FROM BRACHIOPODS TO BIG BLUESTEM: THE CYCLOTHEMS, STRATIGRAPHY, AND STRUCTURE OF MADISON AND WARREN COUNTIES, IOWA

prepared and led by

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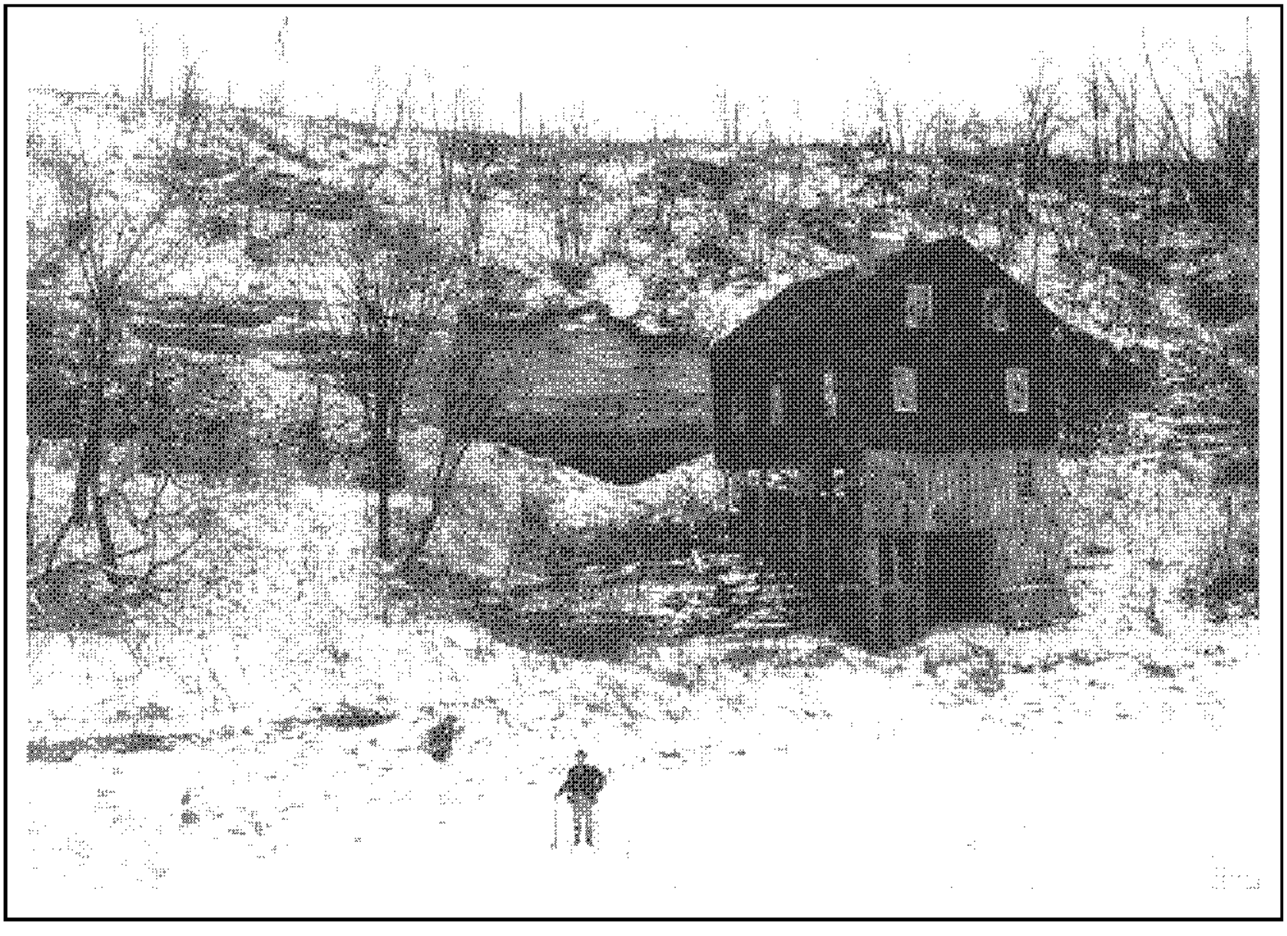
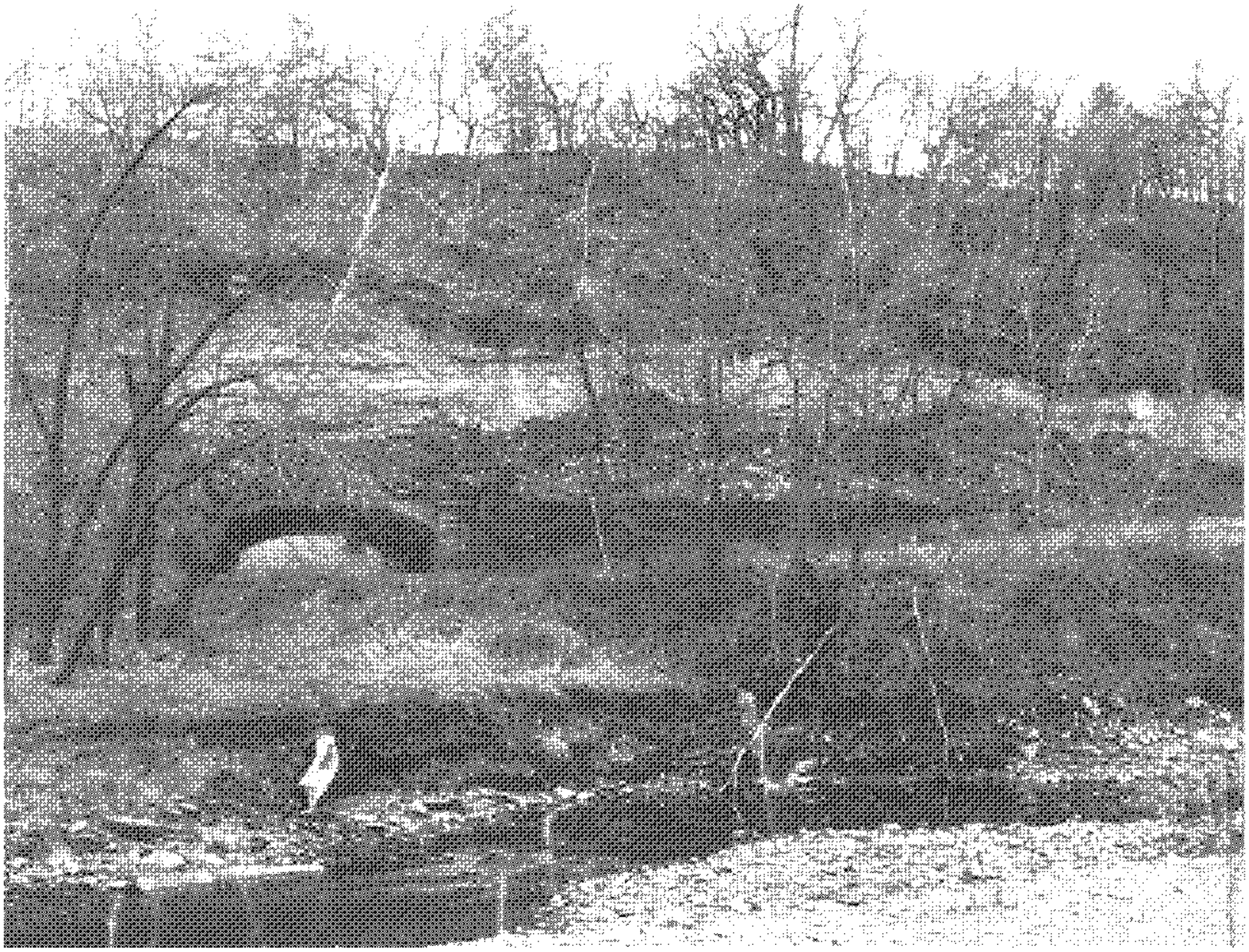


Geological Society of Iowa

April 29-30, 2000 Guidebook 69



Cover photograph : Photo of William Harmon in front of the mill that he constructed on the east side of the Devil's Backbone ridge at what is now Pammel State Park. A tunnel carried impounded water through the ridge to power the water wheel. The mill is now gone, but the tunnel will be seen at Stop 4 of this field trip. Cover photograph from ***Scenic Madison County, Iowa,*** Madison County Historical Society.

The photograph above is a modern view, photographed from about the same location by John P. Pope.

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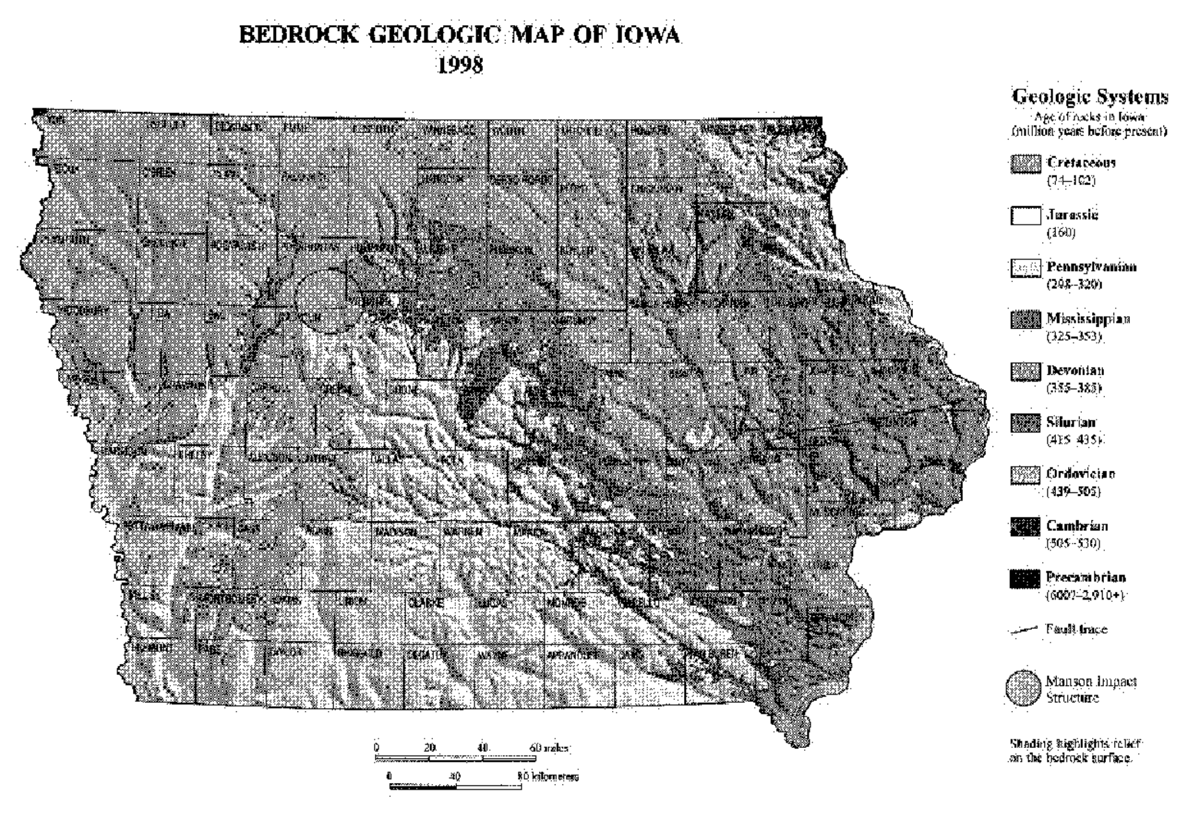
INTRODUCTION

by Raymond Anderson
Geological Society of Iowa Editor

The Geological Society of Iowa's Spring 2000 will include a Saturday examination of the Pennsylvanian strata of Madison County and a Sunday look at two State Preserves in Warren County. Rocks of the Pennsylvanian System cover a major portion of central and southern Iowa (see new Geological Survey Bureau bedrock geology map below). These rocks have been the subjects of a number of previous GSI field trips (GSI Guidebooks 19, 23, 33, 48, 49, 52, and 64). I would specifically mention Guidebook 33, *Field guide to Upper Pennsylvanian cyclothems in south-central Iowa: a field trip along the Middle River Traverse, Madison County, Iowa*, a 1980 field trip run by Phil Heckel which laid the groundwork for much of what we will see today, and Guidebook 52, *A.M.A.T.E.U.R. A Marmaton, Amateur-led Trek to Exposures Unexplored near the Raccoon River (Southeast Dallas County)* a 1990 field trip prepared and run in part by John Pope, and *Stratigraphy and cyclic sedimentation of Middle and Upper Pennsylvanian strata around Winterset, Iowa*, an Iowa Geological Survey Bureau Guidebook prepared by Phil Heckel and John Pope as a NC GSA guidebook in 1992.



John Pope, one of the trip leaders, is a Ph.D. student at the University of Iowa Department of Geoscience, a native of Madison County and multi-talented fellow who has had a long-term interest in the Pennsylvanian geology of Iowa. John has discovered a previously undescribed unit in the Hertha cyclothems that he proposed to name the East Peru Limestone. We will see this unit at Stop 6. Steve Emerman, the other trip leader, is an Assistant Professor of Geology in the Department of Biology and Environmental Science at Simpson College in Indianolla. He received his Ph.D. from Cornell University and joined the Simpson faculty in 1998. He uses some of the exposures that we will be visiting as a part of his teaching curriculum at Simpson. The Geological Society of Iowa wishes to thank John and Steve for their efforts in preparing and leading this field trip.

A BRIEF HISTORY OF MADISON COUNTY

by John P. Pope

Madison County was established January 13, 1846 and named after the fourth president of the United States. The county seat, Winterset, was established in 1849. According to local legend some wanted to call the new town "Summerset" or "Somerset," but it was a cold day so someone else suggested "Winterset."

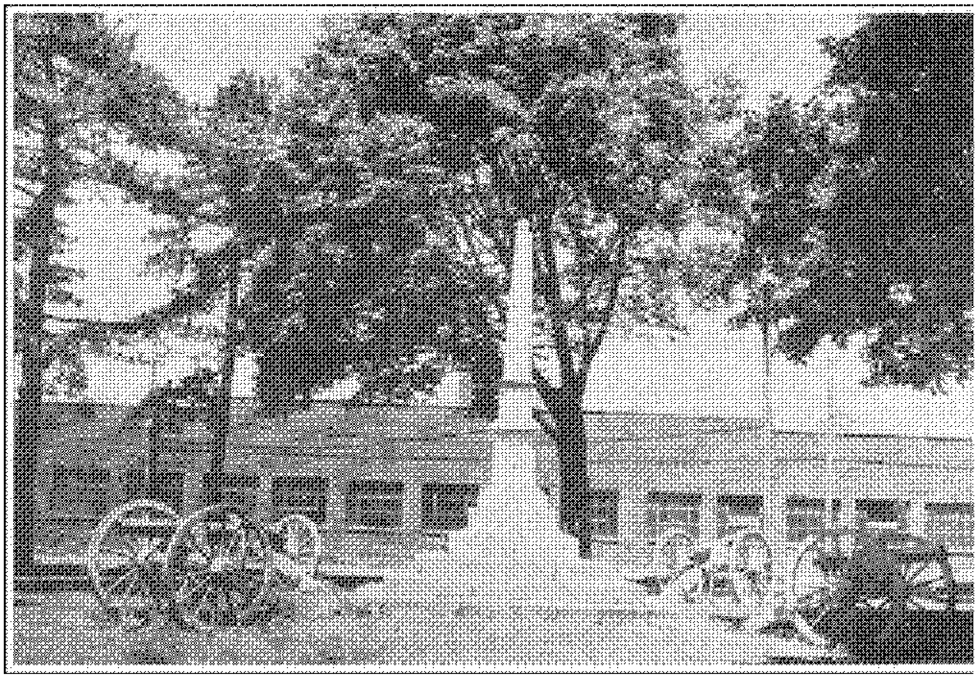


Figure 1. Civil War Memorial in Monumental Park, Winterset. Dedicated in 1867 this memorial is reported to be the first Civil War Memorial in the United States. Photograph from Smith, 1984.

The first courthouse was a log cabin, built in 1849-1850. It stood in what is now Monumental Park (one of the first civil war memorials in the country, dedicated in 1867-see Fig. 1), one block east of the present courthouse. The second courthouse was built in 1868 of native limestone and timbers, but burned in 1875. It was built in the form of a Greek cross with four stone porticos, and a central dome with four clock faces. The third courthouse (see Fig. 2) was built in 1876 and followed the plan of the second one. The outer walls consist mainly of the shoal water calcarenite facies of the Winterset Limestone, quarried just a few miles south of town. Most of the stone was finished locally, but the round pillars were shipped away to be turned.

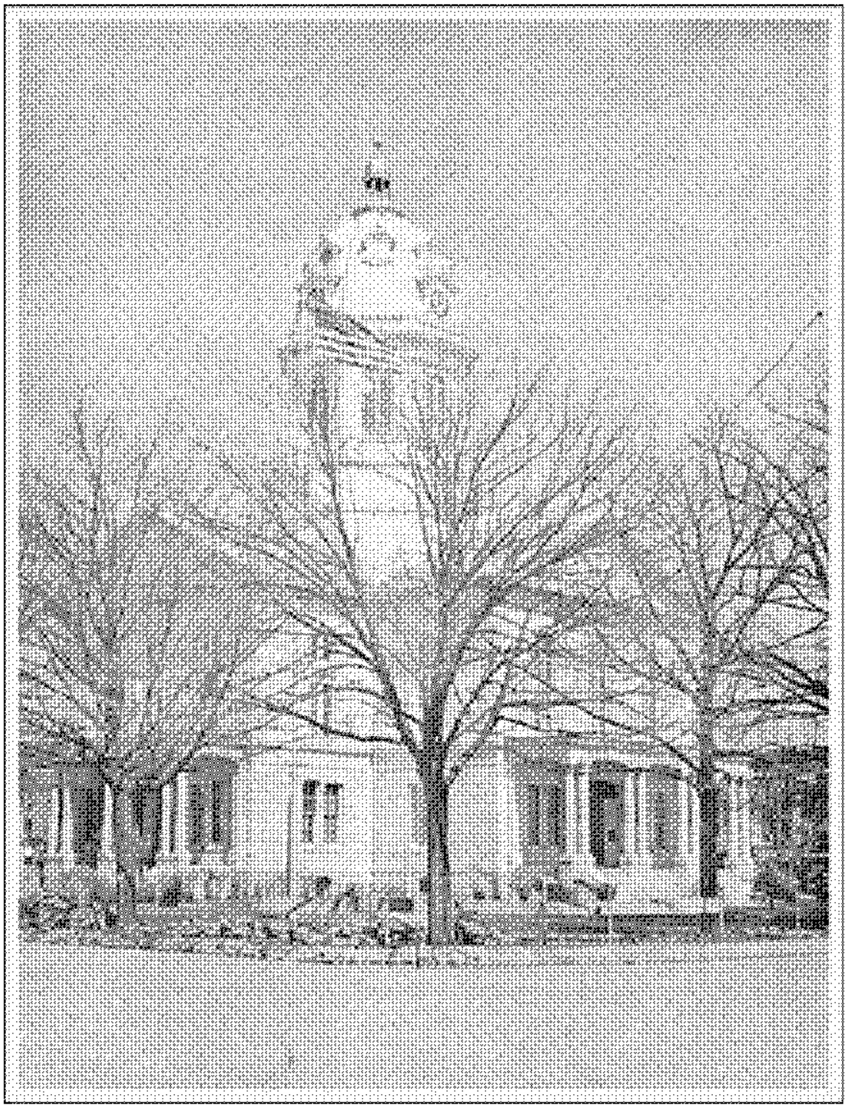


Figure 2. Madison County Court House. This courthouse, built in 1875, is an almost exact duplicate of the second county court house that burned the year before. Photograph from Smith, 1984.

There are also many houses built of native limestone, as well as stone outbuildings, stone barns, businesses on the town square, sidewalks, a stone school house, and gravestones. Most of these were built during the last half of the nineteenth century and are spread over most of the county. Many of these stone houses took three to five years to build. Some were started before the civil war, but many of the stone masons joined the Union army, so the houses were not finished until after the war. Madison County also supplied stone for the state capitol building, for the manufacture of cement, road metal, and agricultural lime.

Just south of stop one on county road P-71, are the limestone foundations of the old Civilian Conservation Corps (CCC) camp. The original CCC camp was located in Pammel Park, but was moved to this site in June 1933. In December of 1933, 343 men worked at the camp. They built shelter houses and trails at Pammel Park, planted trees, built the Cedar Lake Dam for the Winterset city water supply, and helped in land conservation. In 1939 the camp was closed.

The Winterset City Park consists of 120 acres of mainly timber. Of the original 20 acres the first land was purchased in 1869, more in 1872, and the last in 1875. The final 100 acres was purchased in 1917. It contains a covered bridge, a log cabin, three limestone shelter houses, a monument to the delicious apple tree, and Clark's Tower (Fig. 3). The tower is in the newer addition to the park overlooking the Middle River valley. It is 12 feet in diameter, 25 feet high, and is made of native limestone. It was built in 1926-1927 by the descendants of Ruth and Caleb Clark, some of the first settlers in the county. The tower can be seen on the hillside to the left, after crossing Middle River on P-71 and turning left onto G-50.

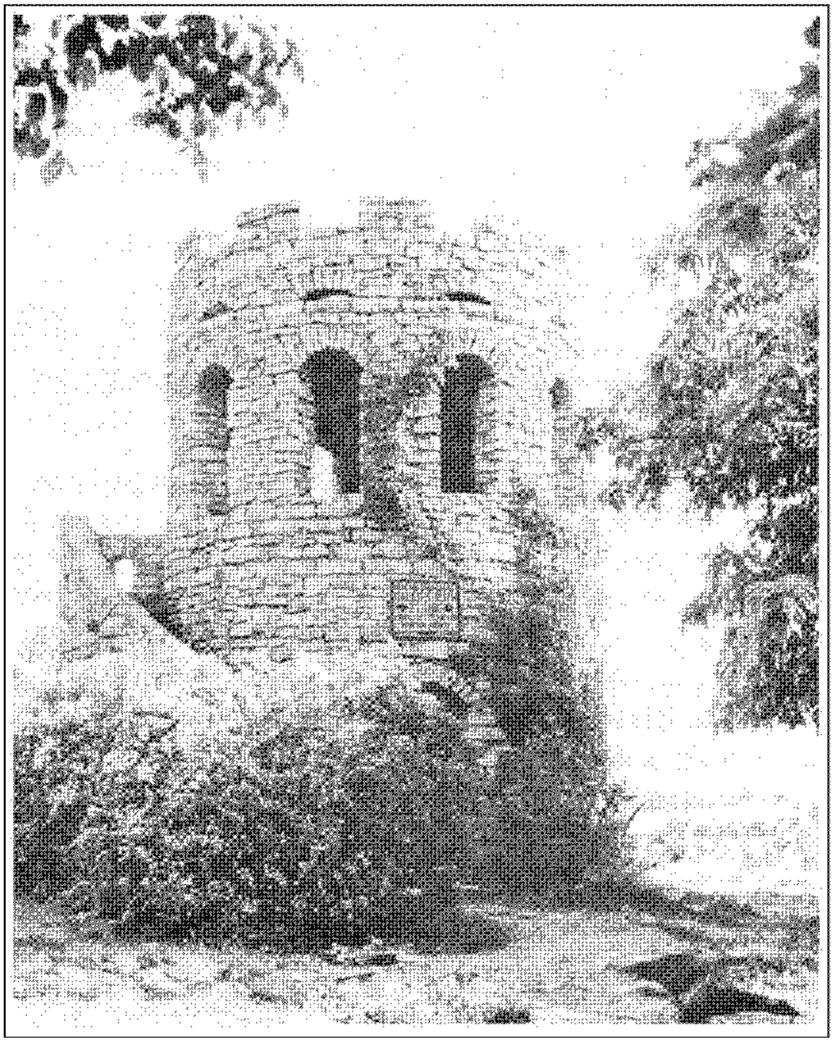


Figure 3. Clark Tower in Winterset City Park was constructed in 1926-1927 of native limestone. Photograph from Smith, 1984.

Pammel State Park was known for many years as the Devil's Backbone State Park and consists of 289 acres of forest, and grassland. It is located about five miles southwest of Winterset in an area of rugged timber covered limestone bluffs. Middle River swings around to the west and north in a great horseshoe loop and doubles back on itself around a ridge known as the Devil's Backbone. The ridge is over 100 ft. (30 m) high and about 150 ft. (46 m) thick at its base near the present day road tunnel. The Sniabar Limestone Member of the Hertha Formation is the lowest strata and is exposed on the northeast end of the tunnel below the road grade. Above this is the Elm Branch Shale Formation, and the Middle Creek Limestone and Hushpuckney Shale members of the Swope Formation. The tunnel is dug through the Hushpuckney Shale, the Middle Creek Limestone, and the upper part of the Elm Branch Shale. Directly overlying the tunnel is the Bethany Falls Limestone Member of the Swope Formation. Above this to the southeast, along the road, the Galesburg Shale, the Dennis Formation (including the Winterset Limestone Member), the Cherryvale Shale Formation, and the lower part of the Dewey Formation are exposed. About 1.75 mi. (2.8 km) to the southwest of the tunnel the Dewey Formation is also exposed along Middle River. This is the proposed type locality for the informally named Pammel Park Limestone (Heckel and Pope, 1992), transgressive limestone member of the Dewey cyclothem.

In 1847 William Harmon, his wife and seven children came to Madison County. They originally lived in a log cabin near Winteset with a dirt floor and no fireplace. In 1849 they moved to the Devil's Backbone area and built a house on the Backbone north of the present tunnel in 1850. In 1855 William and two of his sons began to dig a tunnel under the Bethany Falls Limestone, that would provide water to power a sawmill. The tunnel was dug halfway from the northeast side and halfway from the southwest side. The tunnel was 6 feet (1.8 m) high, 6 feet wide, and over 100 feet (30 m) long. They then dammed the river on the upstream southwest side and built the mill on the downstream northeast side. This provided about 20-25 feet (6-7.5 m) of head to power the waterwheel. The tunnel was completed in 1858 and the "up and down" sawmill was put into operation in 1859 (see photograph on front cover). In 1867 they sold the mill and it was converted into a gristmill that operated until 1904. In 1913 the old mill was demolished, but the old mill wheel is still preserved near the north park entrance.

Later Cash Gray owned the land. He widened the tunnel for machinery storage and access to the other side of the ridge. In 1923 he sold the land to the state for what is now Pammel State Park. In 1925 the tunnel was further widened for use as an automobile tunnel (Fig. 4). It is the only highway tunnel in the state of Iowa. A ford was built across the river west of the tunnel and in 1929 the bridge was built north of the tunnel. The levee south of the tunnel was added to keep the tunnel from flooding.

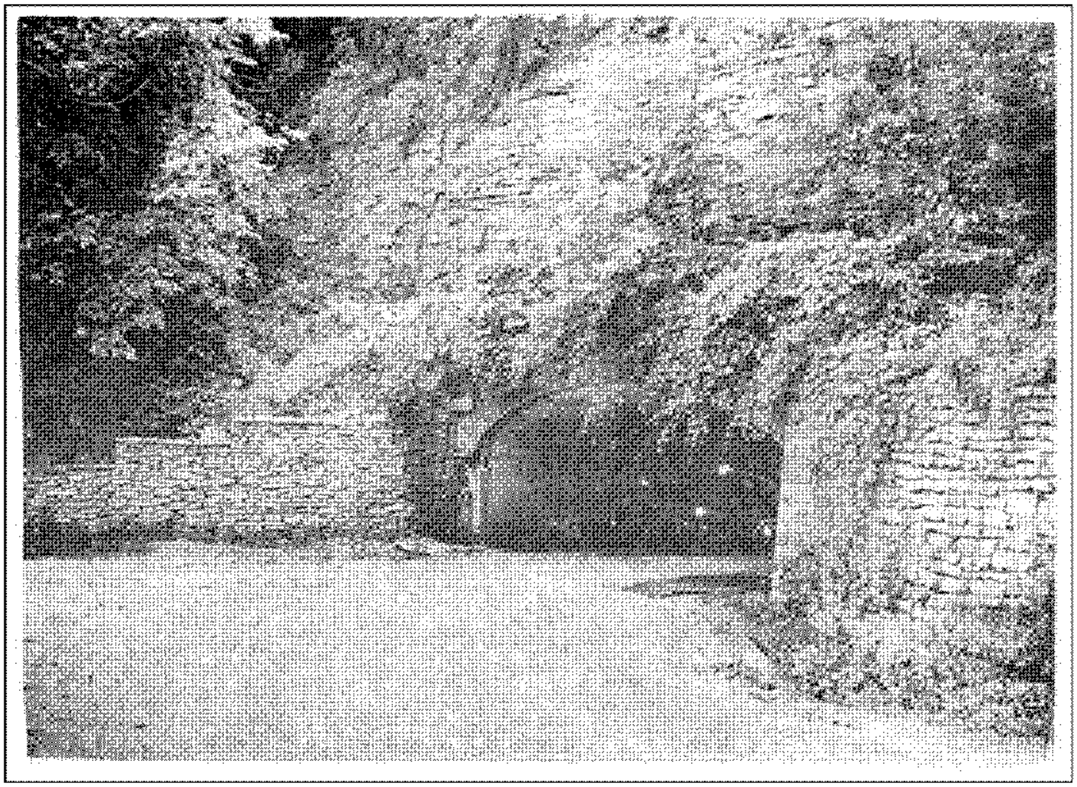


Figure 4. Harmon tunnel at Pammel State Park, converted for automobile traffic, as it appeared in 1961. Photograph from Smith, 1984.

Pammel Park is named after Dr. Louis H. Pammel, who was a professor of botany at Iowa State College, Ames. He was also the chair of the Iowa board of conservation and helped establish 38 state parks. George Washington Carver (who lived in Winterset for two years while attending Simpson College in Indianola) studied with Dr. Pammel in Ames.

Henry C. Wallace, son of H. C. Wallace (editor of the Winterset Madisonian), also taught Carver and eventually became Secretary of Agriculture for Harding and Coolidge. Henry A. Wallace, grandson of H.C. Wallace, became Vice-President of the United Sates in 1941 and founded the Pioneer Hybrid International Company.

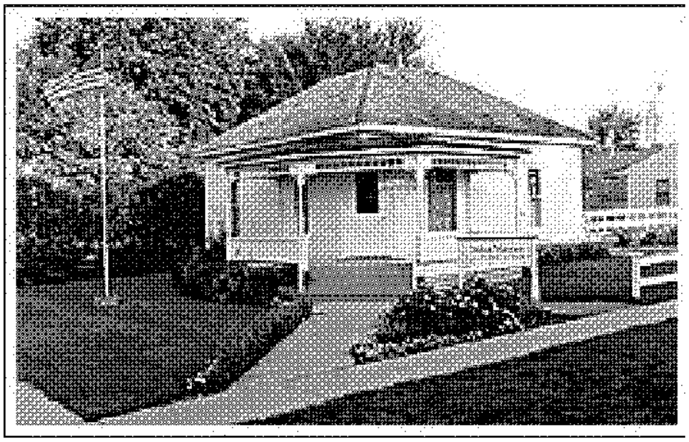


Figure 5. The birthplace of actor John Wayne in Winterset. Photograph from Birthplace of John Wayne.

Another famous person from Madison County is John Wayne (see Fig. 5), born Marion Robert Morrison in 1907. His birthplace is open to the public and was even visited by President Reagan in 1984, during a campaign speech in Winterset. Also, Glenn Martin, who manufactured the Martin bomber in World War II, was born in Macksburg.

Jesse Hiatt, a Quaker, came to Madison County in 1856 and settled near the town of Peru. In the early 1860's he planted an apple orchard. One seedling that came up out of line with the other trees was cut down, but it sprouted up again. He cut it down again, but it sprouted a third time and he let it grow. In 1895 he entered the apples from this tree in a fruit fair and when one of the judges tasted it he thought it was delicious. Thus was the beginning of the Delicious apple. In the early 1940's the tree died from a hard freeze, but again sprouted up from the roots.

The first covered bridge was built in the county in 1854-1855. The roof shielded the bridge from the effects of the weather. At least nineteen covered bridges were built, but due to neglect, floods, fires, and the need for stronger and wider structures, only six of them remain. One of them, Roseman Bridge (see Fig. 6), was in the 1995 movie "The Bridge's of Madison County," starring Clint Eastwood and Meryl Streep. Roseman Bridge is also known as 'the haunted bridge.'

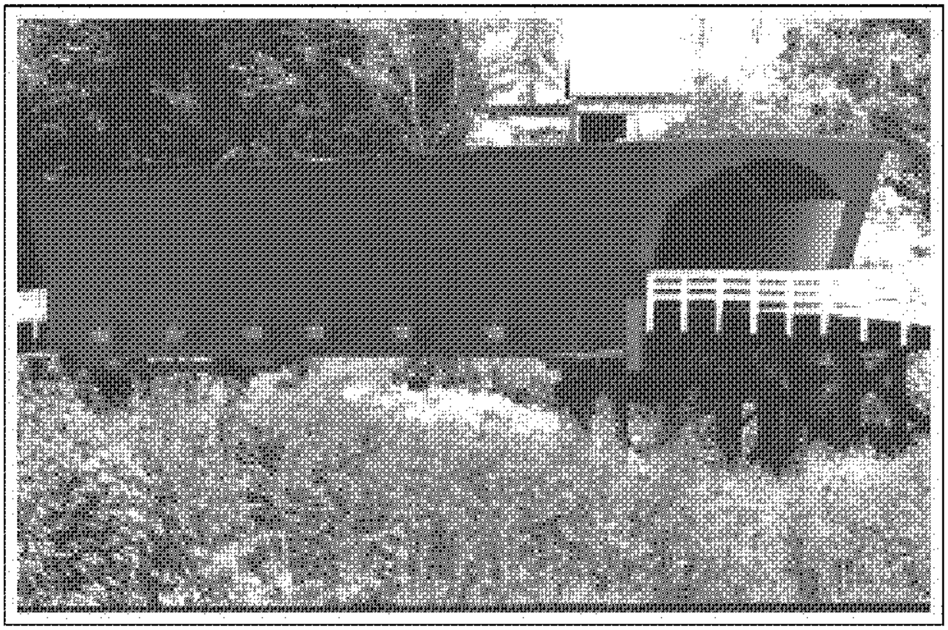


Figure 6. The Roseman Bridge, one of the covered bridges of Madison County. Photograph from Bridges of Madison County, Iowa USA.

In 1848 some people decided rattlesnakes were too numerous, so they had a rattlesnake hunt. By July fourth, 1848 three thousand seven hundred and fifty rattlesnakes had been killed. Rattlesnakes are still a common denizen of the forested areas of the county (see Fig. 7), especially where there are limestone outcrops.

Rattlesnakes have been seen at or near all of the field stops in Madison County.

Figure 7. Eleven rattlesnakes caught in the Winterset area by local residents. Photograph from Smith, 1984.

Much of information was compiled from articles in the Winterset Madisonian, the Iowa Department of Natural Resources, The Madison County Historical Society (Smith, 1984), and Jim Liechty of the Madison County Conservation Commission, who supplied information on the C.C.C. camp.

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OVERVIEW OF PENNSYLVANIAN CYCLOTHEMS IN THE MADISON/WARREN COUNTY AREA

by John P. Pope

PALEOGEOGRAPHY AND PALEOCLIMATE

During Pennsylvanian (Late Carboniferous) time, North America and Eurasia were joined to the east along the northern Appalachians and the Caledonian Highlands. Africa was pushing into the southern Appalachians and South America was attaching to the area south of the Ouachitas, to become the assembling supercontinent of Pangea (Fig. 1). By late Desmoinesian and early Missourian time the paleoequator ran from New England to southern Texas and Iowa was a few degrees north of the equator (Fig. 1). Thus the southern part of the North American Midcontinent Basin was in the humid equatorial zone, while the northern part was in the tropical trade winds belt.

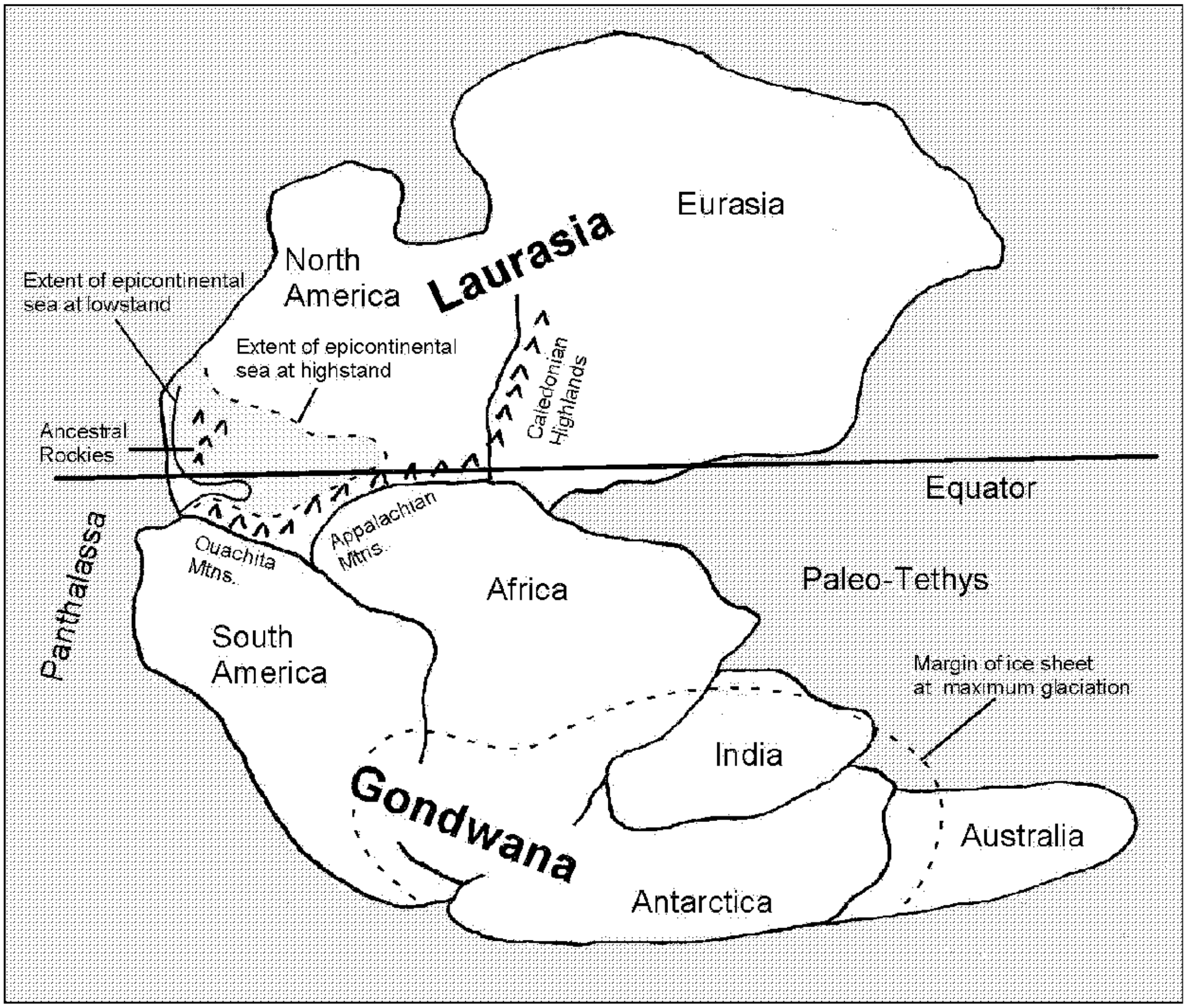

Figure 1. Paleogeography of the assembling supercontinent of Pangea. The outline of the North American Epicontinental Sea is shown at lowstand and at highstand, and the maximum extent of the glaciation in Gonwandland is outlined. Modified from Heckel (1995) and Scotese (2000).

The Midcontinent Basin covers the entire state of Kansas, most of Nebraska, northwestern Missouri, northern and central Oklahoma, west-central Arkansas, and southwestern, Iowa (Fig. 2). The northern and central part of this basin was relatively shallow, and is referred to as the "Northern Midcontinent Shelf." The smaller, shallow structural Forest City Basin covers the region around southwest Iowa and extends into adjacent states. To the south in Oklahoma existed the truly basinal areas of the Arkoma and Anadarko Basins (Fig. 2). During sea-level highstand most of the Midcontinent, from the Appalachians to the ancestral Rockies, westward to the Protopacific Ocean, was covered by a relatively shallow epicontinental sea, indicated by marine clastics and limestones. At sea-level lowstand most of the Midcontinent Basin, except parts of the Anadarko-Arkoma basins, was subaerially exposed, as indicated by paleosols, coals, and terrestrial clastic deposits (Fig.1).

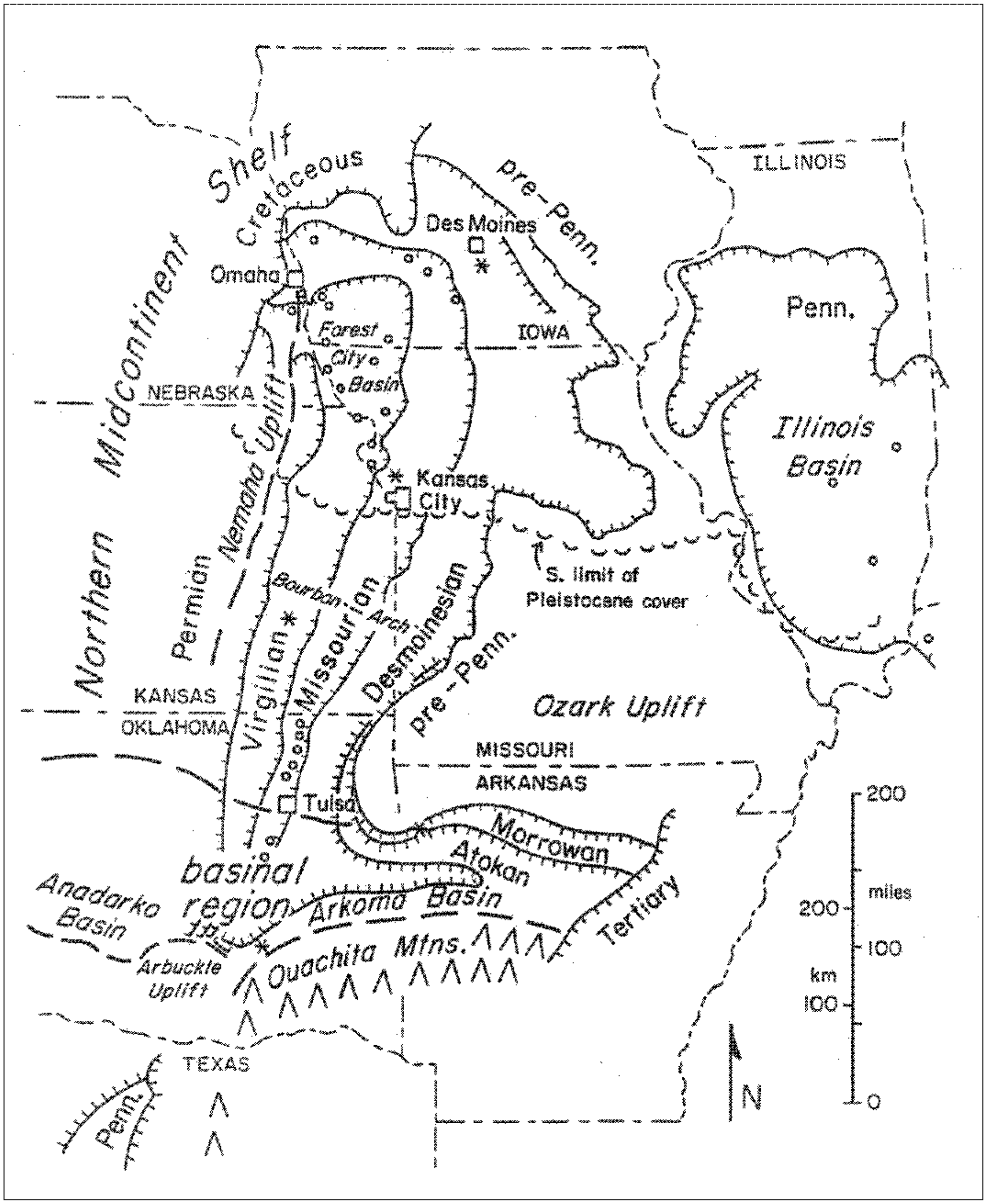

Figure 2. Midcontinent Pennsylvanian outcrop belt, showing most of the Midcontinent Basin, with "Northern Midcontnent Shelf," Forest City Basin area in southwest Iowa, and Anadarko and Arkoma basins in Oklahoma. Modified from Heckel (1990).

CYCLOTHEMS

The northern part of the Midcontinent Basin is characterized by alternating marine (usually with carbonates) and terrestrial clastic deposits. These cyclic patterns, that dominate the upper portion of the Pennsylvanian System in the Midcontinent, were first described by Moore in 1931. Wanless and Weller (1932) gave the name "cyclothem" to the component unit of repeating rock types. Wanless and Shepard (1936) related these cycles to the waxing and waning of Gondwanan glaciers (Fig. 1). The cyclothemic model has best been developed by Heckel (1977, 1984, 1986, 1989, 1990, 1994, 1999), who recognized the cyclothem as a marine transgressive-regressive sequence entered on a thin, non-sandy, phosphatic core shale.

It is now accepted that nearly all Pennsylvanian cyclothems are transgressive-regressive allostratigaphic units or stratigraphic sequences bounded by unconformities. They are the result of glacial-eustatic rise and fall of sea-level. On the northern Midcontinent shelf Heckel has recognized three informal orders of magnitude of cyclothems. **Major cycles** have an abundance of conodonts, including offshore genera, in a gray or black core shale, generally between the transgressive and regressive limestones. They extend across the entire shelf and into the basin. **Intermediate cycles** have abundances within a gray shale or limestone, and are limited in extent on the northern part of the shelf. **Minor cycles** do not have a zone of conodont abundance or are characterized by only nearshore genera, and usually do not extend onto the northern areas of the shelf north of Kansas and Missouri. Some cyclothems may lack one or more of the basic Midcontinent cyclothem members, but they can still be recognized as incomplete major or intermediate cyclothems.

In ascending order, the basic Midcontinent cyclothem consists of the following members: 1) a thin transgressive limestone, 2) an offshore core shale, 3) a thick regressive limestone, 4) a nearshore shale that is also the base of the overlying cyclothem (Heckel, 1977) (Fig. 3).

The **nearshore shale** at the base of the cyclothem usually contains an exposure surface (often a paleosol) that is the base of the overlying cyclothem or stratigraphic sequence. This exposure surface formed during sea-level lowstand and may or may not be overlain by a coal. The coal may indicate ponding of fresh water as the water table rose, forming peat swamps, during the initial phase of transgression. These swamps migrated up-shelf ahead of the transgression and were preserved as coal beds (Heckel, 1995). There is often a thin gray marine shale overlying the coal, that represents the early stages of marine inundation.

The **transgressive limestone** is typically thin and was deposited as marine water transgressed over areas isolated from clastic influx (Fig. 4A). It may contain a calcarenite at the base, deposited in shallow water during early stages of transgression, but mainly consists of dark, dense skeletal calcilutites deposited below wave base during later transgression. Typically they show little meteoric diagenesis, because they were protected by the marine water until covered by later sediment. The limestone is dark due to organic matter preserved in the rock as it was buried in an increasingly deoxygenated environment. Some cyclothems do not contain a transgressive limestone, because the transgression was to rapid for benthic carbonate-producing algae to become established in the photic zone, or the carbonate mud was not preserved. The latter typically occurs above a coal where ecological conditions did favor the production or preservation of carbonate mud. It represents a deepening-upward sequence that forms much of the transgressive systems tract of the stratigraphic sequence. The thinness of most trangressive limestones suggest that the melting of the Gondwanan glaciers was relatively rapid.

The **offshore core shale** is typically a thin, non-sandy, marine, gray to black phosphatic shale deposited at or near maximum transgression in conditions of near sediment starvation and in anoxic to dysoxic conditions. Water was deep enough to inhibit benthic carbonate production and preservation. The black shale facies was deposited in water deep enough to develop a pycnocline that inhibited vertical circulation and prevented oxygen from reaching the bottom (Fig. 4B). This eliminated benthic organisms and preserved large amounts of organic matter over long periods of time. Winds in the tropical trade winds belt blew surface waters to the west that led to quasi-estuarine circulation and periodic upwelling, that resulted in the formation of non-skeletal phosphorite. Some of these phosphate lenses contain ammonoids and

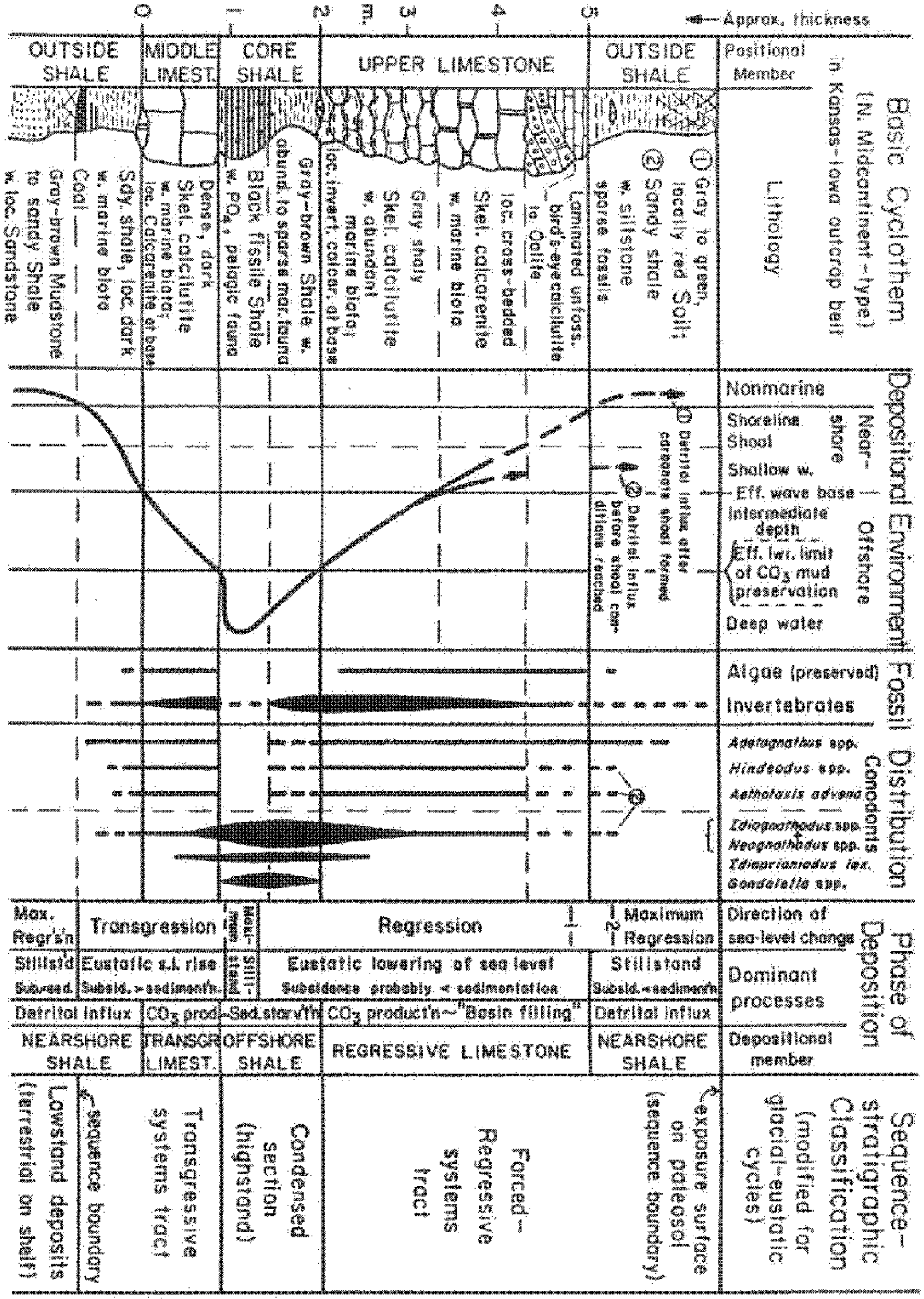

Figure 3. Basic Midcontinent major cyclothems on mid to low shelf, representing one complete marine inunda-

radiolarians and the shale contains abundant conodonts, because they were not diluted by sediment influx. The offshore shale is the sea-level high stand deposits or the major part of the high-stand systems tract of sequence-stratigraphy. It was at this point that the transgression reached a maximum, stayed at or near this point for some time and then reversed (the sea began to regress). Gray shales above and below the black facies were deposited in more oxygenated conditions.

The **regressive limestone** is typically a thick shallowing upward sequence of carbonate consisting of skeletal wackestone at the base to skeletal packstones and grainstones at the top. The grainstone often consist of abraded grains, cross-bedding, algal/foram coatings, and local oolites. It is commonly capped with laminated, dolomitic peritidal calcilutites and an exposure surface. Subaerial exposure and infiltration of meteoric water resulted in the oxidation of most of the organic matter in the carbonate. The top often contains mud cracks, root molds and microkarst features. Because it was deposited entirely during a sea-level fall (Fig. 4A), Heckel prefers the term "forced reressive systems tract" rather than it being part of the highstand systems tract (French and Heckel, 1994), because only the core shale represents the true highstand deposits. The thickness of the regressive limestone suggests that the buildup of the Gondwanan glaciers was relatively slow. The Winterset Limestone (a regressive limestone) displays a complex series of minor cycles termed "parasequences" in Exxon terminology. They represent a "phased regression" (Felton and Heckel, 1996; Felton and Pope, 1996), where the regression was not just a single shallowing upward sequence, but was interrupted by several minor transgressions. This pattern has been detected in the Desmoinesian Pawnee Limestone (Price, 1981), in the Missourian Bethany Falls Limestone Member (Pope, 1994, 1995, 1996), in the Flat Creek Limestone of Illinois and in the Cement City Limestone Member of the Dewy Limestone, the correlative equivalent of the Flat Creek Limestone in the Midcontinent (Pope, 1999).

The **nearshore shale** at the top of the cyclothem consists of both marine and terrestrial deposits of shale and locally sandstone. Some represent fluvial and deltaic clastic deposits, and especially to the north they are dominated by gray to red blocky mudstones. These mudstones are identified as paleosols (Jockel, 1994) and represent the lowstand deposits and the upper sequence boundary of the underlying cyclothem or stratigraphic sequence.

Conodont Distribution

Detailed work by Heckel and Basemann (1975), Swade (1985), and others has resulted in the establishment of a distinctive vertical succession of conodont genera that characterizes all the major cyclothems on the Northern Midcontinent Shelf (Fig. 5). The gray and black facies of the offshore core shale are characterized by the greatest abundance of conodonts, commonly hundreds to thousands per kilogram of shale. These faunas are dominated by *Idiognathodus, Streptognathodus*, with common *Neognathodus* (in the Desmoinesian), *Idioprioniodus* and *Gondolella.*

The marine part of the nearshore shale usually contains only sparse conodonts, 10's per kilogram of shale. These faunas are typically dominated by *Adetognathus* with *Idiognathodus* and *Streptognathodus*, and less commonly *Hindeodus*. *Idioprioniodus* and *Gondolella* are conspicuously absent.

The transgressive and regressive limestone members often contain faunas intermediate and gradational between the two shales. Typically the base of the transgressive limestone has a fauna more similar to the outside shale, while the top has a fauna more similar to the offshore core shale, but lacking *Gondolella.* The base of the regressive limestone also has a fauna similar to the offshore core shale, lacks *Gondolella*, but only has abundances of 100's per kilogram. The top of the regressive limestone is usually dominated by *Adetognathus* with abundances of less than 10 per kilogram. The centers of both limestone units carry a sparse fauna (10's per kilogram) of *Hindeous*, *Idiognathodus* and *Streptognathodus*, with rare *Adetognathus*. Thus it can be seen that the two limestones are often mirror images of each other, both in conodont distribution and to a certain extent in the general lithology, and are symmetrical about the core shale.

The distinctive differences in the conodont distribution between the offshore and nearshore shales seems to be related to the depth of the water that covered the shelf at different sea-level stands (Heckel and Basemann, 1975; Swade, 1985). *Idiognathodus* and *Streptognathodus* (with *Neognathodus* in the Desmoinesian) dominated the normal open-marine warm surface water mass (Fig. 5), during all sea-level stands. This explains their dominance throughout the cyclothem. *Idioprioniodus* most likely occupied the cooler water near the top of the thermocline, which explains its occurrence in the offshore shale and the deeper-water facies of the two limestones. *Gondolella* probably lived in even deeper cooler water in the thermocline, which could explain its occurrence often only in the most offshore facies. These were probably pelagic genera, as all are abundant in the anoxic black shale facies that otherwise tends to lack any benthic species. *Adetognathus* apparently lived in the nearshore shallow water where fluctuating ecological conditions inhibited the other genera. *Hindeodus* probably lived in the open marine carbonate environment where it is commonly associated. The latter two genera were possibly benthic as they do not occur in the most offshore facies.

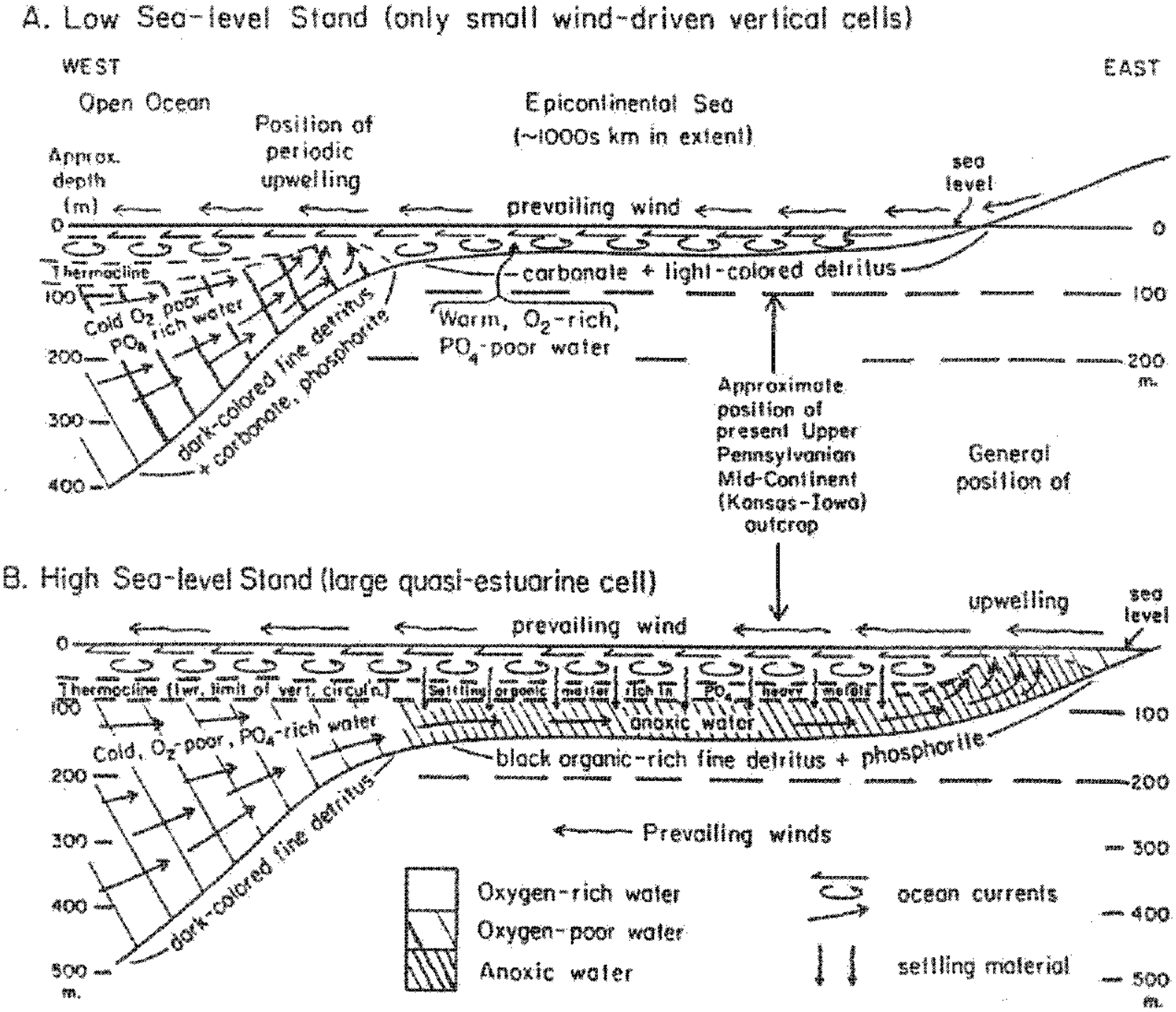

Figure 4. Pattern of vertical circulation in the tropical Midcontinental Sea: A. Low sea-level stand when vertical circulation maintains bottom oxygen and benthic algae produce carbonate for the deposition of both the transgressive and regressive limestone members. B. High sea-level stand when a thermocline and prevailing trade winds help to establish a large quasi-estuarine circulation cell, which results in the depletion of bottom oxygen and the deposition of the black phosphatic core shale. From Heckel (1977)

The change in conodont species upward through the stratigraphic succession, especially with the use of *Idiognathodus* and *Streptognathodus*, allows biostratigraphic discrimination of these cyclothems (Swade, 1985; Heckel, 1989; Boardman et al., 1990; Barrick et al., 1996). This allows not only cycle-by-cycle correlation of the isolated and laterally variable outcrops in the Midcontinent Basin, but correlation into other North American basins.

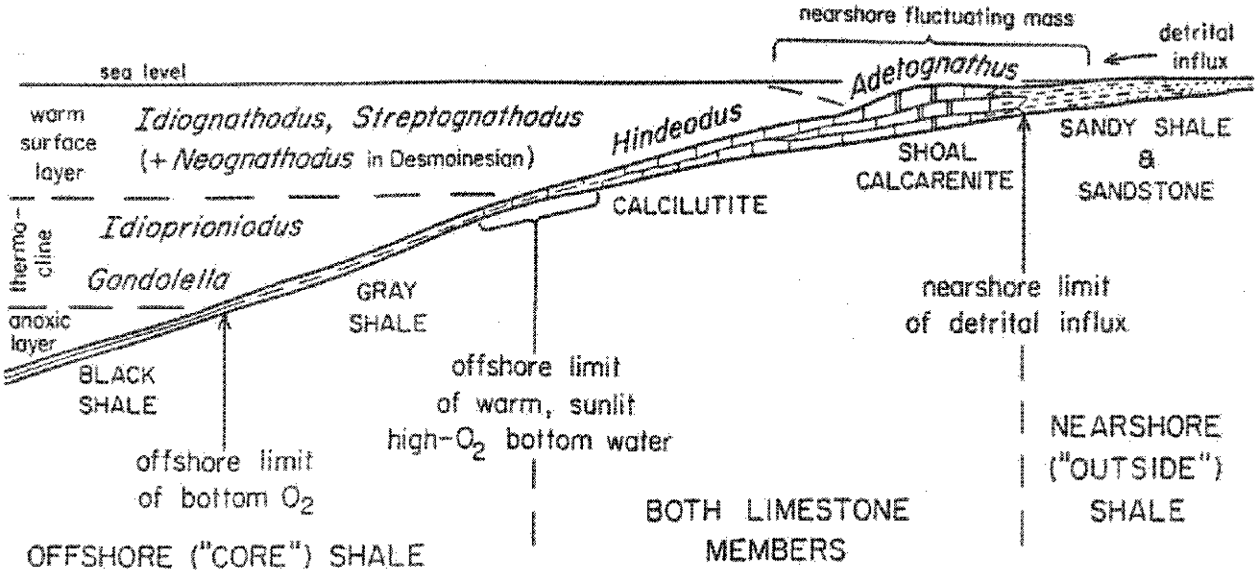

Figure 5. Depositional Model for cyclic rock types that developed on the shelf in relation to shoreline and water depth, showing the inferred positions of major conodont genera in a water mass generated at sea-level highstand. Conodont environments derived from generic distribution patterns shown in Figure 3. From Heckel (1994).

Factors Controlling Formation of Cyclothems

During the upper Middle to lower Upper Pennsylvanian, Midcontinent cyclothems were best developed. Three factors that ultimately controlled formation of these cyclothems have been recognized as: tectonic (Weller, 1930); glacial-eustatic (Wanless and Shepard, 1936); and delta shifting (Ferm, 1970).

Delta shifting can be ruled out as the main control over the major cyclothems. First, delta shifting is a local process and results in stratigraphic units of limited lateral extent, and highstand deposits of major cyclothems can be traced from Oklahoma to the Appalachians. Second, deltas are lacking over much of the Midcontinent Basin north of Kansas City, where most marine units are separated by paleosols. These well-developed paleosols require long periods of subaerial exposure to develop. Soils on modern deltas are typically immature and sink beneath the sea, inhibiting further development after delta lobe abandonment. Third, the black phosphatic core shales of the highstand deposits require thermoclines with water depths on the order of 100 m or more. This is extremely unlikely above shifting delta lobes with a fixed sea level.

Tectonic controls can be regional variations in uplift or subsidence, which results in statigraphic units of lateral extent limited by the tectonic feature (Pope, 1999). Tectonic controls can also be large-scale movements in major orogenic belts that result in units of widespread lateral extent (Tankard, 1986).

Glacial eustasy requires the presence of large ice sheets that wax and wane in higher latitudes. This can result in stratigraphic units of widespread extent, correlatable on a global scale. The greatest amount of Gondwanan glaciation occurred during the Middle and Late Pennsylvanian (Veevers and Powell, 1987). Analysis of probable lengths of time for Midcontinent cyclothems are estimate to have ranged from 235,000 to 400,000 years for major cyclothems, 120,000 to 220,000 years for intemediate cycles, and 44,000 to 120,000 years for minor cycles (Heckel, 1986). These estimated ranges of the transgressive-regressive events fall within the range of the earth's orbital cycles, that form the Milankovitch insolation theory for control of the Pleistocene ice ages. These cyclic orbital parameters are: eccentricity, with dominant periods of 95,000-136,000 years and 413,000 years; obliquity, with a dominant period near 41,000 years; and precession, with dominant periods of about 19,000 and 23,000 years (Imbrie and Imbrie, 1980. The apparent control of these orbital parameters over the timing and duration of Pleistocene ice ages, suggest that they probably controlled Pennsylvanian ice ages on Gondwana as well. Thus they were probably the major factor responsible for the frequent rise and fall of the North American Midcontinent Sea. Because some of these parameters are variable, they give rise to the wide variety of minor, intermediate and major cyclothems (Heckel, 1986).

It is apparent that tectonic flexure, on the order of 3 to 5 million years, in a distant orogenic belt would not have played a major role in the formation of Midcontinent cyclothems, unless the tectonic episodes happened to coincide with a Milankovitch orbital cycle.

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THE CONTROL OF INFILTRATION AS A MECHANISM FOR THE SELF-REGULATION OF PRAIRIE ECOSYSTEMS: PRELIMINARY STUDIES AT ROLLING THUNDER PRAIRIE STATE PRESERVE, WARREN COUNTY, IOWA

by Steven H. Emerman

The Prairie as a Self-Regulating System

Prairie and forest ecosystems interfinger in many natural areas of the Midwest. The prairie grasses and forbs are more drought-tolerant than the woody plants. Therefore, the prairie occupies the drier summits, upper slopes and west-facing and south-facing slopes. The forest occupies the moister ravines, lower slopes and east-facing and north-facing slopes.

The boundary between prairie and forest is dynamic. Trees can invade prairie and the invasion has a positive feedback. A pioneering roughleaf dogwood (*Cornus drummondii*) or smooth sumac (*Rhus glabra*) provides shade which kills prairie plants and increases soil moisture. The pioneer trees provide perches for birds to drop tree seeds and also increase soil moisture by trapping snow drifts. Thus, a favorable environment is created for the further encroachment of trees. Despite the mechanisms for invasion of prairie by trees, the prairie has existed continuously throughout Iowa since 3400 B.C. (Anderson, 1998). It was the twentieth century that saw a progressive invasion of the prairie by forest (Bragg and Hulbert, 1976; Steinauer and Bragg, 1987; Mutel, 1989; Fuller and Anderson, 1993; Wang et al., 1993).

Mutel (1989) has suggested three explanations for the recent invasion of prairie by forest: climate change, overgrazing and the suppression of fire. The first explanation presumes that the moister climate of the twentieth century no longer favors the existence of prairie. Unfortunately, the accurate precipitation data which could compare the nineteenth and twentieth centuries does not exist. Moreover, the critical parameter is not simply precipitation but soil moisture which combines the effects of precipitation and changing land use patterns. Weaver (1954) conducted numerous experiments to demonstrate the injurious effects of overgrazing. However, overgrazing as an explanation for the loss of prairie is difficult to test in the complete absence of any prairie which has not been excessively grazed. Bragg and Hulbert (1976) demonstrated from historical data that trees have invaded prairie in the Flint Hills of Kansas only in those portions of the prairie which have not undergone controlled burning. However, Mutel (1989) has pointed out that experiences from controlled burning of Iowa's Loess Hills have been disconcerting in that often burning is ineffective without the subsequent manual removal of woody plants. Of course, the recent invasion of prairie may result from the interaction of all three of the above causes. Underlying the three causes must also be the fragmentation of the prairie. Iowa's prairie, which once covered 85% of the state, is now contained in preserves which range in size from 0.5 to over 8000 acres so that, at the present time, no portion of the prairie is very far from the seed or rhizome of a woody plant.

The above discussion assumes that the movement of the boundary between forest and prairie is largely a *passive* response to external forces. The alternative assumption of this proposal is that an ecosystem, such as a forest or a prairie, is a self-regulating system which *actively* prevents the intrusion of competing ecosystems and which seeks to expand its boundaries at the expense of other ecosystems. An ecosystem repels invaders by creating the minimum conditions which it needs to survive and thus creating an inhospitable environment for invaders. In particular, the prairie ecosystem prevents the invasion of the forest by growing in such a way as to maintain a soil which is too dry for woody plants but which is sufficiently moist for the survival of prairie plants. The soil moisture is kept low by inhibiting the infiltration of water. An ecosystem has two principal means of controlling infiltration. The first is the rooting patterns of plants, the second is the activity of burrowing animals. Fuller and Anderson (1993) studied a prairie in Saskatchewan which was being invaded by forest and found lower pH, cation exchange capacity (CEC), exchangeable Ca and Mg, organic C and clay content on the forest side of the boundary, all of which are consistent with greater infiltration beneath trees than beneath prairie grasses.

The rooting patterns of plants lead to two important pathways for the infiltration of water into soil, which are the abandoned channels of dead roots (Gaiser, 1952) and the spaces created when roots shrink away from soil during soil drying (Nobel and Cui, 1992). Thus, thin roots will inhibit infiltration. Table 1 compares the root diameters of the important woody invaders of the prairie and the dominant prairie grasses (data compiled from Weaver (1919, 1954, 1958). The woody invaders have considerably thicker roots than those of the prairie grasses.

Table 1. Root Diameters of Prairie Grasses and Woody Invaders

Prairie Grass	**Root Diameter (mm)**
Little Bluestem (*Andropogon scoparius*) (upland)	0.1-0.8
Needlegrass (*Sorghastrum nutans*) (upland)	1-1.5
Junegrass (*Koeleria cristata*) (upland)	<0.2
Big Bluestem (*Andropogon gerardi*) (lowland)	1-3
Prairie Cordgrass (*Spartina pectinata*) (lowland)	3-5
Switchgrass (*Panicum virgatum*) (lowland)	3-4
Canada Wild-Rye (*Elymus canadensis*) (lowland)	<0.5

Woody Invader	**Root Diameter (mm)**
Coralberry (*Symphoricarpos vulgaris*)	3-7
Smooth Sumac (*Rhus glabra*)	13-30
Hazel (*Corylus americana)*	>15
Frost Grape (*Vitus vulpina*)	10-18

Our hypothesis, that the prairie inhibits infiltration by growing fine roots, leads to a variety of interesting implications. The first implication is that the more drought-tolerant portions of the prairie should have even finer roots. The tallgrass prairie could be regarded as two sub-ecosystems, the upland prairie and the lowland prairie, in which the upland prairie grasses are more drought-tolerant than the lowland prairie grasses. In Table 1 the dominant prairie grasses are separated into upland and lowland grasses. With the exception of Canada wild-rye (*Elymus canadensis*), the upland grasses all have finer roots than the lowland grasses. The second implication is that the invasion of forest by prairie and the invasion of prairie by forest may not be symmetrical processes. When trees grow thick roots into prairie soil, the soil becomes moister. However, when prairie grasses grow fine roots into forest soil, the soil does not necessarily become drier as long as the large root channels of woody plants are still present. Therefore, it may be easier for the forest to invade the prairie than for the prairie to invade the forest. A third related implication is that some woody plants may have the ability to accomplish a long-term restructuring of the prairie soil which they are invading. Even after woody invaders are burned or manually removed, if the large-diameter root channels remain open, the prairie soil will remain wetter than it was prior to the woody invasion. This implication has important consequences for the management of prairie preserves.

This paper was inspired by suggestions throughout the work of Prof. J.E. Weaver (1954, 1968) that particular species of prairie plants play a role in controlling their environment. For example, Weaver (1954) documented the eastward spread of the very drought-tolerant western wheatgrass (*Agropyron smithii*) during the drought of the 1930's. Robertson (1939) reported very low infiltration rates beneath stands of western wheatgrass. Weaver (1954) explained the low infiltration rates as due to the low amounts of surface organic debris produced by western wheatgrass which exposed much bare soil and led to surface crusting. The hypothesis of this paper is also related to the Gaia Hypothesis (Lovelock, 1987) which views the ocean, atmosphere, soil and living things as a single self-regulating system.

Preliminary Results

Preliminary measurements were made at Rolling Thunder Prairie State Preserve in southern Warren County during the summer of 1999. The dominant grasses at Rolling Thunder are big bluestem (*Andropogon gerardi*), little bluestem (*Andropogon scoparius*), switchgrass (*Panicum virgatum*), prairie cordgrass (*Spartina pectinata*) and indiangrass (*Sorghastrum nutans*). As is typical for most prairie preserves, woody plants occupy the ravines and are gradually moving upslope. The moister, east-facing slope at Rolling Thunder is entirely occupied by woody plants. The dominant woody invaders are rough-leafed dogwood, smooth sumac, multiflora rose (*Rosa multiflora*) and Mexican plum tree (*Prunus mexicana*). On the west-facing slope, the northern portion of the preserve was burned in early April of 1999. The southern portion has not been burned since late April of 1997.

The objective of the preliminary study was to determine whether the field saturated hydraulic conductivity K_{fs} was greater under the woody invaders than under the prairie plants. The field saturated hydraulic conductivity is easier to measure than the infiltration rate and is independent of antecedent soil moisture and precipitation rate. Eight widely-separated sites were selected within the unburned southern portion where the boundary between the prairie and forest was especially sharp. At each site, K_{fs} was measured with a Guelph permeameter (SoilMoisture, Inc.) at the bottom of a 25-cm well. Measurements were made within the prairie, 5 m upslope from the boundary (measured along the slope), and within the living woody plants, 5 m downslope from the boundary. The paired measurements are shown in Table 2. In five cases, K_{fs} was greater within the woody plants, in three cases K_{fs} was the same within the woody plants and the prairie, in no case was K_{fs} greater within the prairie. Occasionally, K_{fs} exceeded the upper range of the permeameter (approximately 10^{-2} cm/s) and it was necessary to repeat the measurement at a slightly different location. The number in parentheses in Table 2 indicates the number of times a measurement exceeded the range of the instrument. In no case did a measurement within prairie exceed the range of the instrument. There is considerable spatial heterogeneity in K_{fs}. As also shown by Kleb and Wilson (1997) for soil N, the soil beneath woody plants is more heterogeneous than the soil beneath prairie plants.

Table 2. Paired Measurements of Field Saturated Hydraulic Conductivity K_{fs} (10^{-6} cm/s)

Within prairie (upslope from living woody plants)	Within living woody plants
21	226 (3)
28	149
15	68 (2)
5	23
55	129 (1)
4	5
21	24
33	33

Three sets of paired measurements were also made in the recently burned northern portion of the preserve. In this case the measurements downslope from the boundary were made within thickets of dead trees which had not leafed out in the summer. The purpose of these measurements was to determine whether the roots of dead trees were still effective in promoting a greater infiltration rate. The limited data in Table 3 shows that in one case, K_{fs} was the same within the prairie and the dead woody plants, in one case, K_{fs} was greater within the prairie and, in one case, K_{fs} was greater within the dead woody plants by three orders of magnitude. This limited data set does not yet argue for an important role for the roots of dead trees.

Table 3. Paired Measurements of Field Saturated Hydraulic Conductivity K_{fs} (10^{-6} cm/s)

Within prairie (upslope from dead woody plants)	Within dead woody plants
2	2005
6	4
2	2

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FIELD TRIP STOPS

ROAD LOG

SATURDAY, APRIL 29

miles	
0.0	Begin in parking lot of Madison County Secondary Roads Building, 1103 E. Court St., Winterset. Head west on E. Court St.
0.5	Turn left onto John Wayne Drive.
0.9	John Wayne Drive becomes P-71.
1.2	**STOP 1**
2.3	Turn left onto G-50.
3.4	Turn left onto Norwood Ave.
4.1	Turn left into entrance to Wastewater Treatment Plant.
4.3	**STOP 2**
4.3	Turn around to leave Wastewater Treatment Plant.
4.6	Turn left onto Norwood Ave.
5.4	Turn left onto E. Court St.
7.0	Turn left onto John Wayne Drive.
7.3	Turn right onto W. Summit.
8.8	Turn left onto Hwy. 169 S.
10.4	**STOP 3a** (north of Middle River bridge)
11.3	**STOP 3b** (south of Middle River bridge)
11.3	Turn around and head north on Hwy. 169.
11.8	Turn left on P-69.
14.2	Turn right onto Pammel Park Trail.
14.7	Enter Pammel State Park.
15.4	Turn left and drive through ford across Middle River.
15.7	**STOP 4** (picnic area)
15.7	Turn around and cross ford again.
16.0	Turn left and drive through tunnel.
16.2	Leave Pammel State Park on Hwy. 322 N.
18.9	Turn right onto Hwy. 92 E.
19.7	Turn right onto Hwy. 169 S.
25.6	Turn left onto Peru Road (also called G-68).
27.2	Cross P-71.
32.3	Enter East Peru.
33.0	**STOP 5**

33.3 Turn left onto 295th Street.

33.8 **STOP 6**

34.1 Turn right onto Settlers Avenue.

34.5 Turn left onto Peru Road (also called G-68).

37.2 Enter Truro.

38.4 As G-68 ends, veer left onto R-35.

39.2 Veer right onto G-64.

41.7 Take entrance ramp onto I-35 N.

50.9 Leave I-35 N at Exit 56 and take Hwy. 92 E.

53.7 Just after crossing the Middle River, turn left onto 40th Avenue (a dirt road). (Opposite 40th Avenue is R-45).

53.8 Park at end of dirt road. The Geological Society of Iowa has permission to walk onto the property of Weigert Disposal. Walk towards the small creek which is flowing into the Middle River (**STOP 7**).

53.8 Turn around to return to Hwy. 92.

53.9 Turn left onto Hwy. 92 E.

63.2 Turn right onto Jefferson Street (Hwy. 65 / 69).

68.2 Turn right onto Hwy. 349.

69.3 Enter Lake Ahquabi State Park.

STOP 1: ROADCUT ON THE SOUTH EDGE OF WINTERSET: SWOPE AND DENNIS CYCLOTHEMS (Location: NW SE NW Sec. 6, T75N., R27W).

by John P. Pope

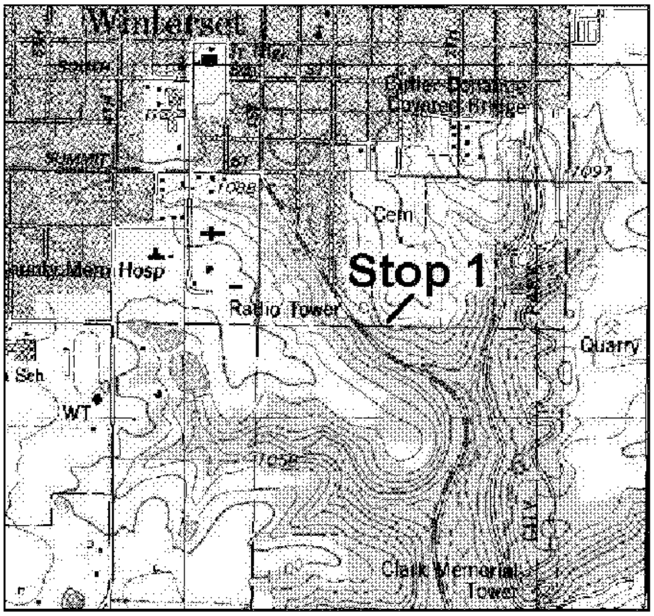


Figure 1. Location of Stop 1 on topographic map.

This outcrop (Figs. 1 & 2) exposes the Swope and Dennis cyclothems of the Bronson Group of the Missourian Stage (Upper Pennsylvanian). The Swope is the third highest major marine cyclothem of the Missourian Stage and is the next one above the Hertha cyclothem (seen at stops 2, 5, and 6). The Dennis cyclothem is the fourth highest major marine cyclothem.

Elm Branch Shale (named from Kansas) is mainly a gray blocky mudstone, with a thin gray fossiliferous shale at the top. The mudstone represents a paleosol while the thin upper shale is part of the transgressive systems tract of the overlying Swope cyclothem.

The Swope cyclothem is named for Missouri and contains the thickest regressive limestone (Bethany Falls Ls.) in the Missourian of Iowa. It and the overlying regressive limestone (Winterset Ls.) of the Dennis cyclothem are the most extensively quarried units in this area of the state.

Middle Creek Limestone Member (named from Kansas) is about 4-6 in. (10-15 cm) of dark gray, dense, skeletal wackestone. It contains macrofossils including brachiopods, clams, snails, crinoids, and bryozoa. It is the transgressive limestone of the Swope cyclothem and represents the calcareous part of the transgressive systems tract that was deposited below effective wave base, but within the photic zone.

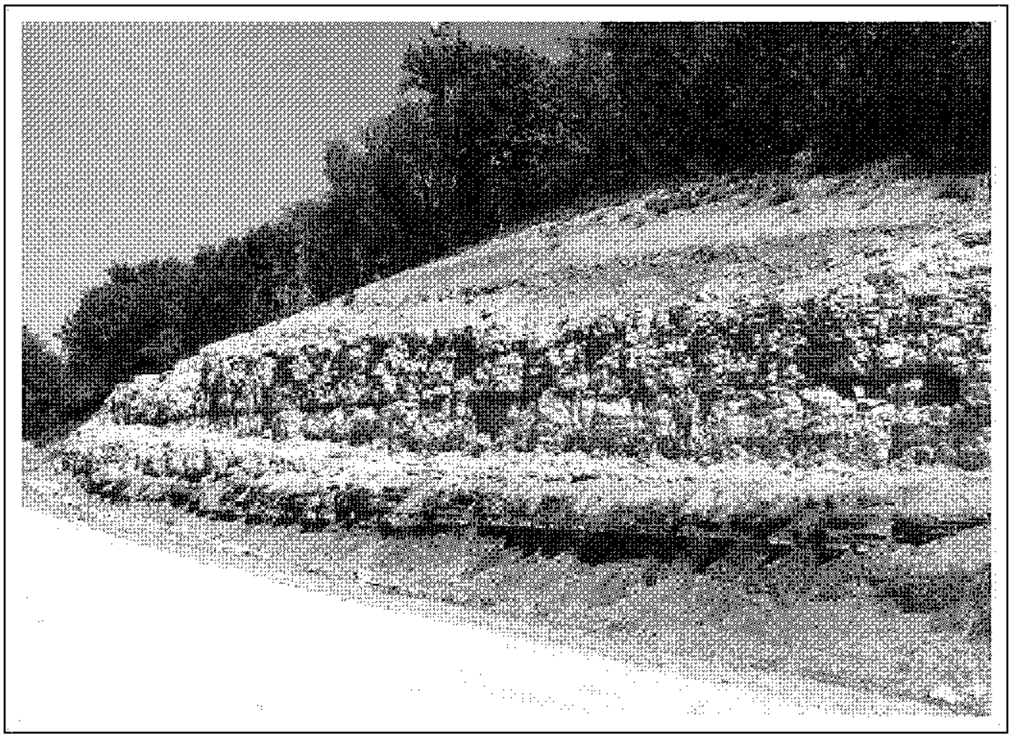


Figure 2 Photograph of Stop 1 road cut exposure along County Road P-71. The cut exposes rocks of the Swope and Dennis cyclothems.

Hushpuckney Shale Member (named from Kansas) is the "core shale" or portion of the high-stand systems tract containing the condensed interval. It is represented here by about 3.7 ft. (1.1 m) of shale. The lower part is about 6 in. (15 cm) of gray fossiliferous shale, with fairly abundant conodonts, deposited as water deepened below the photic zone. The middle is about 20 in. (51 cm) of black fissile shale containing abundant conodonts including *Idiognathodus sulciferous, I. eccentricus, I. clavatulus, I.* n. sp. A, *Idioprioniodus,* the first appearance of *Gondolella sublanceolata,* the next appearance of *G. denuda* above the Lost Branch cyclothem, and the first occurrence of the genus *Streptognathodus, S. cancellosus.* It was deposited offshore in deeper anoxic water at highstand, probably below a thermocline, with very slow deposition and no production or preservation of carbonate material. It contains numerous lenses and laminae of phosphorite. The upper gray part, about 18 in (45 cm) thick, contains a similar conodont fauna (lacking *Idioprioniodus* and *Gondolella* in the upper part), but a more diverse benthic fauna deposited as water shallowed into the photic zone.

Bethany Falls Limestone Member (named from Missouri) is the regressive limestone of the Swope cyclothem and represents most of the forced-regressive systems tract. At this location it is about 24 ft. (7.3 m) thick. The lower part is a skeletal wackestone with a diverse biota that represents deposition below effective wave base, but above the base of the photic zone during early regression. Near the middle are two beds of packstone to grainstone that record deposition within wave base in shoal water. In the Martin-Marietta Quarry 1 mi. (1.6 km) to the east a conodont-rich zone lies above the lower shoal water bed, and another conodont-rich zone of shale occurs about 4.5 ft. (1.4 m) above the base of the limestone. These conodont-rich zones form the bases of 'parasequences' that represent minor transgressions that interrupted the major regressive phase of the Bethany Falls Limestone (Pope, 1994, 1995, 1996). These have been termed "phased regressions" by Felton and Heckel (1996). The upper capping wackestones with a less diverse fauna than in the basal beds, are marked (in the upper part) by laminations, probable root molds, solution tubes, and micro-karst features that all reflect shallowing upward from lagoonal to tidal flats environments to eventual subaerial exposure at the top of the cyclothem, as the seas withdrew southward. The Bethany Falls also contains the only occurrence of the fusulinid foraminifer *Eowaeringella ultimata* (Thompson, 1957) in the Midcontinent. A relatively rare, but locally abundant brachiopod, *Isogramma,* occurs in the Martin-Marietta Quarry to the east.

Galesburg Shale (named from Kansas) is about 7-8 ft. (2.1-2.4 m) of gray blocky mudstone that represents a paleosol (Joeckel, 1999), the lowstand deposits (lowstand systems tract) that terminated the Swope cyclothem. The Davis City Coal occurs as a thin coal and rooted mudstone with ostracodes, or carbonaceous shale, near the top of the formation. Above this is a few in. (cm) of gray shale that represents initial marine flooding of the overlying cyclothem. The base of the coal or the top of the mudstone marks the top of the Swope cyclothem.

The Dennis cyclothem named from Kansas lies above the Swope cyclothem. It is the highest cyclothem in the Bronson Group.

Canville Limestone Member is a dark, dense, gray, thin, lenticular, fossiliferous wackestone. Its lenticular occurrence may be due to a rapid transgression over the area or acids from the underlying coal, that prevented production or preservation of carbonate mud. Lenses are often no more than 4 in. (10 cm) thick and their occurrence is rare at this outcrop. It and the thin underlying gray shale above the Davis City Coal, represents most of the transgressive systems tract of the Dennis cyclothem.

Stark Shale Member (named from Kansas) is about 2.5 ft (0.8 m) thick and consists of black fissile shale with phosphorite nodules and laminae grading upward into a gray shale at the top. The black fissile facies is the condensed interval of the 'core' shale of the Dennis cyclothem and was deposited below a thermocline with anoxic bottom conditions during maximum highstand. It has an abundant conodont fauna that includes *Idiognathodus, Idioprioniodus, Gondolella, Streptognathodus cancellosus,* and the first northern appearance of *Streptognathodus confragus* (Heckel, 1999).

Winterset Limestone Member (named from the Winterset area by Tilton and Bain, 1898) is the regressive limestone of the Dennis cyclothem. It exhibits the shallowing-upward sequence like that seen in the Bethany Falls Limestone below. Only the lower 13 ft. (4 m) are present at this outcrop. The lower part is mainly skeletal wackestone deposited below effective wave base, capped by a thick coated-grain

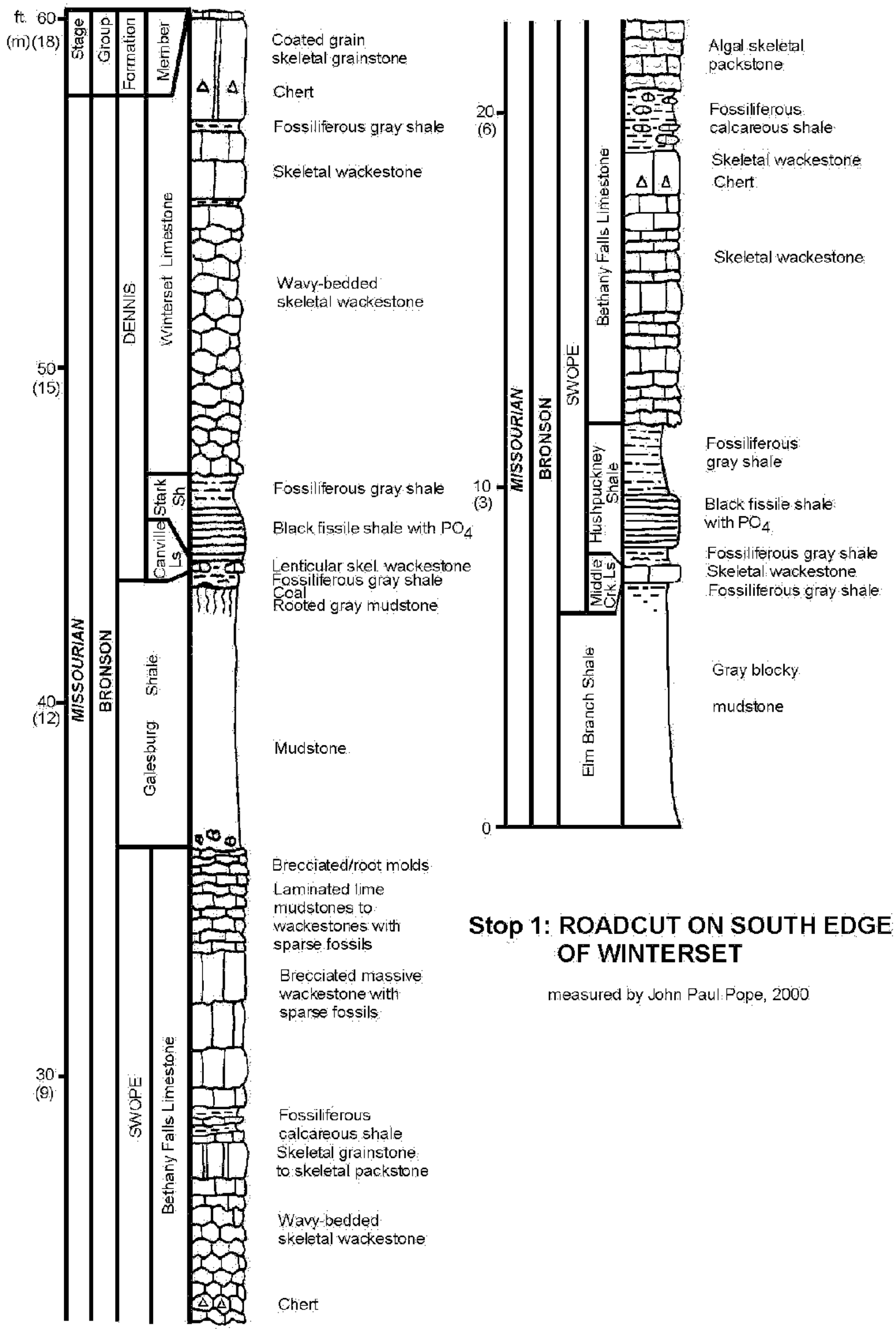


Figure 3. Graphic section of the Pennsylvanian rocks exposed at Stop 1.

skeletal grainstone with scattered oolites deposited above wave base in shoal water conditions. The upper part seen in the Martin-Marietta Quarry to the east, but eroded away here, consists of thin laminated, sparsely fossiliferous wackestones with probable rootmolds and micro-karst, recording peritidal deposits followed by subaerial exposure. The Winterset becomes very complex to the south toward southern Kansas and exhibits a similar "phased regression" as seen in the Bethany Falls (see Felton and Heckel, 1996; Heckel, 1999). Thompson (1957) reported the fusulinid foraminifers *Triticites ohioensis* and *Kansanella winterensis* from this area. This is the first appearance of the triticitid fusulinids in the Midcontinent, which along with the distinctly different fusulinids in the underlying Bethany Falls Limestone, have resolved several correlation problems (Heckel and Meachum, 1981; Heckel and Pope, 1992).

STOP 2: CUT ON ROAD TO WASTE WATER TREATMENT PLANT SOUTH OF WINTERSET. Hertha, Exline, and Lost Branch Cyclothems

(Location: SW NE SW Sec. 5, T75N., R27W).

by John P. Pope

This outcrop exposes the upper part of the Marmaton Group of the Desmoinesian Stage (Middle Pennsylvanian) and the lower part of the Bronson Group of the Missourian Stage (Upper Pennsylvanian). The boundary is currently placed at the base of the Exline Limestone Member of the Pleasanton Formation.

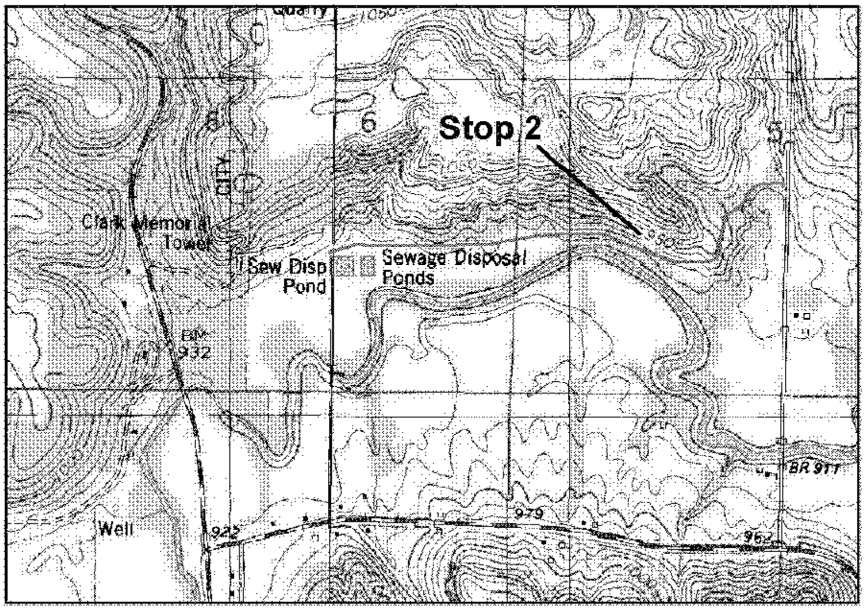


Figure 1. Location of Stop 2 on topographic map.

Nowata-Memorial Shale (both named from northern Oklahoma) is several tens of feet (meters) of red to green, sometimes arenaceous mudstones and shales, interbedded with lenticular argillaceous sandstones (Fig. 2). It may extend down to the red shale exposed just west of the gate. The Nowata Shale is mainly a terrestrial sequence of low-stand deposits that terminated the underlying Altamont cyclothem and may be represented here by the lower part of the red mudstones, most of which are a paleosol.

The Lenapah minor cyclothem (named from northern Oklahoma) above the Nowata Shale is not recognized (if present) at this outcrop because of poor exposures of this interval, but a marine horizon in CP-37 (the Osceola, Clarke Co. core) about 22 miles (35 km) to the south, is consistent both by position and by a compatible conodont fauna (Swade, 1985), to the Lenapah in northern Missouri, but is only a tentative correlation pending further study.

The Memorial Shale (Fig. 3) may be represented here by the upper part of the red mudstones, most of which are also a paleosol. It mainly represents low-stand terrestrial deposits that terminated the Lenapah cyclothem. At this time at this location, until/if the Lenapah is recognized here, this interval will be referred to as the Nowata-Memorial Shale.

Lost Branch cyclothem (named from southeastern Kansas) is the youngest Desmoinesian major marine cycle in the Midcontinent, at the top of the Marmaton Group. It also contains the youngest Desmoinesian fauna. The boundary at the top of the Desmoinesian Stage and the base of the Missourian Stage marks a distinctive biostratigraphic extinction event. Extinctions include aborescent lycopods, chaetetids, the brachiopod *Mesolobus*, the conodont *Neognathodus*, and changes in ammonoids and fusulinids occur at this boundary. The first appearance of the conodont *Idiognathodus eccentricus* (in the Exline Limestone) marks the stage boundary (Heckel, Boardman, and Barrick, 1999).

Sni Mills Limestone Member (named from Missouri) is a thin, fossiliferous skeletal wackestone to packstone that rests just above the exposure surface at the top of the paleosol of the underlying Memorial Shale. It and the thin gray/green shale at the top of the Memorial Shale represents most of the marine part of the transgressive systems tract that developed as sea-level rose.

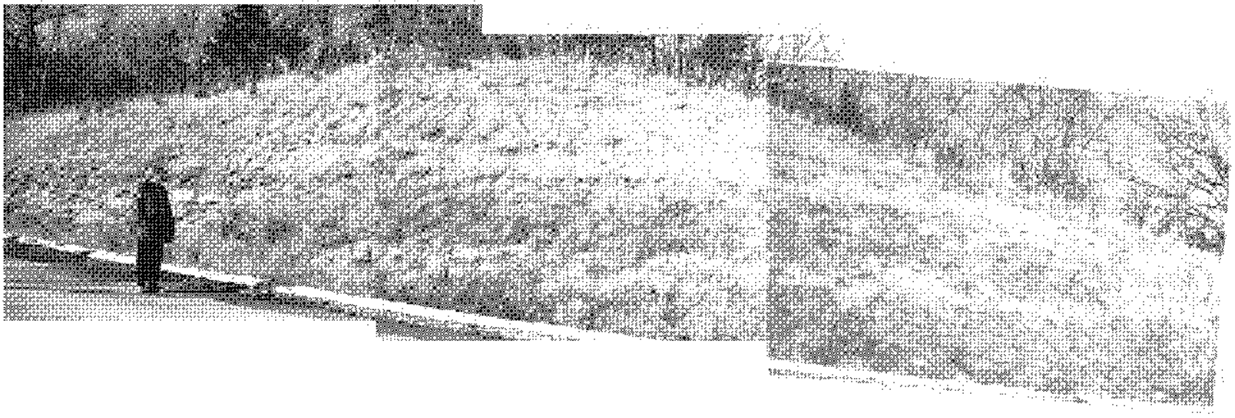


Figure 2. Photo mosaic of rocks exposed at Stop 2.

Nuyaka Creek Shale 'Member' (named from Oklahoma) is a very thin, green, phosphatic shale with sparse carbonate nodules. It is the condensed interval that represents sea-level highstand (part of the high-stand systems tract). It contains the youngest common occurrence of *Neognathodus* in the Midcontinent as well *as Idiognathodus* sp. 6 (Swade, 1985), *Idiognathodus* sp. 1 (Swade, 1985*), Idioprioniodus* sp., *Gondolella magna*, and *Gondolella denuda*, with abundances estimated at >2000/ kilogram.

The limestone interval above the Nuyaka Creek Shale (Fig. 3) and the overlying Mantey-Guthrie Mountain Shale, at this location, needs further study of the conodont fauna. It may consist of both the Cooper Creek and Exline limestones. Since there is no distinct lithologic break between the two members in this interval, at this location it will be referred to as the Cooper Creek-Exline Limestone and only a tentative boundary will be recognized.

Cooper Creek Limestone Member (named from Appanoose Co., Iowa) is possibly 3 ft. (0.9 m) of nodular, 'rubbly,' brecciated-appearing, argillaceous wackestone nodules/ lenses/thin beds and green shale. It is characterized by darker-colored limestone 'clasts' in a lighter-colored matrix. Laterally it may become bedded with thicker interbeds of green shale. Macrofossils include brachiopods, crinoids, and bryozoa. It is the highly weathered remnant of the early part of the forced-regresssive systems tract that formed as sea level lowered and withdrew southward from this area. This is the uppermost Desmoinesian stratum at this location.

Exline Limestone (named from Appanoose Co., Iowa) is possibly 3 ft. (0.9 m) of 'rubbly,' karsted, leached, and weathered wackestone. It is massive with only small zones of interbedded green shale. Southward in CP-37 it is separated from the Cooper Creek Limestone by a thin 0.3 ft. (9 cm) mudstone (Swade, 1985), but at this location there is no distinct lithologic break between it and the underlying Cooper Creek Limestone. Nielson (1987) studied this interval in the Stanzel core (ISC core) in western Madison Co. about 12 mi. (19 km) to the west. Using a compatible conodont fauna for both the Cooper Creek and the Exline, as compared to that in CP-37, he was able to separate the two limestones. Conodont work has not been done at this location and we are tentatively placing the boundary between the Cooper Creek and the Exline limestones at the base of the massive wackestone. It is the highly weathered remnant of what is probably the condensed interval and early regressive deposits of the Exline cyclothem. At this location it is the oldest Missourian stratum.

Mantey and Guthrie Mountain shales are both named from Oklahoma. The Mantey Shale represents the regressive phase of the Exline cyclothem. The Critzer Limestone of the minor Critzer cyclothem, that separates these shales farther south in Kansas and Oklahoma is not present in Iowa. The Guthrie Mtn. Shale is part of the regressive phase of the Critzer cyclothem. Since the Critzer Limestone is not present at this location and the two shales cannot be distinguished from each other (because they may represent continuous soil formation from the regression of the Exline cyclothem to the transgression of the Hertha cyclothem) this interval will be referred to as the Mantey-Guthrie Mountain Shale. It is represented here

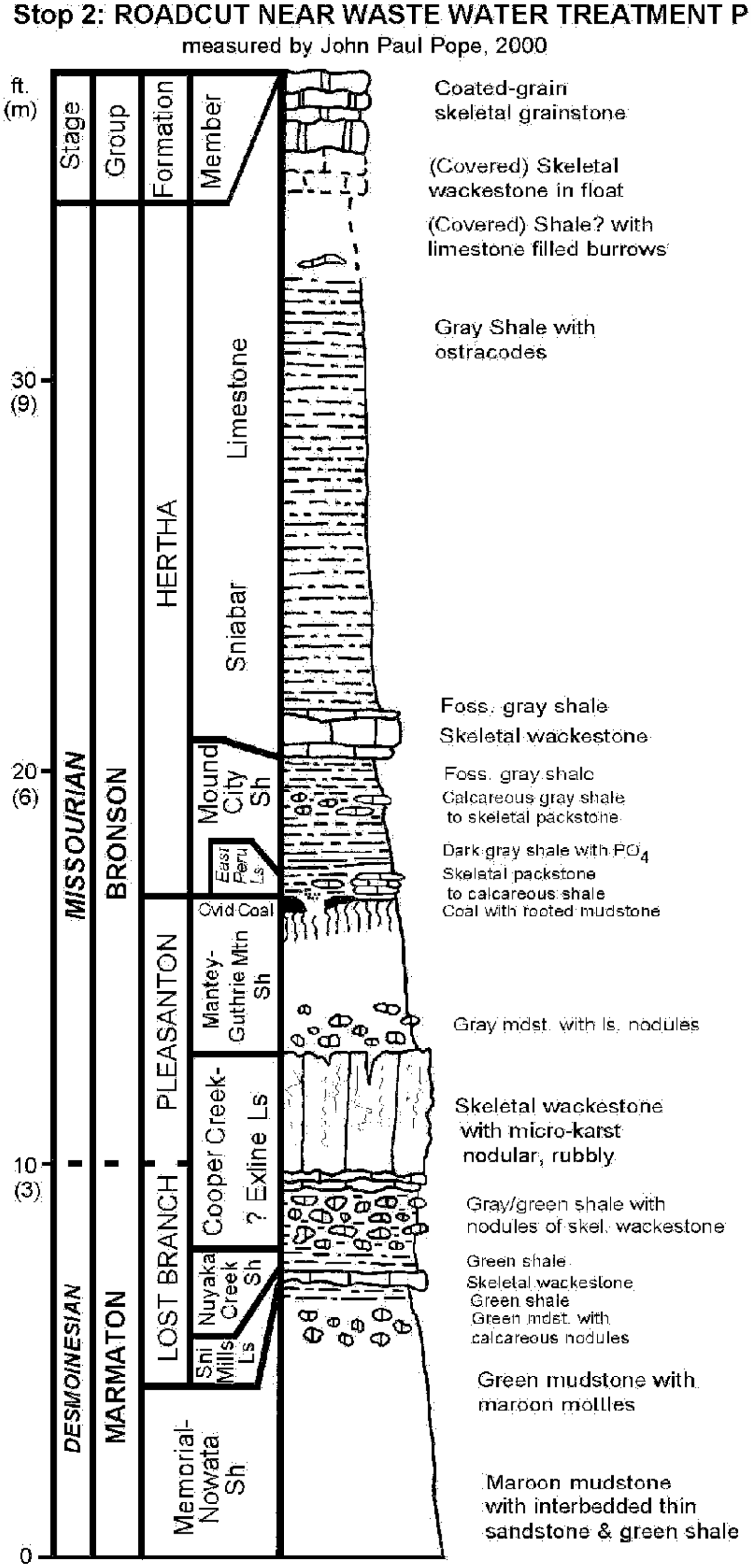


Figure 3. Graphic section of rocks at Stop 2.

by 3 ft. (0.9 m) of gray blocky mudstone that is a paleosol. The lower part contains numerous carbonate nodules, while the top is a rooted mudstone with a few well-preserved macrospores. Above this lies a coal and a thin, gray, marine shale.

Ovid Coal (named from Missouri) at this location is a 1-5 in. (2.5-13 cm) thick coal. It seems to be thinnest below the overlying limestone and in one area a channel about 1 ft. (30 cm) wide at the top and 6 in. (15 cm) deep has cut through the coal. The channel is filled by gray/green shale, and a thin cross-bedded sandstone with carbonized wood debris caps the channel fill. The Ovid Coal represents the ponding of fresh water and peat deposition in the early phase of the Hertha cyclothem transgression. The coal is more genetically related to the overlying marine units so the sequence boundary for the Hertha cyclothem would lie at the base of the coal or the top of the paleosol (Pope, 1999; Heckel, Weibel, and Pope, ms. in prep), as this is the most widespread exposure surface.

East Peru Limestone bed at this location is a lenticular, argillaceous, thin-bedded skeletal packstone that grades laterally into gray/green shale. It is a new informal name applied to this area for the local development of the transgressive limestone of the Hertha cyclothem. This section is designated the principle reference section for the East Peru Limestone bed. We will see the type section at stop no. six, east of the town of East Peru. The upper part contains numerous phosphorite nodules indicating deeper water and a slowdown in depositional rates.

Mound City Shale (named from Oklahoma), in the darker zone a few in. (cm) above the base, represents the condensed interval part of the high-stand systems tract, developed below the photic zone during maximum transgression. This zone contains phosphorite and a diverse conodont fauna including many adult *Gondolella* (a deeper water more offshore form), *Idioprioniodus* (another deeper water more offshore form), *Idiognathodus sulciferous, I. eccentricus*, and the first appearance of the more nodose form *Idiognathodus clavatulus,* and *I.* n. sp. A (Barrick et al., 1996), with extrapolated abundances of about 700/ kilogram. This grades upward into about 1 ft. (30 cm) of fossiliferous gray/green shale with conodont abundances of less than 100/ kilogram. Most of these are juvenile elements and *Gondolella* is no longer present. *Idioprioniodus* is rare and *Hindeodus* (a more nearshore form) appears. There is some phosphorite and a few fossil grains are replaced by glauconite. In the upper 6 in. (15 cm) of this shale conodont abundances increase to over 700/kilogram. This shale grades upward into a 6 in. (15 cm) thick very fossiliferous, lenticular, argillaceous, lime wackestone, that grades laterally into gray/green shale. Conodont abundances decrease to about 150/kilogram with mainly juveniles. *Gondolella* is still absent, *Idioprioniodus* is very rare, *Hindeodus* becomes much more abundant, and *Adetognathus* (a near-shore form) appears. Phosphorite and glauconite are present. This interval may represent shallowing to within the photic zone where carbonate was both produced and preserved and diluted conodonts. Above this is an abrupt contact with a darker gray shale with conodont abundances of over 500/kilogram and abundant phosphorite and glauconite. This grades upward into gray shale with conodont abundances of less than 11/kilogram. This lower shale/ limestone/ upper shale interval may represent a minor deepening event within the dominantly regressive phase of the upper Mound City Shale. Overall most of the Mound City Shale seems to represent relatively slow deposition (abundant conodonts along with phosphorite and glauconite) in relatively deep water (presence of *Gondolella* and *Idioprioniodus*).

Sniabar Limestone Member (named from Missouri), at its base, is a dense, brown-weathering, lime wackestone about 15 in. (38 cm) thick. Macrofossils include brachiopods, bryozoa, and crinoids. Conodonts include *Hindeodus* and *Idiognathodus* with an abundance of about 20/kilogram. Above this is about thirteen feet (4 m) of gray shale with relatively few fossils except ostracodes. The lower foot (30 cm) is a darker gray shale with abundant macrofossils, like that seen in the underlying wackestone, and conodont abundances of 150/kilogram, including *Adetognathus, Hindeodus*, and *Idiognathodus*. Six feet (1.8 m) above the limestone only 1 *Idiognathodus* was recovered, and 10 feet (3 m) up only one *Adetognathus*. The upper two to three feet (0.6-0.9 m) are covered, but there are numerous limestone filled burrows weathering out of the grassed over interval. The basal 1 to 2 ft. (0.3-0.6 m) of the upper limestone is covered, but may in part be a wackestone, as it is seen in float. The upper part is an abraded-grain skeletal grainstone. The lower limestone represents shallowing to within the photic zone, but below wave base. The middle shale may represent clastic influx from a nearby delta at this location, with relatively slow deposition in the beginning that overwhelmed carbonate production. The upper limestone may represent shifting of the delta and deposition of the grainstone in a shoal-water environment.

STOP 3A: ROADCUT ALONG HIGHWAY 169, SOUTH OF BRIDGE OVER MIDDLE RIVER (LOCATION: E1/2, SW SEC. 11, T75N., R28W).

by Steven H. Emerman

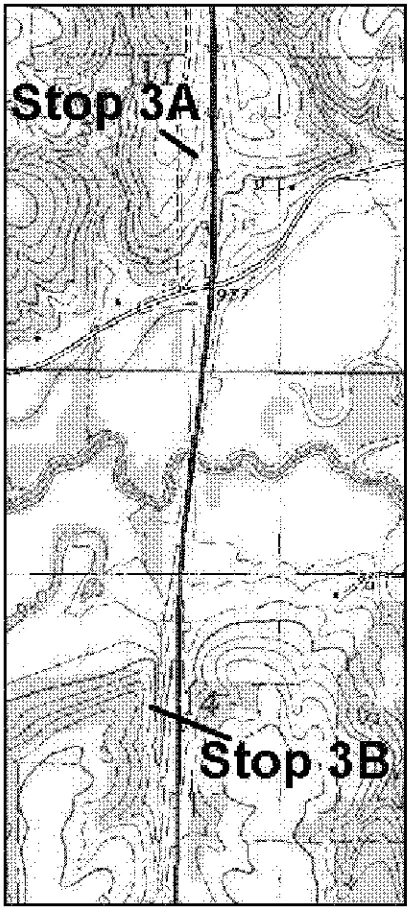


Figure 1. Locations of Stops 3a and 3b on topographic map.

A roadcut just north of the Middle River bridge (Fig. 1) exposes beds of the Bethany Falls Limestone Member (below) through the Winterset Limestone Member (above) dipping 2° roughly to the north. This outcrop (Fig. 2) was described by Heckel (1987) (see Figure 3). The prominent ledge is the Winterset Limestone below which can be seen the Stark Shale Member and Galesburg Shale. South of the driveway on the eastern side of the highway, the Bethany Falls Limestone can be seen in a gully. Due to extensive slumping, the Cherryvale Shale and Canfield Limestone Member can no longer be found.

The dip and strike of the beds cannot be accurately measured due to both the rough surfaces and gentle dip. Although the Winterset Limestone is heavily jointed, the surfaces are very rough and their orientations cannot be measured with any accuracy either. Note, however, that the Bethany Falls Limestone has two well-defined joint surfaces.

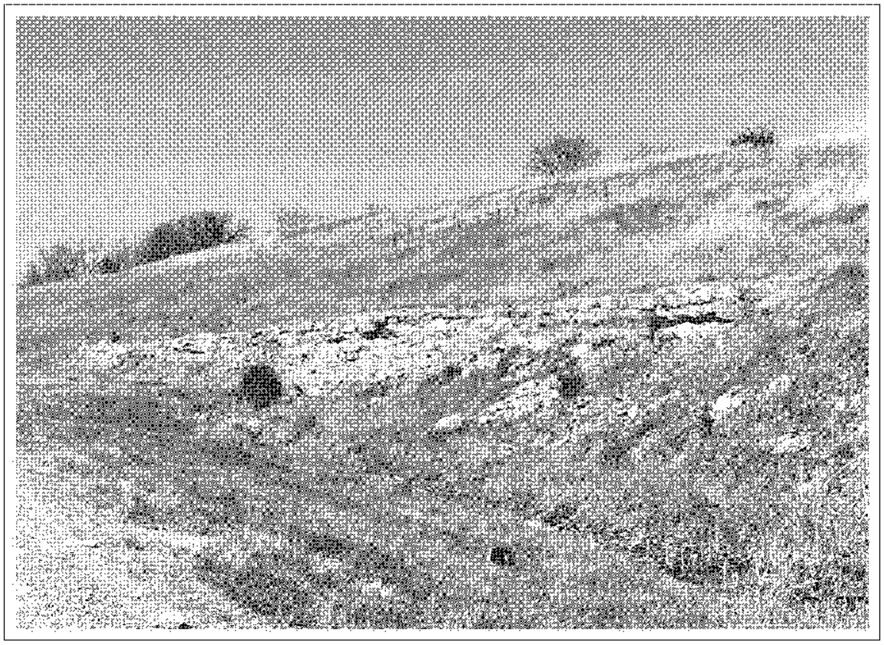


Figure 2. Photograph of exposure at Stop 3A.

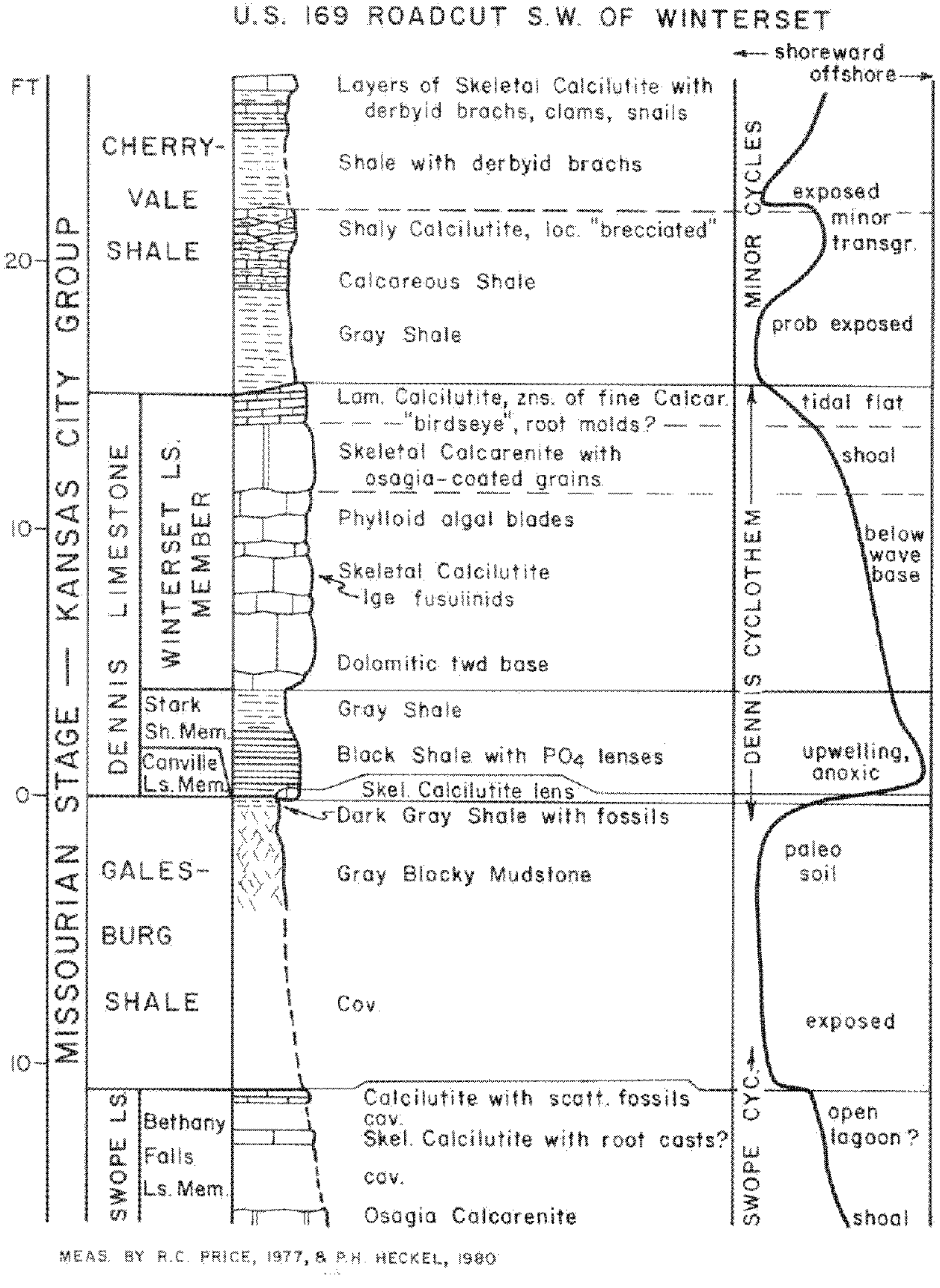


Figure 3. Graphic section of rocks exposed at highway 169 roadcut at Stop 3. From Heckel, 1987

STOP 3B: ROADCUT ALONG HIGHWAY 169, SOUTH OF BRIDGE OVER MIDDLE RIVER (LOCATION: E1/2, NE, SW SEC. 14, T75N., R28W).

A roadcut just south of the Middle River bridge exposes beds dipping less than 1° roughly to the south (see Figure 4). Apparently, the Middle River cuts through the crest of a gentle anticline, the only known anticline in Madison County. The prominent ledge is the Bethany Falls Limestone. The very weathered Winterset Limestone is poorly exposed in the hillside above the ledge. The Bethany Falls Limestone on the south side of the bridge is substantially above the Bethany Falls Limestone on the north side of the bridge. The ditch at the base of the roadcut exposes the Sniabar Limestone Member of the Hertha Formation.

As on the north side of the bridge, it is very difficult to measure the dip and strike of the beds due to the gentle dip and rough surfaces. However, both the Bethany Falls Limestone and Sniabar Limestone are very well-jointed and it is possible to determine the axis of compression of the anticline through an analysis of joint orientations. Eighty-four joints were measured in the Bethany Falls Limestone on the south side, two joints were measured in the Bethany Falls Limestone on the north side and eight joints were measured in the Sniabar Limestone. The table below summarizes the strikes of the ninety-three joint measurements.

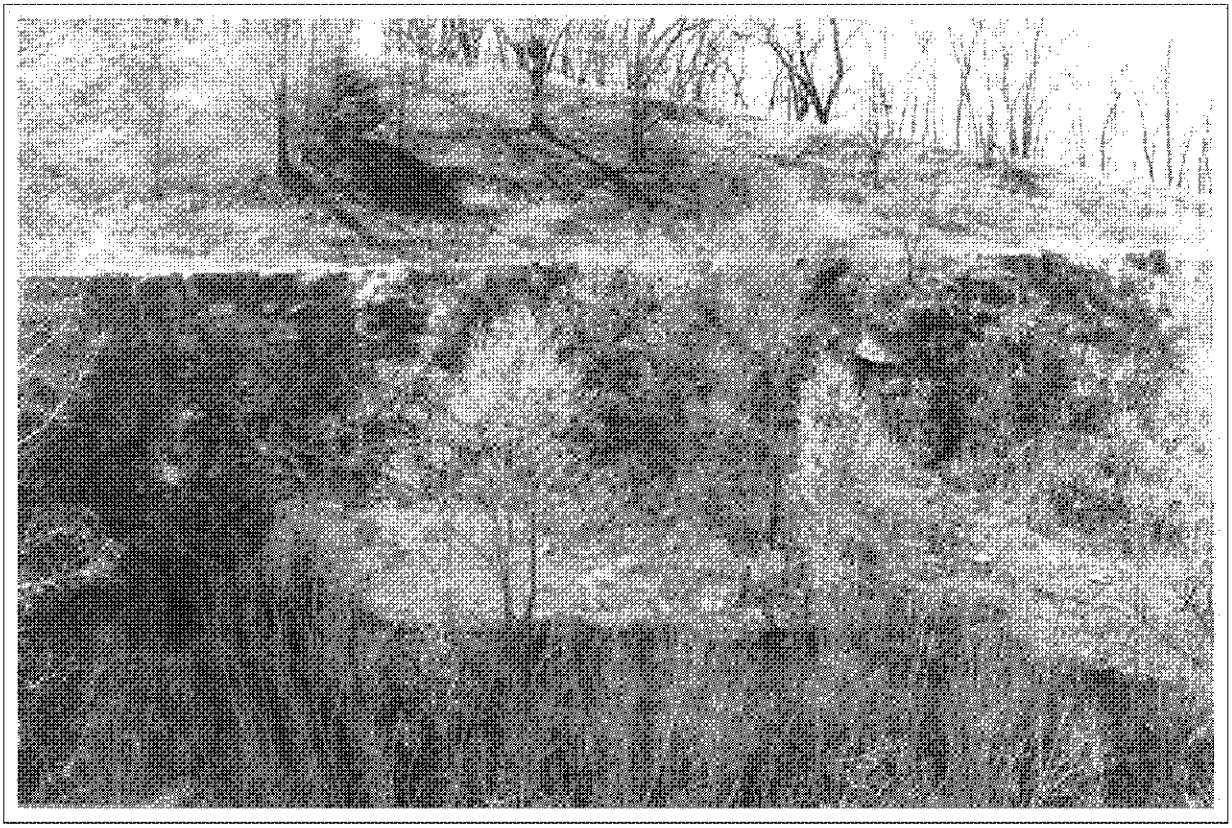


Figure 4. Photograph of rocks exposed at highway 169 roadcut on south side on Middle River, Stop 3b.

Joint Strikes	Number of Measurements
0 – 9.5°	3
10 – 19.5°	1
20 – 29.5°	3
30 – 39.5°	0
40 – 49.5°	4
50 – 59.5°	12
60 – 69.5°	18
70 – 79.5°	5
80 – 89.5°	1
90 – 99.5°	1
100 – 109.5°	1
110 – 119.5°	0
120 – 129.5°	0
130 – 139.5°	6
140 – 149.5°	13
150 – 159.5°	16
160 – 169.5°	8
170 – 179.5°	1

There appear to be two sets of joints with one joint accounting for all strikes between 40° – 79.5° and the other joint accounting for all strikes between 130° - 169.5°. The two joint sets account for all but eleven joint measurements. The table below summarizes the features of the two joint systems.

	Strike	Dip
Joint Set #1	(62 ± 1)°	(88 ± 3)° SE
Joint Set #2	(151 ± 2)°	(85 ± 1)° NE

The angle between the two sets of joints is either (91 ± 3)° or (89 ± 3)°. Therefore, the angle between the joints cannot be distinguished from a right angle. The two sets of joints indicate an axis of compression of 16.5°.

REFERENCES

Heckel, P.H., 1987. Pennsylvanian cyclothem near Winterset, Iowa: Geological Society of America Centennial Field Guide – North-Central Section, p. 119-124.

STOP 4. BETHANY FALLS LIMESTONE AND TUNNEL AT PAMMEL STATE PARK

(LOCATION: W1/2 SEC. 15, SEC 16, T75N., R28W).

by John Pope

this will be our lunch stop

Pammel State Park is 281 acres of peaceful and picturesque beauty located two miles west of Winterset, on Highway 162 in Madison County (Fig. 1). The park offers a wide range of year-round activities ranging from picnicking and camping to hiking and snowmobiling.

Pammel State Park was acquired by the state in 1923 and was originally named Devil's Backbone State Park because of the unique limestone ridge that cuts through the park. In 1930, the park was renamed in honor of Dr. Louis Pammel, former head of the Botany Department at Iowa State University and an active conservationist. Cutting through the ridge is the Harmon Tunnel, the only highway tunnel in the State of Iowa. It was originally constructed in the 1850s by settlers named Harmon who built it to divert water from the Middle River to operate a grist mill and sawmill. After the State acquired the land, the tunnel was enlarged to accommodate vehicles and the park road was built through it.

In a study done in the 1970s, Pammel was found to have some of the oldest oak trees in Iowa, some of which date back to the 1640s. These are primarily located in the timber around the Backbone Picnic Area.

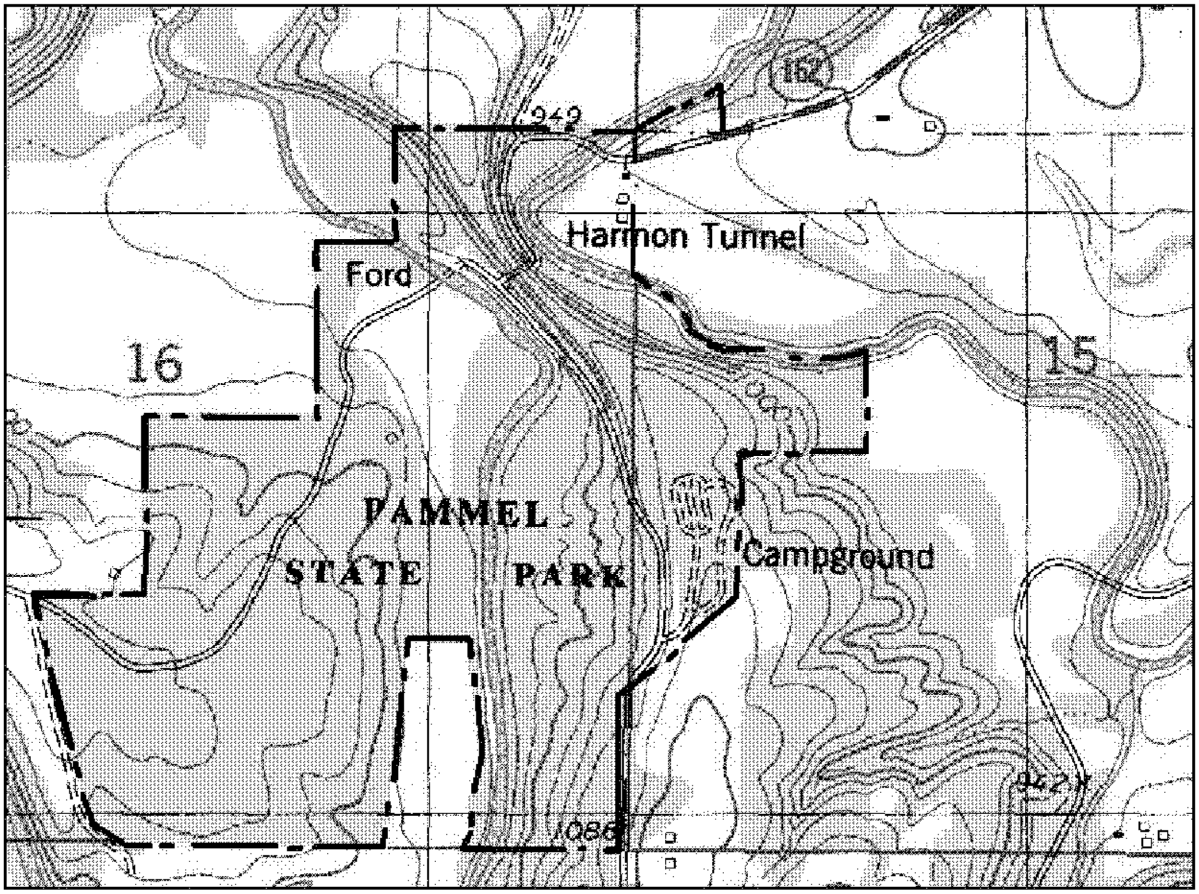


Figure 1. Topographic map of Pammel State Park. Distance between section numbers is about 1 mile.

Devil's Backbone

Middle River swings around to the west and north in a great horseshoe loop and doubles back on itself around a ridge known as the Devil's Backbone. The ridge is over 100 ft. (30 m) high and about 150 ft.

(46 m) thick at its base near the present day road tunnel. The Sniabar Limestone Member of the Hertha Formation is the lowest strata and is exposed on the northeast end of the tunnel below the road grade. Above this are the Elm Branch Shale Formation, and the Middle Creek Limestone and Hushpuckney Shale members of the Swope Formation. The tunnel was excavated through the Hushpuckney Shale, the Middle Creek Limestone, and the upper part of the Elm Branch Shale. Directly overlying the tunnel is the Bethany Falls Limestone Member of the Swope Formation. Above this to the southeast, along the road, the Galesburg Shale, the Dennis Formation (including the Winterset Limestone Member), the Cherryvale Shale Formation, and the lower part of the Dewey Formation are exposed. About 1.75 mi. (2.8 km) to the southwest of the tunnel the Dewey Formation is also exposed along Middle River. This is the proposed type locality for the informally named Pammel Park Limestone (Heckel and Pope, 1992), transgressive limestone member of the Dewey cyclothem.

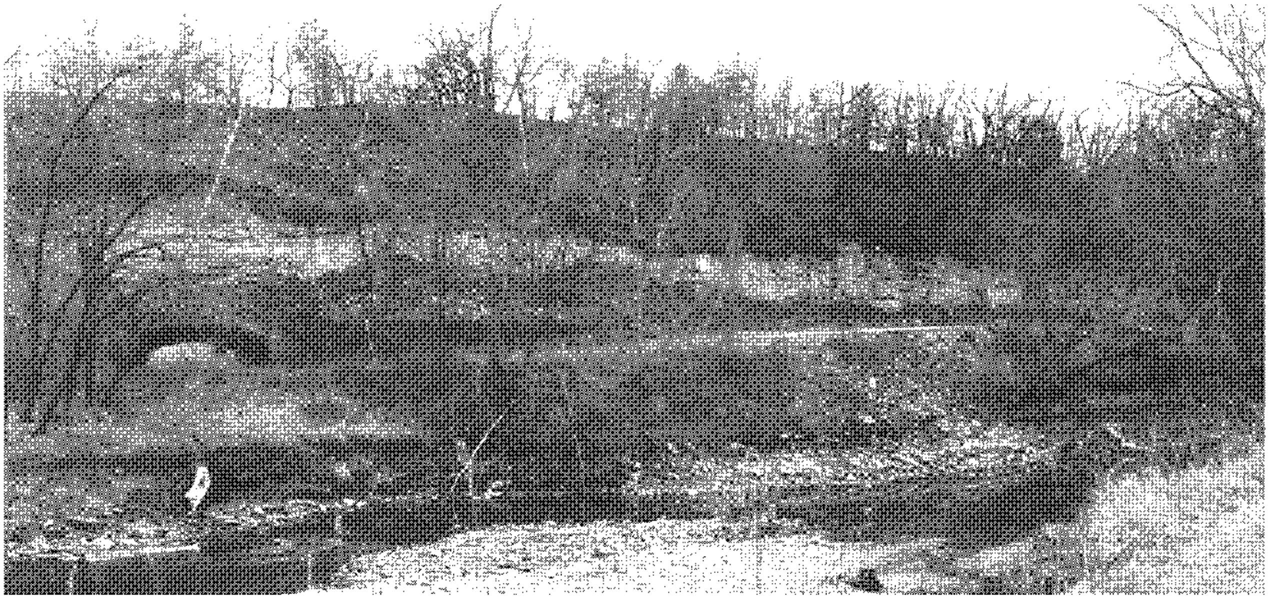


Figure 2. View of The Devil's Backbone at Pammel State Park. Note the Harmon Tunnel in the left side of the photo. Photograph was taken looking to the west-southwest.

In 1847 William Harmon, his wife and seven children came to Madison County. They originally lived in a log cabin near Winteset with a dirt floor and no fireplace. In 1849 they moved to the Devil's Backbone area and built a house on the Backbone north of the present tunnel in 1850. In 1855 William and two of his sons began to dig a tunnel under the Bethany Falls Limestone, that would provide water to power a sawmill. The tunnel was dug halfway from the northeast side and halfway from the southwest side. The tunnel was six feet (1.8 m) high, 6 feet wide, and over 100 feet (30 m) long. They then dammed the river on the upstream southwest side and built the mill on the downstream northeast side. This provided about 20-25 feet (6-7.5 m) of head to power the waterwheel. The tunnel was completed in 1858 and the "up and down" sawmill was put into operation in 1859 (see photograph on front cover). In 1867 they sold the mill and it was converted into a gristmill that operated until 1904. In 1913 the old mill was demolished, but the old mill wheel is still preserved near the north park entrance (Fig. 3).

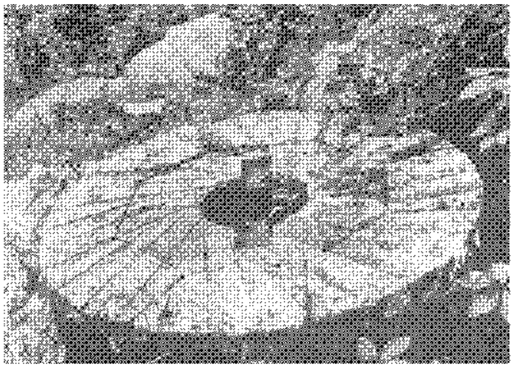


Figure 3. Old millstone from Harmon Mill, on display at Pammel State Park (Stop 4).

Later Cash Gray owned the land. He widened the tunnel for machinery storage and access to the other side of the ridge. In 1923 he sold the land to the state for what is now Pammel State Park. In 1925 the tunnel was further widened for use as an automobile tunnel (see Fig. 4, p. 6 for a view of the tunnel as it appeared in 1961). It is the only highway tunnel in the state of Iowa (see Fig. 4 below).

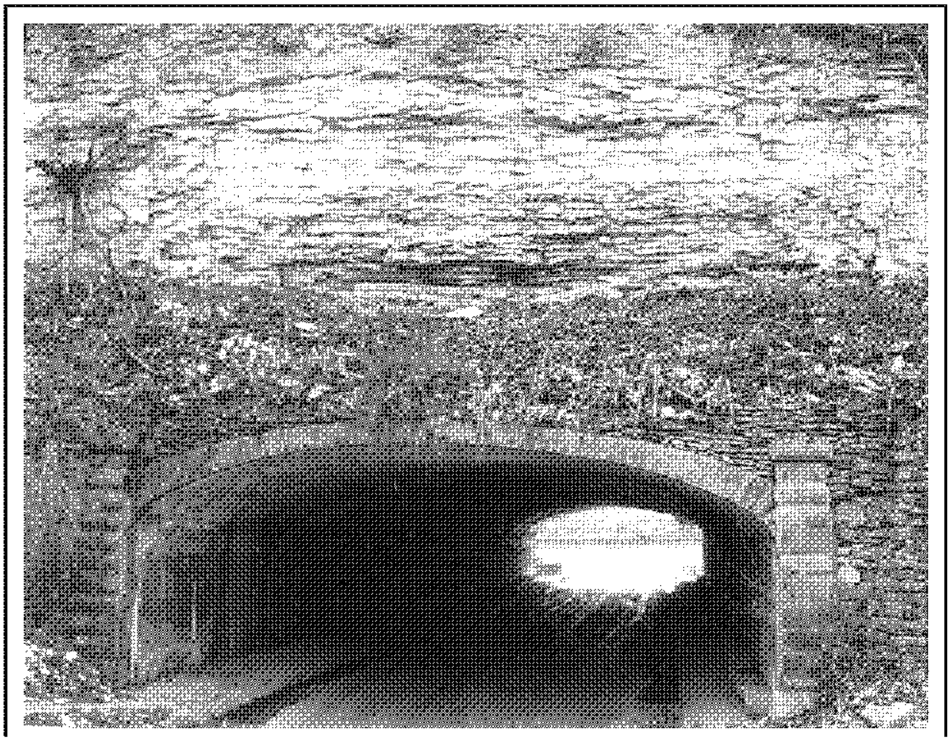
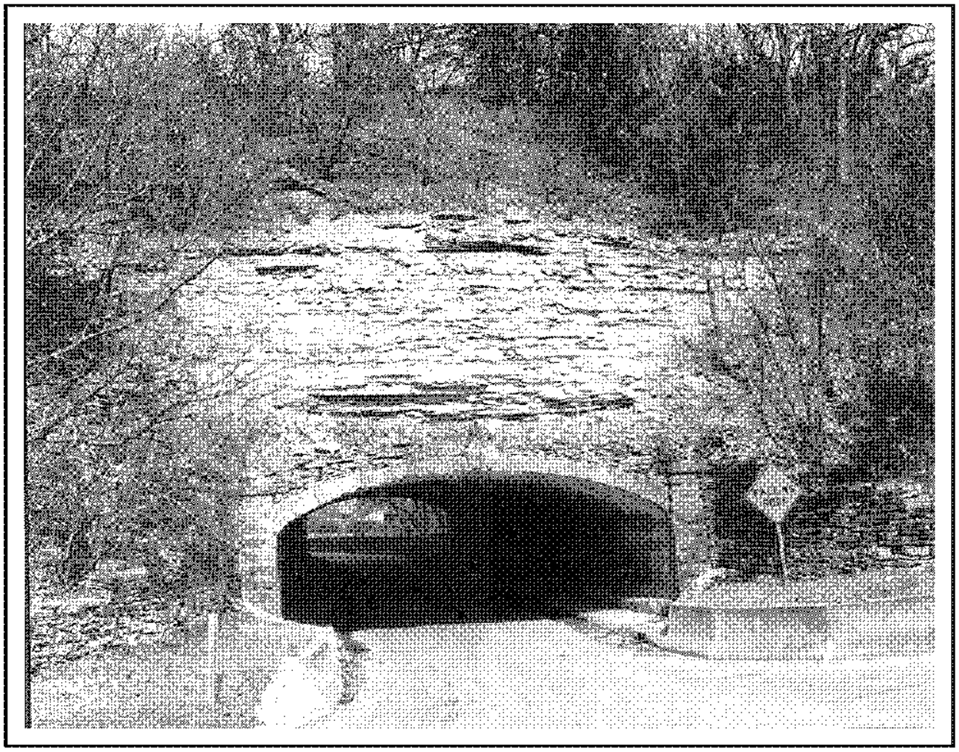


Figure 4. Two views of the Harmon Tunnel. The Photo above shows the eastern entrance to the tunnel, the photo below is a view of the western entrance. Photographs by John Pope.



REFERENCES

Heckel, P.H., and Pope, J.P., 1992, Stratigraphy and cyclic sedimentation of Middle and Upper Pennsylvanian strata around Winterset, Iowa: Iowa Department of Natural Resources, Geological Survey Bureau, Guidebook Series No. 14, 53 p.

Smith, L. H., 1984, Scenic Madison County, Iowa: Historical Significance: Madison County Historical Society, Winterset, Iowa, 60 p.

STOP 5: ROAD CUT EAST OF EAST PERU. Lost Branch? / Exline?, Hertha, and Swope cyclothems (Location: W line E1/2 NW¼ sec. 12, T74N., R27W).

by John P. Pope

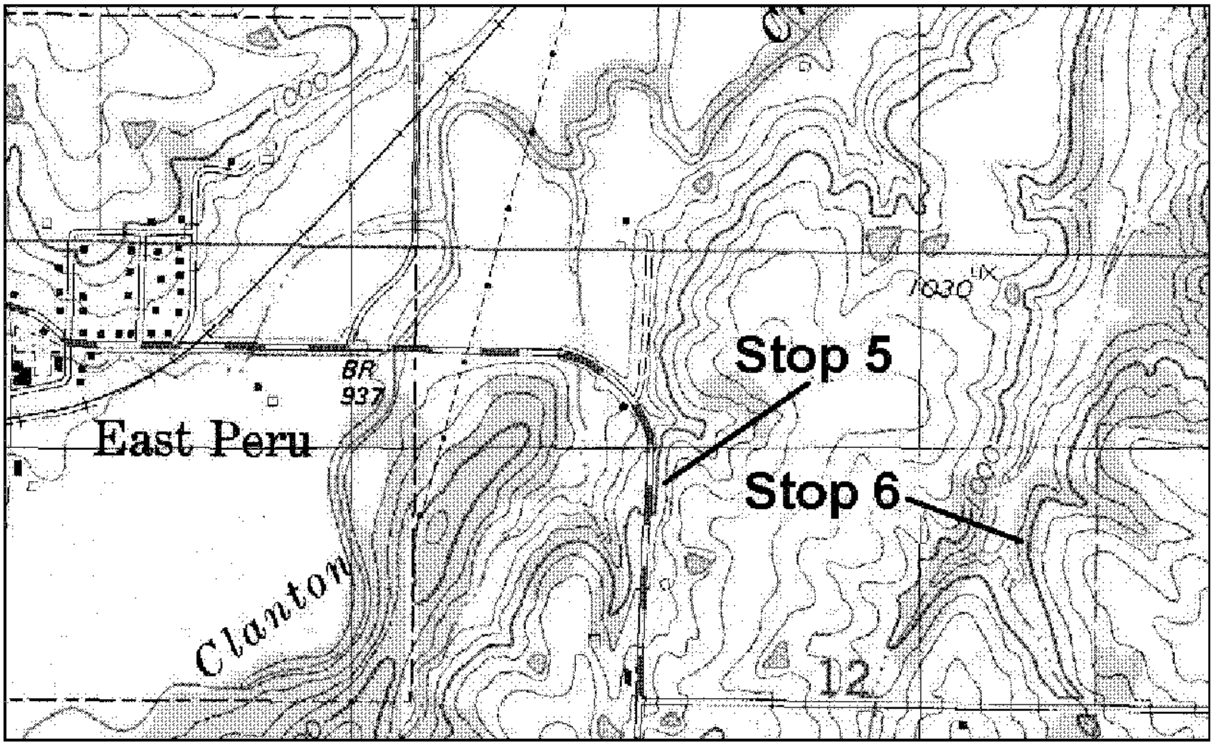


Figure 1. Locations of Stops 5 and 6 on a topographic map.

More conodont work needs to be done at this location, as it is not sure at this time how some of the lower units correlate to those exposed at Stop 6. We will also see the Hertha cyclothem of the Bronson Group of the Missourian Stage as well as the overlying Elm Branch Shale and the base of the Swope Formation (cyclothem).

At this location (Fig. 1) a poorly exposed, rubbly, argillaceous limestone crops out in the ravine in the pasture to the north of the main roadcut (Fig. 2). Heckel and Pope (1992) described this as the Exline Limestone (part of the oldest cyclothem in the Missourian in Iowa), but no conodont work has been done on this outcrop at this location. In light of recent preliminary conodont work done in the ravine about 0.5 mi. (0.8 km) to the southeast this limestone may be the Cooper Creek Limestone Member of the Lost Branch cyclothem (the youngest cyclothem in the Desmoinesian). A sandy zone below a red mudstone (now covered) in the grader ditch reported by Heckel and Pope (1992) in their upper member of the Pleasanton Shale, may actually be correlative to the coal and sandy zone above a poorly-drained gray paleosol seen at Stop 6, in the Guthrie Mountain-Mantey Shale. This sandy zone may be equivalent to the Exline Limestone. The red mudstone (a well-drained paleosol) above this sandy zone would then be the Mantey-Guthrie Mountain Shale.

Figure 2. Exposure at Stop 5.

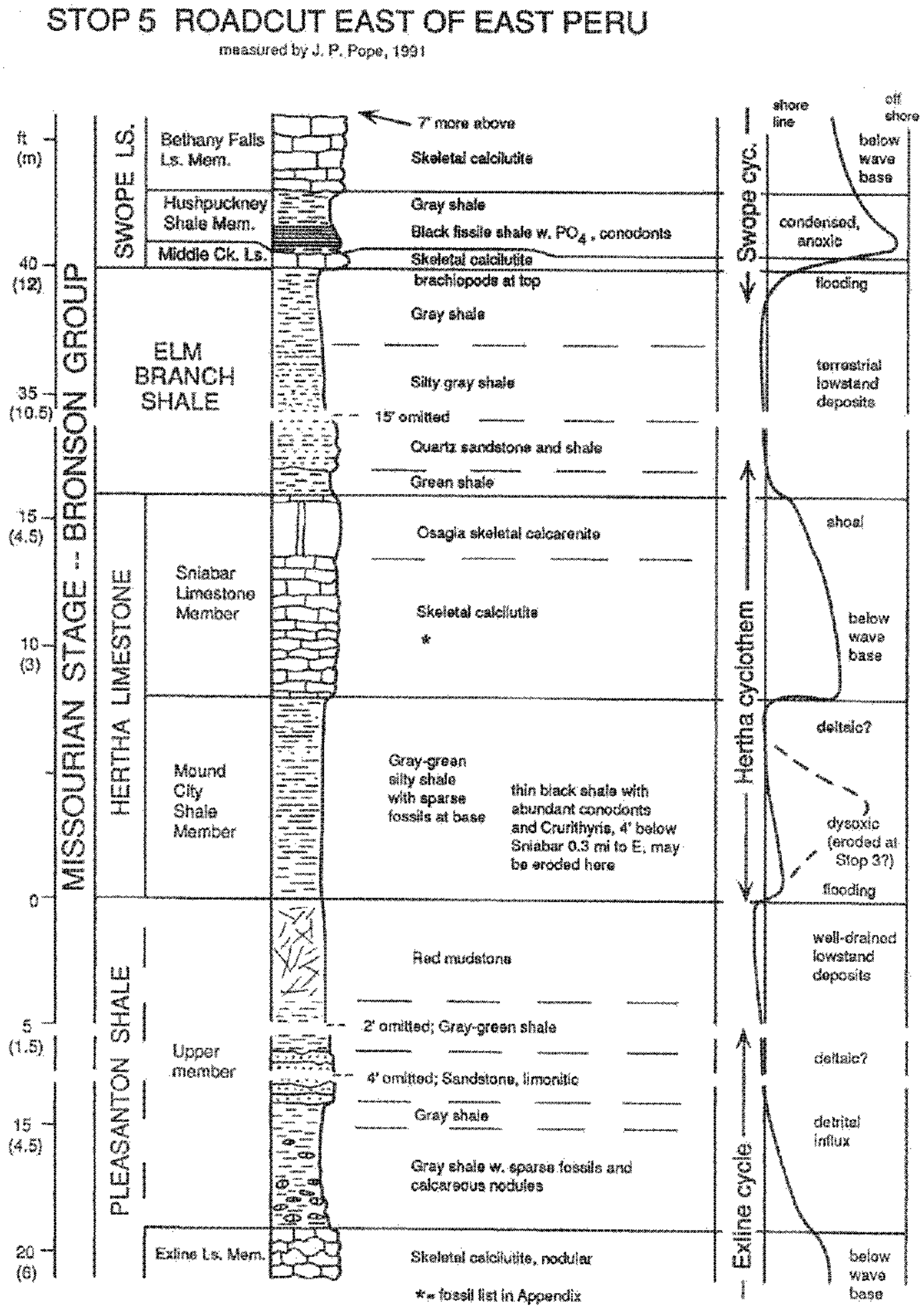


Figure 3. Graphic section of rocks exposed at Stop 5.

Mound City Shale (Fig. 3) at this location is about 7-8 ft (2.1-2.4 m) of gray-green silty shale. The transgressive limestone and dark conodont-rich shale seen at Stop 2 (and to be seen at Stop 6) are not present at this location. As of yet not even a gray conodont-rich shale zone has been found at this site. This indicates the condensed section was not deposited here, it may have been diluted by clastics, or it was eroded away. The silty shale at this location includes both the transgressive systems tract and the highstand systems tract of the Hertha cyclothem. A recently discovered exposure, in the small ravine to the north of the roadcut, has a thin coaly zone above a gray/green arenaceous mudstone about 4 ft. (1.2 m) above a red mudstone. This coaly zone is only about 1 ft. (30 cm) below the base of the Sniabar Limestone. Thus the Mound City Shale (a gray/green shale) in the ravine exposure is only about 1 ft. (30 cm) thick.

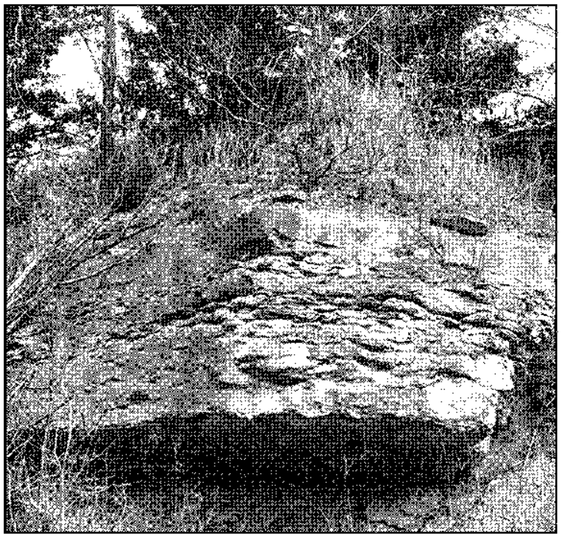


Figure 4. Sniabar Limestone at Stop 5.

Sniabar Limestone Member (Fig. 4) is the regressive limestone and includes most of the regressive systems tract of the Hertha cyclothems. Adrian Goettemoeller, a graduate student at the University of Iowa, did a petrographic study of the Sniabar Limestone at this location in 1997 to test the depositional model of Heckel (1977, 1983, 1994). The limestone is about 9 ft. (2.7 m) thick and was sampled at about 1 ft. (30 cm) intervals. Adrian recognized six depositional facies, in general ascending order: 1) a sparry algal lime wackestone, 2) an algal skeletal lime wackestone, 3) a skeletal lime wackestone, 4) a sandy skeletal lime packstone, 5) a sandy, abraded-grain, coated-grain lime grainstone, 6) a sandy coral lime framestone facies that occurred in patches within facies number 5. The algal blades in facies one were identified as codiacean green algae. This is unusual because the base of the regressive limestone is typically in an environment that is somewhat deeper water than green algae live in. This may indicate that when carbonate production and preservation started at this location, it was at a topographically higher position in the photic zone than usual, for this part of the regressive limestone. Facies 1, 2, 3 were deposited below wave base where mud was not winnowed out by waves. Facies 5 and 6 were deposited above wave base where mud was winnowed out and grains were abraded. Facies four represents a transition zone between the lower mud dominated facies and the upper grain dominated facies. Facies six is interesting in that large syringoporid tabulate corals, up to 2 ft. (60 cm) across, are intergrown with several species of rugose corals. Facies four thru six contain abundant fine quartz sand indicating a nearby clastic source. Sand may have been carried into these shallower water facies by currents, and periodic storm waves, but clastic mud was carried out of the system. The top of the Sniabar does not develop the laminated peritidal facies that is common in many other regressive limestones, including that of the overlying Bethany Falls Limestone (seen at stop one). This indicates that carbonate production was overwhelmed by clastic influx during development of the shoal water facies, or that this location was a topographic high. The top of the Sniabar Limestone shows evidence of dissolution and microkarst associated with an exposure surface. The result of the study by Adrian, shows that the Sniabar Limestone is a shallowing upward sequence deposited as a result of a regression or shallowing of the sea.

The Elm Branch Shale at this location is about 23 ft. (7 m) of silty gray shales and sandstone. Most of it represents terrestrial lowstand deposits that terminated the Hertha cyclothem. The fossiliferous shale in the top foot (30 cm) represents the initial marine flooding deposits of the Swope cyclothem, and the base of this shale is probably close to the sequence boundary.

The Middle Creek Limestone Member, Hushpuckney Shale Member, and Bethany Falls Limestone Member of the Swope cyclothem are essentially the same as at Stop 1.

STOP 6: Ravine at Donna Phillips farm east of East Peru roadcut: Lost Branch, ?Exline, Hertha cyclothems (Location: SW1/4 NE1/4 Sec. 12, T74N., R27W).

by John P. Pope

This location of two outcrops in two stream meanders, exposes the Lost Branch, Exline, and Hertha cyclothems (see map figure 1 on page 43 for location). This section is very similar to the one seen at stop two, except the interval between the transgressive limestone of the Hertha cyclothem and the top of the Lost Branch cyclothem is considerably thicker here. The ?Exline cyclothem is also separated from the Lost Branch cyclothem by several feet (meters) of mudstone and a coal. This is the proposed type section for the East Peru Limestone, the transgressive limestone of the Hertha cyclothem, named for the nearby town of East Peru, about 0.5 mi. (0.8 km) to the west.

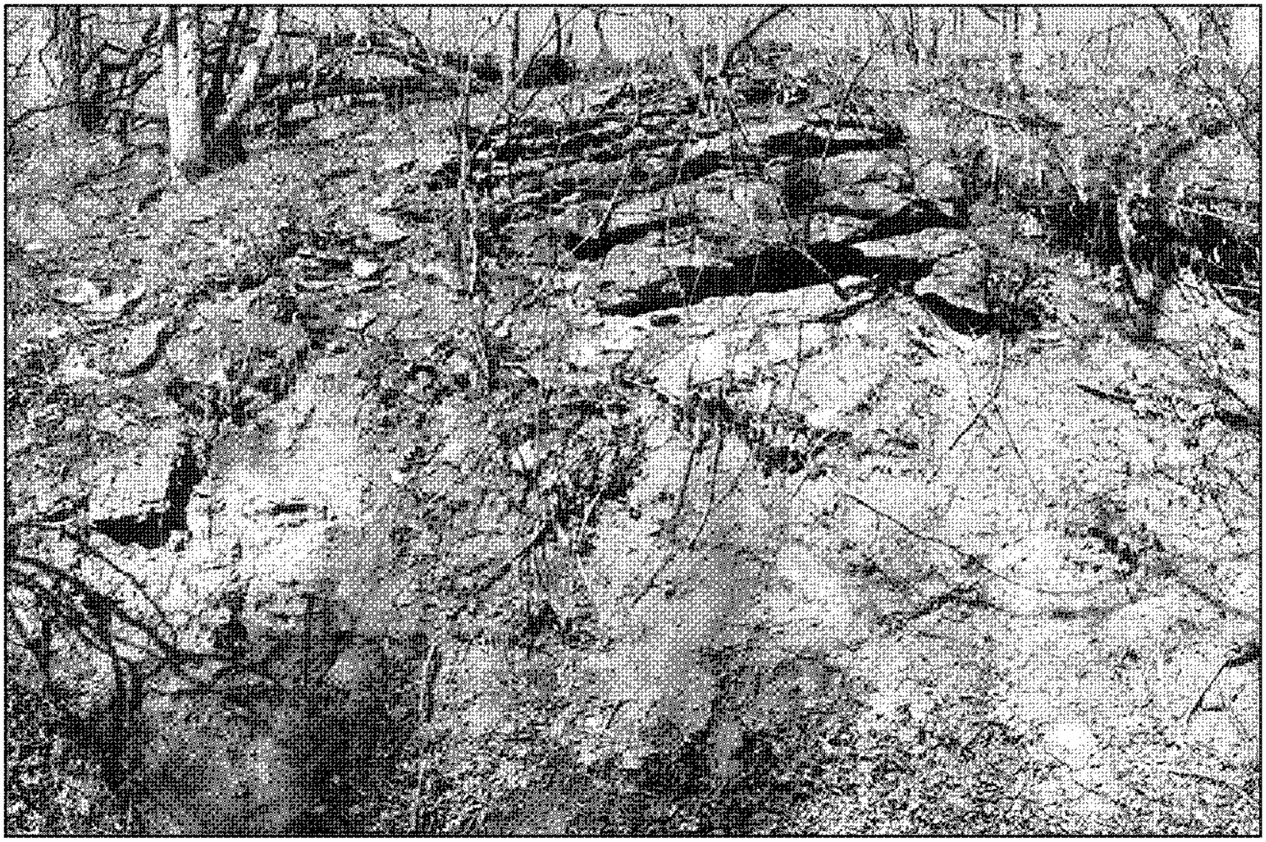
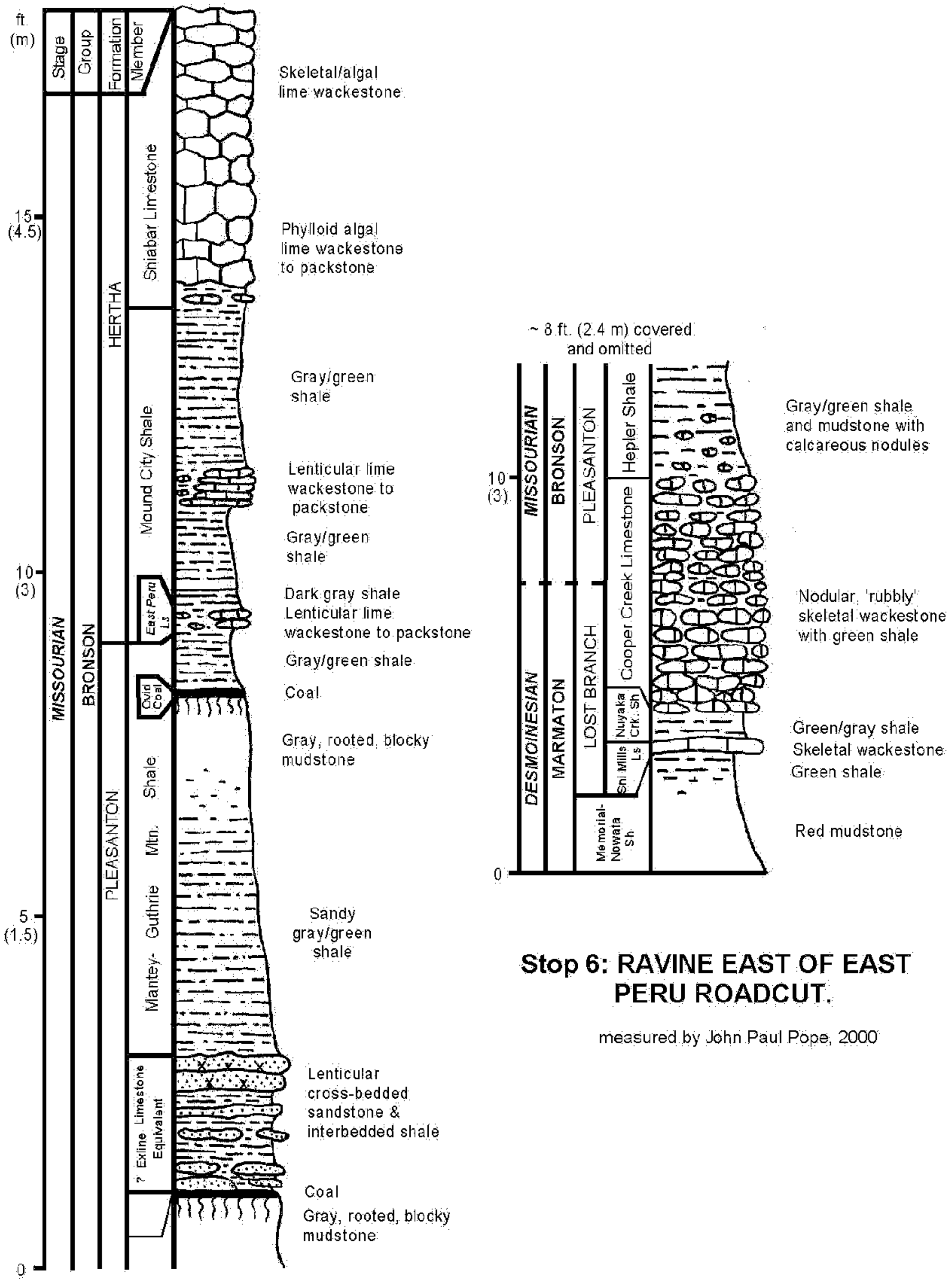


Figure 1. Exposure of rocks of the Hertha cyclothems at Stop 6.

Unless time permits we will not examine the Lost Branch cyclothem at the north fence line of the property. It is very similar to the limestone seen at Stop 2 except the massive bed at the top at stop two is more nodular and rubbly here.

At the base of the streamcut just below the Hertha cyclothem, is about 2 ft. (0.6 m) of gray, rooted, blocky mudstone containing a few macrospores, overlain by a thin 1-2 in. (2.5-5 cm) coal. This is the Hepler Formation, named from Kansas, containing the Grain Valley Coal. Above the coal is about 2 ft. (0.6 m) of thin-bedded, calcareous, lenticular, micaceous, cross-bedded sandstone with interbedded shale. A sample within this sandstone interval produced no conodonts, but a sample from the base of the sandy shale just above the sandstone contained 12 platforms of *Idiognathodus*. This preliminary sampling indicates that the sandstone is probably equivalent to the Exline Limestone, but may be an estuarine or paleovalley fill, and open marine conditions did not occur until after the sandstone deposition. It is probably not equivalent to the Critzer Limestone that is dominated by *Adetognathus* as far south as Kansas City (pers. comm. from P.H. Heckel, 2000). It is not yet known if the ?Exline equvalent



Stop 6: RAVINE EAST OF EAST PERU ROADCUT.

measured by John Paul Pope, 2000

Figure 2. Graphic section of rocks exposed at Stop 6, ravine east of East Puru roadcut.

sandstone here, is the same as the sandstone seen below the red mudstone at Stop 5. The Mantey-Guthrie Mountain Shale interval, about 5 ft. (1.5 m) thick, does not exhibit a red mudstone at this location as it does at Stop 5. The upper sequence boundary of the ?Exline cyclothem lies at the top of the rooted blocky mudstone at the base of the Ovid Coal. The coal represents the initial stages of transgression of the overlying Hertha cyclothem, with the ponding of fresh water associated with a rising water table. The 1 ft. (30 cm) shale above the coal represents the beginning of the marine part of the transgression. The top of the shale just below the East Peru Limestone yielded about 17 conodonts/ kilogram, including *Hindeodus* and *Idiognathodus*.

Figure 3. Exposure of East Peru Limestone and Mound City Shale at Stop 6. Shovel for scale at top of section. See Figure 4 for close-up view of East Peru Limestone.

The lower part of the Hertha cyclothem is well developed here, and it looks very similar to that seen at Stop 2. This includes a dark conodont-rich zone and a thin lime wackestone to packstone in the Mound City Shale, and the East Peru Limestone, none of which were seen at Stop 5 0.5 mi. (0.8 km) to the west.

The East Peru Limestone bed (see Fig. 2, 3 and 4) is an argillaceous, lenticular lime wackestone to packstone, up to 6 in. (15 cm) thick. It has conodont abundances of 57/kilogram, including *Hindeodus* and *Idiognathodus*, with some phosphorite nodules. The base of the Mound City Shale is about 18 in (45 cm) thick and consists of gray-green shale with dark gray shale at the base. The dark gray shale yielded over 2860 conodonts/kilogram, including *Hindeodus, Idiognathodus, Idioprioniodus*, and *Gondolella*. It also contains abundant phosphorite. About 300 feet (90 m) to the west, this zone is a well laminated black phosphatic fissile shale. This represents the condensed interval of the core shale deposited at highstand or maximum transgression. The dark gray shale grades upward into gray/green shale with a conodont abundance of about 200/kilogram, including *Idiognathodus, Hindeodus,* and *Idioprioniodus*. The upper gray/green part of this shale has 446 conodonts/kilogram dominated by *Idiognathodus*, with sparse *Idioprioniodus. Gondolella* is conspicuously absent in the two samples above the dark zone. Above the lower shale is a 6 in. (15 cm) thick argillaceous, lenticular, lime wackestone to packstone. Conodont abundance is about 290/kilogram with abundant *Idiognathodus* and lesser numbers of *Hindeodus*, with *Idioprioniodus* absent. Phosphorite and glauconite are abundant as nodules and replaced fossils. Three hundred feet (90 m) to the west, this becomes a massive bed of lime wackestone with very little shale about 1 ft. (30 cm) thick. Above this is about 2.5 ft. (0.8 m) of gray/green shale. The base of this shale, just above the upper wackestone/packstone, has a conodont abundance of nearly 560/kilogram, with *Idiognathodus, Hindeodus*, and *Adetognathus* present, along with phosphorite and glauconite. The upper part of this shale yielded only 4 *Idiognathodus* elements. The zone of low conodont abundance, just above the dark gray zone of high abundance, may represent a shallowing of the sea. The interval of shale/limestone/shale with abundant phosphorite and glauconite, above the zone of low conodont abundance seems to represent a minor deepening event with relatively slow deposition, followed by shallowing into the photic zone where carbonate production and preservation produced the Sniabar Limestone. Most of the Mound City Shale represents relatively slow deposition in relatively deep water as shown by the abundance of conodonts and the presence of phosphorite and glauconite, that is nearly the same as seen at stop two. The upper Mound City Shale, above the conodont-rich dark gray zone, may represent a "phased regression" during the relatively early dominantly regressive phase of the Hertha cyclothem.

Figure 4. Close up of East Peru Limestone in exposed section at Stop 6 (knife for scale).

The base of the Sniabar Limestone Member is about 4 ft. (1.2 m) of wavy-bedded algal lime wackestone to packstone. It is probably very similar to that seen at Stop 5, but no petrographic work has been done at this location.

Overall the interval from the top of the Cooper Creek Limestone Member of the Lost Branch cyclothem to the base of the Sniabar Limestone Member of the Hertha cyclothem represents deposition in a wide variety of depositional environments. Distinct changes in the vertical stacking pattern and facies changes of these sediments over a very short lateral distance can probably be related to changes in topography, both on the sea floor and on the land surface.

STOP 7. STREAMCUT ALONG HWY. 92 EAST OF MARTENSDALE AT MIDDLE RIVER: SWEDE HOLLOW FM (Location: SW1/4 NE1/4 Sec. 12, T74N., R27W)

by Steven H. Emerman

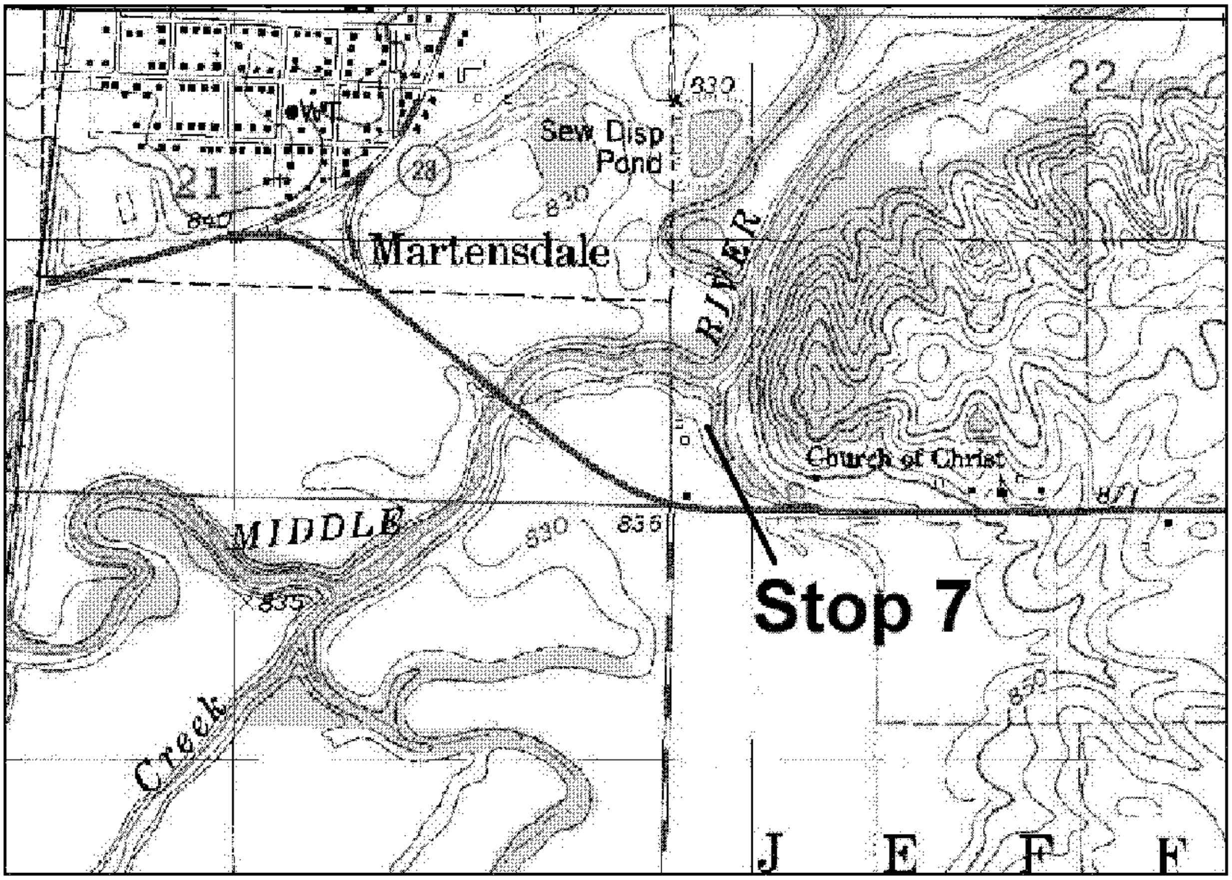


Figure 1. Location of GSI fieldtrip Stop 7 on a topographic map.

Springs emerge from bedding planes of fine-grained sandstone beds of the Swede Hollow Formation on the banks of the Middle River. Excellent plant fossils are found in this exposure. Frequent saturated conditions result in rotational slumping of large blocks of the Swede Hollow Formation. An unnamed tributary to the Middle River has a six-foot waterfall, which is easily the highest waterfall in Warren County (see Photo). The waterfall is maintained only by unconsolidated soil and is rapidly cutting headward. The waterfall is a highly transient feature and must result from very recent changes in land use.

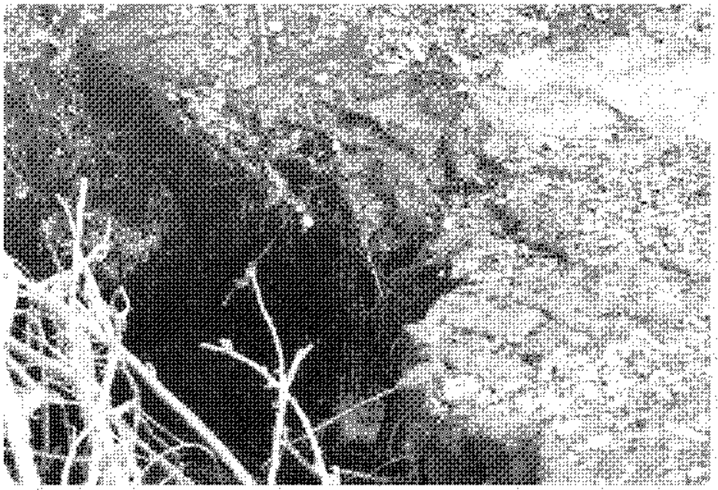


Figure 2. Waterfall at Stop 7 exposure.

ROAD LOG

SUNDAY, APRIL 30

miles	
0.0	Leave Lake Ahquabi State Park on Hwy. 349.
1.0	Turn right onto Hwy. 69 S.
8.9	Turn right onto G-76.
11.9	Turn right onto 80th Avenue (also called R-57).
12.5	**STOP 8** (parking area for Rolling Thunder Prairie State Preserve)
12.5	Turn around to head south on 80th Avenue.
13.1	Turn left onto G-76.
16.1	Turn left onto Hwy. 69 N.
24.0	Hwy. 69 N becomes Hwy. 65 / 69 N.
29.1	Turn right onto Hwy. 92 E.
33.4	Enter Ackworth.
33.5	Turn left onto 173rd Avenue.
34.7	Turn left onto S-23.
35.6	Turn left onto Keokuk Street.
36.9	Keokuk Street becomes 193rd Avenue.
37.0	193rd Avenue becomes Kirkwood Street.
37.3	Turn left into Woodland Mounds State Preserve.
37.6	Park at Woodland Mounds State Preserve (**STOP 9**).

STOP 8: ROLLING THUNDER STATE PRESERVE (Location: Sec 19, T74N, R24 W)

by Steven H. Emerman

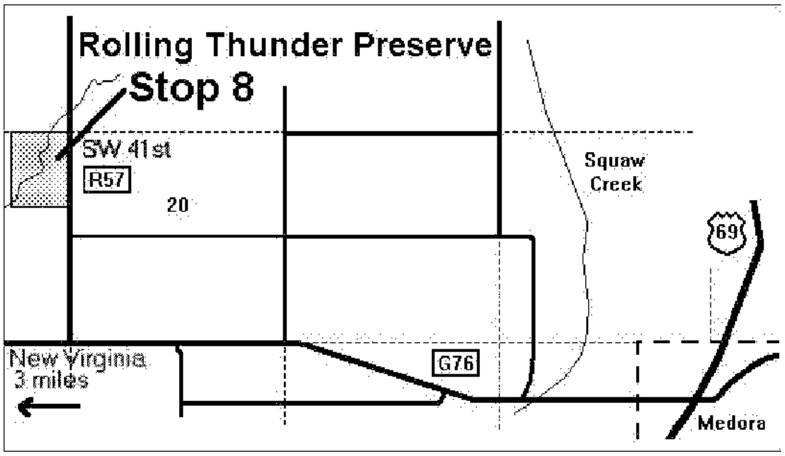


Figure 1. Location of Rolling Thunder State Preserve in southwestern Warren County.

Rolling Thunder Prairie is a tallgrass prairie on a steeply rolling landscape. The area, classified as a biological and geological preserve, includes 123 acres and was dedicated in 1983. It is owned and managed by the Warren County Conservation Board.

This region of Iowa was last glaciated over 500,000 years ago, but the soils have been leached since then, resulting in higher clay content and lower nutrient levels compared to soils in the more recently glaciated part of the state. The well-drained topography is characteristic of the Southern Iowa Drift Plain.

Vegetation ranges from dry prairie dominated by needlegrass and junegrass along the ridgetops to mesic prairie dominated by big bluestem and Indian grass on the slopes, to woodland along the creek bottom. The site was grazed before acquisition as a preserve. Fire management is being used to control the growth of trees and shrubs.

The dominant tallgrass prairie species at Rolling Thunder Prairie State Preserve, big bluestem, little bluestem, indiangrass, switchgrass and prairie cordgrass, are being invaded by woody plants such as smooth sumac, rough-leaf dogwood and multiflora rose (see Fig. 2). Measurements with the Guelph permeameter show that saturated hydraulic conductivity is significantly lower on the prairie side of the prairie / forest boundary. The suggestion is that the prairie ecosystem attempts to repel woody invaders by maintaining a dry soil (see "The Control of Infiltration as a Mechanism for the Self-Regulation of prairie Ecosystems: Preliminary Studies at Rolling Thunder Prairie State Preserve, Warren County Iowa," beginning on page 19 of this guidebook.).

The photo below (Fig. 2) is a view to the west. The moister east-facing slope in the background has already been completely overrun by trees. On the west-facing slope in the foreground, smooth sumac in flower is steadily advancing up a ravine.

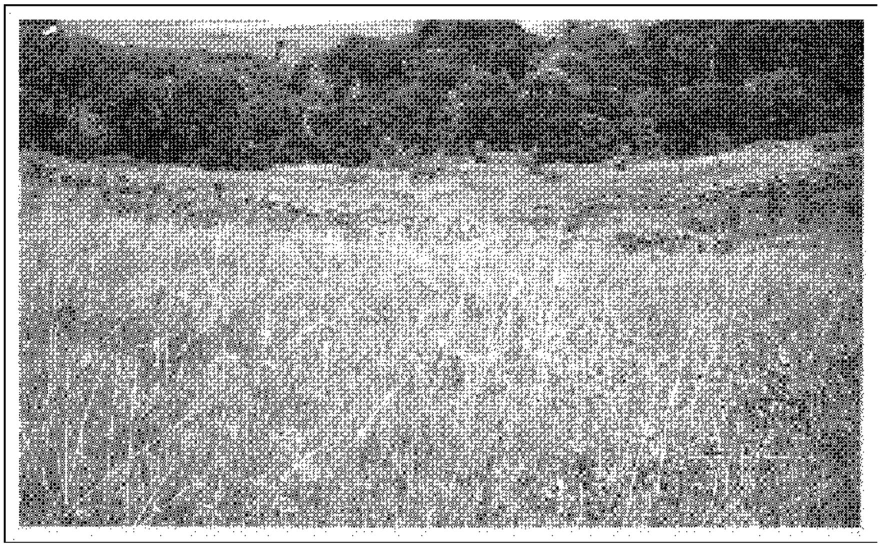


Figure 2. Photograph of slope in Rolling Thunder State Preserve, Stop 8. See associated text for discussion.

STOP 9: WOODLAND MOUNDS STATE PRESERVE (Location: Secs 19, 30, 31, T76N, R22 W)

by Steven H. Emerman

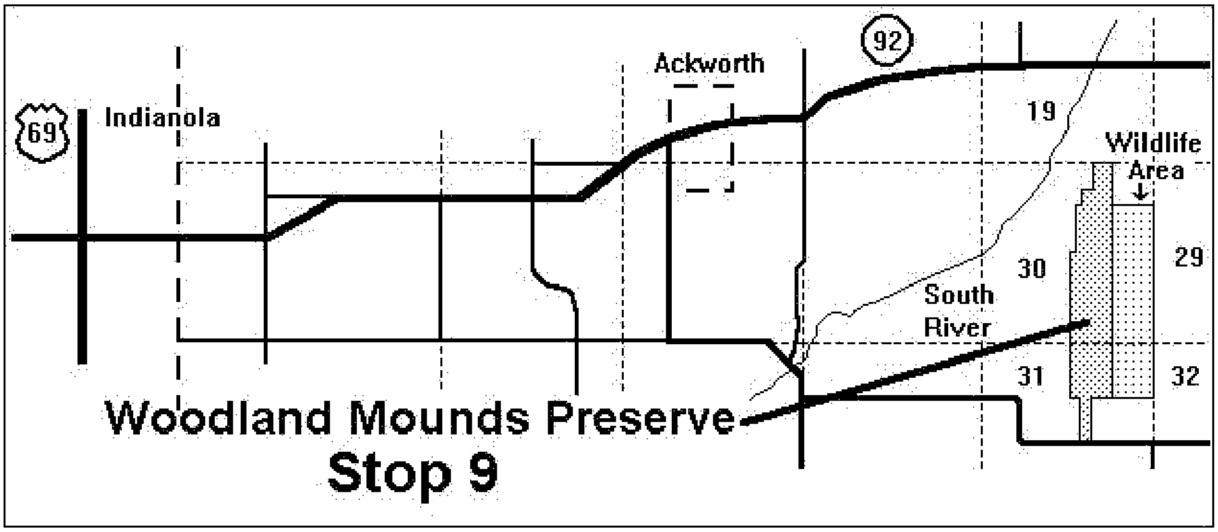


Figure 1. Location of Woodland Mounds State Preserve in eastern Warren County.

Woodland Mounds is a 195-acre archaeological and biological preserve preched on a ridge overlooking the South River valley in eastern Warren County. The area is owned and managed by the Warren County Conservation Board and was designated a State preserve in 1983. Several steep ravines cross the preserve. This steep topography is typical of the Southern Iowa Drift Plain, a landscape last glaciated 500,000 years ago.

Plant communities on the site include floodplain woodland dominated by hackberry and upland woodland dominated by red and white oak and hickory.

Abandoned meander scars of the South River cut through steep forested hillsides in Woodland Mounds State Preserve. The meander scars expose sandstone, siltstone, shale and coal beds of the Swede Hollow Formation (see Fig. 2).

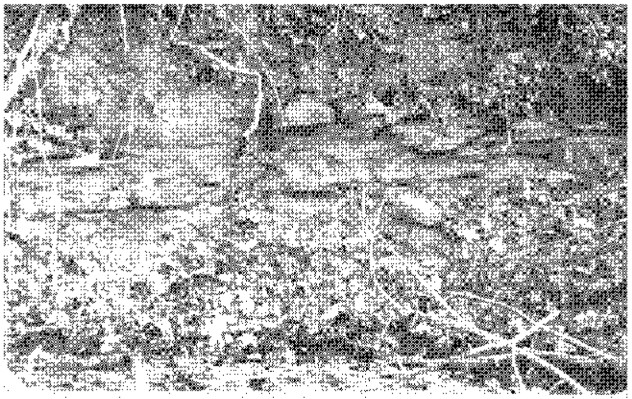


Figure 2. Rocks of the Swede Hollow Formation exposed at Stop 9.

Burial mounds built by the Woodland people between 500 B.C and 1000 A.D. are found at Woodland Mounds State Preserve. Beautiful examples of these mounds are seen in a clearing in the woods (see Fig. 3).

Figure 3. Burial mounds at Woodland Mounds State Preserve.

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Geological Society of Iowa
Spring 2000 Field Trip

FROM BRACHIOPODS TO BIG BLUESTEM: THE CYCLOTHEMS, STRATIGRAPHY AND STRUCTURE OF MADISON AND WARREN COUNTIES, IOWA