74th ANNUAL FIELD CONFERENCE OF PENNSYLVANIA GEOLOGISTS

HISTORY AND GEOLOGY OF THE OIL REGIONS OF NORTHWESTERN PENNSYLVANIA

Hosts: Pennsylvania Geological Survey
Pittsburgh Geological Society

October 8-10
Titusville, Pennsylvania

Guidebook for the
74th ANNUAL FIELD CONFERENCE OF PENNSYLVANIA GEOLOGISTS

HISTORY AND GEOLOGY OF THE OIL REGIONS OF NORTHWESTERN PENNSYLVANIA

Editor:
John A. Harper,
Contributors and field trip leaders:
Gordon C. Baird, Department of Geosciences, S.U.N.Y. Fredonia, Fredonia, NY
Gary M. Fleeger, DCNR, Pennsylvania Geological Survey, Middletown, PA
Jeffry J. Gryta, Department of Geosciences, Edinboro University of Pennsylvania, Edinboro, PA
John A. Harper, DCNR, Pennsylvania Geological Survey, Pittsburgh, PA
Augie Holtz, Pennsylvania Historical and Museum Commission, Titusville, PA
Jocelyn Lewis-Miller, Glacial Sand and Gravel Co., Kittanning, PA
Scott C. McKenzie, Department of Geology, Mercyhurst College, Erie, PA
Jerry Knickerbocker, Pennsylvania Historical and Museum Commission, Titusville, PA
D. Jeffery Over, Department of Geological Sciences, S.U.N.Y. Geneseo, Geneseo, NY
Shirley Pulawski, 293 Burch Avenue, West Seneca, NY
Amy Randolph, DCNR, Bureau of Forestry, Minerals Section, Harrisburg, PA
Joseph S. Sullivan, 293 Burch Avenue, West Seneca, NY

October 8-10, 2009

Hosts: Pennsylvania Geological Survey
Pittsburgh Geological Society

Headquarters: Cross Creek Resort, Titusville, PA

Cover: Faux watercolor painting of the Drake Well, Titusville, PA.
Artwork by John A. Harper (and Corel PhotoPaint!).

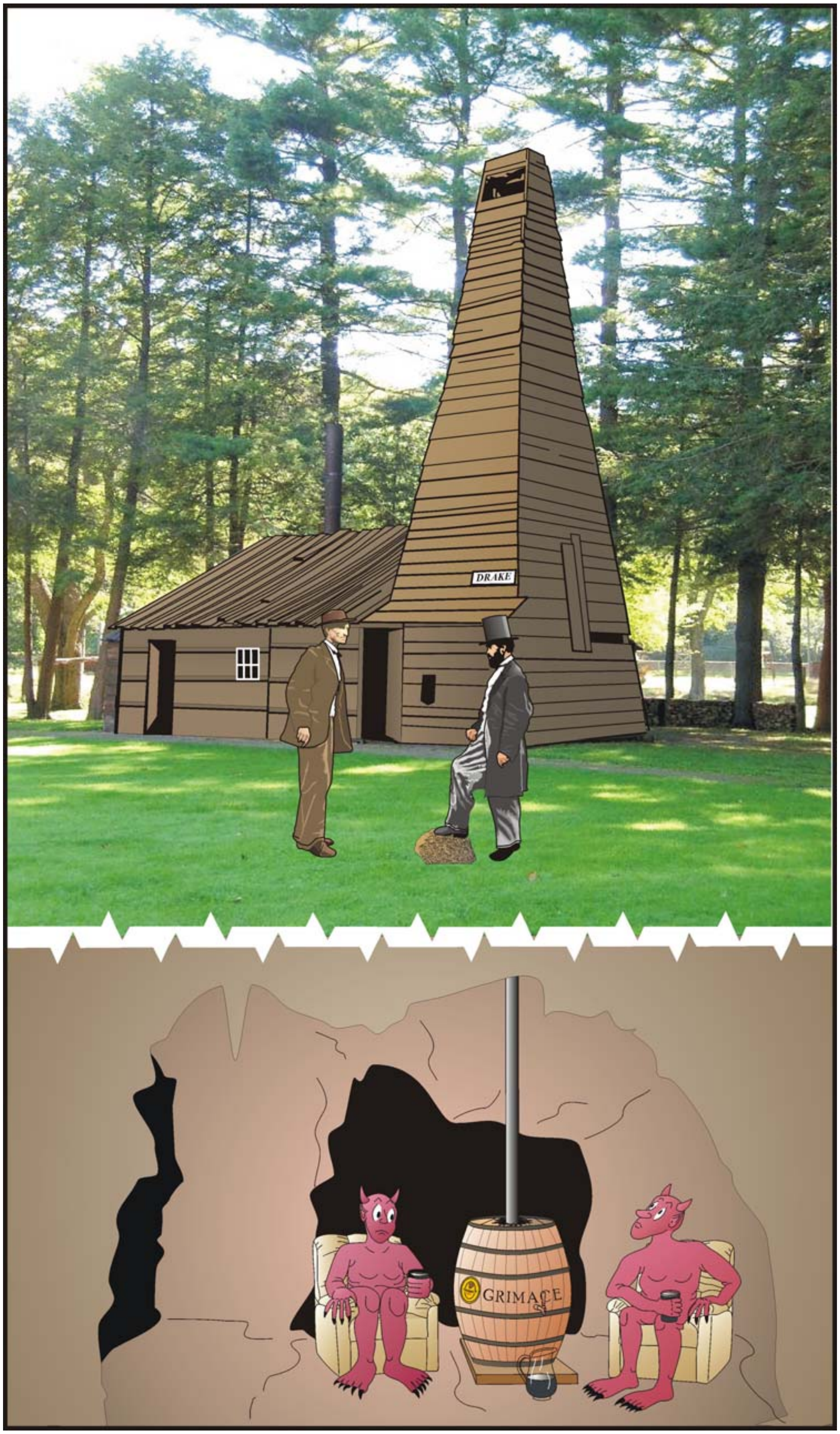
Cartoons: John A. Harper

Guidebooks distributed by: Field Conference of Pennsylvania Geologists, Inc.
3240 Schoolhouse Road
Middletown, PA 17057

TABLE OF CONTENTS

Field Trip:

Frontispiece: 2008 Field Conference of Pennsylvania Geologists group photograph at Devils Den (STOP 10) . Conferees are relaxing on the York Haven Diabase.


DRAKE
GRIMACE

CELEBRATING THE SESQUICENTENNIAL OF OIL

John A. Harper

Welcome to Titusville and the 150th Anniversary Celebration of the drilling of the Drake Well. What, you may ask, was so special about the Drake Well? Most of us learned in school that an unassuming former railroad conductor named Edwin L. Drake drilled the world's first oil well near Titusville, Pennsylvania in 1859. But this statement is only one of many things wrong with the whole story. Drake wasn't the first to discover crude (or "rock") oil, nor was he the first to drill a well and produce oil. He wasn't even the first to sink a well specifically to produce oil. So, if Drake was not the first to do any of these things, what makes him and his well so special?

A historical look at oil shows us that the petroleum industry was already in full swing at least four millennia before Drake was born. The Sumerians, Assyrians, Persians, Egyptians, and other ancients dealt in crude oil and oil products in 4,000 BC, and the business was old even then. There were various uses for oil products: Noah supposedly waterproofed the Ark with asphaltic pitch; pharaohs went into the afterlife wrapped in cloth and pitch; oil made a great grease for chariot axles; the walls of Jericho and Babylon were made of bricks cemented by bituminous mortar (Owen, 1975). In fact, the uses for oil products were so great that even then people were complaining about shortages. The Greeks, Romans, and Carthaginians used crude oil and its products for a variety of purposes, including military ones, such as hurling fireballs at their enemies with catapults, or spreading oil on the sea and setting fire to it to burn enemy boats (Figure 1 top).

By 100 BC, the Chinese were drilling wells, piping oil and gas in bamboo pipelines, and hauling oil around on large junks (Figure 1 bottom) – the oil and gas transportation industry flourished for lighting and heating. In Eurasia, burning gas wells drew crowds that worshipped the awe-inspiring blazes. Some Europeans living in the Dark Ages burned crude oil

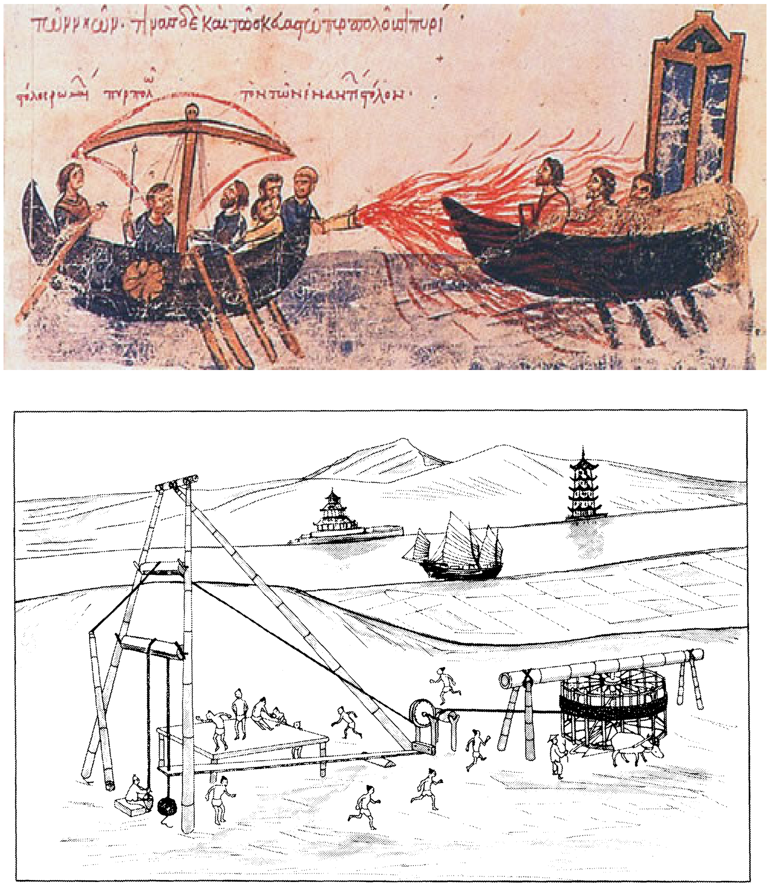


Figure 1. Top—Depiction of Greek Fire in the Madrid Skylitzes manuscript (from Ostrogorsky, 1969). Bottom—The Chinese had a complet petroleum industry over 2,100 years ago. Drawing by Lajos J. Balogh (from Harper, 1998)

Harper, J. A., 2009, *Celebrating the sesquicentennial of oil*, in Harper, J. A., ed., *History and geology of the oil regions of northwestern Pennsylvania*. Guidebook, 74th Annual Field Conference of Pennsylvania Geologist, Titusville, PA. p. 1-4.

rather than vegetable oil for lighting. The Incas were using petroleum products for waterproofing, embalming, and medicine when Europeans “discovered” the New World.

Many Europeans during and after the Renaissance knew the history of oil, and were aware of its occurrence throughout the world. Experimental organic chemistry and technology were taught in universities, leading eventually to the more sophisticated sciences we know today. When the early European settlers arrived in North America, the natives taught them the many uses for using the crude oil seeping from the ground in many places. In remote parts of North America, people used crude oil as a form of energy.

Crude oil had its practical uses; mixed with flour, it made an acceptable axle grease; it was used both internally and externally for medicinal purposes; and it was great for waterproofing canoes and clothing. Still, most early European settlers considered oil a nuisance. It burned with a thick, foul smelling smoke, created fire hazards, contaminated streams, and, in many places spoiled salt production. Because of the high cost of salt, which was as essential as water to our ancestors, enterprising frontier settlers began extracting salt by boiling brine collected from shallow holes dug or drilled into salt water aquifers. By the late 1700s, most of the salt consumed west of the Allegheny Mountains came from evaporated salt water obtained from wells. In fact, a whole industry sprung up around saline aquifers that provided the impetus to improve digging and drilling methods. But settlers quickly learned that salt water often came associated with crude oil and natural gas (Owen, 1975). In 1806, David and Joseph Ruffner drilled a salt well near the Kanawha River in western Virginia (now West Virginia) using a spring pole and lengths of drive pipe, casing and tubing, but the well produced oil instead of salt water. In many places, such as the Tarentum area on the Allegheny River north of Pittsburgh, salt-well drillers would also drill a hole for salt water and encounter a flow of crude oil. After cursing their rotten luck, they would then drill another hole nearby and hope salt water was all they encountered. One of these Tarentum-area salt-well operators, Samuel M. Kier, played a major role in the history of oil and gas by refining illuminating oil from crude oil in a still in Pittsburgh in 1858 (see Stop 6), thus providing a potential market for what was otherwise seen as a nuisance.

Even before Kier, however, Abraham Gesner (Figure 2), the provincial geologist of New Brunswick, Canada experimented with the distillation of fluids from Nova Scotia coal in the 1840s; he patented illuminating gas in 1850 and illuminating oil, or "kerosene", in 1854. James H. Williams, an American by birth, dug and bored wells up to 100 feet deep in the “gum beds” near Enniskillen, Ontario, Canada and began distilling crude oil in 1857. The community grew up around the wells, and Williams sold his distilled oil for lighting purposes. He had, in fact, created an entire integrated petroleum industry before Drake ever left New England. Today, Canada claims to have started the oil industry at least one year before Drake drilled his well.

So, why is Drake credited with founding one of the most important industries in the modern world, and in a technological backwater like Titusville, Pennsylvania at that?

Figure 2. Abraham Gesner, the Canadian geologist who distilled kerosene from coal as early as 1850.

The answers to these questions lie in the vagaries of timing and vision. Owens (1975, p. 1) stated, "The fact that the cumulative experience became productive at this location – and that the ancient tradition did not mature until this time (1859) – constitutes one of the great paradoxes of economic history." By 1859, long history of oil and gas had been mostly forgotten. That, and six additional factors, came together in the late 1850s to ensured Drake's place in history.

1. The world's supply of whale oil, which was the primary source of fuel for lighting in the "civilized world", was being rapidly depleted as a result of overwhaling. The price for whale oil was as high as $100 per barrel in the U.S. in the late 1850. The only other readily available sources of illumination were oil and gas distilled from coal and tallow candles. These also were expensive, and were being produced in limited quantities in America.
2. Through an interesting series of circumstances, a sample of crude oil from a seep on the Hibbard farm property on Oil Creek came to the attention of George A. Bissell, a New York lawyer and promoter, in 1854. Bissell convinced his partner, Jonathan G. Eveleth, to help him organize the Pennsylvania Rock Oil Company. They bought the Hibbard farm with the idea of developing the oil spring and marketing the crude oil.
3. Benjamin Silliman, a prominent chemistry professor at Yale University, had found a way to break crude oil into eight distinct products through distillation, each of which had its own potential value. Paraffin, the last of Silliman's distillation products, is still used for making candles and sealing wax, among other things.
4. Samuel Kier, the salt-well operator from Tarentum, invented and promoted a method of refining crude oil to remove most of the impurities by 1854. He also invented an improved lamp burner that allowed the refined oil, or kerosene, to burn with a bright flame and little or no foul odor. By 1858 he was selling large quantities of his kerosene in New York.
5. A group from New Haven, Connecticut, headed by James M. Townsend, bought stock in the Pennsylvania Rock Oil Company. Because of a resulting lack of harmony between the New York and Connecticut shareholders, Townsend and the New Haven group organized their own company, the Seneca Oil Company, in 1858. They leased the Hibbard farm from the Pennsylvania Rock Oil Company, selected Edwin L. Drake as General Agent of the company, and sent him to Titusville in the spring of 1858 to drill for oil.
6. Drake realized that digging pits in the sand and gravel of Oil Creek Valley, and collecting oil in buckets, was not the answer. He bought a steam engine and other equipment, designed an engine house and derrick, and hired a salt well driller to man the drilling.

As a result, on August 27, 1859, Drake's well (Figure 3) came in at a paltry 69½ feet, but produced approximately 2,000 barrels throughout the remainder of the year.

Many people think Pennsylvania's promoters were just better publicists than those in Germany, Canada, and other places that actually had better claims to the "Guinness World Record" of the first oil well. Today, you will hear that Canada, or West Virginia, or some remote location out in the middle of nowhere deserves tribute for being the first. But the point is not about who discovered oil, who was the first to drill a well and produce oil, nor who was the first to sink a well specifically to produce oil? The point is about who was responsible for founding the industry that includes Exxon Mobil, and British Petroleum, and thousands of other companies, from Fortune 500 bigwigs to mom-and-pop operations that might, in a good year,

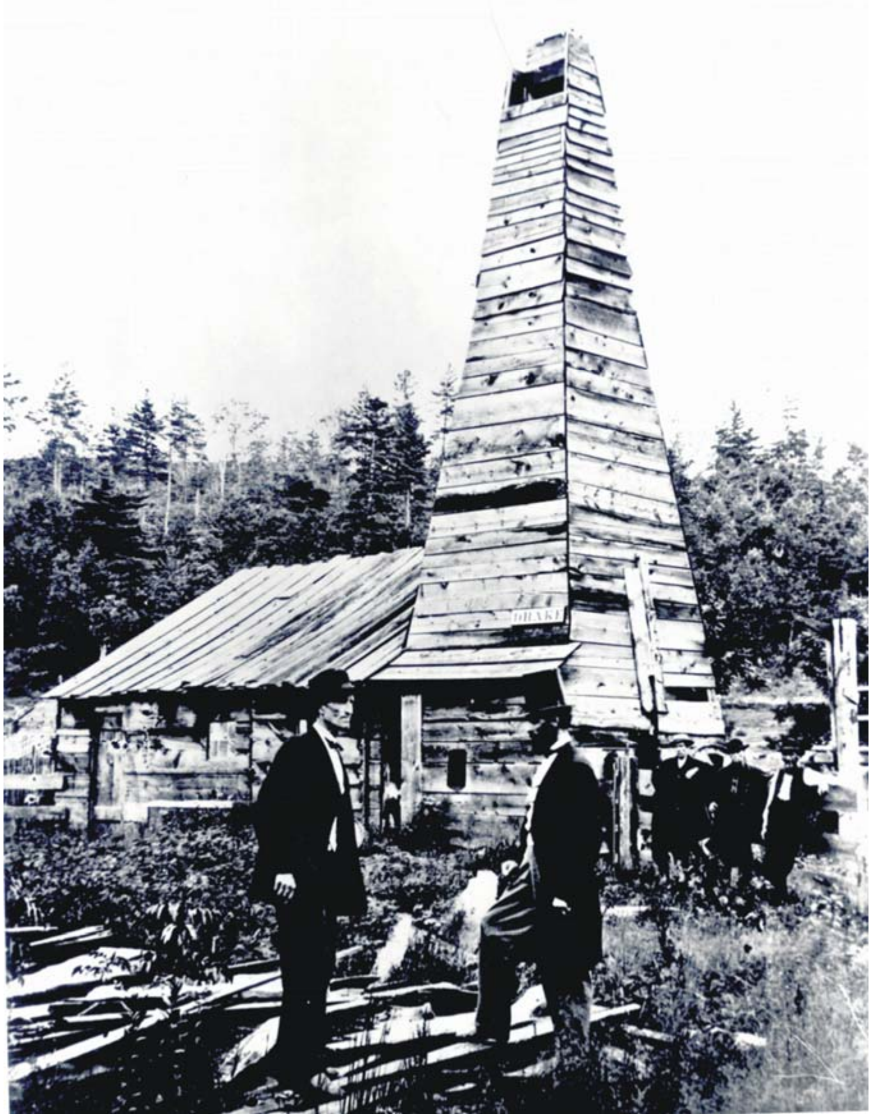


Figure 3. Edwin L. Drake (right) and his good friend, Titusville druggist Peter Wilson, stand before the Drake Well. This famous photograph was believed for many years to have been taken by John Mather in 1861, but is now considered to have been taken in 1866 when Drake returned to Titusville in ill health. The derrrick and engine house are the second on the well. The first burned down on October 6, 1859 when the driller accidentally set fire to the well while using an open lamp to check the level of oil in the vats. Photo courtesy of Drake Well Museum (DW 676).

produce an average of ½ barrel of oil per day.

In 1959, the Pennsylvania Historical and Museum Commission described Drake as the founder of the modern petroleum industry because he provided the one thing that no one else had been able to provide up to that time – he demonstrated that a plentiful and reliable supply of oil could be obtained simply by drilling a hole in the ground. This probably would have happened numerous times at somewhat later dates, just because many events tend to repeat themselves. But it happened at a time when “rock oil” was just becoming an important commodity, supplying illumination during nights and dark days. It also just happened to save the whales from extinction. Time and chemistry went on to find thousands of other uses for oil and its distilled products as well, from transportation fuels to medicines, from plastics to chemicals, and our world was never the same again. Drake wasn’t the first. He was just the beneficiary of excellent timing.

REFERENCES

Harper, J. A., 1998, *Why the Drake Well?* Pennsylvania Geology, v. 29, no. 1, p. 2-4.

Ostrogorski, G., 1969, *History of the Byzantine State*. Rutgers University Press, Rutgers, NJ, 624 p.

Owen, E. W., 1975, *Trek of the oil finders—A history of exploration for petroleum*. American Association of Petroleum Geologists Memoir 6, 1,647 p.

DECONVOLUTING THE END-DEVONIAN STORY IN THE “OIL LANDS REGION” OF NORTHWEST PENNSYLVANIA

Gordon C. Baird, G.C.’ Jeffry J. Gryta, Scott C. McKenzie,
D. Jeffery Over, Shirley Pulawski, Joseph S. Sullivan

Summary

Recent mapping of end-Devonian units in Crawford County and adjacent areas of northwest Pennsylvania has been undertaken to reassess the long-problemmatic stratigraphy of this area and to reexamine the succession of neritic faunas identified by Caster (1934) and Sass (1960). Key objectives of our ongoing work is to sort out the temporal relationships of several key sandstone and siltstone marker units (Corry Formation, Cussewago Sandstone, Bartholomew Bed) through physical correlation in outcrops and through conodont biostratigraphy. Preliminary results presented below are based on surface examination of approximately 100 sites at the time of this writing effort.

Given the developing recognition of global paleoclimatic changes, biotic crises, and pronounced isotopic excursions during the latest Devonian, the Upper Devonian succession of northwest Pennsylvania has acquired a new importance. Additional, potentially correlative, enigmatic events (Spechty Kopf diamictites, “Haystacks Sandstone” in eastern Pennsylvania; red Bedford facies, megadeformed Berea Sandstone in Ohio; granite boulders in Cleveland Shale of Kentucky) demand chronostratigraphic refinement of this interval. In contrast to equivalent deposits in northern Ohio (Cleveland Shale, Bedford Shale, Berea Sandstone), the Crawford County succession may be more continuous and richer in fossils.

Proceeding eastward and southeastward across Crawford County, using regional event-stratigraphic markers and sequence-stratigraphic principles, we have discovered that the key Upper Devonian units of Ohio (Cleveland Member, Bedford Member-equivalent succession), known to be absent near the PA/Ohio state line due to pre-Berea (sub-Murrysville/Cussewago) erosion, progressively reappear eastward below the base-Cussewago disconformity from the French Creek Valley eastward into central Crawford County (Baird and others, 2009a). The lowest of these units, herein designated the West Mead Bed, characterized by dark, bioturbated siltstone and black shale partings, appears to be a condensed Cleveland Shale equivalent division; it is floored by a detrital pyrite/bone lag, probably corresponding to the Skinner Run Bed underlying the Cleveland Member in Ohio. A higher and distinctly thicker, siltstone-dominated succession, roughly corresponding to the “Drake Well Formation” *sensu* Harper (1998) emerges eastward progressively to the Oil Creek Valley. A discontinuity at its base is believed to correlate regionally to a marker unit (“*Syringothyris* Bed”) in the Oil Creek Valley-Warren area, which Caster (1934) equated to the base of the Bedford succession in Ohio. These interpretations await confirmation pending further analysis of conodonts recently obtained from the base-West Mead and base-”Drake Well” lag deposits (see text). The “Drake Well Formation” is particularly notable for the occurrence of articulated echinoids at numerous localities.

Another discovery is the presence of a regional discontinuity at the base of the Corry

Baird, G. C., Gryta, J. J., McKenzie, S. C., Over, D. J., Pulawski, Shirley, and Sullivan, J. S., 2009, *Deconvoluting the end-Devonian story in the “oil lands region” of northwest Pennsylvania*, in Harper, J. A., ed., *History and geology of the oil regions of northwestern Pennsylvania*. Guidebook, 74th Annual Field Conference of Pennsylvania Geologist, Titusville, PA. p. 5-31.

Formation which may be regionally angular. If strata do progressively appear southward below this unconformity down the Oil Creek Valley, this increases the probability of locating the signature of the end-Devonian (Hangenberg) paleoclimatic crisis and associated mass-extinction. Ongoing work is devoted to deconvoluting the temporal relationships of several key sandstone units in the “snagbox,” an area of persistently problematic correlation south of Union City.

Introduction

Herein, we present preliminary results of a two year initiative to characterize the end-Devonian chronostratigraphic succession in the Meadville, Titusville, and Oil City areas in northwest Pennsylvania. Our contribution follows many others in a series of stratigraphic papers attempting to establish a stable chronostratigraphic story through this interval. Our specific methodological approaches, aside from conventional matching of similar beds and unit-successions, include: making greater use of available fossils, particularly conodonts, employing a sequence stratigraphic approach through the recognition of, and tracing of, regional discontinuity surfaces, and through the use of a variety of distinctive, thin event-beds. We have employed a brute force approach in walking out and writing up all available sections in critical areas. In particular, the present authors seek to locate and characterize old outcrops mentioned in earlier reports, but never adequately described, as well as locate and describe new ones. To date, a total of 100 places (actual sections as well as sites displaying no rock) have been seen. Future compilation and publication of this information should provide a stable database, focusing our efforts and those of others. The present report summarizes initial results of our ongoing project.

Geologic Setting

During the latest Devonian (Upper Famennian Stage) into the earliest Mississippian, the region that is now northwest Pennsylvania was situated near the southeastern margin of the “old red continent” (Euramerica) between 30^{o} and 45^{o} south of the paleoequator, based on more recent paleomagnetic estimates (Miller and Kent, 1988; Van der Voo, 1988). This was a time predominantly characterized by warm, tropical to sub-tropical climatic conditions (Frakes and others,1992). The southeast edge of Laurentia experienced a series of tectonic collision events, beginning in the latest Silurian and continuing throughout the Devonian which are collectively referred to as the Acadian Orogeny. These disturbances, involving transpressive collision of the Avalon and Carolina terranes, came as a series of overthrust pulses (tectophases), starting in the maritime region of eastern Canada and continuing southward into the central-southern Appalachian region (Ettensohn and others, 2009). These collisional tectophases, in turn, produced characteristic sedimentary depophases recording initial thrust-loading of the craton margin followed by foreland basin filling as sediments, derived from the erosion of collisional mountain belts, filled in the structural basins. This series of depophase events generated a thick, detrital wedge long known as the Catskill Delta complex. Accumulation of stratigraphic units discussed in this report was timed with the latest part of Ettensohn’s “tectophase III and “tectophase IV” (Ettensohn and others, 2009). This last tectophase (Ettensohn’s “Neo Acadian event”) will be discussed further below.

Stratigraphic units comprising the latest Devonian succession in Erie, Crawford, and western Warren counties are dominantly marine shelf deposits which are predominantly characterized by numerous lenticular to tabular siltstone and fine sandstone beds with thin, intervening shale partings. Hummocky cross-stratification, ripples and megaripples on bedding surfaces, erosional scour surfaces (sole marks) along bases of numerous beds, and concentrations of disarticulated brachiopod, echinoderm, and bivalve debris serve as testament to the passage of numerous storms across the upper prodelta ramp. Storm (tempestite) deposits will be seen to particular advantage in the Chadakoin section (STOP 10), at Cora Clark Park (STOP 9), and in the "Drake Well Formation" "type section" (STOP 6).

The paleosetting of the northwest Pennsylvania region is that of an inland sea bordering an irregular, prograding lowland coast. The inferred regional alignment of the paleocoastal zone has been reconstructed by Dodge (1992) and Hopkins (1992) as generally trending northeast-to-southwest as exemplified by long-axis orientation of subsurface, delta front sandstone bodies in the Chadakoin and Venango successions under Warren County and adjacent areas. One of these sandstone units (Panama Sandstone, = "Venango Third sand") will be seen at the Union City Dam spillway at French Creek (see STOP 11).

Proceeding to the northwest from this belt was a broad, gently-sloping shelf ramp characterized by flaggy to slabby siltstone and fine sandstone layers or lentils with associated coquinitic fossil debris. These tempestites both thin and become finer grained downslope as the substrate deepens from the influence of pervasive fair-weather-wave-base influence to the domain of infrequent deep-storm influence. Proceeding west into Ohio, shelf deposits of the Chadakoin-through-Riceville succession pass downslope into shale-dominated,,basin-margin ramp facies (Chagrin Member of the Ohio Shale) yielding sparse body fossils, abundant trace fossils, and a few thin siltstone layers.

Global End-Devonian Events

As noted by numerous authors, the Middle and Late Devonian was characterized by a series of biotic crises which resulted in widespread extinctions events and contributed to the breakdown of global biotic provinciality. The Frasnian-Famennian ("FF") extinction was the greatest of these events, but the late Middle Givetian Taghanic bioevent and the latest Famennian Hangenberg extinction and succeeding "icehouse Earth" event are increasingly seen as major setbacks to the biosphere. The temporal "window" or time-slice of the Devonian, defined by conodont biostratigraphy that we will emphasize in this report, extends from the base of the *expansa* zone (approximate position of the Cleveland Member of the Ohio section and equivalent beds in Crawford County) up into the earliest Mississippian *sulcata* zone (Sunbury Shale in Ohio; Bartholomew Bed in Crawford County). This requires a brief review of global end-Devonian events as presently understood (see Figure 1).

A global episode of anoxia is recorded by the "Dasberg Event" (Figure 1) which by differing accounts falls within the lower or medial *expansa* conodont zone of the Late Famennian stage (Becker and Hartenfels, 2008). This event also coincides with the establishment of a new, cosmopolitan flora suggested by global abundance of the miospore *Retispora lepidophyta* by Middle *expansa* time (Streel, 2008).As best estimated presently, the black Cleveland Shale of the Ohio section is believed to be the regional expression of this event based tentatively on conodont biostratigraphy (Zagger, 1993; Over and others, 2009).

The later, and more intense, end-Devonian Hangenberg event is understood to be a two-part, paleoclimatic crisis (Figure 1). It is believed to record an initial episode of global heating,

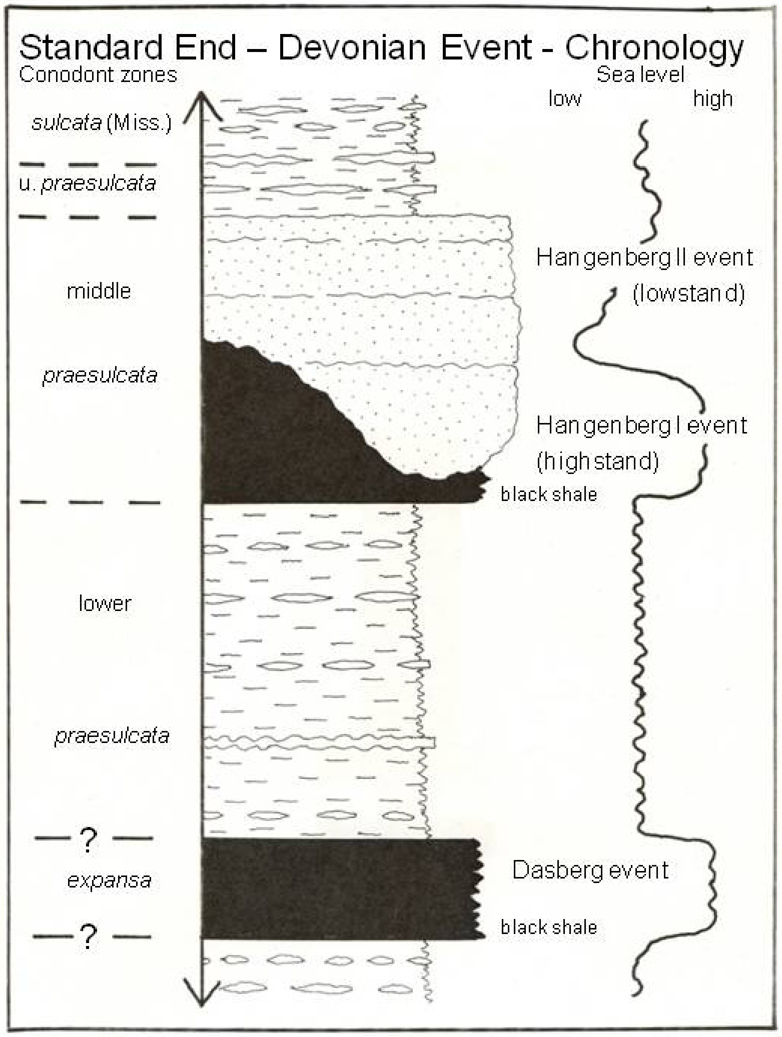


Figure 1. Generalized end-Devonian chronology in inferred eustatic and global bioevent context. Not that the Cleveland Shale Shale may be the regional expression of the "Dasberg event" and that the base-Berea/Cussewago disconformity may be the signature of the end-Devonian glacially-driven eustatic drawdown event (see: Brezinski and others, 2008; Ettensohn and others, 2009).

sea-level highstand, and biotic mass-extinction, closely associated with massive global burial of organic carbon in black, organic mud deposits, recorded by a strong positive C^{13} excursion (Algeo and others, 1995, 1998; Kaiser and others, 2006). Subsequent consequent loss of atmospheric CO_2, due to this carbon sequestration, then led to short-term, intense global cooling and development of glaciation on Gondwana with a consequent drop in sea-level (Kaiser and others, 2006). This global "cold event" is recorded by extensive diamictite development on Gondwana at this time (= "Hangenberg glaciation event;" see: Caputo, 1985; Frakes and others, 1992; Crowell, 1999). Similarly, a significant sea level drop at this time is inferred for the Appalachian Basin region (Pashin and Ettensohn, 1995; Sandberg and others, 2002; Brezinski and others, 2008; Ettensohn and others, 2009). The two Hangenberg events, recorded in Europe, North Africa, and elsewhere, are timed with the Middle *Siphonodella praesulcata* conodont zone and with rapid floral changes associated with the LE-LN miospore biozones (Streel, 2008). Hence, a key objective in current investigations is to find these biomarkers and evidence of these global crises in northern Appalachian Basin sections.

During the very brief, latest division of the Devonian (upper *praesulcata* zone), the "icehouse" event ended, eustatic transgression ensued, and the global climate stabilized (Figure 1). Although the full extent of this extinction event is yet to be fully realized, its effect on marine vertebrates was evidently catastrophic; a 70% drop in taxonomic diversity of lobed finned fish and total extinction of placoderms has been recently documented across the Hangenberg bioevent interval (Sallen, 2009).

Regional End-Devonian Discoveries

Recent discoveries of unusual and/or enigmatic end-Devonian features by others in the Appalachian Basin succession underscores the importance of refining end-Devonian stratigraphy in northwest Pennsylvania. The most significant of these is recent substantial confirmation of glacial origin for the Spechty Kopf diamictites in eastern Pennsylvania and Maryland (Cecil and others, 2004; Brezinski and others, 2008). The possibility that these mud-supported, cobble-rich deposits were glacier-related goes back to Sevon, 1973, who presented the possibility that they represented mudflow deposits of glacial origin. Subsequent recognition of striations on the larger clasts, the presence of metamorphic and igneous clasts within diamictites, evidence of channelized diamictite occurrence in evident paleovalleys, and association of diamictites with dropstone-bearing laminites, collectively supports a glacial origin for these deposits (Brezinski and others, 2008). Moreover, Ettensohn and others(2009) report the occurrence of an *in situ* granite boulder in the topmost part of the Cleveland shale in the Morehead area of eastern Kentucky. This boulder, witnessed by one of us (Baird) this past June, is believed to weigh approximately three tons! It is quite credibly interpreted as an iceberg -rafted dropstone with an origin, based on petrographic analysis, in altered Grenville basement from one of the western New England massifs (Ettensohn and others, 2009). Dennis (2007) and Ettensohn and others (2009) argue that oblique convergence of the Carolina superterrane into the southern part of the New York Promontory, near the end of the Devonian, would have produced a pulse of mountain building ("Neo-Acadian collision event"); this uplift, coupled with the brief, rapid "icehouse" conditions, noted above, could have permitted development of tidewater glaciers bordering this orogen according to Ettensohn and others (2009). Moreover, thrust-loading, associated with this collision, could explain a major eastward marine transgressive pulse at this time which would have allowed for the release of icebergs from coastal glaciers (Ettensohn and others, 2009).

Other enigmatic depositional features, correlative with-, or correlative in part, to the northwest Pennsylvania end-Devonian succession, include the "Haystacks" Sandstone within the Huntley Mountain Formation of northeast Pennsylvania (see: Woodrow, 2006; Gillmeister and Hill, 2006), the "red bed" phase of the Bedford Shale in northern Ohio, and widespread large-scale deformation of the Bedford-Berea succession in Ohio (Pashin and Ettensohn, 1995). Clearly, the Devonian did not go out quietly; a goal of the present initiative is to clearly identify the key eustatic, biotic, and paleoclimatic signals from these events in the local stratigraphic sections.

End-Devonian Succession

Overview

In sections below, we will first review key units in the standard northeast Ohio succession in ascending order for comparison to northwest Pennsylvania. We will then review key contributions of earlier workers in the northwest Pennsylvania region. Finally, we will present our new findings.

Ohio End-Devonian Succession

Chagrin Shale: The Late Famennian interval in northeast Ohio is predominantly represented by the Chagrin Shale of the Ohio Shale succession. It includes a very thick deposit of green-grey to dark grey shale with a few intervals of flaggy siltstone beds and lentils particularly in sections in the Grand River Valley in northeast Ohio. Although trace fossils are abundant in the Chagrin, body fossils such as brachiopods and bivalves occur only sparsely. Chagrin exposures are typified by the monotonous creek bank exposures visible along I-90 between the PA/NY line and Cleveland. The topmost part of the Chagrin grades eastward (upslope) into silty, tempestitic shelf facies of the Venango group and overlying Riceville Formation in Erie and Crawford Counties in Pennsylvania.

Cleveland Shale: The Cleveland Shale Member of the Ohio Shale is largely a fissile black shale unit in northern Ohio which is particularly renoun for its fish fauna of chondrichthyians and placoderms (Newberry, 1889; Carr and Jackson, 2008). The Cleveland Shale is highly variable in thickness across the Cleveland metropolitan area, ranging in thickness from 2.1 meters (7 feet) south of Cleveland near Peninsula, Ohio, to nearly 30 meters (90+ feet) along the Rocky River in west Cleveland (Mausser, 1982; Baird and others, 2009b). Where it is thick, as at Rocky River and Big Creek in Cleveland, it displays a distinctive, rhythmic, “ribbed” appearance in stream bank sections. This unit has been traced eastward to the west side of the Grand River Valley, but is presently unknown in sections further east according to published reports; it is understood to be overstepped by erosion beneath the Cussewago Sandstone and has not been identified in Pennsylvania sections (Caster, 1934; Pepper and others, 1954; Pashin and Ettensohn, 1995). Standing literature tentatively places the Cleveland Member in the middle part of the *expansa* conodont zone (Zagger, 1993). As such, it may be the regional signature of the global Dasberg event.

The base of the Cleveland Shale is understood to be marked by a regional erosion surface from Cleveland southward up the Cuyahoga Valley and eastward to the Grand River Valley (Baird and others, 2009b). A distinctive lag deposit of detrital pyrite, permineralized wood debris, and fish bones, known as the Skinner’s Run Bed (Hlavin, 1976; Hannibal and Feldmann, 1983) occurs along the Chagrin-Cleveland contact wherever this discontinuity is developed. Unusual conditions of low oxygenation, erosive bottom current activity, and transgression-related, sediment-starvation, are believed to explain the concentration of detrital pyrite on the open sea floor at such times (Baird and Brett, 1991; Baird and others, 2009b).

Bedford Shale: This internally variable unit usually rests abruptly on the Cleveland Member in northern Ohio sections. It is predominantly a grey shale unit in northeast Ohio sections, but the medial and upper parts of this unit grade westward into distinctly pink and red shale facies west of the Cuyahoga River. This “red bed” phase gave rise to the concept of the “Red Bedford delta” of Pepper and others (1954). This red shale facies has since been reinterpreted as an offshore, not terrestrial, deposit (Pashin and Ettensohn, 1995). In some Cuyahoga Valley sections, the base of the Bedford is marked by a concentration of brachiopod shells which directly overlies Cleveland black shale. However, much of the Bedford succession is very sparse in fossil content. Locally, a succession of massive siltstone beds (Euclid Sandstone) is developed in the lower part of the Bedford on the east side of Cleveland. Extensive soft-sediment deformation, red shale development, and the localized massive siltstone deposits suggest that this unit is not well understood and that it may record several different regional events. As presently understood, the Bedford extends eastward to the west side of the Grand River Valley. East of the Grand River Valley it is overstepped by the younger Cussewago Sandstone (Pepper and others, 1954; Pashin and Ettensohn, 1995).

Berea Sandstone: This unit, known as Ohio's "State Rock," is a widespread division which extends from eastern Kentucky, across most of Ohio, into Crawford County, Pennsylvania (Pepper and others, 1954; Pashin and Ettensohn, 1995). Although the Berea displays an approximate thickness range from 10 meters (33 feet) to 75 meters (80 feet) across northeast Ohio, it can locally reach thicknesses of 80+ meters (260+ feet) as observed in dimension stone quarries west of Cleveland. The Berea is texturally a siltstone or fine sandstone which is distinctly quartzose. Beyond these generalities, the Berea is extremely complex internally; large channels, cross-bed foresets, large-scale ball-and-pillow structures, and localized diaper-like structures are present at many localities. West of Cleveland, huge soft-sediment displacements are inferred around several of the deep dimension stone quarries (see Pashin and Ettensohn, 1995).

The Bedford-Berea succession is interpreted to be a deltaic basin-fill fed from fluvial feeder channels connecting eastward into Pennsylvania and West Virginia (Pashin and Ettenson, 1995). The northern of these two channels (Murrysville-Cussewago Sandstone) is mostly developed in the subsurface of western Pennsylvania. However, pebbly sand deposits of this channelized phase are poorly exposed in a few creek beds near the Ohio/Pennsylvania state line. Substantial erosion beneath the Cussewago-Berea succession east of the Grand River Valley has removed the Cleveland and Bedford shales in this region (Pepper and others, 1954; Pashin and Ettensohn, 1995).

Sunbury Shale: Above the Berea is a thin, hard, fissile, 3—6.5 meter (10—20 foot)-thick, black shale unit which is traceable from eastern Kentucky into northeastern Ohio. Its base marks the Devonian-Mississippian boundary as presently understood. The Sunbury is succeeded by a softer, dark grey, fissile shale division comprising the Orangeville Shale of the Cuyahoga Formation. As understood presently, the Sunbury black shale does not extend as far east as northwest Pennsylvania, but the Orangeville is known to extend eastward past the Oil Creek meridian in Crawford and Venango counties (White, 1881; Caster, 1934; Pepper and others, 1954; Pashin and Ettensohn, 1995).

Previous Work in Northwest Pennsylvania

In 1881, I.C. White published a survey of the Geology of Erie and Crawford counties in Pennsylvania. Through this work he established the following unit-succession in ascending order: Venango Formation (equivalent to Chagrin Shale in Ohio), Riceville Member ("straddling the Devonian-Carboniferous boundary"), Cussewago Sandstone ("probably equivalent to lower part of Berea Sandstone in Ohio"), Cussewago Shale ("probably equivalent to some part of Berea Sandstone in Ohio"), Corry Sandstone ("presumably corresponding to upper part of Berea Sandstone in Ohio"), and Orangeville Shale corresponding to the Sunbury-Orangeville succession in Ohio (White, 1881). One major marker unit recognized in Crawford County is the Cussewago Sandstone, a coarse, sometimes pebbly unit which weathers to a punky, unconsolidated state in most outcrops. It varies considerably in thickness, displays much internal variability, and displays a sharp erosional base. Another key marker unit is the Corry Sandstone which is actually a massive, hard, quartzose siltstone unit. Unlike the Cussewago, it displays a more regular internal stratigraphy and more uniform thickness regionally. Although earlier workers extended it westward across Crawford County, later work shows that this unit is restricted to the Oil Creek Valley and areas east of there (see below). The Corry is distinctive for a diverse marine fauna in its lower part which has been studied extensively (Caster, 1934; Sass, 1960).

In 1925, George Chadwick subdivided the Venango into a number of named subdivisions, but did not formally establish type sections for these units. He also renamed White's "Cussewago Shale," between the Cussewago Sandstone and the Corry as the Hayfield Shale for exposures in Hayfield Township west of Meadville, PA (Chadwick, 1925).

Subsequently, Kenneth Caster (1934), on both physical and paleontological evidence, subdivided White's "Riceville" entity into two divisions; a lower, restricted Riceville interval which was Devonian in age and correlative with the topmost Chagrin Shale, and an upper division ("Kushequa Member") which he believed to mark the base of the Carboniferous succession (Figure 2). This Kushequa division correlated eastward to the lower part of the Knapp Formation in the Warren-Bradford area and westward to the Bedford Shale of Ohio (Caster, 1934). A fossiliferous marker unit ("*Syringothyris* Bed" or "Marvin Creek Bed") marked by abundant spirifers, phosphatic pebbles and fish bones was recognized by Caster as flooring the Kushequa Member at White's old Riceville type section near Riceville in central Crawford County. This marked an unconformity where beds equivalent to the Cleveland Shale

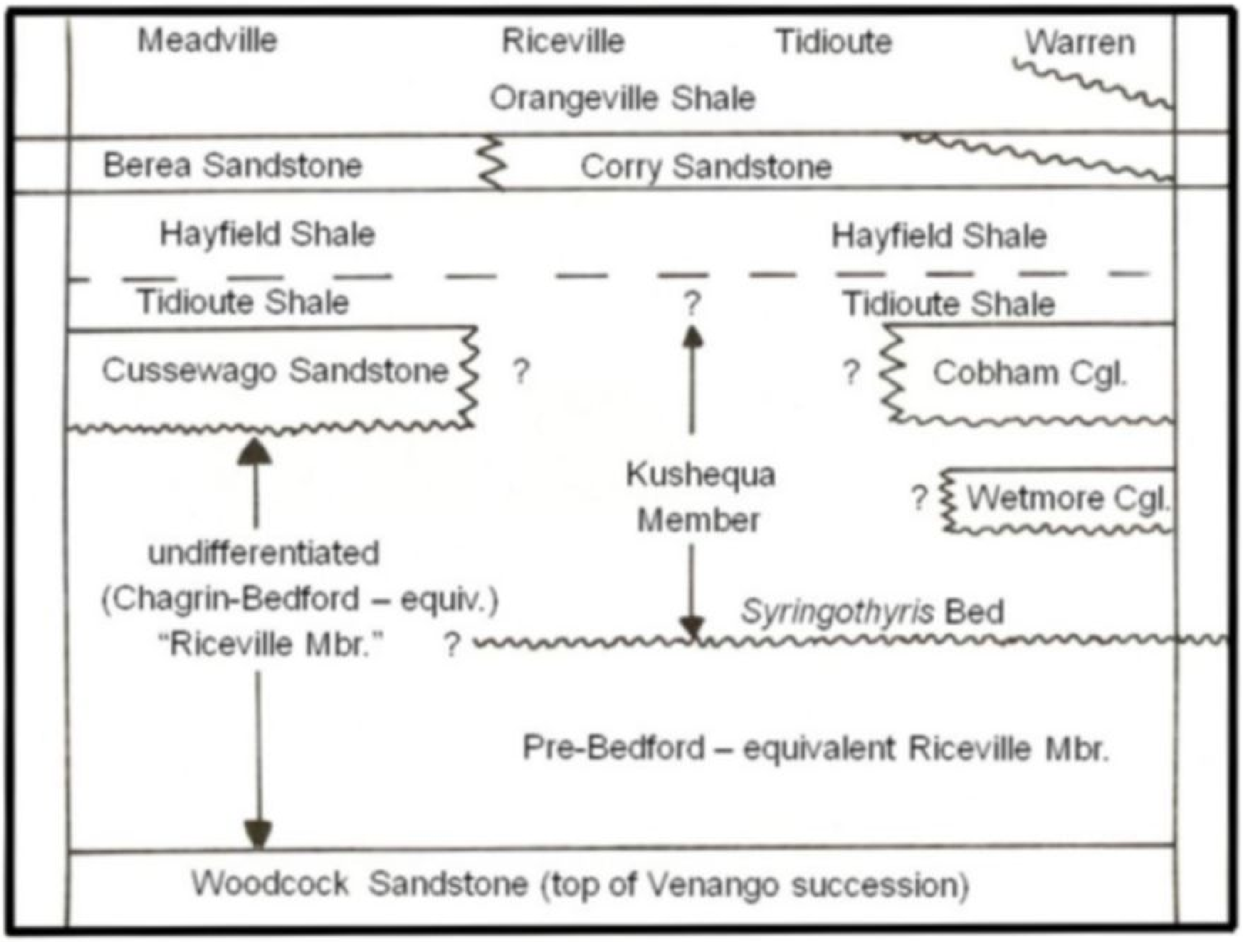


Figure 2. Time-rock reconstruction showing end-Devonian unit relationships as envisioned by Kenneth Caster in 1934. Note position of his Kushequa Member which is an approximate forerunner of the term Drake Well Formation used in the present paper.

of Ohio were absent due to erosion. He introduced a new designation “Tidioute Shale” as a distinctive marker unit above the siltier Kushequa interval in the Tidioute-Oil Creek Valley region. Caster (1934) tentatively linked the Cussewago Sandstone to the lower part of the Berea Sandstone of Ohio and retained Chadwick’s name Hayfield Shale (Figure 2). However, he extended the Hayfield Shale eastward between the underlying Tidioute Shale and the overlying Corry Sandstone eastward into McKean County (Figure 2).

Although Caster (1934) completed the most comprehensive physical and faunal description of unit relationships of anyone working in the study area, he left few actual outcrop descriptions in his report; these include: the type Kushequa section (brick clay quarries) at Gaffney, McKean County (now slumped and covered), the type Tidioute Shale section by Dennis Run along the long, steep PA Route 127 grade southwest of Tidioute, Warren County (now slumped in and covered), and White’s (1881) type Riceville stream section southwest of Riceville, Crawford County (still exposed and accessible).

Pepper and others (1954) published an extensive stratigraphic-paleoenvironmental synthesis of the Bedford-Berea succession in Ohio, Kentucky, and western Pennsylvania in a well known U.S. Geological Survey Professional Paper. They envisioned the major, laterally separated sandstone units in Crawford County as the record of several deltas converging into that area from various sources. Given that they thought that the Cussewago Sandstone correlated westward to the post-Cleveland-sub-Bedford unconformity in Ohio, they renamed the Hayfield Shale as “Bedford Shale” because it overlies the Cussewago. They noted that both their Bedford division and the overlying thin Berea Sandstone in western Crawford County thins dramatically near the Meadville meridian, grading into an undefined muddle of thin sandstones and shales below the regionally persistant, base-Mississippian Bartholomew Bed. Pepper and others (1954) designed this thinned, problematic interval the Shellhammer Hollow Formation. Even more probemmatic was evident eastward disappearance of the Cussewago Sandstone near the headwaters of Oil Creek very near the northwestward limit of the distribution of typical Corry Sandstone near Riceville, PA. Nothing resembling soft, friable, Cussewago “grit” was to be seen in the Oil Creek Valley, Tidioute, or Tionesta region. Pepper and others (1954) simply defined the eastern limit of the Cussewago on their east-west stratigraphic transect with a question mark placed near Riceville. Meanwhile, various other workers (Dickey 1941; Sherrill and Matteson, 1941; Dickey and others, 1943) connected the Cussewago eastward into a much thicker succession of fossiliferous sandstone, siltstone and shale beds in Oil Creek Valley-, and Tidioute-Tionesta area, sections, which corresponded largely to Caster’s (1934) former Kushequa Member (see below).

Earlier workers had extended the name “Corry” westward from its area of typical occurrence to the Meadville-Cussewago area but were never very confident in doing so. In the Meadville area, the sandstone called “Corry” generally lacks fossils, is generally thinner-bedded, and is highly variable in thickness. Moreover, Pepper and others (1954) interpreted this western silty-sandy unit as passing eastward to shale within their Shellhammer Hollow Formation above the Cussewago Sandstone. However, they did infer temporal equivalency of the western sandstone (which they termed “Berea”) with the Corry Formation except that the two units were laterally separated by a thin belt of shale.

Pepper and others (1954) recognized the regional importance of the thin Bartholomew Bed as a correlation marker. The Bartholomew Bed is typically a compact, 0.25—0.7 meter (0.7—2.0 foot)-thick ledge of dark, biotubated siltstone which underlies dark-grey, fissile shale of the Orangeville Shale and which marks the base of the Mississippian System as presently understood. The Bartholomew Bed is widely distributed from central Crawford County westward into Ohio. Additionally, Pepper and others (1954) described a new unit, the "Hungry Run Member" as a localized entity with a type section in a quarry southeast of Union City in southeasternmost Erie County. The type section is a 3.6 meter (12 foot)-thick coarse sandstone with high-angle cross-bedding and a quartz pebble bed at its top. Other occurrences of this unit at Riceville and Little Cooley were distinctly thinner, finer grained, and more "marginal" in character. Pepper and others (1954) tentatively correlated the thin phases of the Hungry Run to the still thinner Bartholomew Bed in sections further to the west.

Pepper and others (1954) did not produce an evident published log of locality descriptions in their monograph, but they did plot the positions of their numbered sections on base maps. One of us (Baird) is locating these localities for description in the ongoing mapping project.

Schiner and Kummel (1972), working from outcrops and subsurface log, began the characterization of the subsurface phase of the Cussewago Sandstone ("Murrysville Delta") centered to the south of the study area. In addition, they attempted to plot the "pinch-out" limits of various sandstone bodies" extending into Crawford County from various directions. In so doing, they recognized an additional coarse unit (their "unnamed sandstone") beneath the Corry Formation in the southern part of the Oil Creek Valley and in subsurface areas further south. The "unnamed sandstone" can be easily seen in the numerous road cut sections around Rouseville and Oil City, but it is absent in sections from Petroleum Centre northward up the Oil Creek Valley.

Most published accounts up to the 1980s placed the Devonian-Carboniferous boundary at lower horizons reflecting earlier biozonal understandings (Caster, 1934; Pepper and others, 1954; deWitt, 1970; Berg and others, 1980; Gutschick, 1987). Upward realignment of the base-Mississippian boundary to the base of the *Siphonodella sulcata* zone of the base-Mississippian global standard has moved the base of the Carboniferous succession to the base of the Sunbury Shale in Ohio and the base of the Bartholomew Bed in Crawford County, Pennsylvania (Gutschick and Sandberg, 1991).

Pashin and Ettenson (1995) published a major stratigraphic-paleoenvironmental synthesis of the Bedford-Berea successions in Ohio, Kentucky, West Virginia, and westernmost Pennsylvania. Although the eastern limit of their work was at the Meadville meridian, they made important subsurface interpretations of the Murrysville/Cussewago channel complex, and completed both surface and subsurface analyses of the poorly exposed end-Devonian succession under northeast Ohio. They linked the Cussewago Sandstone of the visible type Cussewago succession in western Crawford County to the lower part of the visible Berea Sandstone succession west of the Grand River. This, however, unconformably overlies a discrete lower, channelized phase of coarse pebbly sandstone (Murrysville Sandstone) which occurs in a narrow belt traversed near the OH/PA state line (Pashin and Ettensohn, 1995). The post-Cussewago shale unit ("Hayfield Shale" of Chadwick, 1925) was correlated to the medial and upper-middle parts of the Ohio Berea section, and the thin Berea Sandstone of Pepper and others (1954) was matched to the top of the Berea in Ohio. However, for reasons not explained, Pashin and Ettensohn (1995) retained the name "Bedford" for the post-Cussewago shale even though that unit is shown to be two sedimentary packages younger than the Bedford Shale of Ohio in their figures.

Harper (1998) building on the subsurface data of Schiner and Kimmel (1972) and Dodge (1992), informally erected a new unit called the "Drake Well Formation." As background for this, we must go back to the work of Dickey (1941), Sherrill and Matteson (1941), and Dickey and others (1943) who, for various reasons, concluded that 80 feet of strata below the Corry in the Oil Creek Valley belonged in the Cussewago Sandstone and that the Cussewago included all strata between the Riceville and the Corry, in spite of what Caster (1934) had earlier concluded. This revision was then "rolled over" into later papers and guidebook articles well into the late 1980s (see Lytle, 1959; Ward and others, 1976; Fox, 1989; Burgchardt and Fox, 1989). Dodge (1992) studying data from southwestern Warren County, realized that a significant thickness of strata, termed "Cussewago" by these various authors, was actually an entity older than Cussewago, younger than Riceville, and correlative with the lower part of the Knapp succession of the Warren area. Harper (1998) recognized the same log and lithic signatures in the Oil Creek Valley and came to a similar conclusion, in essence returning tentatively to Caster's concept of a "lower Knapp-equivalent" succession, but under the new name "Drake Well Formation."

We will examine the "Drake Well Formation" "type section" in the small railroad exposure across from the Drake Well Museum and original Drake Well location south of Titusville (STOP 6). The "Drake Well Formation," as defined, includes strata between the Riceville Formation below and the Tidioute Shale above. As background, it turned out that Caster's (1934) type "Kushequa" section was problematic and could not be adequately matched to strata termed "Kushequa" in the Warren-Riceville area (Fettke, 1938). Hence, that term was dropped, and Caster's old "Kushequa" interval was simply referred to as "unnamed member" on the Berg and others (1980) Pennsylvania geologic map. By renaming this interval and reviving the old Caster name "Tidioute", Harper (1998) reaffirms the importance of a post-Riceville, lower Knapp division independent of-, or distinct from, "Cussewago." As defined by Harper (1998), this unit comprises about 19 meters (60 feet) in the vicinity of Titusville; it includes bundles of siltstone alternating with shale-dominated intervals. Because it is based partly on subsurface log information, its boundaries are still somewhat uncertain with respect to defined units in outcrop. The upper boundary with the Tidioute Shale may be easier to place than the lower boundary with the Riceville Formation (see discussion below).

Mapping Objectives and Progress

Our preliminary observations, presented below, are based on observations at more than 100 localities (stream, road cut, and quarry sections) in Crawford County and adjacent areas, completed over the past 18 months. This mapping project, currently in its second year, is intended to be a multi-year effort aimed at building an information database of surface outcrop information for the end-Devonian-into-basal Mississippian succession in northeastern Ohio and northwest Pennsylvania. In particular, we aim to locate and redescribe sections discussed by earlier workers as well as new sections not yet examined professionally. Eventually, this database will significantly complement subsurface log information for the region. Key initial observations are presented below.

Preliminary Discoveries

Eastward reemergence of Ohio divisions in Crawford County: The most important discovery linked to the current initiative is apparent evidence for eastward reappearance of key Ohio divisions (Cleveland Member-, Bedford Shale-stratigraphic equivalent deposits) beneath the sub-Cussewago regional disconformity (Figures 3A and B); Baird and others, 2009a-c). At

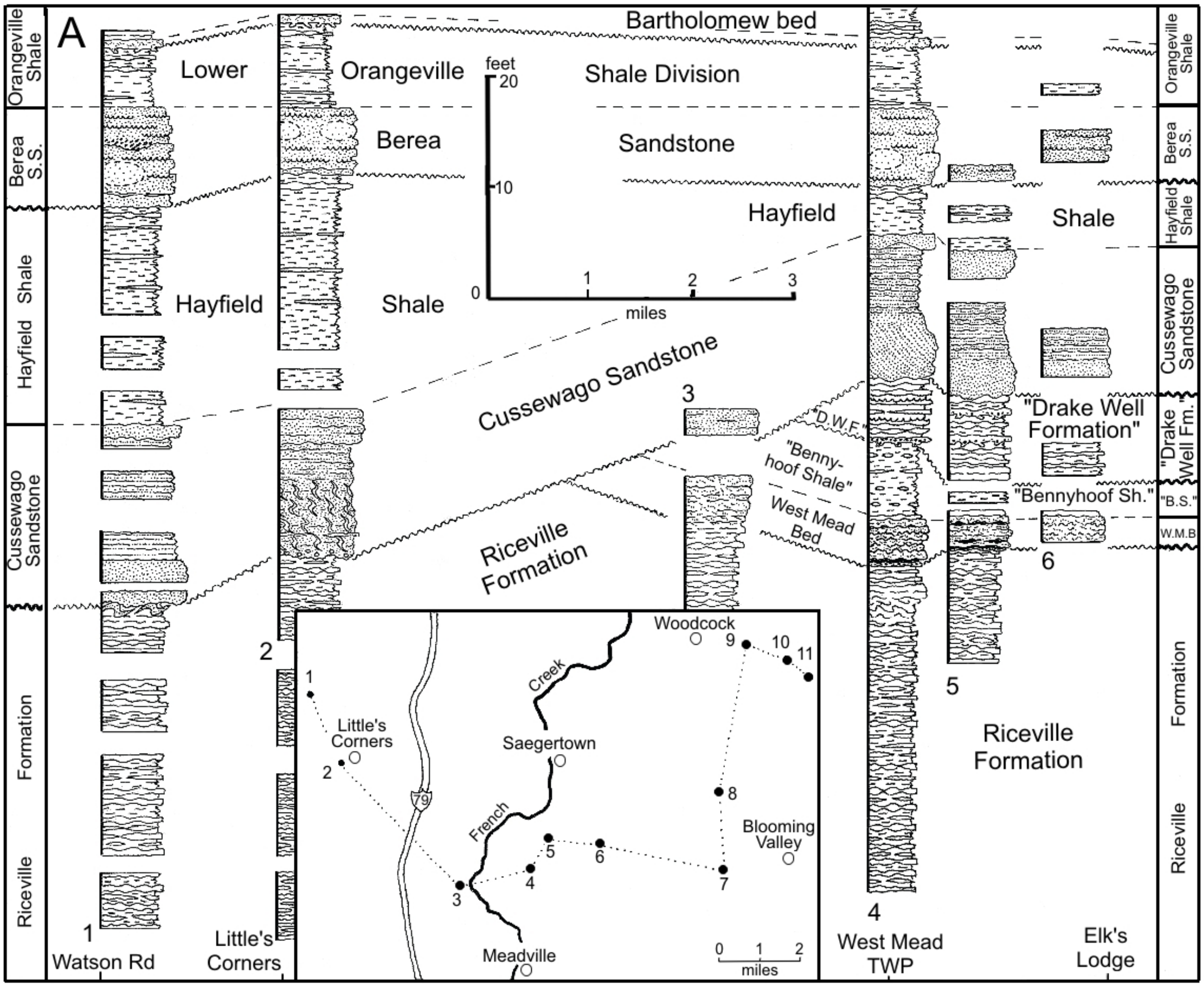
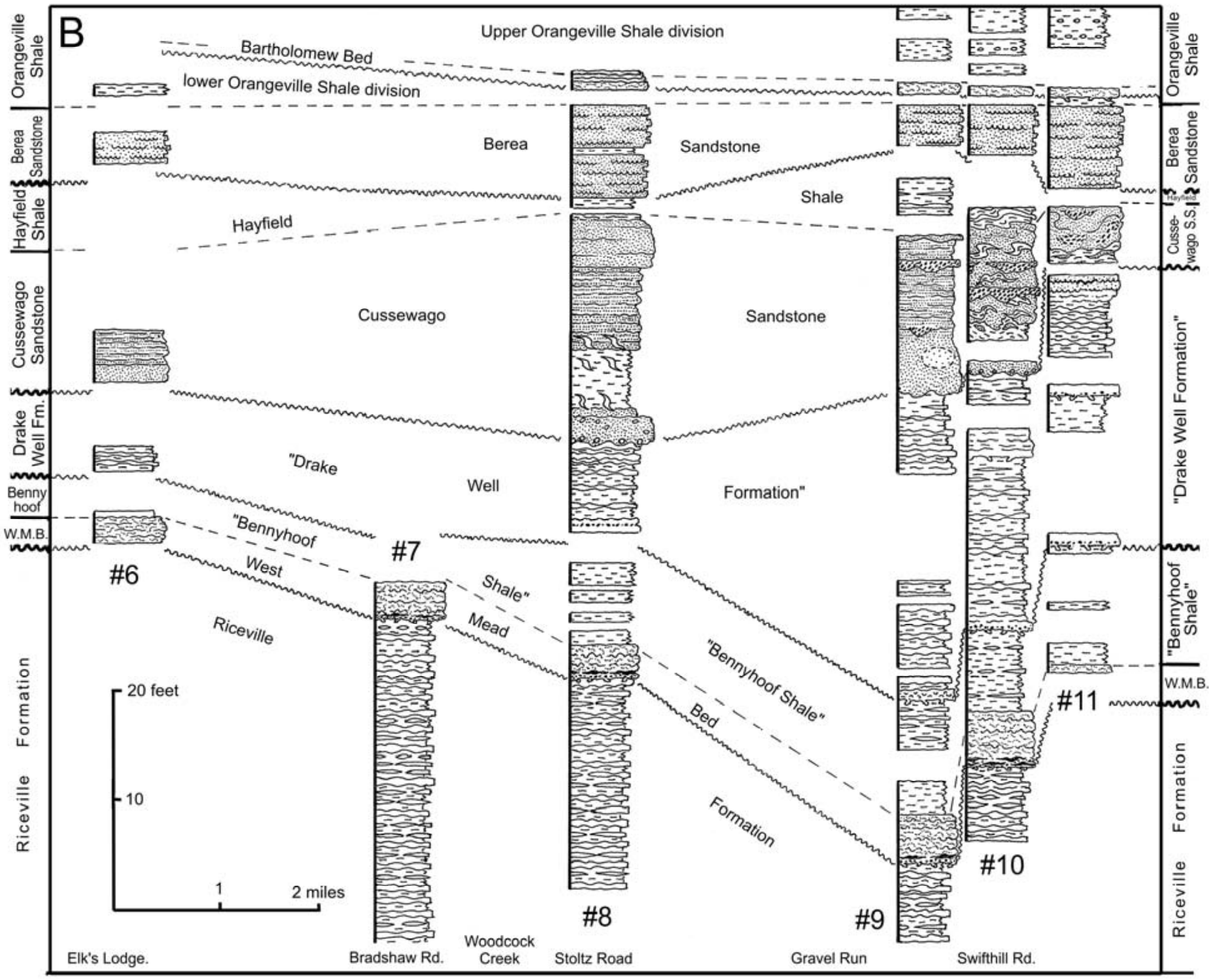


Figure 3 (above and on facing page). Stratigraphic transect of the end-Devonian-basal Mississippian succession across the French Creek Valley (Meadville area)and the Blooming Valley Quadrangle, to the northeast of Meadville, based on recent work of Baird. A, French Creek Valley transect. Note the progressive eastward appearance of key divisions (West Mead Bed, Bennyhoof Shale, "Drake Well Formation") along this transect; B, Blooming Valley area transect. Note continuing pattern of eastward-northeastward appearance of beds as the "Drake Well Formation" succession thickens.

localities on the west side of the Cussewago Valley near the hamlets of Little's Corners and Denny's Corners, the Cussewago Sandstone rests directly on the Riceville Formation. This Riceville succession is interpreted to be equivalent to the topmost Chagrin interval of Ohio sections. This interpretation substantiates the interpretation of White (1881) and subsequent workers that the Cleveland and Bedford members are absent from the section at this meridian. However, just to the east of this area, new units progressively appear below the sub-Cussewago disconformity in an eastward-younging pattern across central Crawford County (Figures 3A and B). These units are described below; names attached to them are informal and provisional pending completion of our work.

"West Mead Bed": We, herein, introduce the term "West Mead Bed" for a distinctive, compact, erosionally-resistant, bundle of brown-weathering, bioturbated siltstone layers with associated dark grey to black shale partings. The type section for this unit is on Bennyhoof



Creek north of Meadville in West Mead Township (Figure 4). This 1.0—1.5 meter-thick unit is characterized by microbioturbated siltstone beds and black shale partings which weather to a rusty red-brown in many sections. As such, layers in this unit contrast with the lighter, grey, tempestitic siltstone beds and green-grey shale partings in the underlying Riceville Formation and with overlying grey shale beds in the "Bennyhoof Shale" division (see below). Brachiopods, in this interval, include the spirifers *Syringothyris* and *Cyrtospirifer* as well as numerous productids and rhynchonellids. The problematic taxa *Coleolus* and *Sphenothallus* are often abundant on bedding plane surfaces. Unidentified inadunate crinoids as well as tests of the echinoid *Hyattechinus* occur more sparingly. Trace fossils include *Thallassinoides* , *Chondrites*, and, more significantly, *Scalarituba.* This fauna, the intense bioturbated nature of component beds, and the black color of some shale partings are suggestive of slow deposition under conditions of fluctuating substrate oxygenation.

At localities where the base of this unit can be accessed, a lag bed of detrital pyrite with associated fish debris, conodonts, and *Sphenothallus* is observed (Figures 4 and 5A). Current-aligned *Coleolus* (Figure 5B) and gastropod steinkerns (Figure 5A) are often abundant in these lag zones. Sometimes two, closely-spaced lag beds are associated with the base of this unit; the first roofed by fissile grey shale and the second by black shale or dark, microbioturbated siltstone. We interpret these contacts to record transgressive backstepping associated with marine transgression. It is notable that complete or partial sections of the West Mead Bed has been identified at a total of 27 localities in the Geneva, Meadville, Edinboro South, Blooming Valley, and Cambridge Springs quadrangles to date. Further east, near Riceville and Centerville in central Crawford County, the West Mead Bed is tentatively identified in three additional sections (Figure 6). This testifies to the widespread nature of this thin marker unit. The West Mead Bed will be seen by participants at Cora Clark Park in Meadville (STOP 9).

We provisionally interpret the West Mead Bed to be an eastern correlative of the Cleveland Member of the Ohio succession (Baird and others, 2009a-c). Moreover, the basal lag zone at and above the base of this unit is interpreted to be the lateral equivalent of the Skinner's Run pyrite/bone bed and to have formed similarly. One of us (Jeff Over at S.U.N.Y. Geneseo) has isolated conodonts from the base-West Mead lags; preliminary yields have turned up the elements *Bispathodus aculeatus aculeatus* and *Polygnathus symmetricus*? (M-U *expansa* zones), permissive of West Mead-Cleveland Member correlational linkage (Baird and others, 2009 A,C) (Figure 7). Figure 8 is a hypothetical reconstruction showing the West Mead Bed to be a condensed, upslope phase of the black Cleveland Shale. We believe that the West Mead accumulated in a sediment-starved transgressive regime under the influence of deep-storm turbulence, and/or bottom current-impingement associated with pycnocline-related internal waves (Figure 8). Episodes of dysoxia would have alternated with oxic, storm-influenced intervals, accounting for the complex stacking of dark shales and siltstone beds in this unit.

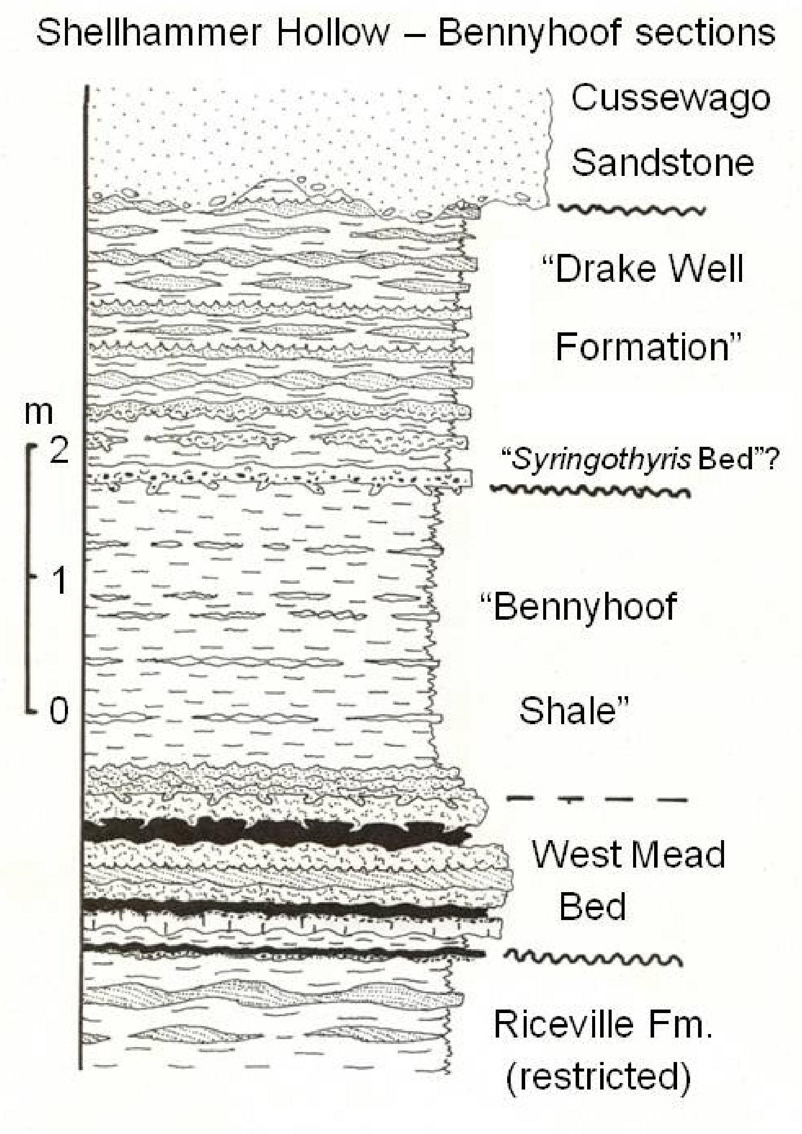


Figure 4. Top-Riceville-Formation-into-Cussewago Sandstone succession generalized from composite profiles of Bennyhoof Creek and nearby Shellhammer Hollow at the north edge of Meadville, Pennsylvania. Note presence of black shale partings and microbioturbated dark siltstone beds in the West Mead Bed as well as prominent discontinuities flooring both the "Drake Well Formation" and overlying Cussewago Sandstone.

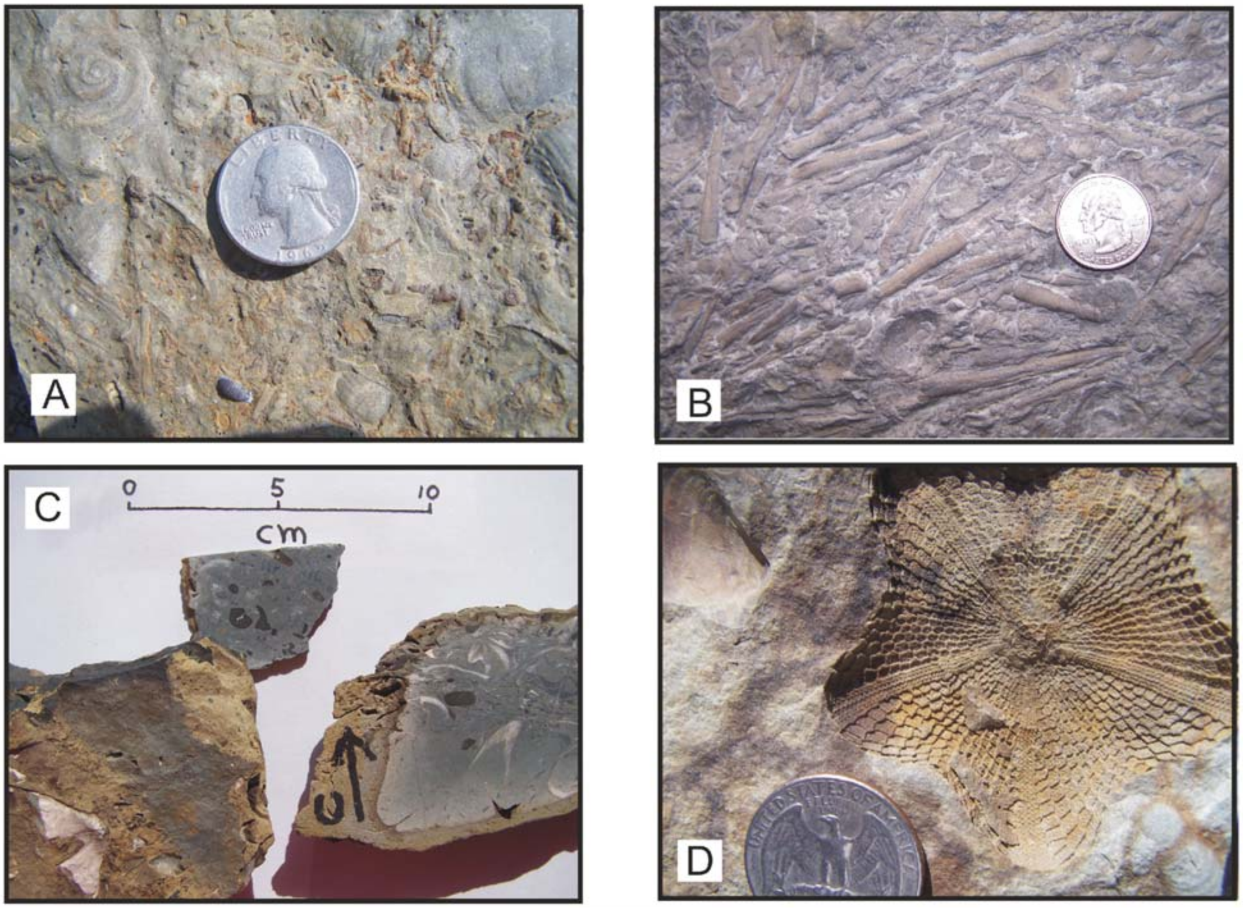


Figure 5. Distinctive features in the West Mead Bed and "Drake Well Formation." A—Concentration of detrital (reworked) pyritic grains, gastropods, and fish bone debris which marks the base-West Mead Bed discontinuity. This lag deposit is believed to be correlative with the Skinner's Run Bed of the Ohio section (see text). Note ovoidal chondrichthyan crusher tooth (black object) in the lower left. This specimen is from a west-flowing tributary of French Creek above the Liberty Street overpass, two miles south of Meadville. B—Current-aligned shells of the problematic molluscan organism *Coleolus* from the lower part of the West Mead Bed at Dick Run below the East College Street overpass at the east edge of the Allegheny College campus in Meadville. C—Concentration of phosphatic pebbles, fish bone debris, conodonts, and spiriferid brachiopods which corresponds to the "*Syringothyris* Bed" of Caster (1934). This lag unit marks the position of the regional, base-"Drake Well Formation" discontinuity (see text). Note the large syringothyrid brachiopod in the lower left. This material is from a creek southwest of Riceville which corresponds to the original Riceville type section of I.C. White (1881). D—Articulated echinoid *Hyattechinus pentagonus* from the "Drake Well Formation." This specimen, preserved as a three-dimensional open mold, was found in the bed of a northeast-flowing tributary of French Creek, 3.6 kilometers (2.2 miles) southeast of Cambridge Springs.

Bennyhoof Shale: Above the West Mead Bed is a 1.2-2.7 meter-thick interval of soft, green-grey shale and lenticular-to-tabular siltstone layers, herein designated the "Bennyhoof Shale". The type section for this division is also on Bennyhoof Creek north of Meadville in West Mead Township (Figure 4). The Bennyhoof is characterized by a conformable (gradational) lower contact with the West Mead Bed, but displays a sharper, unconformable, contact with the overlying "Drake Well Formation" (Figure 5). Usually the Bennyhoof is siltier and intensely bioturbated in the basal 0.3-0.5 meter portion of the unit. The top 0.5-1.0 meter of this unit is also siltier: channelized siltstone lentils occur within the top of this shale unit at a number of

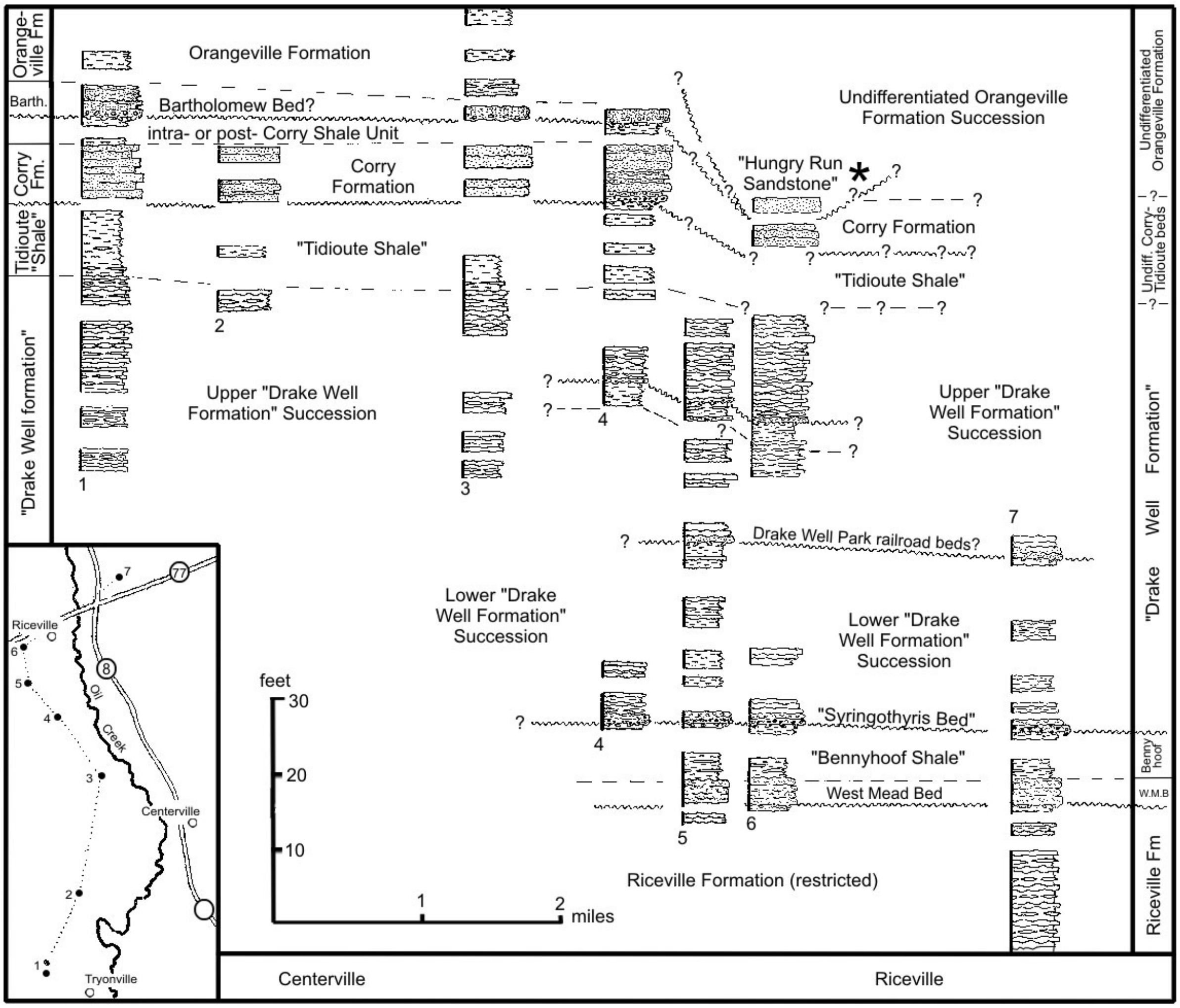


Figure 6. Stratigraphic transect across the Riceville-Centerville area bordering the Oil Creek Valley in east-central Crawford County. The original type Riceville section of I.C. White (column number 6) is complemented by measurement and inclusion of all adjacent sections in this area, so that the "*Syringothyris* Bed" of Caster (1934) and the westernmost sections of the Corry Formation could be fully characterized. Asterisk denotes inferred truncation of the topmost Corry Formation by the Hungry Run Sandstone at the Riceville section (column 6) as observed by Pepper and others (1954); this contact is presently concealed.

---

localities. Owing to the soft nature of the shale, the Bennyhoof fauna has yet to be fully characterized. The Bennyhoof Shale has been tentatively traced as far east as the Riceville-Centerville area in central Crawford County (Figure 6). We will see the Bennyhoof Shale at STOP 9.

"Drake Well Formation": Above the Bennyhoof Shale is an abrupt upward change to a substantially thicker, siltstone-dominated, succession characterized by bundles of slabby, tabular-to-lenticular, tempestitic siltstone beds, frequently displaying ripple marked surfaces, basal scour features, and coquinitic fossil debris concentrations (Figure 4). Intervening shales occur both as thin partings and, locally, as more substantial (1.0—2.0 meter (3—6.5 foot)-thick

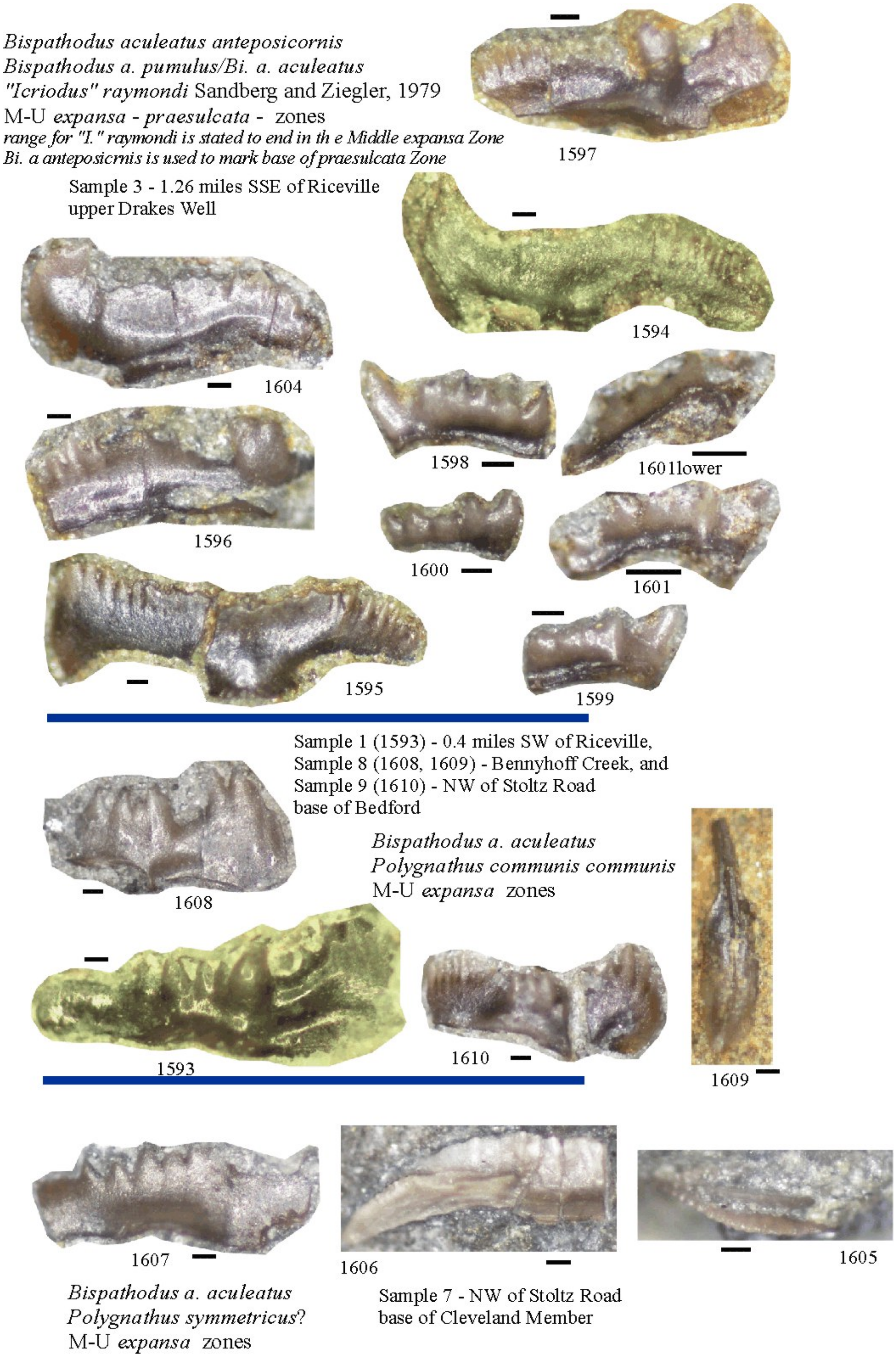


Figure 7. Conodonts from the West Mead Bed and "Drake Well Formation" (see discussion in text). The basal three elements are from the West Mead Bed. The middle four elements are from the base of the "Drake Well Formation." The upper ten elements are from a single horizon in the upper part of the "Drake Well Formation" at a unnamed stream locality north of Centerville, PA.

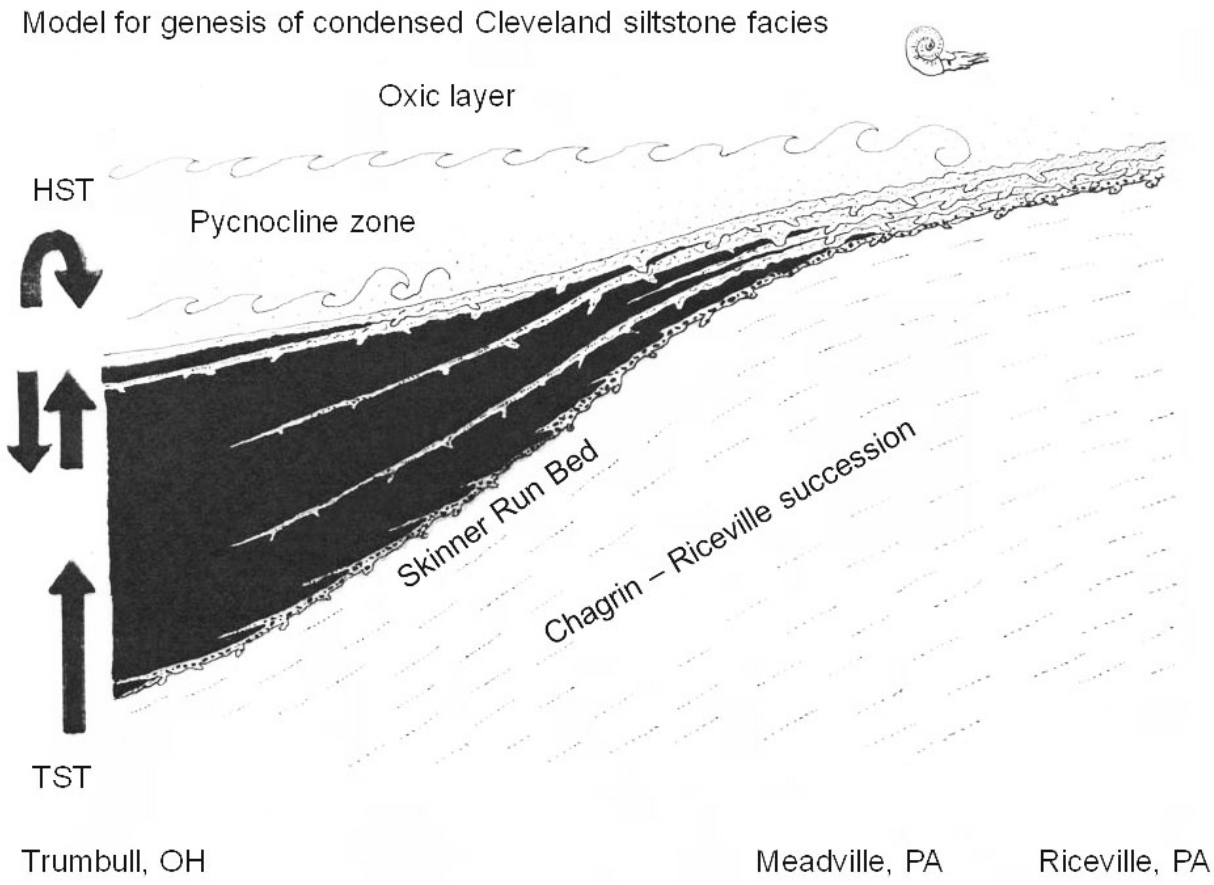


Figure 8. Model for eastward (upslope) condensation of the Cleveland Member succession in a sediment-starved, eustatic highstand regime. This model works from the inferred context of a northwestward-westward-sloping submarine ramp during Cleveland mud deposition. The Skinner's Run Bed is a result of ttransgressive submarine erosion under dysoxic conditions; deep-storm wave-, or internal wave-impingement on the substrate served to erode the substrate on slope during reduced sediment supply. Thinner, microbioturbated Cleveland-equivalent siltstone facies (West Mead-interval) in upslope areas reflects a combination of intense, long-term burrowing, episodic bottom erosion, and prolonged sediment-starvation.

divisions. We, herein, refer to this unit as the "Drake Well Formation" for lack of a better, alternative designation (see below). The base of this succession is marked by channelized lag debris, consisting of detrital pyrite, fish bone fragments, conodonts, and phosphatic mollusk steinkerns is association with disarticulated brachiopod valves (Figures 4 and 5C). Where concentrated, this lag is often associated with calcareous concretionary siltstone lentils and pods which weather to a distinctive knobbly, "popcorn"-like texture. Fossils associated with the basal lag zone and above it include: the spirifers *Cyrtopspirifer* and *Syringothyris* as well as numerous rhynchonellids in association with bivalves and occasional glass sponges. Most significant is the discovery of fully articulated echinoids in this interval at a number of Meadville-area localities (Figure 5D). Both *Hyattechinus pentagonus* and *Hyattechinus rarispinus* have been found in the lowest 1.5 meter interval of this unit (Baird and others, 2009a, c). *Hyattechinus pentagonus* usually occurs in clusters on bedding surfaces; many of the great *Hyattechinus* clusters in university and museum displays are probably from this interval. We will see *Hyattechinus* at this level at Cora Clark Park. Conodonts secured from the base of this interval to date include: *Bispathodus aculeatus aculeatus* and *Polygnathus communis communis* which are indicative of the Middle and Upper *expansa* zones, and conodonts obtained from the upper part of the "Drake Well Formation" near Centerville have yielded *Bispathodus aculeatus anteposicornis, Bispathodus stabilis, Bispathodus aculeatus aculeatus, and "Icriodus" raymondi* Sandberg and Ziegler, 1979 , which are indicative of the Middle and Upper parts of the *expansa* zones and parts of the overlying *praesulcata* zone (Baird and others, 2009a, c) (Figure 7).

The "Drake Well Formation" first comes into view below the base-Cussewago disconformity east of the meridian of Interstate 79. Its base descends eastward across the county with the appearance of successively higher beds (Figures 3A and B). Examination of sections in the Riceville-Centerville area in central Crawford County, suggest that the base-"Drake Well Formation" discontinuity connects eastward to Caster's (1934) base-Kushequa "*Syringothyris* Bed" at White's (1881) original Riceville type section (Figure 6). However, since the name "Kushequa" is no longer used, the designation "Drake Well Formation", *sensu* Harper (1998) is used provisionally for strata between the top of the Bennyhoof Shale and the Cussewago Sandstone east to the Union City meridian, and for strata between the Bennyhoof Shale and the overlying Tidioute Shale in the Oil Creek Valley (Figures 3 and 6). Given that the term "Drake Well Formation" was defined largely from subsurface log information (Harper, 1998), it ultimately might not ultimately fit surface sections, but that will be an issue solved by future work. The "Drake Well Formation" "type section" will be seen at the west-facing railroad cut exposure across from the Drake Well museum and park complex (STOP 6) and the base of this division will be seen at Cora Clark Park (STOP 9).

Tidioute Shale: This is a term originally coined by Caster (1934) which dropped from use for a while. Harper (1998) revived the term, using it for a shale-dominated interval above the "Drake Well Formation" for surface and subsurface use in the southern and eastern parts of Crawford County, southwestern Warren County, and parts of Venango County. The Tidioute Shale has been observed in outcrop by us in the Riceville-Centerville area (Figure 6), in the Hydetown area further south, and in hanging gully sections along Oil Creek at Miller Farm and at Petroleum Centre. Harper's concept of Tidioute is more inclusive than that of Caster (1934); it includes additional strata between Caster's original Tidioute interval and the Corry Sandstone which Caster termed "Hayfield" at Titusville-Tidioute area sections in his 1934 report. As such, Harper's Tidioute Shale extends up to the base of the Corry Sandstone throughout the Riceville-Titusville-Tidioute area southward as far as Petroleum Center along Oil Creek.

Where seen to better advantage, as in sections northwest of Centerville, the Tidioute Shale is a soft, fissile, grey-green shale unit which weathers to an olivaceous green-brownish color. Sideritic concretions and thin siltstone beds also occur in this unit. The base of this unit appears to be conformable with the underlying "Drake Well Formation." Caster (1934) described a sandstone layer marking the base of the Tidioute Shale which yielded numerous echinoid tests and large, distinctive platyceratid gastropods in the Warren and Tidioute areas. The present authors have endeavored to locate this unit, but have not yet encountered it in sections.

The Tidioute Shale appears to thicken in a southward direction; we have encountered only 2—3.5 meters of this unit in the Riceville-Centerville area. Reinterpreting Caster's measurements at Dennis Run near Tidioute, we get approximately 13 meters. Based on interpretation of information and discussions in Fox (1989), Burgchardt and Fox (1989) by one of us (Baird), the Tidioute should be in excess of 15 meters at Petroleum Centre in the southern part of the Oil Creek Valley (see STOP 3).

"unnamed sandstone" division: This term, coined by Schiner and Kimmel (1972), refers to a unit restricted in outcrop only to the southernmost part of the study and to the subsurface to the south of there. This unit occurs above the Tidioute Shale and below the Corry Sandstone in outcrop from the "Columbia Farm" area of Oil Creek State Park southward to Oil City. North of Columbia farm, this unit is absent, and the Corry rests directly on the Tidioute. As seen by the present authors, the "unnamed sandstone" encompasses a 6—7 meter (19—22 foot)-thick interval of stacked, muddy siltstone and fine sandstone beds which are variably siderite and pyrite-rich. Beds and lentils in this interval are variably bioturbated and yield a modest fauna of brachiopods and bivalves. It is well displayed in roadcuts at and near Rouseville. A small part of this unit will be seen below the Corry Formation at STOP 1.

Corry Sandstone: The Corry Formation has been an important reference unit for the mapper and the driller since the time of White (1881) or earlier. The Corry is typically a massive, white, quartzose, siltstone or fine sandstone unit which yields a diverse fauna in its lower part (Caster, 1934; Sass, 1960). It has been divided into three informal "member" (Caster, 1934; Pepper and others, 1954). The lower and thickest of the members displays a 2.5—6 meter (7.5—19 foot)-thick succession of massive, 0.5—1.8 meter-thick beds which have been quarried in many areas. The fossil-rich base of this unit is often very calcareous and it is the horizon of numerous flowing springs in outcrops, giving rise to the name "fountain horizon" in older literature. Although the Corry hilltop quarry type section south of Corry has been destroyed, the present authors have examined outcrops of this unit from the Riceville area southward to Oil City and southeastward to Tidioute and Tionesta.

Contrary to earlier workers (White, 1881; Caster, 1934), who interpreted the base of the Corry to be gradational, we find that its base is sharp and regionally erosional in character. A distinctive, laterally discontinuous, channelized, lag of detrital pyritic burrow casts, permineralized wood fragments, fish teeth and bones, coprolites, shale clasts, and the occasional quartz pebble is characteristic of Corry sections (Figure 9A). Given the aforementioned northward termination of the "unnamed sandstone", followed, in turn, by northward thinning of the Tidioute Shale, we are investigating the possibility that the sub-Corry discontinuity is regionally angular, and that a more continuous end-Devonian section is available for study in the Petroleum Centre-Oil City area.

Above the shaley Corry "middle member", is a highly variable 1.0—2.5 meter-thick, bundle of thinner siltstone and sandstone beds which comprises the Corry "upper member". In several Oil Creek Valley outcrops, the base of this bundle is marked by a bioturbated muddy sandstone bed abounding in quartz pebbles and granules. This unit closely resembles the "thin phase" of the Hungry Run Member (*sensu* Pepper and others, 1954). It also resembles the eastern sandy phase of the Bartholomew Bed as well. These observations motivate our ongoing effort to further identify key base-Mississippian markers in this area. We will drive by good Corry roadcut sections along PA Route 8 north of Rouseville. We will examine a Corry roadcut section along the Route 8 bypass opposite Oil City (STOP 1).

Cussewago Sandstone: The Cussewago Sandstone is spatially the most variable and complex division that we have mapped. It is unique among the units examined here in that it is typically very poorly consolidated or unconsolidated, displays steep internal cross-stratification, and is frequently deformed. The Cussewago varies greatly in thickness over very short distances; near Little’s Corners, northwest of Meadville, it is 6.5 meters (20 feet)-thick, but at the I-79 Meadville interchange, northbound entrance ramp cut, 6.3 miles to the southeast of there, it is only 0.5 meter (1.5 foot)-thick. Continuing 1.9 miles northeast to Cora Clark Park (STOP 9), it thickens again to 5 meters (16.5 feet). The base-Cussewago contact is usually sharp with underlying units; as noted above, it rests disconformably on underlying units regionally. However, this basal contact is not always well defined in sections. At Cora Clark Park (STOP 9) and at several other outcrops, the base of the Cussewago is deformed; sandstone ball-and-pillow masses are sometimes observed to occur in a green-grey shale matrix at the bottom of the unit. In addition to soft-sediment deformation, the base of the Cussewago , as well as

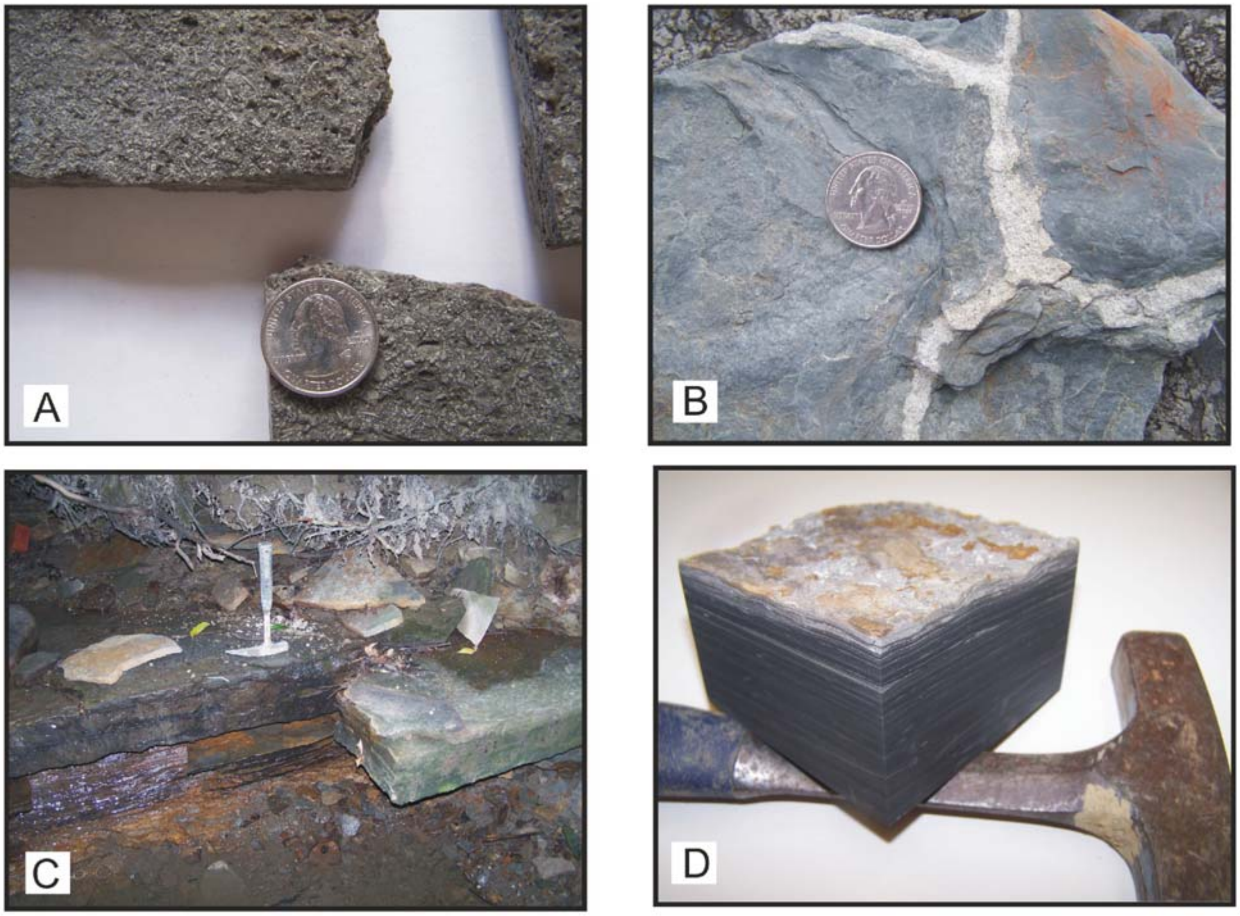


Figure 9. **Key features of the end-Devonian-basal Mississippian succession. A—Concentrated detrital (reworked) pyrite grains at the base of the Corry sandstone. This pyrite occurs in association with fish bone debris and fragmental plant material in channelized lag deposits associated with the base-Corry discontinuity. The pyrite illustrated here is on the Corry basal surface, viewed from below. Figured material is from an east-facing cut along Waitz Road opposite Rouseville. B—Clastic dikes penetrating a shale bed in the Cussewago Sandstone. These dikes of coarse sandstone form networks resembling mudcracks as seen in bedding plane view. Specimen from northeast-flowing tributary of Cussewago Creek, 0.8 kilometer (0.5 mile) southwest of the intersection at Little’s Corners in Hayfield Township. C—Bartholomew Bed at Cora Clark Park (Stop 9). Note compact character of this unit and its sharp basal contact. D—Laminated black shale deposit observed below the Bartholomew Bed in western Crawford County. This 10 cm (4 inch) -thick unit is here shown inverted with its basal contact surface shown uppermost. This bed is believed to be the easternmost, feather-edge expression of the basal part of the Sunbury Shale (see text). Specimen from west-flowing tributary of Conneaut Creek, 3.3 kilometers (2.0 miles) southeast of Conneautville in Summerhill Township.**

variable intervals of underlying units, are permeated by networks of small, usually vertical, dikes of coarse sandstone which frequently blur the basal boundary, as seen at Littles Corners, Cemetary Run in Meadville, and at the I-79 Meadville interchange (Figure 9B). These dikes can also occur at higher levels within the Cussewago interval as well (Pashin and Ettensohn, 1995). On a northeast-flowing stream, 0.8 kilometer (0.5 mile) southwest of Littles Corners, the basal 2.2 meters (7 feet) of the Cussewago is thoroughly crazed with networks of dikes which form polygon-, ring-, and boxwork patterns on bedding surfaces (Figure 9B). This pervasive internal deformation and evidence of internal fluid release links the Cussewago to the Berea in Ohio which displays similar features. It is curious that the problematic Haystacks Sandstone in the Huntley Mountain succession is also characterized by complex, vertical dike networks (Gillmeister and Hill, 2006).

Bartholomew Bed: One of the most easily recognized marker units, used in our mapping work, is the Bartholomew Bed, which is widely understood to mark the base of the Mississippian System in northwest Pennsylvania (Figures 3 and 9C). We agree with earlier workers (Pepper and others, 1954; Schiner and Kimmel, 1972, and others) as to its physical aspects and regional extent as a key bed. In northeast Ohio and northwest Pennsylvania, it is typically expressed as a thin, discrete ledge of rusty-weathering, dark grey, intensely bioturbated siltstone which floors dark grey, fissile shale deposits of the Orangeville Shale (Figure 9C). It also overlies an eastwardly thinning interval of grey, fissile shale (basal Orangeville division) which also extends across much of the study area (Figures 3A and B). The Bartholomew Bed is characterized by dense workings of the deposit-feeding ichnotaxon *Scalarituba.* Hence, this bed was referred to as the “cuniform sandstone” by early workers. The base of the Bartholomew Bed is sharp, and it is marked by a basal sculpture of protruding burrows and an associated lag of fragmental *Lingula* valves. We believe that this contact is regionally disconformable; in Summerhill Township in western Crawford County, a thin, laminated, back shale unit can be seen below the Bartholomew Bed which, in turn, displays a sharp basal contact on the underlying post-Berea shale interval (Figure 9D). We believe that this black shale represents the basal, easternmost, feather-edge of the Sunbury Shale of the Ohio section. To the east and southeast of Summerhill Township, this black unit is absent, and the Bartholomew Bed comes to rest on progressively lower and older units. We are currently investigating the possibility that the Bartholomew Bed is correlative with the “thin phase” of the Hungry Run Member (*sensu* Pepper and others, 1954), and/or, with the “upper member” of the Corry Formation.

The “Snagbox”

Ongoing work is directed to working out the temporal relationship of the Corry Sandstone with the Cussewago-Berea succession across central Crawford County. As noted above, the Cussewago Sandstone can be traced as far east as Rootville and Glovers Corners in the northern part of the Oil Creek Valley south of Union City, but not to the east or southeast of there. Similarly, the Corry Sandstone can be easily followed westward and northward to the vicinity of Riceville, but not any further west of there. A gap of only a couple of miles intervenes where sections are few and small. This area we refer to as the “snagbox”; it is particularly well shown on the east-west cross-section of Pepper and others (1954) through this area. Pepper and others (1954) interpreted the central Crawford County region area to have been a “shaley basin” between deltas sourcing from different directions.

Working from the more recent context of sequence stratigraphy, fundamentally different relationships can be inferred from the data so far assembled. Eustatic or tectono-eustatic lowstand episodes usually produce sequence-bounding unconformities, and marine transgressions produce condensed units in offshore regimes or the characteristic backstepping stratigraphic patterns of transgressive systems tracts. Two minor and three potentially major mappable discontinuity surfaces are recognized from the work done to date; these are, in upward ascending order: the base-West Mead discontinuity (minor); the base-"Drake Well" discontinuity (minor); the base-Corry discontinuity (potentially very major); the base-Cussewago disconformity (very major), and the base-Bartholomew Bed (potentially major).

The upper three discontinuities (base-Corry, base-Cussewago, and base-Bartholomew Bed) all converge into close proximity in the region between Blooming Valley and Centerville as the bounding sandstone units become very thin. In this context, it seems likely that the Cussewago Sandstone pinches out eastward due to eastward depositional onlap, erosional overstep, or a combination of both processes. The type Hungry Run section southeast of Union City may be a residual outlier of Cussewago in that area. Similarly, given the stable, tabular, widespread character of the Corry Formation, its abrupt westward demise to the west of Riceville suggests the possibility of overstep from either the sub-Cussewago or sub-Bartholomew Bed. Pashin and Ettensohn (1995) speculated that the sub-Cussewago disconformity was the expression of the big eustatic drawdown associated with the Hangenberg glaciations on Gondwana. Given the new Spechty Kopf information reviewed above, this interpretation has a new relevance and urgency. All of these questions and more are being addressed through ongoing mapping work. We believe that the snagbox riddle can be solved and solved soon.

REFERENCES

Aigner, T., 1985, *Storm depositional systems: dynamic stratigraphy in modern and ancient shallow-marine sequences*. Springer-Verlag, Berlin, 174 p.

Algeo, T. J., Berner, R. A., Maynard, J. B., and Scheckler, S. E., 1995, *Late Devonian oceanic anoxic events and biotic crises: "rooted in the evolution of vascular land plants?"* GSA Today, v. 5, p. 45, 64-66.

Algeo, T. J., and Scheckler, S. E., 1998, *Terrestrial-marine telecommunications in the Devonian: links between the evolution of land plants, weathering processes, and marine anoxic events*. Philosophical Transactions Royal Society London, v. B 353, p. 113-130.

Baird, G. C., 1991. *Anoxic-to-oxic biofacies spectrum in a Famennian foreland basin deposit: example from the Ellicott Shale Member, Lake Erie region*. Geological Society of America, Northeast Section Meeting, Baltimore, v. 23, no. 1, p. 94.

Baird, G. C., and Brett, C. E., 1991, *Submarine erosion on the anoxic sea floor: Stratinomic, paleoenvironmental and temporal significance of reworked pyrite-bone deposits*, in Tyson, R. V., and Pearson T. H., eds., *Modern and ancient continental shelf anoxia*. Geological Society of London Special Publication 58, p. 233-257.

Baird, G. C.; Over, D. J. and Brett, C. E., 2009a, *The upslope limits of transgressive Late Devonian –basal Mississippian black shales on the Catskill Delta prodeltaic slope: Physical characteristics and controls (abs)*. Geological Society of America, Northeastern Section Meeting, Portland, ME, p. 2.

Baird, G. C., Carr, R. K., Hannibal, J. T., Brett, C. E., and Brett, B. L., 2009b, *Uppermost Devonian (Famennian) stratigraphy of the Cleveland area, northeastern Ohio*, in Brett,

C. E., Bartholomew, A. J., and DeSantis, M. K., eds., *Middle and Upper Devonian sequences, sea level, climatic, and biotic events in east-central Laurentia: Kentucky, Ohio, Michigan*. Guidebook, North American Paleontological Convention, Cincinnati, p. 154-168,

Baird, G. C., Over, D. J., Sullivan, J. S., McKenzie, S. C., Schwab, J. C., and Dvorak, K. A., 2009c, *Conodonts and the end-Devonian event-stratigraphic chronology in the classic Pennsylvania "oil lands" region: Latest-Famennian Riceville Formation-Berea sandstone-succession*. International Conodont Symposium ICOS 2009 Abstracts, Permophiles no. 53, Supplement 1, p. 3.

Becker, R. T. and Hartenfels, S., 2008, *The Dasberg Event in the Rhenish massive Carnic Alps, and Anti-Atlas (Tafilalt, Maider) – implications for Famennian eustatics and chronostratigraphy*, in Becker, R. T., ed., Subcommission on Devonian Stratigraphy, Newsletter 23, p. 40-44.

Berg, T. M., Edmunds, W. E., Geyer, A. R., Glover, A. D., Hoskins, D. M., MacLachlan, D. B., Root, S. I., Sevon, W. D., and Socolow, A. A., 1980, *Geologic map of Pennsylvania*. Pennsylvania Geologic Survey, 2nd ser., Map 1, two sheets.

Brezinski, D. K., Cecil, C. B., Skema, V. W. and Stamm, R.,2008, *Late Devonian glacial deposits from the eastern United States signal an end of the mid-Palaeozoic warm period.* Palaeogeography, Palaeoclimatology, Palaeoecology, v. 268, p.143-151.

Burgchardt, Carl, and Fox, J. S., 1989, *Field Trip # 1: Oil region of Titusville, Pleasantville, Tidioute, and Tionesta*, in Pees, S. T., and others, *History of the Petroleum Industry Symposium*. American Association of Petroleum Geologists Guidebook, p. 17-30.

Caputo, M. V., 1985, *Late Devonian glaciations in South America*, Palaeogeography, Palaeoclimatology, Palaeoecology, vol. 51, p. 291-317.

Carr, R. K. and G. L. Jackson, 2006. *The vertebrate fauna of the Cleveland Shale (Famennian, northern Ohio)*. Field Guide, Geological Society of America, North-Central Section Meeting 2006.

Caster, K. E., 1934, *The stratigraphy and paleontology of northwestern Pennsylvania, Part 1, Stratigraphy*. Bulletins of American Paleontology, v. 21, no. 71, 185 p.

Cecil, D. K., Brezinski, D. K., and Dulong, F., 2004, *The Paleozoic record of changes in global climate and sea level: central Appalachian Basin*, in Southworth, S., and Burton, W., eds., U.S. Geological Survey Circular 1264, p. 77-135.

Chadwick, G. H., 1925, *Chagrin Formation of Ohio*. Geological Society of America Bulletin, v. 36, p. 455-464.

Crowell, J. C., 1999, *Pre-Mesozoic ice ages: their bearing on understanding the climate system*. Geological Society of America Memoir 192, 112 p.

Dennis, A. J., 2007, *Cat Square Basin, Catskill clastc wedge: Silurian-Devonian orogenic events in the central Appalachians and the crystalline southern Appalachians*, in Sears, J. W., Harms, T. A., and Evenchik, C. A., eds., *Whence the mountains? Inquiries into the evolution of orogenic systems: a volume in honor of Raymond A. Price*. Geological Society of America Special Paper 201, p. 91-106.

deWitt, Jr., W., 1970, *Age of the Bedford Shale, Berea Sandstone, and Sunbury Shale in the Appalachian and Michigan basins*. U.S. Geological Survey Bulletin 1294-G, 11 p.

Dickey, P. A., 1941, *Oil geology of the Titusville quadrangle, Pennsylvania*. Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 22, 87 p.

Dickey, P. A., Sherrill, R. E., and Matteson, L. S., 1943, *Oil and gas geology of the Oil City quadrangle, Pennsylvania*. Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 25, 201 p., reprinted in 1984.

Dodge, C. H., 1992, *Bedrock lithostratigraphy of Warren County, Pennsylvania,* in Sevon, W. D., ed., *Geology of the upper Allegheny River Region in Warren County, northwestern Pennsylvania*. Guidebook, 57th Annual Field Conference of Pennsylvania Geologists, Warren, PA, p. 1-20.

Ettensohn, F. R., Lierman, R. T., Mason, C. E. and Clayton, G., 2009, *Changing physical and biotic conditions on eastern Laurussia*. Guidebook, North American Paleontological Convention Field Trip No. 2.

Fettke, C. R., 1938, *The Bradford oil field, Pennsylvania and New York*. Pennsylvania Geological Survey, 4th series, Mineral Resource Report 21, 454 p.

Fox, J. S., 1989, *Some geological aspects of the Oil Creek Valley region,* in Pees, S. T. and others, *History of the Petroleum Industry Symposium*. American Association of Petroleum Geologists Guidebook, p. 46-53.

Frakes, L. A., Francis, J. E. and Sykius, J. I., 1992, *Climate modes of the Phanerozoic*. Cambridge University Press, Glasgow, 286 p.

Gillmeister, N. M. and Hill, J., 2006, *Petrology of the "Haystacks" Sandstone,* in Inners, J. D., and Fleeger, G. M., eds., *The Haystacks, "Ricketts Folly," and the end of the world: Geology of the Glaciated High Plateau, Sullivan, Luzerne and Columbia Counties, Pennsylvania*. Guidebook, 71st Annual Field Conference of Pennsylvania Geologists, Ricketts Glen State Park, PA, p. 20-31,

Gutschick, R. C., 1987, *Devonian shelf-basin, Michigan Basin, Alpena, Michigan,* in Biggs, D. L., ed., *North-central section of the Geological Society of America*. Geological Society of America Centennial Field Guide, v. 3, p. 297-302.

Gutschick, R. C. and Sandberg, C. A., 1991, *Upper Devonian stratigraphy of the Michigan Basin*. Geological Society of America Special Paper 256, p. 155-179.

Hannibal, J. T. and Feldmann, R. M., 1983, *Arthropod trace fossils, interpreted as echinocarid escape burrows, from the Chagrin Shale (Late Devonian) of Ohio*. Journal of Paleontology, v. 57, p. 705-716.

Harper, J.A., 1998, *Stop 6 and lunch, Drake Well Memorial Park*, in Harper, J.A., ed., *Geotectonic environment of the Lake Erie crustal block*. Guidebook, 63rd Annual field Conference of Pennsylvania Geologists, Erie, PA, p. 61-74.

Hlavin, W. J., 1976. *Biostratigraphy of the Late Devonian black shales on the cratonal margin of the Appalachian geosyncline*. Unpublished PhD dissertation, Boston University. 211 p.

Hopkins, E. M., 1992, *Paleogeomorphic and sedimentologic framework of Bradford and Venango Group shorelines in northern Pennsylvania*, in Sevon, W. D., ed., *Geology of the upper Allegheny River region in Warren County, northwestern Pennsylvania*. Guidebook, 57th Annual Field Conference of Pennsylvanian Geologists, Warren, PA, p. 21-46

Kaiser, S. I., Steuber, T., and Becker, R.T., 2006, *Geochemical evidence for major environmental at the Devonian-Carboniferous boundary in the Carnic Alps and Rhenish Massif*. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 240, p. 146-160.

Lytle, W. S., 1959, *Introduction to bedrock and oil geology of northwestern Pennsylvania and the Great Oildorado*. Guidebook, 24th Annual Field Conference of Pennsylvania

Geologists, Titusville, PA, Trip B, p. 12-76.

Mausser, H. F., 1982, *Stratigraphy and sedimentology of the Cleveland Shale (Devonian) in northeast Ohio*. Unpublished thesis, Case Western Reserve University.

Miller, J. D. and Kent, D. V., 1988, *Paleomagnetism of the Silurian-Devonian Andreas red beds: evidence for an Early Devonian supercontinent?* Geology, v. 16, p. 195-198.

Murphy, J. L., 1973, **Protosalvinia** (**Foerstia**) *zone in the Upper Devonian sequence in eastern Ohio, northwestern Pennsylvania, and western New York*. Geological Society of America Bulletin, v. 84, p. 3405-3410.

Newberry, J. S.,1889, *The Palaeozoic fishes of North America*. U.S. Geological Survey Monograph 16, 340 p.

Over, D. J., Lazar, R., Baird, G. C., Schieber, J., and Ettensohn, F. R., 2009, **Protosalvinia** *Dawson and associated conodonts of the upper* **Trachytera** *zone, Famennian, Upper Devonian, in the eastern United States*. Journal of Paleontology, v. 83, p. 70-79.

Pashin, J. C. and Ettensohn, F. R., 1995, *Reevaluation of the Bedford-Berea sequence in Ohio and adjacent states: Forced regression in a foreland basin*. Geological Society of America Special Paper 298, 68 p.

Pepper, J. F., deWitt, Jr., Wallace, and Demarest, D. F., 1954, *Geology of the Bedford Shale and Berea Sandstone of the Appalachian basin*. U. S. Geological Survey Professonal Paper 259, 111 p.

Sallan, L., 2009, *The impact of the Late Devonian biotic crisis on global vertebrate diversity: results from a new Paleozoic database* (abs). Ninth North American Paleontological Convention, Cincinnati Museum Center Contribution 3, p. 462-463.

Sandberg, C. A., Morrow, J. R., and Ziegler, W., 2002, *Late Devonian sea-level changes, catastrophic events, and mass-extinctions*, in Koeberl, C., and MacLeod, K. G., eds., *Catastrophic events and mass extinctions: impacts and beyond*. Geological Society of America Special Paper 356, p. 473-487.

Sandberg, C. A., and Ziegler, W., 1979, *Taxonomy and biofacies of important conodonts of the North American styriacus – zone, United States and Germany*. Geologica et Palaeontologica, v. 13, p. 173-212.

Sass, D. B., 1960, *Some aspects of the paleontology, stratigraphy, and sedimentation of the Corry Sandstone of northwestern Pennsylvania*. Bulletins of American Paleontology, v. 41, p. 247-381.

Schiner, G.R. and Kimmel, G.E., 1972, *Mississippian stratigraphy of northwestern Pennsylvania*. U. S. Geological Survey Bulletin 1331-A, 27 p..

Sevon, W. D., 1973, *Glaciation and sedimentation in the Late Devonian and early Mississippian* (abs), Geological Society of America, v. 6, p. 218-219.

Sherrill, R. E., and Matteson, L. S., 1941, Oil and gas geology of the Franklin quadrangle, Pennsylvania. Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 24, 71 p.

Streel, M., 2008, *Upper and uppermost Famennian miospore and conodont correlations in the Ardenne-Rhenish area*. Subcommission on Devonian Stratigraphy Newsletter 23, p. 35-39.

Tesmer, I. H., 1963, *Geology of Chautauqua County, New York: Part I, Stratigraphy and Paleontology (Upper Devonian)*. New York State Museum Bulletin 391, 65 p.

Van der Voo, R., 1988, *Paleozoic paleogeography of North America, Gondwana, and intervening displaced terranes: Comparisons of paleomagnetism with paleoclimatology* *and biogeographical patterns*. Geological Society of America Bulletin, v. 100, p. 311-324.

Ward, A. N., Chapman, W. F., Lukert, M. T., Craft, J .L., 1976, *Bedrock and glacial geology of northwestern Pennsylvania in Crawford, Forest and Venango Counties*. Guidebook, 41st Annual Field Conference of Pennsylvania Geologists, Titusville, PA, 64 p.

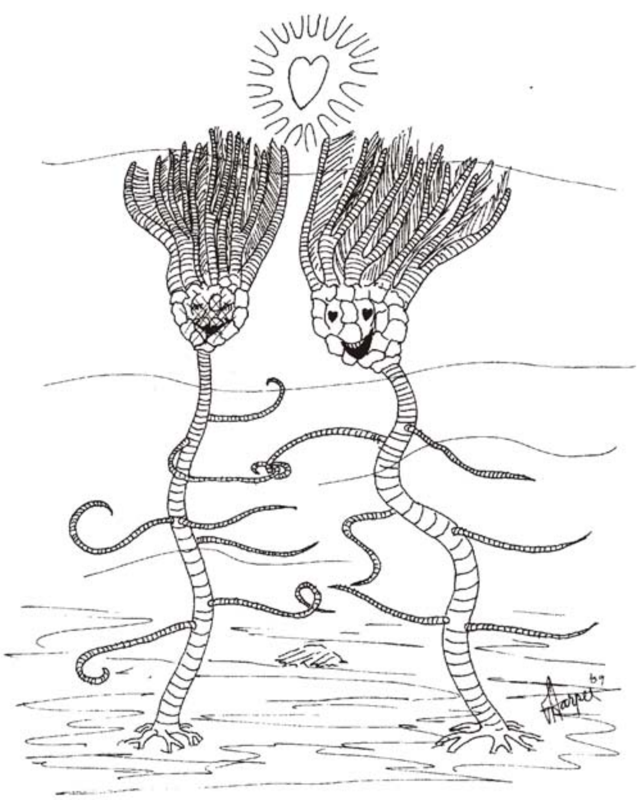
White, I. C., 1881, *The geology of Erie and Crawford counties*. Pennsylvania Geological Survey, 2nd ser., Report Q4, 406 p.

Woodrow, D. L., 2006, *Haystacks without hay*, in Inners, J. D., and Fleeger, G. M., eds., *The Haystacks, "Ricketts Folly," and the end of the world: Geology of the Glaciated High Plateau, Sullivan, Luzerne and Columbia Counties, Pennsylvania*. Guidebook, 71st Annual Field Conference of Pennsylvania Geologists, Ricketts Glen State Park, PA, p. p. 17-31.

Zagger, G. W., 1993, *Preliminary conodont biostratigraphy of the uppermost Famennian Ohio Shale in northeast Ohio*. Geological Society of America, Abstracts with Programs, v. 25, no. 7, p. 92.

GREAT MOMENTS IN GEOLOGIC HISTORY

Part 3: The Mississippian



Ahh, mon Cheri, I love ze way your ambulacral grooves flutter when you laugh . . . ze rosy blush of your thecal plates . . . ze soft calcitic touch of your cirri. Come wizz me to ze PanThallassic and we'll filter-feed together!

IS *TITUSVILLIA* A SPONGE?

Scott C. McKenzie

The fossil *Titusvillia drakei* (Figure 1) was named by Kenneth Caster in 1939 based on fossils recovered at several localities near the Drake Well in Titusville, Pennsylvania (Caster, 1939). In the original description, Caster identified the fossil as a glass sponge (Hexactinellida: Reticulosa) from the Mississippian period. In his 1941 article, he discusses several other fossils that he and others interpreted as related sponges: *Armstrongia* and *Protoarmstrongia* (Caster, 1941). Further examination of Caster's illustrations and casts as well as specimens recently collected by the present author raise serious questions as to whether *Titusvillia* is actually a sponge.

Figure 1. A typical "*Titusvillia*" (*Armstrongia oryx)* from the "Drake Well Formation," Venango County, PA. 6 cm long. Collections of S. C. McKenzie.

Hexactinellid reticulose sponges possess spicules that form a window-screen-like surface on the fossils. Although Caster did show detailed drawings of these spicules in his article, he did note that they were too poorly preserved to analyze and called the spicules he drew "possible," and the other anatomical structures as being "apparently" there. None of the illustrations or casts of his specimens, or any of the recently examined materials show the features in the Caster diagrams.

Caster, also partly based his interpretation on comparisons with *Armstrongia* (Figure 2), which was also interpreted to be a sponge (Clarke, 1920). In the late 1800's through early 1900's, a gentleman collector named Edwin J. Armstrong was actively seeking fossils from Devonian outcrops and quarries in the area of Erie, Pennsylvania. Armstrong was co-inventor of the steam shovel, a situation that allowed him to build a mansion on "millionaires' row" in the City of Erie and gave him the time and freedom to collect. Armstrong often sent unusual or hard to identify fossils to John Clark, a co-worker of James Hall. Armstrong found several curious fossils in Erie County, PA that Clark identified as a new Late Devonian sponge he named *Armstrongia oryx* after the diligent collector.

Although Caster believed *Titusvillia* to be a Mississippian relative of *Armstrongia* the formation that yielded *Titusvillia* has since been reassigned to the Late Devonian (see Baird and others, this volume, p. 5-30). *Armstrongia* closely resembles *Titusvillia;* both show a variety of

McKenzie, S. C., 2009, *Is* **Titusvillia** *a sponge?* in Harper, J. A., ed., *History and geology of the oil regions of northwestern Pennsylvania*. Guidebook, 74th Annual Field Conference of Pennsylvania Geologist, Titusville, PA. p. 32-34.

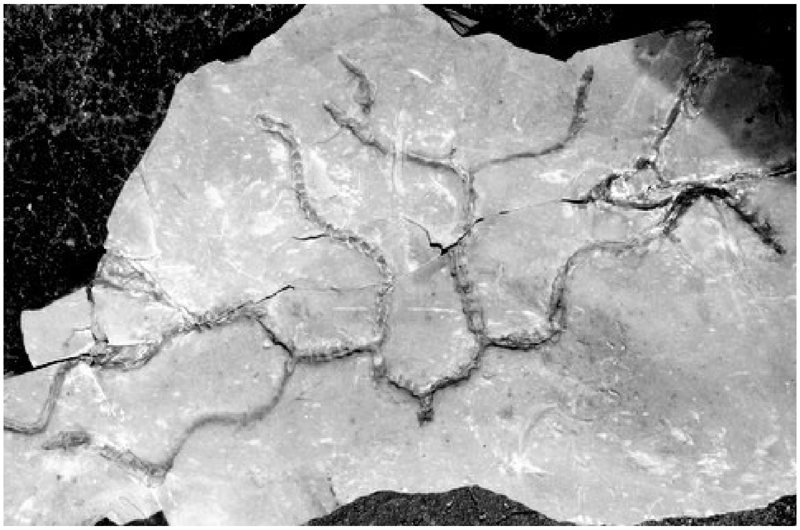


Figure 2. ***Armstrongia oryx*** **showing horizontal graphoglyptid-like habitus that looks superficially sponge-like but close examination shows no sponge structure. From the Chadakoin Formation near Waterford, Erie County, PA. 57 cm wide. Collections of S. C. McKenzie.**

Figure 3. ***Armstrongia oryx*** **showing the plunging tube shape connected to the annulated mode. From the Chadakoin Formation near Waterford, Erie County, PA. 14 cm. long. Specimen seen in field.**

forms that are preserved with and are preserved like undisputed trace fossil genera. Specimens have been observed in the field showing where the trace maker plunged down through layers of sediment halting its annulated form and turning into a simple tube (Figure 3). In addition, this trace is often found telescoped with the "branches" tightly together (Figure 4), its form probably reflecting a change in feeding pattern or nutrient level in the sediments. The abrupt annulations on *Titusvillia* could be interpreted as the action of peristaltic motion of a linear, worm-like organism in soft sediment. However, the confirmation of this hypothesis will require careful comparative study of soft-sediment trace-making in modern settings where similar structures are being

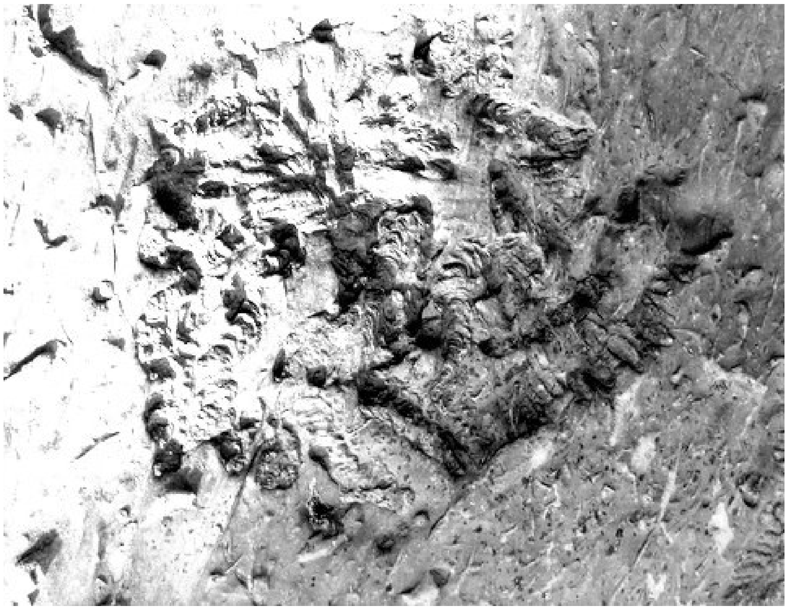


Figure 4. ***Armstrongia oryx*** **showing telescoping closely spaced annulations and crowded branches. From just below the Cussawago Sandstone near Meadville, Crawford County, PA. 12 cm wide. Specimen seen in field.**

formed today.

Both of these genera seem to be trace fossils and not sponges. In addition, the name *Titusvillia* is a junior synonym of *Armstrongia*. Other supposed sponges that are probably also icnogenera include *Protoarmstrongia,* Caster, 1941 *Ozospongia,* Clark, 1918 and *Iowaspongia* Thomas, 1923. The family Titusvillidae Caster, 1939 needs to be seriously reexamined.

There are unusual glass sponge fossils in the North Western Pennsylvania sections. Magnificent *Ceratodictya*, as much as 30 inches long, are found in the Northeast Shale, and one rare *Hydnoceras* was found in the Riceville Sandstone near Saegertown, other genera such as *Prismodictya* are occasionally found as well as other undescribed forms. Serious searches will undoubtedly turn up additional interesting sponge material in this region.

REFERENCES

Caster, K. E., 1939, *Siliceous sponges from Mississippian and Devonian strata of the Penn-York embayment*. Journal of Paleontology, v. 13, p. 1–20.

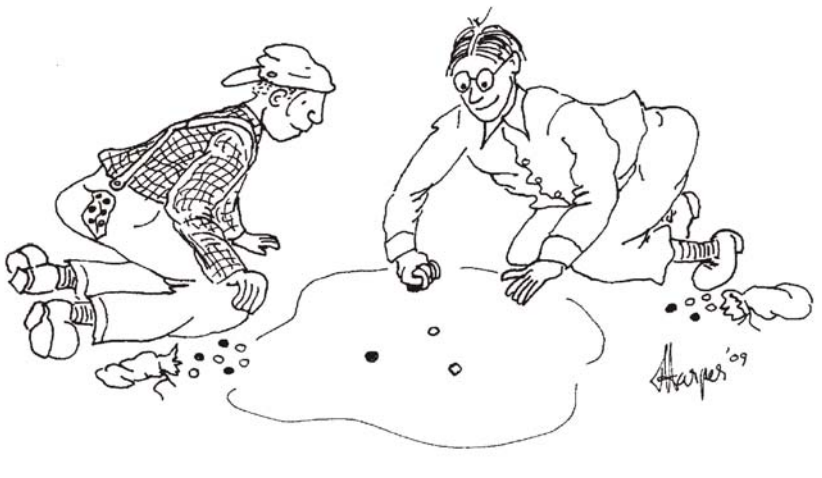
Caster, K. E., 1941, *The Titusvillidae: Paleozoic and Recent branching Hexactinellida*. Palaeontographica Americana, v. 2, p. 470–523.

Clarke, J. M., 1918, *Devonian glass sponges*. New York State Museum Bulletin 196, p. 177-198.

Clarke, J. M., 1920, **Armstrongia**, *a new genus of Devonian glass sponges*. New York State Museum Bulletin 219–220, p. 143–146.

Thomas, A. O., 1923, *Some new Paleozoic glass-sponges from Iowa*. Proceedings, Iowa Academy of Science, 1922, v. 29, p. 85-88.

HARPER'S GEOLOGICAL DICTIONARY



LITHOSPHERE - A small sun-dried clay ball your grandparents used to play marbles with. Also, see AGATE.

PHYLLOCARIDS FROM THE LATE DEVONIAN OF NORTHWESTERN PENNSYLVANIA

Scott C. McKenzie

Phyllocarid arthropods are unusual fossils in the Upper Devonian succession of northwestern Pennsylvania. Most that have been found are of the genus *Echinocaris:* one, identified by Joe Hannibal (Cleveland Museum of Natural history) as *E. multinodosa*, was found by Sandy Porter in a streambed near Saegertown in Crawford County Pennsylvania some years ago. Another *Echinocaris* was collected by Gordon Baird near Waterford, Erie County Pennsylvania.

The present author found several specimens of *Echinocaris randallii* (see Feldmann and others, 1992) at the "type section" of the "Drake Well Formation" south of Titusville in Venango County PA; this outcrop (see Stop 6) is a west-facing railroad cut exposure across from the entrance to the Drake Well museum and park complex. Most of the specimens collected at this section are currently reposited in the invertebrate Paleontology collections at the Carnegie Museum. It is interesting to note that these phyllocarids are associated with *Lingula*-rich shell hash. This is similar to the situation in the Chagrin Shale in Ashtabula County Ohio, where several species of *Echinocaris* are found with coprolites containing *Lingula* hash. The duraphagus echinocarids had a molariform mandible that may have crushed *Lingula*. In the "Drake Well Formation," as in the Chagrin, the phyllocarids are associated with a diverse fauna that includes trace fossils, echinoderms, mollusks, brachiopods, sponges, placoderms, sharks and rarer elements.

Associated with the echinocarids at the Titusville site are the first reported examples of *Tropidicaris alternata* Beecher, 1884 (Figure 1). *Tropidicaris* has a strongly ridged carapace and abdomen which may have helped anchor it in loose sediment. Both species of phyllocarid are represented by tiny as well as large individuals. It is present in approximately the same abundance as *Echinocaris*. *Tropidicaris* probably had a different life style from *Echinocaris*. The Chagrin also has rare *Elmocaris*- like phyllocarids (similar to *Tropidicaris*) in association with its echinocarids.

Tropidocaris was originally found in the Waverly Group in Warren County, PA with the original *E. randallii* specimens. This indicates a faunal association that

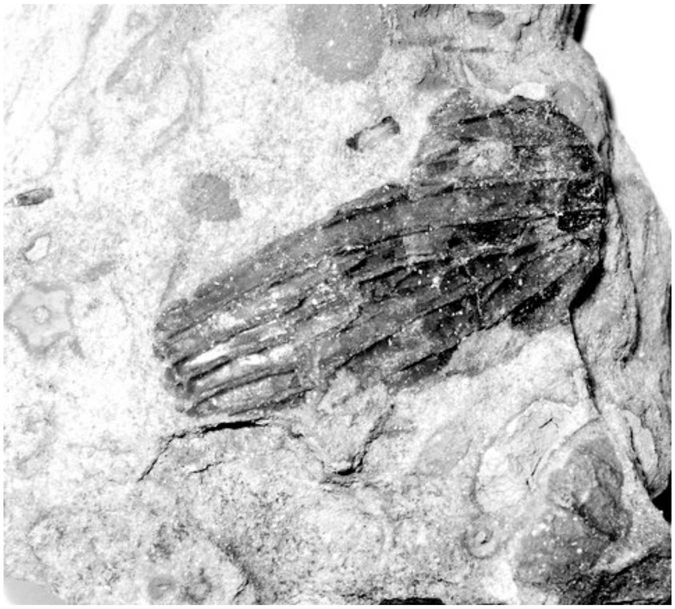


Figure 1. *Tropidocaris alternate,* 2 cm-long carapace, showing the right valve and partial left valve, from the "Drake Well Formation" near Titusville, Venango County, PA. Collections of S. C. McKenzie.

McKenzie, S. C., 2009, *Phyllocarids from the Late Devonian of northwestern Pennsylvania*, in Harper, J. A., ed., *History and geology of the oil regions of northwestern Pennsylvania.* Guidebook, 74th Annual Field Conference of Pennsylvania Geologist, Titusville, PA. p. 35-37.

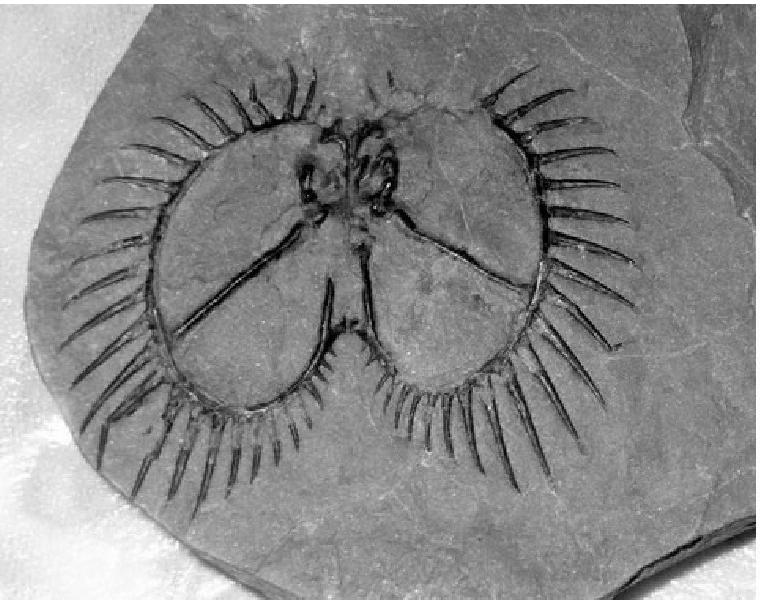


Figure 2. *Pephricaris* from Cattaraugus County, NY. Total width of fossil, 34 mm. Collections of S. C. McKenzie.

mirrors the occurrences of echinoids such as *Hyattichinus* and other fossil taxa in the two formations. This is the first occurrence of *Tropidocaris alternata* outside of Warren County. One additional example has been recovered near Waterford in the Chadakoin Formation.

In the early 1990's a huge specimen of the aberrant phyllocarid *Pephricaris* sp. (Figure 2) was recovered from a Meadville-area stream bed by Sandy Porter in the "Drake Well Formation." *Pephricaris* was known by three Western New York specimens described by Clark (1898). A few others were found by Dan Sass at Alfred Station, New York (Sass and Condrate, 1985). These specimens from the Late Devonian Alfred Shale may show differences in morphology (longer needle like spines and smoother carapace topography) from the others and may represent a new species. One additional example has been found circa: 1997 in the Chautauquan Series of Cattaraugus County, New York (Figure 3). Apparently the marginal spines shortened during ontogeny.

The Meadville *Pephricaris* specimen may be the largest ever found. Its odd body plan may reflect adaptations for feeding. The animal might have used its spines and bivalved carapace to form a cage to corner prey items while swimming in the water column. Another hypothetical feeding mode is where the spines along the valves fit with the large abdominal spikes to allow water to be fanned backwards straining out prey items on the sea floor. It should be noted however that the longer spines on smaller examples may have been protective. The paired raised anterior areas probably housed muscle attachments for powerful crushing mandibles. The carapace of *Pephricaris* and the related Ohiocaris (see: Rolfe, 1962; Delle Cave and Simonetta 1991; Rode and Lieberman 2002) was characterized by separate hinged valves. *Pephricaris* and

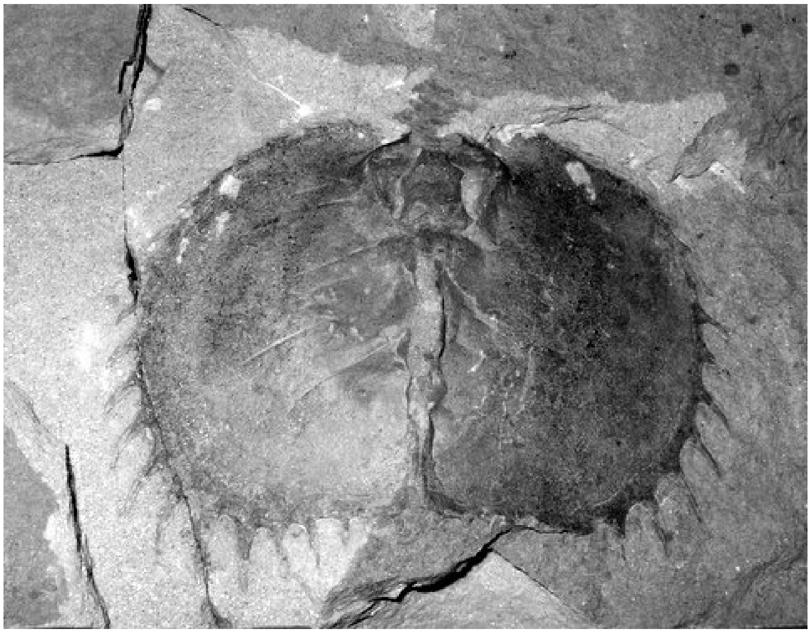


Figure SCM2-3. *Pephricaris horripilata* from the "Drake Well Formation." Width of fossil, 83 mm. Collections of S. C. McKenzie.

Ohiocaris, have highly restricted stratigraphic ranges and are among the rarest of Devonian phyllocarids. The occurrence of *Pephricaris* in the "Drake Well Formation" either indicates that this taxon was a rare component of the paleocommunity or simply a drifted molt.

REFERENCES

Beecher, C. E., 1884, Ceratiocarididae from the Chemung and Waverly groups of Pennsylvania. Second Geological Survey of Pennsylvania, v. PPP, p. 1-22.

Clark, J. M., 1898, Notes on some crustaceans from the Chemung Group of New York. 1. A singularly ornamented phyllocarid genus, *Pephricaris*. New York State Museum, 49th Annual Report of the Regents, 1895, v. 2, p. 731–733.

Delle Cave, L., and Simonetta, A. M., 1991, Early Paleozoic arthropods and problems of arthropod phylogeny; with some notes on taxa of doubtful affinities, *in* Simonetta, A. M., and Conway Morris, S., eds., The early evolution of Metazoa and the significance of problematic taxa. Clarendon Press, Oxford, p. 189–244.

Feldmann, R. M., Hannibal, J. T., Mullett, D. J., Schwimmer, B. A., Tshudy, D., Tucker, A. B., and Wieder, R. W., 1992, The paleoecology of *Echinocaris randallii* Beecher from Drake Well, Titusville, Pennsylvania, *in* Proceedings of the F. D. Holland, Jr., geological symposium, Erickson, J. M., and Hoaganson, J. W., eds., North Dakota Geological Survey Miscellaneous Series 76, p. 137-147.

Rode, A. L., and Lieberman, B. S., 2002, Phylogenic and biogeographic analysis of Devonian phyllocarid crustaceans. Journal of Paleontology, v. 76, p. 271-286.

Rolfe, W. D. I., 1962, A new phyllocarid crustacean from the Upper Devonian of Ohio. Breviora, v. 151, p. 1-7.

Sass, D. B., and Condrate, R. A., 1985, Destruction of a Late Devonian ophiuroid assemblage: A victim of changing ecology at the Catskill delta front, in Woodrow, D. L., and Sevon, W. D., eds., The Catskill Delta. Geological Society of America Special Paper 201, p. 237–246.

. . . +click+ . . . Good evening, Mr. Phelps. Your mission, should you choose to accept it, will be to . . . +click+ . . . self destruct in five seconds . . . +click+ . . . Good evening, Mr. Phelps . . . +Click+

TABULATE CORALS FROM THE LATE DEVONIAN OF NORTHWEST PENNSYLVANIA

Scott C. McKenzie

Corals are rarely found in the Upper Devonian rocks of northwest Pennsylvania. This succession, including the Chadakoin Formation, Venango Group, Riceville Formation, and the "Drake Well Formation" were deposited after the Frasnian/Famennian extinction event which may have been the result of a bolide impact (see McGhee, 1996). It is possible that a major global cooling followed making corals and trilobites virtually absent from local formations. Perhaps cool water-tolerant glass sponges replaced the warmth loving corals and both phyllocarids and horseshoe crabs took the place of the trilobites at this time.

Only three coral occurrences are known to this author from the Late Devonian rocks of northwest Pennsylvania. A single unidentified Favositid specimen was found in the Chadakoin Formation in an outcrop near Waterford, Erie County, PA along with a suspected auloporid colony attached to *Cyrtospirifer,* a spiriferid brachiopod. A few tabulate corals belonging to the genus *Pleurodictyum* have been collected in the Northeast Shale near Lawrence Park in Erie, and one Pleurodictyum specimen was found in the Venango Formation near Waterford in the 1970's.

The "Drake Well Formation" also yields *Pleurodictyum* in moderate numbers. Although Feldmann and others (1992) did not record any specimens from this unit, the present author has

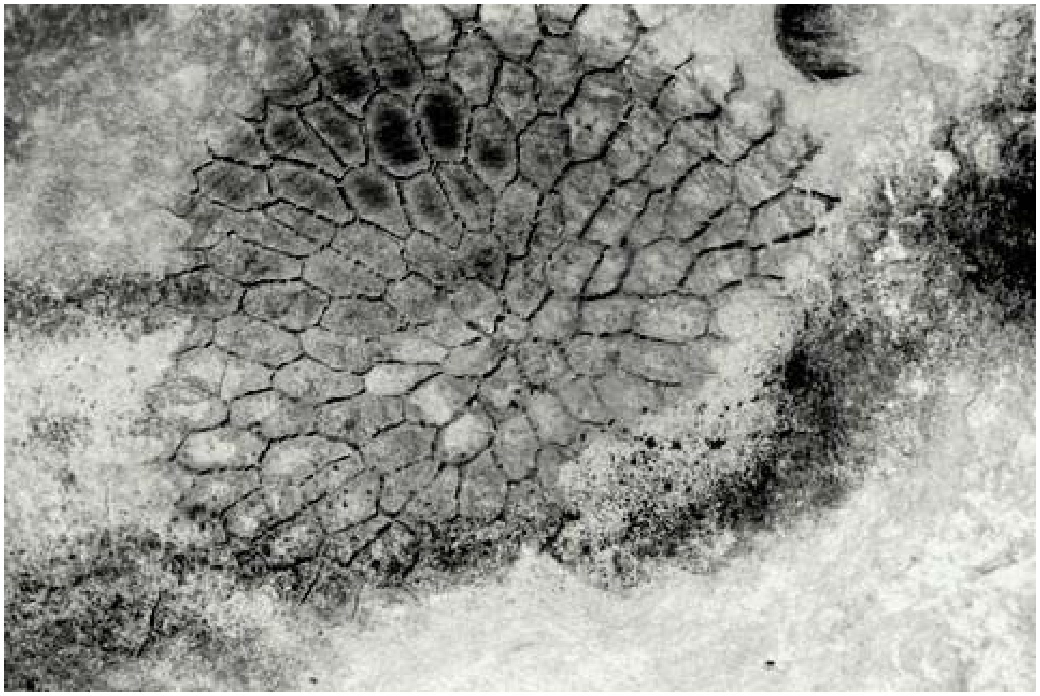


Figure SCM3-1. A large 5 cm-diameter *Pleurodictyum* colony from the "Drake Well Formation" found in the west-facing railroad cut opposite the entrance to the Drake Well Museum (see Stop 6). Collections of S. C. McKenzie.

McKenzie, 2009, *Tabulate corals from the Late Devonian of northwest Pennsylvania*, in Harper, J. A., ed., *History and geology of the oil regions of northwestern Pennsylvania*. Guidebook, 74th Annual Field Conference of Pennsylvania Geologist, Titusville, PA. p. 38-39.

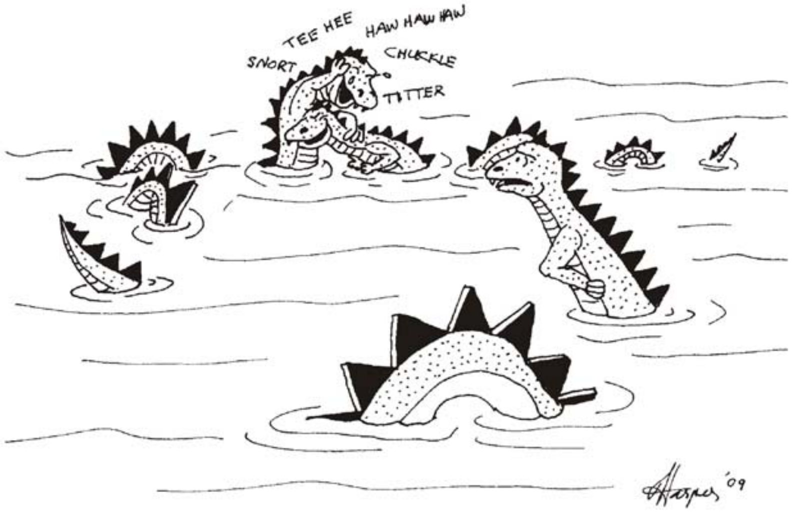
found about a dozen specimens at the “Drake Well Formation type section” opposite the Drake Well museum and park complex (see Stop 6). These distinctive tabulate colonies are discoidal with sub radial corallites. Under optimal growth conditions, such as associated with deposition of the Middle Devonian Onondaga Formation in Southern Ontario, they could reach 10-inch horizontal diameters. *Pleurodictyum* from the Middle Devonian Hamilton Group is typically found attached to hard shells or debris, preserving an impression of the hard object on the lower side of the colony. This phenomenon has not yet been observed in the Upper Devonian of Pennsylvania. The commensal worm tube *Hicetes* also appears to be absent here.

The largest colony, found at the “Drake Well Formation” railroad section, is preserved as a mold, measuring about two inches across (**Figure SCM3-1**).

REFERENCES

Feldmann, R. M,. Hannibal, J. T., Mullett, D. J., Schwimmer, B. A., Tshudy, D., Tucker, A. B., and Wieder, R. W., 1992, The Paleoecology of *Echinocaris randallii* Beecher From Drake Well, Titusville, Pennsylvania, *in* Erickson, J. M. and Hoganson, J. W. eds., Proceedings of the F. D., Holland, Jr. Geological Symposium. North Dakota Geological Survey Miscellaneous Series 76, p. 137-147.

McGhee, Jr., G. R., 1996, The Late Devonian mass extinction the Frasnian/ Famennian crisis. Columbia University Press, New York, 303 p.



But I tell you, I DID see a human. They AREN'T just figments of our imaginations!

A BRIEF OVERVIEW OF THE ECONOMIC GEOLOGY OF VENANGO COUNTY, PENNSYLVANIA

John A. Harper

Introduction

Northwestern Pennsylvania is a classic area for the study of both Upper Paleozoic and Quaternary geology. It has attracted interest from geologists dating back to the early days of geological studies in the United States. Comprehensive surveys of the geology of the region (together with the remainder of Pennsylvania) were undertaken in the 1870s by the Second Pennsylvania Geological Survey. The early publications resulting from that effort (e.g., Carll, 1875; White, 1881; Lesley, 1885) remain a useful source of information more than a century later. On this field trip we will have the opportunity to examine some outcrops of representative Upper Devonian, Mississippian, and Pennsylvanian strata.

Northwestern Pennsylvania, and Venango County in particular, is the region where the petroleum industry was born, and its history is rich with anecdotes as well as solid scientific fact. Many publications of the Second Geological Survey of Pennsylvania were devoted to the origin and occurrence of petroleum (e.g., Carll, 1875, 1880, 1883; Randall, 1875), and these were followed in the Fourth Pennsylvania Geological Survey by such worthy additions as Dickey (1941), Sherrill and Matteson (1941), Dickey and others (1943), and Kelley (1967).

Extension of stratigraphic terminology eastward has resulted in major confusion of the limits and names of many Upper Devonian units. West of Venango County, Upper Devonian units traditionally include, from youngest to oldest, the Berea Sandstone, Bedford Shale, Cussewago Sandstone, Riceville Formation, and Venango Formation. This division has often been extended eastward into Venango County and beyond. Typically, the only exception has been the replacement of the Berea with the Corry Sandstone, which is lithologically distinct. The problems caused by this extension are substantial, but are addressed in great detail by Baird and others (this guidebook – see p. 5-31) and will not be discussed here.

Venango County has had a long history of economic mineral resources. Petroleum (oil and natural gas) is the most noticeable of these, but it certainly isn’t the only one. The earliest non-fuel mineral resource was limestone, used by farmers for agricultural lime. Sand and gravel, which are abundant in the county, became important as aggregate with the development of the construction industry. Coal probably was mined locally by farmers and iron manufactures, but has not been a major mineral resource in the county. The discovery of siderite nodules and layers associated with some of those limestones led to Venango County’s first industry—iron manufacturing.

Oil and Natural Gas

By 1860, Venango County had a thriving oil business and by 1880, western Pennsylvania supplied more than half of the total world supply of oil. In fact, it wasn’t until the discovery of oil in Texas in 1903 that Pennsylvania lost its place as the world’s primary oil producer. Many

Harper, J. A., 2009, *A brief overview of the economic geology of Venango County, Pennsylvania,* in Harper, J. A., ed., *History and geology of the oil regions of northwestern Pennsylvania*. Guidebook, 74th Annual Field Conference of Pennsylvania Geologist, Titusville, PA. p. 40-57.

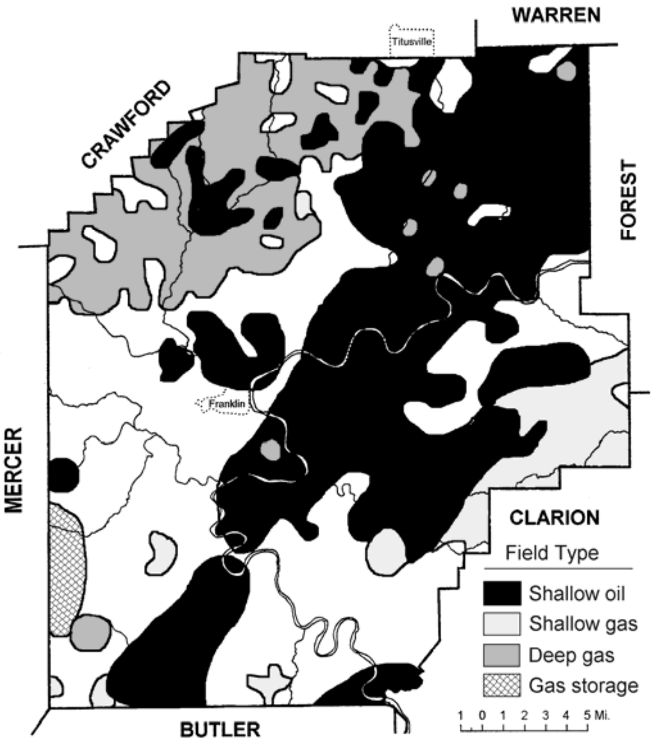


Figure 1. Oil and gas fields map of Venango County (modified from Pennsylvania Geological Survey, 1993).

modern production, refining, and transportation industries originated in this area. Petroleum geology and engineering were invented here, primarily by John F. Carll, a geologist with the Second Geological Survey of Pennsylvania (Lytle, 1957; Owen, 1975; Harper, 1990, 2002). Today, Pennsylvania produces less than 1 million barrels of oil annually, and Venango County is known more for its oil history than its oil industry.

The oil and gas industry of Venango County is still in business, although it has slowed considerably since the heyday of the late 1800s. Oil from the Upper Devonian Venango Formation, and oil and natural gas from the Bradford Group, are not nearly as important now as they were up to about 1970. Many of the old oil and gas fields (Figure 1) have long been abandoned, the oil depleted or too difficult to draw from the reservoirs. The abnormally low price for crude oil, plus the high cost of adhering to current environmental laws, has essentially made the oil business a liability for all but the most ardent companies. There are still wells producing oil in Venango County, and the major refineries still cook up some of the best motor oils in the world, but the “black gold” fever of yesterday is little more than a memory. Today, drilling for natural gas in the Lower Silurian Medina Group constitutes the majority of petroleum activity in northwestern Pennsylvania. This is also true for Venango County where Medina activity has been slowly but steadily creeping southeastward from the main fields of Crawford and Mercer counties.

Source Rocks and Traps

According to Laughrey (1991), the black, organic-rich mudrocks of the Upper and Middle Devonian and Upper Ordovician are the only reliable source rocks for all known hydrocarbons in Pennsylvania.

Traps typically are stratigraphic, consisting of lateral pinchouts, diagenetic changes (porosity and permeability barriers), and mudrock seals. During his tenure as State Geologist in the late 1800's, J. P. Lesley tried to impress upon the oil industry that oil production in northwestern Pennsylvania occurs as a result of stratigraphy and regional dip, without benefit of anticlinal control (Lesley, in Carll, 1886). However, structural traps are important locally where subtle folds and minor faults occur.

Although Medina Group reservoirs produce primarily as a result of stratigraphic traps, regional fracture patterns may also be important. As these become better known, the use of

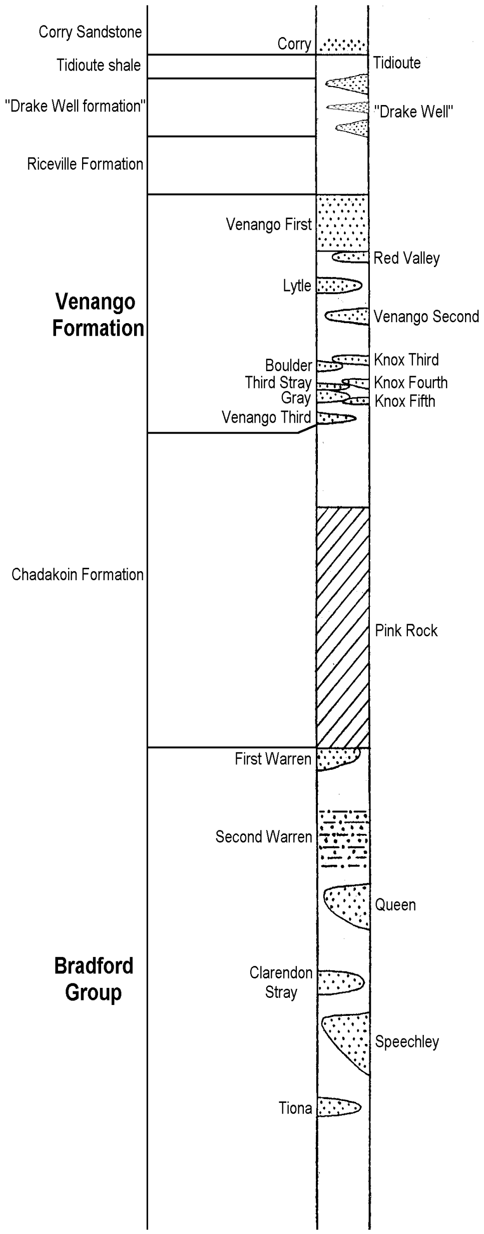


Figure 2. Stratigraphic column of the Venango Formation and Bradford Group showing both the formal names (left) and the drillers names (adjacent to the column).

lineament studies may benefit Medina operators in Venango County as they have benefitted certain operators in Crawford and Venango Counties (Zagorski, 1991).

Major Reservoir Rocks

The major reservoir rocks of Venango County include the Upper Devonian Venango Formation and Bradford Group (Figure 2) , and the Lower Silurian Medina Group. Subsidiary production has been found in the Mississippian, but it is essentially restricted to a few small fields or pools. To date, nothing has been found in the Middle Devonian Onondaga Limestone, the Lower Devonian Oriskany Sandstone, or Upper Silurian Lockport Dolomite.

Venango Formation: In Venango County the Venango Formation consists of a variable amount of interbedded sandstone, siltstone, and shale sandwiched between two fairly persistent zones of sandstone called the Venango First and Venango Third sandstones (Figure 2). The group as a whole can be traced across the county, and throughout western Pennsylvania, but specific identification of the reservoir sandstones within it becomes increasingly difficult toward the east where Catskill "red bed" lithologies (the Cattaraugus Formation of earlier authors) tend to dominate the section between the upper and lower sandstones. To complicate matters further, to the south and east additional sandstone units develop below the Venango Third. These sandstones act to extend the group downward into the subjacent Chadakoin Formation.

Typical Venango Formation reservoir rocks consist of relatively thick sequences of interbedded sandstones, siltstones, and shales with the pay section restricted to the sandstones. These rocks consist of fine-grained quartz sand thoroughly cemented by authigenic silica, but lenses of coarse-grained sandstones and pebble conglomerates are common, especially near the tops of the beds. There seems to be a direct relationship between grain size and amount of cement, such that the finer the grain size the more cementation; the pebbly beds commonly are friable (Dickey, 1941). Constituent grains consist mostly of white quartz, but yellow quartz is common. Feldspars, rock fragments, and heavy minerals are rare to absent. Sandstone geometries suggest that these rocks developed in very nearshore conditions that may be interpreted as beaches, barrier bars, and tidal channels (Dickey, 1941; Dickey and

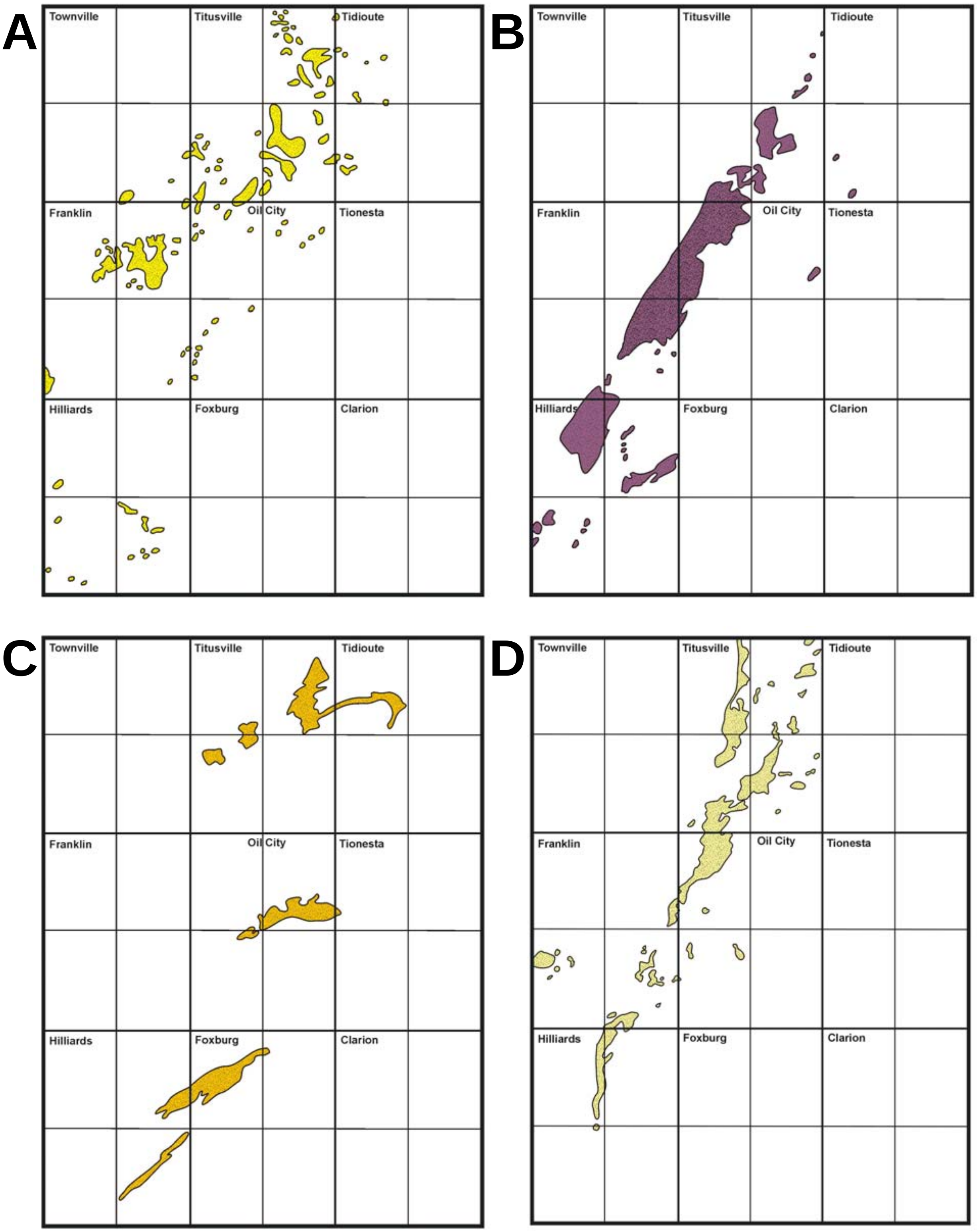


Figure 3. Most productive areas of the Venango sandstones in Venango County, illustrating their beach, bar, and shelf sand depositional environments (modified from Dickey and others, 1943). A—Venango First sandstone. B—Venango Second sandstone. C—Venango Third Stray sandstone. D—Venango Third sandstone. Names indicate 15-minute quadrangles.

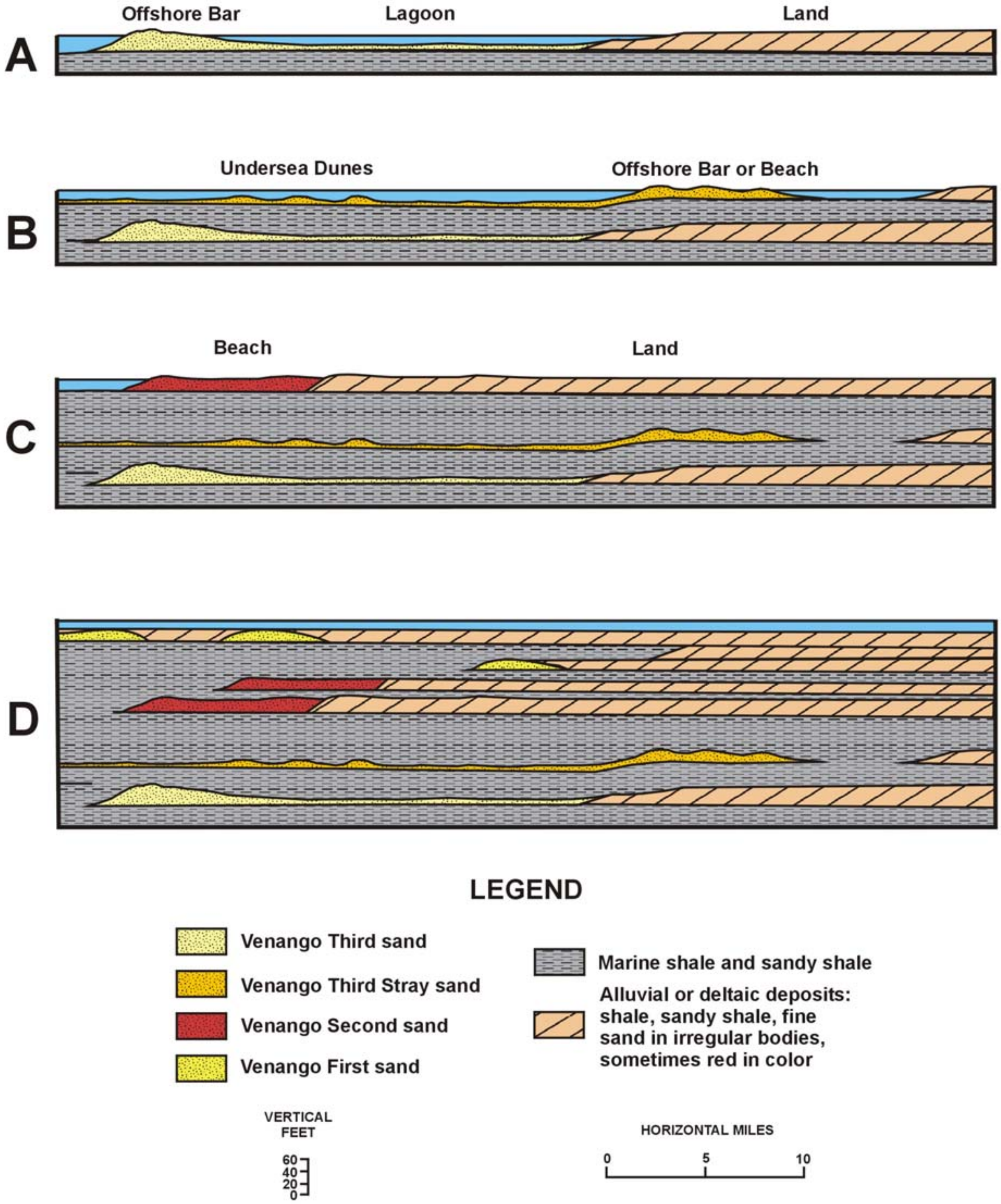


Figure 4. Depositional sequence of the primary Venango oil sandstones in Venango County (modified from Dickey and others). A—Venango Third sandstone. B—Venango Third Stray sandstone. C—Venango Second sandstone. D—Venango First sandstone.

others, 1943; Kelley, 1967). (Figures 3 and 4)

Venango Formation sandstones have exceedingly variable porosities and permeabilities (Figures 5 and 6). Porosities range from less than 5 to 25 %, averaging 15 % in the pay zones. Permeabilities range from less than 0.1 to 4,000 millidarcies, with a range of 10 to 500 millidarcies in the best reservoirs. Oil saturations range from 10 to 50 %, averaging less than 30 %, whereas water saturations typically range from 40 to 60 %. Of course, these data were derived from the more productive portions of the reservoirs, most of which were drilled prior to World War II. Since that time much of the Venango Formation drilling in Venango County has been relegated to the more marginal parts of the reservoirs where porosities, permeabilities, and oil saturations are lower and water saturations are higher.

Venango Formation sandstones traditionally have been produced naturally by flush production, and by secondary recovery methods, including vacuum pumping and air-gas injection (Dickey, 1941; Lytle, 1955, 1959). In the latter method, air or natural gas is pumped into the reservoir rock to drive the oil toward one or more producing wells. Waterflooding, steam injection, and *in situ* combustion techniques also have been tried (Caspero and others, 1963; Lytle, 1966) but with little success. The highly variable nature of the rock, including broad ranges in permeability and fluid saturations, undoubtedly had a great effect on these methods, helping to channel fluids into the more permeable, already depleted portions of the reservoir.

*Bradford Group***:** Upper Devonian Bradford Group stratigraphy is shown in Figure 2. Like the Venango Formation, the Bradford Group consists of numerous reservoir sandstones interbedded with non-productive sandstones, siltstones, and shales. Based on cores recovered in McKean County and interpretation of lithology from geophysical logs in the Indiana-Westmoreland County area, the Bradford Group also contains a few thin marine limestones and numerous marine shale and siltstone zones. Future study of this group in the subsurface of western Pennsylvania may determine that these marine zones are regional in nature, thus providing ideal datums for stratigraphic correlation.

Although the Bradford Group consists of numerous major and minor sandstone strata in the primary producing areas of western Pennsylvania, in Venango County the only oil- and/or gas-producing strata within the group are the Speechley and Tiona sandstones.

Most Bradford Group reservoir sandstones consist of light-colored to reddish- or chocolate -brown, very fine- to coarse-grained sublitharenites. The dominant grain size is very fine to fine, but several of the reservoir sandstones contain abundant quartz pebbles near the tops of the units. The reservoir sandstones of the Bradford Group appear to have been deposited in a series of nearshore and shallow marine shelf environments. Distinctive beach/bar forms appear throughout the group in reservoir sand maps throughout western Pennsylvania (e.g. Ingham and others, 1956). Other depositional systems probably will be delineated as these rocks are studied more fully.

Although Bradford Group reservoirs exhibit variable porosities and permeabilities, they are not nearly so variable as those of the Venango Formation sandstones. Porosities generally range from about 5 to 25 %, averaging 10 % in the pay zones. Permeabilities range from less than 0.1 to more than 10,000 millidarcies in at least one field, but most reservoirs average about 0.3 millidarcy. oil saturations range from 5 to 45 %, averaging about 20 to 25 %. Water saturations typically are higher than oil saturations.

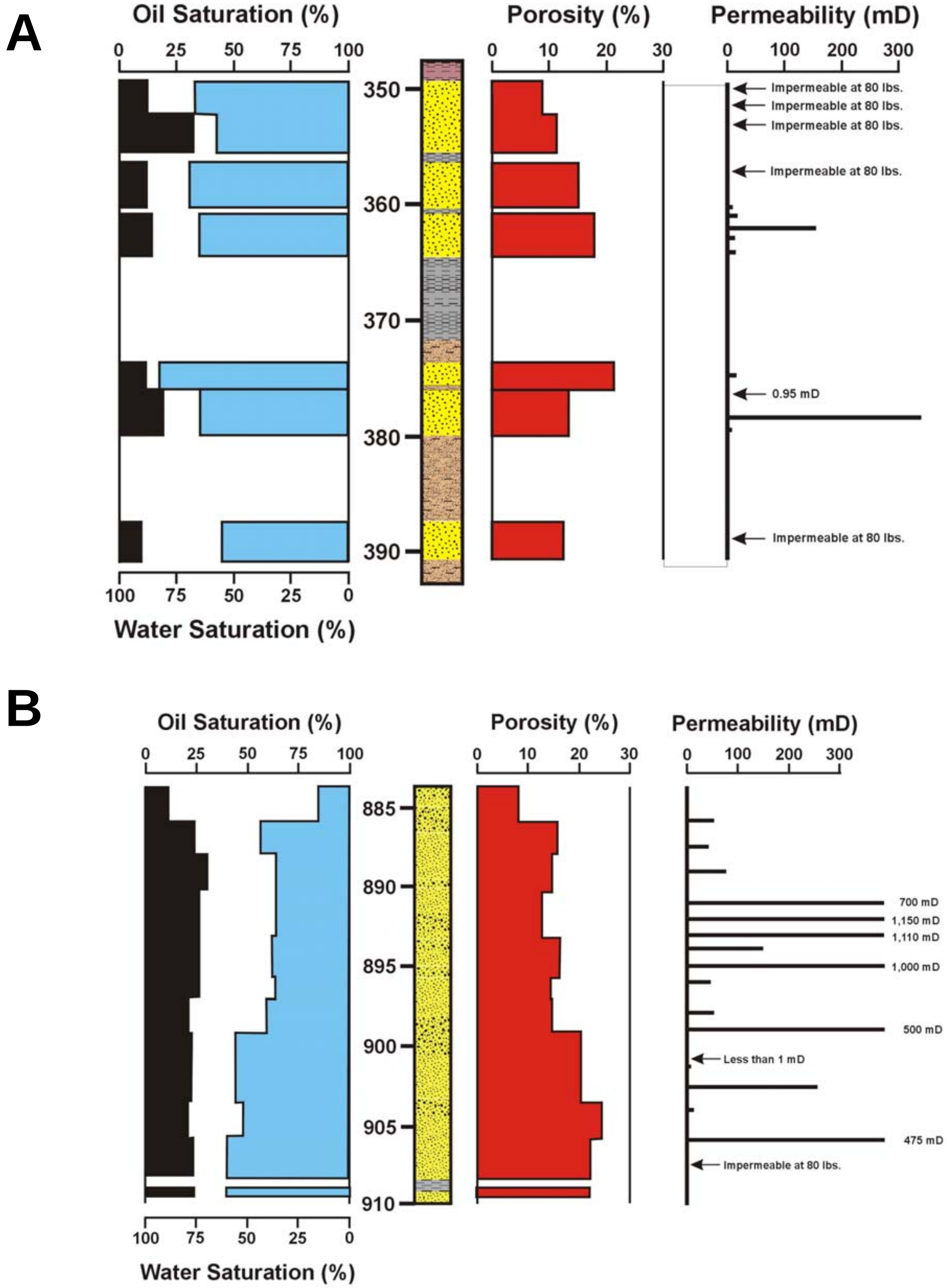


Figure 5. Characteristic core analyses of the Venango oil sandstones from Venango County. A—Venango First sand (modified from Dickey, 1941). B—Venango Second sand (modified from Sherrill and Matteson, 1941).

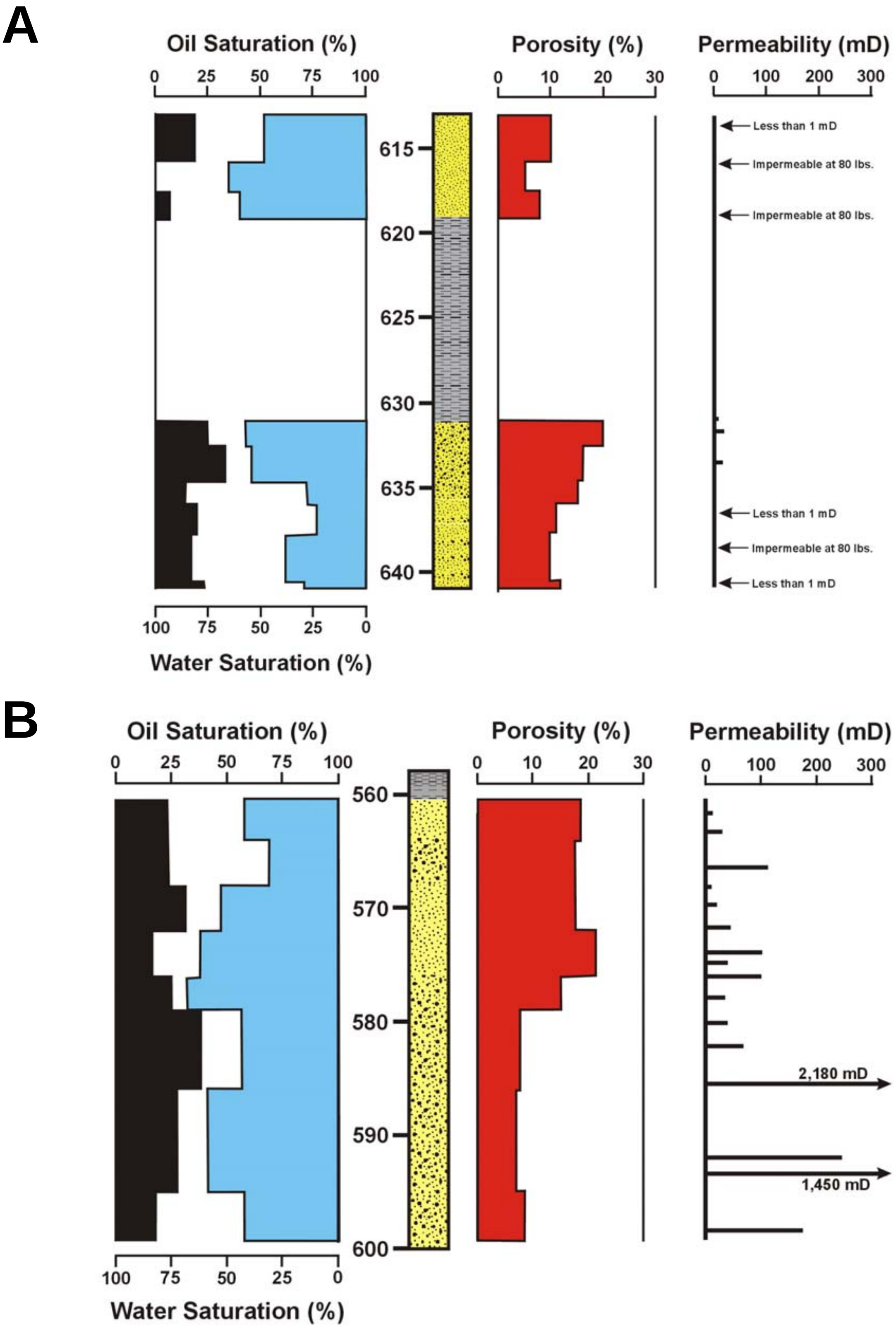


Figure 4. Characteristic core analyses of the Venango oil sandstones from Venango County. A—Venango Third Stray sand (modified from Sherrill and Matteson, 1941). B—Venango Third sand (modified from Dickey, 1941).

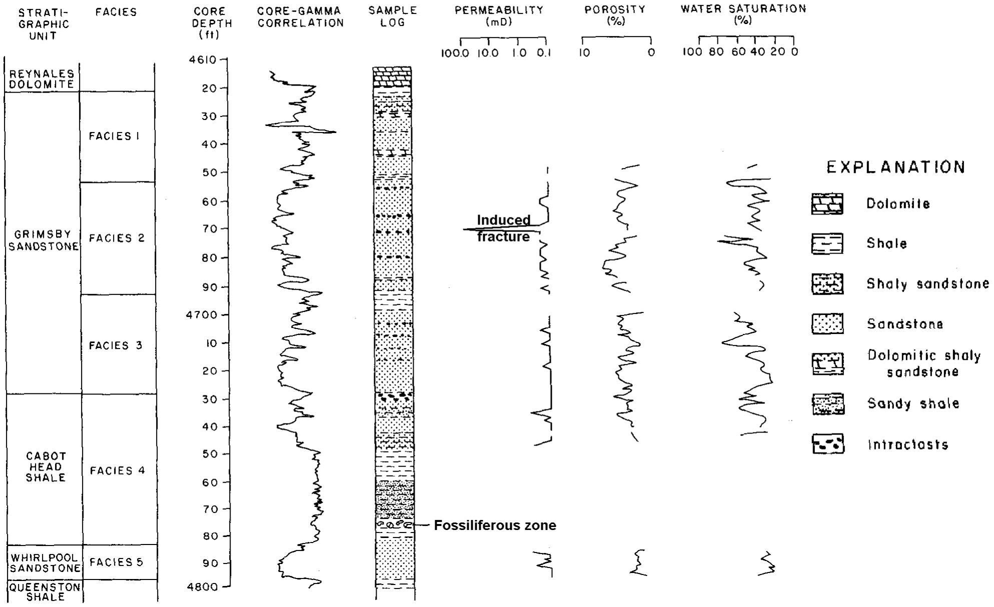


Figure 7. Stratigraphic column of the Medina Group and core analyses of the Craecraft #1 well in Athens Township, Crawford County (modified from Laughrey, 1984).

Medina Group: The Medina Group in Pennsylvania consists of three formations, an upper Grimsby Formation comprised of interbedded sandstones and shales, a middle Cabot Head Shale, and a lower Whirlpool Sandstone (Figure 7).

Grimsby sandstones typically consist of light gray to reddish-colored, very fine- to fine-grained quartz arenites, wackes, subarkoses, and sublitharenites interbedded with siltstones and mudstones of varying colors and compositions. Whirlpool sandstones typically are composed of light gray, very fine-grained, glauconitic, quartz arenites and subarkoses with light colored mudstone interlaminae. Medina sandstone geometries In are reminiscent of fluvial-deltaic deposits, and commonly are so described as far west as Ohio. Laughrey (1984), however, interpreted the Medina as mixed fluvial and paralic to marine deposits. Most authors describe the Whirlpool as a basal transgressive sandstone deposited on a low, eroded coastal plain developed on the Upper Ordovician Queenston Formation. The Grimsby sandstones apparently developed in mixed fluvial and nearshore settings, with individual sandstones representing ephemeral braided fluvial and paralic deposits (Laughrey, 1984)

The Medina Group sandstones have been characterized as "tight", that is, having very low porosities and permeabilities, throughout most of northwestern-Pennsylvania. Exceptions include areas of intense fracturing. Average measured and calculated permeabilities are less than 0.1 millidarcy throughout the section, but fracture permeabilities as high as 117 millidarcies have been measured by core analysis (Laughrey, 1984). Medina porosity ranges from less than 2 to almost 12 %, but average about 5 % (Laughrey and Harper, 1986). Water saturations as measured by core analysis range from 20 to more than 80 %.

For many years, Medina gas in producible economic quantities was almost restricted to the western third of Venango County (Figure 1, Deep gas). Since the mid-1980s most of the Medina activity has been infill drilling in developed fields. A few outpost/extension wells (wells drilled two or more locations away from established production) are reported every year, and these generally define the limits of risk in the Medina. This might change with renewed incentives such as considerably higher prices for natural gas.

Because the Medina Group sandstones are "tight" they require hydraulic fracturing to induce economic gas flow. Operators have been cautioned in designing stimulation procedures, however. Laughrey (1984) pointed out that there are a number of potential problems inherent in the composition of Medina sandstones that may be induced with the wrong type of stimulation material. Porosity and permeability reduction may occur as a result of: 1) acid-sensitive authigenic chlorite releasing iron as a gelatinous ferric hydroxide; 2) authigenic illite occurring as delicate fibers that tend to accumulate in the presence of fresh water; and 3) water-sensitive and acid-sensitive mixed-layer illite-chlorite clays that have properties of both. The mixed-layer clays are even more important as false indicators of high water saturation. Geophysical logs indicating high water saturations may be reading irreducible water locked up in clay micropores. Laughrey (1984) cautioned Medina operators to carefully evaluate their wells before abandoning them.

Sand And Gravel

Although sand and gravel (Figure 8) are not considered especially exciting mineral resources, they are essential to modern construction, especially paving and building. They are especially important for local uses because their relatively low value precludes long-distance shipping. In fact, construction sand and gravel typically is used within 30 mi. of the source (Craft, 1979). However, despite their low unit cost, the total amount produced in Pennsylvania during any given year exceeds 14.5 million tons and is worth more than $75 million. About 40% of this value is for sand and 60% is for gravel.

Sand and gravel rank third in both quantity produced and in dollar value in Pennsylvania among all non-fuel mineral resources. In 1997 Pennsylvania produced 14.5 million metric tons of sand and gravel, worth $84.4 million. Only crushed stone (93 million metric tons) and dimension stone (54.6 million metric tons) accounted for more volume (US Geological Survey, 1998).

By far the most important use for sand and gravel is in Portland cement concrete. Such concrete typically contains 80 to 85% aggregate by weight. In 1997, Pennsylvania concrete construction projects used 4,970 metric tons of sand and gravel valued at $34.2 million (US Geological Survey, 1998). The commercial sand and gravel industry uses the term *aggregate* to apply to sand or to sand-size crushed stone, and *coarse aggregate* to gravel or to crushed stone of gravel size. Sands are dominantly quartz, commonly with some admixture of lithics, micas, cherts, and "heavy minerals” such

Figure 8. Sand and gravel operation in glacial outwash on the Allegheny River near Franklin, Venango County.

as magnetite, olivine, and garnet. They are known more for their uniformity of composition than are gravels because the dominant constituents of gravel are rock fragments rather than mineral grains; thus, gravels are notably heterogeneous in composition. Gravel varieties may range from “soft” shales and mica schists to “hard” granites and quartzites. Sandstone, limestone, dolomite, chert, and cryptocrystalline volcanic rocks might also be found in gravel deposits. Sand often occurs without gravel (beaches and dunes), but gravel is seldom found without sand; in Venango County, you don’t get one without the other.

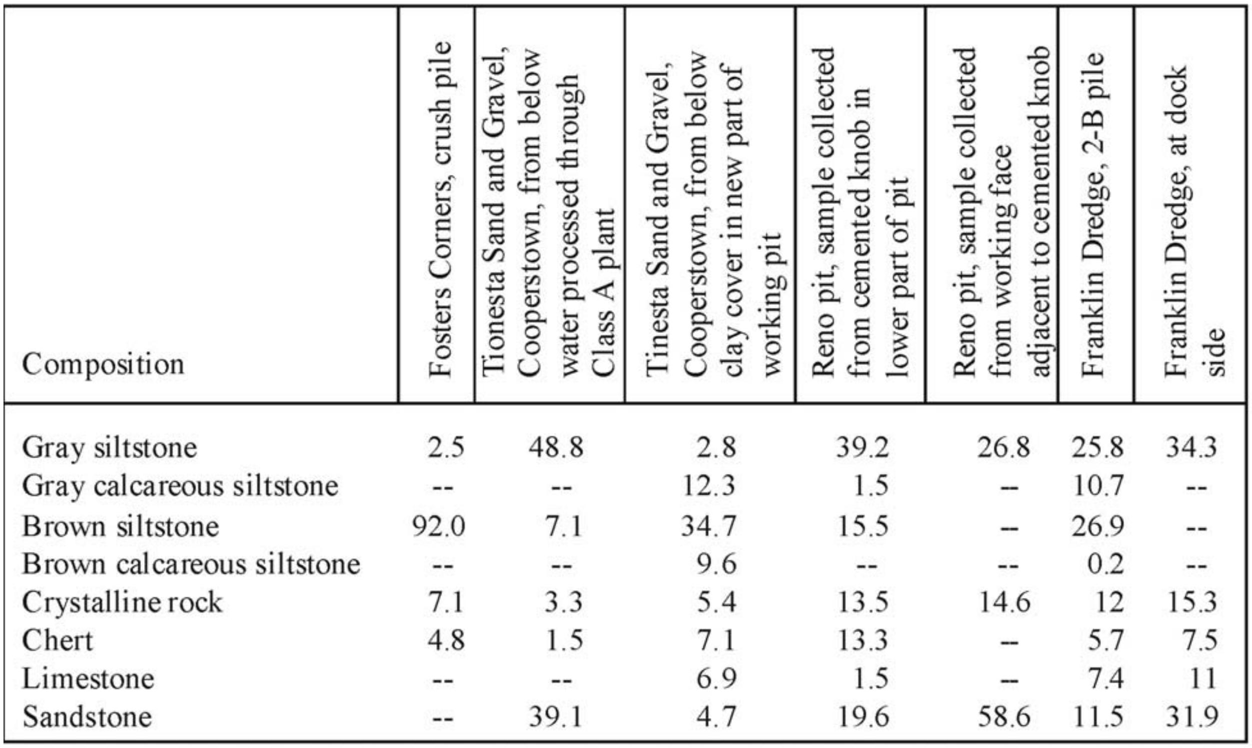
The properties of aggregates that make them commercially acceptable can be determined by visual inspection, but laboratory tests or petrographic examination should be used for quality control. Sand and gravel must be clean, free of dirt, mica, and organic matter. Silt and clay, in too great a quantity, could render them noncommercial. They must be resistant to abrasion. As such, sand rarely has a problem being commercially acceptable. Weak or crumbly gravel, on the other hand, cannot be tolerated for commercial aggregate. Commercial aggregate must be highly resistance to wetting and drying, and to freezing and thawing, so cracked and porous gravel is unacceptable. Particle shape is also important. Particles of equal dimension are preferred over angular or flat and elongated ones. Certain sand and gravel aggregates must have other properties as well, such as compressibility, elasticity, thermal conductivity, and specific gravity.

One of the more critical factors, especially where gravel is concerned, is chemical inertness when enclosed in cement. As cement hardens, it produces heat and liberates alkalies such as calcium, sodium, and potassium hydroxides. Quartz, feldspar, calcite, and most of the dark silicate minerals are essentially nonreactive, so rocks such as granite, gneiss, sandstone, and limestone are preferred. Materials such as shale, opaline and chalcedonic chert, siliceous limestone, rhyolite, dacite, and andesite, however, react chemically with the alkalies released by the cement (Bates, 1969) and must be rejected unless the expense of obtaining better materials is exorbitant. Sodium and potassium react with these materials to produce alkalic silica gel. The gel absorbs water during the setting phase of the cement, developing expansive stresses that can exceed the tensile strength of the concrete. This can cause cracking or blisters in the concrete, forcing structures out of alignment and buckling pavement. Even in cases where the cracking and blistering are not serious, they can promote freeze-thaw or wet-dry cycles that will ultimately cause the concrete to deteriorate.

As such, composition, especially of the gravels, is an important determination. Composition of the glacial gravels from the Franklin, Venango County area, as shown in Table 1, indicates that the bulk of any particular deposit is composed of local bedrock material, most of which meets quality tests. Even the small amount of material in the glacial deposits that was transported from hundreds of miles away consists of quality rock that would withstand tests for quality. Any soft bedrock material such as shale that might have been in the glacial deposits has deteriorated and been washed out.

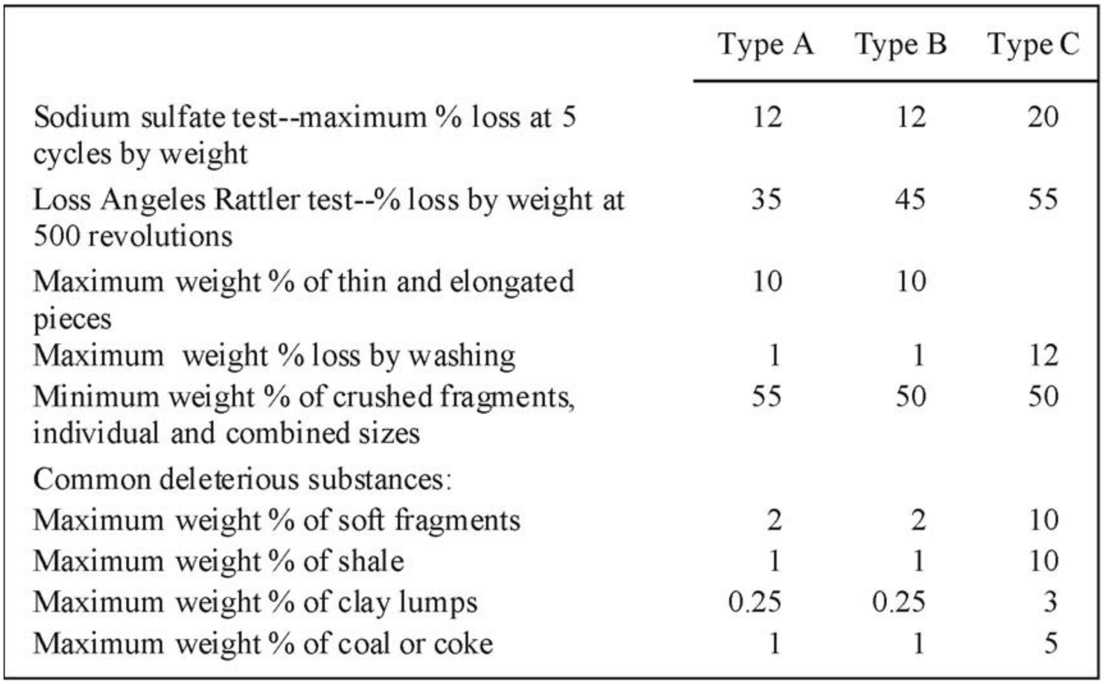
One of the largest users of sand and gravel aggregate in Pennsylvania is the Department of Transportation (PennDOT). Because of its great need for quality materials, PennDOT has established specific quality and grade-size standards for use in the different phases of highway construction. A number of Pennsylvania municipalities and architectural and engineering firms also use PennDOT specifications for construction material. Table 2 shows the quality requirements. The three categories, A, B, and C, refer to PennDOT subdivisions of aggregate. Type A material is the highest quality, required for all concrete and surface courses in asphalt roads. Either type A or type B aggregates are required for bituminous base course and crushed

Table 1. Lithologic Composition, by Weight Percent, of Gravel Deposits in the Franklin Area of Venango County (data from Craft, 1979).



Composition	Fosters Corners, crush pile	Tionesta Sand and Gravel, Cooperstown, from below water processed through Class A plant	Tinesta Sand and Gravel, Cooperstown, from below clay cover in new part of working pit	Reno pit, sample collected from cemented knob in lower part of pit	Reno pit, sample collected from working face adjacent to cemented knob	Franklin Dredge, 2-B pile	Franklin Dredge, at dock side
Gray siltstone	2.5	48.8	2.8	39.2	26.8	25.8	34.3
Gray calcareous siltstone	--	--	12.3	1.5	--	10.7	--
Brown siltstone	92.0	7.1	34.7	15.5	--	26.9	--
Brown calcareous siltstone	--	--	9.6	--	--	0.2	--
Crystalline rock	7.1	3.3	5.4	13.5	14.6	12	15.3
Chert	4.8	1.5	7.1	13.3	--	5.7	7.5
Limestone	--	--	6.9	1.5	--	7.4	11
Sandstone	--	39.1	4.7	19.6	58.6	11.5	31.9

Table 2. PennDOT Specifications—Physical Requirements for Coarse Aggregate (Modified from Craft, 1979)



	Type A	Type B	Type C
Sodium sulfate test--maximum % loss at 5 cycles by weight	12	12	20
Loss Angeles Rattler test--% loss by weight at 500 revolutions	35	45	55
Maximum weight % of thin and elongated pieces	10	10	
Maximum weight % loss by washing	1	1	12
Minimum weight % of crushed fragments, individual and combined sizes	55	50	50
Common deleterious substances:			
Maximum weight % of soft fragments	2	2	10
Maximum weight % of shale	1	1	10
Maximum weight % of clay lumps	0.25	0.25	3
Maximum weight % of coal or coke	1	1	5

aggregate base coure. Type C or better aggregate is required for subbase as well as some other types of base course (Craft, 1979).

Iron Manufacturing

When one thinks of nineteenth century industry in Venango County, the first thing that comes to mind is oil. But long before Colonel Drake set foot in the Oil Creek valley, Venango County had a very different mineral resource industry - iron manufacturing.

Iron was mined and smelted in Pennsylvania from the early Colonial days. The industry grew rapidly, Pennsylvania taking and maintaining the lead in iron ore mining and in the production of pig iron until 1880. By 1880 Pennsylvania was importing iron ores from other regions, particularly the great deposits in Michigan and Minnesota. This led to the abandoning of much of the iron ore mining in Pennsylvania with the exception of the magnetite ores of Cornwall, French Creek, and a few other localities which continued to be mined into the second half of the 20th century. At one time there were 32 iron furnaces operating in Venango County, producing 12,000 tons of pig iron per year.

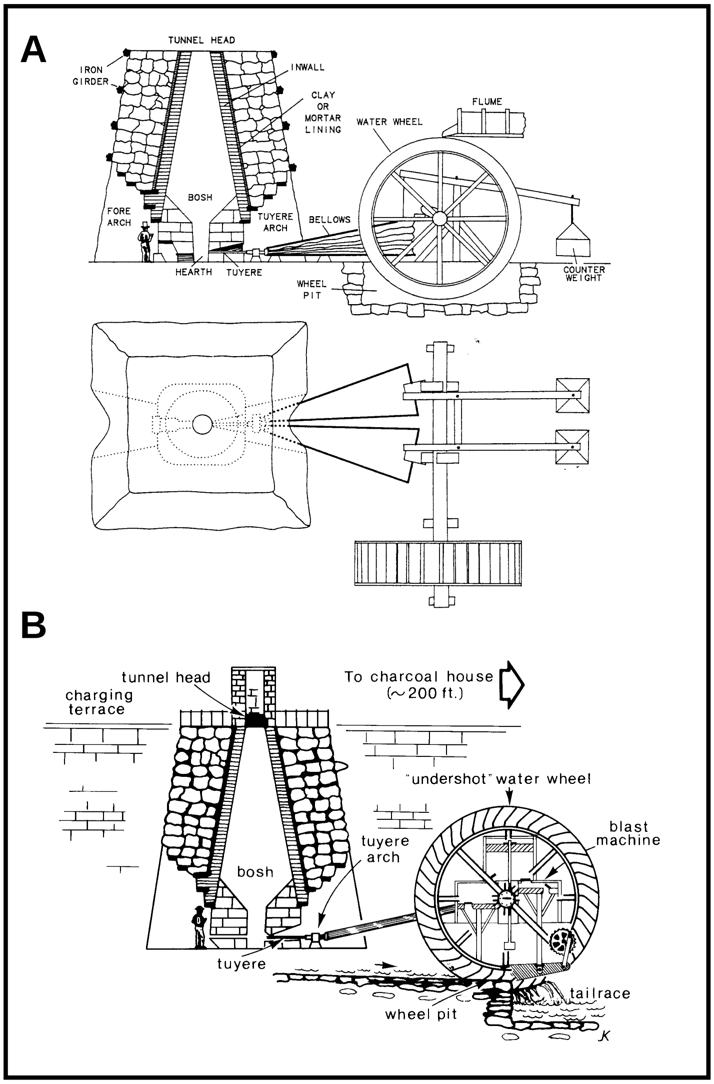


Figure 9. Generalized plans of early American iron furnaces. The earliest furnaces (A) were equipped with bellows to provide the blast (modified from Bining, 1938). In the 1800s, however, iron manufactures developed a different kind of blast machine (B) consisting of pistons and cylinders (from Inners, 1986).

Iron manufacturing in the early 1800s was a relatively simple affair, with a small stone furnace for smelting ores (Figure 9) built where the most important resources could be found in sufficient quantity to assure many years of production. These resources included: 1) iron ore, generally of low quality, especially in western Pennsylvania (see below); 2) limestone beds that could be quarried for flux; 3) wood for charcoal, which was used exclusively as a fuel and for carbon until the iron masters began using anthracite coal (in eastern Pennsylvania) or coke made from bituminous coal (in western Pennsylvania) (Swank, 1878); and 4) running water to generate the power needed to keep the blast machine operating. The old iron furnaces of western Pennsylvania commonly were situated along a small or moderate sized stream having a steady flow of water. Exceptions such as Stapley Furnace (Figure 10, no. 20) in Richland Township, Venango County used steam engines to power the blast machine.

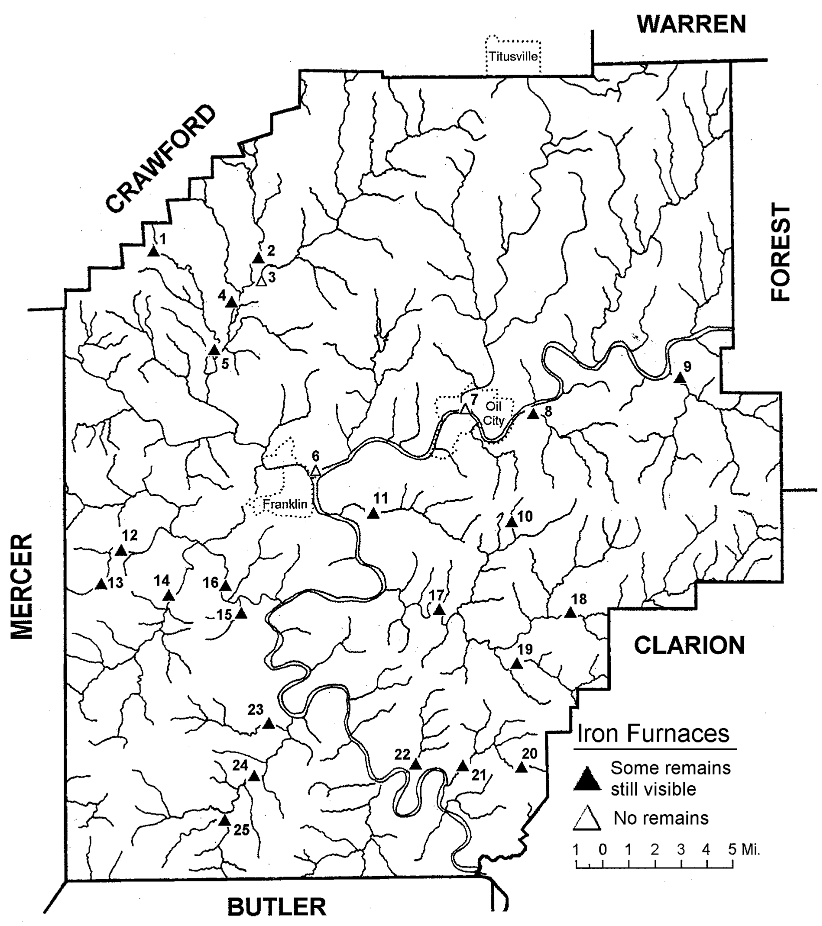


Figure 10. Stream map of Venango County showing the locations of early American iron furnaces. Numbers refer to the list in Table 3.

Early iron manufacturers operated their furnaces only six to nine months each year. The remaining time was spent cutting lumber for charcoal and making repairs to the furnace and equipment. They made iron by dumping alternating charges of ore, limestone, and charcoal or coke into the bosh through the tunnel head at the top of the furnace (Figure 9). The blast machine, a waterwheel-powered bellows or air pump, forced air into the furnace through a tuyere, a small opening leading to the hearth. There the air blasted into the bosh, raising the temperature high enough to smelt the iron. At the front of the furnace was a casting shed where the iron master drew off the slag, a scum of cinders, for discarding. The iron ran into sand molds for pig iron ingots that could be forged into nails, wagon wheels, horseshoes, and a variety of other useful domestic products. Two tons of local ore, one or two tons of charcoal or coke, and a few shovelfuls of limestone would produce about one ton of pig iron (Anonymous, 1988). When you consider the Venango County furnaces produced between 150 and 800 tons of iron per year you can

Table 3. List of the Iron Furnaces Shown in Figure 14.
(Compiled from Anonymous, 1988 and Lesley, 1859)

	Furnace Name		Furnace Name		Furnace Name
1	Liberty	11	Van Buren	21	Porterfield
2	Union	12	Reno	22	Rockland
3	Kroemer	13	Raymilton	23	Bullion
4	Texas	14	Castle Rock	24	Anderson
5	Valley	15	Victory	25	Jane
6	McCalmont	16	Sandy		
7	Oil Creek	17	Slab		
8	Horse Creek	18	Jackson		
9	President	19	Webster		
10	Halls Run*	20	Stapley		

readily imagine the kind of pick-and-shovel labor that went into mining and lumbering to keep them stocked.

Four common types of iron ores were used in early Pennsylvania smelting: black iron ore, or magnetite (Fe_3O_4), theoretically contains 72.4% iron; red iron ore, or hematite (Fe_2O_3), contains 70% iron; brown iron ore, or limonite ($2Fe_2O_3,3H_2O$), is 59.8% iron; and siderite ($FeCO_3$) contains 48.27 % iron. Magnitite and hematite do not occur in western Pennsylvania. Limonite and siderite, on the other hand, occur widely scattered over western Pennsylvania in Mississippian and Pennsylvanian rocks. They were mined in hundreds of places in western Pennsylvania in the 1800s. In some cases the ore bodies covered extensive areas and contained many tons of ore. These are residual ores that owe their origin to the action of ground water that removed the soluble carbonates and concentrated the iron compounds originally disseminated throughout the strata. The concentration was most pronounced in fractured zones of the limestone where there was free circulation of the ground water. In the case of siderite, the iron only partially replaced the carbonate.

The principle ore used in western Pennsylvania furnaces was siderite, which typically occurs in the form of nodules associated with numerous Mississippian and Pennsylvanian age marine limestones and calcareous shales (Figure 11). Siderite varies in color, but typically is some shade of bluish gray, light gray, or very dark gray and has a weathered rind the color of rust. The ore is dense and commonly breaks with a conchoidal fracture. Although pure siderite contains 48.27% iron, in nature the impurities reduce the iron content to between 25 and 45%.

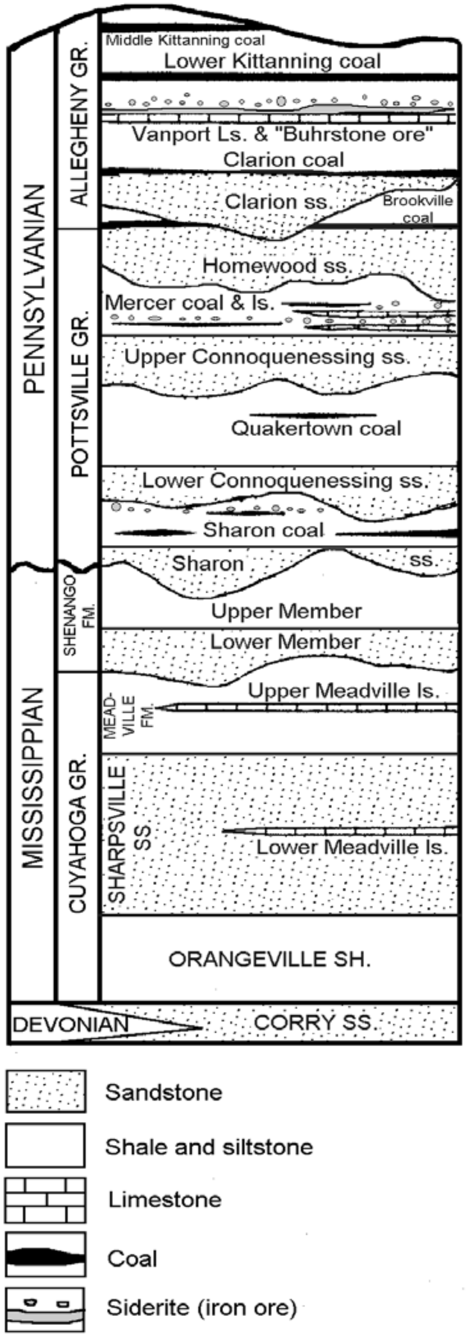


Figure 8. Generalized stratigraphic column for Venango County.

The primary siderite bed throughout western Pennsylvania is the "Buhrstone ore", a layer associated with the Vanport Limestone of the Allegheny Formation (Figure 11). This layer, which is about 40 % iron in composition, averages one foot in thickness in the Butler-Clarion-Venango county area, but thicknesses of between two and six feet have been noted. White (1877, p. 101) even reported that the siderite literally replaced the entire Vanport (22 feet of iron ore) at one locality in Lawrence County. The Vanport and, presumably, the Buhrstone, are developed in patches near the tops of the highest elevations in Irwin, Clinton, Scrubgrass, Richland, Rockland, and Cranberry townships

Figure 12. Rockland iron furnace, one of Venango County's many historic furnaces, as it looks today. Location is shown on Figure 10 (#22).

in the southern part of the county. There, at least the limestone is similar to that found in Butler, Armstrong, and Lawrence counties where it is best developed. Another common type of ore used in some of the Venango County furnaces – for example, Van Buren Furnace in Cranberry Township (Figure 10, no. 11) – is bog iron ore. Bog iron ore is formed through precipitation. The iron component is gathered from soils and rocks through the action of acids from decaying organic matter, and is held in solution as a soluble iron bicarbonate ($Fe(HCO_3)_2$). It is precipitated in shallow waters, such as springs and swamps, as a yellow- or orange-colored sediment that consolidates to become ore. Bog ore is spongy, yellow-brown in color, and contaminated with impurities, chiefly clay. Ore bodies vary in thickness and lateral extent, ranging from nodules to sheets of several acres. They range from a few inches to several feet thick, but typically average between one and two feet.

The first iron furnaces built and operated in Venango County were erected in 1824. John Anderson, who had experience in the iron industry in Juniata County, built the Anderson Furnace on Big Scrubgrass Creek near present day Kennerdell in the southern part of the county (Figure 10, no. 24). He also built Oil Creek Furnace, situated at the mouth of Oil Creek, on land bought from Chief Cornplanter, the head of the Seneca Indian Nation. By 1858 Venango County had 25 iron furnaces (Swank, 1878). By that time, however, most of the furnaces had been abandoned for a variety of reasons, any one of which could have single-handedly subverted the industry. The primary reasons included overlumbering which exhausted the source for charcoal, depletion of iron ore, increased mining and hauling costs, increased tariffs (always a business killer), and increased competition from large manufacturing towns like Pittsburgh and Sharon. These latter towns found it was far more profitable to use coke and high quality iron ores from the Lake Superior region.

Venango County had a rich trade in iron manufacturing while it lasted. Many of the wealthier people in the region invested in the industry and got back a tidy dividend for their investment. Iron provided a considerable amount of money to the local economy during times when few other industries could. In a sense, iron manufacturing helped the county residents weather the economic problems of the early to mid-1800s until oil came along to take on the mantle of "primary industry". Today, iron manufacturing in Venango County is just a memory. Fortunately, many picturesque remains of old furnaces, such as Rockland Furnace (Figure 12), help us remember. Some of them are in out-of-the-way places that require long arduous hikes in the woods and creek beds in order to find the remains.

REFERENCES CITED

Anonymous, 1988, *Exploring Venango County*. Venango County Commissioners, 30 p.

Bates, R. L., 1969, Geology of the Industrial Rocks and Minerals. Dover Publishing Co., New York, 459 p.

Bining, A. C., 1938, Pennsylvania iron manufacture in the eighteenth century. Pennsylvania Historical and Museum Commission, v. IV, 227 p.

Carll, J.F., 1875, Report of progress in the Venango County district. Second Geological Survey of Pennsylvania, v. I, p. 1-49.

Carll, J. F., 1880, Geology of the oil regions of Warren, Venango, Clarion and Butler Counties, including surveys of the Garland and Panama conglomerates in Warren and Crawford, and in Chautauqua Co., N.Y., descriptions of oil well rig and tools, and a discussion of the preglacial and postglacial drainage of the Lake Erie country. Second Geological Survey of Pennsylvania, v. I3, 482 p.

Carll, J. F., 1883, Geological report on Warren County and the neighboring oil regions, with additional oil well records. Second Geological Survey of Pennsylvania, v. I4, 439 p.

Carll, J. F., 1886, Preliminary report on oil and gas, *in* Lesley, J. P., Annual report of the Geological Survey of Pennsylvania for 1885. Second Geological Survey of Pennsylvania, Annual Report for 1885, p. 1-81.

Caspero, N. A., Wertman, W. T., and Eckard, W. E., 1963, Underground combustion oil-recovery experiment in the Venango First sand, Warren County, Pa. U.S. Bureau of Mines, Report of Investigations 6320, 39 p.

Craft, J. L., 1979, Quality of gravel resources in northwestern Pennsylvania. Pennsylvania Geological Survey, 4th ser., Information Circular 86, 54 p.

Dickey, P.A., 1941, Oil geology of the Titusville quadrangle, Pennsylvania. Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 22, 87 p.

Dickey, P.A., Sherrill, R.E., and Matteson, L.S., 1943, Oil and gas geology of the Oil City quadrangle, Pennsylvania. Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 25, 201 p.

Harper, J.A., 1990, John F. Carll: Pennsylvania's prophet of the oil fields. Pennsylvania Geology, v. 21, no. 5, p. 8-12.

Harper, J. A., 2002, The incredible John F. Carll: The world's first petroleum geologist and engineer. Oilfield Journal, v. 2 (2001-2002), p. 2-14.

Ingham, A. I., Lytle, W. S., Matteson, L. S., and Sherrill, R. E., 1956, Oil and gas geology of the Sheffield quadrangle, Pennsylvania. Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 38, 72 p.

Inners, J. D., 1986 , Mount Etna Iron Furnace Plantation, Blair County. Pennsylvania Geology, v. 17, no. 2, p. 2-6.

Kelley, D. R., 1967, Geology of the Red Valley sandstone in Forest and Venango Counties, Pennsylvania. Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 57, 49 p.

Laughrey, C. D., 1984, Petrology and reservoir characteristics of the Lower Silurian Medina Group sandstones, Athens and Geneva fields, Crawford County, Pennsylvania. Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 85, 126 p.

Laughrey, C. D., 1991, Utility of petroleum geochemistry in the search for new gas reserves in Pennsylvania (abs.), *in* Exploration strategies in the Appalachian basin. 22nd Annual Appalachian Petroleum Geology Symposium, Program and Abstracts, I. C. White Memorial Fund Publication 3, p. 49-50.

Laughrey, C. D. and Harper, J. A., 1986, Comparisons of Upper Devonian and Lower Silurian tight formations in Pennsylvania -- geological and engineering characteristics, p. 9-43 *in* Spencer, C. R., and Mast, B. E., eds., Geology of tight reservoirs: American Association of Petroleum Geologists, Studies in Geology 26, 299 p.

Lesley, J. P., 1859, The Iron Manufacturer's Guide to the Furnaces, Forges and Rolling Mills of the United States with Discussions of Iron as a Chemical Element, an American Ore, and a Manufactured Article in Commerce and in History. John Wiley, New York, 772 p.

Lesley, J.P., 1885, A geological hand atlas of the sixty-seven counties of Pennsylvania, embodying the results of the field work of the survey, from 1874 to 1884. Second Geological Survey of Pennsylvania, Report of Progress X, p. 112 p.

Lytle, W. S., 1955, Summary secondary recovery operations in Pennsylvania to January 1, 1954, including petroleum reserves and production by counties. Pennsylvania Geological Survey, 4th ser., Progress Report 148, 23 p.

Lytle, W.S., 1957, The story of John F. Carll, Second Pennsylvania Survey's pioneer petroleum geologist. Pennsylvania Department of Internal Affairs Monthly Bulletin, v. 25, no. 5, p. 19-22.

Lytle, W. S., 1959, History, present status and future possibilities of secondary recovery operations in Pennsylvania. Interstate Oil Compact Commission Committee Bulletin, v. 1, no. 2, p. 28-42.

Lytle, W. S., 1966, Steam injection operations in Pennsylvania. Producers Monthly, v. 30, no. 12, P. 2-5.

Owen, E.W., 1975, Trek of the oil finders – a history of exploration for petroleum. American Association of Petroleum Geologists Memoir 6, 1647 p.

Pennsylvania Geological Survey, 1993, Oil and gas fields of Pennsylvania, 3rd ed. Pennsylvania Geological Survey, 4th ser., Map 10, scale 1:2,000,000.

Randall, F.A., 1875, Observations on the geology around Warren. Second Geological Survey of Pennsylvania, v. I, p. 50-55.

Sherrill, R.E., and Matteson, L.S., 1941, Oil and gas geology of the Franklin quadrangle, Pennsylvania. Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 24, 71 p.

Swank, J. M., 1878, Introduction to a History of Ironmaking and Coal Mining in Pennsylvania. Privately published, Philadelphia, 125 p.

US Geological Survey, 1998, The mineral industry of Pennsylvania. US Geological Survey (downloaded from the Internet), 6 p.

White, I. C., 1877, The geology of Lawrence County. Second Geological Survey of Pennsylvania, Report Q2, 336 p.

White, I. C., 1881, The geology of Erie and Crawford Counties: Second Geological Survey of Pennsylvania, Report 04, 355 p.

Zagorski, W. A., 1991, Trapping models for the Lower Silurian Medina Sandstone Group - A comparison of trapping styles and exploration methodology for both "deep" and "shallow" Medina plays in the Appalachian basin (abs.). American Association of Petroleum Geologists Bulletin, v. 75, p. 1329.

COLUMBIA FARM OF THE OIL CREEK VALLEY, OIL CREEK STATE PARK, VENANGO COUNTY, PA: 150 YEARS OF PETROLEUM HISTORY LEGACY

Amy Randolph

William Story Farm – The Early Beginnings

The Oil Creek Valley began to be settled by peoples of European decent circa 1800, with small farms and some lumber mills being established. The glacial till deposits of the creek valley and thin soil cover on the adjacent hillsides made for relatively unproductive farmlands. Several decades later these poor dirt farms were transformed into rich oil farms when the first "black gold" rush took place in this valley and forever changed the world.

In August 1859 Edwin Drake's well successfully produced oil, and land in the area along Oil Creek quickly began to be bought or leased. William and Margaret Story owned farmland located on both sides of Oil Creek, south of what later became the town of Petroleum Centre.

As legend goes, their property on the west side of the creek was the subject of intense competition from two bidders in 1859. One was reportedly George Bissell, who, along with Jonathan Eveleth, had formed the Pennsylvania Rock Oil Company in 1854, and four years later formed the Seneca Oil Company, which subsequently hired Colonel Drake. The other was an agent for a Pittsburgh investment group by the name of Ritchey, Hartje and Company. Margaret Story apparently refused or hesitated in accepting the first offer she and her husband received from Bissell. A second offer was apparently made and accepted later that same day by the investment group's agent, who'd sweetened the deal by including the offer of a new silk dress along with the purchase price. George Bissell reportedly returned the following day with a better offer for the Storys, but it was already too late – the Storys had signed with the Pittsburgh group (McLaurin, 1896).

The truth will probably never be known, but this appears to be more of an urban legend than fact. Based on existing deed records, William and Margaret Story got in on the land leasing rush very early, only *weeks* after Drake's well "came in". In October 1859, they leased to Albert G. Egbert the "exclusive right to dig or mine for oil, salt or minerals" on 350 acres of their farm. This lease was apparently lost and replaced by a presumably similarly-worded memorandum of agreement dated January 19, 1860, which was more permanently memorialized by being recorded at the Venango County courthouse. This agreement gave Egbert three months to begin his exploration efforts, and if any oil, salt or minerals were found, Egbert was to pay the Storys an equal half-part of everything removed from the ground.

The Storys obviously recognized a golden opportunity, and between April and May 1860 they sold various other of their land parcels totaling about 300 acres to extended family members and other local neighbors for an amount totaling less than $500.00. This included a $200.00 sale of 198 acres to Elizabeth M. Tarr, a relative by marriage, and a $33.00 sale for a 108 acre parcel later operated by Dalzell Petroleum. The Tarr farm went on to become famous in its own right for its prolific production of oil. Most of this land was located on the eastern side of Oil Creek. However, the Storys didn't appear to have been as generous when it came to selling their land to "outsiders".

Randolph, Amy, 2009, *Columbia Farm of the Oil Creek Valley, Oil Creek State Park, Venango County, PA: 150 years of petroleum industry history legacy*, in Harper, J. A., ed., *History and geology of the oil regions of northwestern Pennsylvania.* Guidebook, 74th Annual Field Conference of Pennsylvania Geologist, Titusville, PA. p. 58-72.

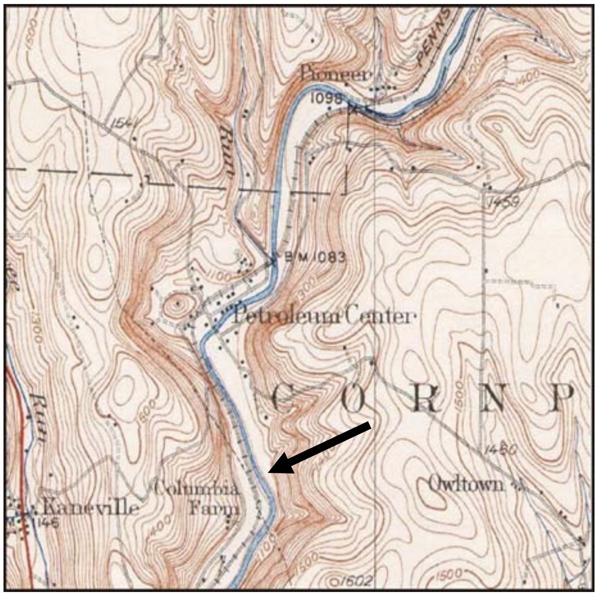


Figure 1. Location of the Columbia Farm, currently part of Oil Creek State Park, on the Titusville 15-minute quadrangle.

Based on the Columbia Oil Company's third annual stock report, it appears that the Pittsburgh group of Richey, Hartje & Co. had one or more early lease agreements with the Storys, during which wells were drilled as early as 1860 on the property. These wells were apparently successful enough that the company decided to buy the land and itself (Anderson, 1865).

On April 11, 1861, the Storys conveyed two land parcels totaling just under 500 acres to a group of Pittsburgh investors for $20,000.00. One-hundred acres of this was located primarily on the east side of Oil Creek (known as William Story's "lower tract"), and the remaining nearly 400 acres was located on the western side of Oil Creek. (Venango County deed book T, p. 463-466). These parcels have historically been referred to as both the Story Farm and the Columbia Farm, named after the Columbia Oil Company. Today, the Columbia Farm is typically thought of as being that parcel located solely on the western side of the creek.

A story written for a local newspaper, (Szalewicz (1972), suggests that the Storys' contractual agreement with Columbia Oil Company didn't end with the deed transfer of their land. According to this newspaper article, the Storys were paid $20,000 for their land, which matches with the deed information. Apparently, there was a separate agreement that they were to be paid an additional $10,000.00 if their land produced at least one 10 barrel well (per day?), and yet another $1000.00 if the land produced a second 10 barrel well. The Storys were living in Crawford County at the time of the sale of their farm to Columbia Oil, and the Pittsburgh investors apparently told Story that his farm was dry. Upon returning to check on his farm at a later date, William Story was informed by a local resident that oil had indeed been found. Story later sued Richey, et al in US Court in Erie, and on January 22, 1873 Judge McKennon awarded Story $31,095. The original court documents related to this case have recently been located (in the Mid-Atlantic branch of the National Archives, located in Philadelphia) which will most certainly be able to provide more details about this aspect of the land transaction and history of this parcel.

Columbia Oil Company

On May 1, 1861 the Pennsylvania Legislature approved an Act of Incorporation for the Columbia Oil Company (Figure 1). The Act allowed the company to buy and own up to 500 acres of land in Venango and Allegheny Counties in order to "bore for oil, salt, mine, prepare for market, sell and dispose of any cannel and bituminous coal, iron ores and other minerals or products on their lands, and to manufacture lubricating and illuminating oils, iron or other products of their minerals or land, and to convey the same to market, and grant leases of said lands, or any portions thereof." The act further authorized the company to sell 10,000 shares of capital stock worth $200,000.00 (Hamilton, 1862). Only the name of David Richey, one of the original seven corporators, is also listed as one of the purchasers of the William Story farm lands in April 1861.

On June 4, 1864, a supplement to Columbia's Act of Incorporation was passed by the state legislature, allowing its land holdings to increase to 1000 acres (presumably also within Venango and Allegheny Counties), and its capital stock to increase to $2,500,000.00 (Johnston & Co., 1864). PA Department of State Records show that on March 28, 1870, the legislature passed another Act (no. 579) which empowered the company to hold up to 10,000 acres at any one time anywhere within the Commonwealth west of the meridian line making up the western boundary of the Potter County line.

Soon after the company's acquisition of the Story lands, they wrote that, "The general opinion of men well informed on the subject is that the Company's lands are among the best territory on Oil Creek," and that, "the prospects are good for obtaining it (i.e., oil), in fair quantities, for an indefinite period in the future." The company also had a lot of foresight for the time, noting that, "Discoveries of Oil (sic) in other regions, will in all probability be made, so that larger quantities will be brought into market. But the demand will be likely to keep pace with the increased supply," and that oil would have, "various new uses" (Anderson, 1865).

While the Story Farm was Columbia Oil's first investment property, the company's stock reports reflect that they eventually operated in Butler, Clarion, McKean and Warren Counties in Pennsylvania, and even in Allegheny County, New York State. Columbia also branched out into the Butler, Bradford and Tidioute fields (Oil City Derrick, 1898).

Profits

The company made almost monthly dividend payments to its stockholders between July 1863 and January 1866, when it was decided to pay quarterly dividends for more efficiency (Anderson, 1866). A sampling of dividend payments is as follows (Anderson, 1874):

1863 - $249,600
1864 - $943,000
1865 - $500,000
1866 - $250,000
1867 - $112,500
1868 - $325,000
1869 - $425,000
1870 - $150,000
1871 - $287,500
1872 - $225,000

By January, 1873, the company had paid over $3.5 million in dividends to its stockholders since its inception about 10 years earlier (Anderson, 1874).

Andrew Carnegie's ties to Columbia Oil Company:

Numerous publications make reference to Andrew Carnegie (Figure 2), either as an individual or as a business partner, being responsible for the incorporation of Columbia Oil, or as a purchaser of the oil company or of the Story Farm. No direct evidence has been found so far to substantiate these claims.

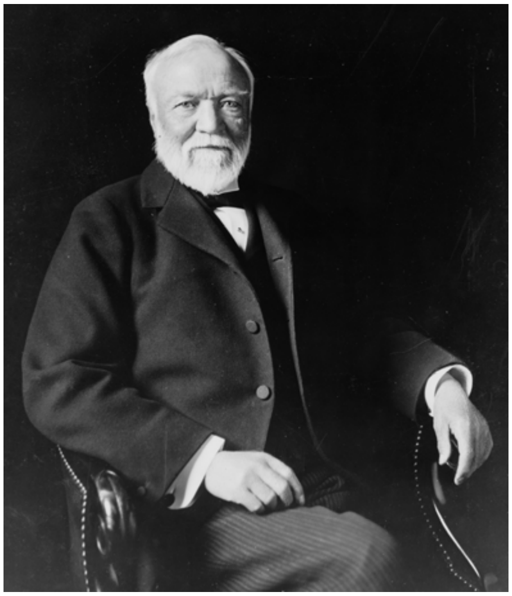


Figure 2. Portrait of Andrew Carnegie.

Carnegie’s autobiography indicates that he and his business partner, William Coleman, purchased a stock option in Columbia Oil in the early 1860s, worth $40,000 after being impressed by the company’s well-managed Story Farm operations during their visit to the Oil Creek Valley area to see the oil rush first-hand (Carnegie, 1920). PA Department of State records show that in February 1881, Carnegie is listed as owning 635 shares, and was one of the larger stockholders at that time. His investment in the company reportedly allowed him to leave his position with the Pennsylvania Railroad and allowed him to go on to concentrate on his steel and other money-making ventures (King, 2006).

In the company’s fifth annual stockholder report (Anderson, 1867), mention is made of Carnegie being appointed Chairman of the company; however, no other references to Carnegie were noticed in a cursory review of the stockholder reports held by the Carnegie library.

“Carnegie’s Folly” – A Failed Oil Storage Impoundment:

In his autobiography, Carnegie relates how he and his business associate, William Coleman, believed that the oil would quickly be tapped to exhaustion from the ground. Hoping to make a huge profit based on its short supply and high demand when it did, Coleman suggested that a surface impoundment - which he referred to as a “lake of oil” - be constructed on the Columbia Farm property which would be capable of holding 100,000 barrels of oil. Coleman and Carnegie expected that oil could be priced as high as ten dollars per barrel when, as they believed, the oil ran out, thereby netting them at least one million dollars for the supply within their holding pond. But the oil continued to flow from the ground, and the oil in the impoundment was lost, presumably to both evaporation and leakage, and the idea of its storage in this manner was apparently abandoned (Carnegie, 1920). Unless the impoundment was mentioned in the first annual stockholder’s report (a copy of which has not yet been found), there was no reference to this in the company’s subsequent annual reports dated 1864 to 1888 and reviewed by this author at the Carnegie library located in the Oakland section of Pittsburgh.

It’s unclear as to why consideration was given to storing the oil in an impoundment when large iron and wooden tanks were being constructed for this purpose. Tanks may have been in short supply, so great was the demand for them, and perhaps it seemed easier, quicker and cheaper to construct an impoundment at the time. Based on its presumed location today, the impoundment certainly would have also been subject to flooding along Oil Creek. Due to the failure of the storage impoundment idea, some have subsequently referred to it as “Carnegie’s folly”, even though the concept was more that of Coleman than Carnegie. Although the exact location of this impoundment is not well-documented in written records, Oil Creek State Park personnel have indicated that it existed at a location they refer to as “the brick pond,” which is located between State Route 1007 (SR 1007) and Oil Creek, just north of the bend in the road where the road changes orientation from northeast-southwest, to northwest-southeast (Figure 3).

Today, the pond is overgrown with cattails and any remaining bricks, if not previously salvaged, have probably been covered with sediment.

Figure 4. "Carnegie's Folly," an oil impoundment for storing crude oil when the oil wells ran dry.

Geology of the Columbia Farm and Environs

The prolific early oil-bearing rocks underlying the Oil Creek valley are sandstones, or in the lingo of the oil and gas business, "sands." These "sands" belong to the Venango Group of sandstones, which are upper Devonian in geologic age (minimum 360 million years old).

The oil-bearing sands in the Oil Creek Valley occur in large lenticular-shaped pods, or "pools." Smaller and relatively more discontinuous layers of sandstone are referred to as "stray sands."

The Drake well was drilled to a depth of 69.5 feet, and oil was produced in this well from an approximately 2' thick sandstone located between layers of shale in the Riceville formation. This thin "stray" sandstone (also called the "Drake sand") apparently yielded oil nowhere else where it was drilled (Pees, 1994; Dickey, 1941), so Drake was extremely fortunate. Had his well been unsuccessful, some other part of the country or the world may have been able to claim notoriety for the world's first oil boom.

They couldn't have known it at the time, but the Columbia Oil Company founders were nearly as lucky as Drake in their purchase of the Story Farm. Its underlying geology in combination with the company's management and systematic development of its resources made it one of the most successful and long-lived oil producing farms of the valley.

Below the Drake sand are, in order from shallowest to deepest, the First Sand, the Second Sand (aka the Salt Sand), the Third Stray Sand (aka Third Sand, Black Oil Sand, and Gray Sand) and the Third Sand, also known as the Fourth Sand and the Green Oil Sand – so named because of its characteristically greenish color (Dickey, 1941).

The Columbia Farm was underlain by all four of these sandstone units, within the boundaries of what is referred to as the combined Pioneer and Petroleum Center oil pools. The Third Sand unit below the Columbia Farm ranges from 30-50 feet in thickness, much of which is characterized by being of a pebbly sand composition, the porosity (ranging from 11-16%) and permeability of which provided for exceptionally good oil reservoir properties (Dickey, 1941). The Columbia Farm wells encountered the Third Sand between approximately 450-830 feet below ground surface (Carll, 1877) although this unit may be shallower (450-500 feet below ground surface) elsewhere in the flatlands bordering Oil Creek where most of the earliest wells were drilled, making it fairly easily accessible. The oil contained within it also occurred under natural pressures that resulted in gushers of high flow rates when first tapped by wells (Pees, 1994). These flow rates diminished naturally over time as the oil and gas drained from the rock unit.

John Carll's (1877) Second Geological Survey of Pennsylvania report, pages 122-125, includes a tablular listing of 71 wells on the Columbia Farm (aka the Old Story Farm), and it also provides simplified stratigraphic listings for a select few wells.

Columbia Farm Operations

Columbia Oil put down its own wells for the first time in 1863; prior to that, all oil had been produced by its lessees (Anderson, 1868). The Story Farm was divided up into at least 44 lease lots (Anderson, 1865) (Figure 4).

The earliest drilling took place along the flatlands, bordering Oil Creek, no doubt following the "creekology" concept of finding oil. In the company's 1866 stock report, they write, "Recent successes have created a general belief that the hills will hereafter be as productive of oil as the valleys," (Anderson, 1866) and in that same year, most of the company's wells were being drilled on western side of the creek, and on its uplands (Anderson, 1867).

The Columbia Farm is often cited for its reputation of being well-run, following systematic drilling and development operations. Examples for the basis of these claims can be seen in the company's annual stock reports, a repository of which (covering the years 1864-1888) was recently discovered and reviewed at the main Carnegie Library in Pittsburgh. These examples include the following (Anderson, 1866 through 1871):

- reducing the cost/foot of drilling by paying for drilling by the day, rather than by the foot;
- using natural gas from the wells to fuel boilers instead of expensive coal
- burying boiler water supply pipes below the frost line, to ensure a steady supply of water;
- substituting larger boilers for smaller ones, to run more pumps per boiler
- keeping machinery well-maintained and repairing immediately when necessary
- using more substantive drill rigs
- thoroughly testing every abandoned well
- spacing wells 250'-300' apart, to reduce impacts from overlapping drainage radii
- permanently casing wells to prevent water infiltration. This was noted to cost $150 to $200 more per well than other drilling completions, but the company saw this as a savings in the long-run through increased longer-lived production.

The company also plugged at least some of its abandoned wells (Anderson, 1873), a practice that was probably not followed by many others.

Environmental impacts were also noted in the stock reports. In 1866, the company began using coal to fuel its boilers, because the trees which once covered the Story Farm had been cut down and the wood supplies exhausted (Anderson, 1867). In 1871, adverse effects on the boilers were noticed due to the degraded quality of surface waters impacted by discharges from refineries and the acid works located upstream (Anderson, 1868).

The stock reports also reflect economic conditions strikingly similar to modern-day events, including observations about increased domestic and international dependence on oil, consumption exceeding production, the "odious" state income taxes (which the oil lobbyists successfully had repealed), the credit system overextending itself to "irresponsible parties" for the purchase of machinery, etc., and the company's necessity to reduce the number of its employees and their wages in order to remain profitable (Anderson, 1869, 1873 and 1874).

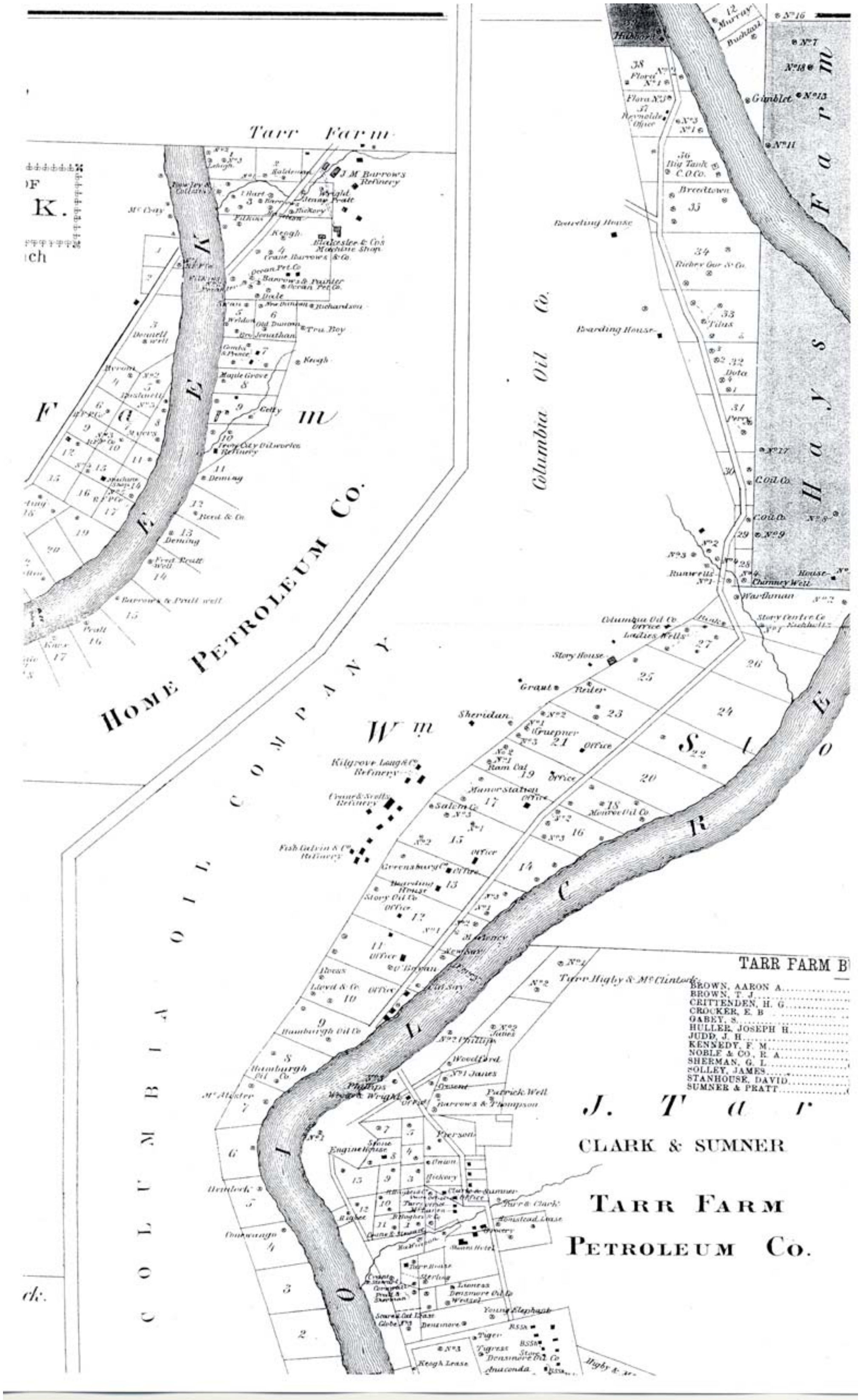


Figure 4. Portion of Beers (1865) *Atlas of the Oil Region of Pennsylvania* showing the location of Columbia Farm lease lots.

When new oil fields were discovered in Butler and Clarion Counties and production subsequently exceeded demand, the Columbia Oil Company joined with other producers in shutting down production for 30 days in late 1872 in an effort to boost oil prices. When that didn't work, there was a proposal made to suspend drilling for up to six months (Anderson, 1873).

Wells

In the company's eleventh annual stock report, it listed the cost for drilling its "well no. 129" (Anderson, 1873), indicating that it had drilled at least this many wells as of December, 1872. Carll's 1877 Second Geological Survey includes a listing up to well no. 139 for the farm. Many other wells had no doubt been drilled on leases the company had with others. Many of those leases reverted back to Columbia Oil over time, as the lessees were unable to live up to the terms of their lease.

Some of the best known well names include the Reynolds, Breedstown, Ram Cat, Run, Eicholtz and Marston wells (Beers, 1865) and the Sheridan, Manhattan, Big Tank, Floral and Ladies wells (Cone and Johns, 1870). Some of the wells were named after the men associated with the company, including the Goe, Reiter and Boulton wells (Carll, 1877) – Bateman Goe and Conrad Reiter were directors of the company, and were among the original purchasers of the property from the Storys, and George Boulton the Story Farm's superintendent for many years.

Torpedos Used on Columbia Farm

Paraffin is a characteristic component of the oil found in northwestern Pennsylvania. While this waxy substance lent itself to the oil's use in heavy machinery of the nascent industrial age, it was also detrimental to a well's production over time. A Civil War veteran, Colonel E. A. Roberts, used his experience in military ordnances to experiment with and develop a black-powder or nitroglycerine explosive charge called a "torpedo" that was packed into an iron shell casing, and put down a well to break up the paraffin, in order to re-stimulate the flow of oil. This became known as "shooting" a well, and Colonel Roberts eventually received a patent for this technology (Michener, 2007). In 1867, he was licensed by Alfred Nobel to use their dynamite in his torpedoes (Beates, et al.).

Torpedos were reportedly used on the Story Farm, including on the Manhattan, Hunter and Hamburgh Oil Company wells (Henry, 1873), and the Say well on the Hunter lease (Oil City Derrick, 1898), however, their use doesn't appear to have been specifically noted in any of the stockholder reports reviewed.

Early Secondary Recovery

In his book, "Empire Oil," author John P. Herrick credits the first *recorded* unintentional water flood as occurring on the Columbia Farm circa 1876-1877, in which abandoned wells on the Columbia Farm became flooded with water, resulting in an increase in production to wells being operated by David Barcroft and John Kirkwood, on lands adjacent to and west of the Columbia Farm (Herrick, 1949). A water-flooding event *is* documented as having occurred on the Columbia Farm, but it occurred more than a decade before Herrick's account, and the situation was reversed.

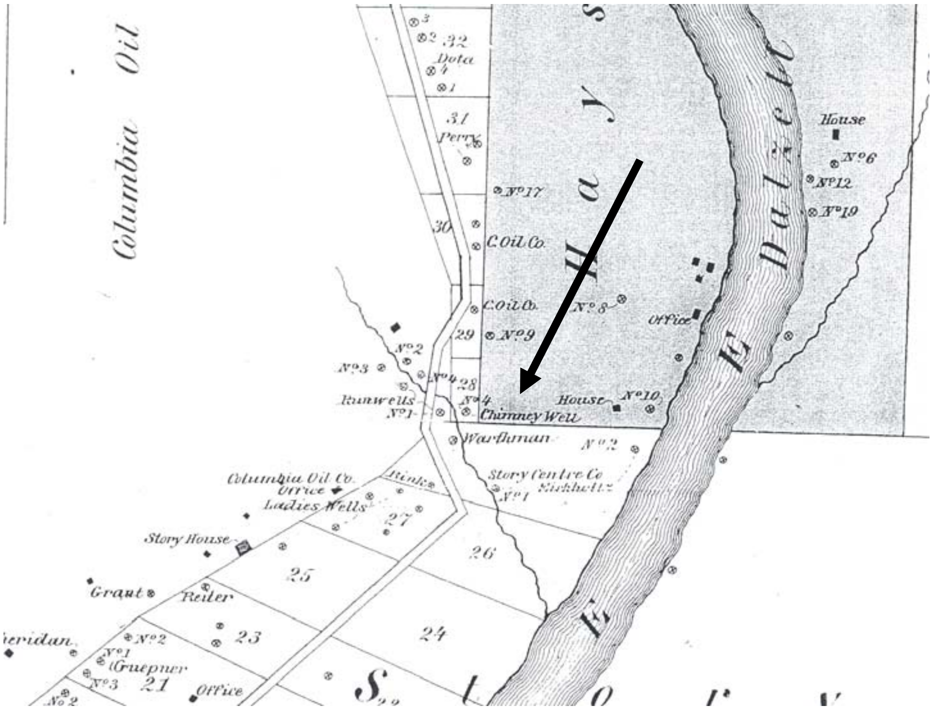


Figure 5. Portion of Beers' (1865) Atlas of the Oil Region of Pennsylvania showing the location of the Chimney Well (at the arrow).

In the Columbia Oil Company's stockholder report reflecting the events of the year 1864, mention is made of damage to some of the company's wells, caused by an infiltration of water from a well on the adjacent Dalzell Petroleum Company tract, when the well's tubing (casing) was pulled out of the well (Anderson, 1865). The stockholder report doesn't identify any of the wells, but the *Atlas of the Oil Regions of Pennsylvania (Beers,* 1865) notes that when the tubing was removed from the Chimney Well (Figure 5) located on the Dalzell tract, the adjacent Run and Eicholtz wells (on the Columbia Farm tract) were flooded with water. However, this did not necessarily have an unhappy ending. Columbia Oil's stockholder report indicates that this had a "favorable outcome" on the affected wells, after which the company entered into an agreement with Dalzell Petroleum which specified that, after deducting 133 barrels from the daily production of those affected wells, Dalzell was entitled to the proceeds of 15% of the increased production of the wells. The agreement was good until May 1, 1865, or until annulled by either party (Anderson, 1865). So the company's description of "damage" to their wells actually ended up stimulating production in them, and this in fact, may be an account of the first documented case of enhanced oil recovery by a water drive.

It's likely that other unintentional water flooding events took place on or about this same time which were simply not documented. Water flooding later became standard industry practice by which the recovery of oil could be enhanced by the purposeful injection of water in wells surrounding an oil extraction well. The water was used to drive the oil towards an extraction point. This technique was later experimented with again in the 1970s on the uplands of the Columbia Farm (see Maraflood™ section below).

Production

The volume of a barrel of oil varied in the early years of oil production. Columbia Oil's seventh annual stock report noted that in 1864, a barrel of oil was equivalent to 40 gallons, while during 1867 and 1868, it had increased to 43 gallons (Anderson, 1869). Early records were difficult to keep too, as much oil was lost due to inadequate storage. The following is a summary of the company's production, reported in their stockholder reports (Anderson, 1865-1874). These figures include that oil produced by both the company itself, and its lessees on the Story Farm:

1863 – 380,565 barrels
1864 – 241, 976
1865 – 210,996
1866 – 177,567
1867 – 141,181
1868 – 154,190
1869 – 131,901
1870 – 123,702
1871 – 153,894
1872 – 118,766
1873 – 116,922

So over this 11 year period, nearly 2 million barrels of oil was produced from just the Story Farm alone.

Refineries

The *Atlas of the Oil Region of Pennsylvania* (Beers, 1865) shows three refineries located on the Columbia Farm hillside, west of Oil Creek (Figure 4). These include the Fish, Colvin & Co. Refinery, Crane & Scott's Refinery, and Kilgrove, Long & Co. Refinery. *The Derrick's Handbook of Petroleum* (Oil City Derrick, 1898) also notes the following refinery names – Clark, Crane & Pierce; and Alexander, Schofield & Co., while Cone and Johns (1870) mention the Crystal Oil Works, Big Tank Oil Works, and Croton Oil Works. Some of these refineries may have changed names over time. The refineries appeared to have been owned independent of Columbia Oil Company.

Columbia Farm Company Town

The Columbia Farm village was a small community that included housing for some of its workers, a schoolhouse (which also held church services), library and reading room, and its own post office, which opened in 1870. Company employees played in its cornet band, and President Grant made a short speech at the farm (presumably at the railroad stop) in September 1871 (Oil City Derrick, 1898).

Post-Columbia Oil Ownership/Operation

On January 16, 1893, the Columbia Oil Company deeded its approximately 400 acres of the Columbia Farm located on the western side of oil creek to Robert Lamberton, and its operations of those lands presumably ceased on or before that date. This author has not yet been able to determine what ultimately became of this company. However, it apparently operated for nearly 30 years at this location, between circa 1861 and 1893. In an environment of overnight booms and busts, this relatively long-lived business venture was quite remarkable.

Based on land records for the property maintained in DCNR's files, Brundred Oil Corporation eventually took possession of the property in 1905 and worked it for many years before it assigned it assets to Quaker State Oil Refining Corporation in 1952.

Brundred Oil Corporation employed repressuring operations and ran a casinghead gasoline manufacturing plant on the property, along Oil Creek.

Repressuring Operations

By the late 1800s the underlying oil reservoir had been largely depleted of its original pressure necessary for primary production, and had also been flooded by infiltration of water from early poorly constructed wells. Circa 1920, the reservoir was de-watered by Brundred and put under suction, or vacuum, and the gas was re-injected (Walker, 1971). Use of this technique dates back to about a decade after Drake's well was drilled, and was used to enhance the recovery of oil. The method was most widely used in Pennsylvania between 1918 and 1925, and it had the effect of also increasing the amount of casinghead gasoline (see below) along with oil (Lytle, 1960).

Brundred drilled wells to the Venango 3rd sand sometime after 1920, and installed a vacuum plant and casinghead gasoline compressor plant (Figure 6). They began dewatering the reservoir to recover the oil and also collected the gas by vacuum. By 1928, production had dwindled to an average of 210 barrels per month, and a decision was made to begin active repressuring operations. Air lines were connected between the compressor and certain inlet wells, and they began to repressure both the 2nd and 3rd sands, more than doubling average monthly production from the Venango 3rd sand (Brundred, date unknown).

Casinghead Gasoline Manufacturing

Casinghead gasoline (CHG) was so named because it was produced at the casinghead of a well, typically one which was under vacuum as part of enhanced oil recovery (Weber, *The Titusville Herald*, date unknown). It is sometimes referred to as "natural gasoline", and it was produced on the flats of the Columbia Farm by the Brundred Oil Corporation during the early to mid-1900s (Augie Holtz, personal communication).

Figure 6. Top—Casinghead gasoline compressor at Columbia Farm. Bottom—Compressor coils.

CHG is generated from wells that were drilled for the extraction of oil, not for the extraction of natural gas. CHG is “wet gas.” Whereas natural gas (or “dry gas”) is predominantly composed of the lightest hydrocarbon, methane, “wet gas” also includes hydrocarbons heavier in molecular weight than methane, including ethane, propane, butane, pentane and hexane, among others. Not all oil wells produce “wet” gas, but wet or CH gasoline is generally only produced from oil wells, particularly those drilled in a low rock pressure environment. The CHG needed to be physically produced from the gas flowing from the oil well, at the well’s casinghead, through various steps of compression and cooling or refrigeration. For the reasons detailed below, it was desirable for a CHG plant to also be located close to both a water supply and rail transport facilities (Westcott, 1922).

Not long after the Drake well was drilled, oil producers in NW PA began noticing the accumulation of a flammable liquid in their pipelines during cold weather. The accumulation of this liquid was both a nuisance and a fire hazard. In the early 1880s, William Helm of Tidioute developed a process by which to remove the liquid through a simplified condensing process. Helm blended this liquefied gas with the oil produced from his wells, thereby increasing the volume of produced liquid hydrocarbons. Other producers in PA and West Virginia established CHG production plants. This crude gasoline could also be used to power on-site equipment, such as steam boilers used to drive pump jacks (Weber,*Titusville Herald*, date unknown). The National Gasoline Company of Tidioute, PA is believed to be the first CHG plant built for the purpose of producing natural gasoline to power its own oil wells, and in establishing the first pipeline system to collect CHG made from leases in the surrounding area such that it could be marketed on a larger commercial scale (*The Petroleum Gazette*, 1916).

As the number of automobiles, motor boats, airplanes and other internal combustion-powered farm and other industrial equipment and factories grew in the early 20th century, so did the need for the fuel, which created more of a market for CHG (Weber, *Titusville Herald*, date unknown and Westcott, 1922).

By the early 1920s, over 1200 CH gas plants were operating in the U.S., having a retail sales value of more than $75 million, which grew steadily as the number of automobiles increased (Westcott, 1922). CHG was regulated through rationing during WWII, but well owners or lessees who produced it for themselves were harder to be regulated by the government at that time, and such producers were expected to regulate themselves during the war effort by not driving more than necessary (*The Titusville Herald*, 1942).

In short, the wet gas was piped from individual wells to a central location where it was first typically compressed by a low-pressure cylinder. This raised the temperature of the gas which was then cooled by passing the gas through narrow-diameter coils which were cooled with dripping water. The condensed liquid was collected in an accumulator tank before being put through the process again, this time through a higher-pressure cylinder prior to a second stage of condensation. Sometimes the process included an expansion stage, which effectively cooled the gas, which was then used to help further cool and condense the gas coming from the high pressure compression stage. In some processes, a refrigerant such as ammonia or a brine solution was used to cool the gas (Lang, 1983).

Because this “straight” casinghead gasoline was very volatile it was usually blended with naphtha, or sometimes other gasoline products. This ensured a product which was composed of a more desirable blend of volatile constituents, and was safer to both transport and use. Unblended CHG could be used directly in automobiles, but it caused “knocking”; blending it created a better engine fuel. Tie blending process could be done at the CHG plant site, with the final product being loaded on to rail cars for transport, or the CHG could be transported to local refineries for blending (*Titusville Herald*, date unknown and Westcott, 1922).

The buildings associated with the casinghead gasoline plant on the Columbia Farm were removed by the Bureau of State Parks in 2008. All that remains are some foundations and the compressor, which is believed to have also used for the secondary recovery repressurization operations (David L. Weber, Drake Well Museum, personal communication, 2007).

Columbia Farm – Circa 1970 to Present

When the Commonwealth of PA decided to create a park along the Oil Creek Valley, circa 1970, it only purchased the surface rights; the subsurface was held jointly by Quaker State (which had acquired the parcel in 1952) and a private individual. Quaker State was later acquired by Belden & Blake Corporation, of Canton, Ohio. In 2005, Belden & Blake's parent company was sold to EnerVest Management Partners, Ltd. (redOrbit, 2005).

At the time the Commonwealth exercised condemnation rights to the Columbia Farm property, there were six residential structures and a barn still located at what was once the area of the company town. Tenants were paying $10 to $20 per month for rent. Some of these homes had no central heat, but were served by water from a well located on the hillside above. These structures were razed as part of the park's development. A small cemetery is still located on the property, and some foundations and old oil equipment are scattered through the woods. On the flats, between the location of the former casinghead gasoline plant and Oil Creek is a relict "central power", a building within which a gear or gears was located which could operate numerous oil well pump jacks by means of a connection of tie rods.

Maraflood™ Experimental Secondary Recovery Project

In March 1970, Quaker State Oil Refining spud well 2-Q, which was intended to be an injection well for their experimental Maraflood™ secondary recovery project. The idea was to use a patented product developed by Marathon Oil, a petroleum sulfonate compound, to inject into a well which would essentially act as a detergent, to loosen the oil from the rock by lowering its surface tension, thereby making the oil easier to recover. Quaker State planned to inject this liquid into the Venango 3rd sand unit, at a depth of about 800-850' below the surface on the uplands of the Columbia Farm, and to monitor its effect using surrounding observation wells, several of which were drilled for this purpose. While this technology had proven successful in laboratory and field testing to be capable of recovering more than 90% of the oil in reservoir rock, the pilot program conducted on the Columbia Farm was apparently not as successful or economically feasible as hoped, and Quaker State terminated injection operations on February 28, 1974 (Walker, 1971 and 1973, and Wiesner, 1974).

Old Wells/Plugging Operations

Numerous old, abandoned oil wells still exist on the Columbia Farm parcel. Efforts have been made over the years to document the location of these and other wells within Oil Creek State Park so that they can be properly plugged. In 2003, three such wells were plugged on the Columbia Farm by the Commonwealth of Pennsylvania, under the oversight of the Department of Environmental Protection's Bureau of Oil and Gas Management. In 2004, 29 wells were plugged, and in 2009, eight wells have been or will be plugged.

New Wells

While old oil wells are still being plugged, relatively new gas wells have been drilled on or near the Columbia Farm. On December 11, 1996, Belden & Blake Corporation completed a nearly 6000’ deep natural gas well to the underlying Lower Silurian Medina Group, and specifically, developing the Grimsby and Whirlpool sandstones. And on January 11, 2004, the same company completed a similar well just west of the Columbia Farm, but located on private lands. Oil drilling is still very actively taking place within the Allegheny National Forest, located in Warren, Forest, Elk and McKean Counties, not too far east of the Oil Creek Valley. And the Commonwealth is being actively explored for what are estimated to be very large quantities of shale gas associated with the Middle-Devonian Marcellus Formation, which exists about 4000’ below Oil Creek State Park. Since the Commonwealth does not own the subsurface below the park, it’s conceivable that the 150-year legacy of the Columbia Farm could continue to live on as the result of new gas well drilling.

REFERENCES

Anderson, 1865, *Third Annual Report of the President and Directors to the Stockholders of the Columbia Oil Company*. Anderson, A.A. & Sons, Printers.

Anderson, 1866, *Fourth Annual Report of the President and Directors to the Stockholders of the Columbia Oil Company*. Anderson, A.A. & Sons, Printers.

Anderson, 1867, *Fifth Annual Report of the President and Directors to the Stockholders of the Columbia Oil Company*. Anderson, A.A. & Sons, Printers.

Anderson, 1868, *Sixth Annual Report of the President and Directors to the Stockholders of the Columbia Oil Company*. Anderson, A.A. & Sons, Printers.

Anderson, 1869, *Seventh Annual Report of the President and Directors to the Stockholders of the Columbia Oil Company*. Anderson, A.A. & Sons, Printers.

Anderson, 1870, *Eighth Annual Report of the President and Directors to the Stockholders of the Columbia Oil Company*. Anderson, A.A. & Sons, Printers.

Anderson, 1870, *Eighth Annual Report of the President and Directors to the Stockholders of the Columbia Oil Company*. Anderson, A.A. & Sons, Printers.

Anderson, 1871, *Ninth Annual Report of the President and Directors to the Stockholders of the Columbia Oil Company*. Anderson, A.A. & Sons, Printers.

Anderson, 1872, *Tenth Annual Report of the President and Directors to the Stockholders of the Columbia Oil Company*. Anderson, A.A. & Sons, Printers.

Anderson, 1873, *Eleventh Annual Report of the President and Directors to the Stockholders of the Columbia Oil Company*. Anderson, A.A. & Sons, Printers.

Anderson, 1873, *Twelfth Annual Report of the President and Directors to the Stockholders of the Columbia Oil Company*. Anderson, A.A. & Sons, Printers.

Beates, Susan, Neil McElwee, and David Weber, undated, *Oil History Timeline*. Oil150: Celebrating the Story, Progress from Petroleum, [http://www.oil150.com/ about-oil/ timeline/](http://www.oil150.com/about-oil/timeline/).

Beers, F. W., 1865, *Atlas of the Oil Regions of Pennsylvania*, Beers, Ellis & Soule, New York, 60 p.

Brundred, W. J., date unknown, *Results of Repressuring Depleted Sands In Old Pennsylvania Fields*, presented before the Eastern district meeting API, Division of Development and

Production Engineering, Oil City, PA,.

Carll, J. F., 1877, *Oil Well Records and Levels*. Pennsylvania Geological Survey 2nd ser., Report II, 398 p.

Carnegie, Andrew, 1920, *Autobiography of Andrew Carnegie*. Houghton Mifflin Company, The Riverside Press, Cambridge, 385 p.

Cone, Andrew and Johns, W. R. , 1870, *Petrolia: A Brief History of the Pennsylvania Petroleum Region, Its Development, Growth, Resources, Etc. from 1859 to 1869*. Appleton and Company, New York, 652 p..

Dickey, P. A., 1941, *Oil Geology of the Titusville Quadrangle, Pennsylvania*. Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 22, 87 p.

Hamilton, 1862, *Act of the General Assembly, Pamphlet Law*. A. Boyd Hamilton.

Henry, J. T., 1873, *The Earlier and Later History of Petroleum, with Authentic Facts in Regard to Its Development in Western Pennsylvania*. James B. Rodgers, Philadelphia, 607 p. (reprinted in 2006 by the Oil Region Alliance, Oil City, PA)

Herrick, J. P., 1949, *Empire Oil The Story of Oil in New York State*. Dodd, Mead and Company, New York, 1949, 474 p.

Johnston, 1864, *Second Annual Report of the President and Directors to the Stockholders of the Columbia Oil Company*. W. G. Johnston & Co.

King, B. W., 2006, *Columbia, the gem of the Oil Patch*. Whiskey & Gunpowder, June, 2006, also available at http://www.energybulletin.net/16881.html.

Lang, Jr., D. W., 1983, *William Lang and the Gasoline Plant*. Kane, PA.

Lytle, W. S., 1960, *History, Present Status and Future Possibilities of Secondary Recovery Operations in Pennsylvania*. Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 41, 23 p.

McLaurin, J. J., 1896, *Sketches in Crude-Oil: Some Accidents and Incidents of the Petroleum Development in All Parts of the Globe*. Privately printed, Harrisburg, PA, 406 p.

Michener, Carollee, 2007, *Nitroglycerine Saved Many Wells*. http://www/oil150.com/essays/2007/04/nitroglycerin-saved-many-wells.

Pees, S. T., 1994, *Silurian Medina gas revitalizing Pennsylvania's historic Oil Creek*. Oil and Gas Journal, v. 92, no. 2, p. 116-121.

The Petroleum Gazette, An Independent Oil and Gas Journal, Volume XII, no. 4, July 1907, p. 13.

redOrbit, 2005, Belden & Blake Corporation Provides Post Merger Update and Announces Conference Call. redOrbit.com, http://www.redorbit.com/news/science/240910/belden__blake_corporation_provides_post_merger_update_and_announces/.

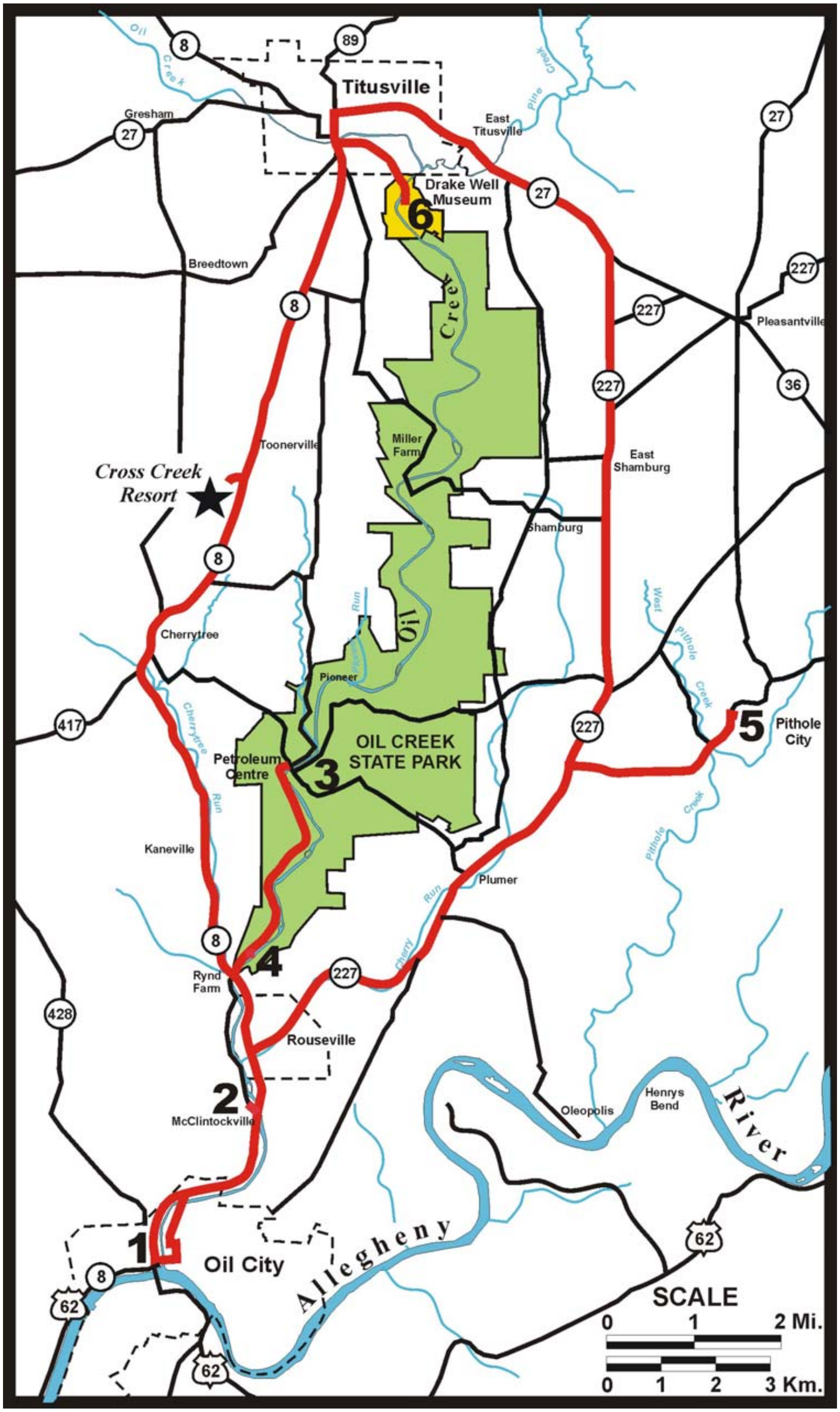
Szalewicz, Steve, 1972, *Columbia Farm, Oildom's Youngest Ghost Town*. Oil City Derrick, January 26.

Oil City Derrick, 1898, *The Derrick's Hand-Book of Petroleum: A Complete Chronological and Statistical Review of Petroleum Developments from 1859 to 1998*. Derrick Publishing Company, Oil City, PA, 1062 p.

The Titusville Herald, 1942, *Casinghead Gas Use Is Matter of Patriotism*. Titusville, PA, November 12, 1942.

Walker, J. T., 1971, Division of Minerals, PA Bureau of Forestry, internal memo, October 6, 1971.

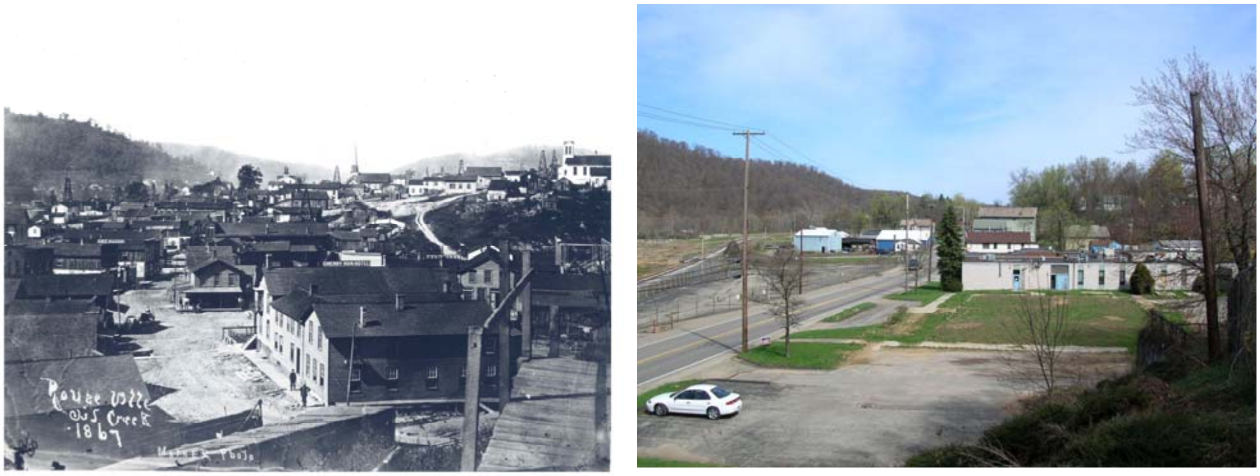
Walker, J. T., 1973, Division of Minerals, PA Bureau of Forestry, internal memo, October 29,



Day 1 Route Map
Cross Creek Resort is shown as a star

DAY 1

Miles		
Int.	**Cum.**	**Description**
0.0	0.0	Leave parking lot of Cross Creek Resort and head for exit. The resort is in the old Toonerville oil field, discovered in 1868 and producing primarily from the Venango Third sand. There has been plenty of "recent" (1980s and 1990s) drilling for Medina gas in the field, but the resort apparently has refused to lease its land, because there is a large "gap" in the Medina production surrounding it.
0.1	0.1	Entrance to Cross Creek. Turn right onto PA 8 south.
1.4	1.5	Turn off to Petroleum Centre to left. Proceed straight.
1.0	2.5	Enter village of Cherry Tree. We are also entering the old Oakland oil field, discovered in 1900 and producing primarily from the Venango First and Third Stray sands. Medina production here, also.
0.2	2.7	Intersection PA 417 in Cherry Tree on right. Continue straight on PA 8.
0.4	3.1	Enter Oakland Township. The valley to the left is Cherrytree Run. The Corry Sandstone crops out there.
0.6	3.7	Enter Cornplanter Township.
0.3	4.0	Outcrop to the right is the Lower Mississippian Cuyahoga Formation.
0.5	4.5	Enter village of Kaneville and Oil City-Rouseville oil field. This field was discovered in 1861 by the Phillips #2 well, located on Oil Creek about halfway between Petroleum Centre and Rynd Farm. This well had an initial production of 3,900 barrels of oil per day (Bopd). Production in this field is primarily from the Venango Second and Third sands.
0.5	5.0	Harper Road on left (not to be confused with Harper Intersection - see Day 2 road log). Continue straight on PA 8.
0.4	5.4	Outcrop to the right is more Upper Devonian Corry Sandstone.
0.7	6.1	Enter village of Rynd Farm.
0.3	6.4	Cross Cherry Tree Run.
0.1	6.5	State Park Road to Petroleum Center & Oil Creek State Park on the left. Continue straight on PA 8.
0.1	6.6	Cross Oil Creek. The road to the right just before the bridge is Waitz Road, where Coal Oil Johnny lived when he wasn't travelling the world. The house is no longer there. It was moved to the area behind the trees on the left at the south end of the bridge.
0.4	7.0	Enter Borough of Rouseville and cross the Oil Creek & Titusville Railroad tracks. Pepper and others (1954) noted an excellent section of the Corry Sandstone section at this position (their section # 118), which showed the three-part Corry succession. Caster (1934) indicated that the road that is now PA 8 passed over the railroad at this place. He placed the base of the Corry in the adjacent cut as being 15 feet above the track level at this crossing.
0.6	7.6	Traffic light at intersection with PA 227. Continue straight on PA 8. Just beyond the intersection is a historical marker that reads: *HENRY R. ROUSE (1823-1861) A former teacher and Warren County legislator who became a successful oil lease owner. One of 19 persons killed when the Little &*



Rouseville then and now. Left—John Mather photo of Rouseville taken in 1867. Right—The same scene today. Mather photo courtesy of Drake Well Museum (DW 531).

		Merrick oil well at Rouseville exploded and burned on April 17, 1861. As he lay dying, Rouse dictated a will that provided liberally for roads and the poor. Buchanan Farms had been renamed Rouseville that February; three-year-old Ida Tarbell (later famous as an oil industry critic) was a resident.
0.1	7.7	The empty field to the right was the former home of Pennzoil's refinery and packaging plant, situated along Oil Creek since the 1880s. Pennzoil and its predecessors had been turning Penn Grade crude oil into motor oil, waxes, and other petroleum products. When Pennzoil and Quaker State merged in 1998, the company closed the refinery due to declining supplies of Penn grade crude and rising transportation costs. The facility was sold to Calumet Lubricants Co. in 2000 to produce wax products, but Calumet razed the refinery and turned the property over to Rouseville in 2006. Nothing remains now but the packaging plant and about 25 acres of brownfield.
0.3	8.0	Enter Cornplanter Twp.
0.2	8.2	Cross Oil Creek and enter McClintockville.
0.1	8.3	South end of Waitz Road to right. Historical marker reads: *OLDEST PRODUCING OIL WELL McClintock No. 1 Oil Well has produced continuously since August, 1861. Drilled only two years after the famous Drake Well, it is located 240 yards away, across the railroad.*
0.3	8.6	As the oil boom faded in the late 1800s, the McClintock and Clapp Farms oil production was replaced with other businesses. The area is now home to Merisol Antioxidants LLC, which has been producing 12 million pounds of butylated hydroxytoluene (BHT) per year since they bought the plant in 1997.
0.3	8.9	Fenced areas are sites of former Quaker State, Pennzoil and Wolf Head oil refineries.
0.6	9.5	Enter Oil City.
0.2	9.7	Cross Oil City & Titusville Railroad tracks.
0.3	10.0	Intersection with Business PA 8 to left, which crosses Oil Creek and enters downtown Oil City. Continue straight on PA 8 Bypass.
0.2	10.2	Beginning of outcrop of Upper Devonian Corry Sandstone and "Unnamed sandstone" and Lower Mississippian Orangeville Shale (Cuyahoga

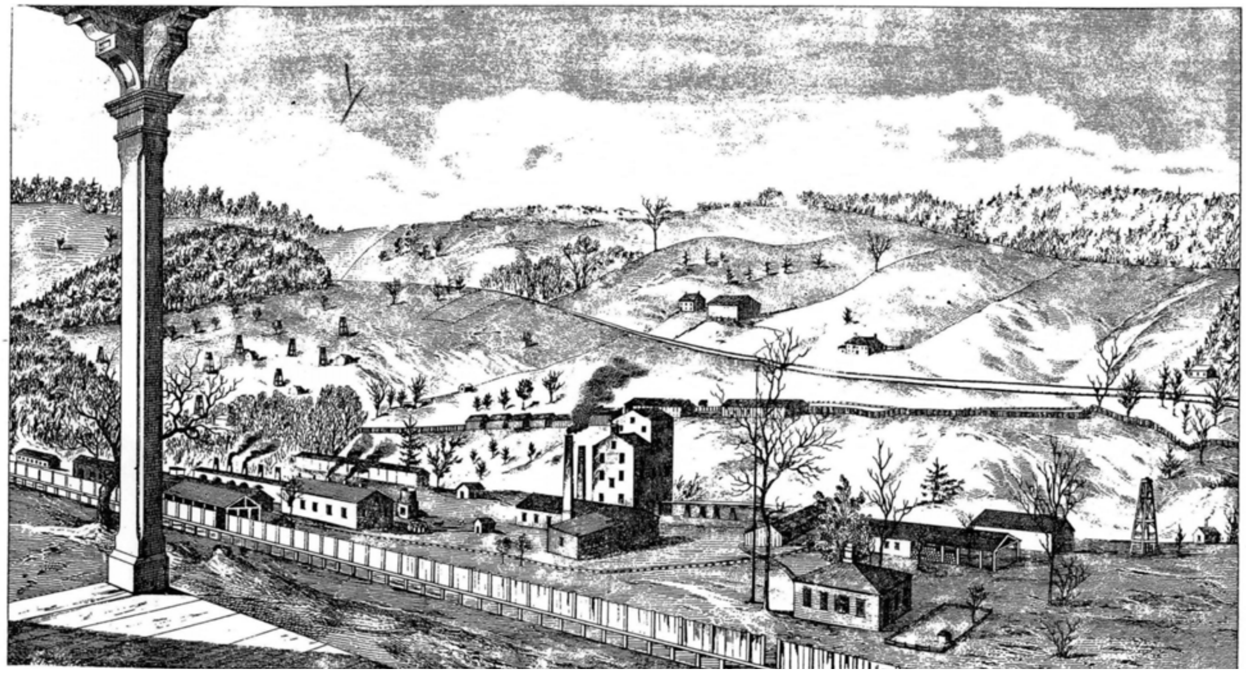
		Formation) on right. By Ward's (1976) account, only the upper part of the Corry is visible above the road. Fox (1989) argues that both the "unnamed sandstone" and overlying Corry Sandstone can still be seen here.
0.4	10.6	Abandoned railroad tunnel entrance on right. Pull buses to the right side of the road.
		STOP 1: OIL CITY AND END-DEVONIAN SUCCESSION – "UNNAMED SANDSTONE" THROUGH ORANGEVILLE SHALE SUCCESSION
		Depart from vehicles at the closest practical pull-off area, on or immediately off the PA 8 Bypass. Gather before the south end of the long roadcut opposite Oil City at the wide shoulder in front of the abandoned railroad tunnel. See detailed stop description on page 84.
		Leave STOP 1. Turn left at traffic light and follow Business PA 8 (Center Street) across Oil Creek into downtown Oil City.
0.2	10.8	Intersection with Seneca Street at traffic light. The red brick building on the left is the National Transit Building. Continue straight on Center Street.
0.1	10.9	Turn left at traffic light onto Elm Street. Two blocks south of this intersection is the Arlington Hotel (formerly Holiday Inn), which was erected on the site of the Oil Creek iron furnace built in 1825 (Pees, 2001).
0.1	11.0	Turn left at traffic light onto Duncomb Street, then turn right at the next traffic light onto North Seneca Street.
0.5	11.5	Cross Oil Creek and turn right at stop sign onto PA 8.
1.6	13.1	Turn left onto Waitz Road and park buses in the large lot near the fence on the left.
		STOP 2: MCCLINTOCKVILLE AND THE MCCLINTOCK #1 WELL
		Depart from the vehicles and walk across the railroad tracks to the McClintock #1 well. See detailed stop description on page 89.
		Leave STOP 2. Turn left onto PA 8 and cross Oil Creek.
0.2	13.3	The outcrop on the right is the contact between the "Unnamed sandstone" below and the Corry Sandstone above. This roughly corresponds to Pepper and others (1954) "section # 119".
0.2	13.5	Enter Borough of Rouseville.
0.4	13.9	Intersection with PA 227 on right at traffic light. Continue straight on PA 8.
0.7	14.6	Cross Oil Creek & Titusville Railroad Tracks and enter village of Rynd Farm.
0.3	14.9	Cross Oil Creek.
0.1	15.0	Turn right onto State Park Road and enter Oil Creek State Park.
0.6	15.6	Blood Farm day use area on right. Continue straight on State Park Road.
0.1	15.7	Steep bank along road to the left (sections of Tidioute Shale, "unnamed sandstone", and Corry Sandstone) may be visible here.
0.2	15.8	Oil Creek Dam and Ice Control Project on right.
0.3	16.1	Tarr Farm on right across Oil Creek. The Tarr Farm was a 198-acre tract that proved to be one of the most productive farms along the creek. Among the

Left—John Mather photo of the Tarr Farm in 1864. Courtesy of Drake Well Museum (DW 139). Right—The same scene today.

many wells drilled on this property were the famous Phillips and Woodford wells, renowned for their amazing production. The Phillips well (actually, the Phillips #2), drilled in 1861, began flowing at an unheard of rate of 4,000 barrels per day in October of that year. Eight months later it was still producing 3,660 barrels per day. Eventually, it settled to 2,500 barrels per day, but it continued at that rate for months. By 1865, when John Mather took this photograph, it had produced somewhere around 300,000 barrels of oil, and it held the record for largest open flow in Pennsylvania until 1884. In December 1861 the Woodford well was completed at 3,000 barrels per day. Only 66 feet away from the Phillips #2, the Woodford produced from the same reservoir (Venango Third sand) and probably contributed to the Phillips well's slow decline. Phillips, Frew & Co., owners of the Phillips well, bought the Woodford well for $600,000 in 1862. James Tarr, original owner of the farm, lived on the property until 1865, despite having sold most of it to the oil speculators. The royalties for the portion Tarr still owned amounted to about one million dollars. When Tarr sold the remainder of the farm for two million dollars, he retired to Meadville, Crawford County, a very wealthy man.

0.6	16.7	Columbia Farm on right (see p. 58-72). Continue straight on State Park Road.
0.2	16.9	Enter Petroleum Centre-Pioneer oil field. Discovered at Pioneer, just north of Petroleum Centre, in 1861 by the Empire Well, which came in at 2,500 Bopd.
0.8	17.7	Enter the ghost town of Petroleum Centre.
0.1	17.8	To the left is the entrance to Wildcat Hollow Environmental and Historic Area. Wildcat Hollow is an old cutoff meander of Oil Creek. It is separated from the channel of Oil Creek by a teardrop-shaped “hogback.” According the Lytle (1959), the Corry Sandstone is visible at the east end of the ridge. Fox (1989) described and figured the top of the “Cussewago Sandstone” in the cut, succeeded by a shale-rich unit (“Bedford Shale”) displaying thin, flaggy siltstone beds. According to Harper (1998) these divisions should be, in ascending order, the “Drake Well Formation” and the “Tidioute Shale.” Fox (1989) indicates that the shale division is about 60–70 feet thick in this

		area. Moreover, the “unnamed sandstone,” visible below the Corry Sandstone in the Rouseville area, is absent at Petroleum Center and at sections further north.
0.1	17.9	Cross Oil Creek & Titusville Railroad Tracks turn left into the Petroleum Centre Railroad Station parking lot.
		STOP 3: PETROLEUM CENTRE, WILDCAT HOLLOW, THE HYDE AND EGBERT FARM, AND THE GREAT PETROLEUM SHAFT
		See detailed stop description on page 94.
		Leave STOP 3. Turn right out of parking area onto Stevenson Hill Road (Google Maps calls it Old Petroleum Centre Road).
0.1	18.0	Turn right onto State Park Road.
1.0	19.0	Enter Oil City-Rouseville oil field.
1.3	20.3	Turn left into Blood Farm day use area. Drive to the circle past the restrooms and debark.
		STOP 4: THE BLOOD FARM AND LUNCH
		See detailed stop description on page 103.
		Leave STOP 4 and turn left onto State Park Road.
0.4	20.7	The white house on the hill to the right is the Blood House.
0.5	21.2	Turn left onto PA 8 and cross Oil Creek.
1.0	22.2	Turn left at traffic light onto PA 227.
0.1	22.3	Oucrop of Corry Sandstone and "Unnamed sandstone" on the left.
0.8	23.1	Enter Cornplanter Township.
0.2	23.3	Cross Cherry Run.
1.6	24.9	Enter village of Plumer. To the left is a historical marker that reads: *HUMBOLDT REFINERY One of the largest and most scientifically advanced petroleum refineries of its time occupied 47 acres along Cherry Run immediately northwest of this site. It was placed in operation by chemist Jon Bruns and the Lodovici Brothers in 1862. Named for the naturalist Alexander von Humboldt, it incorporated such innovations as a 2 mile oil pipeline, oil -fired boilers, and a means of producing aniline dye. The refinery remained in operation until 1868.*
1.1	26.0	Petroleum Centre Road to Oil Creek State Park on left. Continue straight on PA 227. We are entering the Rattlesnake oil field, discovered in 1870 and producing primarily from the Red Valley and Venango Second sands.
1.6	27.6	Medina well on right is operated by Range Resources. Drilled in 1991, it produces from the Grimsby Sandstone between 5,964 and 6,108 feet depth.
0.1	27.7	Turn right onto Pithole Road. The historical marker just before the turnoff reads: *PITHOLE Created in 1865 by the discovery of oil. Within a few months it was a boom town of 15,000 with banks, churches, hotels, newspaper, post office, water system, and railroad. Oil wells began to go dry in less than a year, and in time only excavations and street lines remained. Site is about two miles northeast*.
0.8	28.5	Cross Allender run on one-lane bridge.



The Humboldt Refinery in 1865, as seen from the Manager's house. From Beers (1965).

1.1	29.6	Cross West Pithole Creek on one-lane bridge. Enter the Pithole-Cashup oil field, discovered in 1865 and producing primarily from the Red Valley and Venango First and Third Stray sands.
0.3	29.9	Turn right into parking lot of historic Pithole **STOP 5: ANATOMY OF A GHOST TOWN - PITHOLE** See detailed stop description on page 108.
		Leave STOP 5 and turn left onto Pithole Road. Return to PA 227.
2.3	32.2	Turn right onto PA 227.
0.2	32.4	Medina well on left. Drilled by Mark Resources (now Range Resources) in 1990, it produces from the Grimsby Sandstone between 5,946 and 6,009 feet down.
1.3	33.7	Enter Oil Creek Township.
0.3	34.0	Historical marker on the right reads: *FIRST OIL PIPELINE Constructed in the fall of 1865. Following a straight course about 5 miles in length, it transported oil by pumps from Pithole to a railhead at Miller Far, thus revolutionizing the transportation of petroleum. Dug up when Pithole wells were pumped dry. Trench is visible here and at points along the course of the old pipeline.*
1.0	35.0	Enter Shamburg oil field, discovered in 1866 by the Shamburg well. The field produces primarily from the Venango Third sand.
0.9	35.9	East Shamburg, at intersection with Fleming Road on left. Continue straight on PA 227.
0.5	36.4	Shamburg Road on the right goes to Pleasantville. Continue straight on PA 227.

1.0	37.4	PA 227 turns right and runs east through Pleasantville. Continue straight on Jerusalem Corners Road. Pleasantville was the home of John Franklin Carll during the years he lived in Venango County. Carll was appointed assistant geologist in charge of the oil regions during the Second Geological Survey of Pennsylvania in the 1870s to 1890s by J. P. Lesley. He is credited with being the world's first petroleum geologist and engineer (Lytle, 1957; Harper, 1990 and 2002). A historical marker dedicated on October 23, 2007 in front of the house he lived in reads: *JOHN FRANKLIN CARLL (1826-1904) Pioneer petroleum geologist and engineer, Carll originated many standard oil industry practices, including accurate drilling records, correlating and mapping subsurface reservoir rocks, and explaining the increased productivity resulting from reservoir flooding. In the 2nd Geological Survey of Pennsylvania (1875), he provided basic explanations of northwestern Pa. surface and subsurface geology. He lived and worked here from 1864 until his death.* In the 1940s, what is now the Pittsburgh Office of the Pennsylvania Geological Survey consisted of William S. Lytle and some support staff. Their offices were in the house Carll lived in.

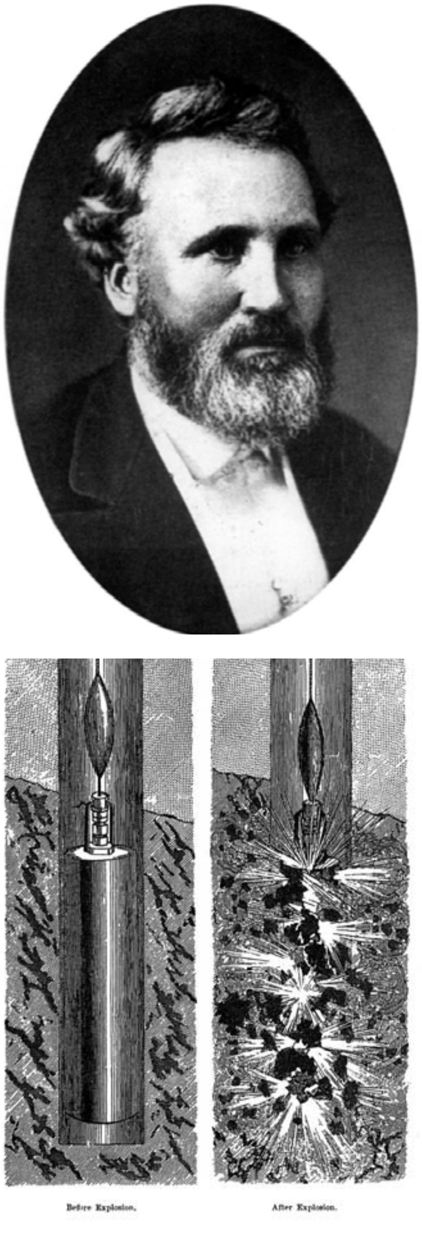
Portrait of John F. Carll, Pennsylvania's pioneering petroleum geologist and engineer.

0.9	38.3	Turn left onto PA 27.
1.6	39.9	Enter Crawford County and the village of East Titusville.
0.2	40.1	Cross Pine Creek.
0.2	40.3	Cross railroad tracks and enter Church Run oil field. Church Run field was discovered in 1865 when the Eureka well came in at 52 Bopd. The field produces oil primarily from the Venango Third Stray and Third sands, and gas from the Medina Group.
0.6	40.9	Enter Titusville. Titusville was first settled in the late 1700s by Jonathan Titus, a surveyor for the Holland Land Co. Until 1859, its principal industry was lumbering, with as many as 17 sawmills scattered around the area, including those of the Brewer, Watson & Company on whose land Edwin L. Drake drilled his famous well.
0.2	41.1	Titusville Waste Water Plant on left.
0.6	41.7	Traffic light at N. Brown Street. A new (as of August 28, 2009) historical marker on the left reads: *JOHN WILLIAM HEISMAN Legendary college football coach, the coveted Heisman Trophy was named for him. He revolutionized the sport w/ the center snap, the Heisman shift, and promoted legalization of the forward pass. He also advocated numerous safety improvements.* Continue straight on PA 27 (E. Central Avenue).
0.1	41.8	Cross Church Run.

Left—When Drake moved to Titusville to drill his well, he stayed at the American Hotel on Spring Street, pictured here in an 1865 photo. The American Hotel is the 3-story building behind the standing clock on the left (north) side of the street. Photo courtesy of Drake Well Museum (DW 1068). Right—the same scene in 2008. All of the buildings in the historical photo have been replaced over the years.

0.3	42.1	Turn left at traffic light onto S. Franklin Street, which is PA 8 in the opposite direction, and enter Octave oil field. Octave field was discovered on August 27, 1859 when the Drake Well came in at an estimated 10 Bopd.
0.1	42.2	Traffic light at Diamond Street (on the left) and W. Spring Street (on the right). Continue straight on S. Franklin Street. When Edwin Drake first arrived in Titusville in 1857 to scope out the prospects of drilling an oil well, he stayed at the American Hotel on Spring Street around the corner and just down the street to the right. The hotel, which is the three-story building at left center behind the standing clock in this 1865 photograph, was a hospitable inn in a village of friendly people. Drake made many friends with the inhabitants, including Peter Wilson who was the village apothecary. As the oil boom grew, Titusville became, for a time, the financial, commercial, and cultural capital of the oil fields with a population of between ten and twelve thousand. The American Hotel lasted until 1880 when it was torn down to make way for the Titusville Oil Exchange.
0.1	42.3	Cross Oil Creek & Titusville Railroad tracks. Just beyond the tracks, St. John Street (PA 8 southbound) intersects from the right. Continue straight on S. Franklin Street (now PA 8).
0.1	42.4	Cross Oil Creek and turn left at the traffic light onto E. Bloss Street. Historical marker on the right at the end of the bridge reads: *OIL CREEK Along this stream the first white explorers found Indians skimming surface oil. From 1859 to 1865, the center of oil production and its refining was along the banks of Oil Creek.*
0.1	42.5	Cross Hammond Run.
0.8	43.3	Enter Venango County, Cherrytree Township.
0.1	43.4	Stop sign at west side of one-lane bridge. Wait for any traffic to dissipate, then cross bridge over Oil Creek. The parking area adjacent to the stop sign is at the north end of Oil Creek State Park, and those who want to ride the bike trail along the old railroad grade can park here.
0.1	43.5	Turn right at end of the bridge and enter Drake Well Park.

0.3	43.8	Drake Well Museum and Park. Park vehicles in upper lot. **STOP 6. DRAKE WELL MUSEUM AND “TYPE” “DRAKE WELL FORMATION” OUTCROP"** See detailed stop description on page 120.
		Leave Stop 6 and return to PA 8.
1.3	45.1	Turn left onto PA 8.
0.2	45.3	Historical marker on left reads: *ROBERTS TORPEDO First successful device for increasing the flow of oil by setting off an explosion deep in a well. It was publicly demonstrated in 1865. The nitroglycerin was made .4 mile south of here, along Hammond Run.*
0.3	45.6	Enter Venango County, Cherrytree Township. Exposure of Corry Sandstone to the right.
0.6	46.2	The grassed-over roadcut on the left is the Titusville Till type section. As with all glacial type sections, the exposure is temporary. From this section, samples were taken on which some of the world's pioneering clay mineralogy studies of tills were done. Clay mineral analysis is now a standard procedure to help determine stratigraphy, provenance, and weathering characteristics of tills worldwide. A small borrow pit at the north end of the roadcut was a stop on the 1976 Field Conference.
2.0	48.2	Enter Toonerville oil field.
0.7	48.9	Historical marker on right reads: *DENSMORE TANK CARS The first functional railway oil tank car was built in 1865 at nearby Miller Farm along Oil Creek. Named after its inventors, James and Amos Densmore, it consisted of two wooden tanks placed on a flat railway car, each tank holding 40-45 barrels of crude oil. A successful test shipment was sent in September, 1865 to New York City. By 1866, hundreds of tank cars were in use. The Densmore Tank Car revolutionized the bulk transportation of crude oil to market.*
0.2	49.1	Turn right into Cross Creek Resort.
0.4	49.5	Cross Creek Resort parking lot. End of Day 1.



Top—Portrait of Colonel A. E. Roberts, former Civil War soldier and inventor of the torpedo for shooting (blasting fractures in reservoir rocks) oil wells. Bottom—Illustration of the torpedo mechanism.

DAY 1 ROAD LOG REFERENCES

Beers, F. W., 1865, *Atlas of the Oil Region of Pennsylvania*. F. W. Beers, A. D. Ellis & G. G. Soule, New York, 60 p.

Caster, K. E., 1934, *The stratigraphy and paleontology of northwestern Pennsylvania, Part 1, Stratigraphy*. Bulletins of American Paleontology, v. 21, no. 71, 185 p.

Fox, J. S., 1989, *Some geological aspects of the Oil Creek Valley region*, in Pees, S. T. and others, *History of the Petroleum Industry Symposium*. American Association of Petroleum Geologists Guidebook, p. 46-53.

Harper, J. A., 1990, *John F. Carll: Pennsylvania's prophet of the oil fields*. Pennsylvania Geology, v. 21, no. 5, p. 8-12.

Harper, J.A., 1998, *Stop 6 and lunch, Drake Well Memorial Park*, in Harper, J.A., ed., *Geotectonic environment of the Lake Erie crustal block*. Guidebook, 63rd Annual field Conference of Pennsylvania Geologists, Erie, PA, p. 61-74.

Harper, J. A., 2002, *The incredible John F. Carll: The world's first petroleum geologist and engineer*. Oilfield Journal, v. 2 (2001-2002), p. 2-14.

Lytle, W. S., 1957, *The story of John F. Carll, Second Pennsylvania Survey's pioneer petroleum geologist*. Pennsylvania Department of Internal Affairs Monthly Bulletin, v. 25, no. 4, p. 19-22.

Lytle, W. S., 1959, *Introduction to bedrock and oil geology of northwestern Pennsylvania and the Great Oildorado*. Guidebook, 24th Annual Field Conference of Pennsylvania Geologists, Titusville, PA, Trip B, p. 12-76.

Pees, S. T., 2001, *Field excursion: Oil Creek Valley and Pithole, Pennsylvania*. Guidebook and Essays, privately printed, Meadville, PA, 44 p.

Pepper, J. F., deWitt, Jr., Wallace, and Demarest, D. F., 1954, *Geology of the Bedford Shale and Berea Sandstone of the Appalachian basin*. U. S. Geological Survey Professonal Paper 259, 111 p.

Ward, Jr., A. N., 1976, *Bedrock stratigraphy*, in Ward, Jr., A. N., Chapman, W. F., Lukert, M. T., and Craft, J. L., *Bedrock and glacial geology of northwestern Pennsylvania in Crawford, Forest and Venango Counties*. Guidebook, 41st Annual Field Conference of Pennsylvania Geologist, Titusville, PA, p. 7-17.

STOP 1: OIL CITY AND END-DEVONIAN SUCCESSION – “UNNAMED SANDSTONE”THROUGH ORANGEVILLE SHALE SUCCESSION

Leaders: Gordon C. Baird, D. Jeffery Over, Shirley Pulawski, and John A. Harper

Oil City – Historical Overview

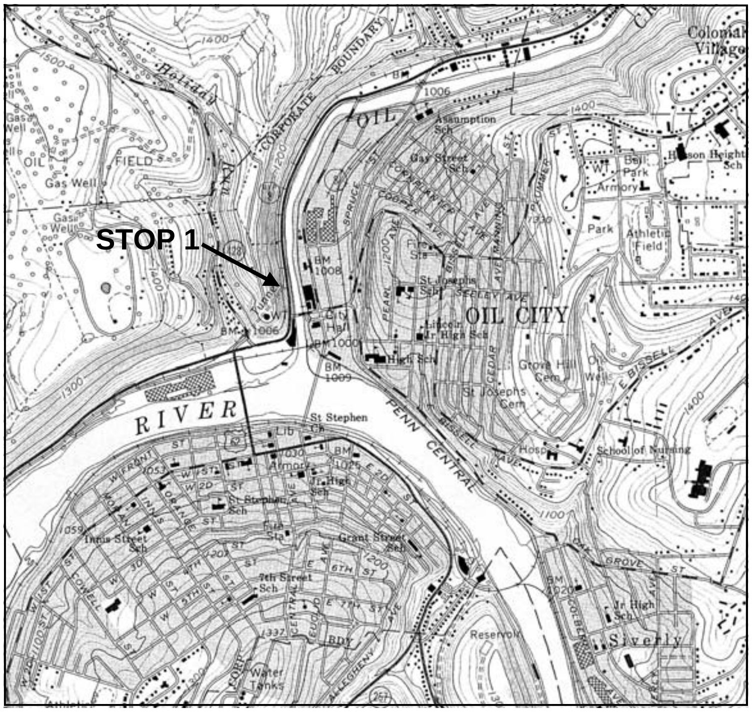


Figure 1. Location of STOP 1 in the Oil City 7.5-minute

Oil City (Figure 1) was originally called Cornplanter after the renowned chief of the Seneca Nation, who had been given three tracts of land at the junction of Oil Creek and the Allegheny River as a gift from the State of Pennsylvania in the late 1700s. The land was purchased from the Seneca Nation in 1818, then changed hands several times until 1825 when three partners bought it and erected an iron furnace (Oil Creek Furnace) (Flaherty, 2003). The furnace went out of business in the early 1850s. In 1856, Captain William Hasson and his family settled on the site. A few small houses made up the town, and served as a resting spot for craftsmen. During the 1850s, three inns, one store, a house of entertainment, a tavern, a blacksmith, and toolmaker’s shop were added. Still, by 1859, it was little more than a stop-over for raftsmen running lumber from as far away as Coudersport (Potter County) to Pittsburgh. It was a small village with a grist mill, a general store, the Moran House, and a few dwellings besides the establishments previously mentioned (Giddens, 1948; Flaherty, 2003); the land was owned mostly by Graff, Hasson & Co. (Miller, 1968), which quickly laid out town lots when news reached the area about the Drake Well. The village grew rapidly and, in 1861, its name was changed to Oil City. It was made a borough in 1862, and quickly acquired both a newspaper and a population of around 8,000. Disaster struck in 1865 when the borough was partially destroyed by a flood; then in 1866, it was hit with the “double whammy” of flood and fire. It was chartered as a city in 1874, but once again was nearly destroyed in 1882 when lightning struck some oil tanks upstream and Oil Creek transported burning oil into the city. Some 60 lives were lost, and property damage exceeded $1 million.

Because it lies at the junction of the Allegheny River, a major transportation corridor, and Oil Creek, it quickly became a hub of shipping. Oil moved from the producing wells upstream

Baird G. C., Over, D. J., Pulawski, Shirley, and Harper, J. A.., 2009, *Stop 1: Oil City and end-Devonian succession—”unnaned sandstone” through Orangeville Shale succession,* in Harper, J. A., ed., *History and geology of the oil regions of northwestern Pennsylvania*. Guidebook, 74th Annual Field Conference of Pennsylvania Geologist, Titusville, PA. p. 84-88.

Figure 2. 1864 Mather photograph of flatboats on Oil Creek at Petroleum Centre, about 18 miles upstream from Oil City. Photo courtesy of Drake Well Museum (DW 268).

to the Allegheny River by flat-bottomed boat (Figure 2), or by oil barrels lashed together, using Oil Creek as the primary form of transportation. From that point, barrels were loaded onto steamboats or barges and sent to Pittsburgh and other locations. Oil Creek is very shallow, so that it generally is navigable only by very light or very shallow-draft boats, and typically only for about six months out of the year. In order to assure the water was high enough to navigate, oilmen used a technique called the "pond freshet." This was a series of dams, with floodgates, that had been built by the area sawmills on the principal branches and tributaries of Oil Creek, some as much as 10 miles upstream from Titusville. The lumbermen had used this system for transporting lumber, but now the oilmen used it for transporting oil-laden flatboats. The dams would collect water; then, at the appropriate time, when all the boats had been loaded and the tariffs had been collected on each barrel (Giddens, 1948), the floodgates would be opened to raise the water level in the creek. By the time the high water reached Titusville, it was anywhere from 2 to 2.5 feet above the rocks normally sticking out of the water (Flaherty, 2003). As the wave approached, the boatmen would cut their boats free and ride the higher water down to Oil City and beyond.

A typical flatboat held 100 barrels of oil. Since around 200 flatboats operated on Oil Creek, a pond freshet shipment carried as much 20,000 barrels to Oil City where the barrels would transferred to river flatboats headed to Pittsburgh. In 1862, there were 15 steamers with an 800-barrel capacity making three trips between Oil City and Pittsburgh per week (Flaherty, 2003).

Transporting oil by flatboat could be disastrous, especially when the boatmen were unable to control their boats sufficiently. Sometimes one would turn sideways and become wedged against something in the creek, causing a veritable log-jam of flatboats. Often oil would spill into the creek, making a thorough mess. The volatile oil also had a bad habit of igniting and turning a pond freshet event into a series of flaming flatboats. In addition, the flatboats leaked, and when water flowed into the boats, oil flowed out. As much as 30% of a shipment could be lost in transit on the waterways (Flaherty, 2003). Oil Creek also tends to ice up during winter months. Ice jams often clogged the creek for miles (Figure 3), playing havoc with the oil business. The coming of the railroad in the region in the mid-1860s solved the transportation problem and the pond freshets were discontinued.

Oil City thrived during the latter half of the 19th century and into the 20th century as many oil men made it their headquarters. For many years, it was the headquarters for the Pennzoil, Quaker State and Wolf's Head motor oil companies, but by the 1990s, they had all relocated headquarters elsewhere (Pennzoil and Quaker State merged and are now owned by Royal Dutch/Shell. Today, tourism plays a prominent role in the region, promoting Victorian architecture, oil heritage sites, nature trails, and rail-trails. Ice jams are certainly not a thing of the past. The city still suffers chronic ice jams, such as one in 1982 that caused damages in excess of $4 million in downtown Oil City. An ice control dam on Oil Creek in Oil Creek State Park helps, but has not completely alleviated the problem.

Figure 3. 1862 Deming photograph of an ice jam on Oil Creek near its junction with the Allegheny River in 1862. Photo courtesy of Drake Well Museum (DW 1536).

Geology Along Pa 8 Bypass

The roadcut along the PA Route 8 Bypass (Figure 4) is the largest of several good end-Devonian-basal Mississippian sections in the Oil City area, though not the best for access of beds above the Corry Formation. It is described in the classic Pepper and others (1954) report and is mentioned in several subsequent guidebook roadlogs. Due to the regional southward dip, the Devonian section is gradually descending into the subsurface in this area as we trace units southward down the Oil Creek Valley; the "Unnamed Sandstone" of Schiner and Kimmel (1972) can be seen below the thick, massive sandstone beds of the Corry Formation at the northern end of this long roadcut, but they have dropped out of

Figure 4. Recent photograph of the PA Route 8 roadcut at Oil City.

view at the southern end of this exposure where we are standing. Earlier workers place the thickness of the Corry Formation in this area at about 8 meters (25 feet); resistant Corry strata, constituting the informal "lower member" of the Corry (*sensu* Caster, 1934; Pepper and others, 1954), comprise a 4.5 meter- (14 foot) – thick interval of massive, grey siltstone beds in the outcrop face. Above this is the shaley "middle member", followed, in turn, by a return to siltstone beds in the "upper member". The 2.5 meter (8 foot)-thick, middle member and the 2 meter (6.5 foot)-thick upper member are not accessible in this cut face, but they have been examined nearby at Rouseville. Above the greater Corry succession is the base of the Mississippian Orangeville Formation. This can be seen as chippy grey shale at the top of this exposure.

"Unnamed Sandstone" Division

Schiner and Kimmel (1972) initially identified the "unnamed sandstone" in the subsurface of Mercer County and extended it into portions of Venango County, including the Oil City-Rouseville area where it can be seen in outcrops. It is absent below the Corry Formation in sections from Petroleum Centre northward. It is described as including fine grained sandstones, minor siltstone beds, and shale. Fox (1989) describes this unit as being unfossiliferous and characterized by hummocky cross-stratification and peculiar teardrop-shaped sandstone bodies. Examination of this interval by Baird at the Rouseville Post Office and along Waitz Road opposite Rouseville, revealed an interval of variably bioturbated, muddy sandstone and siltstone beds. This interval does display hummocky cross-stratification and it contains a modest brachiopod and bivalve association. In short, it resembles portions of the underlying Riceville and "Drake Well" formations.

Corry Formation "Lower Member"

The only division which can be effectively examined at this locality is the Corry "lower member". It is conspicuous for a stacked succession of massive, 0.5-0.9 meter-thick beds of light grey siltstone or very fine sandstone which are mutually separated by thin bioturbated mudstone partings or shale bands. The basal 0.5-1.5 meter (1.5-4.5 feet) of the Corry is notably fossiliferous; compilations of this biota are in the published reports of Caster (1934) and Sass (1960). The base of the Corry throughout its area of occurrence appears to be sharp and unconformable. In Oil Creek Valley sections, prominent erosional lags are developed as laterally separated channel-fill features along the basal contact. Detrital pyrite, in the form of reworked pyritic burrow casts, fish teeth and fish bone fragments, pyrite-permineralized wood debris, coprolites, and disarticulated brachiopods occur abundantly in these lags.

Given that the Tidioute Shale, which underlies the "unnamed sandstone", appears to thicken greatly southward from Centerville to Petroleum Centre, and the "Unnnamed Sandstone" is observed to appear below the Corry Formation south of Petroleum Center (see Fox, 1989), a pattern of regional angularity may be developed along the sub-Corry unconformity. Progressive southward appearance of sub-Corry strata toward Oil City may increase chances of locating the signature of the Hangenberg bioevent in this area. One curious feature of the upper part of the Corry 'lower member' is the presence of a thin, rusty-weathering black shale bed in several sections. This black shale is currently being sampled for disaggregation and conodont extraction.

Corry Formation “Upper Member”

At sections around Rouseville, the base of the Corry “upper member” locally displays concentrated quartz pebbles. Moreover, the basal bed, as well as the higher siltstone layers in this division, are rather muddy and are pervasively bioturbated. Recent observations by Baird suggest that the Corry “three member” succession in the Oil City-Rouseville area closely mimics the Corry-Hungry Run Sandstone succession in the Centerville-Riceville area. A thin, muddy phase of the Hungry Run Sandstone, originally described by Pepper and others (1954) south of Riceville, displays prominent bioturbation, a sharp basal contact, and scattered quartz pebbles and granules at that contact. Moreover, this unit is separated from the underlying typical Corry Sandstone by an intervening shale resembling the Corry “middle member”. Given that Pepper and others (1954) believed that their Hungry Run Sandstone was, most likely, a Mississippian –age, eastern correlative of the Bartholomew Bed, this opens the possibility that the Corry “upper member” may be of similar status.

REFERENCES

Caster, K. E., 1934, *The stratigraphy and paleontology of northwestern Pennsylvania, Part 1, Stratigraphy*. Bulletins of American Paleontology, v. 21, no. 71, 185 p.

Flaherty, K. J., 2003, *Hills, dales, and oil trails: A guide to some historic oil fields between Pittsburgh and Titusville, PA.* Field Trip Guidebook, American Association of Petroleum Geologists-Society of Petroleum Engineers 2003 Joint Eastern Meeting, Pittsburgh, PA, 91 p.

Fox, J. S., 1989, *Some geological aspects of the Oil Creek Valley region*, in Pees, S. T. and others, *History of the Petroleum Industry Symposium*. American Association of Petroleum Geologists Guidebook, p. 46-53.

Giddens, P. H., 1948, *Early Days of Oil: A Pictorial History of the Beginning of the Industry*. Princeton University Press, Princeton, NJ, 150 p. (reprinted in 2000 by The Colonel, Inc., Titusville, PA.)

Miller, E. C., compiler and editor, 1968, *This Was Early Oil: Contemporary Accounts of the Growing Petroleum Industry, 1848-1885*. Pennsylvania Historical and Museum Commission, Harrisburg, PA, 211 p.

Pepper, J. F., deWitt, Jr., Wallace, and Demarest, D. F., 1954, *Geology of the Bedford Shale and Berea Sandstone of the Appalachian basin*. U. S. Geological Survey Professonal Paper 259, 111 p.

Sass, D. B., 1960, *Some aspects of the paleontology, stratigraphy, and sedimentation of the Corry Sandstone of northwestern Pennsylvania*. Bulletins of American Paleontology, v. 41, p. 247-381.

Schiner, G.R. and Kimmel, G.E., 1972, *Mississippian stratigraphy of northwestern Pennsylvania*. U. S. Geological Survey Bulletin 1331-A, 27 p..

STOP 2: MCCLINTOCKVILLE AND THE MCCLINTOCK #1 WELL

Leader: John Harper and Augie Holtz

Historical Overview

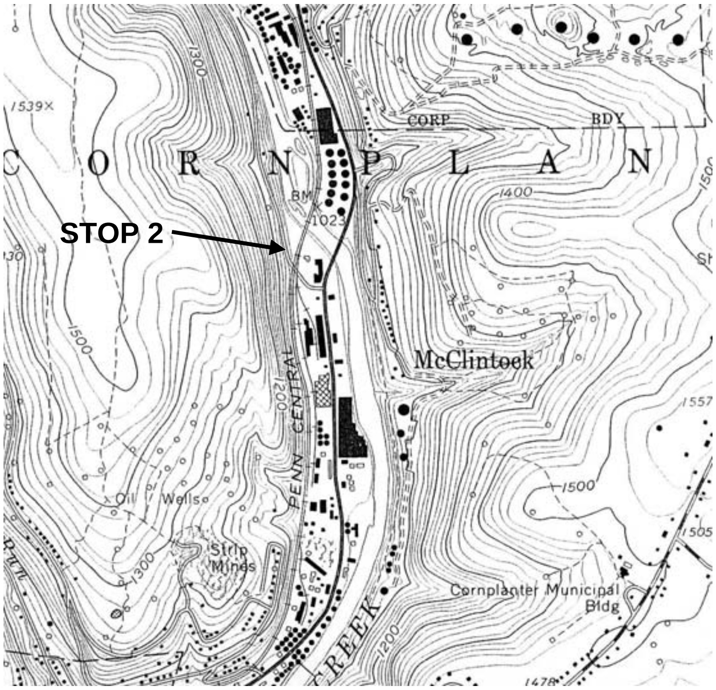


Figure 1. Location of STOP 2 in the Oil City 7.5-minute

McClintockville (Figure 1), located a few miles north of Oil City, and just downstream from Rouseville, was one of the earliest oil towns on Oil Creek. This was originally a farm settled by the McClintock family in 1796. It was also the site of the first oil spring in Pennsylvania to be recorded on a map, Lewis Evans' *Map of the Middle British Colonies in America*, dated June 23, 1755. The spring was located in Oil Creek about 100 yards south of the bridge that carries PA 8 across the creek. Nathanial Carey, an early settler in the area, collected the oil and shipped it by horseback in two five-gallon kegs to Pittsburgh from 1790 to about 1815 (Figure 2). His highest annual production was 10 to 16 barrels (Lytle, 1959), with the oil selling for $1 to $2 per gallon. Later, Hamilton McClintock collected and sold oil from the spring to neighboring farmers and to a bottler of medicine in nearby Cooperstown for anywhere from 50¢ cents to $1 per gallon (Giddens, 1948; Michener, 1997).

At the time the Drake well came in, Hamilton McClintock, a simple farmer, serendipitously owned what would soon become several hundred acres of prime oil land. His was the second property to be leased for drilling, and he must have made a fortune because he not only got the rental money but a royalty on all the oil produced. Brewer, Watson and Company drilled the first well on the farm in November, 1859, less than three months after the Drake well hit pay dirt (Dickey and others, 1943). The farm house was just about the

Figure 2. Nathaniel Carey collected oil from an oil seep in the middle of Oil Creek as early as 1790 and carried it in five-gallon barrels to Pittsburgh on horseback where he sold it for medicinal purposes.

Harper, J. A., and Holtz, Augie, 2009, *Stop 2: McClintockville and the McClintock #1 well*, in Harper, J. A., ed., *History and geology of the oil regions of northwestern Pennsylvania*. Guidebook, 74th Annual Field Conference of Pennsylvania Geologist, Titusville, PA. p. 89-93.

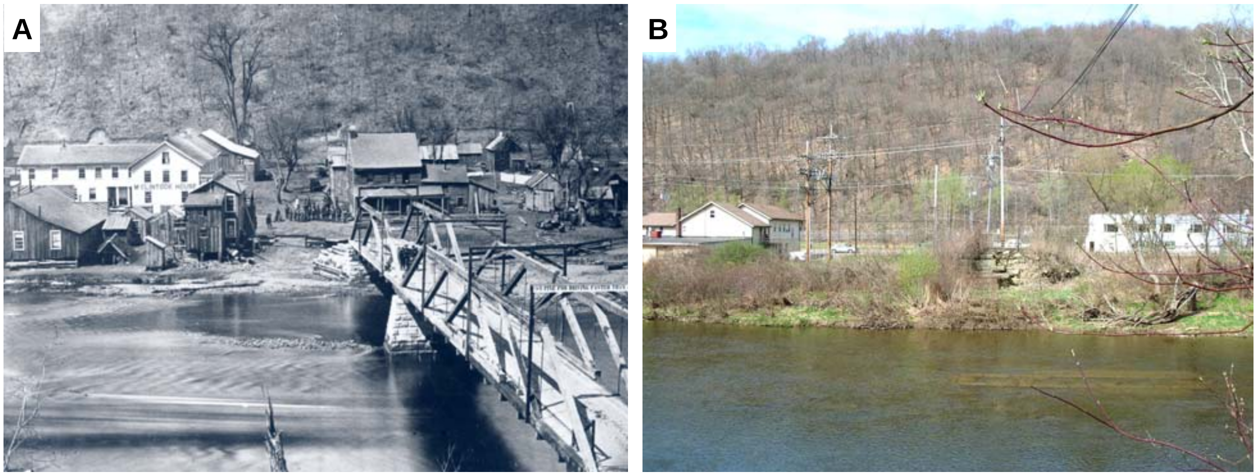


Figure 3. A—Mather photograph of McClintockville in861. If you look closely, you can see a derrick in the right background. It is possible that this is the location of the McClintock #1 well. Photo courtesy of the Drake Well Museum (DW 522). B— The same scene today. The remains of the bridge in the historical photo, including the stonework on either bank of Oil Creek and the base of the mid-creek pier, can still be seen about 200 feet south of the current bridge carrying PA 8 across the creek.

only building in the area in 1859-60 and, as "black gold fever" hit the area, the house became a haven for hoards of speculators. Patrons crammed every room in the house, and even the crannies and nooks commanded at least moderate prices. Eventually, a town began to be built around the farm house with makeshift shacks of every description going up overnight. Some were barns for storing equipment, some doubled as oil company offices and housing for the rabid crowds looking to get rich quickly. In all, about 60 wells were drilled on this property. McClintock himself owned several oil wells, including the historic McClintock #1 well (see below). At one time, McClintockville had a hotel, a number of boarding houses, and several refineries (Giddens, 1948) (Figure 3A).

During the early days of oil, the business was plagued by a hypothesis called "creekology". Oilmen were convinced that oil flowed along in the subsurface in streams beneath the creeks and rivers at the surface (sadly, many people still believe this today!). When the oil craze hit, McClintockville and adjacent areas sprouted hundreds of wells on the Oil Creek floodplain, and even right on the banks of the creek, as a result. Jonathan Watson (Figure 4), a partner of Brewer, Watson and Company, decided to take full advantage of "creekology" by drilling a well at the site of McClintock's oil spring, which McClintock had protected by building a crib to prevent oil from being flushed down the creek (Giddens, 1948). Figure 5 is Mather's photo of the derrick, taken from the east bank of Oil Creek. Thus was born the future of the offshore oil industry.

Today, McClintockville is a small community on both sides of Oil Creek. Most of the features seen in Figures 3A and 5 are long gone, but the bridge pier on the west bank and foundation for the mid-stream pier are still evident today (Figure 3B). The primary business is Merisol Antioxidants

Figure 4. Portrait of Jonathan Watson, partner in the Brewer, Watson & Company lumber operations along Oil Creek.

Figure 5. Mather photograph of the world's first "offshore" oil well, with McClintockville in the background. This well, drilled by Jonathan Watson, was situated on McClintock's famous oil spring in the center of Oil Creek. Photo courtesy of the Drake Well Museum

LLC, manufacturer of butylated hdroxytoluene (BHT).

The McClintock #1 Well

The McClintock #1 well (Figure 6) was drilled in August, 1861 by spring-pole (Figure 7) to a depth of 620 feet, and came in at 50 Bopd from the Venango Second and Venango Third sand reservoirs (Pees, 2001) (see p. 42, fig. 2). It was operated over the years by different companies. Dickey and others (1943) listed the Brundred Oil Co. as operator during the 1940s. Quaker State Oil Refining Corp. operated the well for some time and pumped it once every four months for 24 hours at a stretch. Pees (2001) reported that Quaker State estimated the ANNUAL production for many years was six barrels of oil and some brine (1/164th Bopd). In fact, were it not for its historical value, it would have been abandoned years ago.

The Colonel, Inc. (now called Friends of the Drake Well), a non-profit group interested in oil history, acquired the McClintock well from Quaker State in August, 1998, and briefly acted as an interim holding company until the Pennsylvania Historical and Museum Commission took over ownership and management of the well later that year.

In the meantime, the well was in great need of repair. It had been off line for a while so that, when The Colonel, Inc. acquired it, they set to work repairing it for posterity. Volunteer members and companies lent their expertise and resources to the project. They extracted the sucker rods, replaced sections of the tubing and the sanding valve, and repaired the traveling valve. There were also repairs to the 15 HP Reid gas engine that powers the eccentric. Goss Gas, a Reno company, donated a large propane tank for use in powering the engine.

On November 19, 1998, after the repairs had been made, the engine was started and the pump began pumping. It took a few days, but the well began producing oil again. The brine

Figure 6. The McClintock #1 oil well as it appears today. This is the world's oldest producing oil well.

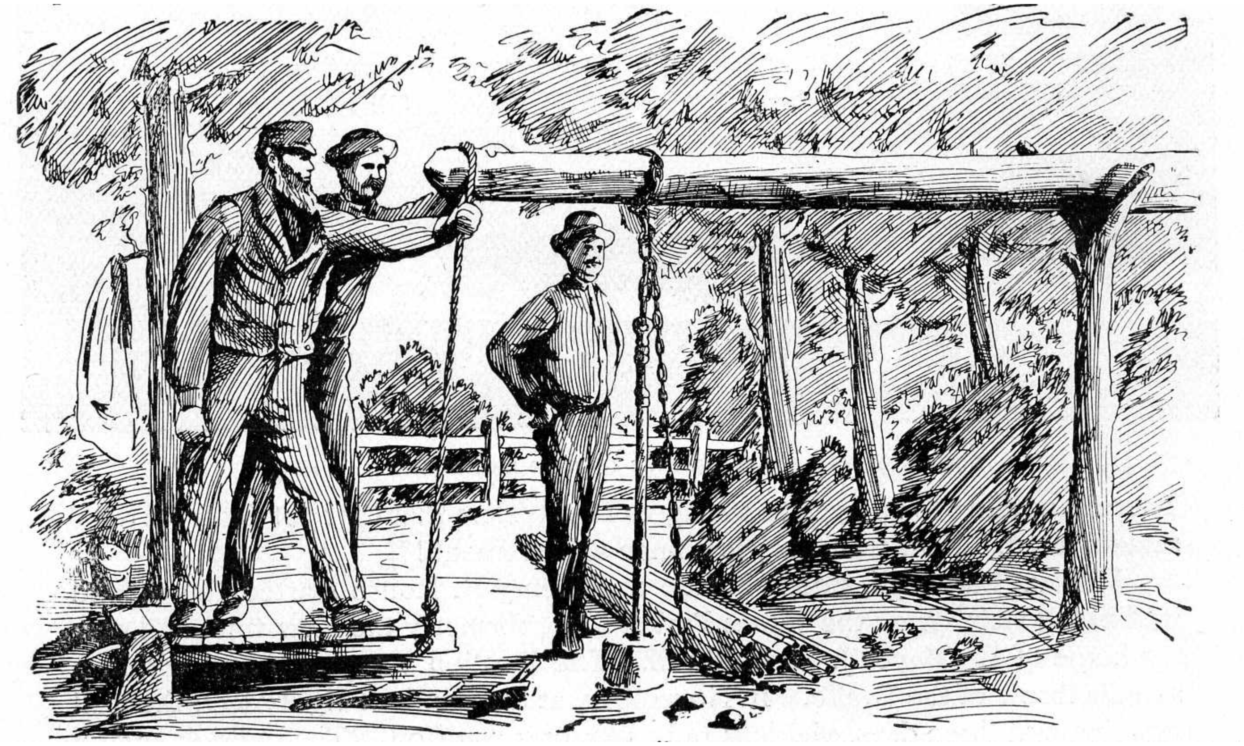


Figure 7. The McClintock #1 well was drilled by springpole to a depth of 620 feet.

tank filled in 18 hours, and on November 23, the brine was hauled to the Franklin Brine Disposal facility where the company disposed of it for free.

Because it is still producing oil today, the McClintock #1 well is considered the world's oldest producing oil well. The well produces very little oil, but it is still operating. Some of the production goes to provide oil for the Drake Well Museum outdoor exhibits, and some is bottled and sold in the museum gift shop as souvenirs for a nominal price.

Reservoir Geology

According to Dickey and others (1943), the Venango Third sand pool in the field typically is characterized by multiple bars or "streaks" of pebbly sandstone, with the pebbles more abundant in the upper part of the reservoir. Productive belts ranging from 500 to 2,000 feet in width trend north-south or northeast-southwest, separated by relatively barren (marginal production) belts of approximately the same width. Porosity ranges from 10 to 16 %, but the permeability is extremely variable, ranging from several darcies in the pebble beds in the northern part of the field to an average of less than one mD in the finer grained sandstone. The permeability, porosity, and oil content, as a rule, decrease as sandstone thickness decreases. Third sand oil is dark green, and has an API gravity of 42^{o} to 47^{o} (as determined by the Hempel method). Parts of the pool were repressurized with air starting around 1930.

The Second Venango sand pool is also productive in this field, and covers a larger area than the Third sand. Most drilling before 1880 was in the hope of finding large Third sand wells, and the Second sand generally was not developed until the late 1880s. The Second sand is 20 to 35 ft thick, generally medium- to coarse-grained, and typically contains a conglomeratic bed either at the top or in the middle of the sandstone body. It has porosities between 15 and 20 %, permeabilities ranging up to 600 mD, and oil saturations between 15 and 30 %. Initial productions typically ranged between 5 and 50 barrels per day, but some of the early wells had much higher initial productions. Much of the reservoir was operated under air drives in the past.

REFERENCES

Dickey, P. A., Sherrill, R. E., and Matteson, L. S., 1943, *Oil and gas geology of the Oil City quadrangle, Pennsylvania*. Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 25, 201 p., reprinted in 1984.

Giddens, P. H., 1948, *Early Days of Oil: A Pictorial History of the Beginning of the Industry*. Princeton University Press, 150 p., reprinted in 2000 by The Colonel, Inc., Titusville, PA.

Lytle, W. S., 1959, *Introduction to bedrock and oil geology of northwestern Pennsylvania and the Great Oildorado.* Guidebook, 24th Annual Field Conference of Pennsylvania Geologists, Titusville, PA, Trip B, p. 12-76.

Michener, C. K., compiler, 1997, *Oil, Oil, Oil.* Venango County Historical Society, 128 p.

Pees, S. T., 2001, *Field excursion: Oil Creek Valley and Pithole, Pennsylvania.* Guidebook and Essays, privately printed, Meadville, PA, 44 p.

STOP 3: PETROLEUM CENTRE, WILDCAT HOLLOW, THE HYDE AND EGBERT FARM, AND THE GREAT PETROLEUM SHAFT

Leader: John Harper

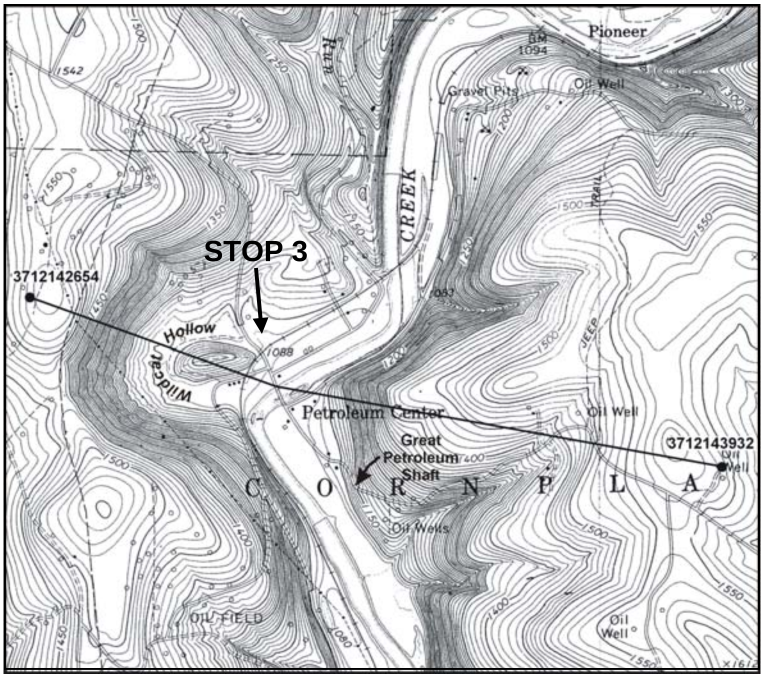


Figure 1. Location STOP 3 on the Titusville South 7.5-minute quadrangle showing the locations of Wildcat Hollow and the Great Petroleum Shaft. The cross section in Figure 5 spans Oil Creek Valley from well # 3712142654 to well # 3712143932.

Located approximately midway between Oil City and Titusville, Petroleum Centre (Figure 1) is the heart of Oil Creek State Park, just as it was the heart of oil activity in Oil Creek Valley in the 1860s. This area can be divided into two. The first, where the buses currently are parked, consists of Wildcat Hollow, the Petroleum Centre railroad station (on the Oil City & Titusville Railroad), and a series of boardwalks with interpretive plaques describing the town and its historic sites. Across Oil Creek, the Oil Creek State Park office overlooks the Egbert Day Use Area, formerly the Hyde and Egbert Farm; and up the hill, along Petroleum Centre-Plumer Road, are the remains of the Great Petroleum Shaft.

Petroleum Centre – Historical Overview

Petroleum Centre originally was a farm of 207 acres on the banks of Oil Creek, which was originally owned by Francis McClintock, a Scots-Irish cobbler (Pees, 1989). George W. McClintock, Francis' son, built a frame house near the bank of Oil Creek and ran a water-powered grist mill (Pees, 2001). The property included Wildcat Hollow.

Crum and Dungan (1911) said that an oil and gas seep was present in Oil Creek near Wildcat Hollow where you could see oil bubbling up through the water. According to Pees (1989), the seep drew oilmen to this sector of the creek soon after the Drake well proved successful in 1859. In fact, Jonathan Watson, partner with Ebenezer Brewer in the Brewer, Watson and Company, originally owned the land where the Drake Well was drilled. Watson probably knew of the oil seep near Wildcat Hollow because he quickly leased George McClintock's farm, as well as Hamilton McClintock's farther south (see STOP 2). Pees (1989; 2001) said you can still occasionally see an oily sheen on the water where the seep is supposed

Harper, J. A.., 2009, *Stop 3: Petroleum Centre, Wildcat Hollow, the Hyde and Egbert Farm, and the Great Petroleum Shaft,* in Harper, J. A., ed., *History and geology of the oil regions of northwestern Pennsylvania.* Guidebook, 74th Annual Field Conference of Pennsylvania Geologist, Titusville, PA. p. 94-102.

Figure 2. Photograph of Washington Street, the main thoroughfare of Petroleum Centre, around 1866. The Bissell Bank is on the extreme left side of the photo. Photo courtesy of Drake Well Museum (DW 251).

to have been.

Watson drilled an early well near the creek in late 1859, but it was never completed. Pittsburgh businessman, Samuel Kier, the first commercially successful oil refiner (see STOP 6), then leased the farm and drilled a well in1860 that had only a small production. As a result, the exciting news from farther up the creek in Pioneer drew attention away from the farm. Finally, in July, 1861, Kier drilled a well on the property that came in at 800 Bopd from the Venango Third sand (Pees, 1989). This caused great excitement and stimulated further activity.

The Central Petroleum Company, which was organized by Frederic Prentice and George H. Bissell, purchased the McClintock farm in 1863 for $385,000. McClintock and his wife moved away, figuring they got the better of the deal. Prentice and Bissell properly managed the land, leasing only to qualified oil operators, rather than to oil speculators who tended to offer huge bonuses, resell the leases for a profit, and then depart without any interest in developing them (Henry, 1873). The leases netted Central Petroleum half of the oil produced and a huge bonus.

They laid out streets and leased lots at exorbitant prices. The McClintock farmhouse was expanded into a hotel, and Bissell established a bank on the main corner (a corner of the building can be seen at the extreme left in Figure 2**)**. Soon, 3,000 people lived there, and the town boasted not only Bissell's bank, but two churches, a theatre, half a dozen hotels, a dozen dry-goods stores, boarding houses, offices, and several livery stables (Giddens, 1948). Since

Figure 3. Photograph of the meeting of the Oil Creek Rail Road and the Farmers Railroad in Petroleum Centre in 1866. This meeting of the railroads ushered in the age of oil transportation by rail and sounded the death knell of transportation by flatboat on the creek. The photo shows a crowd at the Petroleum Centre railroad station gathered to celebrate the feat with the Central House in the background. Photo courtesy of Drake Well Museum (DW 247).

this was essentially a wild town, there was no jail and no sheriff (Pees, 2001). The main thoroughfare was Washington Street (Figure 2); it soon sported many shady businesses, including gambling houses and houses of ill repute. One writer, in describing the town, said it resembled a California mining town, with one side of Washington Street taken up with "free-and-easies" and dance houses, and life was as dangerous as could be expected where men with pistols walked the streets (Michener, 1997).

The Oil Creek Rail Road, which originally ran from Corry, in Erie County, down to Titusville, was expanded down Oil Creek as far as Petroleum Centre. In 1866, it met the Farmers Railroad, which had been built up the creek from Oil City. Figure 3 shows a 4-4-0 steam locomotive sitting by the railroad station and the Central House in Petroleum Centre in the fall of 1966. According to Senges (2008), this photo shows the townsfolk celebrating the completion of the rail line from Oil Creek to Titusville. The Central House later burned down. Now there are only trees.

The town reached its zenith in the late 1860s, but remained alive and active through the 1950s. Among its famous visitors was President Ulysses S. Grant, who visited by train in 1871. George Bissell, who started out as a visionary trying to make money from oil on the land where Drake later drilled his well (see STOP 6), finally made his fortune in land speculation, banking, and oil production at Petroleum Centre. Although the Bissell Bank in Petroleum Centre closed

Figure 4. All that remains of the Bissell Bank in Petroleum Centre is a few blocks of foundation stone and the stone steps at the corner.

in 1873 (all that remains are the corner steps and the foundation - Figure 4), Bissell continued his activities by opening a bank in New York City, establishing some insurance companies, and drilling for oil in Peru (Pees, 1989). He died in 1894 in New York, a millionaire. (He who dies with the most toys wins!)

Wildcat Hollow

Wildcat Hollow (Figure 1) is an abandoned meander channel of Oil Creek. It is a semi-circular ravine, opening eastward at the north and south ends, separated from Oil Creek by a teardrop-shaped hillock that Pees (1989; 2001) called a hogback. The ravine contains a swamp, springs, and a sluggish creek called Wildcat run. Figure 5 shows a cross section across the Oil Creek Valley revealing that the bedrock exposed in the hogback includes much of the end-Devonian succession discussed by Baird and others (see Baird and others, this volume, p. 5-31).

Wells were drilled throughout Wildcat Hollow and even on the hogback separating it from Oil Creek. Because of the myth of “creekology,” many oilmen were reluctant to drill any distance away from the creek. In 1865, Michael E. Hess successfully drilled for oil on the Stephenson farm on the hill west of Petroleum Centre, effectively putting the myth to rest. Prior to that, however, the bold drillers working in Wildcat Hollow, which can’t be seen from Oil Creek, began drilling on the slopes that lined the hollow. As a result, somewhere around 200 wells were drilled in the hollow and along its slopes. Supposedly, the term “wildcat,” which means a rank exploratory well, derives from the speculative, but successful, nature of drilling in the hollow. At the height of production, Wildcat Hollow wells produced between 10 and 1,000 Bopd (Pees, 1989).

In the early 1900s, marginal wells were revived by shooting and, later, by gas injection. As a result of water invading the Venango Third sand through abandoned wells, oil production ceased by the early 1960s. The engines used for pumping the wells either were sold for scrap or acquired by antique collectors. Today, Wildcat Hollow is an environmental education area.

Hyde and Egbert Farm

On the east side of Oil Creek, across the bridge from Petroleum Centre, was a 38-acre farm owned by A. Davidson. A young physician from Cherrytree, Pennsylvania named Dr. A. G. Egbert (Figure 6 left), got caught up in “black gold fever” and bought the farm for $2,600 and half of any oil found. The price was too steep for him alone, so he enlisted the financial aid of a merchant named Charles Hyde (Figure 6 right), who already had some oil experience. The Hyde and Egbert Farm, as it became known, started out slowly, but eventually became one of

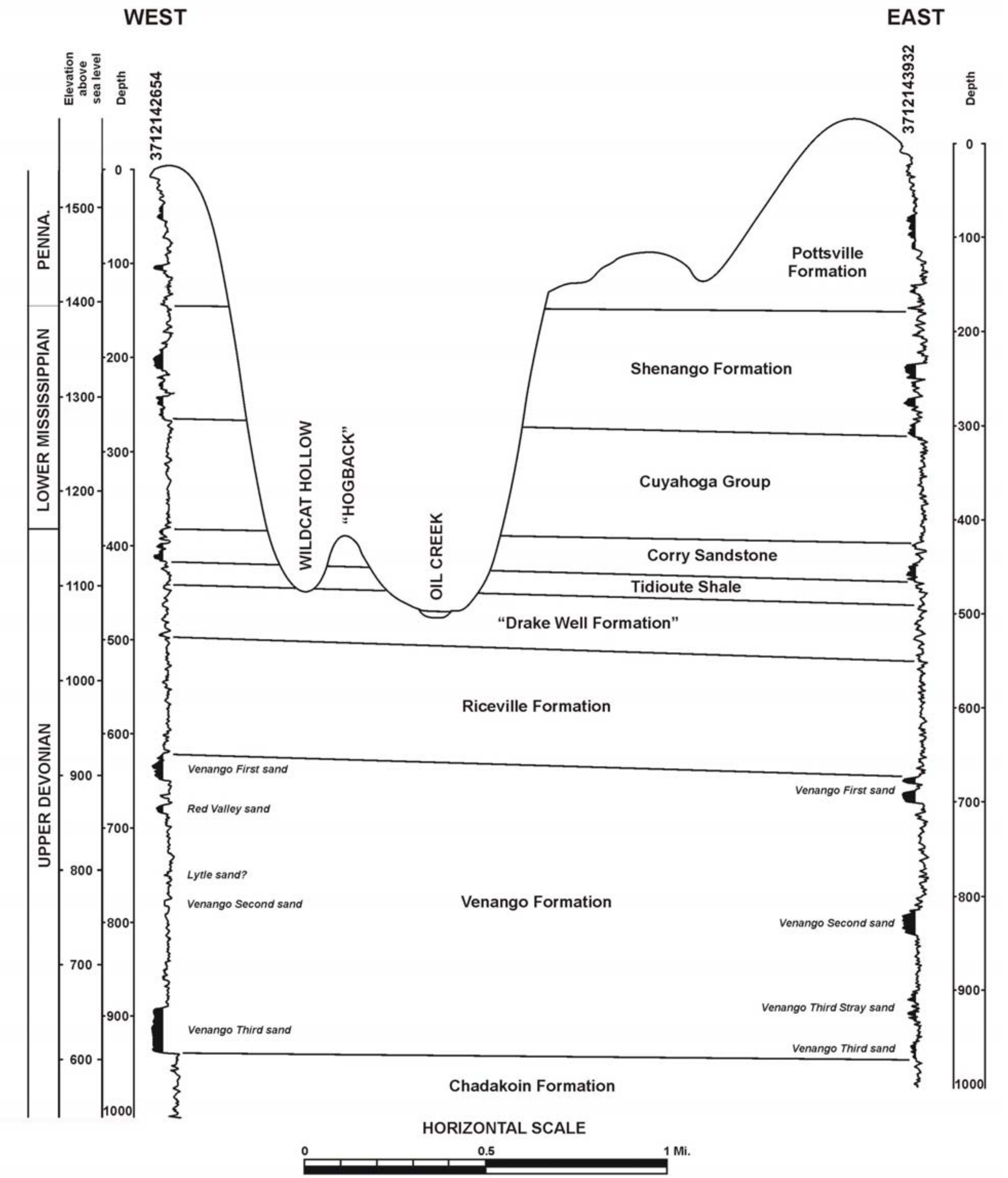


Figure 5. Cross section across the Oil Creek Valley and Wildcat Hollow. Line of section is shown in the location map on p. 94.

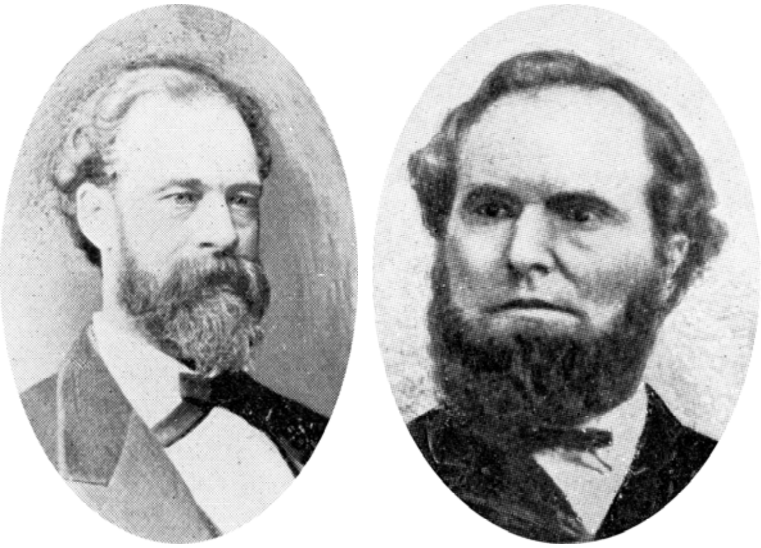


Figure 6. Portraits of Dr. A. G. Egbert (left) and Charles Hyde (right).

the more productive tracts along Oil Creek. On August 5, 1863, the Maple Shade well, probably the property's most notable well, came in at between 800 and 1,000 Bopd, and continued to flow at that rate for several months. This was followed by numerous companies forming to get in on the action between 1964 and 1865.

Above the Hyde and Egbert Farm, on the slopes of the hill, lay the James McCray farm. McCray was startled to find his fortunes changed in 1870 when he encountered numerous demands for leases on his land. By that time, the myth of "creekology" had been dispelled, and many oil speculators were looking for prime acreage on slopes and hillsides. Within four months of leasing the farm, oil production reached 3,000 Bopd, and McCray was receiving $9,000 per day in royalties. In 1871, McCray was offered $1 million for his property, which he refused (Giddens, 1948; Michener, 1997).

Figure 7 shows the Hyde and Egbert Farm at the base of the hill with the McCray Farm on the slopes above.

The Great Petroleum Shaft

In 1865, a group of oilmen formed The Petroleum Shaft and Mining Company to dig to the main producing reservoir on Oil Creek, the Venango Third sandstone. The Great Petroleum Shaft, 12 by 17 feet, was planned to go straight down into the earth 500 feet "for investigating purposes". The backers of the project wanted to see with their own eyes the nature of the strata underneath that was pouring out oil and gas with such profusion almost every time a well was drilled. They hoped "to prove that oil exists in regular veins; the extent and direction of

Figure 7. Mather photograph of the Hyde and Egbert Farm on the creek floodplain, with the McCray Farm on the slopes above, taken in 1862. Photo courtesy of Drake Well Museum (DW 585).

Figure 8. Woodward photograph of the excavation of the Great Petroleum Shaft in 1865. Workmen are busy constructing the framework for the machinery, winches, and pulleys. Photo courtesy of Drake Well Museum (DW 297).

---

same." The site chosen was 20 rods from the Jersey well that flowed 300 Bopd in 1864, and the same distance from the Maple Shade well. It was 40 rods from the Coquette well, which flowed 800 barrels a day.

The shaft was sunk 30 feet in the first two weeks of work in July, 1865 by the 14 hands employed, mostly Welsh coal miners from the anthracite regions of eastern Pennsylvania. The director of the work had also had mining experience in Schuylkill County. He counted on using a windlass to remove debris for the first 100 feet unless water interfered. After that depth was reached, machinery for hoisting, pumping and ventilating would be installed – the pump engine of 90 HP, and the hoisting and ventilating engines of 50 HP each. They estimated it would take 12 months to complete the shaft.

The work went on night and day. They constructed a surface installation for the hoisting machinery and other equipment (Figure 8) from local Pottsville sandstone. In September, 1865, the shaft was 73 feet deep, according to D. W. Davies, engineer and superintendent. Work was suspended pending the arrival of the machinery mentioned above. The cost of transporting the machinery from Schuylkill County was figured at $1,500.

What happened next is not clear to historians. The surface installation was never completed and digging ceased. The shaft was eventually filled in to a level of about 20 feet.

Figure 9. The Great Petroleum Shaft today. Top – The shaft is now just a near-circular depression about 15 or 20 feet deep. Bottom – The masonry for the machinery still exists, although it is not in good repair.

The remaining hole and the masonry can still be seen today in the woods (Figure 9) a few dozen feet south of the Petroleum Center-Plumer Road. These remains stand as mute witness to what one wag called “the absurd undertaking.”

Oil Creek State Park

When oil finally declined in importance in Pennsylvania, the Oil Creek Valley saw the eventual return of the lumber industry. The hills and valleys were soon clear cut, however, and it took the Civilian Conservation Corps (CCC) during the Great Depression to clear brush and replant the forests. In the vision of James B. Stevenson, a Titusville newspaper publisher, Oil Creek Valley could be converted to a state park that would combine the preservation and teaching of petroleum history with raw nature. The Commonwealth of Pennsylvania acquired the surface rights to the old properties during the 1960s, but did not purchase the mineral right, which are still privately held.

The area that is now Oil Creek State Park is a wild area with a thriving wildlife population, diverse second growth forest, and crystal clean streams. Although Oil Creek Valley has largely reverted to wilderness, you can still see signs of oil’s past history in Wildcat Hollow and other areas up and down the valley. Building remnants exist at many of the centers of early oil, including for example, the foundation and corner steps of the Bissell Bank at Petroleum Centre. Abandoned wells, some with pump jacks, tanks, and pipes still on site, can be found in many places, including along the “Geology Trail” on the hillside above Wildcat Hollow (Harper, 1998).

Oil Creek State Park is one of the more beautiful of Pennsylvania’s numerous state parks. Straddling Oil Creek for nine miles between the Drake Well Museum and Rynd Farm, it offers walking and bicycling along the 9.4-mile long paved right-of-way of the former Oil Creek Rail Road. It also offers picnicking, bass and trout fishing, canoeing, and kayaking in the creek, as well as backpacking, snowmobiling, and cross-country skiing along its numerous trails. The former Hyde and Egbert Farm area is the heart of the state park (Figure 10), with the park office overlooking green spaces, playgrounds, and the picnic areas with its two pavilions and modern restrooms.

Figure 10. Oil Creek State Park's Egbert Day Use Area.

If you spend enough time here, you might see some bald eagles soaring above the park or snaring fish from the cold waters of Oil Creek.

REFERENCES

Crum, A. R., and Dungan, A. S., 1911, *Romance of American petroleum and gas*: v. 1, New York.

Giddens, P. H., 1948, *Early Days of Oil: A Pictorial History of the Beginning of the Industry*. Princeton University Press, Princeton, NJ, 150 p. (reprinted in 2000 by The Colonel, Inc., Titusville, PA.)

Harper, J. A., 1998, Oil Creek State Park, Venango County: Ice and oil shape the land. Pennsylvania Geological Survey, 4th ser., Park Guide 22, 12 p.

Henry, J. T., 1873, *The Earlier and Later History of Petroleum, with Authentic Facts in Regard to Its Development in Western Pennsylvania*. James B. Rodgers, Philadelphia, 607 p. (reprinted in 2006 by the Oil Region Alliance, Oil City, PA)

Michener, C. K., compiler, 1997, *Oil, oil, oil*. Venango County Historical Society, 128 p.

Pees, S. T., 1989b, *Wildcat Hollow, historical notes*, in Pees, S. T., and others, *History of the Petroleum Industry Symposium*. American Association of Petroleum Geologists Guidebook, p. 38-45.

Pees, S. T., 2001, *Field excursion: Oil Creek Valley and Pithole, Pennsylvania*. Guidebook and Essays, privately printed, Meadville, PA, 44 p.

Senges, R. A., 2008, *The Oil Creek Rail Road: Pictures tell the story*. Oilfield Journal, v. 7, 2007-2008, p. 48-59.

STOP 4: THE BLOOD FARM (LUNCH)

Leader: John A. Harper

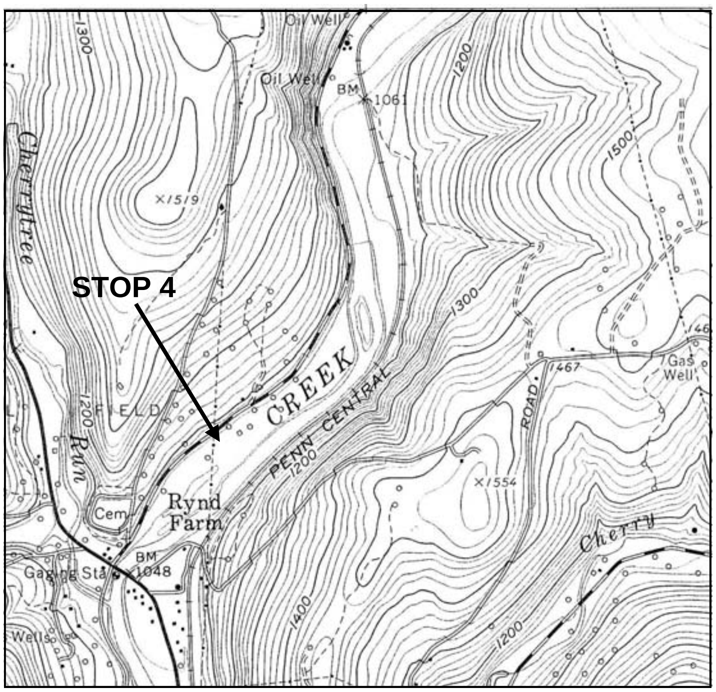


Figure 1. Location of STOP 4 (lunch) on the Oil City 7.5-minute quadrangle.

We will stop for lunch at this picturesque and historic area (Figure 1). There are bathrooms and a picnic pavilion for those who don't want to eat under the fair October sun (or if it's raining . . . or snowing, heaven forbid!). There will be time to walk the nature trail and examine some of the oilfield equipment that occupies a portion of the Blood Farm Day Use Area.

Blood Farm – Historical Overview

John Blood's farm occupied a 440-acre tract on both sides of Oil Creek between the Tarr Farm and the Rynd Farm. John Blood lived in a "dilapidated, unpainted, moss-covered and time-stained house" (Giddens, 1947; McElwee, 2001) on the east side of what is now State Park Road (Figure 2). By 1861, it already had numerous wells drilled on the property with large oil flows from the Venango Third sand (Dickey and others, 1943). These included the Blood #1 that flowed 1,000 Bopd and the Blood #2 that flowed 600 Bopd; and those weren't even the largest. The farm produced more oil during 1861 and 1862 than all the other farms in the region combined. Unfortunately, a fire hit the farm in October, 1862 and destroyed many wells, wooden tanks, and thousands of barrels of oil. The creek ran black with oil from the damaged wells, and the losses were estimated to be about $1 million (Michener, 1997). The Blood #1 and #2, among others, never flowed afterwards.

John Blood sold the farm in 1864 for $550,000 to Southerland M. Seely of Michigan. Giddens (1947, p. 244), quoting from an article in *The Venango Spectator* of April 27, 1864, described the sale as "the only piece of oil territory on the creek not in the hands of speculators, and held at prices three or four times as high in proportion to their value, as the price paid for this tract." Blood and his wife moved to New York City with the proceeds, but after several years of city life, they moved to the country (McElwee, 2001). *The Venango Spectator* article continued, "We have estimated the entire oil product of the farm at 400 to 700 barrels a day – an estimate which we are satisfied is within bounds. Taking the smaller figure as the yield and six dollars per barrel at the wells, as the price of oil, we have a daily cash yield of twenty-four hundred dollars, or a yearly yield – counting 300 working days to the year – of *seven hundred and twenty thousand dollars*." (Giddens, 1947, p. 244)

Southerland Seely, with associates from Franklin, PA and New York City, created two oil

Harper, J. A.., 2009, *Stop 4: Blood Farm and lunch*, in Harper, J. A., ed., *History and geology of the oil regions of northwestern Pennsylvania*. Guidebook, 74th Annual Field Conference of Pennsylvania Geologist, Titusville, PA. p. 103-107.

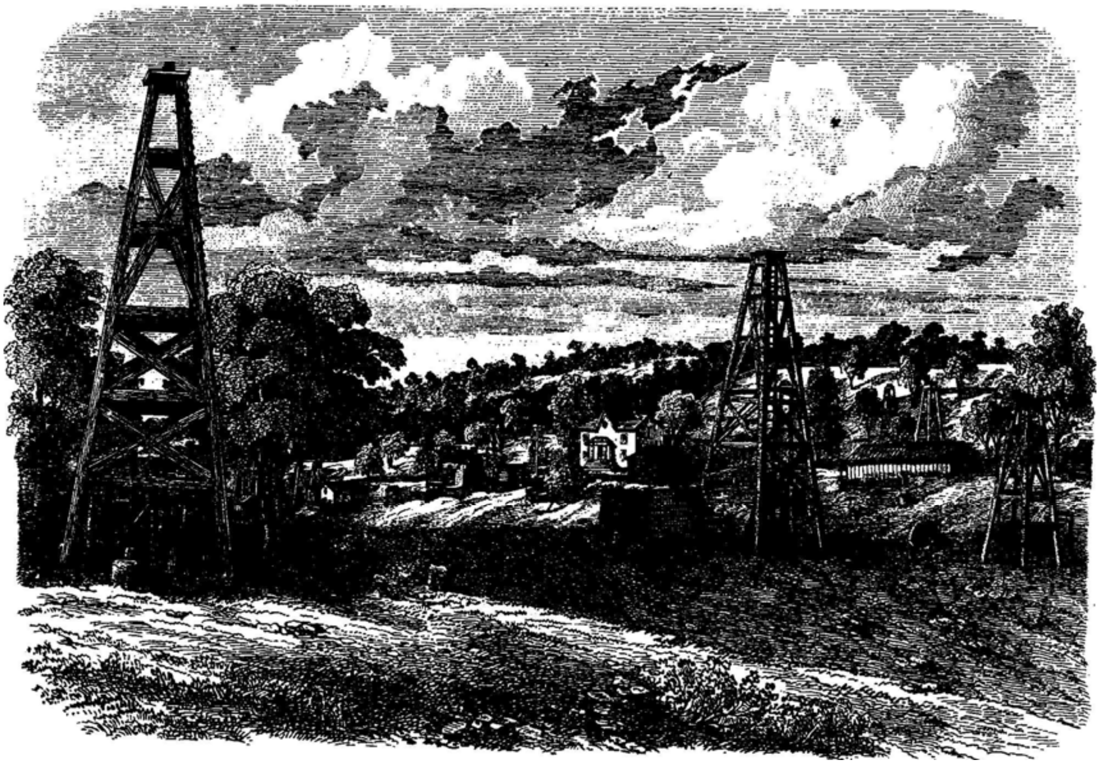


Figure 2. Newspaper illustration of the Blood Farm Petroleum Company. The large house shown in Figure 3 can be seen in the center of the print. Blood's house was across the road and is apparently the building just to the left of the big house.

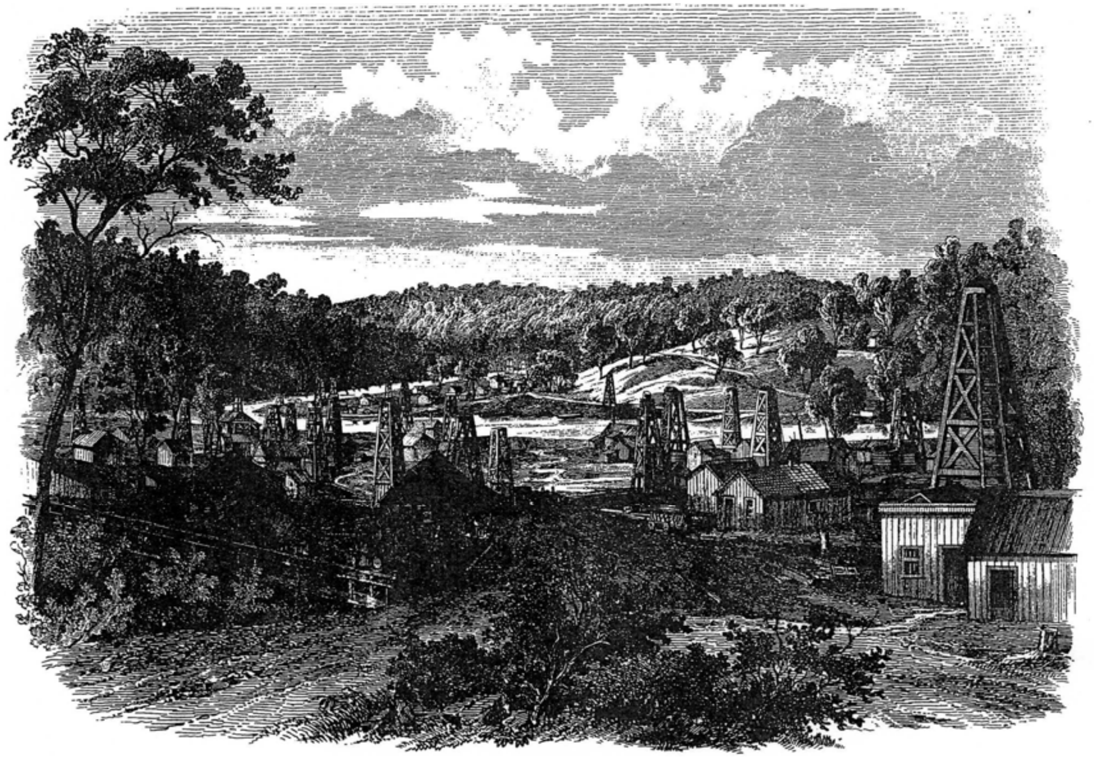


Figure 3. Newspaper illustration of Home Petroleum Company holdings on the Blood Farm.

Figure 4. The Blood Farm Petroleum Company House (also incorrectly called John Blood's house). Top left—the house as it looked then. Top right—As it appears now standing above State Park Road near the entrance to the Blood Farm Day Use Area.

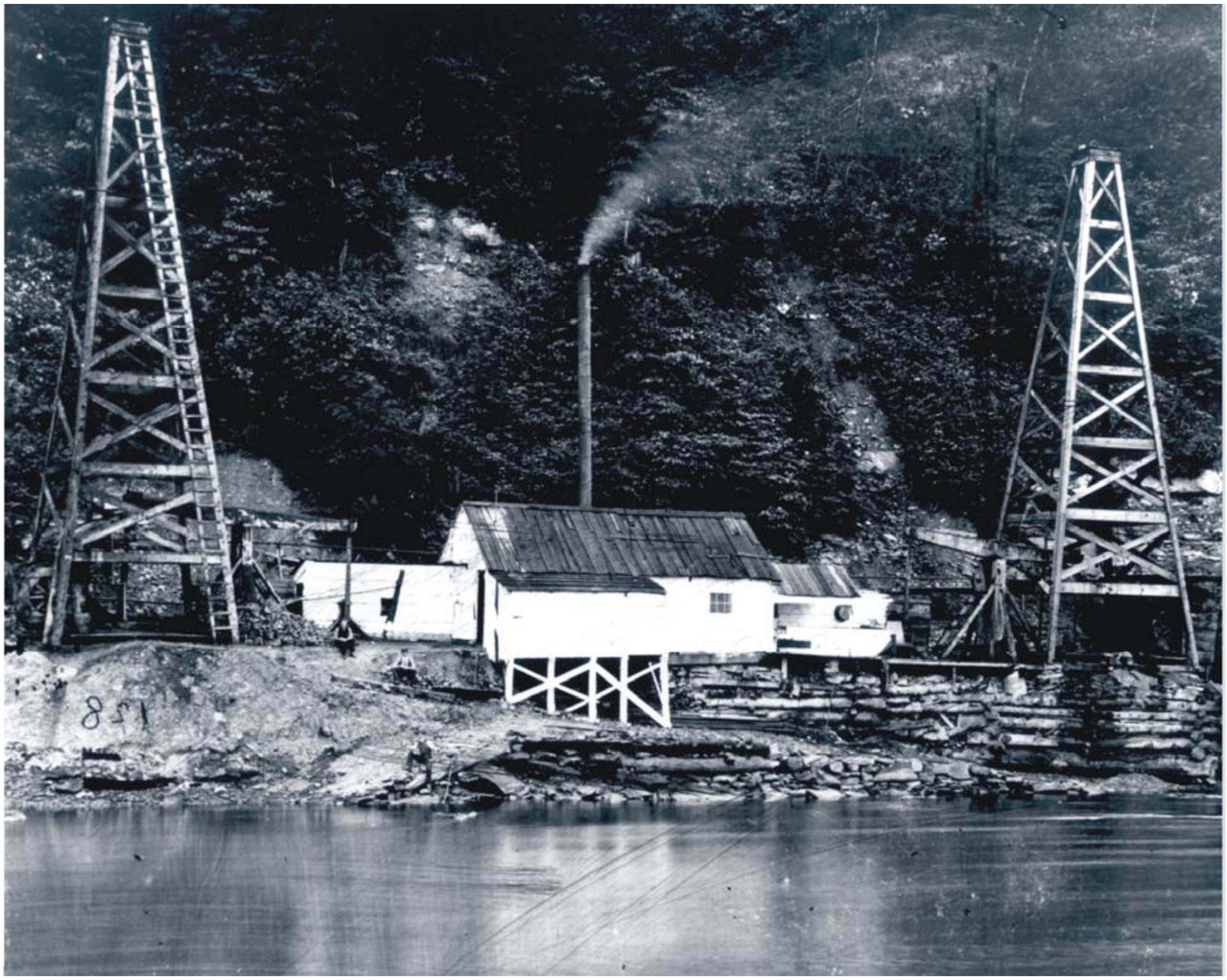


Figure 5. Home Petroleum Company twin wells on the east side of Oil Creek. A ferry connected the two banks. The location of these wells is now occupied by the Oil Creek & Titusville Railroad.

Figure 6. Some of the oilfield equipment that can be found at the Blood Farm Day Use Area.

companies to operate the Blood Farm oil wells – the Blood Petroleum Company (Figure 2) worked the northwest side of the creek and the Home Petroleum Company (Figure 3) worked the southeast side. Sitting above State Park Road and the Blood Farm just south of the entrance to the Blood Farm day use area is a large white house (Figure 4). This house has been called the "John Blood House," presumably because it was part of the Blood Farm. In fact, John Blood and his wife never lived in the house. It had been built by the Blood Farm Petroleum Company as a boarding house and showpiece for the company. Blood's house can be seen across the road from the Blood Farm Petroleum Company house in Figure 2. The two wells in Figure 5 were on the southeast bank of Oil Creek. The undated photograph must have been taken before 1865 because that side of the creek was occupied by the Farmers Railroad by 1866 (construction would have begun well in advance of the celebration shown in STOP 3, Figure 3).

Blood Farm Day Use Area

Today, the Blood Farm is a day-use area of Oil Creek State Park on the northwest side of the creek. It has picnic facilities and a variety of old oil-field equipment illustrating many of the principles of the early industry (Figure 6). A well-tended one half-mile walking path leads through groves of trees, and interpretive signs explain the natural and oil history of the Oil Creek valley. Across the creek, which once required a ferry to get to the other side, the Oil Creek & Titusville Railroad passes through what once was prolific oil territory.

REFERENCES

Dickey, P. A., Sherrill, R. E., and Matteson, L. S., 1943, *Oil and gas geology of the Oil City quadrangle, Pennsylvania*. Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 25, 201 p., reprinted in 1984.

Giddens, P. H., 1947, *Pennsylvania Petroleum, 1750-1872: A Documentary History*. Pennsylvania Historical and Museum Commission, 420 p.

McElwee, Neil, 2001, *Oil Creek . . . the beginning: A history and guide to the early oil industry in Pennsylvania*. Oil Creek Press, Oil City, PA, 138 p.

Michener, C. K., compiler, 1997, *Oil, oil, oil*. Venango County Historical Society, 1

HARPER'S GEOLOGICAL DICTIONARY

METATAXIS - Much more than the government deserves to take from us.

STOP 5: ANATOMY OF A GHOST TOWN – PITHOLE

Leaders: Jerry Knickerbocker and John Harper

What's in a Name?

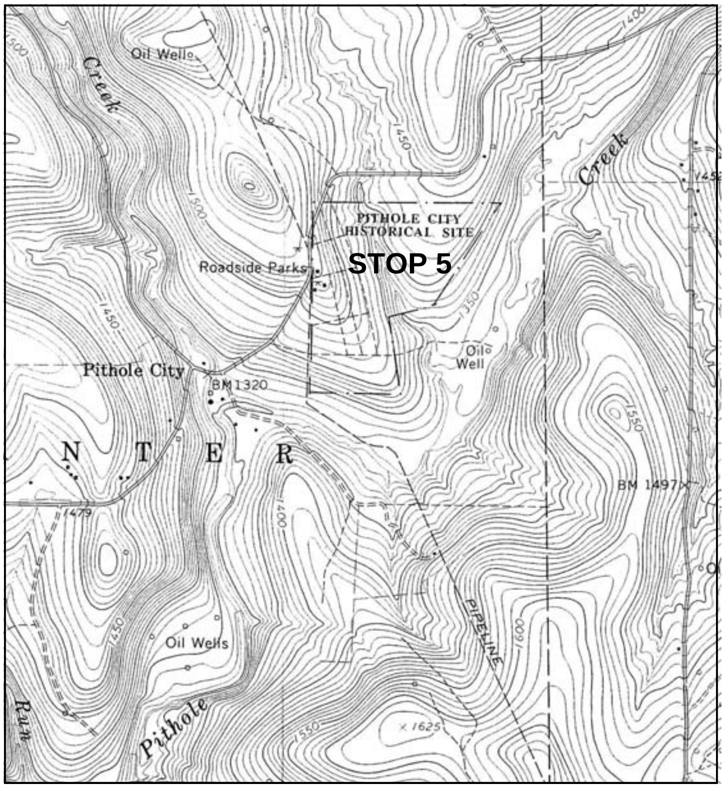


Figure 1. Location of STOP 5 on the Pleasantville 7.5-minute quadrangle.

Pithole City (Figure 1) was once was a prosperous town located along Pithole Creek in Cornplanter Township, Venango County, about seven miles north of the Allegheny River. Although it is a fact that the town of Pithole City got its name from Pithole Creek, the origin of the name "Pithole Creek" is still in dispute. Legend has it the creek was named for a pit or fissure from which foul-smelling vapors emanated, leading folks to claim it was a way into "the Pit" (Hell). One contemporary account, documented by Miller (1968, p. 84) says the creek was named for a bottomless pit on a bluff about 100 feet above the stream. Supposedly, whenever anyone tossed a stone in, no one could hear it hit bottom. It also supposedly had a continuous flow of gas emanating from it, which looked like the heat at the top of a lime kiln. Darrah (1972, p. 1-2), suggested the name probably derived from the thousands of oval pits dug by those who arrived and passed through the area before the Seneca Indians settled in northwestern Pennsylvania. These were dug at oil seeps, cribbed with wooden framework, and used to collect oil for the multitude of purposes the Native Americans found for crude oil. Such pits are plentiful along Oil Creek (see STOP 6), in Cornplanter Township where Pithole and Pithole Creek are located, along the Allegheny River from Oil City to Henry's Bend, and in northwestern Warren County. Pees (2001, p. 42), however, reiterated the story of the deep, wide crack related by Miller (1968). He investigated a crack (widened joint) on the ridge on the west side of the creek that resulted from valley stress release and the gravitational sliding common throughout the area. Because the joints are deep, the air temperature maintains an even 52°F year around. In the winter, air in the crevice would be warmer than outside air, and it would appear that steam was emanating from the crack. Anyone unfamiliar with such a phenomenon might be induced to believe the crack was, indeed, a passage to Hell.

Knickerbocker, Jerry, and Harper, J. A.., 2009, *Stop 5: Anatomy of a ghost town—Pithole,* in Harper, J. A., ed., *History and geology of the oil regions of northwestern Pennsylvania.* Guidebook, 74th Annual Field Conference of Pennsylvania Geologist, Titusville, PA. p. 108-119.

In the Beginning

Lytle (1959) describes the region as a veritable wilderness as late as 1864. Despite all the noise and excitement coming from the Oil Creek Valley only a few miles west of Pithole Creek, no one seemed to think there was anything of interest in this area. There was only forest, with two small farms in the midst. Reverend Walter Holmden, a Baptist preacher, had purchased 200 acres of forest land in 1837. When he died three years later, his sons, Thomas and Walter, divided the tract, cleared most of it of timber, and were raising crops and herds of sheep and cattle. Several other families arrived and settled as well – Darrah (1972) mentions the McKinney, Ball, Hyner, Rooker, and Woods farms; Miller (1968) adds the Blackmer, Haworth, Van Wyck, Tyrrell, and Heckert farms. These folks were all pretty much self sufficient, and few of them traveled beyond the bounds of the region (Pees, 2001). That all changed in 1864.

Two employees of the Humboldt Oil Refinery at Plumer (see p. 79) named I. N. Frazier and James Faulkner leased a number of acres from the Holmden brothers and some of their neighbors. According to Darrah (1972), Frazier leased 35 acres of land in two tracts from William McKinney and Faulkner leased 150 acres from Thomas Holmden and another 114 acres from Walter Holmden. Considering that most of the oil industry seemed to think all of the oil to be had in the world lay within the valleys of Oil Creek and the Allegheny River, this was a spectacular wildcat venture. Frazier and Faulkner teamed with Frederick Jones and Nelson Tappan to form the United States Petroleum Company in the spring of 1864. They sold stock and speculated in oil. In all likelihood, the company was more interested in making money from selling stock than from drilling.

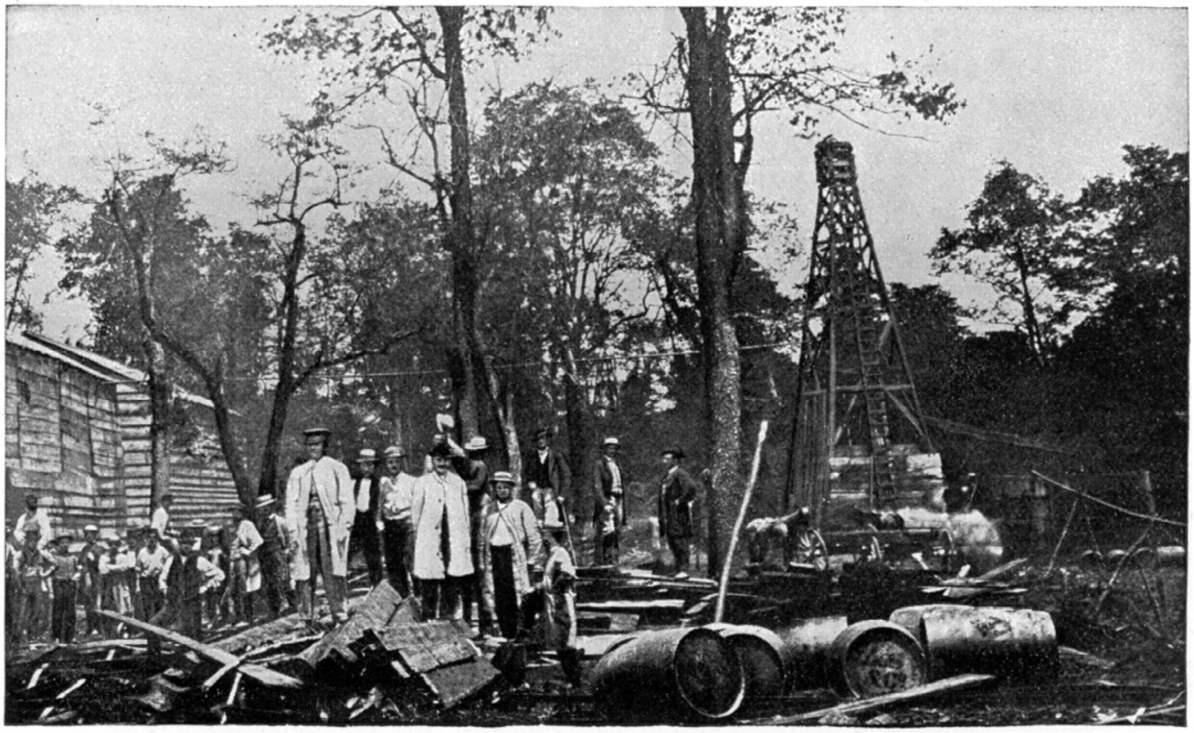


Figure 2. The Frazier well on the Holmden Farm, Pithole, May 1865. Photo courtesy of Drake Well Museum.

The Importance of Serendipity

In the list of serendipitous moments in history, the discovery of the Pithole oil field must rank close to the top. In June, Thomas H. Brown, an employee of the company, crossed the southeast corner of the Thomas Holmden lease with a witch hazel twig. When the twig dipped, he told Frazier and Faulkner to drill. And they did. There was no rhyme or reason to it – just the word of a guy with a witching stick. In July, with the help of Thomas Holmden's son and a man named William Lyons, they began drilling the "United States well," first by spring pole and later by steam engine. That summer, Frazier died of a heart attack (Darrah, 1972), and the well was renamed the "Frazier well" in his honor. Drilling continued slowly through the fall of 1864.

Around the same time, two men named Kilgore and Keenan, who had subleased part of the Holmden lease, were drilling two additional wells they called "the Twins." By Christmas, the three wells had attracted a great deal of attention, exactly what the United States Petroleum Company wanted. The more attention, the more stock it could sell.

On January 7, 1865, the Frazier Well (Figure 2) began to flow oil at 250 barrels a day. Less than two weeks later, the Twin wells (Figure 3) came in, and before you could say "Jack Robinson" the throngs began to arrive by horseback, foot, and sled (Darrah, 1972; Burchardt, 1989b; Flaherty, 2003). The stock of the United States Petroleum Company jumped from $6.25 to $40 a share (Lytle, 1959).

Figure 3. United State Petroleum Company's "Twin Wells" that came in two days apart in June 1865. Photo courtesy of Drake Well Museum (DW 2666).

Figure 4. John Wilkes Booth, Lincoln's assassin, dabbled a bit in oil leases in 1864, including the soon-to-be-famous Homestead well in Pithole. He left Venango County before any of his holdings saw any profit and was not heard from again until that fateful day in April 1865.

Oil Developments of 1865

In April 1865, a Boston company completed a well known as the Homestead Well just 100 feet outside the boundary of the Thomas Holmden farm. It flowed 250 Bopd (Lytle, 1959). That same month, the Civil War ended and President Abraham Lincoln was assassinated at Ford's Theater in Washington, DC by John Wilkes Booth (Figure 4). Booth, and a real estate dealer named Joseph H. Simonds, arrived in Franklin in June, 1864 and roomed at Mrs. Webber's on the corner of Buffalo and Thirteenth Streets (Michener, 1997). Booth attracted attention because he had money, style, and attractive clothing, but he also had a cold demeanor toward strangers.

In December 1863 or January 1864, Simonds had acquired an interest in an oil lease of three and a half acres for Booth. Booth had purchased a 1/3rd undivided interest in a lease on the Allegheny River, near Franklin, operated by the Dramatic Oil Company, and an undivided 1/30th of a contract in the Homestead well (Giddens, 1947; Lytle, 1959; Michener, 1997). According to Simonds, "The whole amounted invested by him in this Allegheny River property, in every way, was about $5,000, and the other investment was about $1,000, making $6,000 in all." (Giddens, 1947, p. 258). As it turned out, all of the investments turned sour. The Dramatic Oil Company drilled only dry holes, and the Homestead well had not yet been drilled. Booth lost interest in his investments, pulled up stakes, and left Franklin on September 27, 1864. Imagine how history might have been different if Booth's investments had paid off and stimulated his interest even further!

The United States Petroleum Company divided its holdings into half-acre leases and sold 60 of its 80 leases at an average of $3,000 (Lytle, 1959; Darrah, 1972). As many as four wells were drilled to an acre. Suddenly the production of the Homestead Well jumped to 500 barrels and that of the Frazier Well to 1,200 (Lytle, 1959; Pees, 2001). At the end of June 1865, the wells along Pithole Creek were producing 2,000 Bopd, or 1/3rd of the total world production of oil. Speculation in oil became a huge business. Tens of thousands of dollars were made and lost by selling and reselling oil leases. In July, 1865, Duncan and Prather sold the Holmden farm for $1,300,000, the largest sum ever paid in the oil region for a single tract of land (Lytle, 1959).

Pees (2001) tells of the Grant well, which appeared to be a dry hole when drilling ceased in August 1865. The drillers were coaxed into running some tubing in the hole to increase speculation that it was, in fact, a producing well, and after pumping for four hours, the well suddenly began producing as much as 800 Bopd. The owner of the half-acre lot next to the Grant Well paid $1,600 for it that spring; after the Grant well came in, he sold it $16,500, the highest price on record for a half-acre lease (Lytle, 1959). Also in August, the Pool Well, which as not far from the Frazier Well, came in at 300 Bopd and jumped to 1,500 Bopd. It was the largest producer at Pithole.

By September 1865, Pithole was producing 6,000 Bopd. As Lytle (1959) pointed out, there are any number of wells being drilled and produced in the world today that produce 6,000 Bopd by themselves. But, in the oil territory of northwestern Pennsylvania in 1865, this was an incredible amount of oil. The Holmden Farm alone had 96 wells either producing or being drilled and the daily rate was 4,000 Bopd. Then, the people who had bought the Holmden farm from Duncan and Prather were unable to meet the terms of the sale; Duncan and Prather took back the farm and resold it to someone else for $2,000,000! (Interesting historical note: Venango County commissioners bought this same land in 1878 for $4.37. The commissioners then sold it to a private owner in 1886 for $83.76.)

The Complications of Transportation

The teamsters were the primary oil transporters of the day. They had the job of getting the oil from Pithole to Titusville, Miller Farm, Shaffer Farm, or Oil City where it would then be loaded onto railroads for shipment. Processions of wagons rumbled back and forth over the unimproved dirt roads, which had become so impassable by July that many teamsters were unwilling to haul anything. In order to keep the oil moving, oil merchants in Titusville raised a fund to maintain the road, and every teamster had to contribute $1 per week to the fund. A long procession of empty and loaded wagons went back and forth over miserable roads. The teamsters charged $3 per barrel to get the oil to the railroad station at Miller Farm, about 5.5 miles to the west on Oil Creek. Since the price of a barrel of oil at that time was about $3 per barrel, the cost of getting a barrel to the refinery was $6. The teamsters were making as much, or more, on a barrel of oil as the people who had drilled the well!

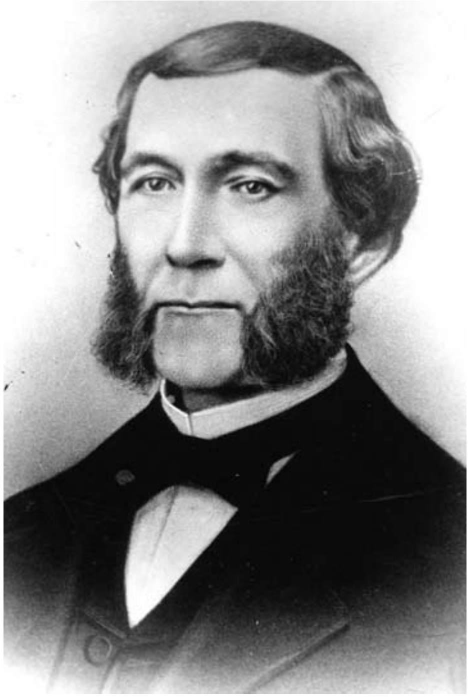


Figure 5. Portrait of Samuel Van Syckel.

A New Jersey man named Samuel Van Syckel (Figure 5) disliked the idea that teamsters were charging so much to transport a barrel of oil. In the fall of 1864, he and two other men formed the Oil Transportation Association with $3,000 borrowed from the First National Bank of Titusville and constructed a 2-inch pipeline from Pithole to Miller Farm. The teamsters didn’t like this. They attacked the pipeline crews and even went so far as to shoot one. Van Syckel tracked the shooter down and beat the tar out of him. After that incident, the teamsters left the pipeline alone (Clark and Spier, 1967). It was successful from the beginning; it had four pumps, but experience soon showed it would operate just as efficiently with only one. It was a well-designed and well-built project, and when the line was finished, it was capable of transporting 81 barrels of oil per hour. It cut the cost of transporting from $3 to $1 per barrel. Figure 6 is a map of the pipeline route from Pithole to Miller Farm on Oil Creek.

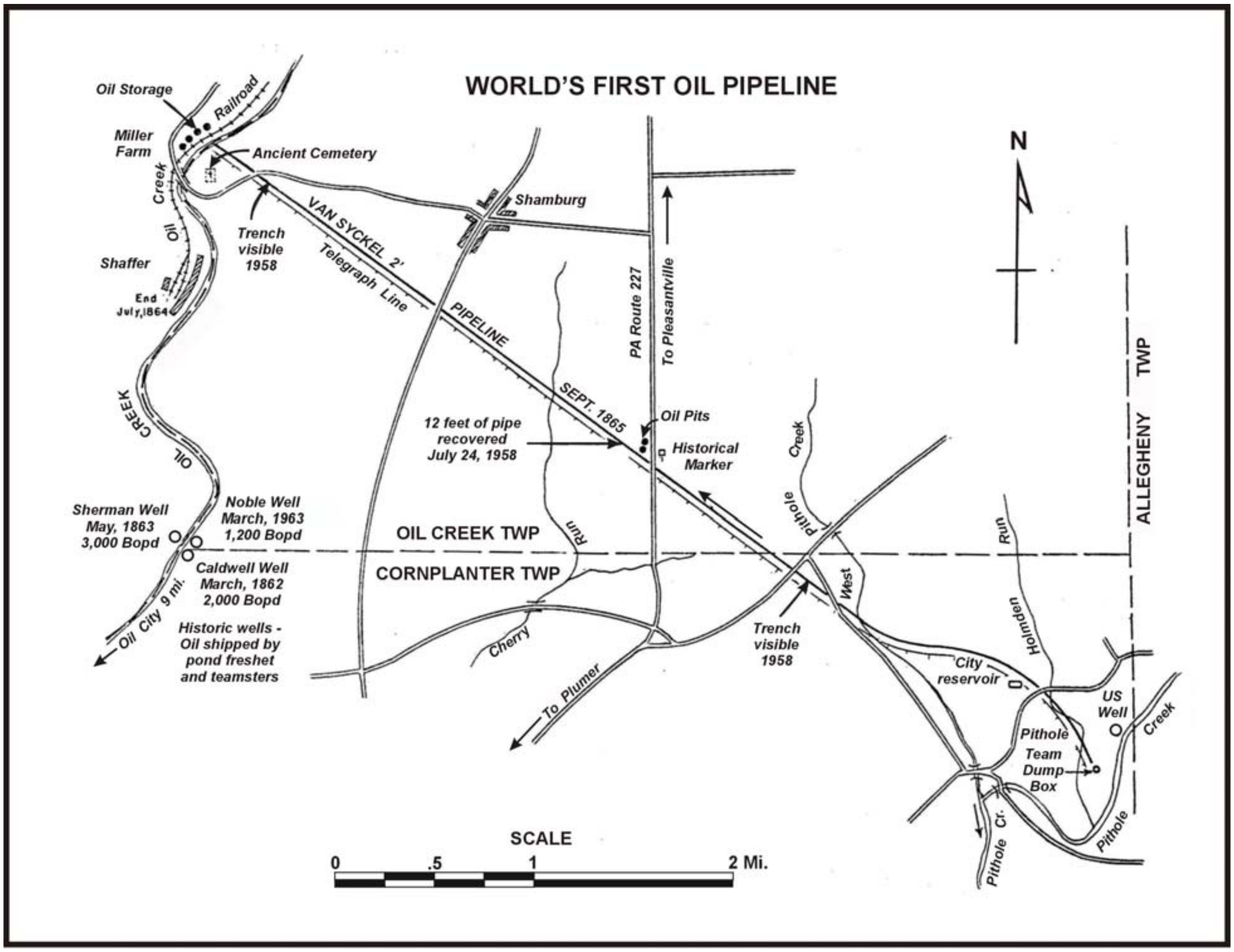


Figure 6. Map of Samuel Van Syckel's pipeline that carried crude oil from Pithole wells to the railroad terminal at Miller Farm. (modified from Lytle, 1959).

As is so often the case of the first person to do something historically valuable (think of Drake's poverty and declining health), Van Syckel had a run of bad luck even though the pipeline was doing well technically and financially. His partners both failed financially for reasons having nothing to do with the business. As a result, Van Syckel was unable to clear all the debts the company had acquired in installing the pipeline, despite the line's success. As a result, the First National Bank of Titusville agreed to operate the pipeline with the understanding that Van Syckel would regain ownership once the $15,000 debt was paid off. Van Syckel lost interest, trying his hand, instead, at the refinery business before moving to Buffalo where he died peacefully in 1894 (McLaurin, 1896). The pipeline was later acquired by Jonathan Watson until it was purchased by William Abbott and Henry Harley who went on to become very successful pipeline and refinery operators.

The Van Syckel pipeline is considered to have been the beginning of the end for the oilfield teamsters. The idea caught on immediately and soon pipelines were built from all of the principal producing fields to the refining centers in Franklin, Oil City, and Titusville. At its operational peak, the Van Syckel pipeline consisted of two 2" pipelines. With the decline of Pithole, both were dug up and salvaged. The trench was never back-filled and can still be seen in some areas along its course.

Pithole City

In May, 1865, Colonel A. P. Duncan (not Thomas G. Duncan as Lytle reported in 1959) and George C. Prather bought the Holmden farm in fee simple, subject to the conditions of the United States Petroleum Company's lease, for $25,000. They later paid Holmden an additional $75,000. Lytle (1959) thought it possible these men of business had found a conscience, but Darrah (1972) stated that it was just good business when they saw so much money in the hands of people who had never had money before. Duncan and Prather didn't care about oil. Real estate was another matter, however. Imagine the fortune they made leasing building and drilling lots to folks with money to burn.

This is important because it was on the Thomas Holmden farm that Pithole City was built, and many of the wells were drilled, especially the most productive wells. What used to be just log cabins and rough outbuildings soon began sprouting all manner of buildings.

Pithole City (Figure 7) was planned and laid out in May 1865, with land available for development through three- or five-year leases (Stephens and Bobersky, 2007). When the lease expired, the buildings would either be removed or sold to the land owner. Most of the lots were leased at $275 per year in the early days, increasing to $850 at the peak of the frenzy (Lytle, 1959). The town was laid out on the hill in 500 lots along some 22 streets, with lots being only 33 feet wide. The wells were sited on the flat land of the creek valley.

New construction began immediately with work enough for a thousand carpenters. Oilmen, professional and amateur alike, stampeded to Pithole Creek to grab what they could. It was the end of the Civil War, the country was flush with people whose pockets were full of paper currency, and many were anxious to invest it in oil with the excellent prospect of making even more money. Soldiers discharged from the army were eager for jobs. Having survived the horror of war after living on military pay, many thought they could make their fortune quickly. In addition, a bubble of speculation that occurred in 1864 and 1865 had reached its peak, newly organized oil companies came into existence, and there were all sorts of people who were willing to lease or buy any scrap of land that held even the remotest prospect of having oil on it. The Pithole area began to see a land rush unheard of, even in the oil region, to date. Thousands came in search of Oildorardo in stagecoaches, and in wagons, on horseback, and even on foot – however they could get there.

Building construction went at a fever pitch. The forest disappeared quickly as trees were cut and shaped for lumber, even though the wood was very green. Many buildings were dangerously flimsy - a contract could be signed to construct a two-story building and it would be finished and ready for occupancy within a week. Only the leading hotels, theaters, churches, and finer establishments were constructed properly. However, not a single brick or stone was used in constructing the building so Pithole (Lytle, 1959).

Potable water was scarce at Pithole in the early days, so it became a profitable business to haul water to the town it from distant wells and sell a drink for 10 cents. As a direct result, the business in "distilled spirits" flourished. Finally, in December 1865, a water system reservoir was competed and pipes were laid along the main street. Since Pithole had no sewage system, the larger hotels had dry wells used for sewage disposal. As a result, many first-time visitors came and went with a first impression of unassailable odor – both human waste and crude oil mixing in a very unpleasant smell.

In September, 1865, Pithole had reached its zenith. It had a population of 15,000, a newspaper, a post office, two banks, two telegraph offices, a fire department, an opera house,

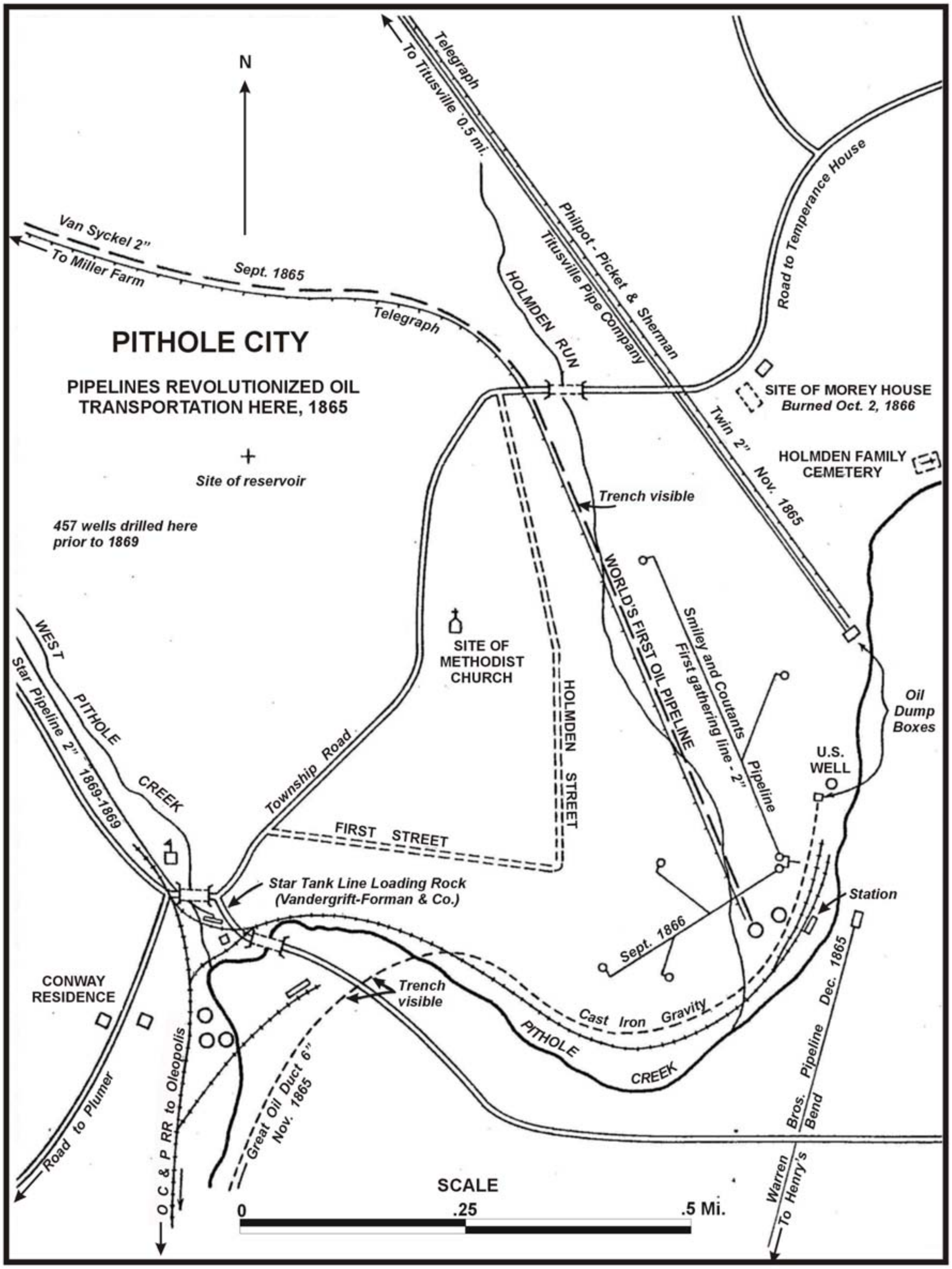


Figure 7. Map of Pithole City (modified from Lytle, 1959)

Figure 8. The corner of First and Holden Street, Pithole City. A—The Danforth House was built on a lot that cost $100 plus a $14,000 bonus. This hotel could house 140 guests. Photo courtesy of Drake Well Museum (DW10). B—2008 photo taken from the same vantage point.   Nothing remains of the Danforth House now but a hole where the foundation used to be.

and a huge number of hotels – more than 50 by most counts (Stephens and Bobersky, 2007). One of these, the Danforth House, was a leading hotel at the corner of Holmden Street and First Street (Figure 8A). Like the Morey, Chase, and Bonta, the Danforth was large, elegant and comfortable, and furnished its guests with all the conveniences of a metropolitan hotel. The Chase House was regarded as the best of Pithole's hotels. It cost $80,000 to build, was about 180 feet long and 60 feet wide, and could accommodate 200 guests and seat 100 in its dining room. The telegraph offices were located there, as was the post office at first, and it was the general headquarters for the stage lines. It boasted a saloon on the ground floor that was furnished with a luxurious bar and numerous pictures. Restaurants did a fantastic business. The "better" hotels served choice foods and oyster bars flourished. Murphy's Theater on First Street could seat 1,000 people, so it naturally was the largest building in Pithole. It was a fine establishment with first-class entertainment. Four religious denominations conducted services at Pithole. There was a church at the top of the hill in which Methodist services were held Sunday morning and Episcopalian services were held in the evening. The United Presbyterians bought a lot and planned a church but never built it. The Roman Catholic Church took over the lot and built St. Patrick's Church. And Pithole even had a social life with balls, concerts, strawberry festivals, and church socials. Pithole was a town of law-abiding citizens (for the most part) early on. Lytle (1959) stated that strangers were surprised how little drunkenness they saw on the streets when the city was young. Still, it took until December 1865 before Pithole was incorporated as a borough and held its first election. Until then, there was no formal government, no law, and no jail.

By the end of 1865, Pithole saw the coming of the ruffians and drifters. Because of an increase in street fights and criminal activity, the borough strengthened the police force by appointing a former Union Army colonel as chief of police. Law and order returned, and Pithole began to chase out the undesirable elements. Among Pithole's more notorious citizens were Ben Hogan and French Kate. Much has already been written about them (e.g. Giddens, 1947; Lytle, 1959; Darrah, 1972; and Burgchardt, 1989a), so the stories will not be repeated here.

The Decline and Fall of Pithole

By August 1865, just a few short weeks before Pithole City attained its record population of 10,000 (15,000 according to Pees, 2001), the Homestead well stopped flowing oil. This happened quite suddenly, and the well had to be pumped. At about the same time, several wells on the Holmden Farm caught fire and burned. A fire in October 1865 destroyed $1.5 million worth of oil and properties on the flats. The Frazier and Island wells stopped flowing in November 1865, but even these downturns couldn't quite dampen people's spirits. While the Frazier and Island wells stopped flowing, a new completion on the Holmden Farm came in at 1,000 Bopd and spurred new interest in the area. But it was not a long-lasting interest.

January 1866 saw the daily production of wells drop sharply, followed, in February and March, by fires on Holmden Street and Brown Street that destroyed two livery stables, a brothel and two dwelling houses, among other establishments (Lytle, 1959). The June 7, 1866 edition of the *Pithole Daily Record*, in an effort to prolong the life of the doomed city, claimed that Pithole had all the qualities of a health resort; "vapors from the surrounding wells render the inhabitants 'distressingly healthy,"' it touted (Flaherty, 2003). By February 1867, production was down to less than 1,000 barrels of oil per day from wells in Pithole.

April 1867 went down in Pithole history as the worst period for major fires with six. With the double whammy of the area's oil production declining and large areas of the town burning to the ground, oilmen, businesses, and common citizens started to desert Pithole. By the end of 1867, the town was essentially dead. The people followed the oil production right out of Pithole, moving on to the next booming area – Triumph, Tidioute, Pleasantville, Cherry Run, and Shamburg (Flaherty, 2003). Only a small handful of people stayed behind, but by 1870 nothing was left except the odd piece of discarded lumber and holes where cellars and foundations used to be. And in the end, the pool of oil that brought so much excitement to the area turned out to be only 100 acres in size (Pees, 2001).

When Pithole declined, the owners of the Chase House moved the hotel to the next "boom town" – Pleasantville. Ironically, after surviving so many fires in Pithole, the Chase House burned to the ground in Pleasantville a few years later.

Pithole's Claim to Fame

To quote Lytle (1959):

> Pithole's secure and unassailable claim to historic fame is not that it was at one time a flourishing city. Rather the claim is based on the fact that at Pithole many of the basic methods for recovering and transporting oil were developed. Most important of these innovations was the world's first commercially successful crude oil pipeline. This pipeline completely revolutionized the transportation of oil, and its effects on transportation generally are growing even in modern times as a network of oil, oil products and gas pipelines knit the nation closer together.

Pithole is now a National Historic Site administered by the Drake Well Museum (Pennsylvania Historical and Museum Commission). It is open to visitors, and many of the sites of the principal buildings have been identified and are marked with signs. Today Pithole is completely covered in grass and trees difficult to realize today that so much excitement and activity once took place at this remote and isolated spot. "Streets" are kept mown, and many places seen in historical photos can still be seen today, albeit most are simply holes in the ground (Figure 8B). The town is quickly approaching the state the area was in when Frazier and Faulkner first came and leased the wilderness farm of Thomas Holmden.

REFERENCES

Burgchardt, Carl, 1989a, *The legend of Ben Hogan*, in Pees, S. T., and others, *History of the Petroleum Industry Symposium*. American Association of Petroleum Geologists Guidebook, p. 76-77.

Burgchardt, Carl, 1989b, *The saga of Pithole City*, in Pees, S. T., and others, *History of the Petroleum Industry Symposium*. American Association of Petroleum Geologists Guidebook, p. 78-83.

Clark, J. A., and Spier, Jo, 1967, *Calendar for the year 1967.* Schlumberger, 108 p.

Darrah, W. C., 1972, *Pithole, The Vanished City: A Story of the Early Days of the Petroleum Industry.* Privately printed, Gettysburg, PA, 252 p.

Flaherty, K. J., 2003, *Hills, dales, and oil trails: A guide to some historic oil fields between Pittsburgh and Titusville, PA.* Field Trip Guidebook, American Association of Petroleum Geologists-Society of Petroleum Engineers 2003 Joint Eastern Meeting, Pittsburgh, PA, 91 p.

Giddens, P. H., 1947, *Pennsylvania Petroleum, 1750-1872: A Documentary History.* Pennsylvania Historical and Museum Commission, 420 p.

Lytle, W. S., 1959, *Introduction to bedrock and oil geology of northwestern Pennsylvania and the Great Oildorado*. Guidebook, 24th Annual Field Conference of Pennsylvania Geologists, Titusville, PA, Trip B, p. 12-76.

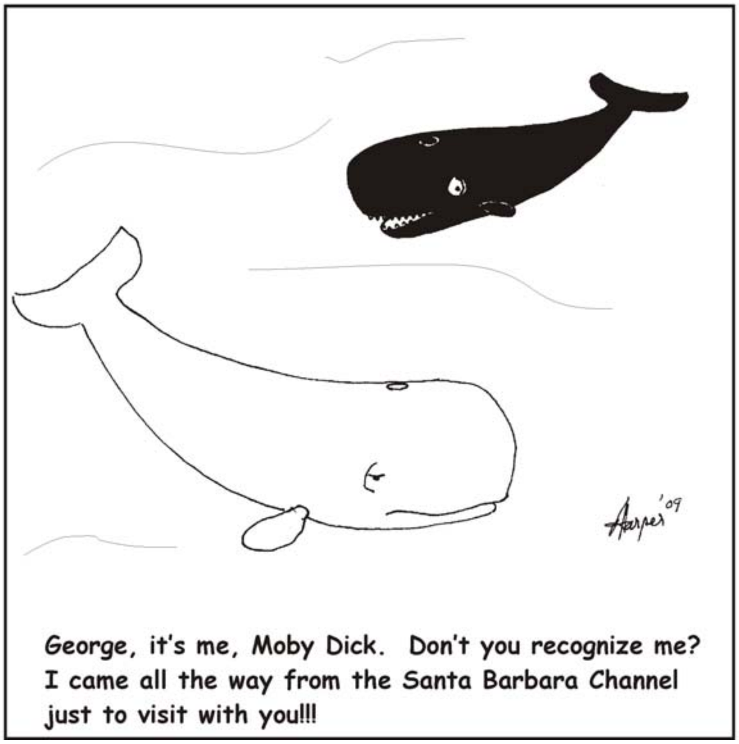
McLaurin, J. J., 1896, *Sketches in Crude-Oil: Some Accidents and Incidents of the Petroleum Development in All Parts of the Globe.* Privately printed, Harrisburg, PA, 406 p.

Michener, C. K., compiler, 1997, *Oil, oil, oil.* Venango County Historical Society, 128 p.

Miller, E. C., compiler and editor, 1968, *This Was Early Oil: Contemporary Accounts of the Growing Petroleum Industry, 1848-1885*. Pennsylvania Historical and Museum Commission, Harrisburg, PA, 211 p.

Pees, S. T., 2001, *Field excursion: Oil Creek Valley and Pithole, Pennsylvania.* Guidebook and Essays, privately printed, Meadville, PA, 44 p.

Stephens, D. T., and Bobersky, A. T., 2007, T*ransitory accommodations in a transitory landscape: The hotels of Pithole City, Pennsylvania and its environs*. OilField Journal, v. 6, 2006-2007, p. 33-55.



STOP 6: DRAKE WELL MUSEUM AND "TYPE" "DRAKE WELL FORMATION" OUTCROP

Leaders: John A. Harper, Scott C. McKenzie, Gordon C. Baird, and Joseph S. Sullivan

The Story Of The Drake Well

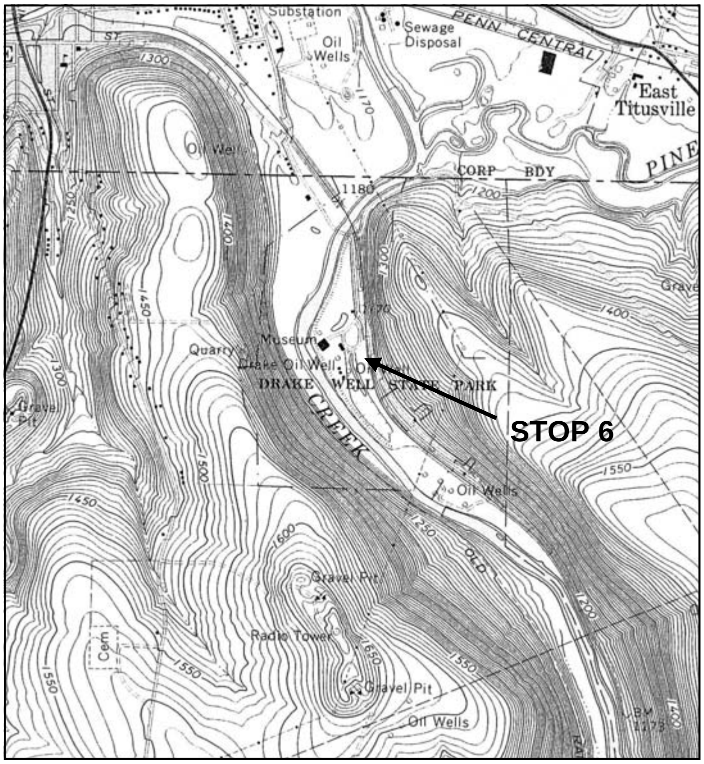


Figure 1. Location of STOP 6 in the Titusville South 7.5-minute quadrangle.

Welcome to the Drake Well Park and Museum (Figure 1). Many people are under the assumption that Edwin L. Drake showed up in Titusville one day, drilled his well, and single-handedly ushered in the modern petroleum industry. In fact, there were many people involved in the effort, from lumbermen and chemists to lawyers and salt-well drillers. Drake was actually only part of the story – a very important part, admittedly – but his place in history would have suffered or been nonexistent were it not for a fascinating series of events, and the people involved in those events. The history of the Drake Well begins far back in the mists of time . . . but for this story we can start with Samuel Kier.

Samuel M. Kier

Samuel Kier (Figure 2), a native of Saltsburg, Indiana County, was a Pittsburgh-area entrepreneur who dabbled in various enterprises with mixed success. With his father, Thomas, as a business partner, he went into the salt business in 1847. They bought some property in Tarentum, then the premier location of western Pennsylvania's salt industry, and had two wells drilled to a brine-producing sand at a depth of 400 feet (Pottsville Formation, one of the

Figure 2. Portrait of Samuel M. Kier.

Harper, J. A., McKenzie, S. C., Baird, G. C., and Sullivan, J. S., 2009, *Stop 6: Drake Well Museum and "type" "Drake Well Formation,"* in Harper, J. A., ed., *History and geology of the oil regions of northwestern Pennsylvania.* Guidebook, 74th Annual Field Conference of Pennsylvania Geologist, Titusville, PA. p. 120-131.

Figure 3. Samuel M. Kier works at his 5-gallon still in the Lawrenceville section of Pittsburgh.

"Salt sands" of drillers – Hughes, 1933). Although the wells produced a substantial amount of brine, after a while they also produced an annoying amount of crude oil, which was considered to be a contaminant.

As luck would have it, Samuel's wife developed tuberculosis in 1848 and the attending physician prescribed "American Medi-cinal Oil," which came from a well in Kentucky (Miller, 1974). Kier quickly realized that the medicinal oil and the salt-well contaminant were the same fluid and, in the best entrepreneurial spirit, he found a way to turn his wife's misfortune into a new and profitable enterprise – he packaged the oil as medicine in half-pint bottles and sold them for 50 cents each.

In 1850, following the advice of Professor James C. Booth, a prominent Philadelphia chemist, Kier set up a small one-barrel still in Pittsburgh and experimented with the distillation process. He eventually was able to distill a form of kerosene from the crude oil. Realizing the importance of this discovery, he switched to a five-barrel still (Figure 3) and began production of "carbon oil" for use in lamps. He also invented a lamp burner that would fit any lamp of the day and burn the "carbon oil" with little or no smoke. Single-handedly, Kier turned the lighting business upside-down. He was soon selling his "carbon oil" and his lamp burners in New York.

Francis Beattie Brewer

Figure 4. Portrait of Dr. Francis Beattie Brewer.

Meanwhile, Ebenezer Brewer, president of Brewer, Watson and Company, a Titusville lumbering operation and saw mill, had a son, Francis Beattie Brewer (Figure 4), who was a physician in Vermont. Brewer, Watson and Company owned the Hibbard farm along Oil Creek about a mile south of Titusville. Like many properties along the creek, the Hibbard farm had numerous oil seeps that caused oil slicks on the water. Francis Brewer, who was educated at Dartmouth College, was fascinated by the oil he found on his father's company's land. Francis had received some "creek oil" from his father; he experimented with it and pioneered the use of crude oil for legitimate medical purposes.

Francis moved back to Titusville in 1851 and convinced his father and other members of the company to gather and sell the oil. On July 4, 1853, the Brewer, Watson and Company signed the first petroleum development lease in the U. S. with J. D. Angier of Titusville (USGS, 1980). Angier kept the oil spring in good shape. He set up some wooden cribs to trap the oil and some inexpensive machinery to separate the oil from the water. This allowed him to collect between three and six gallons a day. Most of this was used for lighting and lubrication in the sawmill (Flaherty, 2003).

In the fall of 1853, Francis collected a sample in a small bottle and took it with him to

Figure 5. Portrait of George H. Bissell.

New Hampshire on a visit. There he met with Dr. Dixi Crosby of the Dartmouth Medical School and Professor 0. P. Hubbard of the Dartmouth Chemistry Department, both of whom examined the sample and decided it had great value. Professor Hubbard, however, said it would never be commercially viable because it could not be obtained in large quantities.

George H. Bissell

Later that fall, another Dartmouth graduate, a New York lawyer and businessman named George H. Bissell (Figure 5), noticed the little bottle of oil in Dr. Crosby's office. He immediately became interested in its potential and paid Crosby's son, Albert, to travel to Titusville to inspect the Brewer, Watson and Company property and report back on the oil springs. Crosby's report was positive; as a result, Bissell and his partner, Jonathan G. Eveleth, decided to organize a company, buy the Hibbard farm, develop the oil springs, and sell the oil. They bought both the 100-acre Hibbard farm and an adjacent 1,200-acre tract from Brewer, Watson and Company for $5,000 in November, 1854.

In December, 1854, Bissell and Eveleth formed the Pennsylvania Rock Oil Company of New York, the world's first oil company. These entrepreneurs faced difficult times from the start, however. Prospective investors were unfamiliar with crude oil and were unwilling to invest in a commodity of unknown commercial value. To make matters worse, New York law stipulated that company stockholders were financially liable for a company's debts.

Figure 6. Portrait of Benjamin Silliman.

Benjamin Silliman

Bissell and Eveleth, at wit's end over the lack of interest in their company, hired Benjamin Silliman, Jr. (Figure 6), a Yale College chemistry professor, to analyze some crude oil from Titusville and suggest ways it could be put to economic use. Silliman, who was probably the country's foremost chemist, performed a series of experiments on the oils and, in April, 1855, wrote a glowing report of the value of the Titusville oil. He found the oil superior to most oils he had examined. It did not harden on exposure to air; it produced a good flame; and it could be distilled into eight distinct products, each with its own use and its own commercial value.

James M. Townsend

With Silliman's report in hand, Bissell and Eveleth were finally able to interest some investors. One such person was James M. Townsend (Figure 7), president of the City Savings Bank of New Haven, Connecticut. Townsend and some of his associates were willing to buy

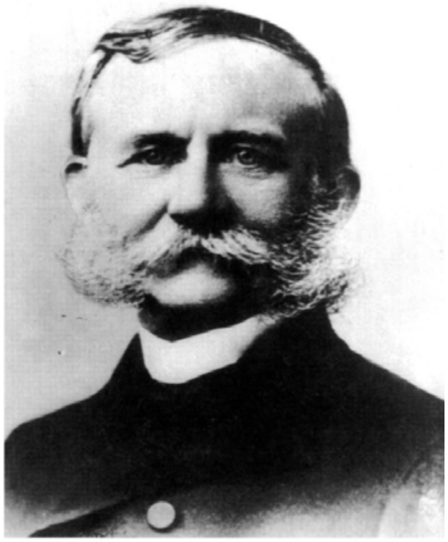


Figure 7. Portrait of James M. Townsend.

into the Pennsylvania Rock Oil Company, but only if Bissell and Eveleth reincorporated the company from New York to Connecticut, which did not hold stockholders liable for a company's debts. The changeover occurred on September 18, 1855 (Giddens, 1948) and Townsend was elected as president of the new company.

Bissell and Eveleth were still in debt as a result of the cost of obtaining the land and incorporating the company. They decided to sell the land to the company and then lease it for oil production. By chance, just a few days before the sale, Bissell learned that Pennsylvania law required property owned by non-Pennsylvania corporations to be forfeited to the Commonwealth of Pennsylvania (Flaherty, 2003). Bissell and Eveleth, instead of selling the land to the company, convinced two of the stockholders to buy it, and then leased the land from them for 99 years.

Unfortunately, it was discovered that the stockholders in question had used worthless securities in the transaction. Bissell and Eveleth already had a strained relationship with Townsend and his New Haven associates; this latest fiasco only caused the company to lapse into inactivity for a couple of years. It didn't help that the panic of 1857 discouraged investors. Still, Townsend continued to be enthusiastic about the Titusville prospects.

Edwin L. Drake

Townsend lived in the same New Haven hotel as a 38-year-old railroad conductor and jack-of-all-trades named Edwin L. Drake (Figure 8). Drake had left home at 19 and, over the years, worked as a clerk on a ship sailing the Great Lakes, as a farm hand on his uncle's farm, as a hotel clerk, a clerk in a dry-goods store, an express agent on the Boston & Albany Railroad, and a conductor on the New York & New Haven Railroad.

Drake knew Townsend very well and actually invested $200 in stock in the Pennsylvania Rock Oil Company of Connecticut. In the summer of 1857, he became ill and gave up his job as a railroad conductor. Knowing that Drake was still eligible for free railroad transportation, Townsend convinced him to go to Titusville to perform some necessary legal actions. When Bissell and Eveleth bought the land from Brewer, Watson and Company, they had neglected to get the signatures of two of the company's owner's wives, as required for the deed (Flaherty, 2003). Drake left in December, 1857 by

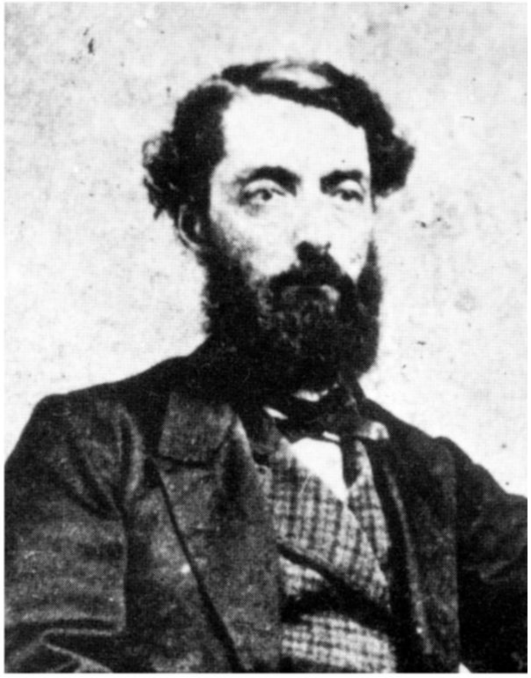


Figure 8. Portrait of Edwin L. Drake.

rail from New Haven to Erie, Pennsylvania, then took the stagecoach from Erie to Titusville. In advance of Drake's arrival in Titusville, Townsend mailed all the legal papers and several letters to Colonel E. L. Drake in care of the Brewer, Watson and Company. Drake was never in the military, but the title "Colonel" carried great weight with the locals, and it stuck.

Drake arrived in Titusville with the kind of fanfare due a military hero. He had his legal work accomplished in about three hours, and then had to sit and wait for the next stagecoach to Erie – about three days. With that much time to spare, he decided to investigate the Oil Creek area. He visited the major oil springs and observed oil being used for lighting and lubrication at Brewer, Watson and Company sawmills. He then proceeded to Pittsburgh where he completed his legal business. While there, he visited the salt works in Tarentum. Upon returning to New Haven, Drake told Townsend all he'd seen and expressed his opinion that oil could be obtained in commercial quantities at Oil Creek.

Townsend and a majority of the board of directors of the Pennsylvania Rock Oil Company of Connecticut were favorably impressed with Drake's report. They leased the Titusville property to Drake and E. B. Bowditch, a cabinet maker from New Haven, for 15 years for one dollar and 1/8 of the oil. A day after signing the lease agreement, Townsend received another offer to lease the land for 15 years and for 12 cents per gallon of oil. Drake and Bowditch agreed to match the offer and signed a supplementary lease changing the terms of the original.

Once the contract was signed, the New Haven investors formed the Seneca Oil Company of Connecticut on March 23, 1858. Drake was named president and leading stockholder, but in accord with a previous agreement, all but 656 shares of the 8,296 shares awarded to him actually went to other stockholders. On March 27, 1858, Drake and Bowditch assigned their lease to the company. Drake was then elected general agent.

On To Titusville

Drake moved his family to Titusville in May, 1858, staying at the American Hotel on Spring Street (see p. 81). At first, Drake went quietly about his work to dig a well at the site of the principal oil spring on the Hibbard farm. But after several weeks of digging, the work-men were flushed from the hole by a gush of water. In frustration, Drake abandoned these works and decided that it would be cheaper to drill. No one in Titusville understood drilling, however; it was completely without precedence in the area. Drake traveled to Tarentum to consult with salt-well owners and hire a driller. When he returned to Titusville, he ordered a six-horsepower steam engine and a "Long John" stationary tubular boiler to furnish power for drilling. He designed an engine house and a derrick, and built them using lumber cut by Brewer, Watson and Company. The derrick was built lying flat on the ground, and then raised into position in an hour by about two dozen men who shook their heads and considered the contraption a joke. The outside of the derrick was boarded over because Drake expected to drill through the snowy northwestern Pennsylvania winter.

By August, 1858 everything was ready for the driller, but Drake was running out of money. He requested additional funds, and the board of directors voted to send it to him in two payments, which didn't arrive until October 30 and December 30, respectively. To make matters worse, the driller he had hired in Tarentum didn't show up. Drake later learned that the driller thought he was crazy and only agreed to drill for oil to get rid of him. Another driller was hired, but some problems at the salt well where he was working prevented him from taking the job. By this time, winter had arrived. Drake satisfied himself with installing the engine and boiler and waiting out the bad weather.

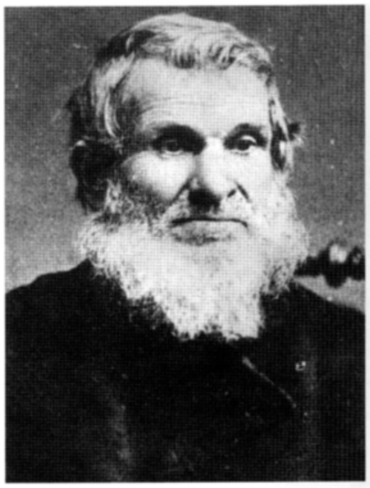


Figure 9. Portrait of William A. "Uncle Billy" Smith.

William A. Smith

In February, 1959, Drake hired another salt well driller, who also failed to appear. Drake was about ready to abandon the idea of drilling when Lewis Peterson, a salt well operator and friend of Drake's, recommended William A. Smith (Figure 9), known locally as "Uncle Billy". Smith, who lived in Salina in Westmoreland County, had worked as a tool maker for both Samuel Kier and Lewis Peterson. He claimed he had had enough of drilling and wanted to try farming instead, but agreed to work for Drake for $2.50 per day. He even threw in the services of his 15-year old son, Samuel, for free. "Uncle Billy" made the drilling tools he would need and arrived in Titusville with his son and daughter in mid-May, 1959. The rest of his family followed in July.

Drake's workers had attempted to dig a hole where the drilling would take place. They shored up the walls of the pit with timbers, but the hole kept caving in due to severe water influx from Oil Creek. Eventually, Drake decided to buy 10-foot-long segments of iron pipe in Erie and drive them into the ground until they hit bedrock. They used an oak battering ram to drive the pipe 32 feet through the glacial outwash of Oil Creek Valley. Then, in mid-August, 1959, they began using the steam engine and drilled at a rate of about three feet per day.

Drake's Folly

Most folks around Titusville thought Drake was daft. Even as far away as New York, those who knew of Drake and his efforts thought he was crazy. One fellow, upon hearing of the goings-on at Titusville, said, "You don't mean to tell me that Drake thinks he can get oil out of solid rock?" (USGS, 1980).

Drake was having financial problems. During the summer of 1859, he ran out of money. Thanks to having friends in Titusville, however, he was able to meet his personal obligations. R. D. Fletcher, a merchant, and Peter Wilson, a Titusville druggist, were both good friends and endorsed a note for $500 at a nearby Meadville bank.

In New Haven, the Seneca Oil Company's stockholders were losing their enthusiasm for the project. James M. Townsend was getting discouraged as well, despite continuing to support Drake financially. Finally, in total frustration, Townsend decided to pull the plug on the whole operation. He sent Drake a final remittance and told him to pay all outstanding bills and return to New Haven. In one of the more serendipitous moments in history, Townsend's message and money failed to reach Drake until after that momentous day in August, 1859.

And The Rest Is History

On Saturday afternoon, August 27, 1859, "Uncle Billy" and his helpers were about to quit work until Monday when the drill bit dropped into a crevice 69 feet down, and then slipped down another six inches. The men put their tools away and went home without further thought.

They thought they were going to have to drill another several hundred feet before they found anything. But on Sunday afternoon, “Uncle Billy” visited the well and saw oil floating on top of the water a few feet down. He lowered a tin container into the hole and pulled it up filled with oil. Samuel Smith ran shouting, “They’ve struck oil! They’ve struck oil!

On Monday morning, August 29, Drake arrived to find “Uncle Billy” and his sons guarding the well, and several tubs and barrels already full of oil. There was a lot of understandable excitement. Unfortunately, no one bothered to gauge the production, so this moment of history is flawed. Still, it has been estimated that the well probably produced between eight and 10 barrels of oil per day.

As luck would have it, the well was destroyed by a spark that ignited gas in the oil on October 7. It was the first oil well fire on record, but certainly not the last. The engine house and derrick were subsequently rebuilt.

Although he appears to have been pleased with his success at Oil Creek, Drake did not let the achievement overwhelm him. It is entirely probable that he had little idea of the importance of his accomplishment. And once the furor over his well dissipated, and the oil industry began its rapid rise to fame and fortune, his influence in the business faded.

Figure 10. Portrait of John Mather.

Drake worked as a justice of the peace, and as an oil buyer, living and working in Titusville until he sold his house and moved his family to New York in 1864. He returned to Titusville in 1866, and John Mather (Figures 10), the famous oilfield photographer, snapped the most famous photograph in oil history, the shot of Drake and Peter Wilson standing in front of the still standing engine house and derrick (see p. 4), as well as the 1896 photo of all that remained of the well in the late 1800s (Figure 11). As a result of bad speculation in oil stocks, he lost everything, and a serious bout of neuralgia kept him confined to an invalid’s chair for the remainder of his life. Destitute and seriously ill, he might not have survived for long were it not for the generosity of the Titusville oil industry, which gave him about $5,000 in 1871 (Pees, 2001). Then, in recognition of the economic importance to the Commonwealth of his success at Titusville, the Pennsylvania legislature voted him an annual pension of $1,500 in 1873. Drake tried to find a place to live where he could be cured, moving from Vermont to New Jersey and finally to Bethlehem, Pennsylvania. But, alas, a cure was not forthcoming and he died in November, 1880. Although he was buried in Bethlehem, his body was removed to Titusville in 1901 and a large monument was erected to his memory.

In Memorium

In 1908, Mrs. David Emery donated an acre of land where the Drake Well had been drilled to the Canadohta Chapter of the Daughters of the American Revolution (DAR). The DAR had a 30-ton boulder of Pottsville Sandstone placed on the property and, on the 45th anniversary of

Figure 11. Reuel D. Fletcher, one of Drake's Titusville merchant friends, stands before all that is left of the Drake Well in August 16, 1896.

the Drake Well's success, August 27, 1904, they affixed to the boulder a large bronze tablet with a dedicatory inscription and a bas-relief of the well (Figure 12).

In 1931, the Board of Directors of the American Petroleum Institute (API) raised $60,000 to construct a dike between the site and Oil Creek, to keep the area from being flooded. They also had the grounds cleared of brush and trees, excavated and drained the area, constructed and furnish a caretaker's house, and established a museum and library. By that time, the property had grown to about 24 acres. Then, on the 75th Anniversary of the Drake Well, August 27, 1934, API turned it all over to the Commonwealth of Pennsylvania as a historical park with the proviso that the state appropriate enough annual funds to maintain and further develop the park.

The monument erected by the DAR was moved to the west side of the center oval in 1945, and a full-scale reproduction of Drake's engine house and derrick was built on the original site of the well. This includes a boiler, steam engine and other machinery of the sort that Drake used to drill his well. The machinery even works, and you can actually watch museum personnel pump oil with it (the oil actually comes from the McClintock #1 well at STOP 2).

Figure 12. DAR memorial to Drake at the Drake Well Museum.

Drake, who had never been in the military, was given the spurious title of “Colonel” by his employers to impress the people of Titusville and thereby make his job a little easier in a backward region of Pennsylvania. Although the title lived on long after Drake’s death, it took until the centennial celebration of Drake’s achievement, to make it valid. At a ceremony that took place at Carter Field in Titusville in 1959, Secretary of Internal Affairs Genevieve Blatt, acting on behalf of Governor David L. Lawrence, posthumously commissioned Drake a Colonel in the Pennsylvania National Guard (Blatt, 1959).

Today the 219-acre park is maintained by the Pennsylvania Historical and Museum Commission. It includes the museum building, a gift shop, the working replica of the Drake Well, the DAR boulder and plaque, pre-Columbian oil pits, and numerous examples of historical oilfield equipment. The museum building houses indoor exhibits, as well as a research library of about 3,500 books and 10,600 photographs among its many interesting holdings.

Geology and Paleontology of the “Drake Well Formation”

“Drake Well Formation” Concept

In the last 1998 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 temporary “type section” of a new, informal “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 his Kushequa type section in McKean County proved problematic, interest in the Kushequa concept waned. Subsequently, a number of workers in the 1940s came to match the thin Cussewago Sandstone of west-central Crawford County to a much thicker succession of fossiliferous sandstones, siltstones, and shales in the Oil Creek Valley which corresponded, in part, to Caster’s Kushequa interval (Dickey, 1941; Sherrill and Matteson, 1941; Dickey, Sherrill, and Matteson, 1943). This confusion was then passed on in a variety of papers spanning several decades. Harper (1998) and Dodge (1992) came to recognize the nature and extent of this problem in subsurface logs. Hence, the “Drake Well Formation” represents an approximate return to Caster’s original Kushequa concept, but with a new name and new type section. Baird, having rediscovered Caster’s old regional, base-Kushequa marker (“*Syringothyris* Bed” bed of spirifers, reworked phosphatic debris, fish teeth, and conodonts) in Centerville-Riceville-area sections north of Titusville, similarly supports the concept of a renamed, lower Knapp-equivalent succession in the Oil Creek Valley region.

This railroad cut displays 7.5 meters (24 feet) which is only a lower-medial subset of the 18 meter (60 foot) total thickness of the “Drake Well” succession (Harper, 1998). The lower 3.5 meters (10 feet) 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). For sake of perspective, it should be noted that, in the older, 1989 AAPG guidebook stop description for this outcrop, Burgchardt and Fox (1989); Fox, (1989) place their “Riceville Formation”-“Cussewago Sandstone” contact at the lithologic

Table 1. Fossils identified from the “Drake Well Formation” in northwestern Pennsylvania. Faunal list based on Feldmann et al. (1992), Harper (1998), and collections of the current authors.

At Drake Well RR cut	**at other localities of D. W. Fm.**
Porifera:	
Hexanctillid sponge	*
Colenterata:	
Pleurodictyum	
Bryozoa:	
Stick and frond forms	
Brachiopoda:	*Trigonoglossa*
Lingula	
Orbiculoidea	*
Cyrtospirifer	*
Rugosochonetes	*
Syringothyris	*
Orthotetid	*
Rhipodomella	
Shumardella	
Bivalva:	
Leptodesma	*
Paleoneilo	
Sphenotus	
Aviculipecten	*
Leiopteria	
Parallelodon	
Gastropoda:	*Porcellia*
Euomphalus	*
Bellerophon	*
Cephalopoda	Problematica: *Coleolus*
Orthoceras	*
Spyroceras	*
Arthropoda:	*Pephricaris*
Echinocaris	
Tropidocaris	
Unidentified arthropods	
Echinodermata	*Hyattechinus pentagonus*
Pelmatozoan ossicles	*H. rarispinus*
Crinoid stems	Camerate crinoids
Chordata:	
Shark cartilage	
Arthrodire plates	*
Cf. Coelacanth parasphenoid	

change in the middle of this section. Based on southward dip projection of the "*Syringothyris* 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.

Paleontological "Gold Mine"

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. 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. The main fossiliferous horizon is the 9 inch sandstone unit approximately 4 meters above the level of the tracks. This layer produces the largest numbers of phyllocarid arthropods. Phyllocarids are also found sparingly below this layer, some with the segmented abdomen attached.

The "sponge" fossil known as *Titusvillia* (but, see p. 32) is found frequently in the light colored sandstone beds below the arthropod-bearing layer. As explained further below, it is possible that this taxon may be a trace fossil. 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. Rarer fossils are found when the blocks are split. We are fortunate to have this excellent locality to collect in. Care must be taken to avoid dislodging heavy blocks from the exposure as these could cause injury. Be sure to avoid placing specimens on the railroad tracks. Table 1 is a list of all the fossils that have thus far been found at this locality.

Starfish remains have been reported from the "Drake Well Formation" but we have not been able to confirm this. Perhaps this is a misidentification based on the star shaped echinoids which are found in the lower "Drake Well Formation" in the surrounding area.

REFERENCES

Blatt, Genevieve, 1959, *Edwin L. Drake posthumously commissioned a colonel in the Pennsylvania National Guard*. Pennsylvania Department of Internal Affairs Monthly Bulletin, v. 27, no. 8-9, p. 1-6.

Burgchardt, Carl, and Fox, J. S., 1989, *Field Trip # 1: Oil region of Titusville, Pleasantville, Tidioute, and Tionesta*, in Pees, S. T., and others, *History of the Petroleum Industry Symposium*. American Association of Petroleum Geologists Guidebook, p. 17-30.

Caster, K. E., 1934, *The stratigraphy and paleontology of northwestern Pennsylvania, Part 1, Stratigraphy*. Bulletins of American Paleontology, v. 21, no. 71, 185 p.

Derrick Publishing Company, 1898, *The Derrick's hand-book of petroleum, a com-plete chronological and statistical review of petroleum developments from 1859 to 1898*. Oil City, Pa., Derrick Publishing Company, 1,062 p.

Dickey, P. A., 1941, *Oil Geology of the Titusville quadrangle, Pennsylvania*. Pennsylvania Geological Survey, 4th ser, Mineral Resources Report 22, 87 p.

Dickey, P. A., Sherrill, R. E., and Matteson, L. S., 1943, *Oil and gas geology of the Oil City quadrangle, Pennsylvania*. Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 25, 201 p., reprinted in 1984.

Dodge, C. H., 1992, *Bedrock lithostratigraphy of Warren County, Pennsylvania*, in Sevon, W. D., ed., *Geology of the upper Allegheny River Region in Warren County, northwestern Pennsylvania*. Guidebook, 57th Annual Field Conference of Pennsylvania Geologists, Warren, PA, p. 1-20.

Feldmann, R. M., Hannibal, J. T., Mullett, D. J., Schwimmer, B. A., Tshudy, D., Tucker, A. B., and Wieder, R. W., 1992, *The paleoecology of* ***Echinocaris randallii*** *Beecher from Drake Well, Titusville, Pennsylvania*, in Erickson, J. M., and Hoaganson, J. W., eds., *Proceedings of the F. D. Holland, Jr., geological symposium*. North Dakota Geological Survey Miscellaneous Series 76, p. 137-147.

Flaherty, K. J., 2003, *Hills, dales, and oil trails: A guide to some historic oil fields between Pittsburgh and Titusville, PA.* Field Trip Guidebook, American Association of Petroleum Geologists-Society of Petroleum Engineers 2003 Joint Eastern Meeting, Pittsburgh, PA, 91 p.

Fox, J. S., 1989, *Some geological aspects of the Oil Creek Valley region*, in Pees, S. T. and others, *History of the Petroleum Industry Symposium*. American Association of Petroleum Geologists Guidebook, p. 46-53.

Giddens, P.M., 1947, *Pennsylvania petroleum, 1750-1872—a documentary history*. Drake Well Memorial Park, Pennsylvania Historical and Museum Commission, 420 p.

Giddens, P. H., 1948, *Early Days of Oil: A Pictorial History of the Beginning of the Industry*. Princeton University Press, Princeton, NJ, 150 p. (reprinted in 2000 by The Colonel, Inc., Titusville, PA.)

Harper, J. A., 1998, *Stop 6 and lunch, Drake Well Memorial Park*, in Harper, J.A., ed., *Geotectonic environment of the Lake Erie crustal block*. Guidebook, 63rd Annual field Conference of Pennsylvania Geologists, Erie, PA, p. 61-74.

Hughes, H. H., 1933, *Freeport quadrangle, geology and mineral resources*. Penn-sylvania Geological Survey, 4th ser., Atlas 36, 272 p.

McLaurin, J. J., 1896, *Sketches in crude oil—some accidents and incidents of the petroleum development in all parts of the globe, with portraits and illustrations*. Harrisburg, Pa., privately published, 406 p.

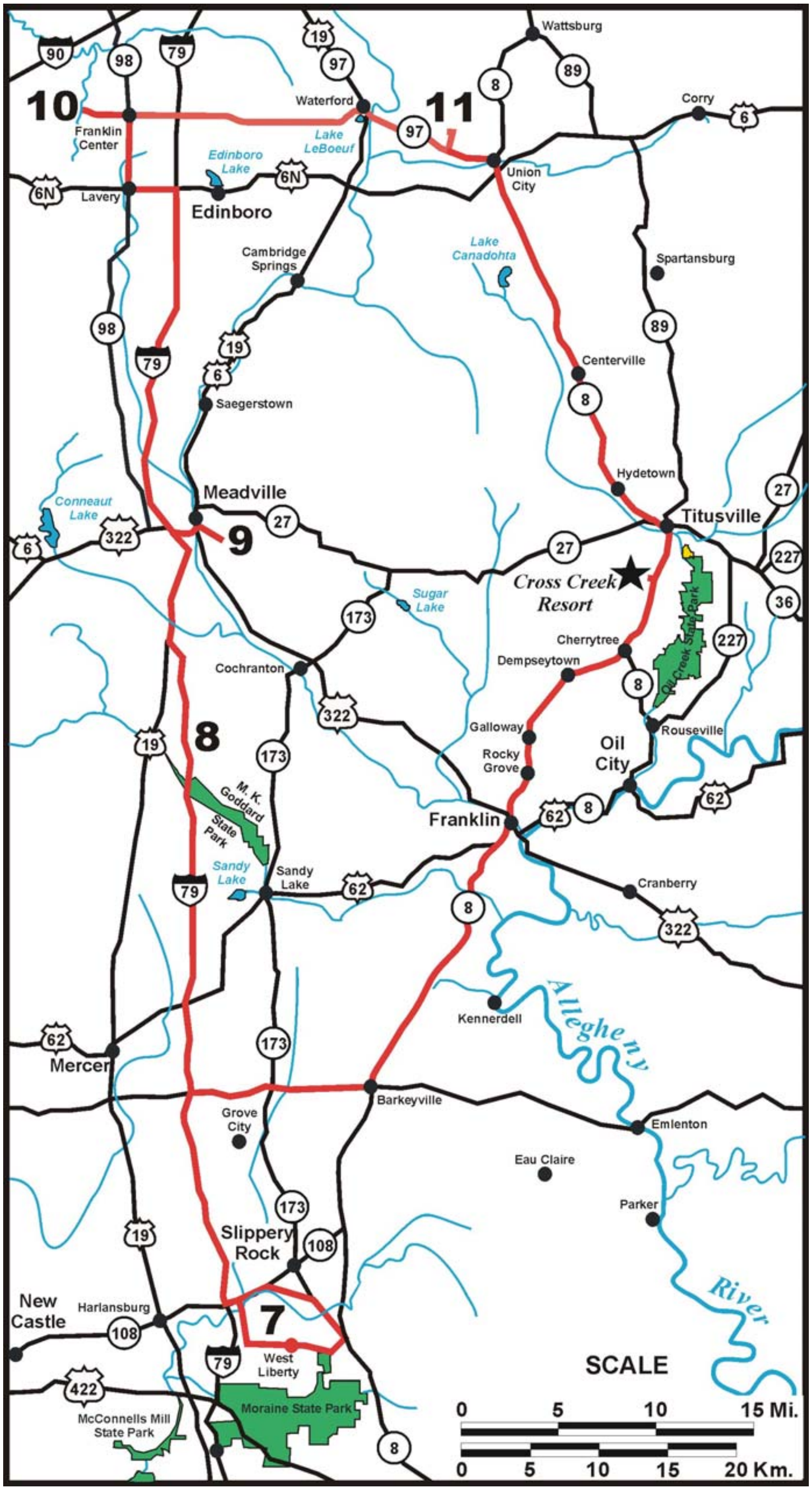
Miller, E. C., 1974, *Pennsylvania's oil industry*. Pennsylvania Historical Association, Pennsylvania History Study 4, 69 p.

Pees, S. T., 2001, *Field excursion: Oil Creek Valley and Pithole, Pennsylvania*. Guidebook and Essays, privately printed, Meadville, PA, 44 p.

Sherrill, R. E. and Matteson, L. S., 1941, *Oil and gas geology of the Franklin Quadrangle, Pennsylvania*. Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 24, 71 p.

USGS, 1980, Success at Oil Creek: August 21, 1859. U. S. Department of the Interior, Geological Survey, Historical Vignette, 22 p.

White, I. C., 1881, *The Geology of Erie and Crawford counties*. Pennsylvania Geological Survey, 2nd ser., Report Q4, 406 p.



Day 2 Route Map
Cross Creek Resort is shown as a star

DAY 2

Miles		
Int.	**Cum.**	**Description**
0.0	0.0	Leave parking lot of Cross Creek Resort and head for exit.
0.1	0.1	Entrance to Cross Creek. Turn right onto PA 8 south.
1.4	1.5	Turn off to Petroleum Centre to left. Proceed straight.
1.0	2.5	Enter village of Cherrytree. We are also entering the old Oakland oil field. Medina production here, also.
0.3	2.8	Bear right onto PA 417.
0.6	3.4	Enter Oakland Township.
1.2	4.6	Enter Dempseytown oil field. Like so many other old oil fields in northwestern Pennsylvania, the shallow oil is basically depleted. The activity now is drilling Medina gas wells.
1.4	6.0	Enter village of Dempseytown.
0.2	6.2	Intersection with PA 428 North to right. Continue straight on PA 417.
0.2	6.4	Intersection with PA 428 South to left. Continue straight on PA 417.
1.1	7.5	Enter Cooperstown oil field.
0.3	7.8	Entrance to Tri-City (Franklin, Oil City, Titusville) Speedway on left.
0.9	8.7	Two-Mile Run County Park to the left along Baker Road. Engineering geology of the Justus Dam on Two Mile run in the county park was Stop VI on the 1976 Field Conference.
1.1	9.8	Enter Franklin-Oak Forest oil field.
0.2	10.0	Enter Borough of Sugar Creek
2.6	12.6	Cherrytree Road to left. Continue straight on PA 417.
0.2	12.8	Enter village of Galloway.
0.9	13.7	Enter village of Rocky Grove.
0.6	14.3	Rocky Grove High School on the right.
0.2	14.5	Outcrop of Cuyahoga sandstone on right.
0.3	14.8	Intersection with US 322 at traffic light. Bear left and follow 13th Street (US 322) into downtown Franklin.
0.1	14.9	Traffic light at Atlantic Avenue. Continue straight on 13th Street (US 322).
0.1	15.0	Cross railroad tracks.
0.1	15.1	Cross French Creek. At the south end of the bridge are two historical markers. One reads: *FORT FRANKLIN Site just west of here. Built in 1787 by U.S. troops under Captain Heart [Hart]. First American fort in the region and base for protecting northwestern Pennsylvania's early settlements.* The other reads: *JOHNNY APPLESEED John Chapman, an actual person as well as a folk hero, lived nearby along French Creek between 1797 and 1804. Records indicate he had a nursery there and one near Warren, Pa., before moving on to Ohio. Born 1774 in Massachusetts, he died in Indiana, 1845.*
0.1	15.2	Traffic Light at Otter Street. Continue straight on 13th Street (US 322).
0.1	15.3	Traffic Light at Elk Street. Continue straight on 13th Street (US 322).
0.1	15.4	Traffic light at Liberty Street. John Wilkes Booth lived in a boarding house near here (13th and Buffalo Streets) for 4 or 5 months during 1864, checking up on some oil interests he had acquired. The wells he had invested in were dry holes, or not very productive. In September, 1864, he abruptly left town.

		Everyone expected him to be back, but the next word they heard of him was in April, 1865 when he assassinated President Lincoln at Ford's Theater in Washington, DC. Turn right onto Liberty Street (PA 8/US 62).
0.1	15.5	Traffic light at 14th Street. Continue straight on Liberty Street (PA 8/US 62).
0.1	15.6	Turn left at blinking yellow light on 15th Street and follow PA 8/US 62.
0.5	16.1	Run-away truck ramp on left.
0.2	16.3	Enter Sandy Creek Township.
0.3	16.6	Mapledale Till type section on left. This was STOP VII on 1976 field conference.
0.2	16.8	Bear left and follow PA 8. US 62 bears right.
0.2	17.0	Leave city of Franklin.
0.4	17.4	Venango Regional Airport to right.
0.6	18.0	PennDOT District 1-5, Venango County, headquarters on right.
0.2	18.2	Pennsylvania Game Commission, Northwestern Pennsylvania Regional Headquarters on left.
0.3	18.5	Apollo Dairy Queen on right. Notice the space capsule in the front yard. At one time, this Dairy Queen held the record for the world's largest banana split.
0.6	19.1	Begin descent into Sandy Creek valley. Enter Foster-Reno oil field.
0.5	19.6	Outcrops on left and right on both northbound and southbound lanes. Strata range from Connoquenessing sandstone (Pottsville Formation) at the highest elevation to Sharpsville Sandstone (Cuyahoga Group) at the level of Sandy Creek. This was STOP VIII on the 1976 Field Conference.
0.6	20.2	Glacial deposits overlying sandstone.
0.2	20.4	Outcrops of weathered shale, probably within the Mississippian Shenango Formation, on the right.
0.9	21.3	Enter Victory Township.
0.1	21.4	Cross Sandy Creek.
0.7	22.1	Remains of the Victory Iron Furnace can still be found along Victory Run in the valley to the right (Al Ward, personal communication, 1999).
2.0	24.1	Twin Oaks Road overpass. Enter Wesley field. Wesley is a sparsely drilled field with, mostly, Medina gas production.
1.7	25.8	Enter Irwin Township. About 3 miles to the west is Henderson gas storage pool in Wolf Creek field with a capacity of 4,808 million cubic feet. National Fuel Gas has been storing natural gas in the Venango First and Venango Third sands since 1934 on a domal structure caused by a pop-up block in the basement at the intersection of at least two major faults.
0.4	26.2	Exit ramp for PA 308 Interchange to Bullion and Pearl. Continue straight on PA 8.
1.7	27.9	Blair Road overpass. The hills to the right have been extensively strip mined for coal in the Allegheny Formation.
1.2	29.1	Exit ramp to Nectarine and Wesley. Continue straight on PA 8.
1.6	30.7	Intersection with old PA Route 8. Cross the contact between the Allegheny and Pottsville formations. The surrounding highlands have been stripped for coal. Continue straight on PA 8.
0.4	31.1	Intersection with Gilmore Road to the right and Melvin Road to the left. Continue straight on PA 8.

0.1	31.2	Enter village of Barkeyville.
0.4	31.6	Turn right onto entrance ramp for I-80 West.
0.3	31.9	Merge on I-80 West. Cross the Kent Till border.
1.1	33.0	Enter Mercer County, Wolf Creek Township.
1.8	34.8	Cross Centertown Road.
0.7	35.5	Outcrop of Homewood sandstone (Pottsville Formation) to the right.
0.9	36.4	Exit ramp to Exit 24, PA 173 to Sandy Lake and Grove City. Continue straight on I-80 West.
1.1	37.5	Enter Volant gas field. The shallow production is long depleted, but extensive Medina drilling has taken place in the last 20 years.
0.1	37.6	Kent moraine topography on right.
0.8	38.4	Enter Pine Township.
1.2	39.6	Enter Findley Township.
1.2	40.8	Hartwick Road overpass.
0.2	41.0	Exit ramp for Exit 19 B, I-79 North. Continue straight on I-80 West and get in right hand land.
0.5	41.5	Bear right onto exit ramp for Exit 19A, I-79 South. Just 0.2 miles west of here is the abandoned Blacktown gas storage pool that, from 1960 to 1968, stored natural gas in the Upper Devonian Venango Third and Berea sandstones.
0.4	41.9	Merge with traffic on I-79 South.
2.7	44.6	Blacktown Road overpass.
0.8	45.4	Exit ramp to Exit 113, PA 208/PA 258 to Grove City, the Grove City Factory Outlets, and New Wilmington. Continue straight on I-79 South.
2.6	48.0	Enter Lawrence County, Plain Grove Township.
0.4	48.4	Brent Road overpass.
0.3	48.7	Rest stop on right. Continue straight on I-79 South.
2.1	50.8	Plain Grove-North Liberty Road overpass.
2.3	53.1	Bear right onto exit ramp at Exit 105, PA 108 to Slippery Rock.
0.3	53.4	Turn left onto PA 108 at stop sign.
0.9	54.3	Turn right onto West Park Road in Moores Corners. Enter West Liberty gas field.
0.3	54.6	Cross Slippery Rock Creek.
0.7	55.3	Intersection with Brandon Road on right and Kelly Road on left. Continue straight on West Park Road.
0.7	56.0	Enter village of Jacksville.
0.1	56.1	Cross Jacksville esker.
0.8	56.9	Turn left onto West Liberty Road at stop sign.
0.9	57.8	View of esker to left and ahead.
0.2	58.0	Intersection with Reichert Road. Continue straight on West Liberty Road.
0.2	58.2	**STOP 7: JACKSVILLE ESKER, DELTA, LAKE PLAIN, AND DRAINAGE DIVERSION COMPLEX** The first six localities on this stop will be viewed from the buses. Conferees will depart the buses only at the final locality (STOP 7G). See detailed stop description on page 146. **STOP 7A: View of Esker**.

0.3	58.5	Intersection with Mt. Union Road on right. Continue straight on West Liberty Road.
0.1	58.6	Intersection with Swope Road on left. Continue straight on West Liberty Road.
0.1	58.7	Gravel pit on right.
0.3	59.0	Turn right onto Moore Road.
0.1	59.1	**STOP 7B: Proximal Side of Delta**.
0.2	59.3	Enter Borough of West Liberty.
0.2	59.5	**STOP 7C: Delta Top**.
0.5	60.0	Intersection with Rohrer Road at stop sign. Continue straight on Moore Road.
0.1	60.1	**STOP 7D: Lake Bottom**.
0.5	60.6	Intersection with Mayer Road. Bear left and follow Mayer Road north.
0.4	61.0	**STOP 7E: Drainage Diversion Gorge #1.**
0.4	61.4	Cross Hogue Run.
0.1	61.5	Intersection with Church Street at stop sign. Proceed straight on Church Street.
0.2	61.7	Intersection with West Liberty Road. Turn left.
0.1	61.8	Cross Hogue Run. Bear left onto Rohrer Road.
0.5	62.3	West Liberty Cemetary on right.
0.1	62.4	Intersection with Moore Road. Continue straight on Rohrer Road.
0.2	62.6	**STOP 7F: View of Distal Delta Front**.
0.2	62.8	Cross Hogue Run.
0.1	62.9	**STOP 7G: Drainage Diversion Channel #2**
0.2	63.1	Enter Worth Township.
0.7	63.8	**STOP 7H: Lake Bottom**.
0.3	64.1	Intersection with Mt. Union Road at stop sign. Turn right onto Mt. Union Road.
0.4	64.5	**STOP 7I: Distal Delta Front and Drainage Diversion Channel #3**.
0.4	64.9	**STOP 7G: Glacial Sand and Gravel Pit in Delta Sediments**.
		Leave STOP 7G and return to Mt. Union Road.
0.1	65.0	Turn right onto Mt. Union Road.
0.6	65.6	Intersection with West Liberty Road. Turn right onto West Liberty Road.
0.8	66.4	Enter Borough of West Liberty.
0.3	66.7	On delta top.
0.6	67.3	Intersection with Rohrer Road. Continue straight on West Liberty Road.
0.1	67.4	Turn right onto Church Street at stop sign.
0.3	67.7	Bear left at intersection with Mayer Road onto West Liberty Road.
0.3	68.0	Intersection with Hill Road on left and Covert Road straight ahead at stop sign. Proceed straight on Covert Road.
1.6	69.6	Turn left onto PA 528 at stop sign.
0.9	70.5	Cross Big Run.
0.1	70.6	Jennings Environmental Center.
0.1	70.7	Turn left onto PA 8 at stop sign.
0.2	70.9	Turn left onto PA 173.

1.5	72.4	Enter Slippery Rock Township.
0.7	73.1	Cross Slippery Rock Creek.
0.3	73.4	Turn left onto Stoughton Road in Doughertys Mills.
0.8	74.2	Intersection with Slippery Rock Road. Continue straight on Stoughton Road.
0.9	75.1	Intersection with Crestview Road. Continue straight on Stoughton Road.
0.5	75.6	Entrance to Allegheny Mineral Corporation gravel pit on left.
0.9	76.5	Turn left onto PA 108 at stop sign.
0.1	76.6	Enter Worth Township.
1.9	78.5	Turn right onto entrance ramp for I-79 North.
0.4	78.9	Merge with traffic on I-79 North.
1.9	80.8	Rest stop on right. Continue straight on I-79 North.
0.3	81.1	Plain Grove-North Liberty Road overpass.
2.5	83.6	North Liberty Road overpass.
0.3	83.9	Enter Mercer County, Liberty Township.
0.2	84.1	Enter Springfield Township.
1.6	85.7	Exit ramp to Exit 113, PA 208/PA 258 to Grove City, the Grove City Factory Outlets, and New Wilmington. Continue straight on I-79 North.
1.6	87.3	Blacktown Road overpass.
1.2	88.5	Enter Findley Township.
1.1	89.6	Exit ramp at Exit 116A, I-80 East. Continue straight on I-79 North.
0.5	90.1	Exit ramp at Exit 116B, I-80 West. Continue straight on I-79 North.
1.3	91.4	Clintonville Road overpass.
1.3	92.7	Enter Jackson Township.
0.2	92.9	Outcrops of Pottsville Formation (Mercer black shales) on right and left (in median).
0.2	93.1	Millbrook Road overpass.
1.3	94.4	Exit ramp to Exit 121, US 62 to Mercer and Franklin. Enter Coolspring oil and gas field. Primary production now is from the Medina. Continue straight on I-79 North.
2.5	96.9	Fox Mine Road overpass.
0.5	97.4	Enter Lake Township.
0.6	98.0	Poole Road overpass.
0.2	98.2	Enter Stoneboro oil and gas field. As with most fields in this part of the state, Medina drilling and production during the past 25 years has dominated oil and gas activities.
1.2	99.4	Fredonia Road overpass.
2.5	101.9	Cross the Shenango River, which flows along a buried glacial valley.
0.1	102.0	Enter New Vernon Township and Sandy Lake gas field.
0.7	102.7	Exit ramp to Exit 130, PA 358 to Greenville and Sandy Lake. Continue straight on I-79 North.
3.0	105.7	Creek Road overpass.
0.3	106.0	Cross bridge over Lake Wilhelm and enter Sandy Creek Township and Kantz Corners gas field. Lake Wilhelm is a 1,860-acre man-made lake lying within M. K. Goddard State Park. The lake was created in 1971 by the damming of Sandy Creek for flood control purposes. Although it is not a glacial lake, Sandy Creek flows (and Lake Wilhelm sits) in a buried glacial valley. Kantz

		Corners field was discovered in 1977 by the N-Ren Corp. #1 Dunn well about 5 miles northeast of Lake Wilhelm. The well had an after treatment open flow of 1 million cubic feet of gas at around 5,100 feet in the Medina.
1.0	107.0	Georgetown Road overpass.
0.7	107.7	Bear right into rest stop.
		STOP 8: COMFORT STOP AND LUNCH.
		We will be stopping briefly to use the restrooms and grab lunches before reboarding the buses for STOP 9 (there is no stop description).
		Bedrock here is Mississippian Shenango Formation. Kent ground moraine makes up the surficial deposits.
0.5	108.2	Leave rest stop and merge with traffice on I-79 North.
1.6	109.8	Enter Crawford County, Fairfield Township at County Line Road overpass.
0.7	110.5	Mule Street overpass.
3.1	113.6	Exit ramp to Exit 141, PA 285 to Geneva and Conneaut Lake. Continue straight on I-79 North.
0.6	114.2	Cross Conneaut Marsh and Conneaut Outlet (the outlet from Conneaut Lake, one of northwestern Pennsylvania's kettle lakes). The broad, 0.6 mile-wide valley is a glacial scour-and-fill feature controlled by basement faulting – part of the French Creek lineament zone (see O'Neil, 1986).
0.2	114.4	Enter Vernon oil and gas field. This field is now mostly Medina production, but also a small amount of oil from the Venango Third sand. Schiner and Gallaher (1979) mapped the LeBoeuf Sandstone, the formal outcrop equivalent of the Venango Third, into Ohio near the Erie County (PA) border. The LeBoeuf Sandstone consists of a white to gray or greenish-gray, fine- to medium-grained sandstone that ranges in thickness from 20 to 45 feet. It is massive and sandy to the south, thin and shaly to the north.
4.4	118.8	Enter Vernon Township.
0.3	119.1	The valley to the right is a buried glacial valley that carries French Creek southeastward to the Allegheny River at Franklin. It wasn't always that way - before the Ice Age, French Creek was actually the "Middle Allegheny River" and flowed from Franklin northwestward to the ancestral St. Lawrence drainage that includes what is now Lake Erie.
0.9	120.0	Bear right onto exit ramp at Exit 147A, US 6/US 19/US322 to Conneaut Lake and Meadville.
0.1	120.1	Merge with traffic on US 6/US 19/US322 toward Meadville.
0.1	120.2	Traffic light at Shaw Avenue on the right and Pennsylvania Avenue on the left. Continue straight on US 6/ US 19/ US 322.
0.3	120.5	Intersection with PA 102 to left. PennDOT Maintenance District 1-1 facility on corner. Notice the colorful decorations. Since 2002, art students from Allegheny College and employees of PennDOT in Meadville have creatively recycled discarded highway signs into large flowers and decorated fences surrounding the maintenance office. Continue straight on US 6/US 19/ US 322 and descend into the French Creek valley.
0.8	121.3	Cross French Creek and enter Meadville oil and gas field.
0.2	121.5	Exit onto Park Avenue, US 322/PA 27, where US 6 and US 19 curve to the left.

0.2	121.7	Traffic light at Willow Street. Continue straight on Park Avenue.
0.2	121.9	Traffic light at Poplar Street. Continue straight on Park Avenue.
0.1	122.0	Turn right onto Pine Street.
0.1	122.1	Intersection at South Main Street. Continue straight on Pine Street.
0.1	122.2	Intersection with Liberty Street. Continue straight on Pine Street.
0.2	122.4	Intersection with Grove Street. Continue straight on Pine Street.
0.3	122.7	Turn right into parking lot and debark.

STOP 9: RICEVILLE FORMATION-ORANGEVILLE SHALE SUCCESSION IN CORA CLARK PARK.

Depart from vehicles and proceed to trail bordering stream. One of us (Baird) will first deliver a brief overview on the Geology and stop-set-up before leading the group to the stream. We will descend by trail from the downhill (west) corner of the grassed park area to the creek bed. The group will, then, turn right at the creek and proceed to the downstream (west) end of the creek bedrock section. Be careful walking as the bedrock surface may be wet and slippery. The stratigraphic succession presented below is in ascending order of units encountered as one proceeds upstream.

See detailed stop description on page 160.

0.1	122.8	Leave STOP 9 and turn left onto Pine Street.
1.0	123.8	Turn left onto Water Street at the stop sign.
0.2	124.0	Turn right on Mercer Street (Willow Street to the left).
0.1	124.1	Turn left onto Grand Army of the Republic Highway, US 6/US 19 at traffic light.
1.7	125.8	Bear right onto entrance ramp to I-79 North.
0.1	125.9	The roadcut on the right exposes rocks of the latest Devonian, including Riceville Formation at the northern end to Berea Sandstone, and possibly the Lower Mississippian Cuyahoga Group, at the top of the ramp. This is one of two "official" Pennsylvania fossil collecting localities in Meadville (Hoskins and others, 1983). Brachiopods, gastropods, bivalves, and even echinoids (sea urchins) have been found here.
0.4	126.3	Merge with traffic on I-79 North.
1.8	128.1	Harmonsburg Road overpass.
1.1	129.2	Cross Cussewago Creek, and another buried glacial valley. Enter Conneaut gas field, producing, again mainly from the Medina Group.
0.5	129.7	Enter Hayfield Township at Rogers Ferry Road overpass.
2.0	131.7	South Mosiertown Road overpass.
0.5	132.2	Outcrops of Cuyahoga Group (Orangeville Shale and Sharpsville Sandstone) on right.
0.4	132.6	Exit ramp to Exit 154, PA 198 to Conneautville and Saegerstown. Continue straight on I-79 North.
1.5	134.1	Cross buried glacial valley. This valley fill only has a small, ephemeral tributary of Cussewago Creek at this point.
1.0	135.1	Maple Drive overpass.
0.3	135.4	Enter Cussewago Township.
3.1	138.5	Fox Road overpass.

0.7	139.2	Enter Cussewago oil and gas field. Production in this field is strictly from the Medina.
2.5	141.7	Rest area on right. Continue straight on I-79 North.
0.6	142.3	Enter Franklin Center gas field.
1.7	144.0	Bear right onto exit ramp to Exit 166, US 6 N to Albion and Edinboro.
0.4	144.4	Turn left onto US 6 N (Lavery Road) at the bottom of the ramp.
0.1	144.5	Cross under I-79.
1.5	146.0	Intersection with Eureka Road at Powers Corners. Continue straight on US 6.
0.4	146.4	Building on right is the office of Kastle Resources, an oil and gas company that has been quietly drilling the Lower Ordovician and Upper Cambrian in Erie and Crawford Counties for several years.
0.7	147.1	Turn right onto PA 98 in Lavery, which is the type locality for the Lavery Till.
1.5	148.6	Intersection with Crane Road. Continue straight on PA 98.
1.2	149.8	Intersection with New Road. Continue straight on PA 98.
1.0	150.8	Enter village of Franklin Center and turn left onto Franklin Center Road (also called Old State Road). Enter Conneaut field.
1.0	151.8	Intersection with Mohawk Road. Continue straight on Franklin Center Road.
1.2	153.0	Enter Girard Township at intersection with Gudgeonville Road on right. Continue straight on Franklin Center Road.
0.6	153.6	Start descent into Little Elk Creek valley.
0.2	153.8	Pull buses to side of the road before the bridge at the small clearing and debark.
		STOP 10: EXPOSURE OF MEDIAL CHADAKOIN FORMATION SUCCESSION, LITTLE ELK CREEK: TOPMOST PART OF PROTOSALVINIA ZONE, LYONS ROAD BED, AND MIDDLE CHADAKOIN "SHALEY MEMBER"
		Buses will turn around across the bridge and park by the side of the road. See detailed stop description on page 167.
		Leave STOP 10 and return to Franklin Center.
0.8	154.6	Enter Franklin Township.
2.2	156.8	Intersection with PA 98 in village of Franklin Center. Continue straight on Old State Road.
1.0	157.8	Intersection with Eureka Road at Mishler Corners. Continue straight on Old State Road.
1.1	158.9	Intersection with Silverthorn Road. Continue straight on Old State Road.
0.5	159.4	Cross I-79.
0.5	159.9	Enter Washington Township at intersection with Fry Road. Continue straight on Old State Road.
1.1	161.0	Intersection with Lay Road to right. Continue straight on Old State Road.
0.8	161.8	Enter village of McLane. Turn left onto PA 99 (Edinboro Road).
0.2	162.0	Turn right onto Old State Road and enter Reeds Corners oil and gas field (Medina, of course).
0.4	162.4	We are entering a field of drumlinoids in the Kent Till that stretches from here to Union City, interrupted only by the buried glacial valley that carries

		Elk and French Creeks northward to Lake Erie. These drumlinoids have a very distinct northwest-southeast orientation. They are not obvious from the bus, but a quick look at the Cambridge Springs NE topo maps shows that they are unmistakeable.
0.8	163.2	Intersection with Hamilton Road on right. Continue straight on Old State Road.
1.2	164.4	Cross Little Conneauttee Creek.
0.3	164.7	Intersection with Corner Road on left. Continue straight on Old State Road.
0.1	164.8	Intersection with Draketown Road on right. Continue straight on Old State Road.
0.2	165.0	Enter Waterford Township.
0.3	165.3	Intersection with Martin Road on left. Continue straight on Old State Road.
0.6	165.9	Stop sign at intersection with PA 86 (Sharp Road) in Phelps Corners. Continue straight on Old State Road and enter Drumlin gas field (an appropriate name!). This field is marked by several producing pools of interest besides the typical Medina production. Greenley pool, about 4 miles northeast of here, produces from the Upper Silurian Bass Islands Dolomite, and two miles northwest of there is the Sibleyville pool, which produces oil and gas from the Middle Devonian Onondaga Limestone. Whether or not these formations were affected by basement faulting that probably controlled the buried glacial valleys is unknown at this time. About 1/2 mile south of here is Conneauttee pool (Edinboro North field), which produces from dolostones of the Upper Silurian Salina Group.
1.0	166.9	Intersection with Smedley Road on right. Continue straight on Old State Road.
0.5	167.4	Intersection with Swails Road. Continue straight on Old State Road.
0.8	168.2	Intersection with Plank Road on right. Bear left and continue on Old State Road. Enter the buried glacial valley that carries Elk Creek and French Creek to Lake Erie.
0.1	168.3	Intersection with Trask Road on left. Continue straight on Old State Road.
0.8	169.1	Enter Borough of Waterford where Old State Road becomes West 3rd Street. The town was laid out in 1794 by Americans who were settling in northwestern Pennsylvania. The town prospered as it became a major stopping point on the route from Pittsburgh to the Great Lakes. It has a lot of history behind it. Today, Waterford's greatest claim to fame is the Troyer Farms Co. that grows, manufactures, and markets Troyer Potato Chips and other snack foods.
0.3	169.4	Cross Trout Run. Aout 1/3 mile to the right is Lake LeBoeuf, another of northwestern Pennsylvania's kettle lakes.
0.3	169.7	Turn right at stop sign onto Walnut Street and follow the circle around the park to the left.
0.1	169.8	Turn right onto US 19/PA 97 (High Street).
0.1	169.9	On the right is the Eagle Hotel, a two-story Georgian/early Federal style hotel built in 1826 by Thomas King from locally quarried stone. The quarry is located on Quarry Road in Le Boeuf Township and can still be seen today. The Eagle Hotel served as an office for the stagecoach line to and from

Pittsburgh. Amos Judson, owner of the Judson House across the street, ran the Eagle Hotel from 1842 to 1853. In 1977 the Eagle Hotel was purchased and restored by the Fort LeBoeuf Historical Society, It is now a restaurant open to the public. The Eagle Hotel was added to the National Register of Historic Places in 1977. Nearby is a statue of George Washington, with a historical marker that reads: *GEORGE WASHINGTON In December, 1753, George Washington came here with notice from the governor of Virginia to the French that they were trespassing on British soil. The statue shows Washington carrying out his first public mission.*

Waterford likes to claim they have the only statue in Pennsylvania of Washington dressed in a British uniform. In reality, the uniform is that of the Virginia militia.

0.1	170.0	Cross unnamed tributary of Lake LeBoeuf, which is off to the right. Enter LeBoeuf gas field. Originally a small, historic gas field in the Venango Formation, it was overwhelmed by Medina drilling in the 1970s and 1980s.
0.1	170.1	Enter Waterford Township.
0.2	170.3	US 19 continues straight at intersection ("Harper's Intersection"). Bear left and continue on PA 97.
0.2	170.5	Cross LeBoeuf Creek.
1.1	171.6	The famous Troyer's Potato Chip factory is on the right.
1.2	172.8	Cross Wheeler Creek.
0.2	173.0	We are back in drumlinoid territory. Over the next 1.8 miles we will be traveling along the southern terminus of the drumlinoid field. They might not be very obvious from the bus. Based on the Waterford topographic map, most of these northwest-southeast oriented hills are about 50 feet high and about 1/2 mile long.
0.9	173.9	Enter LeBoeuf Township.
1.2	175.1	Cross French Creek.
0.2	175.3	Turn left onto Middletown Road.
0.8	176.1	Turn left onto access road to Union City Dam.
0.3	176.4	Park buses as close to the spillway of the dam as possible. **STOP 11: STRATIGRAPHY AND PALEONTOLOGY OF THE CLASSIC UNION CITY DAM SPILLWAY SUCCESSION** See detailed stop description on page 173.
		Leave Stop 11 and return to PA 97.
1.0	177.4	Turn left on PA 97.
0.4	177.8	Enter Union Township and Union City gas field. As with LeBoeuf field, this originally was a small, historic gas field in the Venango Formation. Drilling in the Medina Group in the 1970s and 1980 expanded it tremendously.
1.7	179.5	Enter Union City. French Creek is on the right.
0.2	179.7	Cross small tributary of French Creek.
0.3	180.0	Intersection with PA 8. PA 97 ends. Turn right on PA 8.
0.1	180.1	Cross railroad tracks. US 6 converges with PA 8. Stay straight on PA 8.
0.1	180.2	Cross French Creek.
0.2	180.4	Cross railroad tracks and enter New Ireland gas field.

0.3	180.7	Bear left and follow PA 8. US 6 bears right.
3.1	183.8	Enter Crawford County, Bloomfield Township. Also enter Athens gas field.
2.3	186.1	Lake Road to the left takes you to Lake Canadohta, another of northwestern Pennsylvania's kettle lakes. Continue straight on PA 8.
2.9	189.0	Intersection with PA 77. Continue straight on PA 8.
0.5	189.5	Enter Athens Township.
1.7	191.2	Valley off to the right is Oil Creek.
0.3	191.5	Enter Borough of Centerville.
1.0	192.5	Cross the East Branch of Oil Creek.
0.3	192.8	Cross railroad tracks.
0.4	193.2	Enter Rome Township.
0.7	193.9	Enter Steuben Township.
1.0	194.9	Intersection with Five Corners Road in Five Corners. Continue straight on PA 8 and enter Rome Township.
0.6	195.5	Enter Oil Creek Township.
0.7	196.2	Enter Church Run oil and gas field. Oil production is from the Venango sands, gas production primarily from the Medina.
0.9	197.1	Descending into the valley of Oil Creek. Here, the creek follows a buried glacial valley that was probably controlled by the basement fault whose surface expression is called the Tyrone-Mt. Union lineament.
0.6	197.7	Enter village of Hydetown.
1.6	199.3	Intersection with PA 408. Continue straight on PA 8.
0.3	199.6	Enter Oil Creek Township.
0.6	200.2	Titusville Country Club on the right.
0.8	201.0	Woodlawn Cemetary on the left is the final resting place of Colonel Edwin Laurentian Drake, founder of the modern petroleum industry. The historical marker at the entrance to the cemetary reads: *EDWIN L. DRAKE The man who first sank an oil well is buried in Woodlawn Cemetery and is commemorated by Neihaus's bronze figure, "The Driller." Drake Well is now a State park, a mile and a half south of Titusville.*
0.1	201.1	Enter City of Titusville.
0.5	201.6	Intersection with PA 27. Continue straight on PA 8.
0.2	201.8	Turn right at the traffic light on South Perry Street and follow PA 8.
0.1	201.9	Cross railroad tracks.
0.1	202.0	Cross Oil City & Titusville Railroad track. The OC&TRR Titusville station is to the right.
0.1	202.1	Turn left onto St. John Street and follow PA 8.
0.1	202.2	Turn right onto South Franklin Street and follow PA 8 across Oil Creek.
0.1	202.3	Intersection with Bloss Street at traffic light. To the left is the road to the Drake Well. Continue straight on PA 8.
0.4	202.7	Enter Venango County.
3.6	206.3	Turn right into Cross Creek Resort.
0.4	206.7	Park buses in parking lot and debark. End of 2009 Field Conference of Pennsylvania Geologists. **Drive safely. We hope to see you next year in Lancaster for a 50-year update of some tectonic and structural problems of the Appalachian Piedmont along the Susquehanna River.**

DAY 2 ROAD LOG REFERENCES

Hoskins, D. M., Inners, J. D., and Harper, J. A., 1983, *Fossil collecting in Pennsylvania*. Pennsylvania Geological Survey, 4th ser., General Geology Report 40, 215 p.

O'Neil, C E., 1986, *Characterization of lineaments, French Creek, northwestern Pennsylvania*. Unpublished MS thesis, University of Pittsburgh, 153 p.

Schiner, G. R., and Gallaher, J. T., 1979, *Geology and groundwater resources of western Crawford County*. Pennsylvania Geological Survey, 4th ser., Water Resource Report 46, 103 p.

HARPER'S GEOLOGICAL DICTIONARY

MAGNETIC POLE - An individual from Warsaw with a GREAT personality.

STOP 7: JACKSVILLE ESKER, DELTA, LAKE PLAIN, AND DRAINAGE DIVERSION COMPLEX

Leaders: Gary M Fleeger and Jocelyn Lewis-Miller

The Jacksville Esker complex (Figures 1, 2, and 3) is a remarkably complete complex of related glacial landforms. The 6½-mile long Jacksville Esker terminates at a large (1 mile x ½ mile x 40 feet high) kame delta that prograded into a lake created by the damming of Black Run by the glacier through which the subglacial stream creating the esker flowed. A flat lacustrine plain extends beyond the distal slope of the delta. The delta extends completely across the Black Run valley. Lake drainage channels are eroded through the east side of the Black Run valley wall, and through the delta sediments where they impinge upon the valley walls.

The Esker

The Jacksville Esker (also known as the Miller or West Liberty Esker) is probably the best -preserved esker in Pennsylvania. It was deposited during the Kent glaciation about 23,000 years ago. It occurs in two segments over a distance of 6½ miles between Harlansburg, Lawrence County, and West Liberty, Butler County, separated by post-glacial erosion by Slippery Rock Creek and Taylor Run (Figure 4). The northwestern, upstream segment consists of several short eskers that appear to form a tributary pattern with the main esker. The southeastern segment ends at a kame delta (built in contact with the glacier) or esker delta (kame delta associated with an esker) that was deposited in a proglacial lake. The esker is composed of cobbles, gravel, and sand, with grain size generally increasing downstream. Delliquadri (1951) reported pebble lithologies of predominantly granite, gneiss, sandstone, and quartzite.

Eskers were once assumed to have been deposited only by streams flowing through subglacial meltwater tunnels. However, they can also be deposited in englacial tunnels, open supraglacial channels, or at the glacier front where a meltwater channel or tunnel emerges. A close look at the structure and morphology indicates that the Jacksville Esker was deposited at both subglacial and ice frontal positions.

Evidence that the esker was deposited in a tunnel is the downstream increase in elevation of the base of the esker (Figure 5), from 1100 feet at Slippery Rock Creek to 1215 feet at the kame delta. Water can flow uphill only when a sufficient hydrostatic head is developed in a full flowing tunnel because of the greater thickness of the overlying ice upstream than downstream. An esker extending uphill can also result from the lowering of an englacial tunnel esker or a supraglacial channel esker during melting of the supporting ice, or a time transgressive esker deposited at the ice front as the glacier retreated downhill (Banarjee and McDonald, 1975).

There is no deformation of the entire esker to indicate melting of supporting ice. Faulting only along the edges of the esker (Geyer and Bolles, 1979), because of slope failure during the melting of the ice walls, indicates that the Jacksville Esker was deposited in a subglacial tunnel, and not at an englacial, supraglacial, or ice front position. Some ice front deposition did occur, but is not the main location of deposition.

Fleeger, G. M., and Lewis-Miller, Jocelyn, 2009, *Stop 7: Jacksville esker, delta, lake plain, and drainage diversion complex,* in Harper, J. A., ed., *History and geology of the oil regions of northwestern Pennsylvania.* Guidebook, 74th Annual Field Conference of Pennsylvania Geologist, Titusville, PA. p. 146-159.

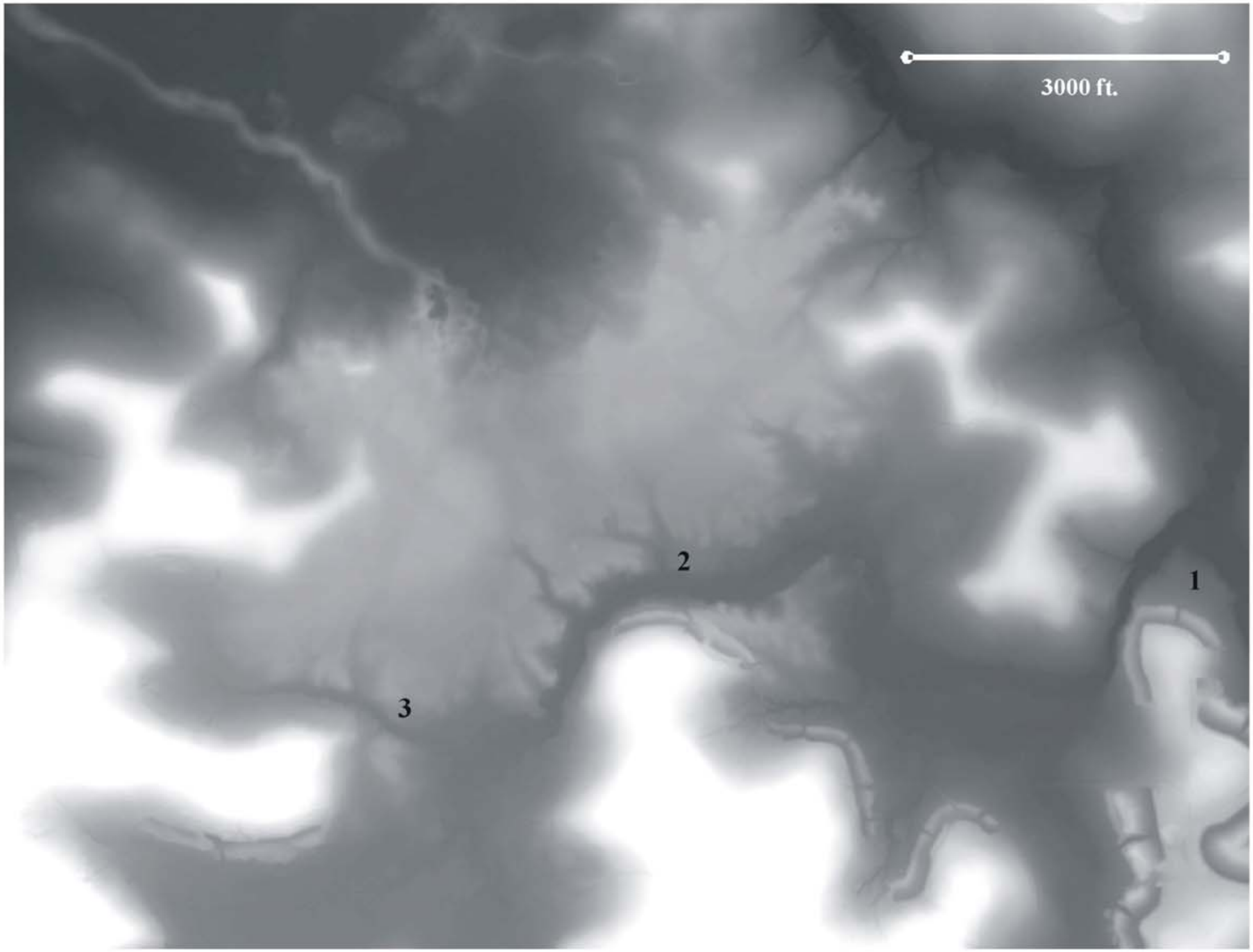


Figure 1- Lidar-based DEM image of the Jacksville Esker-Delta complex. The different shades indicate elevations. White is the highest elevation with darker shades successively lower elevations. The white areas are bedrock hills. The intermediate grays are the esker and delta. The darkest shades are the lacustrine plain and stream valleys. The stream diversions (numbered) are most obvious in this image.

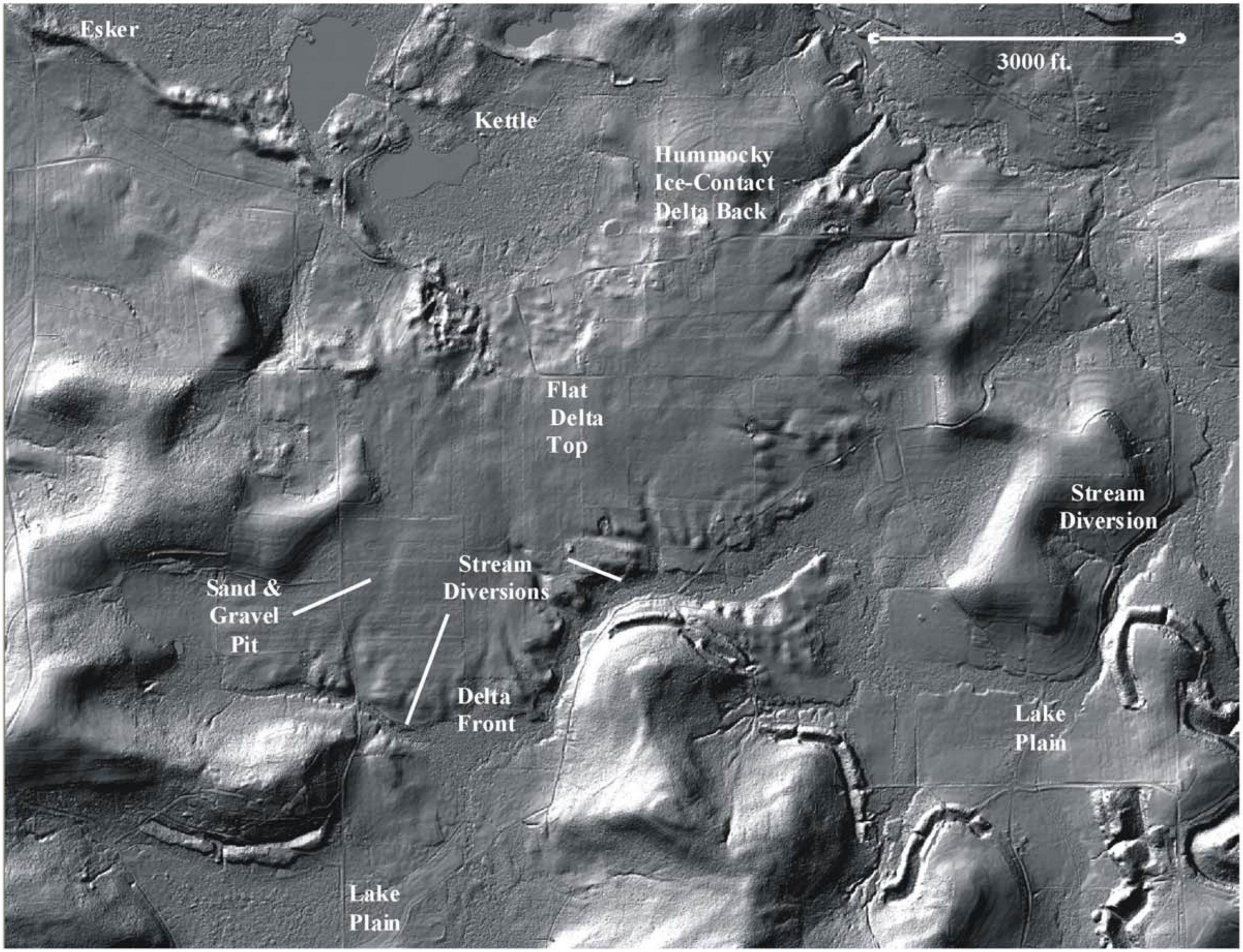


Figure 2. Hillshade image of the Jacksville Esker-Delta complex based on the lidar DEM data from Figure 1. The sun angle is from the northwest. The various parts of the complex are labeled. The hummocky, ice-contact delta back slope is especially clear in the hillshade image.

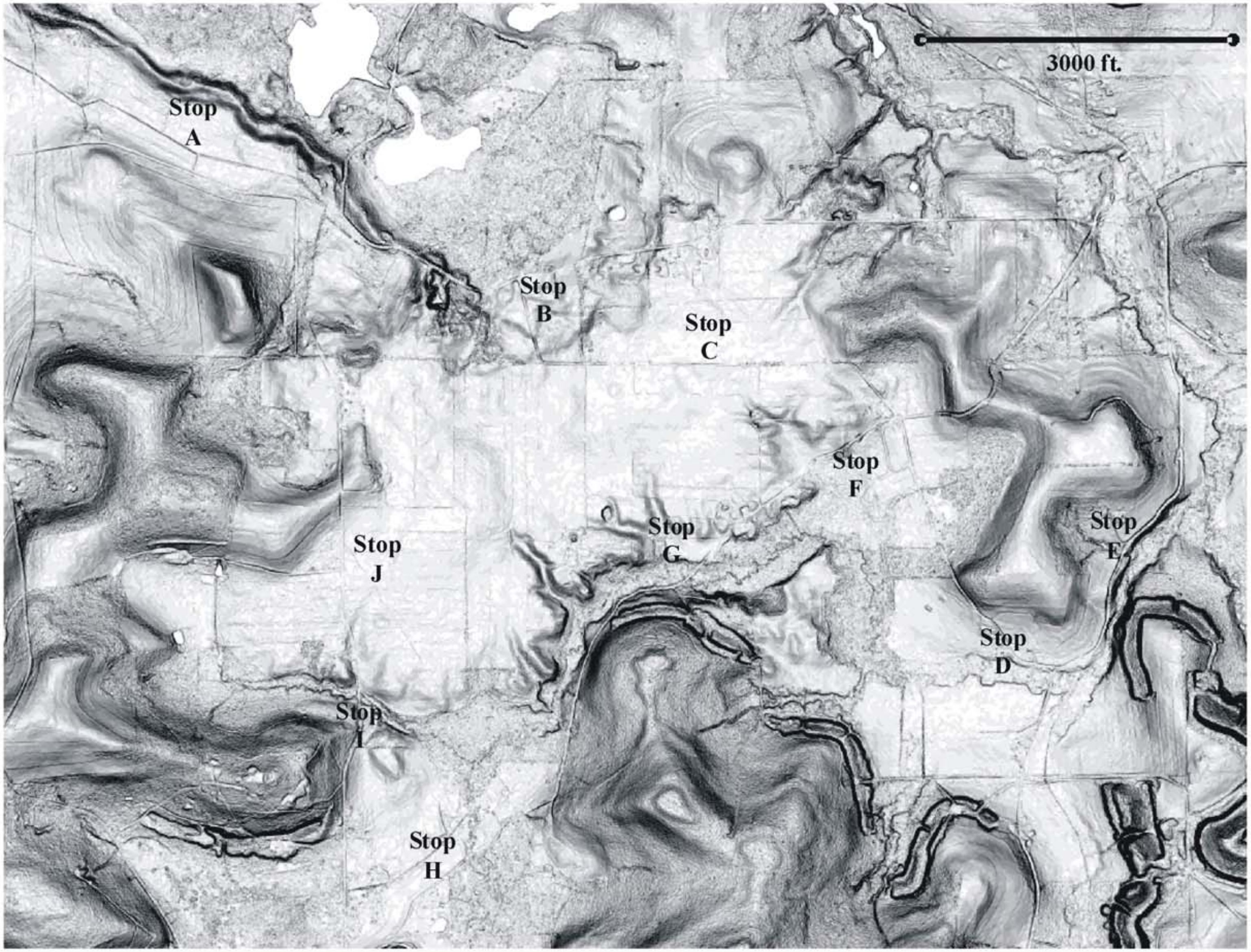


Figure 3. Slopeshade image of the Jacksville Esker-Delta complex based on the lidar DEM data from Figure 1. The light areas are flat, and the dark areas are steep. The flat top and steep sides of the esker, and the flatness of the top of the delta and lake plain are evident in this image. The 10 substops are located on this image.

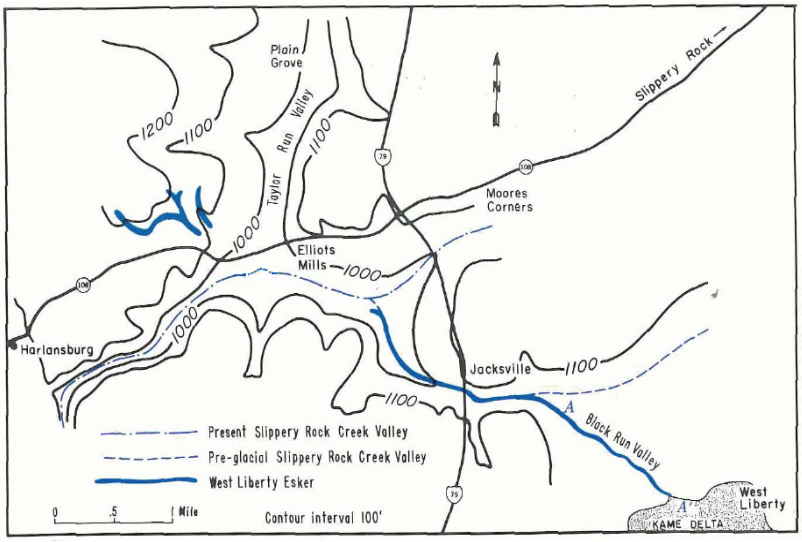


Figure 4. Bedrock contour map (from Poth, 1963) showing location of the Jacksville Esker.

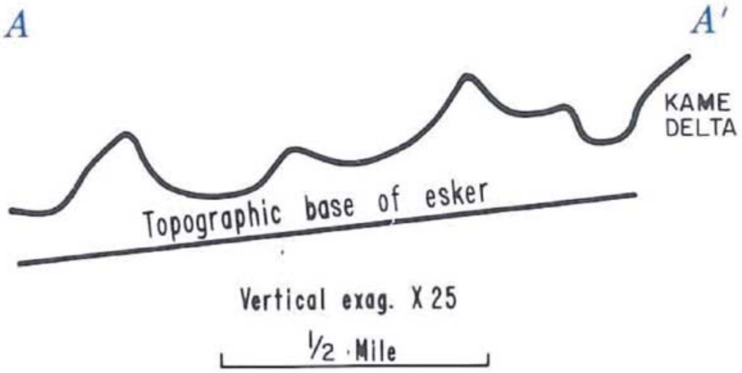


Figure 5. Profile along downstream portion of the Jacksville Esker between locations A and A' shown on Figure 4.

Another indication that the esker was deposited in a subglacial tunnel is that most of it follows the buried, preglacial valleys of Slippery Rock Creek and Black Run (Figure 4). This can happen only if the tunnel is at the base of the glacier, in contact with the land surface (Banarjee and McDonald, 1975).

The morphology of the Jacksville Esker also gives an indication of the character of the Kent glacier. The esker is sinuous in the upstream part, but changes southeast of Jacksville, where it has angular bends and parallel straight segments. This is due to differences in ice thickness. At depths greater than 100 feet in a glacier, the overlying weight causes the ice to behave plastically (Sugden and John, 1976) so that crevasses will not extend into the glacier more than about 100 feet. Subglacial tunnels follow fractures in the ice where they reach the base of the glacier (Stenborg, 1968), suggesting that the Kent glacier was 100 feet thick or less near its terminus when the straight esker segments were deposited. A very thin glacier is consistent with the thin, discontinuous Kent Till in northeastern Ohio and northwestern Pennsylvania (White and others, 1969).

The esker southeast of Jacksville has higher mounds, or beads, at 1700-foot intervals (Figure 5). Increased summer meltwater discharge may have deposited greater amounts of sediment on top of the subglacial tunnel esker at the tunnel mouth as the ice front melted back. This would indicate that the initial rate of annual retreat of the Kent glacier was 1700 feet.

The Delta

Geomorphology

The delta is a very flat-topped feature at an elevation of approximately 1295 feet (Stop 7C). The topography of the proximal, ice-contact side of the delta, the north side, is hummocky, probably due to collapse after the supporting glacier retreated (Stop 7B). The distal delta-front slope is smooth, merging with the lacustrine plain (Stop 7F). The delta impinges upon the valley walls, completely blocking the Black Run valley. The Black Run valley splits upstream into 2 tributary valleys. The center of the delta extends to the divide between the 2 tributary valleys.

Internal Composition- Glacial Sand and Gravel Co. pit (Stop 7J)

A recently opened sand and gravel pit by Glacial Sand and Gravel Company has exposed the internal composition and structure of part of the delta. The following brief description of the sediments is based on the exposure available during about 1½ hours of examination in May and July, 2009.

The sediment within the delta ranges from fine sand to cobbles. Much of the sediment is well sorted, but the coarsest sediment, at the top of the delta, is more poorly sorted, ranging from coarse sand to cobbles. Most of the sedimentary structures are cross bedding and ripples in the sand beds (Figure 6). Contacts between beds is usually sharp, sometimes channeled, and frequently between beds of very different grain size (Figure 7), indicating fluctuating flow. Frequently, there are large pebbles within the sand laminae, with no indication of any deformation of the laminae (Figure 8).

There are few faults in the sediments (Figure 9). Faulting in such sediments is usually a result of slumping in an ice-contact position. More extensive faulting would be expected in exposures along the hummocky ice-contact delta-back slope position. This pit is excavated within the delta well beyond the ice margin. The faults may be due to the melting of ice blocks broken off from the glacier and deposited with the sediment. Faulting occurred above the ice block when it melted.

The most prominent feature is the foresets, up to 15 feet high (Figure 10). Two sets of foresets have been exposed as of this writing. The forests are mostly medium sand, but there are some fine sand or silt beds within them. The dip of the foresets varies (Figure 11). The at least on of the foresets are overlain by a thin, dirty sand and gravel (Figure 12). These foresets were probably deposited on the frontal slope of what was at the time of deposition, the outer margin of the delta. The foresets that are/were exposed here indicate transport from the west or northwest, which suggests that it was NOT from the esker tunnel, which joins the delta to the north-northeast. Perhaps there were multiple

Figure 6- Ripple cross lamination within medium sand.

Figure 7- Sharp contact and abrupt change in grain size.

Figure 8- Pebbles in sand laminae.

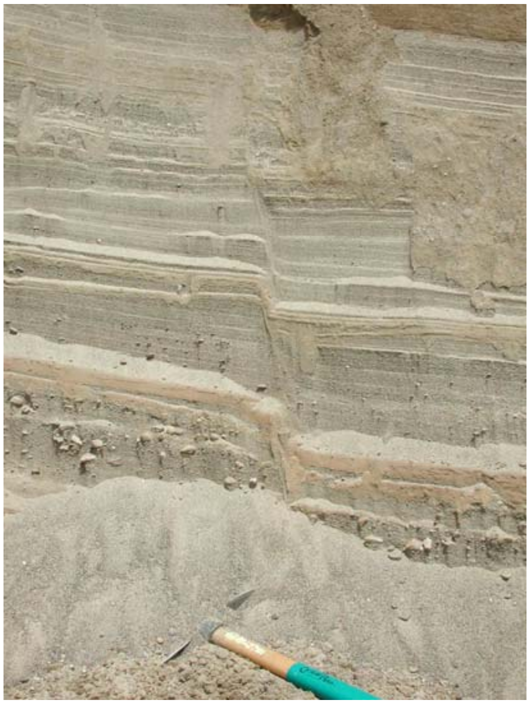


Figure 9- Fault in a foreset bed.

Figure 10- Delta forests.

input locations to the delta. The delta does seem to be quite large in relation to the esker.

The multiple foreset beds indicate that the delta is not a single, simple, large delta, but is a composite feature, built up over a period of time from multiple episodes of deposition, probably though multiple small delta lobes.

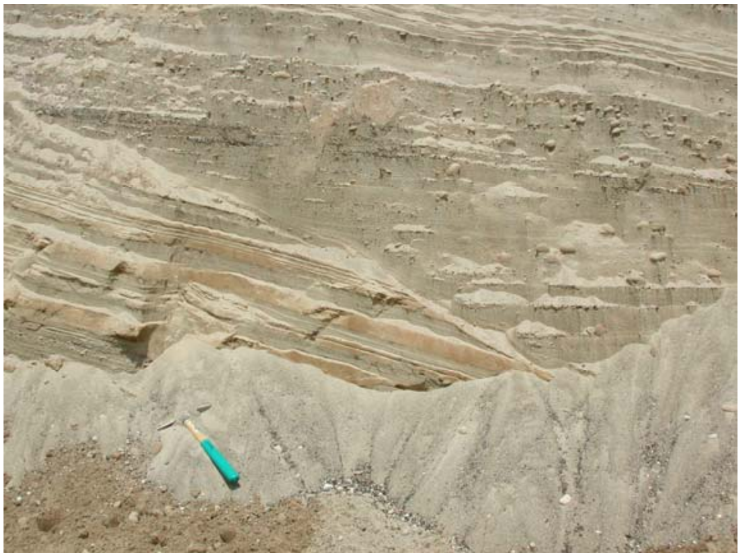


Figure 11- Erosion surface and beds dipping at different angles in the delta forests.

Figure 12- Dirty, weathered-looking sand and gravel at the top of the delta foreset.

The Lake Plain

The lacustrine plain is a flat lowland extending beyond the delta in the two Black Run tributary valleys. The only exposure was a temporary pond excavation just beyond the delta front in the western tributary valley. The sediments in that excavation were gray and black clay, silt, and some till-like material. The latter was seen in the excavated sediments, and not in place. The thickness of the lacustrine sediments is unknown.

Black Run/Hogue Run Diversions

Diversions in the courses of drainage caused by glaciation have been recognized in the area of Butler, Mercer, and Lawrence Counties in Pennsylvania since the late nineteenth century (Preston, 1977). Most of the known major drainage changes probably occurred during the older of the four major glaciations that covered the area (Fleeger, 1984). No permanent drainage changes associated with the youngest and most recent glaciation (Kent) have been previously documented (Preston, 1977). This may be because, based on available evidence, it appears that with each successive glaciation, drainage diversions became smaller and involved lower order streams. Hogue Run, in northwestern Butler County, is an example of a small stream diversion caused by the Kent glaciation.

A drainage anomaly exists along Hogue Run (Figure 13). It flows through the headwater areas of two adjacent, and formerly separate, valleys. Topographic orientation, best seen by observing the 1,300-foot topographic contour line on the Slippery Rock and Prospect 7.5-minute-quadrangle maps, suggests that streams should flow northwest toward Slippery Rock

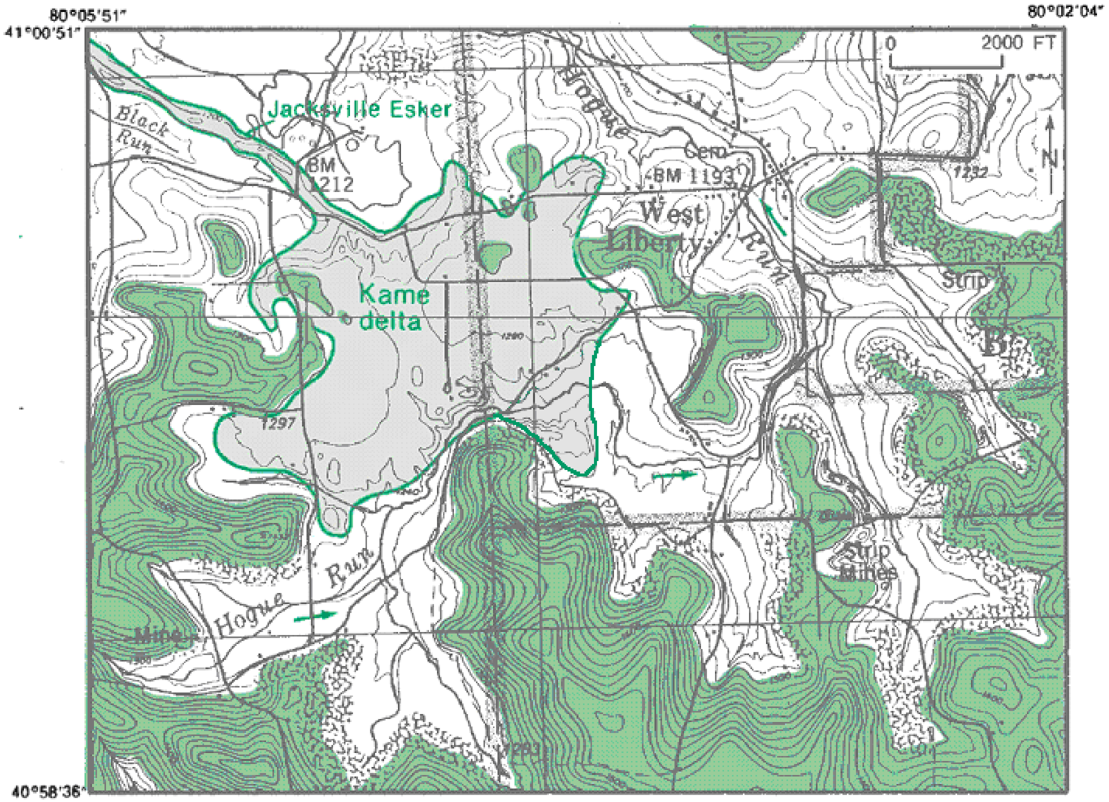


Figure 13. The present topography and features in the area of Hogue Run. The darker color indicates areas that are greater than 1,300 feet in elevation (base map from U.S. Geological Survey Butler County topographic map, scale 1:50,000).

Creek. However, Hogue Run flows northeast across a broad valley, across the regional alignment of valleys, through a small gorge, and into an adjacent valley. There, it turns 90 degrees to the northwest and flows toward Slippery Rock Creek.

Preglacial Drainage

Topographic orientation suggests that preglacial Black Run originated south of the glacial boundary, southwest of West Liberty. Several tributaries joined and flowed northwest to preglacial Slippery Rock Creek (Figure 14). Likewise, Hogue Run, in the adjacent valley to the east, flowed toward Slippery Rock Creek, parallel to Black Run.

Near the headwaters of Black and Hogue Runs, most of the divide between these two streams exceeded 1,300 feet in elevation. However, at one point (site A on Figure 14), the present topography suggests that the preglacial divide was below 1,300 feet.

Kent Glaciation

The Kent glacier advanced into the area about 23,000 years ago (White and others, 1969) and blocked northwest-flowing streams, forming proglacial lakes in their valleys. The lake in the Black Run and Hogue Run valleys was part of Lake Edmund (Preston, 1977). During the Kent advance (Figure 15), the Jacksville Esker formed, more or less, in the position of the lower

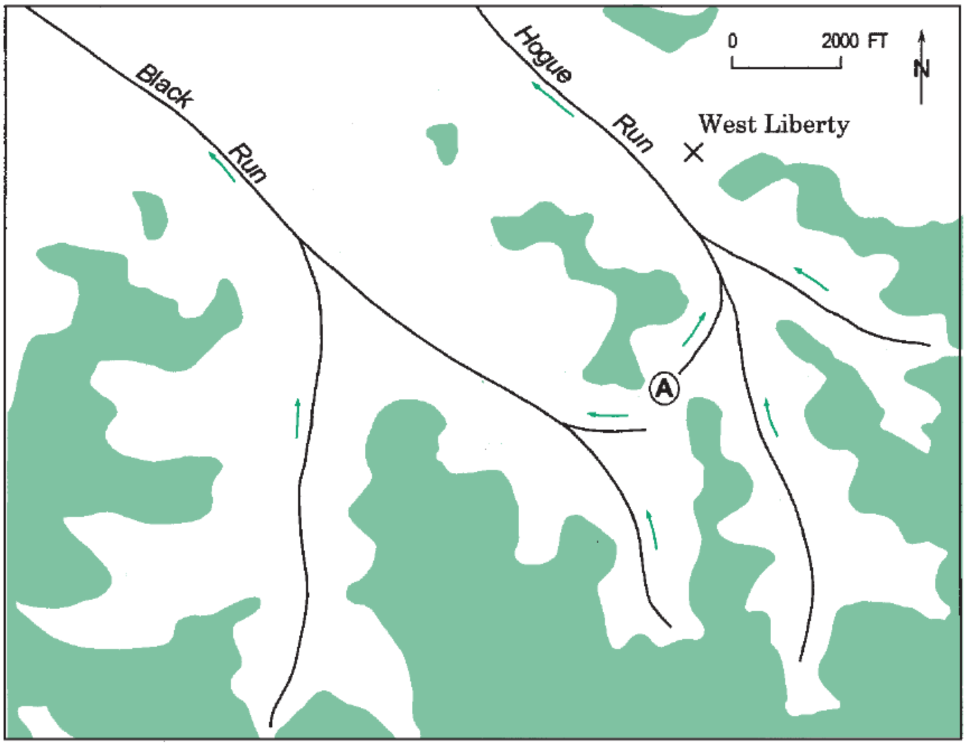


Figure 14. The preglacial configuration of Black and Hogue Runs indicates that the present headwaters of Hogue Run were originally drained by the upper part of Black Run. Areas that are greater than 1,300 feet in elevation today are shown in

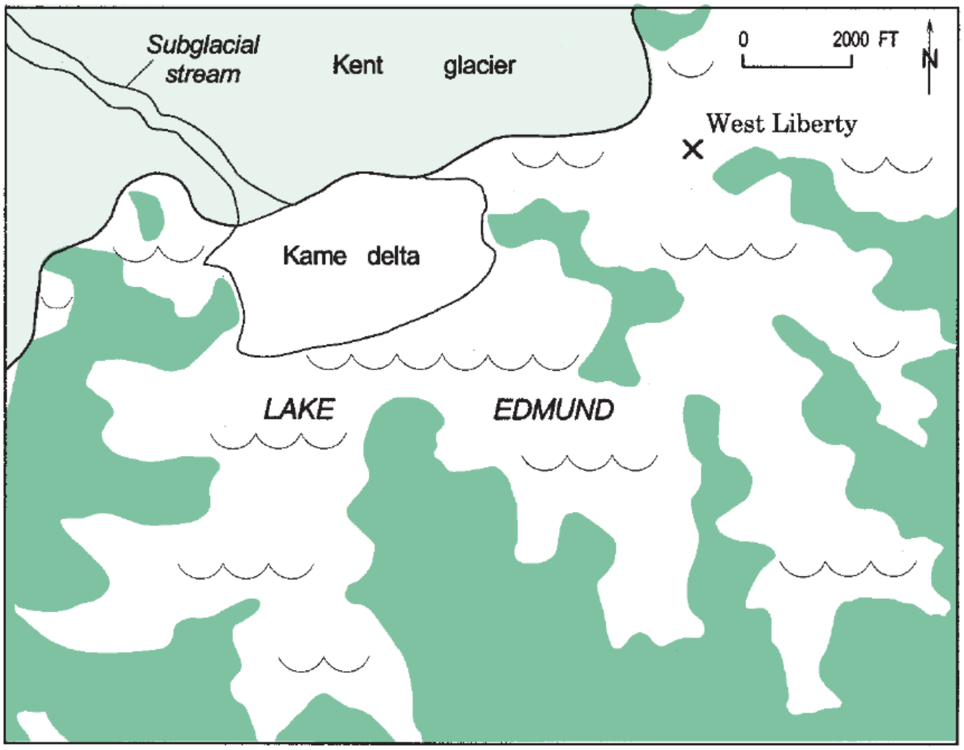


Figure 15. During the Kent glacial maximum, Lake Edmund covered much of northern Butler County, including Black Run and Hogue Run valleys. The lake level was probably about 1,310 feet. Areas that are greater than 1,300 feet in elevation today are shown in the darker color.

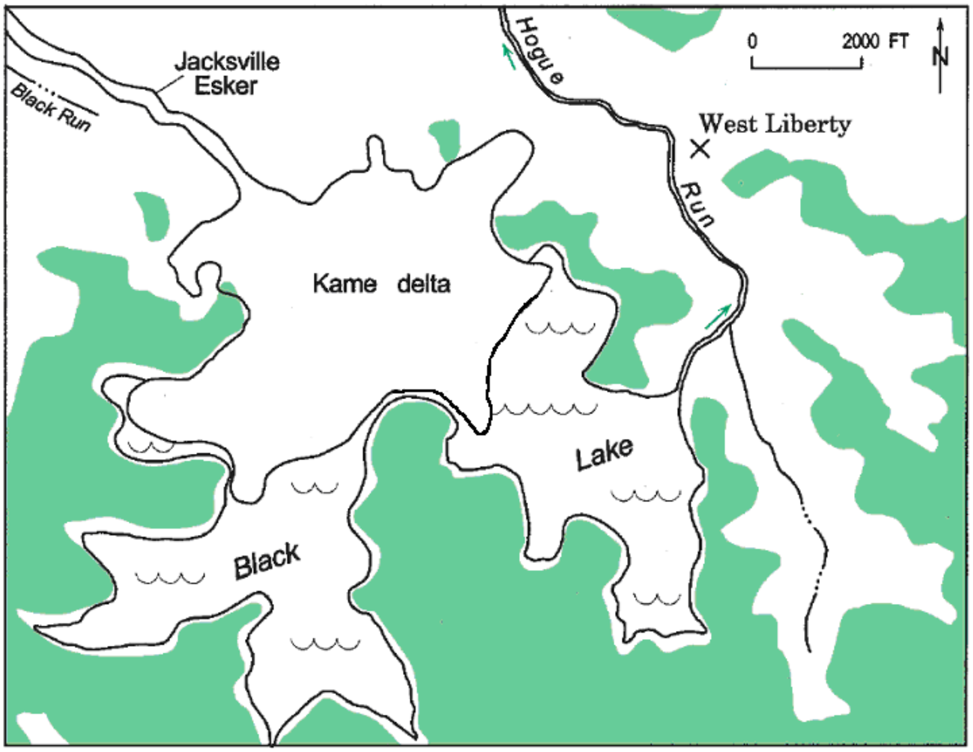


Figure 16. The level of Black Lake, initially at about 1,280 feet, was controlled by the elevation of the low point in the divide between Black and Hogue Run valleys. Areas that are greater than 1,300 feet in elevation today are shown in color. Locations of eventual diversion channels are numbered.

reaches of preglacial Black Run (Fleeger, 1986). Where the subglacial stream discharged from the tunnel into Lake Edmund in the upper reach of the Black Run valley, it built a kame delta. The kame delta completely blocks the upper preglacial Black Run valley with about 177 million cubic yards of sand and gravel.

When the Kent glacier melted, Lake Edmund drained from the area and from Hogue Run valley. However, the kame delta continued to dam the upper Black Run area, and it remained a lake (Black Lake). Overflow from Black Lake drained through an outlet at the low point on the eastern side of Black Run valley, flowed into Hogue Run valley, and then flowed to Slippery Rock Creek (#1 on Figures 1 and 16). Gradually, the lake overflow eroded through the divide, Black Lake was drained, and a diverted stream flowing northeast was established.

The elevation of the spillway at Black Lake must have been slightly below 1,280 feet. Had it been higher than 1,280 feet, Black Lake would have drained through a low, broad channel across the kame delta, and Black Run would have eventually resumed its preglacial course.

Present Drainage

This stream diversion has increased the headwaters area of Hogue Run and has resulted in its present anomalous configuration (Figure 13). Hogue Run now drains the upper part of the preglacial Black Run valley. Black Run continues to flow in the lower reach of the preglacial Black Run valley. The kame delta now forms part of the divide between Black and Hogue Runs.

Presumably, this diversion occurred during the Kent glaciation, based on its association with the Jacksville Esker. This esker has been interpreted to be of Kent age because it terminates at the Kent Till border (Shepps and others, 1959) and because its position appears to have been partly controlled by crevasses in a thin glacier (Fleeger, 1986). The Kent glacier was very thin, whereas the preceding Titusville glacier, which was responsible for most drainage diversions in the area (Fleeger, 1984), is interpreted to have been very thick (White and others, 1969). Thus, this diversion occurred about 21,000 to 22,000 years ago.

Where the delta impinged upon the divide between the eastern and western tributaries of Black Run (Figure 16), a post-glacial channel has eroded between the delta sediments to the northwest and bedrock to the southeast, and through the delta sediments in the eastern tributary valley (#2 on Figures 1 and 16). I suspect that it was eroded by delta-dammed lake overflow from the western tributary valley into the eastern tributary valley while the drainage diversion into the Hogue Run valley was progressing.

Finally, a third, small diversion channel exists just east of Mt. Union Road where a tributary to present-day Hogue Run eroded a channel through the delta sediments (#3 on Figures 1 and 16). After the majority of the southwestern tributary valley was drained by the second diversion, a small side valley continued to be blocked by delta sediment impinging upon bedrock hills along Mt. Union Road. Overflow from the small lake remaining in that side valley eroded a channel through the delta sediments.

Stops

The Field Conference will take a tour to view the geomorphology of the complex. These stops will be drive-bys. We will not get off of the bus, but stop briefly at each place to view the geomorphology of that part of the complex. The final stop will be in the Glacial Sand and Gravel pit on the southwestern side of the delta on Mt. Union Road. The locations of all of the stops are noted on slopeshade image derived from the lidar data (Figure 3).

- Stop 7A- This stop on West Liberty Road provides a view of the Jacksville Esker. The portion of the esker visible here is owned and preserved by the Western Pennsylvania Conservancy. It is maintained by the Miller family, from whom it was acquired in 1976, as pastureland so that its form will be visible. The downstream end of the esker is about ¼ mile to the southeast.

Figure 17- Stop 7A- Jacksville Esker.

- Stop 7B- This stop on Moore Road is the best place to see the delta-back slope. Because this side of the delta was in contact with the glacier, when the glacier melted, and the support removed, the sediments collapsed and were let down, resulting in the hummocky topography evident at this location. The hummocky topography is most evident on the

Figure 18- Stop 7B. Hummocky topography on the ice-contact, proximal side of the delta. This view is of the area to the west of the junction of the esker and delta. Stop 7B is on the east side of the junction.

hillshade image derived from the Lidar data (Figure 2).

- Stop 7C- This is the best location to see the flat top of the delta. Moore Road ascends the back slope and runs along the top of the delta for ¼ mile, then descends the delta-front slope and on to the lacustrine plain.
- Stop 7D- At the intersection of Moore and Mayer Roads is a good place to view the very flat lacustrine plain of the eastern tributary of pre-glacial Black Run.
- Stop 7E- Mayer Road passes through the col containing the largest of the three post-glacial diversion channels (#1 on Figures 1 and 16). The erosion of this channel drained the eastern half of the delta-dammed Black Lake. The small gorge is parallel to the road on the right (east) side of the road. About ¼ mile ahead on Mayer Road, we will cross Hogue Run, now flowing in its own valley.
- Stop 7F- Roher Road runs along the delta front slope, visible to the right (north). Just ahead we will enter the second diversion channel through delta sediments.
- Stop 7G- Further along Roher Road, after crossing Hogue Run (in the Black Run valley), the diversion channel is between delta sediments to the right (north) and bedrock to the left (south). At this location, the delta sediments impinged upon the bedrock (#2 on Figures 1 and 16).
- Stop 7H- We are now on the flat lacustrine plain of the western tributary of pre-glacial Black Run.
- Stop 7I- As we ascend a small bedrock spur on Mt. Union Road, the delta front is visible to the right (east). Just after crossing the bedrock spur, the road descends to our stop at the third drainage diversion (#3 on Figures 1 and 16). The channel passes behind the small knob of delta sediments that we just passed.
- Stop 7J- The Glacial Sand and Gravel pit here exposes sediments deposited in the delta at the end of the Jacksville Esker.

Figure 19- Stop 7C. Flat top of the delta along Moore Road

Figure 20- Stop 7I. Smooth distal delta slope merging with the lacustrine plain in the western tributary from Mt. Union Road. This small knob is isolated from the rest of the delta by the third diversion channel (#3 on Figures 1 and 16).

REFERENCES

Banarjee, I**.**, and McDonald, B. C., 1975, *Nature of esker sedimentation*, in Jopling, A. V., and McDonald, B**.** C., eds., *Glaciofluvial and glaciolacustrine sedimentation*. Society of Economic Paleontologists and Mineralogists Special Publication 23, p. 132-154.

Delliquadri, L. M., 1951, *Physiography and history of glacial Lake Arthur*. Unpublished MS thesis, Clark University, 66 p.

Fleeger, G. M., 1984, *Dating the formation of the Slippery Rock Gorge*. Pennsylvania Geology, v. 15, no. 3, p. 8–11.

Fleeger, G. M., 1986, *The West Liberty Esker*: Pennsylvania Geology, v. 17, no. 1, p. 7–9.

Geyer, A. R., and Bolles, W. M., 1979, *Outstanding scenic geologic features of Pennsylvania*. Pennsylvania Geological Survey, 4th ser., Environmental Geology Report 7, 508 p.

Poth, C. W., 1963, *Geology and hydrology of the Mercer quadrangle*. Pennsylvania Geological Survey, 4th ser., Water Resource Report 16, 149 p.

Preston, F. W., 1977, *Drainage changes in the late Pleistocene in central western Pennsylvania*. Pittsburgh, Carnegie Museum of Natural History, 56 p.

Shepps, V. C., White, G. W., Droste, J. B., and Sitler, R. F., 1959, *Glacial geology of northwestern Pennsylvania*. Pennsylvania Geological Survey, 4th ser., General Geology Report 32, 59 p.

Stenborg, T., 1969, *Studies of internal drainage of glaciers*. Geografiska Annaler, v. 51A, p. 13 -41.

Sugden, D. E., and John, B. S., 1976, *Glaciers and landscape*. Halstead Press, 376 p.

White, G. W., Totten, S. M., and Gross, D. L., 1969, *Pleistocene stratigraphy of northwestern Pennsylvania*. Pennsylvania Geological Survey, 4th ser., General Geology Report 55, 88 p.

STOP 9: RICEVILLE FORMATION-ORANGEVILLE SHALE SUCCESSION IN CORA CLARK PARK

Leaders: Gordon C. Baird, D. Jeffery Over, and Shirley Pulawski.

Riceville Formation

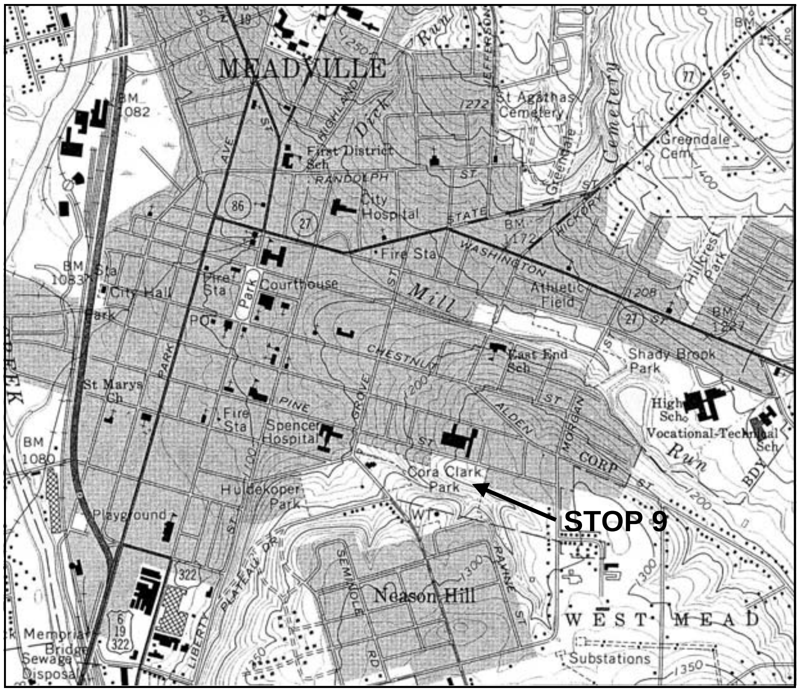


Figure 1. Location of STOP 9 in the Meadville 7.5-minute quadrangle.

The basal 5-meter (16.5 foot) succession on this stream in Cora Clark Park (Figure 1) is developed in the upper part of the Riceville Formation. Based on measurements by White (1881) and Caster (1934), the Riceville is about 26 meters (80 feet)-thick at this meridian. However, some of this aggregate thickness includes strata included by us in younger divisions (West Mead Bed, Bennyhoof Shale, and “Drake Well Formation”) which we will see upstream. The visible (restricted) Riceville interval on this creek is interpreted to be the eastern, upslope phase of the Chagrin Formation in Ohio. At this locality, the Riceville is expressed as an interval dominated by tabular to lenticular, grey, slabby siltstone beds and grey-green shale interbeds. The siltstone beds weather to a grey-brown color and display sharp, erosional sole marks along their bases. Sedimentary structures observed include: ripple marks on some bedding planes, scour surfaces (sole marks) along bases of beds, and disarticulated brachiopods, bivalve, and echinoderm debris.

West Mead Bed

Above the Riceville interval is a compact bundle of siltstone beds which we, herein, designate the “West Mead Bed” for exposures along Bennyhoof Creek north of Meadville (Figure 2). At this creek, this unit includes 1.2 meters (3.6 feet) of resistant, closely-spaced, variably bioturbated, siltstone layers. The base of this unit is marked by a 4-6 cm (2-3 inch-) thick, very dark grey, silty mudstone bed which is floored by a lag of reworked pyrite and conodont/fish bone debris interpreted to mark the horizon of the Skinner’s Run Bed (Figure

Baird, G. C., Over, D. J., and Pulawski, Shirley, 2009, *Riceville Formation-Orangeville Shale succession in Cora Clark Park*, in Harper, J. A., ed., *History and geology of the oil regions of northwestern Pennsylvania.* Guidebook, 74th Annual Field Conference of Pennsylvania Geologist, Titusville, PA. p. 160-166.

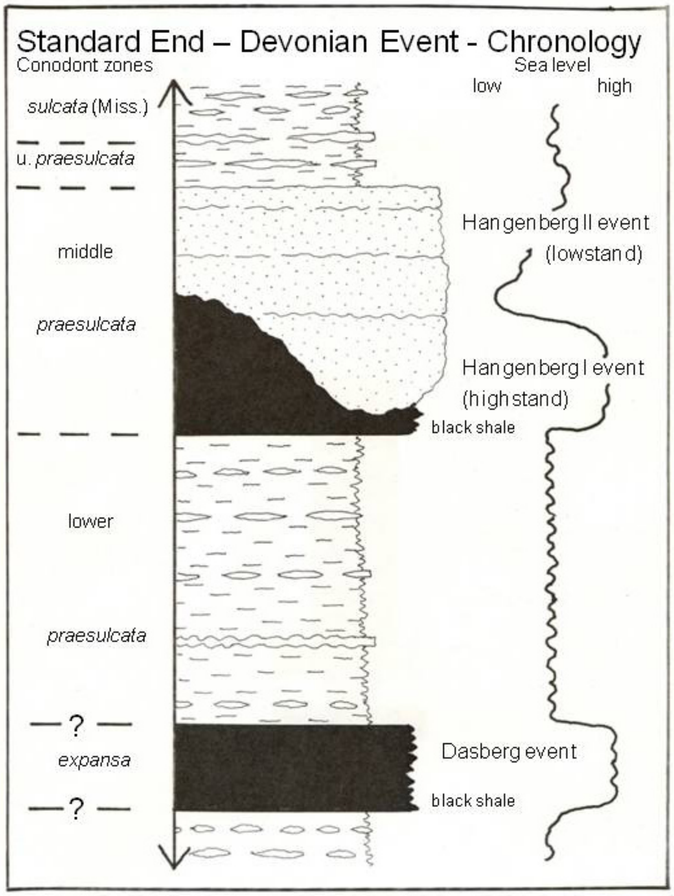


Figure 2. Top-Riceville-Formation-into-Cussewago Sandstone succession generalized from composite profiles of Bennyhoof Creek and nearby Shellhammer Hollow at the north edge of Meadville, Pennsylvania. Note presence of black shale partings and microbioturbated dark siltstone beds in the West Mead Bed as well as prominent discontinuities flooring both the Drake Well Formation and overlying Cussewago Sandstone.

3A). This is succeeded by 25 cm (10 inches) of grey siltstone beds and soft shale. This unit is succeeded by 0.75 meter (2.5 feet) of hard, brown-weathering siltstone beds. The parts of this interval display dark, silty shale partings as well as dark grey siltstone beds which are intensely bioturbated (Figure 2). In particular, the ichnotaxon *Scalarituba* has been observed in this interval at several Meadville area sections; this trace fossil is characteristic of basal Mississippian dysoxic deposits and is abundant in the Bartholomew Bed, a division that we will see upstream at this locality (see below). Other fossils present include the brachiopods *Cyrtospirifer* , *Syringothyris* , productids, gastropods, and the problematical conical taxon *Coleolus* (Figure 3B). We believe, on the basis of conodont yields to date, as well as lithologic features, that this unit is the upslope equivalent of the black Cleveland Shale in Ohio.

Bennyhoof Shale

Continuing upstream, we cross a 2.4 meter (8-foot)-thick interval of soft, grey-green mudstone with associated, thin siltstone beds and lentils. We, herein, provisionally refer to this unit as the "Bennyhoof Shale" for good exposures on Bennyhoof Creek north of Meadville (Figure 2). The lowest 0.3 meter (12 inches) of this unit is heavily bioturbated, distinctly silty, and transitional with the underlying West Mead division. The middle of this unit is very shaley with only thin siltstone bed development. The top 0.7 meter (2 foot) portion of this unit is marked by a return of thicker siltstone beds; these are distinctly lenticular (channelized?) and are associated only with trace fossils.

"Drake Well Formation"

The "Drake Well Formation" is a name herein assigned to strata between the Bennyhoof Shale and the sub-Cussewago disconformity between the French Creek Valley region and the meridian of Union City (see fig. 3 on p. 16-17). It is observed to appear in a few sections west of French Creek as a feather-edge deposit, followed by eastward thickening as younger beds appear progressively beneath the base-Cussewago contact across the study area. Although the upper part of this unit is concealed at Cora Clark Park, the lower four feet of the interval is well

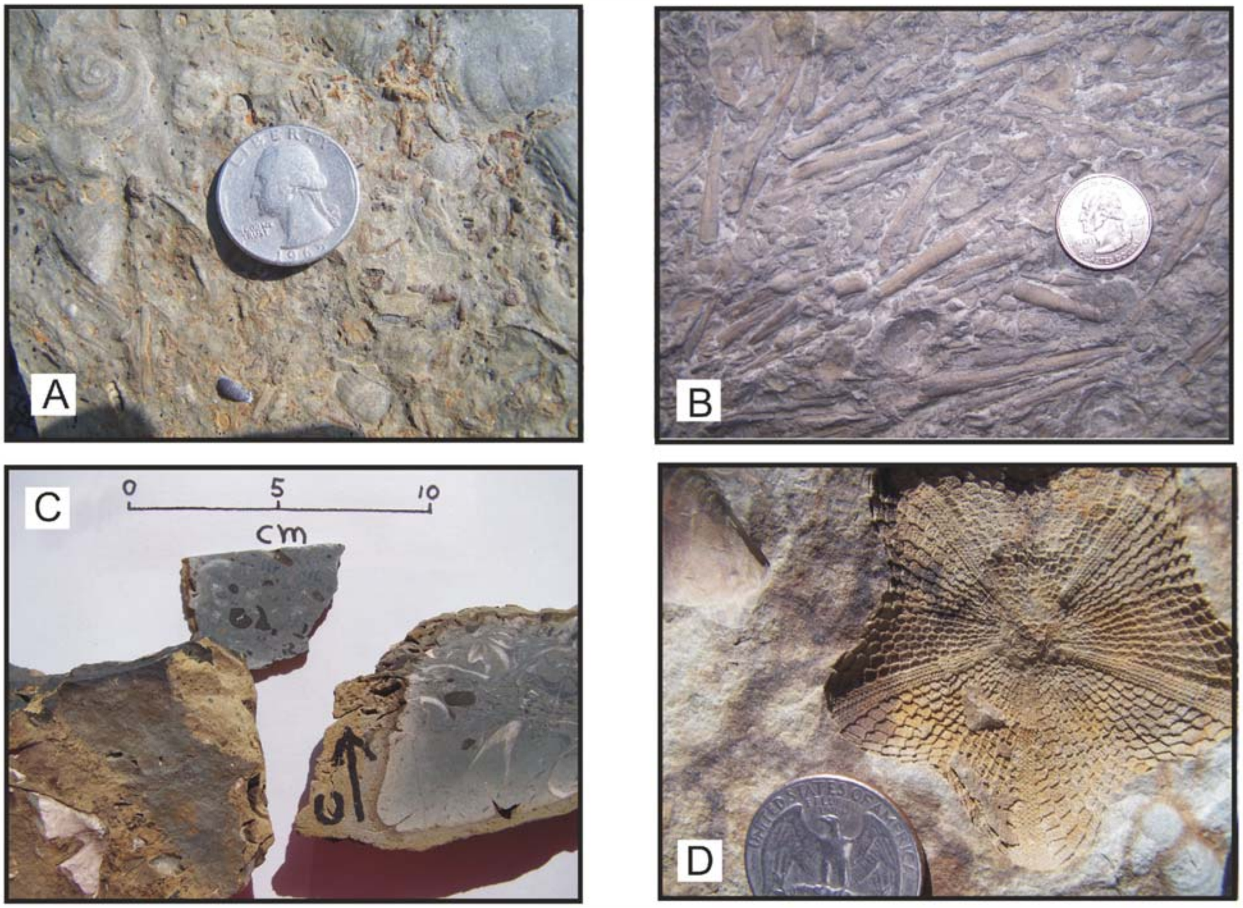


Figure 3. Distinctive features in the West Mead Bed and Drake Well Formation. A, Concentration of detrital (reworked) pyritic grains, gastropods, and fish bone debris which marks the base-West Mead Bed discontinuity. This lag deposit is believed to be correlative with the Skinner's Run Bed of the Ohio section (see text). Note ovoidal chondrichthyan crusher tooth (black object) in the lower left. This specimen is from a west-flowing tributary of French Creek above the Liberty Street overpass, two miles south of Meadville.; B, Current-aligned shells of the problematic molluscan organism *Coleolus* from the lower part of the West Mead Bed at Dick Run below the East College Street overpass at the east edge of the Allegheny College campus in Meadville; C, Concentration of phosphatic pebbles, fish bone debris, conodonts, and spiriferid brachiopods which corresponds to the "*Syringothyris* Bed" of Caster (1934). This lag unit marks the position of the regional, base-Drake Well Formation discontinuity (see text). Note the large syringothyrid brachiopod in the lower left. This material is from a creek southwest of Riceville which corresponds to the original Riceville type section of I.C. White (1881); D, Articulated echinoid *Hyattechinus pentagonus* from the Drake Well Formation. This specimen, preserved as a three-dimensional open mold, was found in the bed of a northeast-flowing tributary of French Creek, 3.6 kilometers (2.2 miles) southeast of Cambridge Springs.

exposed in the creek floor above the Bennyhoof succession. The base of the "Drake Well" succession at this locality is marked by a diastemic contact, above which is localized development of a channelized lag bed (Figure 2). Along this contact, fish teeth and conodonts occur at the base of a concretionary siltstone lentil on the right-hand (south) side of the creek as we continue upstream. This contact and associated lag deposit appears to be coextensive with a brachiopod- and bone-rich unit in Oil Creek Valley sections which Caster (1934) had called the "*Syringothyris* Bed" (Figure 3C), marking the base of Bedford Shale-equivalent deposits. Preliminary conodont information indicates that the base of the "Drake Well" falls in the M-U *expansa* zone age-range (Baird and others, 2009A,C).

Lateral to-, and immediately above, the concretionary lentil, is a change to fossiliferous, burrowed, muddy siltstone which is well exposed in the floor of the creek. Several types of disarticulated brachiopod taxa (*Cyrtospirifer* , *Syringothyris* , and an unidentified rhynchonellid) can be seen on some bedding planes. More significantly, a large cluster of articulated and partially articulated echinoids, identified as *Hyattechinus pentagonus*, is visible on the right-hand (south) side of the creek (Figure 3D). The echinoids occur in association with complete and partial spicule skeletons of glass sponges which were buried with the sea urchins in the same storm event. The sponges can be seen as moldic rectilinear patterns on bedding surfaces.

Cussewago Sandstone

Following a 28-31 meter (90-100 foot)-long concealed interval along the creek, involving only a small vertical gain, an interval of disturbed strata is visible on the left-hand (southeast-facing) cutbank and in a sloped, falls ramp in the creek floor immediately upstream from the cutbank. Although these beds are highly deformed, they appear to belong, in part, within the Cussewago Sandstone succession.

The Cussewago Sandstone has been traced regionally from the Grand River Valley area in Ohio, eastward to the meridian of Union City (Caster, 1934; Pepper, et al. 1954; Pashin and Ettensohn, 1995). The present authors agree with Pashin and Ettensohn (1995) that the Cussewago is the eastern equivalent of the lower (main) part of the Berea Sandstone succession in Ohio. Although the Cussewago is much thinner than the Ohio lower Berea overall, both units locally display large-scale cross-bedding, a complex internal stratigraphy, and both structural and soft-sediment bedding deformation. Pashin and Ettensohn (1995) further speculated that the sub-Cussewago disconformity was the regional signature of the end-Devonian glaciation-related eustatic drawdown event. Although shelly fossils are generally absent from most sections, plant debris and palynomorph are common on some bedding surfaces. The Cussewago is unusual for its often extreme friability; it usually weathers to soft, wet, sloped banks where groundwater exits from this unit.

The deformed interval in the southeast-facing bank is quite problematic in that two lithologies are caught up in the disturbance and that the relationship of the disturbed interval with the underlying “Drake Well Formation” is concealed here. A sharply-bounded block of massive, friable Cussewago Sandstone appears to be bordered or surrounded by a distinctive green-grey shale which is also deformed. It is uncertain at this time whether this shale is a pre-Cussewago unit or whether it is part of the Cussewago succession. Similarly, the adjacent, ramped falls surface may be in the topmost “Drake Well Formation” or it too may be part of the Cussewago as well. For perspective, the basal part of the Cussewago often displays deformed greenish shale at its base in association with sandstone ball-and-pillow structures. Patterns of internal soft-sediment deformation within the Cussewago as well as pronounced spatial thickness variability for this unit accord well with the idea that the Cussewago represents transgressive backfilling of a paleovalley system. Deformed beds in the Cussewago may, thus, may be the record of local sediment-slumping events within coastal channel networks. Proceeding upstream, one can view additional, undeformed Cussewago in the north-facing, right-hand cutbank and in the low waterfall in the creek bed below the overpass of the transverse park path over the creek. An approximate total of 5 meters (16-17 feet) of Cussewago Sandstone is exposed in Cora Clark Park.

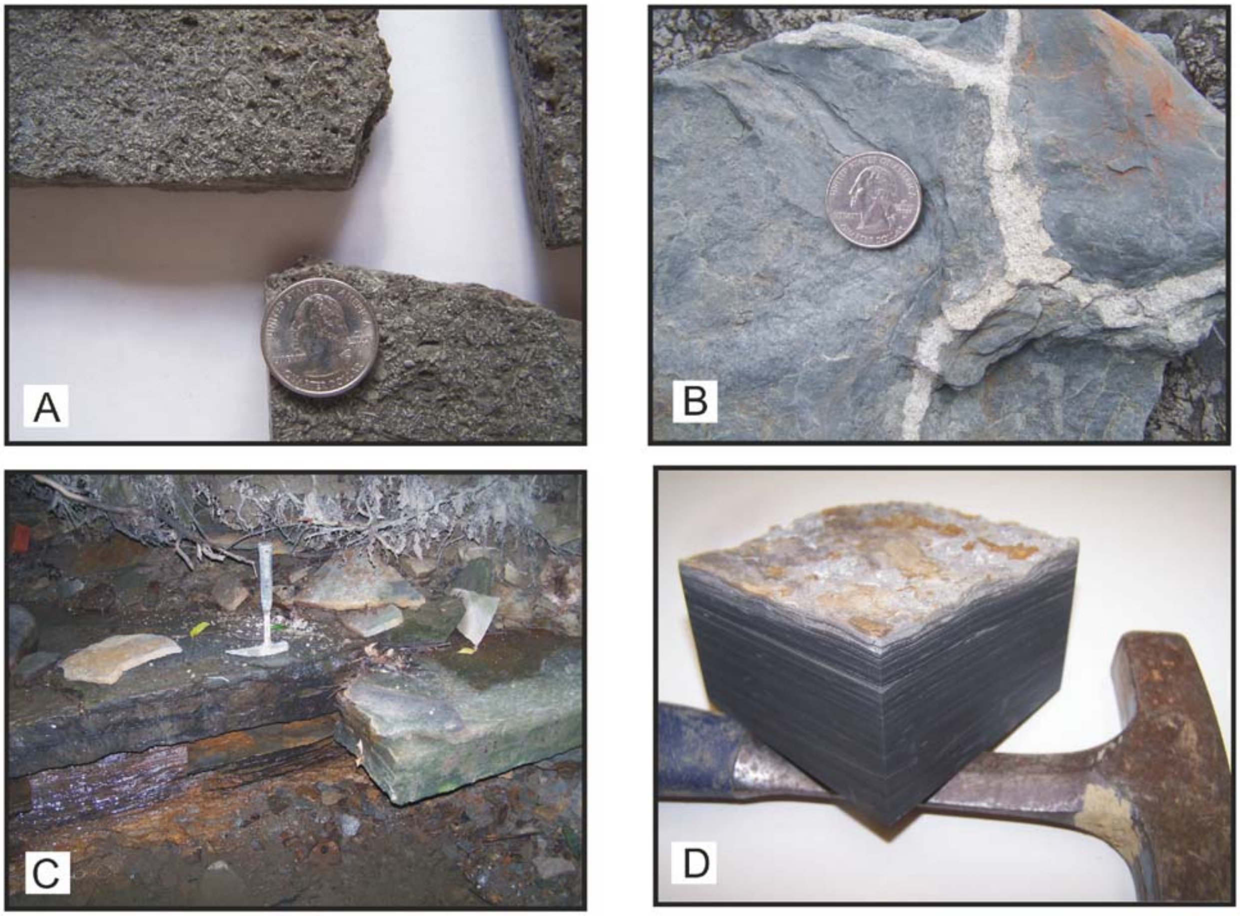


Figure 4. Key features of the end-Devonian-basal Mississippian succession. A, Concentrated detrital (reworked) pyrite grains at the base of the Corry sandstone. This pyrite occurs in association with fish bone debris and fragmental plant material in channelized lag deposits associated with the base-Corry discontinuity. The pyrite illustrated here is on the Corry basal surface, viewed from below. Figured material is from an east-facing cut along Waitz Road opposite Rouseville; B, Clastic dikes penetrating a shale bed in the Cussewago Sandstone. These dikes of coarse sandstone form networks resembling mudcracks as seen in bedding plane view. Specimen from northeast-flowing tributary of Cussewago Creek, 0.8 kilometer (0.5 mile) southwest of the intersection at Little's Corners in Hayfield Township; C, Bartholomew Bed at Cora Clark Park (Stop 9). Note compact character of this unit and its sharp basal contact; D, Laminated black shale deposit observed below the Bartholomew Bed in western Crawford County. This 10 cm (4 inch)-thick unit is here shown inverted with its basal contact surface shown uppermost. This bed is believed to be the easternmost, feather-edge expression of the basal part of the Sunbury Shale (see text). Specimen from west-flowing tributary of Conneaut Creek, 3.3 kilometers (2.0 miles) southeast of Conneautville in Summerhill Township.

Shellhammer Hollow Formation

This is a term erected by Pepper, et al. (1954) for a succession of undifferentiated shale and sandstone units between the underlying Cussewago Sandstone and the overlying, basal Mississippian Bartholomew Bed. It is, herein, understood to include, in upward-ascending order, equivalents of Chadwicks (1925) Hayfield Shale, an upper siltstone division of the Berea Sandstone, and an interval of silty shale below the Bartholomew Bed. At Cora Clark Park, the Shellhammer Hollow interval is 6.3 meters (20 feet)-thick. It is well exposed in a small, steep, south-facing side gully adjacent to the top-Cussewago waterfall below the park path overpass.

Cora Clark Park is unusual for poor development of the Berea upper division siltstone unit; most of the 6.3 meter succession is very shaley, but a thin bundle of flaggy, partly deformed, siltstone beds in the middle of this interval appears to be what is left of the Berea siltstone division in this area.

Bartholomew Bed

The base of the confirmed Mississippian succession in the Meadville area is marked by the discrete Bartholomew Siltstone Bed. The Bartholomew Bed, ranging from 0.15-0.3 meter (5-12 inches) in thickness across western Crawford County is an important regional marker to stratigraphers which is usually easily located in sections (Pepper, et al., 1954; Schiner and Kimmel, 1972). It is typically expressed as a falls-capping ledge of dark grey bioturbated siltstone which weathers to a rusty color in sections (Figure 4C). The base of this bed is sharp and marks an erosional discontinuity. It is also notable for intense bioturbation by the ichnotaxon *Scalarituba* which is characterized by distinctive, curved, hook-shaped markings. *Scalarituba* is widely understood to be a deposit-feeding trace associated with dysoxic, offshore, Mississippian deposits. We will observe the Bartholomew Bed upstream from the park path over the creek (Figure 4C).

Orangeville Shale

Continuing upstream past the thin and compact Bartholomew Bed we, finally, encounter a bank of dark, fissile shale exposed in south-facing cutbank. This is the basal part of a thick succession of dark grey shale, grey shale, and tabular siltstone beds known as the Orangeville Shale of Lower Mississippian age which is a widespread division across northeast Ohio and northwest Pennsylvania. The basal 13 meters (40 feet) of the Orangeville consists of fissile dark grey shale in the Meadville area. In this cutbank, we see only the basal few meters of this greater interval. Body fossils are scarce in the Bartholomew Bed and lower part of the Orangeville Shale. Disarticulated *Lingula* and orbiculoid valves can be found at this locality.

REFERENCES

Baird, G. C., Over, D. J., and Brett, C. E., 2009a, *The upslope limits of transgressive Late Devonian –basal Mississippian black shales on the Catskill Delta prodeltaic slope: Physical characteristics and controls*. Geological Society of America, Northeastern Section Meeting, Portland, ME, p. 2.

Baird, G. C., Carr, R. K., Hannibal, J. T., Brett, C. E., and Brett, B. L., 2009b, *Uppermost Devonian (Famennian) stratigraphy of the Cleveland area, northeastern Ohio*, in Brett, C. E., Bartholomew, A. J., and DeSantis, M. K., eds., *Middle and Upper Devonian sequences, sea level, climatic, and biotic events in east-central Laurentia: Kentucky, Ohio, Michigan*. Guidebook, North American Paleontological Convention, Cincinnati, OH, p. 154-168.

Caster, K. E., 1934, *The stratigraphy and paleontology of northwestern Pennsylvania, Part 1, Stratigraphy*. Bulletins of American Paleontology, v. 21, no. 71, 185 p.

Chadwick, G. H., 1925, *Chagrin Formation of Ohio*. Geological Society of America Bulletin, v. 36, p. 455-464.

Pashin, J. C. and Ettensohn, F. R., 1995, *Reevaluation of the Bedford-Berea sequence in Ohio and adjacent states: Forced regression in a foreland basin*. Geological Society of America Special Paper 298, 68 p.

Pepper, J. F., deWitt, Jr., Wallace, and Demarest, D. F., 1954, *Geology of the Bedford Shale and Berea Sandstone of the Appalachian basin*. U. S. Geological Survey Professonal Paper 259, 111 p.

Schiner, G.R. and Kimmel, G.E., 1972, *Mississippian stratigraphy of northwestern Pennsylvania*. U. S. Geological Survey Bulletin 1331-A, 27 p..

White, I. C., 1881, *The Geology of Erie and Crawford counties*. Pennsylvania Geological Survey, 2nd ser., Report Q4, 406 p.

GREAT MOMENTS IN GEOLOGIC HISTORY
Part 11: The Pleistocene

The Neanderthal are evolving! The Neanderthal are evolving!

STOP 10: EXPOSURE OF MEDIAL CHADAKOIN FORMATION SUCCESSION, LITTLE ELK CREEK: TOPMOST PART OF *PROTOSALVINIA* ZONE, LYONS ROAD BED, AND MIDDLE CHADAKOIN “SHALEY MEMBER”

Leaders: Jeffry J. Gryta and Gordon C. Baird

Chadakoin Formation Succession

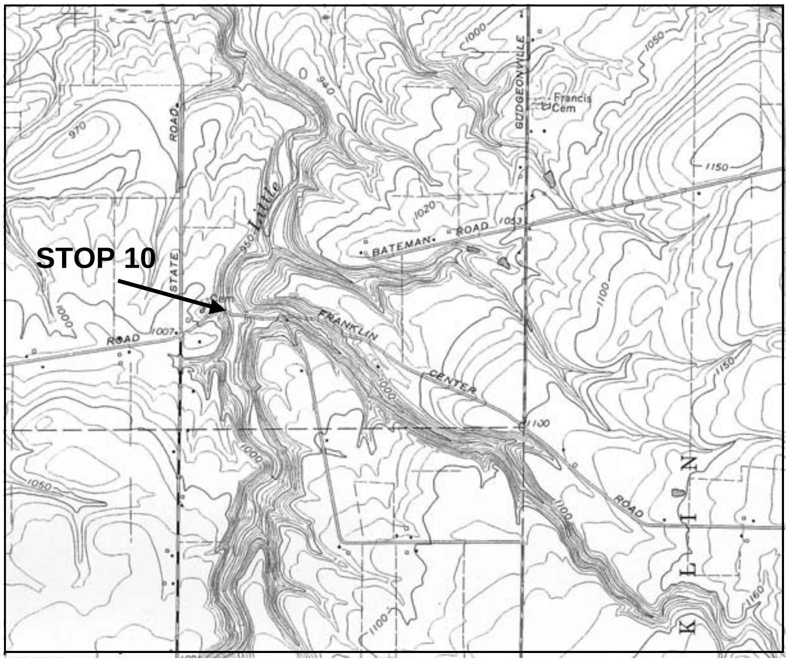


Figure 1. Location of STOP 10 in the Albion 7.5-minute quadrangle.

Approximately 91 meters (300 feet) of section from the upper part of the Girard Shale succession to the base of the LeBoeuf Sandstone is exposed along Little Elk Creek (Figure 1). Figures 2 and 3 shows the outcrops. The position of the STOP 10 section is approximately 39 meters (130 feet) above the top of the Girard shale and 45 meters (150 feet) below the base of the LeBoeuf. The Chadakoin Formation includes a 75 meter (245 foot)-thick succession of beds which is distinctly siltier and more proximal on the basin margin substrate ramp than that of the more distal shale-dominated Girard.

In a regional gradient context (Figure 4), the Chadakoin grades southwestward (downslope) in outcrop into the Chagrin Formation of the Ohio Shale, and both eastward and northeastward into more sandy, shoreward facies of the Chadakoin at Warren and Bradford, and into the coarser Dexterville and Ellicott members in Chautauqua County in New York (see Dodge, 1992; Tesmer, 1963). At this place, we see medial Chadakoin strata which correlate northeastward to the middle part of the Ellicott Member in western Chautauqua County sections (Baird and Lash, 1990).

Generally, the Chadakoin succession is characterized by tabular to lenticular grey siltstone beds and thin, grey-green interbeds. Siltstone beds vary in thickness and spacing as one proceeds up-section; bundles of thicker siltstone beds correspond to regressive, progradational clastic tongues which project downslope into the Chagrin succession; shale-dominated intervals correspond to transgressive “Chagrin” tongues which extend up-ramp into western Pennsylvania. The siltstone beds at this locality are frequently characterized by ripple mark impressions on their upper surfaces and sharp scour surfaces (sole marks) along their bases.

Gryta, J. J., and Baird, G. C., 2009, *Stop 10: Exposure of medial Chadakoin Formation succession, Little Elk Creek: Topmost part of* **Protosalvinia** *zone, Lyons Road Bed, and middle Chadakoin “shaley member,”* in Harper, J. A., ed., *History and geology of the oil regions of northwestern Pennsylvania.* Guidebook, 74th Annual Field Conference of Pennsylvania Geologist, Titusville, PA. p. 167-172.

Figure 2. Photograph A—Exposure of Girard Shale and basal Chadakoin at State Route 98 and Elk Creek (Folley's End recreation facility) . Photograph B—North bank exposure immediately upstream. Photograph C—Concretion containing cone-in-cone sedimentary structure

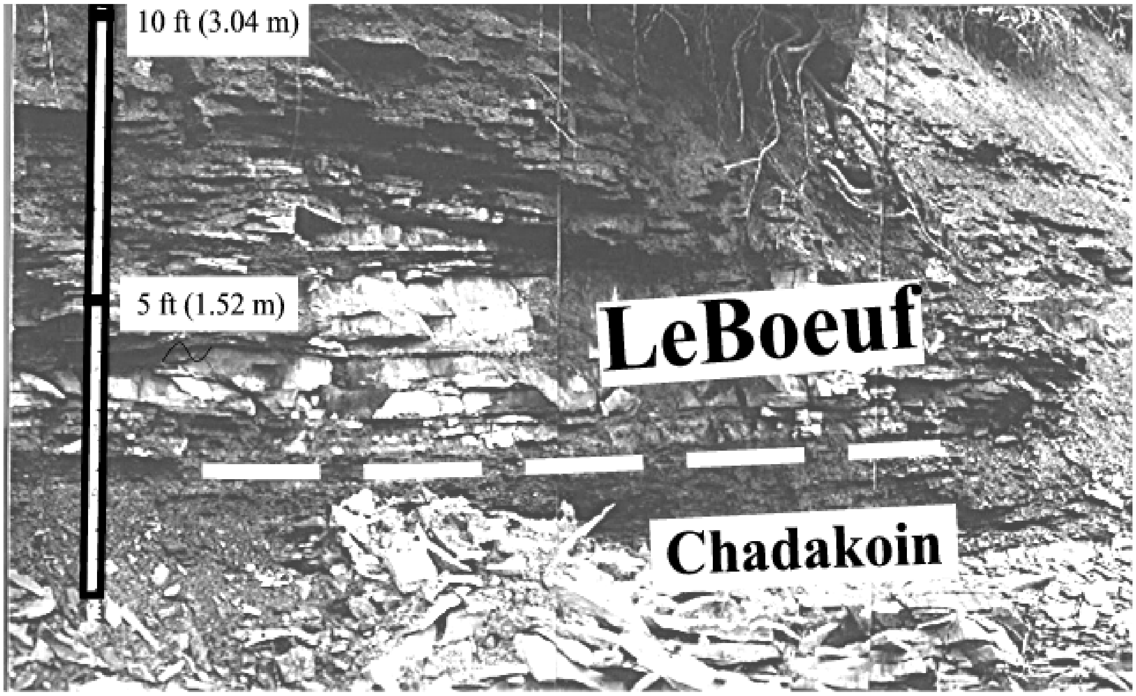


Figure 3. LeBoeuf sandstone and uppermost Chadakoin exposed along Falk Run above Howards Falls (elevation approximately 1040 ft; Edinboro North 7 ½' USGS topographic Quadrangle).

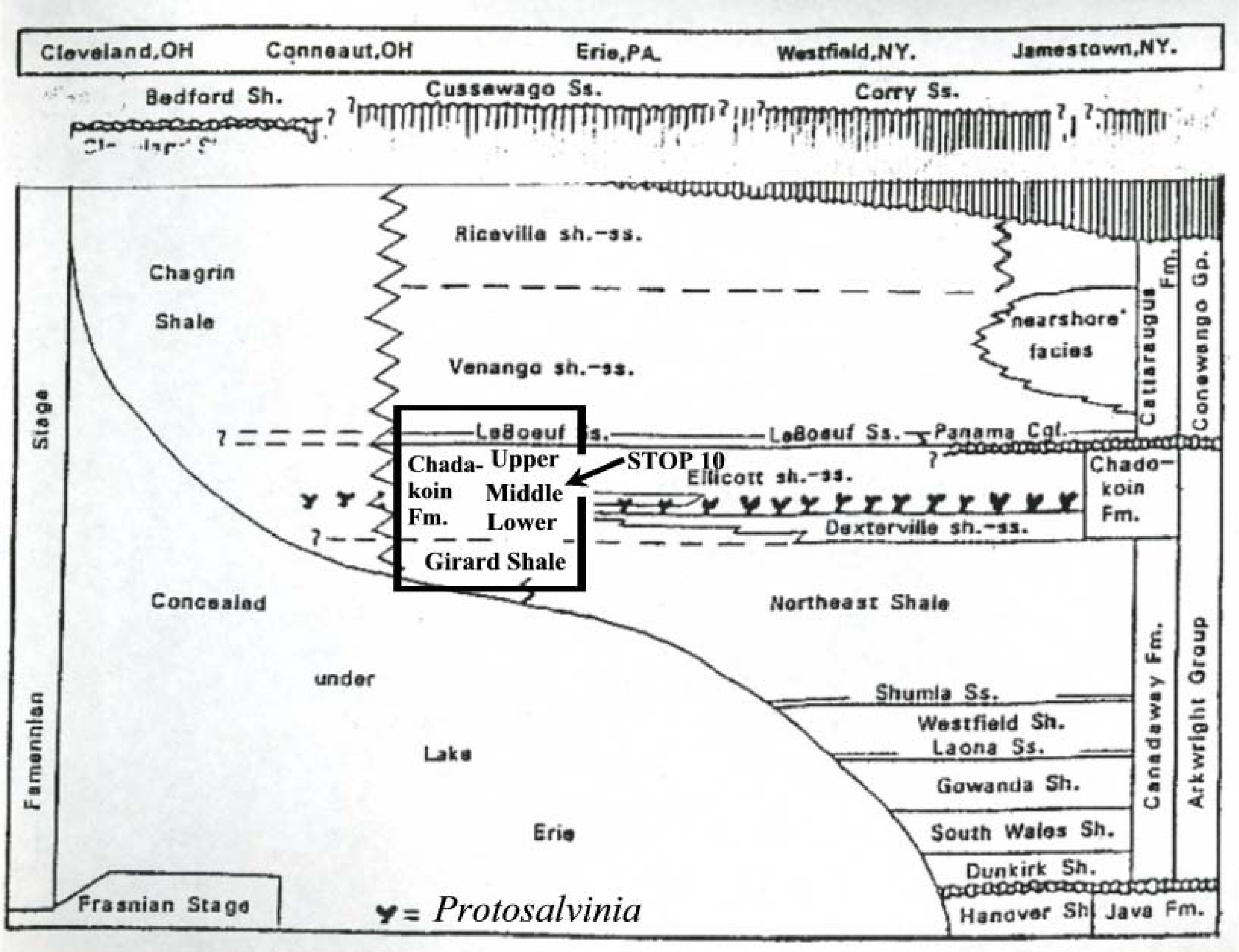


Figure 4. Regional stratigraphic relations showing interval (boxed) discussed in text, as well as approximate stratigraphic position found at Stop 10 (modified from Baird and Lash, 1990; Baird, 1991).

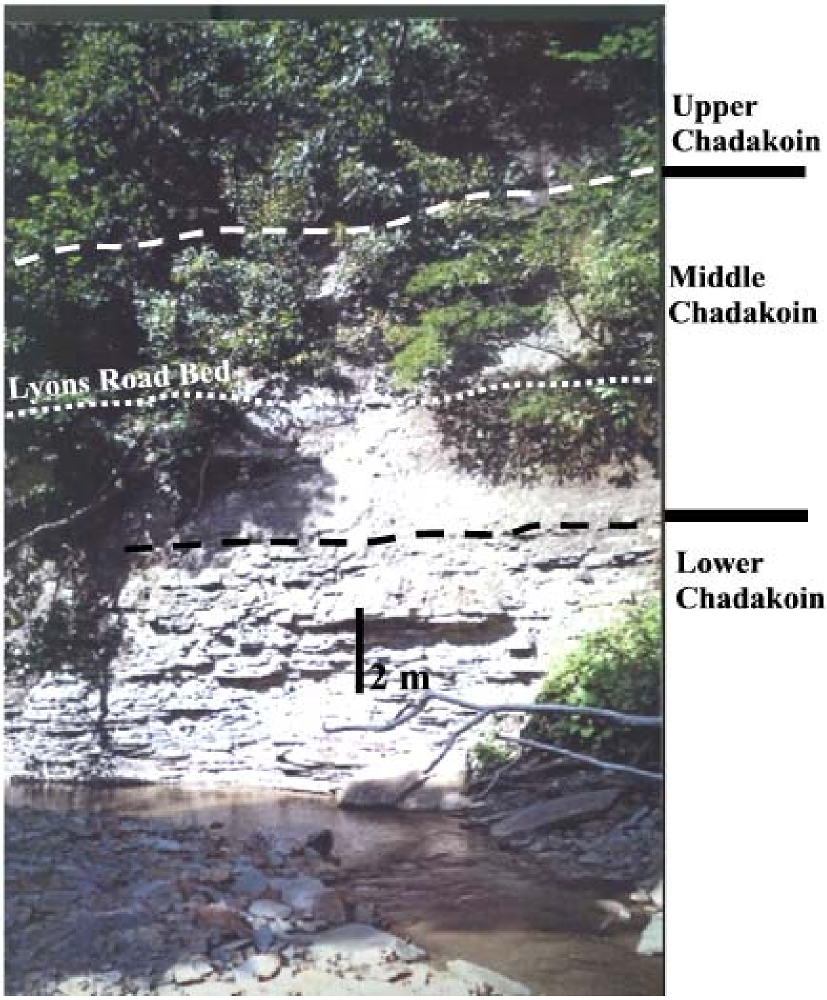
Large-scale bedforms and scour marks record a typical N 45 ^{o} W current direction. Although trace fossils dominate here, localized lenses and pods of disarticulated brachiopods and bivalves can be seen at many levels. Most of these siltstone beds and associated shell coquinites are understood to be tempestites which record discrete storm-wave impingement events (tropical cyclonic events?) on the sea bed (Bowen, et al., 1974; Aigner, 1985; Baird, 1991; Baird and Lash, 1990). At this meridian, the Chadakoin is tentatively interpreted as an oxygenated, outer shelf-ramp setting below the influence of fair-weather wave activity.

Outcrop Unit Succession

This sections shows three regional mappable subunits (Figure 5) which can be seen in the bank opposite our point of entry. These include, in ascending order: the top of the informal Chadakoin "lower siltstone member," a zone of rusty-weathering, bioturbated siltsone beds (Lyons Road Bed), and a shale-dominated interval, understood to mark the base of the informal Chadakoin "middle member" (Baird, 1991; Gryta, et al., 1994-1995).

The Chadakoin lower member is characterized by a succession of complexely-stacked, tempestitic siltstone beds and lentils. The topmost several meters of this division is visible in the creek floor both at, and downstream from, our entry point. The upper part of this

Figure 5. Rock units at Stop 10 as photographed from bridge above the tributary to Little Elk Creek.



succession is notable for the occurrence of *Protosalvinia* (see below).

Above the grey tempestitic siltstone interval is a change to a nodular, rusty-weathering, intensely-bioturbated siltstone-dominated interval which is about 0.5 meters (1.64 feet)-thick. This unit, designated the Lyons Road Bed, by Baird and Lash (1990), is traceable from Conneaut Creek in Ohio, at its western (downslope) visible outcrop limit, into eastern Chautauqua County, New York, at its easternmost confirmed occurrence (Baird, 1991). At our stop, the Lyons Road Bed (Figures 6 and 7) consists of an interval of microbioturbated, dark grey siltstone beds which is marked at the base by a diastemic contact and associated lag concentration of reworked pyrite, conodonts, and *Lingula* fragments and occasional fish bones. This bed grades westward (downslope) into a discrete, thin black shale bed west of the PA/OH state line (Baird, 1991). The Lyons Road Bed is herein interpreted as recording a time of transgressive sediment-starvation prior to accumulation of the shaley Chadakoin “middle member”. The Lyons Road Bed is displayed in the lower part of the creek cutbank directly across from our point of entry and approximately 100 meters upstream from there in the floor of the creek.

Figure 6. Blocky nature of Lyons Road Bed exposed approximately 3 meters above the middle/lower Chadakoin upstream along Little Elk Creek.

Above the Lyons Road Bed in the upper part of the stream

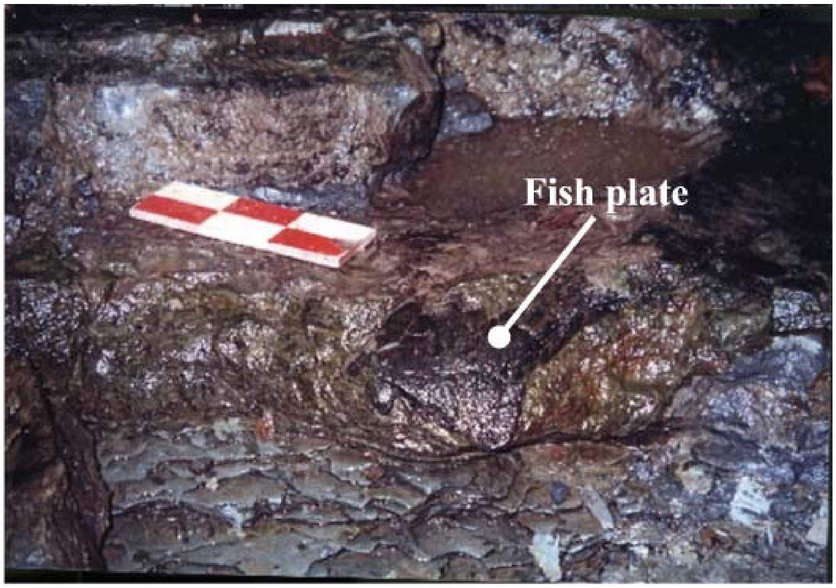


Figure 7. Fish plate in the Lyons Road Bed along Little Elk Creek found by the authors and S. McKenzie (collected September 01, 2009). Scale is 15 centimeters.

cutbank is a shale-dominated interval. This is the Chadakoin “middle member” *sensu* Gryta, et al. (1994-1995) which is approximatley 11 meters (36 feet)-thick in this area. Essentially, this is a recurrent transgressive tongue of Chagrin facies at this meridian. This shale-dominated unit is splendidly exposed on this creek upstream from this stop.

Protosalvinia Zone

Careful examination of the topmost Chadakoin “lower member” at this locality will turn up the remains of a distinctive, usually microscopic, black, ovoidal to bilobate fossil with a resinous exterior luster (Figure 8). These objects, belonging to the taxon *Protosalvinia* (formerly *Foerstia*), are

Figure 8. Close up of *Protosalvinia.* Appearing as black, irregular shaped, carbonized impressions.

believed to have been part of an extinct plant-like organism of possible terrestrial origin (Over, et al., 2009). These remains have been found at numerous localities across eastern North America and they are tightly constrained chronostratigraphically to the Upper *trachytera* Zone of conodonts (Over, et al., 2009). Murphy (1973) traced the *Protosalvinia* – bearing interval from the Chagrin Shale at Conneaut Creek in Ohio northeastward into the Ellicott Member-succession at the New York/Pennsylvania state line. Baird and Lash (1990) and Baird (1991) continued tracing it across Chautauqua County, eastward to the vicinity of Bradford and Eldred in northern McKean County. The Lyons Road bed is at the top of the *Protosalvinia* – bearing stratigraphic interval. Hence, trip participants should focus on collecting the lowest accessible beds at this stop. Individual *Protosalvinia and clusters of* Protosalvinia can often be found on the bases of siltstone beds or where shells are concentrated. Under the microspe, these show up as ovoidal to bilobate, resinous black objects with reticulated, cellular, exterior surfaces. Some of these fossils are infilled with pyrite and occur as three-dimensional forms.

REFERENCES

Aigner, T., 1985, *Storm Depositional Systems: Dynamic Stratigraphy in Modern and Ancient Shallow-Marine Sequences*. Springer-Verlag, Berlin, 174 p.

Baird, G. C., 1991, *Anoxic-to-oxic biofacies spectrum in a Famennian foreland basin deposit: example from the Ellicott Shale Member, Lake Erie region* (abs). Geological Society of America, Northeast Section Meeting, Baltimore, v. 23, p. 94.

Baird, G. C., and Lash, G. G., 1990, *Devonian strata and environments: Chautauqua County region: New York State*. Guidebook, 62nd Annual Meeting, New York State Geological Association, Sat. A1-A46.

Bowen, Z. P., Rhoads, D. C., and McAlester, A. L., 1974, *Benthic marine communities of the Upper Devonian of New York*. Lethaia, v. 7, p. 93-120.

Dodge, C. H., 1992, *Bedrock lithostratigraphy of Warren County, Pennsylvania*, in Sevon, W. D., ed., *Geology of the upper Allegheny River Region in Warren County, northwestern Pennsylvania*. Guidebook, 57th Annual Field Conference of Pennsylvania Geologists, Warren, PA, p. 1-20

Gryta, J. J., Tshudy, D., and Lichtinger, J., 1995, *Bedrock geology of the Edinboro North 7.5' Quadrangle*. Pennsylvania Geological Survey, Open File Report 95-07, 1 map and three stratigraphic cross section sheets.

Murphy, J. L., 1973, **Protosalvinia** (**Foerstia**) *zone in the Upper Devonian sequence in eastern Ohio, northwestern Pennsylvania, and western New York.* Geological Society of America Bulletin, v. 84, p. 3405-3410.

Over, D. J., Lazar, R., Baird, G. C., Schieber, J., and Ettensohn, F. R., 2009, **Protosalvinia** *Dawson and associated conodonts of the upper* **Trachytera** *zone, Famennian, Upper Devonian, in the eastern United States*. Journal of Paleontology, v. 83, p. 70-79.

Tesmer, I. H., 1963, *Geology of Chautauqua County, New York: Part I, stratigraphy and paleontology (Upper Devonian).* New York State Museum Bulletin 391, 65 p.

STOP 11: STRATIGRAPHY AND PALEONTOLOGY OF THE CLASSIC UNION CITY DAM SPILLWAY SUCCESSION

Leaders: Scott C. McKenzie, Joseph S. Sullivan, and Gordon C. Baird

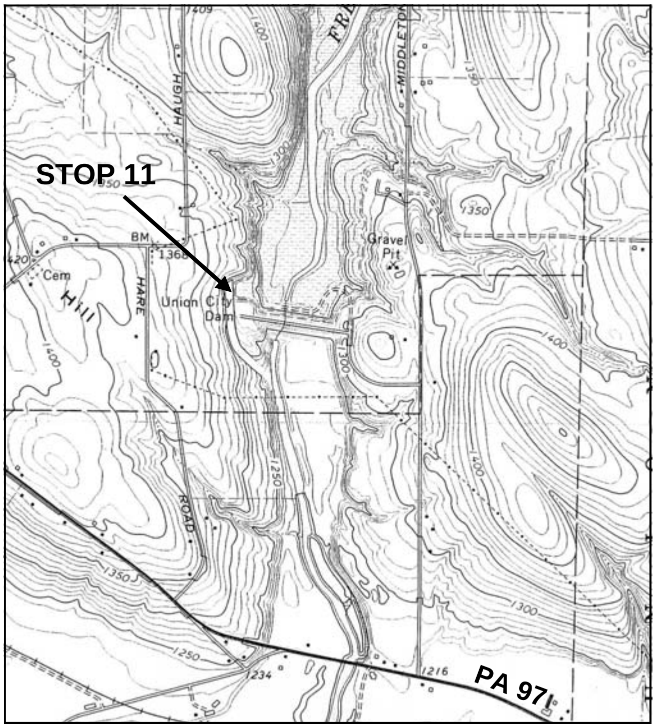


Figure 1. Location of STOP 11 in the Waterford 7.5-minute quadrangle.

Top-Chadakoin Formation-Base-Venango Group Succession

Two key stratigraphic divisions at Union City Dam (Figure 1) are visible in the 30 meter (95 foot)-thick spillway succession. The main, 25 meter (78 foot)-thick part of the section is the shale-dominated uppermost interval of the Chadakoin Formation. This is abruptly succeeded by an approximately 5 meter (15-17 foot)-thick interval of Panama Sandstone, a massive, quartzose unit which is also known by the driller term "Venango Third sand"; prior to recent modifications of this section, the Panama could be seen as a bluff-forming bench along the top of this outcrop. The Panama is the lowest of a long succession of siltstone and sandstone divisions comprising the Venango Group in northwest Pennsylvania (Caster, 1934).

Top-Chadakoin Succession

The top-Chadakoin succession here is exceptionally shaley when compared to the siltstone-dominated, top-Chadakoin succession below the Leboeuf Sandstone in the Erie, PA area. Moreover, this shale interval is notable for soft-sediment deformation and what appears to be disjunctive cleavage at several levels. However, in the Sherman-Stedman area in western Chautauqua County, essentially identical facies occurs 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). The northwestern margin of this shale-dominated unit appears to extend from the Waterford area northeastward to the vicinity of Colt Station, but its southeastward limit is poorly understood. The upward change from silty, tempestite-dominated facies of the typical Chadakoin succession, into this shale-dominated unit, appears to record an initial transgression event followed by a terrigenous pulse associated with pre-Panama sea-level-fall. Discovery by Baird of a quartz pebble-filled channel, 1.5 meters below the base of the Panama Sandstone, within the top-Chadakoin shale unit in a creek near Wattsburg, suggests that this shale unit is closely linked to the regression which culminated in sub-Panama erosion.

McKenzie, S. C., Sullivan, J. S., and Baird G. C., 2009, *Stop 11: Stratigraphy and paleontology of the classic Union City Dam spillway succession*, in Harper, J. A., ed., *History and geology of the oil regions of northwestern Pennsylvania*. Guidebook, 74th Annual Field Conference of Pennsylvania Geologist, Titusville, PA. p. 173-

Panama Sandstone

Although *in-situ* Panama Sandstone is largely inaccessible at this locality, fall-down debris from it was studied and sampled. At Union City Dam, the Panama is a massive sandstone capped by a thin layer of quartz pebble conglomerate at the top. It contrasts with the equivalent Leboeuf Sandstone in the Erie area in that it is coarser and more massive (Caster, 1934; Tesmer, 1963). The base of the Panama appears to mark a discontinuity in this locality; the contact is knife-sharp and the lithologic discordance with the underlying shale succession is very conspicuous. At the top of the massive sandstone interval is a bed containing quartz pebbles in association with disarticulated valves of the brachiopod *Cyrtospirifer*. This may mark the base of the succeeding Venango division, known as the Amity Shale (see Chadwick, 1925); as such this bed may represent a transgressive lag deposit which caps the Panama Sandstone.

Paleontological Notes

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 to take groups into the spillway. Because of safety concerns, hard hats and secure footwear are mandatory. The A.C.E. plans to cut back the Panama sometime this fall to stop SUV 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 for studies like this.

The main fossiliferous units are within the Chadakoin formation. A listing of the fossils can be found in the 63rd Annual Field Conference Guidebook. That list was drawn from the Union City Dam spillway as well as other close exposures of the same units. The other sites are area stream cuts, hillsides in Waterford and the Quarry Road RR cut at Mill Village. Some additions and updates are included here.

Recently, three of us (Scott McKenzie, Joseph Sullivan and Walter Drabec) were given permission by the A.C.E. to collect a large placoderm fish median dorsal plate from a fallen block of the Panama Sandstone at this locality. The three-day project resulted in recovery of the plate followed by its later preparation; it has been recently transported to the A.C.E. for display in their Blooming Valley Educational and Welcome Center. The placoderm plate almost certainly belongs to the genus *Dunkelosteus*. This is the giant arthrodire fish of Cleveland Shale fame (Carr and Jackson, 2008) which is figured in many Late Devonian sea-floor dioramas.

Numerous ophiuroids have turned up at the Dam (deposited in the Carnegie Museum) as well as the unusual asteroid trace *Asteriacites gugelhupf*, which is a common deep burrow, looking like a pentagonal German birthday cake (Seilacher, 2007). A 5 foot trunk section of a fossil lycopod (scale tree) was exposed in the 1980s, but not collected. The unique holotype of the earliest structurally preserved lycopod strobilus *Bisporangiostrobus harrisoni* (Chitaley and McKenzie, 1984) was found in the lowest of the Chadakoin exposed here. The presence of plant fossils like these indicates a "forested" land source nearby.

One of the interesting fossils found in the spillway is the horseshoe crab resting trace *Protolimulus*. 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 glacial till in farm fields along Haire road above the Dam and in the Union City town area. These traces have been recovered from Late Devonian sediments in Cuyahoga, *Lake* and Ashtabula Counties in Ohio, Allegany County, New York and Erie, Warren and McKean Counties in Pennsylvania. The traces are all preserved in marginal marine settings (Babcock et al., 1995).

Kasibelinurus is a member of a primitive horseshoe crab group called the synziphosurines. The Union City Dam occurrence was once thought to be the youngest and last of that kind. However, more recent examples of this taxon have been found in the Mississippian (Moore, et al., 2007). Moreover, we have examined even younger specimens from the Pennsylvanian of Poland. We suspect that the synziphosurines may have persisted to the end- Permian mass extinction.

In our area, the Panama seems to hold the youngest examples of the trace fossil *Protolimulus,* as it has not been found in any overlying units. The Chadakoin here contains a surprisingly large fauna and flora that contains many elements that are scarce or absent in other local formations. A major local faunal turnover seems to be associated with the onset of Amity Shale (lower Venango) deposition. This biotic change is timed with aforementioned post-Panama marine transgression and associated overspread of lower energy, subtidal conditions across the study area.

REFERENCES

Babcock, L., Wegweiser, M., Wegweiser, A., Stanley, T., and McKenzie, S., 1995, *Horseshoe crabs and their trace fossils from the Devonian of Pennsylvania*. Pennsylvania Geology v. 26, no. 2, p. 2-7.

Baird, G. C., and Lash, G. G., 1990, *Devonian strata and environments: Chautauqua County region: New York State*. Guidebook, 62nd Annual Meeting, New York State Geological Association, Sat. A1-A46.

Carr, R., and Jackson, G., 2008, *The Cleveland Shale revisited: Is the fauna the standard for comparison in the Famennian and Late Devonian?* (abs) Journal of Vertebrate Paleontology, v. 28, Supplement to No. 3.

Caster, K. E., 1934, *The stratigraphy and paleontology of northwestern Pennsylvania, Part 1, Stratigraphy*. Bulletins of American Paleontology, v. 21, no. 71, 185 p.

Chadwick, G. H., 1925, *Chagrin Formation of Ohio*. Geological Society of America Bulletin, v. 36, p. 455-464.

Chitaley, S. and McKenzie, S, 1984, *A new structurally preserved lycopsid cone from the upper Devonian of Pennsylvania* (abs). International Paleobotanical Conference, Edmonton, Canada, #7.

Moore, R, McKenzie, S and Lieberman, B, 2007, *A Carboniferous synziphosurine (Xiphosura) from the Bear Gulch Limestone, Montana, USA.* Palaeontology, v. 50, p. 1013-1019

Seilacher, A, 2007, *Trace Fossil Analysis*. Springer-Verlag, 226 p.

Tesmer, I. H., 1963, *Geology of Chautauqua County, New York: Part I, stratigraphy and paleontology (Upper Devonian).* New York State Museum Bulletin 391, 65 p.

Monetary Donors to the 2009 Field Conference of Pennsylvania Geologists

PITTSBURGH GEOLOGICAL SOCIETY
1945

PITTSBURGH ASSOCIATION OF PETROLEUM GEOLOGISTS
PAPG
1984

ABARTA
OIL & GAS COMPANY

Thank you!