and localized sediment aggradation (Snedden and Dalrymple, 1992; Smith and Jacobi, 2006). The complex internal layering of these conglomeratic sandstones reflects the complex interaction of both tidal processes and wave action. The difficulty of correlating these coarse, member-scale divisions regionally in outcrop is well summarized in Fig. 7, where high-energy facies were focused into narrow linear belts and/or channels along the paleocoast; the lateral shifting of these belts under the influence of eustatic controls, structural effects, and depocenter migrations accounts for the very localized distributions of the respective Venango and Cattaraugus Formation conglomerate divisions (Hopkins, 1992).

The location of the bar-barrier systems was controlled by relative sea level changes brought on by eustatic events, differential sediment supply by rivers along the paleocoast, and by local tectonic controls (Harper and Laughrey, 1987; Hopkins, 1992). Subsurface investigations led to recognition of repeated episodes of maximum coastal sand sequestration, most commonly commenced near times of maximum regression (marine still-stand) and initial sea level-rise; at such times, riverine sediment-supply would have begun to taper off and destructive longshore coastal processes would have accelerated to build the barrier bar systems. Continued transgression would have produced thinner, clean, capping sandstones and conglomerates at the top of thicker sandstone bodies; these would have reflected increased transgression-related sediment-starvation to the coast, leading to partial reworking of the older sands, prior to their complete burial under succeeding, finer grained transgressive facies. A long-recognized, temporally repeating, southwest-to-northeast, linear trend is recognized for the barrier sandstone units across northwestern Pennsylvania, as is particularly displayed for several producing Venango Group sandstone units southeast of Titusville and Oil City (Dickey, 1941; Harper and Laughrey, 1987; Hopkins, 1992; Fig. 8). North of the New York-Pennsylvania state line, the regional trend of the linear sandstone bodies is observed to bend into a more easterly direction (Hopkins, 1992). These narrow, high-energy bar-barrier units are understood to have formed seaward of lower energy, mud-dominated, estuarine, coastal settings generally yielding low diversity marine faunas, which were separated from, and protected from, storms on the open shelf (Dickey et al., 1943; Harper and Laughrey, 1987; Dodge, 1992; Hopkins, 1992).

Quartz-pebble conglomerates in the Venango and Cattaraugus formations are distinctive for an abundance of cloudy, white, oblate-discoidal ("flat") pebbles (Fig. 8). Although ovoidal ("round") grains usually predominate, many of the larger shapes are "flattish" discoidal-to-weakly elongate ("lima bean"-shaped) forms with well-rounded margins unlike the distinctly ovoidal pebble forms characteristic of the fluviatile Lower Pennsylvanian Olean Conglomerate in nearby hilltop exposures. The discoidal pebble shapes (Fig. 8) have traditionally been interpreted as a signature of oscillatory beach abrasion by Miller (1974), Tesmer (1975), and

Smith and Jacobi (2006). However, Craft (2017), discussing discoidal quartz pebbles in the Salamanca Conglomerate Member, argues that the flat pebble shape is structurally dictated by the original width of thin hydrothermal milky quartz veins in tectonic foreland source areas and is not a proxy for beach abrasion. In such case, derived vein clasts, hence, would have retained their narrow/tabular shapes despite extensive abrasion during downstream transport to the Devonian coastline. Factoring in the variable of regional orogenic source provenance, such a model is testable through a systematic search for oblate discoidal quartz pebbles within connective fluvial channels traversing the Catskill Formation terrestrial belt; such pebbles should be absent or only minimally present if the flat shape is truly due to littoral wave abrasion, and pervasively present, if Craft's (2017) model is correct.

Figure 8. Vertical profile view of large, Panama Member conglomeratic sandstone block displaying numerous, edge=on, grain-supported, current oriented discoidal white, milky quartz pebbles typical of this coastal high energy facies. Panama Rocks Park concession, Panama, Chautauqua County, New York. Image credit, Joseph S. Sullivan, used with permission.

Board vehicles and retrace route to intersection of Rock Hill
Road and Route 474 at base of hill.
0.2 105,4 Intersection of Rock Hill Road and Route 474. Turn
right (east) onto Route 474 and proceed into Panama,
NY.
0.1 105.5 Intersection of Route 474 with Panama-Stedman Road
in center of Panama. Turn left (north) onto Panama-
Stedman Road. Continue on Panama-Stedman Road to
intersection with I-86.
5.9 111.4 Turn left (west) onto feeder lane for westbound I-86.
Proceed west on I-86.
0.3 111.7 Feeder lane merges westbound onto I-86.
21.6 133.3 Intersection of I-86 and I-90 near Harborcreek, PA; bear

		right (northeast) onto feeder lane to connect to I-90.
0.6	133.9	Lane merges eastward with I-90. Proceed east toward Dunkirk, NY.
3.5	137.4	Descend Lake Erie escarpment. Excellent view of Lake Erie to the left.
6.2	143.6	I-90 becomes New York State Thruway toll road east of NY/PA state line.
10.1	153.7	I-90 crosses over Chautauqua Creek.
0.3	154.0	Exit for Westfield, NY. Continue east on I-90.
14.7	168.7	I-90 crosses over Candaway Creek.
2.5	171.2	Dunkirk, NY exit (Thruway Exit 59). Bear right as exit lane wraps around to connect with NY Route 60.
0.7	171.9	Red light at Route 60 intersection. Proceed straight (west) onto Millard Fillmore Drive toward Quality Inn destination.
0.2	172.1	Quality Inn on the left. Enter hotel driveway and exit vehicles.

End of Day 2 roadlog.

SDS 2023 - pre-meeting trip - Upper Devonian Marine Strata of the Northern Appalachian Basin

Day 3 – 29 July (Saturday)
0.0 0.0 Depart Quality Inn – Fredonia – 8:00

10.4 10.4 Stop 1 – 104 Main Street (Ehmke Drillers), Silver Creek, New York – Walnut Creek - upper Angola, Pipe Creek, and lower Hanover formations. (Private property, access by permission only.)

15.2 25.6 Stop 2 – 6838 Lake Shore Road, Derby, New York, at mouth of Pike Creek – Moscow, North Evans, Genundewa, West River, Middlesex, Cashaqua formations - Middle-Upper Devonian unconformity, Middlesex event, Rhinestreet event. (Private property, access by permission only.)

3.0 28.6 Stop 3 – (optional) – 1731 South Creek Road, North Evans, New York, at Conrail Bridge – Moscow, North Evans, Genundewa, West River, Middlesex, Cashaqua, Rhinestreet

6.0 34.6 Stop 4 - Sturgeon Pont Marina, 618 Sturgeon Point Road – middle Rhinestreet unconformity and fish bed, *Naplesites* Bed, Belpre Tephra Suite if lake level is low – Lunch

11.2 45.8 Stop 5 - 3785 East Church Street, Eden, New York (gps instructions do not know that the bridge is out, so do not follow the instructions to turn south onto Old East Church Street, go almost to NY 75 and turn south onto Old Mill Run Road). Eighteenmile Creek - upper Angola, Pipe Creek, and lower Hanover formations – Lower Kellwasser Bed. (Private property, access by permission only.)

1.7 47.5 Stop 6 – 9511 New Oregon Road, Eden, New York, on Eighteenmile Creek – upper Hanover and Dunkirk formations – Pt. Gratiot Bed, Upper Kellwasser Bed and Frasnian-Famennian boundary. Last occurrence of dacryoconarids. (Private property, access by permission only.)

3.6 51.1 Stop 7 – East Eden Tavern and Smokehouse, 8163 E. Eden Road, Eden, New York 14057, for dinner

60.9 112 End of field trip – Quality Inn – Geneseo and welcoming party at Livingston Lanes.