PENNSYLVANIAN EXPOSURES IN THE WHITE BREAST RECREATION AREA, MARION COUNTY, IOWA

John P. Pope, Adrian E. Goettemoeller,
and Raymond R. Anderson

Geological Society of Iowa
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Iowa Geological and Water Survey

April 20, 2013 Guidebook 91

Cover photo shows the field trip stop area, Pennsylvanian exposure on the south-facing shore of the White Breast Recreation area at Lake Red Rock.

PENNSYLVANIAN EXPOSURES IN THE WHITE BREAST RECREATION AREA, MARION COUNTY, IOWA

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PENNSYLVANIAN EXPOSURES IN THE WHITEBREAST RECREATION AREA, MARION COUNTY, IOWA,
INTRODUCTION TO THE FIELD TRIP

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The GSI 2013 spring field trip will include just one stop, a very spectacular sequence of rocks including a suite of thin silt and clay beds, probably deposited in an estuary by the daily waxing and waning of the tides in the Pennsylvanian seas 309 million years ago. These features are known as tidal rhythmites and were deposited in a stagnant river valley by the tidal effects of a transgressing seaway. They are capped by a thick sandstone that was deposited in the main channel of the river as it reached the sea. The details of the stratigraphy of this exposure has not yet been determined, but the sandstone unit is tentatively associated with the Floris Formation, which includes Cherokee Group units including strata from near the base of the Laddsdale Coal, just above the top of the Kalo Formation, to the base of the Oakley Shale Member of the Verdigris Formation (Pope, 2012). Also visible at the site is a complex sequence of Pennsylvanian sediments including a white to light gray blocky mudstone interpreted as a paleosol, a soil developed on the banks of the ancient river. A coal bed lies above the paleosol, and it is overlain by a black shale, interpreted as a deep water marine shale deposited during maximum transgression

Field trip exposure showing Pennsylvanian channel sandstone above tidal rhythmite paleovalley fill.

To get to the field trip stop we will drive east from Indianola, through Knoxville, then north on 165th Avenue (T-15) then north on S-71 to the Corps of Engineers Whitebreast Recreation Area on the south shore of Lake Red Rock. We will proceed through the campground to the parking area near the Whitebreast Shelter on the far north end of the recreation area. We will then hike down to the lake on the White Breast Creek side of the peninsula.

All of this field trip will be on U.S. Army Corps of Engineers land and no collecting of rocks or other natural materials is allowed. But, you are encouraged to take lots of photographs and ask lots of questions and take a better knowledge of these rocks and processes away. Enjoy the field trip and be safe.

REFERENCES

Pope, J.P., 2012, Description of Pennsylvanian Units, Revision of Stratigraphic Nomenclature, and Reclassification of the Morrowan, Atokan, Desmoinesian, Missourian, and Virgilian stages in Iowa. Iowa Geological and Water Survey, Special Report SR-5, 140p.

OVERVIEW OF LAKE RED ROCK AND THE WHITE BREAST RECREATION AREA

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Lake Red Rock

Lake Red Rock is Iowa's largest flood control reservoir with 19,000 surface acres (USA Corps of Engineers, 2002). The reservoir is operated by the U.S. Corps of Engineers on the Des Moines River, in Marion County about 5 miles north of Knoxville (Fig. 1). Lake Red Rock is Iowa's largest single expanse of public lands with over 50,000 acres. The reservoir is a multi-use area: with camping, hiking, biking, nature areas and a visitor information center. The area encompasses 47,610 acres of U.S. government lands managed by the Corps of Engineers, 25,572 acres under long-term lease to the Iowa Department of Natural Resources (DNR) as a wildlife management area (the Red Rock Wildlilfe Unit – one of the largest in the state), as well as 2,218 acres managed by the DNR as Elk Rock State Park on the southern edge of Lake Red Rock. Additionally, the Corps leases 2,622 acres to the Marion County Conservation Board, which manages the area as Roberts Creek and Cordova County Parks, north of the lake.

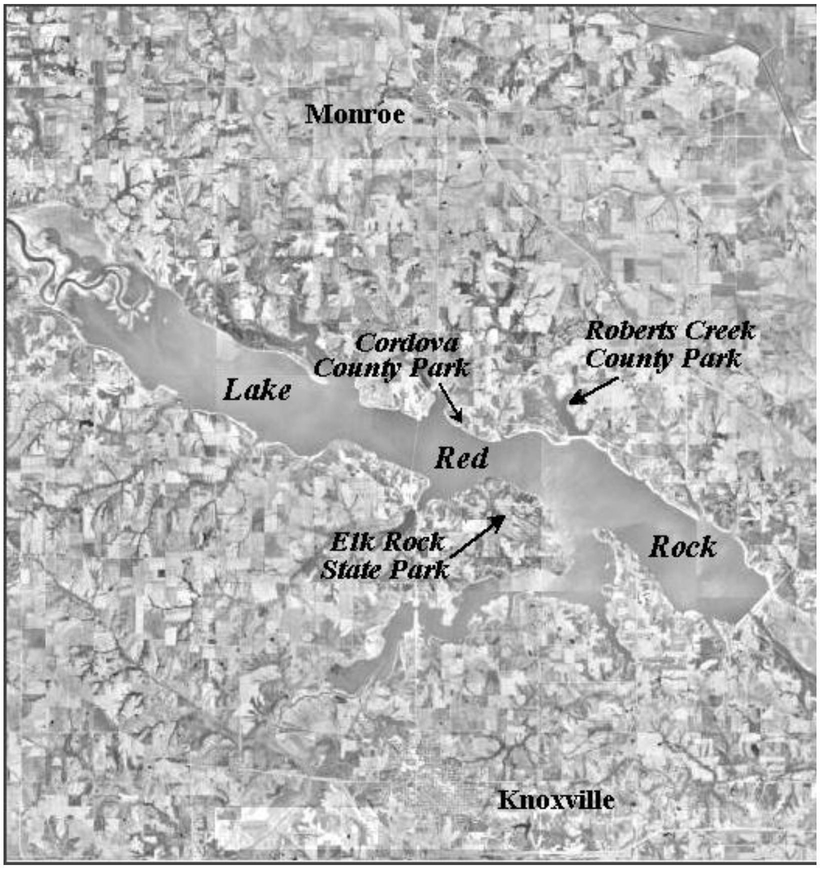


Figure 1. Composite of Digital Orthophoto Quadrangles of the Lake Red Rock Area (from Iowa Geographic Image Map Server).

The Red Rock Dam was authorized by the Congress for flood control purposes. After nine years of construction, the U.S. Army Corps of Engineers completed the mile-long earthen dam (Fig. 2) in 1969. The dam is constructed of embankments made of slowly-permeable clay material with a sand layer that allows for drainage of seepage water. Large blocks of limestone, called rip rap, protect the embankments from wave action on the lake side of the dam. The downstream or riverside of the embankment is covered with a layer of topsoil and seeded with grass. Fourteen hydraulically-operated Sluice Gates (Fig. 3) located inside the dam control structure move lake water past the dam to continue the flow of the Des

Figure 2. Photograph of the Red Rock Dam.

Moines River. Each gate is five feet wide and nine feet tall and are used when lake outflow is less than 38’000 cubic feet per second (one cubic foot is equal to 7.5 gallons of water). When greater water discharges are desired, the water flows over a controlled spillway, which unlike most dam spillways is capable of controlling the amount of water that passes over the dam. The spillway water is controlled by a series of Tainter Gates (Fig. 3), each 41 feet wide and 45 feet tall that allow control of the flood pool level. Water from both the Sluice Gates and the Tainter Gates empty into a Stilling Basin. The Stilling Basin acts to slow the velocity of the water coming through and over the dam, reducing downstream bank erosion. To slow the water, 25 baffles were placed in two rows in the basin, each baffle the size of a passenger van.

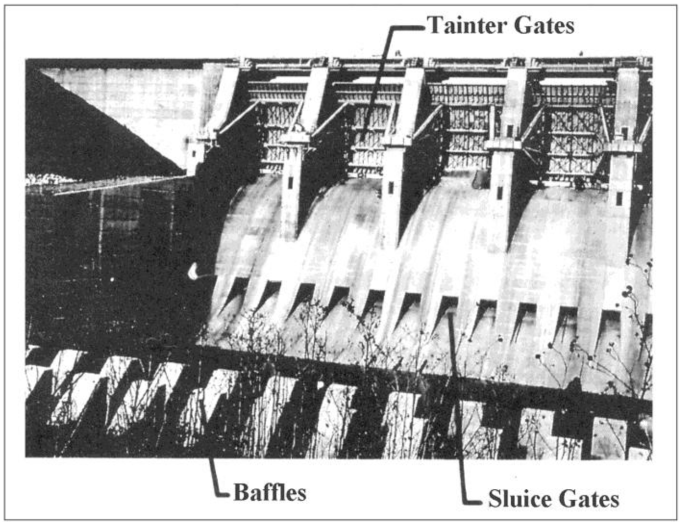


Figure 3. Photo of Red Rock Dam Control Structure showing gates and baffles. Photo from US Army Corps of Engineers.

At the lake's standard elevation of 742 feet above sea level, it has a surface area of 19,000 acres of water. When heavy rains occur in the lake's 12,000 square-mile watershed, the lake can triple in size. Flooding in 1993 pushed the lake to a height of 782.67 feet above-sea-level, creating a lake with an area greater than 70,000 acres. It is interesting to note that the normal maximum pool level for Red Rock Lake is 780 feet, but the lake's spillway is controlled and allows an emergency flood pool level of 791 feet. The Corps owns land around the lake up to the 783 foot level, and could presumably be liable for damages by flood above that level, so they are would be very reluctant to allow waters to rise above that level. Iowa State Highway 14 crosses the lake on the "mile long bridge" (Fig. 4).

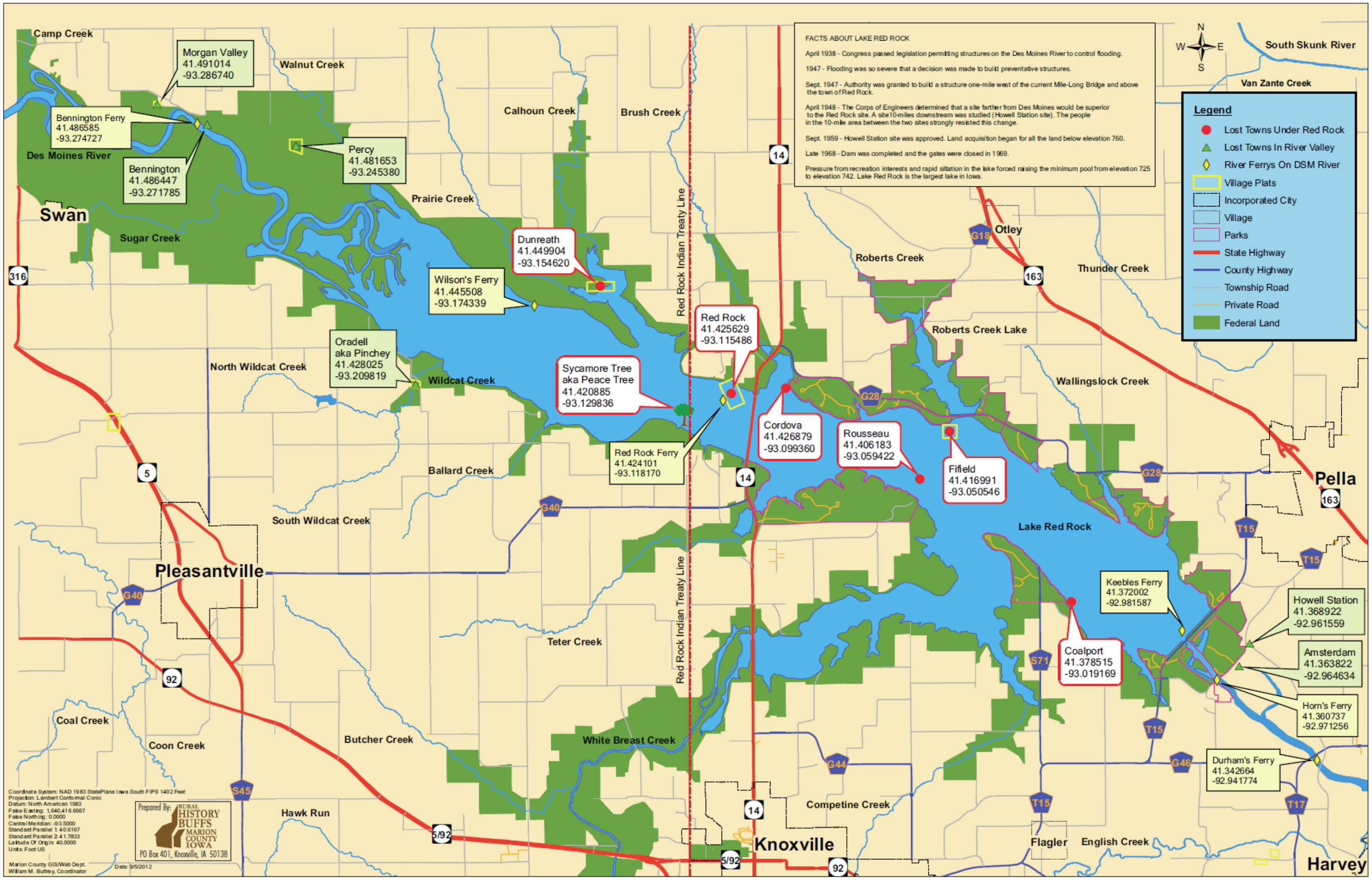
Figure 4. Photograph of the Highwy 14 "mile-long bridge".

While the primary purpose of the dam is controlling water levels on the Des Moines River, another important purpose has evolved over the last two decades. Lake Red Rock has become a premier location for enjoying uncrowded outdoor recreation opportunities. Over 50,000 acres of diverse habitat, from sandy shoreline to wooded rocky bluffs, provides homes to hundreds of wildlife species. Large numbers of whitetail deer can be seen throughout the lake area and river otters are seen occasionally along the shoreline. The large area of open water and extensive associated habitat attracts large numbers and varieties of birds, both permanent inhabitants and migrators. In her web publication on ***Birding the Red Rock Area***, Ann Johnson (2002) stated that "*Although by most standards this area has been under-birded, about 300 species of birds have been found here in the past 20 years. With better coverage, who knows what might be found!*" She goes on to mention a number of the bird species that have been reported in the area and she suggests the best localities to observe them. Birds identified in her article include loons, grebes, herons, cormorants, ducks, pelicans, and gulls. Scarlet Tanagers, Kentucky Warblers Willow Flycatchers, Yellow Warblers, Bell's Vireos, Red-breasted Nuthatches and Long-eared Owls have also been observed. She mentions shorebirds such as Buff-breasted and Baird's sandpipers, Sanderling and Ruddy Turnstones. Ms. Johnson notes that Peregrines Falcons are seen nearly every fall, and a Cooper's Hawk nested near the lake a few years ago. White pelicans migrate through the Lake Red Rock area every spring and fall, and large numbers of waterfowl migrate through the lake every spring and fall.

Also present in large numbers are bald eagles, observed in particularly large numbers during winter months (November through March). Eagles were well on their way to extinction and were eventually included on the federal list of endangered species. But since the 1972 federal ban of the use of the pesticide DDT (which produces thin-shelled eggs in many bird species), bald eagles have been making a huge comeback in Iowa and nationally. Iowa did not have a nesting pair of the eagles for 70 years before one was spotted in 1977, and a second pair was not seen until 1982. Then populations expanded rapidly, with five to 10 nesting pairs appearing in the state every year. Today Iowa Department of Natural Resources biologists estimate the state now has 130 nesting pairs in 54 counties.

The Lost Towns Under Lake Red Rock

The construction of Lake Red Rock flooded 15,520 acres (normal pool) to about 70,000 acres (maximum flood pool) of land along the Des Moines River. This included six Marion Iowa towns and many other areas of historic interest. Figure 5 is a map of the lake area, listing and locating the six towns and other features



FACTS ABOUT LAKE RED ROCK

April 1938 - Congress passed legislation permitting structures on the Des Moines River to control flooding.

1947 - Flooding was so severe that a decision was made to build preventative structures.

Sept. 1947 - Authority was granted to build a structure one-mile west of the current Mile-Long Bridge and above the town of Red Rock.

April 1948 - The Corps of Engineers determined that a site farther from Des Moines would be superior to the Red Rock site. A site10-miles downstream was studied (Howell Station site). The people in the 10-mile area between the two sites strongly resisted this change.

Sept. 1959 - Howell Station site was approved. Land acquisition began for all the land below elevation 760.

Late 1968 - Dam was completed and the gates were closed in 1969.

Pressure from recreation interests and rapid siltation in the lake forced raising the minimum pool from elevation 725 to elevation 742. Lake Red Rock is the largest lake in Iowa.

Coordinate System: NAD 1983 StatePlane Iowa South FIPS 1402 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
False Easting: 1,640,416.6667
False Northing: 0.0000
Central Meridian: -93.5000
Standard Parallel 1: 40.6167
Standard Parallel 2: 41.7833
Latitude Of Origin: 40.0000
Units: Foot US

Marion County GIS/Web Dept.
William M. Buttrey, Coordinator

Figure 5. Map of Lost towns under Red Rock Reservoir The under Six Marion County river towns and other historical points of interest that were lost in the development of Red Rock Reservoir. Prepared by Rural History Buffs of Marion County, Iowa, 2012

prepared by the Rural History Buffs of Marion County, Iowa (2012). The towns include Rousseau, Coalport, Cordova, Redrock, Dunreath, and Fifield.

Elk Rock State Park

Elk Rock State Park is located on southern shore of Lake Red Rock, just east of Iowa Highway 14 (Fig. 5). The park includes 2,218 acres, and along with the traditional camping, hiking, and fishing facilities, the park features an equestrian campground with 13 miles of equestrian trails. The park also allows mountain bikes on the trails.

The area in and around Elk Rock State Park was inhabited by American Indians for more than five thousand years, back to the Archaic Culture. In 1842, the Sac and Fox Indians granted white settlers right to this land. The name "Elk Rock" has been attributed to the unusual rock formation, which is located on the south side of the river in the park. With the influx of Euro-American settlers and traders, many small towns sprung up along the Des Moines River in the Red Rock area. They included: Cordova, Cunreath, Fifield, Percy, Red Rock and Raouseau. All these settlements existed in the area now covered by Lake Red Rock.

The State once leased land both north and south of the lake. The lease on the land north of the lake, known as North Elk Rock, was not renewed by the state because of the difficulties in managing two non-adjacent areas. That northern area is now managed by Marion County as Cordova County Park. In 1978, the state obtained a lease for property on the south shore of the reservoir. This land became known as South Elk Rock. Today Elk Rock State Park comprises the main southern Elk Rock Park area, which has both day and night facilities, and the bridge area that is a day use picnic area (Iowa DNR, 2002).

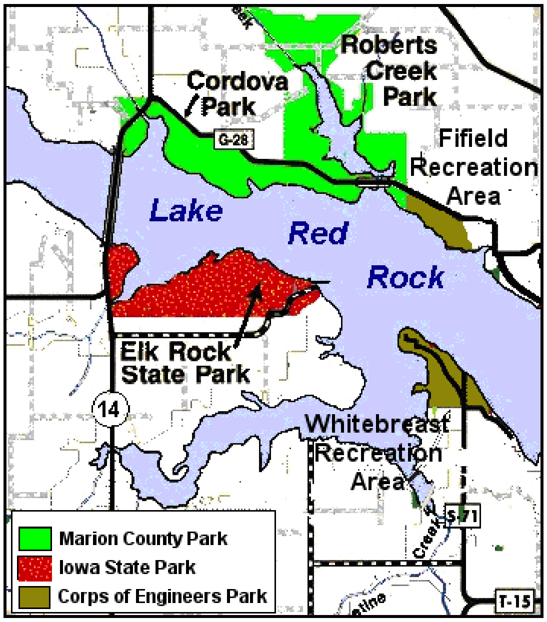


Figure 5. Location of Elk Rock State Park and Roberts Creek and Cordova County Parks.

Cordova and Robert's Creek County Parks

Cordova County Park is located on the north side of Lake Red Rock, off County Road G-28 (Fig. 5). Managed by the Marion County Conservation Board, the park boasts 7 cabins for rent year-round. The park also offers a nature trail, picnic facilities, and a boat ramp. A new observation tower is also open throughout the year.

Robert's Creek County Park is also located on the north side of Lake Red Rock, just east of Cordova Park (Fig. 5). Managed by the Marion County Conservation Board, the park provides two camping areas, a hiking trail, and two boat ramps with access to Robert's Creek. (from Lake Explorer, 2002).

Fifield Recreation Area

Fifield offers a fantastic location for a picnic! This recreation area includes four reservable picnic shelters and access to the Volksweg bike trail. A playground and modern restrooms are also available.

Whitebreast Recreation Area

The U.S. Army Corps of Engineers Whitebreast Recreation Area is located on a peninsula of land that is bounded by Lake Red Rock, with the flooded valley of White Breast Creek bounding it on the west.

The recreation area includes a campground with 128 camping spots, a group camp, access to a boat ramp, swimming beach, an amphitheater, playgrounds, hiking trail, fish cleaning station, numerous picnic shelters and shower facilities. Wildlife is abundant around Lake Red Rock.

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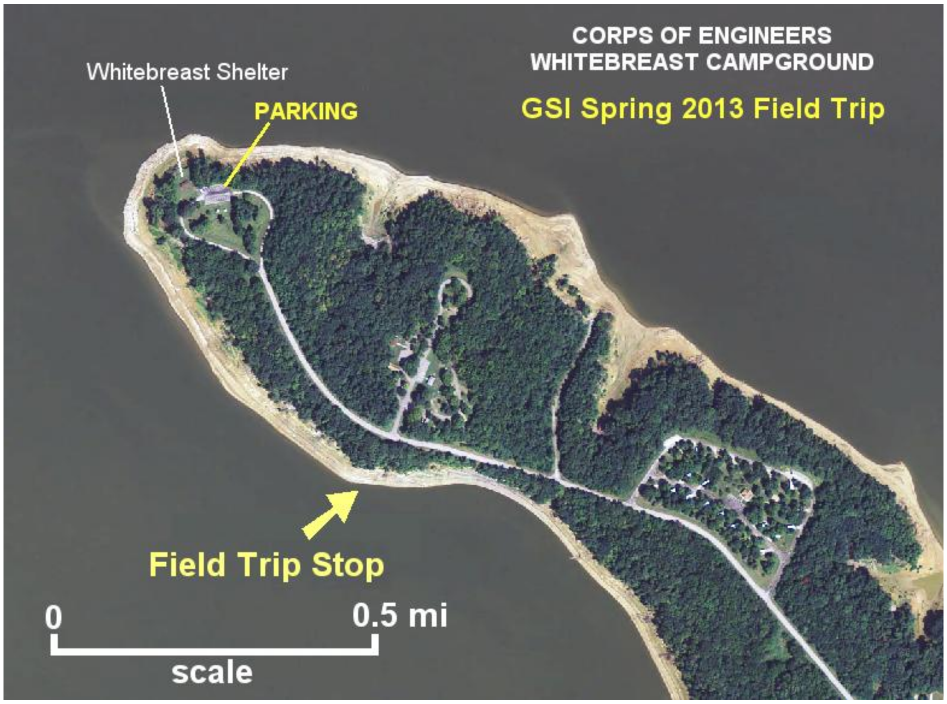
USA Corps of Engineers, 2002, Welcome to Lake Red Rock - The Largest Lake In Iowa, Rock Island District Internet, Lake red rock corps web page http://www.mvr.usace.army.mil/redrock/default.htm

Lake Explorer, 2002, The Official Guide to Lake Red Rock, Lake Red Rock Association, Pella, IA.

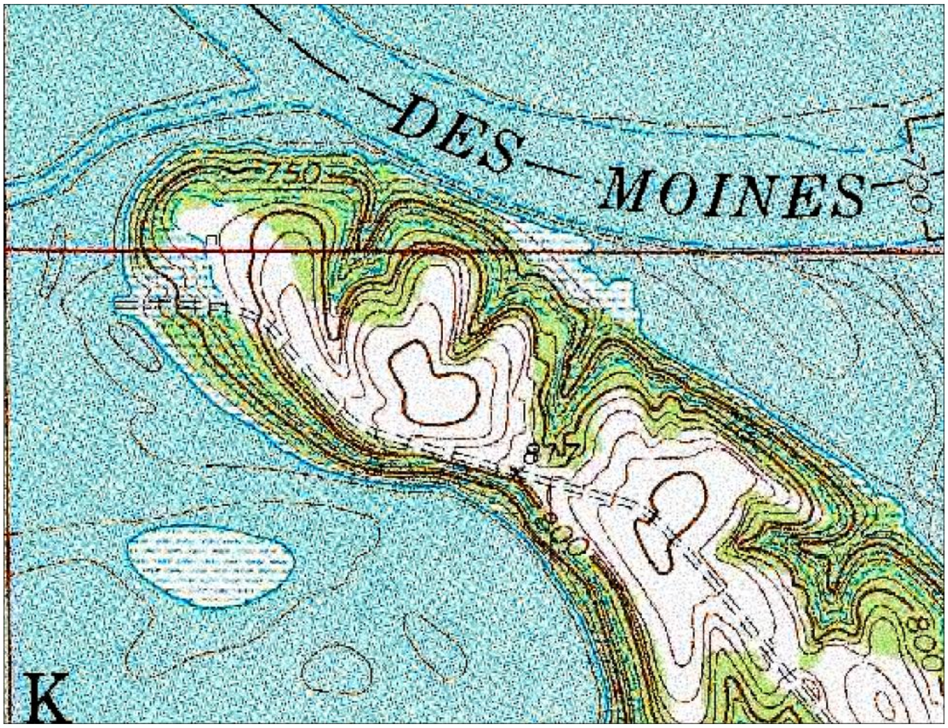
Rural History Buffs of Marion County, Iowa, 2012, The Lost Towns of Lake Red Rock. Published Brochure, PO Box 401, Knoxville, IA 50138. http://www.co.marion.ia.us/maps/historical/LostTownsOfLakeRedRock_Brochure.pdf

IMAGES AND MAPS OF THIS AFTERNOON'S FIELD TRIP STOP

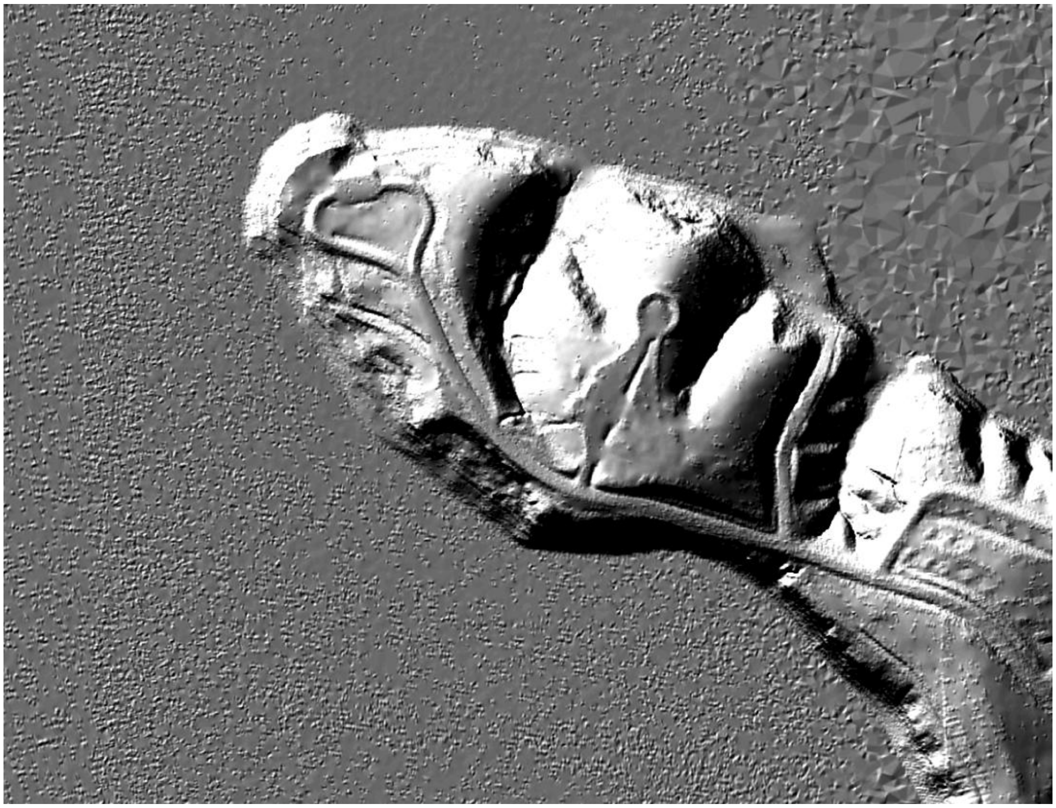
All maps and images from Iowa DNR Natural Resources Geographic Information Systems Library (NRGIS), developed and maintained by the GIS Section of the Iowa Geological and Water Survey. http://www.igsb.uiowa.edu/nrgislibx/



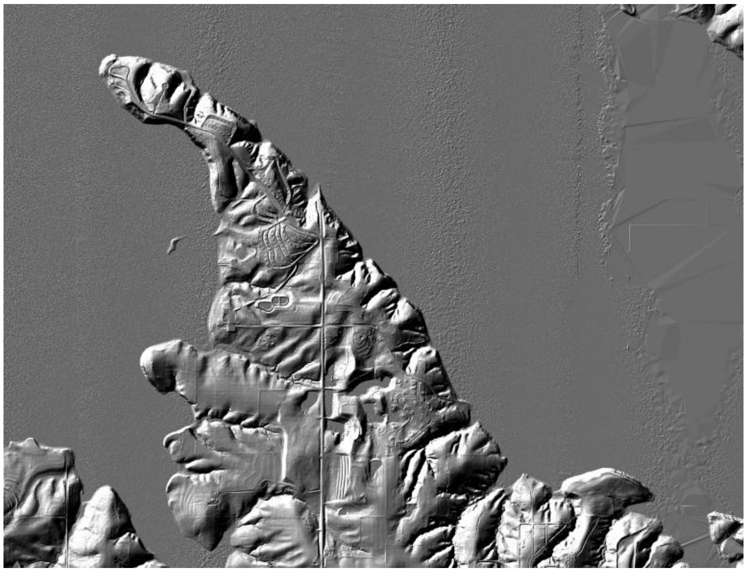
2010 color aerial photo of the White Breast Campground and location of field trip stop.



USGS 7 ½ minute Topographic Map, Otley Quadrangle 1965. c.i.=10 feet



LiDAR (Light Detection and Ranging) images collected in April 2009. To collect LiDAR data a plane flying at an elevation of about 5,000 feet shoots up to 150,000 laser pulses per second towards the ground. These hit the surface and bounce back to a receiver which measures time from pulse to return (providing data to interpolate elevation values) and intensity (measure of reflectance percentage values depending on surface type). This produces elevation measurements with 1m accuracies or better in most cases. This image is a hillshade of the Digital Elevation Model (DEM) which is a shaded relief raster created by taking an elevation raster and setting an illumination source at a user specified azimuth and altitude.



OVERVIEW OF LOWER DESMOINESIAN (PENNSYLVANIAN) STRATIGRAPHY IN SOUTH-CENTRAL IOWA

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PENNSYLVANIAN PALEOGEOGRAPHY AND THE MIDCONTINENT BASIN

During the Pennsylvanian or Late Carboniferous, Euramerica (North America and Europe) were joined to the rest of the continents in the south (Gondwana) by the Appalachian-Hercynian Orogenic belts. The Caledonian Mountains extended from the northern Appalachians thru the present day United Kingdom, Greenland, and Norway (Fig. 1). Together, Euramerica and Gondwana comprised the assembling supercontinent of Pangea, with most of its land area in the southern hemisphere. During this time, most of the midcontinent lay within a few degrees south or north of the equator (Heckel, 1999).

The sediments deposited during the Pennsylvanian are now exposed in several structural basins including the Appalachian, Michigan, Illinois, and Midcontinent (Fig. 2). In addition, there were a number of smaller tectonic basins in the western United States.

The Midcontinent or Western Interior Basin (Fig. 2) extends from southwest Iowa, northwest Missouri, and Nebraska in the north, to central Oklahoma to the south. It extends westward from west-central Arkansas to eastern Colorado at essentially the position of the present day Front Range of the Rocky Mountains. The northern part of the basin is known as the Northern Midcontinent Shelf and contains three main structural features: the Nemaha Uplift, the Bourbon Arch and, the Forest City Basin. The southern part of the basin contains the forearc Anadarko and Arkoma basins, north of the Arbuckle-Wichita-Amarillo uplift and the Ouachita uplift, respectively. During times of low sea-level stand, the Midcontinent Basin was open to the Panthalassa Sea (Protopacific Ocean) thru the Oklahoma basins and the Midland Basin of western Texas, but most of the area north and east of the Oklahoma basins was subaerially exposed. During times of high sea-level stand, most of the present United States north of the Ouachita Mountains and west of the Appalachian Mountains was covered by a relatively shallow epiric sea (Heckel, 1999).

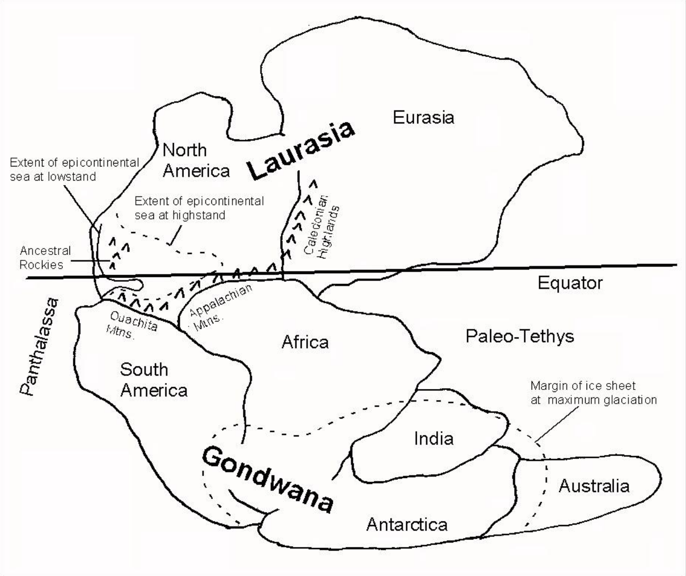

Figure 1. Paleogeography of the assembling supercontinent of Pangea. The outline of the North American Epicontinental Sea is shown at lowstand and highstand, as well as the maximum extent of glaciation in Gowganda. Modified from Heckel (1995) and Scotese (2000).

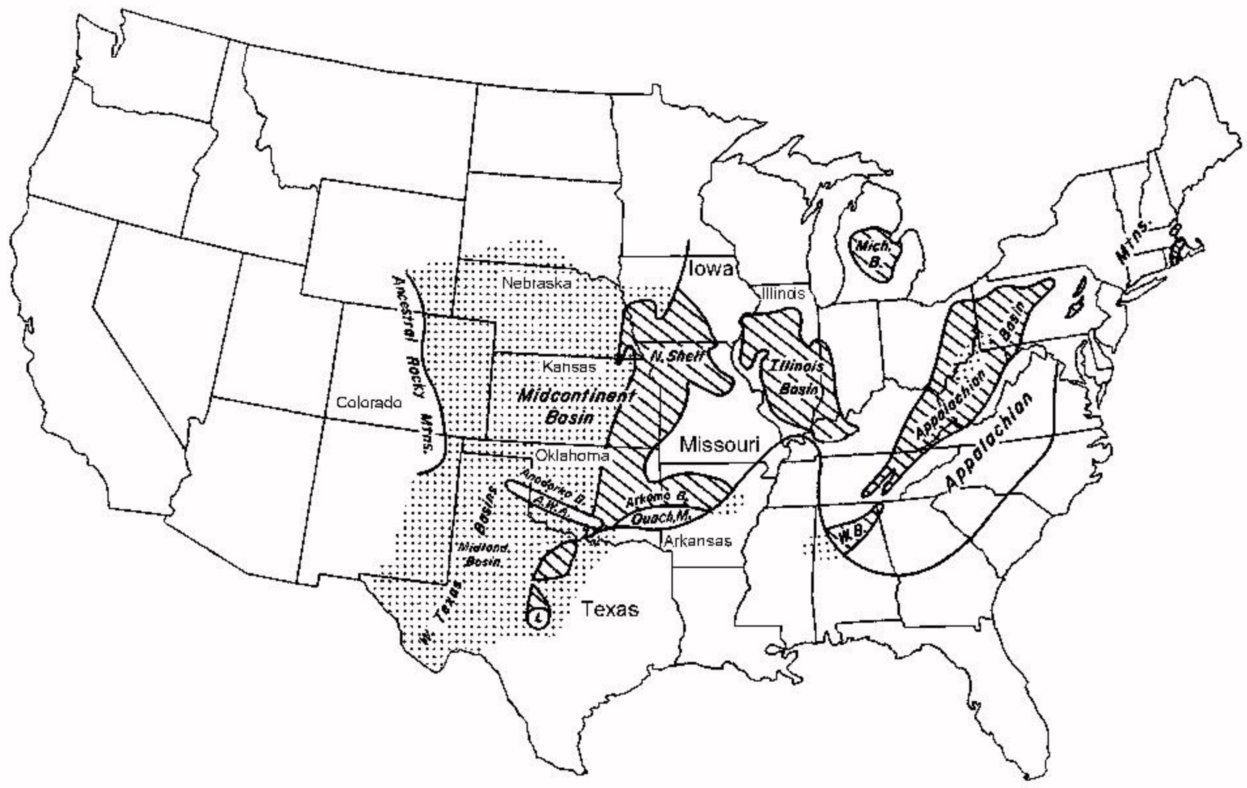

Figure 2. Pennsylvanian Structural Features of the United States (modified from Heckel (1999)). AWA = Amarillo – Wichita – Arbuckle Uplift, L = Llano Uplift, WB = Warrior Basin, lined area = outcrop, dots = subsurface.

REGIONAL STAGES AND THE DESMOINESIAN STAGE

The Midcontinent Basin is the area in which the North American regional stage names were established. They are in ascending order: Morrowan, Atokan Desmoinesian, Missourian, and Virgilian. The Morrowan is lower Pennsylvanian, the Atokan and Desmoinesian are middle Pennsylvanian, and the Missourian and Virgilian are upper Pennsylvanian. This part of the fieldtrip will highlight selected exposures of the Desmoinesian Stage near Red Rock Lake in Marion County of south-central Iowa.

In Iowa, the major area of deposition and present exposure of Pennsylvanian sediments is the Forest City Basin that occupies about the southwestern third of the state. Here Pennsylvanian strata unconformably overlie Mississippian carbonates and generally dip to the south and west. Nearly 1700 feet (520 m) of Pennsylvanian sediment are known in the subsurface of southwestern Iowa. To the northeast successively older Paleozoic strata are exposed, while to the north and northwest the Pennsylvanian deposits are unconformably overlain by Cretaceous deposits of the Dakota Formation.

The Desmoinesian Stage was derived from the Des Moines formation named by Keyes (1893) from outcrops along the Des Moines River in Iowa. In Iowa, it is comprised of a succession of cyclic shales, sandstones, coals, and rare limestones. It is generally less than 940 feet (285 m) thick in Iowa, but thickens to about 6600 feet (2000 m) in the Arkoma Basin of Oklahoma (Heckel, 1999).

The Desmoinesian is characterized by the presence of the fusulinid foraminifer *Beedeina* (*Fusulina*), chaetetid sponges, the conodont *Neognathodus*, brachiopods *Mesolobus* and *Desmoinesia*, certain ammonoid cephalopods, and plants represented by aborescent and subaborescent lycopods, ferns, calamites, and cordaites.

Cherokee and Marmaton Groups

The Desmoinesian Stage is subdivided lithostratigraphically into the Cherokee and Marmaton Groups in ascending order (Fig. 3). Only sediments of the Cherokee Group will be examined during this trip.

The Marmaton Group encompasses the uppermost Desmoinesian and is comprised of several limestone-dominated cyclothems representing more open marine conditions than those conditions represented by Cherokee cyclothems. The marine units are separated by locally thick shales, mudstones, sandstones, and some coals.

The Cherokee Group was named by Haworth and Kirk (1894) for exposures in Cherokee County, Kansas. It comprises a succession of shale-dominated, coal bearing cyclothems, with locally prominent sandstones and rarer thin limestones. It is about 800 feet (245 m) thick in extreme southwest Iowa, but thins to the east in the outcrop belt of south-central Iowa to 500 feet (150 m). The Cherokee contains most of the coal resources of Iowa.

The Cherokee Group appears to represent four major episodes of sedimentation, with each major episode comprised of several minor, intermediate, and in one case a major scale cyclothem (a transgressive-regressive allostratigraphic unit mainly resulting from the glacial-eustatic rise and fall of sea-level) (Ravn et al., 1984). In ascending order these major lithostratigraphic packages, each delineated by certain characteristics, are designated the: Kilbourn, Kalo, Floris, and Swede Hollow formations (Fig. 3).

In Iowa, the Cherokee is divided into a lower and upper part. The Kilbourn, Kalo, and Floris formations from the Mississippian-Pennsylvanian unconformity to the base of the Whitebreast Coal comprise the lower Cherokee Group. The Swede Hollow Formation includes strata from the base of the Whitebreast Coal to the base of the Excello Shale and comprises the upper Cherokee Group. The Swede Hollow includes the only major marine cyclothem of the Cherokee Group and generally records a period of increasing marine influence on sedimentation in southern Iowa (Pope, and Chantooni, 1996). This field trip will focus on the lower Cherokee formations, especially the Floris Formation, but may include some of the upper Kalo Formation.

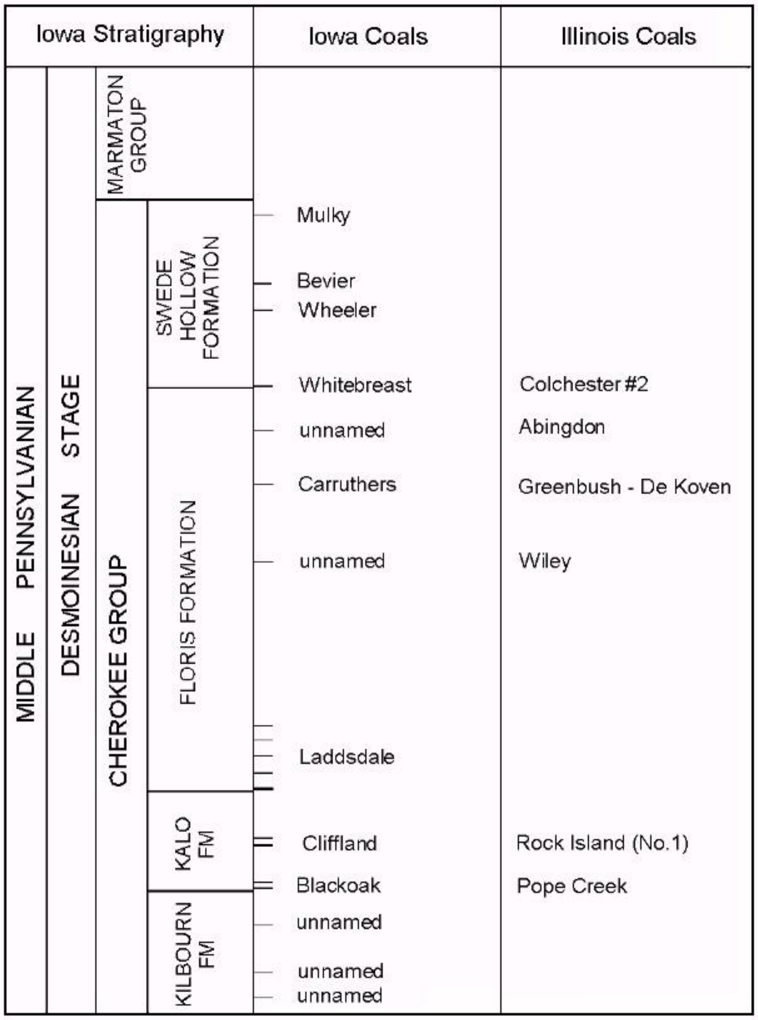

Figure 3. Cherokee Group coals of Iowa and Illinois (modified from Ravn, 1986).

Kilbourn Formation

The Kilbourn Formation was named for exposures near the town of Kilbourn in Van Buren County, Iowa by Ravn et al. (1984). It comprises basal Cherokee Strata that rest unconformably upon Mississippian rocks and extends upward to the base of the Blackoak Coal of the Kalo Formation. The Kilbourn represents initial deposition on the land surface that was being developed on argillaceous Mississippian carbonates. Stream incision on these carbonates had produced a surface of considerable relief and irregularity (Fig. 4). The distribution and orientation of these stream valleys was controlled by regional dip, structural trends, outcrop distribution and karst development. Kilbourn deposition was the result of gradual subsidence in the Forest City Basin in combination with several eustatic marine transgressions and regressions (Ravn et al., 1984). This deposition predominantly took place in the incised paleovalleys during rise in relative sea-level while pedogenesis (soil formation) and erosion continued on the interfluves. As many as seven depositional cycles are encountered in the subsurface of south-central Iowa, dominated by nonmarine sandstones, shales, siltstones, and coals. Thin marine shales and limestone were deposited in the distal ends of estuaries and river systems during maximum transgression. Most of the sediments are thin and discontinuous, but eventually filled in the paleovalleys that had developed on the Mississippian erosional surface and nearly leveled the topographic relief (Fig. 5).

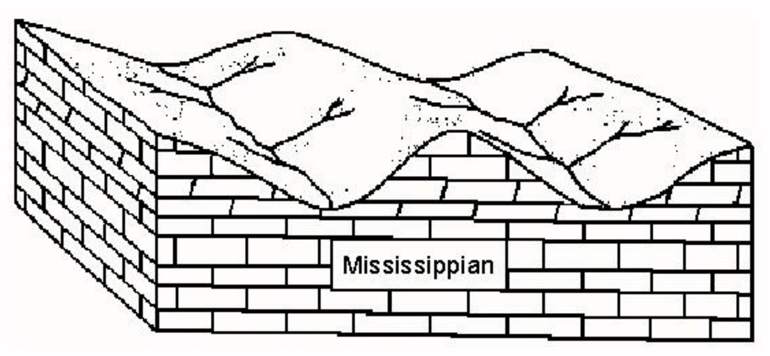

Figure 4. Block diagram showing relief on the Mississippian surface prior to Kilbourn deposition (modified from Ravn, 1984).

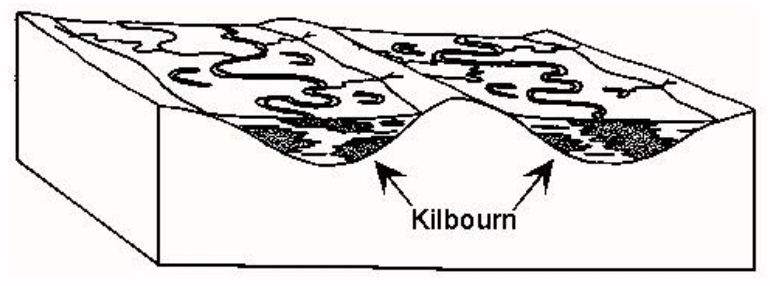

Figure 5. Block diagram showing mode of Kilbourn deposition (modified from Ravn, 1984).

Kalo Formation

The Kalo Formation was named for exposures near the town of Kalo in southern Webster County in north-central Iowa by Ravn et al. (1984). It includes strata from the base of the Blackoak Coal to the base of the Laddsdale Coal in the overlying Floris Formation. Two major coals, the lower Blackoak and the upper Cliffland, are the only two named members of the Kalo Formation in Iowa. Because of the leveling of the Mississippian erosional surface by Kilbourn deposition, the first widespread episodes of coal deposition occurred in Iowa (Fig. 6). The widespread occurrence of Kalo coals suggest that peat deposition resulted from a eustatic rise in sea-level that allowed swamp conditions to develop over a wide area of the state. As sea-level continued to rise, the swamps kept pace with the transgression allowing marine units to be deposited over the peat swamps to the southwest, where the topography was lower. Widespread occurrence of the marine facies was prevented by local development of delta lobes prograding seaward and delta switching as the result of differential compaction. Stream gradients, though, apparently remained low as thick fluvial channel-fill sandstones are less abundant than in the underlying Kilbourn Formation or the overlying Floris Formation (Ravn et al., 1984).

The Blackoak Coal is equivalent to the Pope Creek Coal of Illinois, which is considered to be upper Atokan in age. The Cliffland Coal is equivalent to the Rock Island (No. 1) Coal of Illinois and is considered to be lower Desmoinesian in age. Thus the Atokan-Desmoinesian boundary should be placed in the middle of the Kalo Formation between the Blackoak and Cliffland coals (Ravn et al., 1984).

Floris Formation

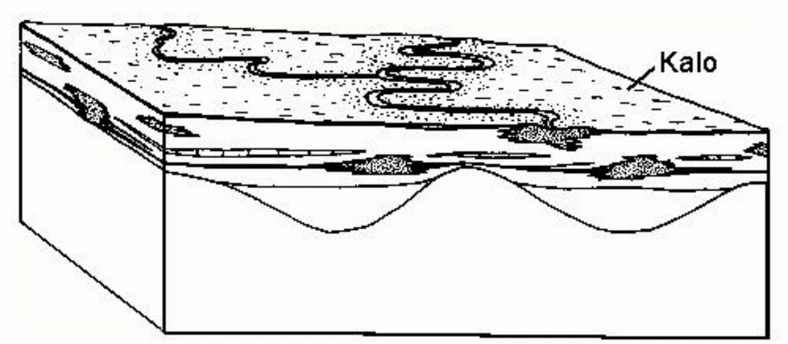

Figure 6. Block diagram showing mode of Kalo deposition (modified from Ravn, 1984).

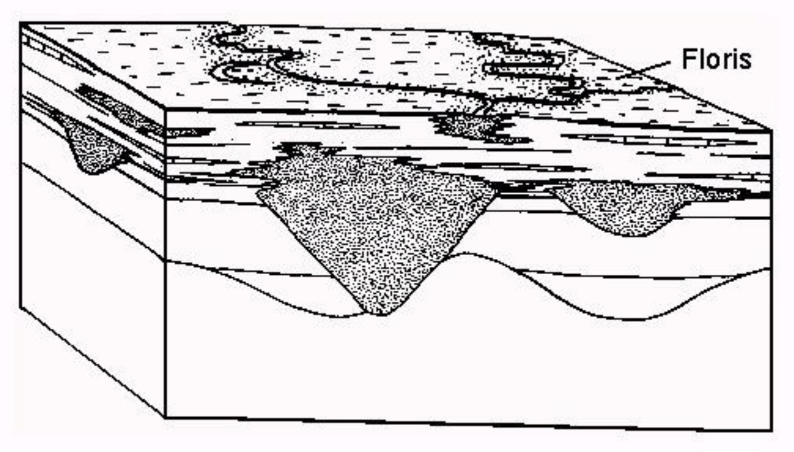

Figure7. Block diagram showing mode of Floris deposition (modified from Ravn, 1984).

The Floris Formation includes strata from the base of the lower Laddsdale Coal to the base of the Whitebreast Coal at the top of the formation. It was named for the town of Floris in Davis County by Ravn et al. (1984), but the type area is east of Ottumwa in Wapello County. The lower part of the Floris is characterized by the Laddsdale Coal Member, consisting of one to six coals that are usually lenticular and locally reach economic thicknesses. The associated strata are predominantly nonmarine shales and siltstones, which may coarsen-upward into sandstone. In some instances a fossiliferous marine shale or limestone may occur. Thus, these coals may represent from one to six depositional cycles over a period of time in which there was little change in the flora. As with the Blackoak and Cliffland Coals, they are palynologically distinct from other Cherokee coals, but the individual coals cannot be distinguished from each other (Ravn et al., 1984).

Above the Laddsdale are one or more palynologically distinct unnamed coals. Lenticular marine limestones are often associated with these coals. At this point the relationship of these coals and marine units in this interval to each other is poorly understood (Ravn, 1986).

Higher up is another palynologically distinct coal, the Carruthers. In contrast to the lower Floris coals, it is relatively persistent over a wide area. A fossiliferous marine shale and/or limestone usually directly overlie the coal and thin, persistent, phosphatic black shale with a distinct conodont fauna lies two to ten feet above the coal. The Carruthers correlates with the Greenbush and De Koven coals of Illinois. A persistent coal smut and lenticular marine sequence that lies several feet above the Carruthers Coal near the top of the Floris Formation, is thought to correlate with the Abingdon Coal of Illinois.

In general the Floris represents a transition from nonmarine fluvial and deltaic processes to more marine processes (Pope, and Chantooni, 1996). Major incised valleys and their associated thick sandstone fills probably occurred before deposition of the Carruthers Coal. These sequences of sandstone, 140 feet (42 m) or more thick, cut downward into the underlying Kalo and Kilbourn formations, and occasionally into the Mississippian (Fig.7). Keyes (1891) proposed the name Redrock Sandstone for calcite cemented, brown, red, and orange iron oxide stained sandstones near the former town of Red Rock just west of the north end of the mile long bridge on Highway 14 across Red Rock Lake in Marion County, Iowa. The name Cliffland has been used for similar sandstones along the Des Moines River in Wapello County.

Generalized Floris Formation Depositional Environments in a Sequence-Stratigraphic Framework

In siliciclastic depositional regimes in a relatively high shelf setting, sequence boundaries can be represented by subaerial exposure and erosional truncation. During times of low sea-level stand, incised streams produce erosional truncation (Eble et al., 2002). These erosional surfaces pass laterally into paleosols on the interfluves formed during subaerial exposure (Fig.8a). The paleosols and areas of low deposition to erosion represent the lowstand systems tract (LST). Due to low rates of deposition or nondeposition, the paleosols represent condensed intervals formed in a terrestrial environment, usually during times of a low water table. The paleosols are usually strongly developed due to long exposure times and rapid rates of weathering in a humid tropical environment. They often contain sphaerosiderites that formed later when the water table was high. In a vertical sequence, they are often overlain by a coal and subsequently overprinted by a histosol, which in turn may be overlain by estuarine, fluvial, deltaic, and/or marine facies during sea-level rise and highstand.

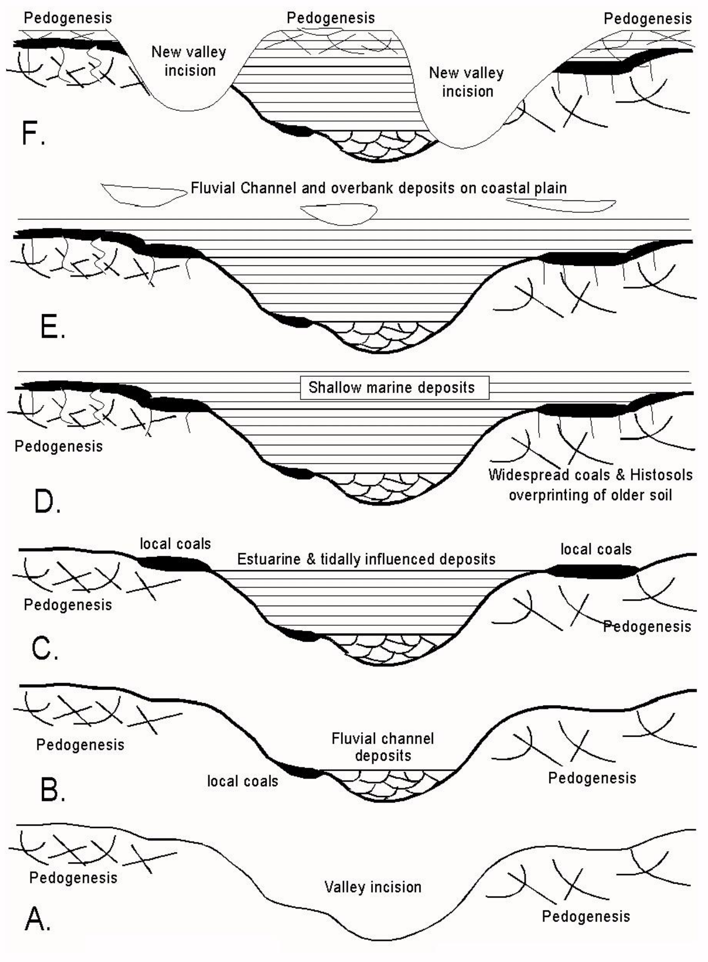

Figure 8. Siliciclastic depositional regimes in a high shelf setting during a single transgressive-regressive sequence (modified from Eble et al., 2002).

During sea-level rise (transgression), valley fills are often aggredating (Fig.8b) and prograding coarsening upward sequences produced by fluvial filling of the drowning valley (estuary), while pedogenesis proceeds on the interfluves (Eble et al., 2002). Tidally influenced deposits often overlie fluvial deposits (Fig.8c). Ponding of fresh water ahead of rising sea-level produces peat accumulation in areas of low clastic influx and shales, siltstones, and sandstone in areas of higher clastic influx. This can result in laterally discontinuous coals developed as narrow lenses in the proximal parts of the estuaries and marine facies developed in the more distal (seaward) regions of the estuary. Eventually, if sea-level continues to rise and the estuaries completely fill, sediments spread out over the interfluves (Fig. 8d). This can result in more widespread coals and marine facies resting on paleosols. The above described deposits represent the transgressive systems tract (TST).

During sea-level highstand, low gradient streams can produce isolated fluvial channel deposits adjacent to finer overbank deposits as the coastal plain experiences rapid aggradation due to increased accommodation space (Fig. 8e). At maximum highstand, deltas can prograde over earlier deposited marine facies, because estuaries are filled. These are called highstand system tract (HST) deposits.

As sea-level falls (regression), fluvial incision once again starts to erode valleys and subaerial exposure leads to soil development on shallow marine and coastal plain sediments (Fig. 8f). This results in an upper sequence boundary for the underlying depositional package and a lower sequence boundary for the overlying depositional package (Eble et al., 2002).

Incised valley fills are larger than single channel fills. Valley fills produced during a transgression often include amalgamated fluvial channel deposits overlain by estuarine facies of various types, often capped by tidally influenced fluvial or shallow marine facies. In valley fills produced by more than one transgressive-regressive cycle, complex compound fills may be found. They often show multiple episodes of incision and filling. In isolated outcrops of small lateral extent, the intricate relationship of these deposits may not be readily apparent. Some outcrops exposing strata in incised valleys may contain more cycles of deposition than the outcrops exposing strata deposited on the interfluves, and younger strata deposited in the incised valleys may lie adjacent to and below older strata on the interfluves. Laterally extensive exposures are relatively rare in the Pennsylvanian of Iowa. Stop 5 of this field trip affords an excellent opportunity to observe several hundred lateral feet and nearly a hundred vertical feet of complex terrestrial, fluvial, deltaic, estuarine, and marginal marine deposits. This is but one of several related exposures around the shores of Red Rock Lake.

COMMON LAND PLANTS FROM THE RED ROCK LAKE AREA

True ferns (Division Pteridophyta; Bold et al., 1987) were common in the Pennsylvanian. They reproduce by spores contained in sporangia arranged on the underside of leaves. Groups of sporangia are known as sori. Most have highly elaborate compound leaves or fronds. The petiole or stalk extends into the leaf blade as the rachis. From this arise pinnae or primary leaf divisions. Pinnules are the secondary divisions of pinnae. Stems may be trunk-like or rhizomes (underground horizontal stems).

Modern tree ferns exceed 20 m (66 ft.) in height. The unbranched trunks lack secondary xylem (wood) and are covered by a mantle of adventitious roots that helps support the main stem. The top of the stem supports a crown of leaves, which in some modern species may reach 4 m (13 ft.) in length. *Psaronius* was one of the most common of the tree ferns in the Pennsylvanian. *Pecopteris* (Fig. 9) is a common leaf form genera associated with *Psaronius*.

The Division Arthrophyta (Bold et al., 1987) is represented by herbaceous *Sphenophyllum* and arborescent *Calamites*, a large tree-like form related to the modern *Equisetum*. *Equisetum* is familiarly known as “horsetails” (branching species) and “scouring rushes” (unbranched species). The latter name comes from the fact that the epidermal cells are heavily silicified. Some Pennsylvanian forms may have reached 30 m (98 ft.) in height and 40 cm (15 in.) in diameter.

The stem of *Calamites* grew from a large horizontal underground rhizome. Both the aerial stem and rhizome have well-defined nodes and internodes. From the stem nodes leaves and branches grew and from the rhizome nodes roots grew. Stems were hollow, usually with a very large pith region. During fossilization the pith cavity often filled with sediment and a “pith cast” was formed (Fig. 10). Grooves in the pith cast correspond to separate primary xylem strands, while the ridges are vascular rays between the xylem strands. Horizontal grooves are the result of parenchymous pith diaphragms that occurred at the nodes. Leaves are assigned to the organ genera *Annularia* (Fig. 11a, b) and *Asterophyllites*.

Some species of *Sphenophyllum* may have been vine-like while others had several dichotomous branching, meter long stems, growing upward from a rhizome. Instead of having a hollow pith like *Calamites*, there was a triarch protostele of primary xylem surrounded by secondary xylem. Some had small webbed leaves (Fig. 12).

Lycopods ranged from small herbaceous plants to subarborescent forms to immense arborescent trees, with some exceeding 50 m (165 ft.) in height. Lycopod trunks had a small pith surrounded by generally thin primary and secondary xylem. The rest of the trunk is composed of an inner and outer cortex. The cortex may have provided support, considering the relatively small amount of xylem tissue. The root system, known by the form genus *Stigmaria* (Fig. 13), consists of rhizophores. They branched dichotomously in a nearly horizontal plane and bore small roots on the distal parts. The roots, like the

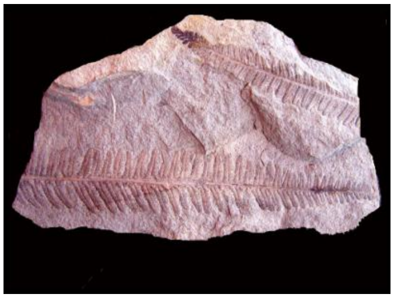

Figure 9. Terminal part of two pinnae of *Pecopteris*, associated with the tree fern *Psionius*. *Longer specimen 13 cm (5 in.) in length.*

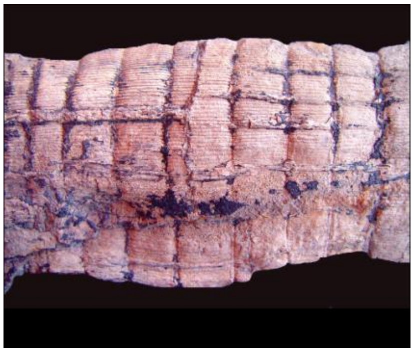

Figure 10. Pith cast of *Calamites*. Note the short internodes and numerous nodes. *Length 20 cm (8 in.)*.

a.

b.

Figure 11.a) Leaves of *Calamites*, **.b)** Incomplete leaf whorl. Width 2.5 cm (1 in.). *Width 5 cm (2 in.).*

Figure 12. Sphenophyllum leaf whorl. Width 1.5 cm (0.6 in.).

Figure 13. Lycopod rhizophore (*Stigmaria*). Note the root scars arranged in spiral rows. *Length 25 cm (10 in.)*

Figure 16. Vertical rows of leaf cushions of *Sigillaria*. *Length 15 cm (6 in.).*

Figure 14. Unidentified lycopod stem compression showing spiral arrangement of horizontally elongate leaf cushions. Note probable outer cortex between widely separated leaf cushions. *Width 10 cm (4 in.)*.

Figure 15. *Lepidodendron* stem compression. Leaf cushions are elongated vertically. *Width 10 cm (4 in.)*.

Figure 17. Unidentified fern-like leaf of a probable seed fern. *Length 2.5 cm (1 in.).*

leaves, are arranged in spiral rows and may be over a meter (3.3 ft.) in length. Lycopod rhizophores and roots are a common component of rooted paleosols below coals. Detached leaves are known by the form genera *Lepidophylloides*. Figure 14 shows a compression fragment of an unidentified lycopod from Pella, Iowa.

Lepidodedron and *Lepidophloios* were two common lycopods that are inferred to have inhabited swampy areas. The root system had aerenchymatous tissues to help in gas exchange, and the cortex had a resin-like substance that was inferred to help "waterproof" the tree (Eble et al., 2002). Both trees bore leaves in a spiral arrangement and as the stems matured the leaves fell off exposing a rhomboidal leaf cushion elongated in the vertical direction in *Lepidodedron* (Fig. 15) and in the horizontal direction in *Lepidophloios*. Only the upper few meters of the aerial trunks were branched.

Sigillaria was another arborescent lycopod similar to *Lepidodedron* and *Lepidophloios. Sigillaria*, though, has the leaf cushions in vertical rows (Fig. 16) and the aerial trunk is unbranched or divides one or two times. They exceeded 30 m (98 ft.) in height and 1 m (3.3 ft.) in diameter at the base. *Sigillaria* is inferred to have inhabited drier areas than most other lycopods (Eble et al., 2002).

Gymnosperms are represented by the Division Coniferophyta, Order Cordaitales (cordaites) and the Division Pteridospermophyta (seed ferns) (Bold, et al., 1987). Gymnosperm ("naked seed") generally refers to a seed plant lacking an enclosing structure for the seeds.

Cordaites were a diverse group of trees that attained maximum heights of 5-30 meters (16-98 ft.), while at least one species may have been a shrub-like plant (Stewart, 1983). Most species had large (up to a meter long), simple, stemless, strap-like leaves borne in a spiral arrangement. The shorter species had stilt-like roots resembling those of modern mangroves and probably inhabited swamps along rivers, marine shores, and estuaries. Other species may have inhabited a variety of environments, including drier uplands.

The stems of cordaites resemble those of conifers quite closely (Bold, et al., 1987), consisting of a pith, small primary xylem strands, secondary xylem tissue (wood), and tracheids with circular, bordered pits on the radial walls. Because of differential growth between the pith and the rest of the stem the pith became septate, alternating with air chambers and plates of parenchyma tissue. The distinctive cast of the pith is known by the generic name *Artisia*, the leaves *Cordaites*, the roots *Amyelon*, the reproductive structures *Cordaianthus*, and the seeds *Cardiocarpus*.

Seed ferns (Pteridospermophyta) were plants with fern-like foliage (Fig. 17) that bore seeds on the fronds instead of sporangia. Many of the so called 'ferns' from the Pennsylvanian are now known to be seed ferns, but it is still nearly impossible to determine if some foliage is fern (Pteridophyta) or seed fern (Pteridospermophyta). Seed ferns ranged from vine-like (*Callistophyton*) to tree-like (*Medullosa*) forms. *Neuropteris* and *Alethopteris* are two common leaf form genera of probable medullosan affinities.

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SPHAEROSIDERITES IN PALEOSOLS OF THE PENNSYLVANIAN CHEROKEE GROUP OF SOUTHERN IOWA: PHYSICAL AND GEOCHEMICAL TRACERS OF EQUATORIAL PALEOPRECIPITATION

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INTRODUCTION

Participants on today's field trip will have an opportunity to examine relict sphaerosiderites in diagenetic calcite concretions within several underclays of the Pennsylvanian Cherokee Group. Subtle sedimentologic features that are easily overlooked, sphaerosiderites are millimeter-scale spherulites of pure siderite ($FeCO_3$) that form in the reducing groundwaters of wetland soils in siliciclastic sediments (Ludvigson et al., 1998). Research experience has consistently shown that the stratigraphic occurrence of coals is a reliable predictor of the occurrence of sphaerosiderites in associated sediments, as they are related by shared paleohydrologic and paleoenvironmental requirements.

ZONAL CLIMATIC BELTS AND THEIR CHARACTERISTIC PEDOGENIC CARBONATES

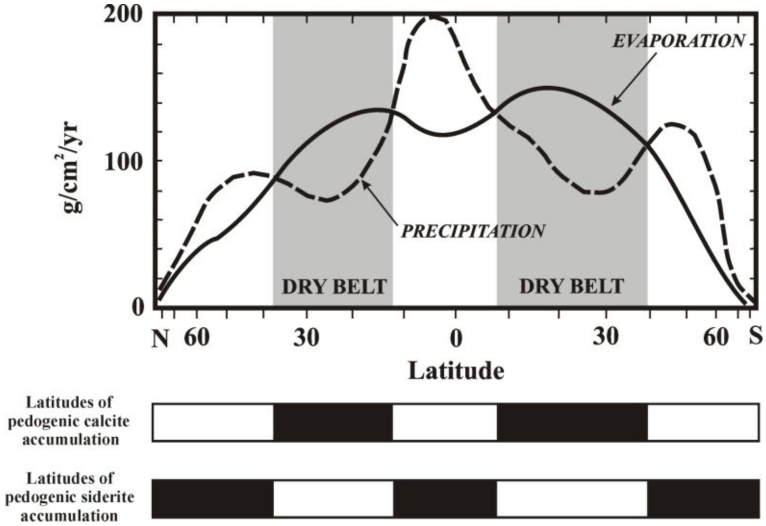

Figure 1. Zonal distribution of climatic belts (in black) that are dominated by accumulation of pedogenic calcite (calcretes) and siderite (sphaerosiderites). The zonally averaged precipitation and evaporation rates are from the modern climate system, and are modified from Barron and Moore (1994).

The formation of calcareous soils is generally well known in the soil science and geologic literature (Birkeland, 1999, p. 127-132). Calcareous soils accumulate in regions of precipitation-evaporation deficit, where groundwater infiltration is insufficient to leach calcite from the soil profile, and there is net evaporative accumulation (Goudie and Kenneth, 1983). The term "pedogenic carbonate" is often used as a synonym for pedogenic calcite, but such usage fails to account for the common occurrence of siderite as a pedogenic mineral, and the extensive reaches of the globe in which it accumulates in soils.

While the zonal dry belts do cover a substantial portion of the globe, they are by no means ubiquitous to the terrestrial paleoenvironments that are preserved in the sedimentary record.

Hard-cemented calcareous soils, or calcretes, accumulate in continental deposits that are largely confined to the subtropical dry belts (Fig. 1), with the exceptions related to "rain shadow" orographic effects. Over the remainder of the globe where there is precipitation excess, calcite commonly is chemically leached from soil profiles. Within the humid belts, in poorly-drained soils that remain saturated through most of the year, oxidation of soil organic matter leads to the development of strong vertical redox gradients within soil waters, and the presence of reducing groundwaters near the land surface. In these settings, dissolved Fe^{2+} that is released from the cannibalization of detrital or pedogenic ferric oxides by reducing groundwaters is taken up by the formation of siderite. Sphaerosiderite, a morphologically distinct millimeter-scale spherulitic form of siderite, is common in buried soils in the geologic record (Retallack, 1981). Ludvigson et al. (1998) showed that sphaerosiderites from a given paleosol have a characteristic carbon and oxygen isotopic signature that they referred to as ***meteoric sphaerosiderite lines*** (MSLs; see Fig. 2). They argued that the invariant $\delta^{18}O$ values in MSLs are determined by the $\delta^{18}O$ values of soilwaters (i.e. the weighted mean annual $\delta^{18}O$ of local paleoprecipitation) and local mean annual temperature, and that the highly variable $\delta^{13}C$ values are determined by differing biogeochemical processes that produce dissolved inorganic carbon in wetland soils (aerobic oxidation of organic matter; methanogenesis; methane oxidation; see Fig. 3). Paleogeographic and stratigraphic variations in MSL values in Cretaceous mid-latitude paleosols have recently been utilized for the development of dramatic new insights on sequence stratigraphy and continental-scale paleoclimatology (Ludvigson et al., 1998; White et al., 2001; Ufnar et al., 2001).

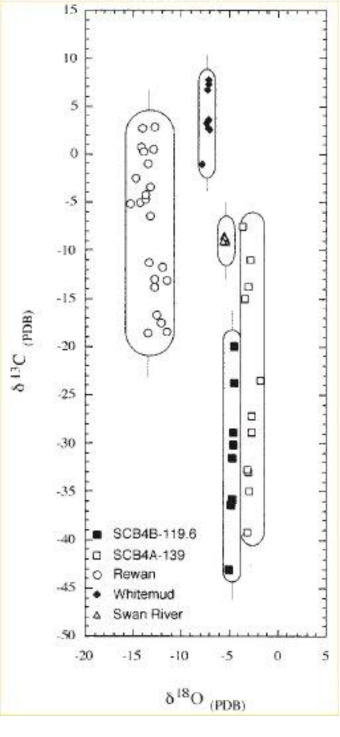

Figure 2. Carbon and oxygen isotope plot showing the characteristic diagenetic trends of meteoric sphaerosiderite lines. From Ludvigson et al. (1998).

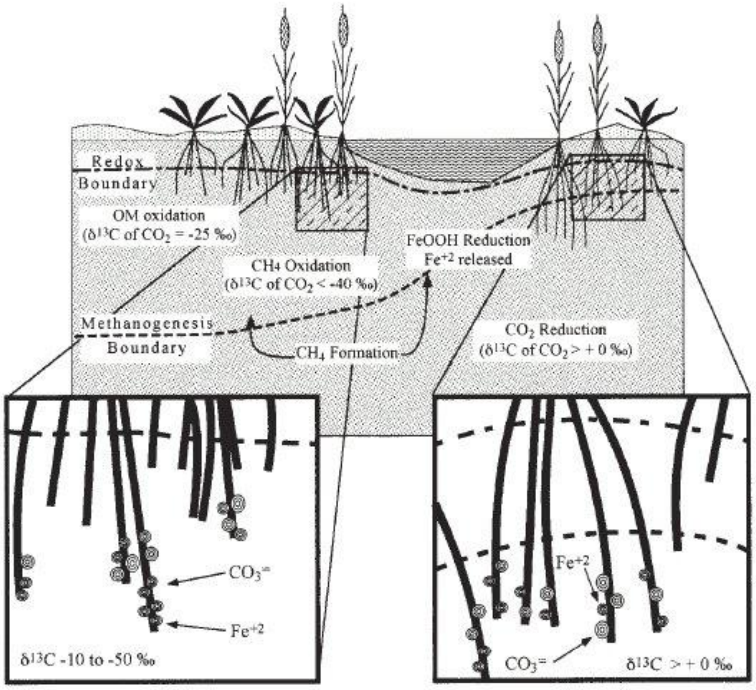

Figure 3. Schematic drawing illustrating the formation of sphaerosiderites arrayed along root traces in a wetland setting, and the geomicrobiological processes controlling $\delta^{13}C$ variations in meteoric sphaerosiderite lines. From Ludvigson et al. (1998).

MODERN EXAMPLES OF PEDOGENIC SIDERITE

Siderite has not been commonly reported as a pedogenic mineral in modern hydromorphic soils, but this general oversight is probably related to the microscopic size of siderite crystals found in modern occurrences, and sampling difficulties related to the chemical instability of reduced iron minerals in wet soil samples once they are exposed to the oxidizing atmosphere. Stoops (1983) and Llanduydt (1990) provided some of the first micromorphologic descriptions of Holocene sphaerosiderites, with maximum diameters in the 200 micron range. They often are associated with the chemically unstable reduced iron phosphate mineral vivianite, and also fine-grained pyrite in wetland settings influenced by infiltration of brackish fluids. Kim et al. (1999) reported on sphaerosiderites in Early Holocene paleosols with diameters up to 300 microns. Other reports of siderite accumulation in Holocene wetland sediments include Postma (1981), Moore et al., (1992), Virtanen (1994), McMillan and Schwertmann (1998), Aslan and Autin (1999), and Ellis (2001).

PALEOGEOGRAPHIC SETTING OF SPHAEROSIDERITE-BEARING PENNSYLVANIAN PALEOSOLS IN NORTH AMERICA

It has been the senior author's experience that many sedimentologists who have worked on coal-bearing Pennsylvanian strata in North America commonly are aware of the occurrence of sphaerosiderite in underclays—the clay-enriched gleyed silicilastic mudstone paleosols that typically occur beneath coal beds. Scal (1990, p. 96-107) described and illustrated sphaerosiderites in Desmoinesian sandstone units in Iowa. Browne and Kingston's (1993) descriptions of sphaerosiderites in Westphalian paleosols from maritime Canada are the best-known published examples to date. Recalling the aforementioned relationship between coals and sphaerosiderites, it is instructive to consider the paleogeographic distribution of mid-Pennsylvanian coals with reference to the paleoclimatic setting of the Cherokee Group in Iowa. Witzke's (1990) reconstruction for the Westphalian (Fig. 4), using climatically-sensitive lithic

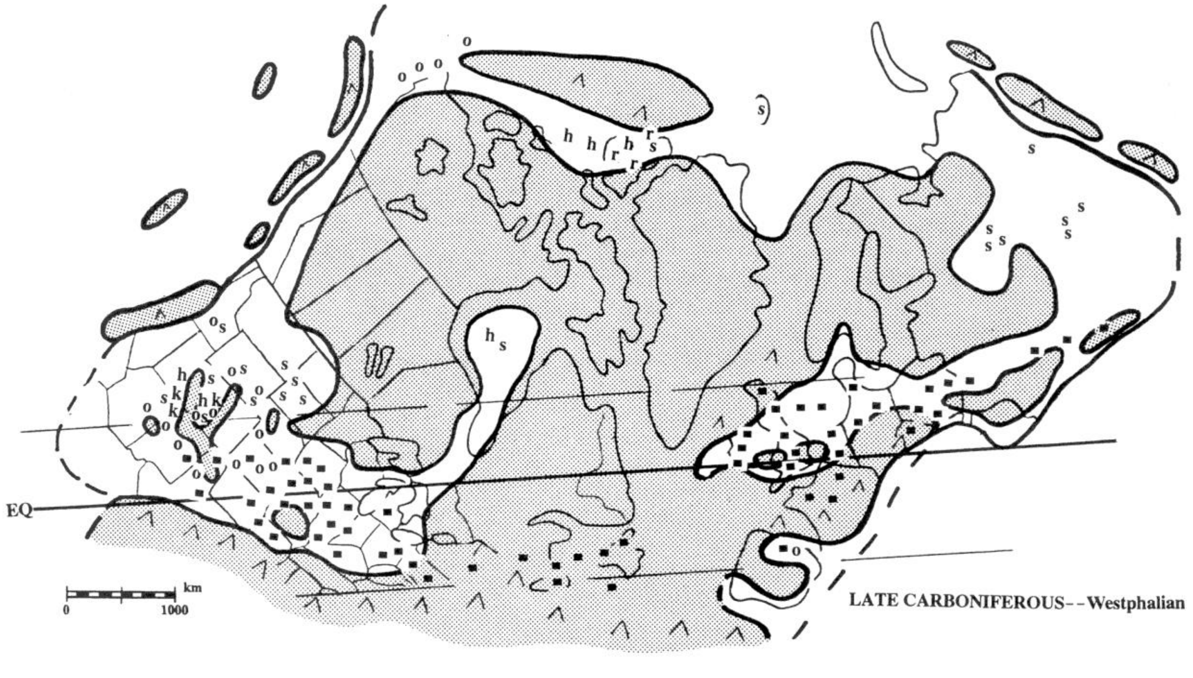

Figure 4. Interpreted North American and European paleogeography for the Westphalian (Morrowan, Atokan, Desmoinesian, mid- to late Baskirian, and Moscovian). Square symbols represent occurrences of coal in the equatorial humid belt, whereas sulfate (s), halite (h), and potash (k) evaporite occurrences denote a contemporaneous dry belt. From Witzke (1990).

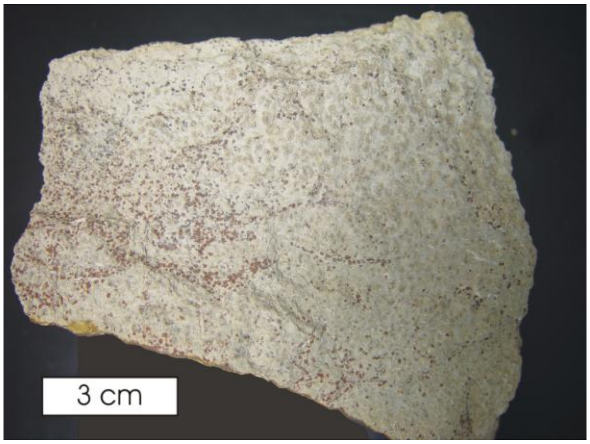

Figure 5. Photograph of hand sample of calcite concretion with contained sphaerosiderites visible as dark spots from their contained pseudomorphic iron oxides. From Melcher-Dallas locality in southwestern Marion County, Iowa. This sample comes from a siliciclastic mudstone paleosol (underclay) in the Laddsdale coal interval from the lower Floris Formation (Desmoinesian) of the Cherokee Group.

data, established a paleogeographic scheme that has not changed with subsequent work, and clearly places Iowa astride the mid-Pennsylvanian paleoequator.

The paleogeographic scheme shown in Figure 4 was specifically designed to place coal-bearing strata from the mid-continent United States and maritime Canada in the equatorial high precipitation belt (see Fig. 1), with a relatively sharp boundary with dry belt paleoenvironments at about 10° N paleolatitude.

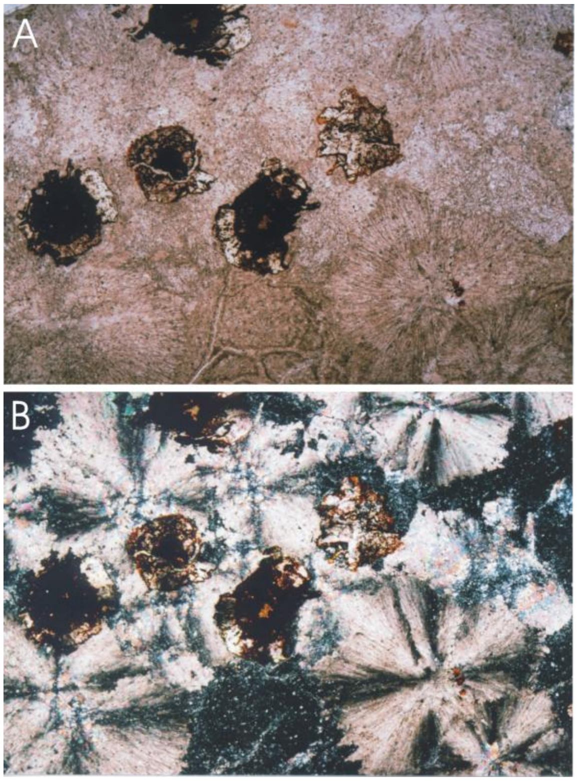

Figure 6. Thin section photomicrographs from the hand sample shown in Figure 5. Partially intact sphaerosiderites and pseudomorphic ferric oxides stand out in relief against surrounding background of calcite spherulites and mudstone matrix. A. Plane-polarized light. Note corroded margins of siderite spherulites. B. Same view in cross-polarized light. Note “pseudo-uniaxial cross” extinction pattern in both the siderite and calcite spherulites. Mudstone matrix has grey speckled birefringence. Horizontal field of view is 3.2 mm.

SPHAEROSIDERITES IN THE PENNSYLVANIAN CHEROKEE GROUP OF IOWA

Continuing field studies in south-central Iowa, in support of new bedrock geologic mapping, has resulted in the discovery of some remarkable occurrences of sphaerosiderites in underclays of the Cherokee Group. These sphaerosiderites are preserved in larger calcite concretions within underclay units, and remain as partially intact siderite with pseudomorphic ferric oxides (Fig. 5). Intact sphaerosiderites very seldom are found in field exposures, with the exceptions occurring in new excavations in operating clay pits, or in actively-spalling cutbanks. In the case of these concretions, sphaerosiderite engulfment by later diagenetic calcite nodules apparently has partly protected them from oxidation by modern weathering processes.

In thin section view, sub-millimeter scale sphaerosiderites and their pseudomorphing iron oxides float in a mudstone matrix with grey-speckled birefringence. Both of these components are engulfed and superimposed by 1.5 mm- to 2 mm-diameter calcite spherulites that coalesce to form the body of the calcite concretions within the underclay unit. The petrography of the calcite spherulites in these calcite concretions very closely resembles that shown by Siewers et al. (2000) from Pennsylvanian coal balls, which are early diagenetic, pre-compaction calcite concretions in coal beds that delicately preserve the cellular microstructure of vascular coal-swamp plants. Inspection of acetate peels taken from coal balls collected from Iowa coal mines in the Cherokee Group shows that these spherulitic calcite cements are common to all such concretions that we have examined so far. On the basis of these initial observations, it appears that the underclay and coal-ball concretions with spherulitic calcite cements may be products of the same early diagenetic processes.

A GENERAL THEORY FOR EARLY CARBONATE DIAGENESIS IN PENNSYLVANIAN COALS AND UNDERCLAYS IN IOWA

Gerdon et al. (1997) reported that Late Paleozoic coal balls from North American and European deposits are principally cemented by radial-fibrous (i.e. spherulitic) low magnesium calcite, with 2-9 wt. % Fe and 0.3-2 wt. % Mn substitution for Ca in the calcite lattice. They further reported highly variable $\delta^{13}C$ values ranging between –40 to –5 ‰ PDB, relatively invariant $\delta^{18}O$ values averaging around –9 ± 2 ‰ PDB, and $^{87}Sr/^{86}Sr$ ratios suggesting a radiogenic strontium source. They also noted that these data collectively indicate that coal balls were principally formed by early meteoric phreatic diagenesis, with dissolved carbonate produced from the decay of organic matter in the hosting peat deposits. Given that all of the deposits in question accumulated in the equatorial humid belt (see Fig. 4), the relatively depleted $\delta^{18}O$ values of these early meteoric phreatic calcites is highly suggestive of oxygen isotopic rainout effects resulting from high precipitation rates along the paleoequator (Rozanski et al., 1993).

The formation of sphaerosiderites in Pennsylvanian underclays, and their subsequent engulfment by spherulitic early meteoric phreatic calcite cements that apparently precipitated in both overlying coal and underlying underclay beds suggests that all of these phenomena might be related to the paleohydrologic effects of rising local base levels. Micromorphologic studies of many sphaerosiderite-bearing paleosols have shown that meteoric phreatic sphaerosiderites are often superimposed on earlier pedogenic features that developed in formerly oxidizing vadose soil profiles (McCarthy and Plint, 1998; Ufnar et al., 2001).

The most parsimonious interpretation is that underclay paleosols like that shown in figures 5 and 6 might have originally developed as oxidizing vadose soil profiles, and that sphaerosiderites formed from the cannibalization of earlier pedogenic iron oxides by reducing groundwaters during the gleization of the profiles as the local water table passed upward through the soil profile during base level rise. Continuing base level rise and the eventual establishment of perennial standing water would lead to the deposition of coal swamps, and the rapid accumulation of histosol soils (peats). The early meteoric phreatic precipitation of spherulitic calcite concretions in the histosols (coal balls) and underlying gleyed siliciclastic mudstone paleosol (underclay concretions) could have resulted from the production of dissolved carbonate from the decay of organic material in the histosol, in a more iron-limited groundwater flow system. Why are spherulitic calcite morphologies shared among all these early diagenetic products? Do high concentrations of organic acids play a role? Alternatively, Gonzalez et al. (1992) indicated that radial-fibrous morphologies in low-Mg calcites can result from high rates of fluid flow. Perhaps these calcite fabrics resulted from vigorous groundwater flow systems that developed in domed peats as they rapidly aggraded in the tropical paleoenvironments of the Pennsylvanian equatorial belt.

ACKNOWLEDGMENTS

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STRATIGRAPHY AND PRELIMINARY INTERPRETATION OF DEPOSITIONAL ENVIRONMENTS FOR FIELDSTOPS IN THE FLORIS FORMATION, RED ROCK LAKE, MARION COUNTY, IOWA

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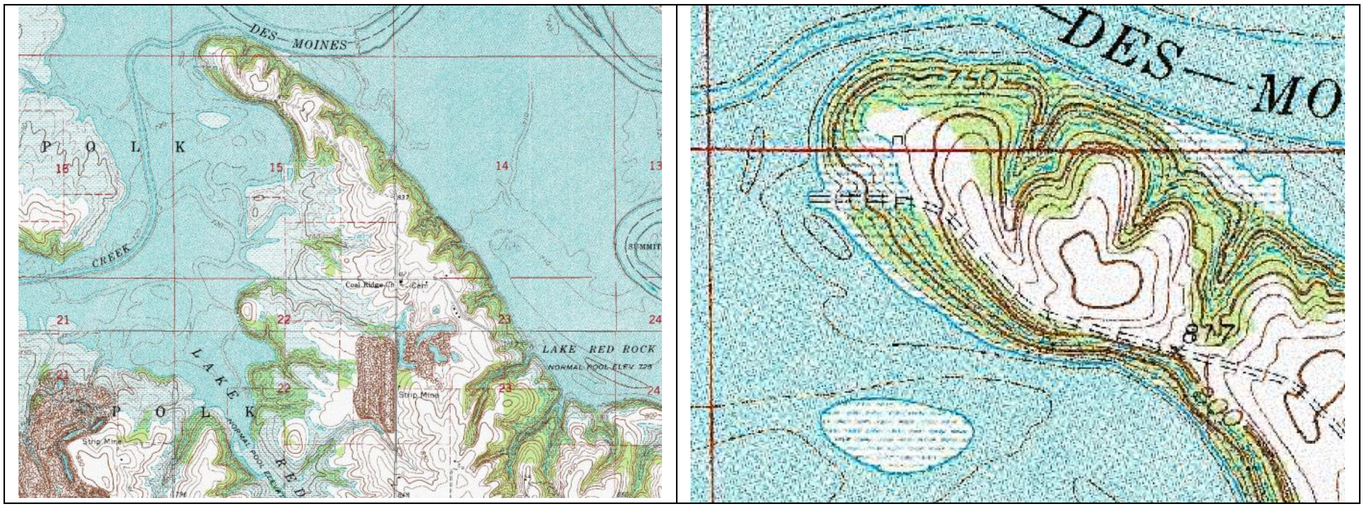


Figure 1 Topographic maps of the White Breast Recreation area and location of field trip stops

FIELD TRIP STOP

Coal Ridge Southside Section
S1/2 NE NW Sec. 15, T. 76 N., R. 19 W.

The section exposed at this stop is unusual in south-central Iowa in that it is almost 30 m (100 ft.) high and nearly 0.8 km (0.5 mi) long. It is a very complex exposure showing major lateral lithologic changes, as seen in the diagrammatic cross section. Three vertical transects that illustrate the lateral variability within the exposure will be discussed here, one on the western end, one near the center, and one at the eastern end of the outcrop. The elevation of the lake at normal pool level is used as the main datum and a high water bench approximately 7.6 m (25 ft.) above this is used as a secondary datum. All descriptions will be from bottom to top starting at the lake level datum.

At the western end of the outcrop the lower 2.1 m (7 ft.) is covered. Above this is 4.3 m (14 ft.) of light gray to nearly white blocky mudstone. Within this mudstone are several irregular zones of large cacilutite nodules. The upper zone of nodules is imbedded in a sandy, calcite-cemented, rooted siltstone and can reach 0.9 m (3 ft.) in thickness. Within these nodules are zones of centimeter sized spherulitic radial-fibrous calcite, some of which also show concentric banding. The top of this zone has an apparent dip to the east where at it lowest point, it is overlain by 1.5 m (5 ft.) of medium to dark gray shale with stringers of iron-rich siltstone.

The mudstone is interpreted to be a soil horizon with pedogenic carbonate zones. The dark shale above this, which thins over highs in the soil, could be overbank fines deposited in low areas that preserved organic material, during a rise in base level or sea-level.

Near the center of the exposure on a small point extending into the lake, the outcrop becomes highly complex. The base of this section is a coal exposed just above lake level. Above this is a rooted, sandy, blocky mudstone to rooted sandstone and another coal, all of which have an apparent dip to the west. The upper coal thins up-dip to less than 2.54 cm (1 in.) and thickens to over 46 cm (1.5 ft.) down-dip in about 4.6 m (15 ft.) of horizontal distance. Overlying this coal is about 2.7 m (9 ft.) of laminated black shale and sandstone that grades upward into a laminated sandstone (Fig. 9). The same mudstone with carbonate nodules seen at the western section is seen a few feet above the laminated sandstone, but here it has an apparent dip to the west. The eastern end of this central part of the outcrop seems to have a surface that truncates the coals, laminated shale and sandstones, and the upper mudstone with carbonate nodules. The truncation surface has a high angle dip to the east. This surface is overlain by blocky mudstone and

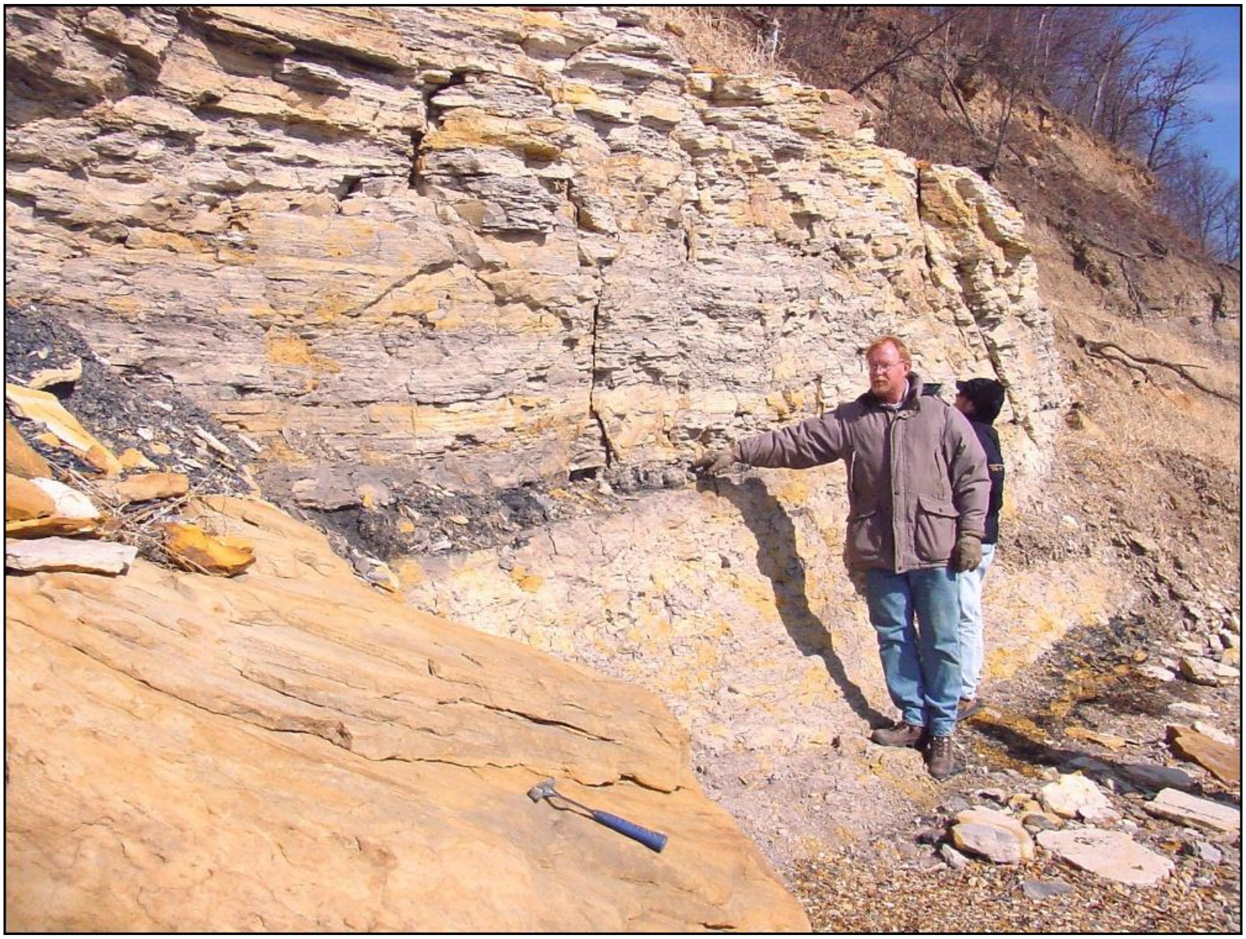


Figure 2. Photograph of center of the field trip stop exposure. Trip leader John Pope is standing on the lower coal and pointing at the upper coal. The tidal rhythmites are exposed above the upper coal.

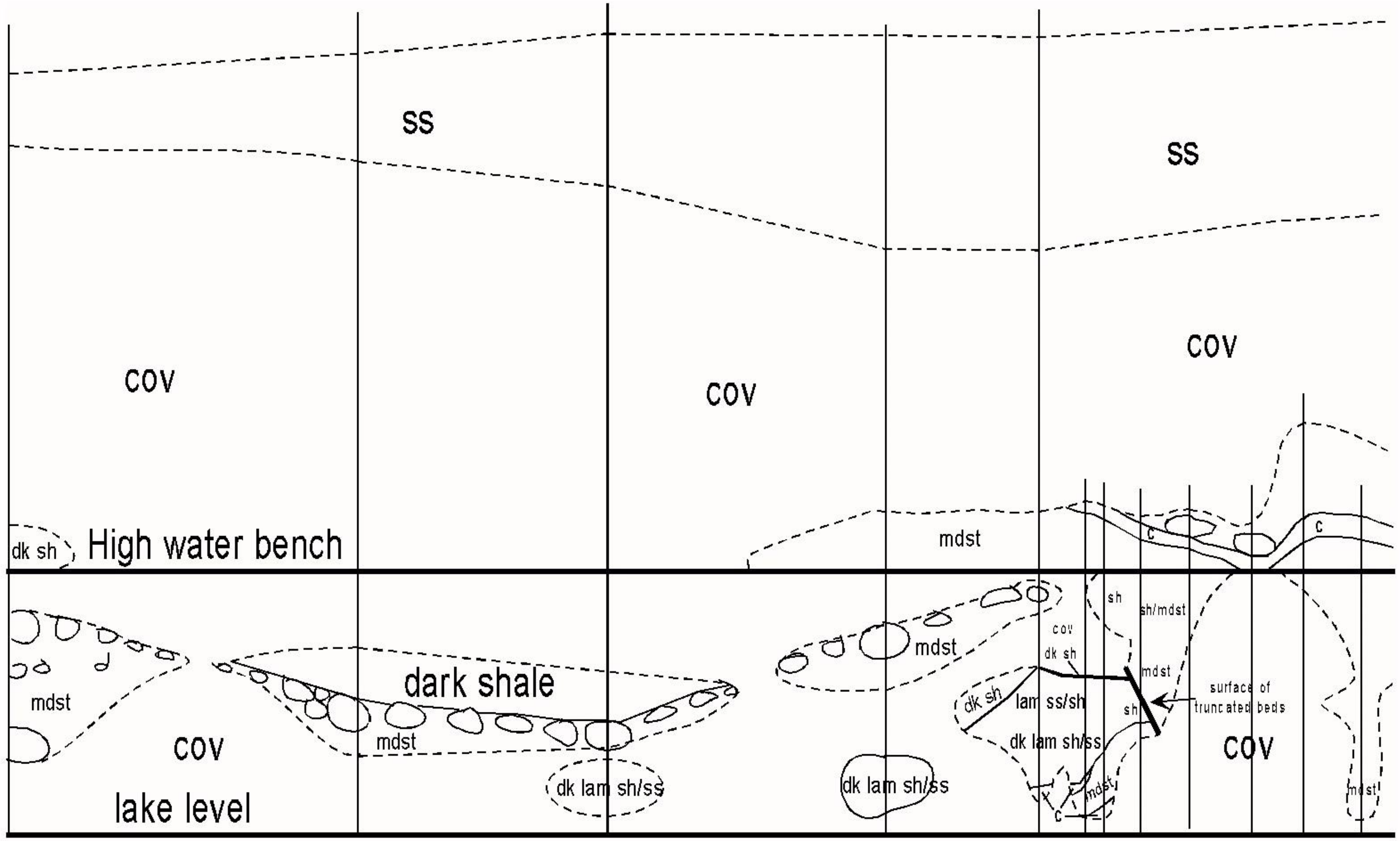
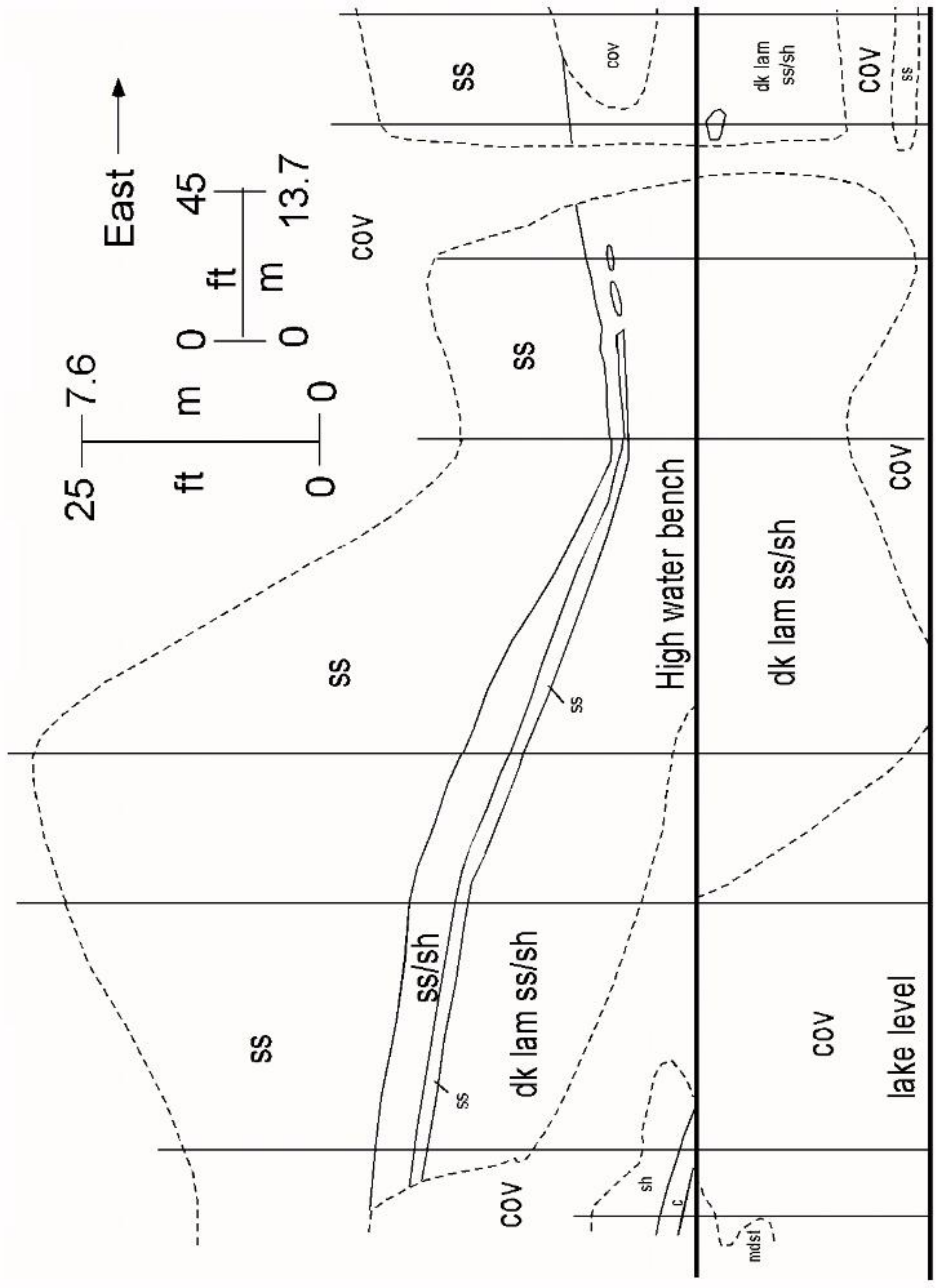


Figure 3. Diagrammatic cross –section of the rocks exposed at the field trip stop. This page illustrates west end of exposure; facing page illustrates east end of exposure.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poorly bedded shale that thicken to the east. Above this is an undulose coaly shale to coal that attains a maximum thickness of 30 cm (1 ft.). It contains numerous compressions of 'fern' leaves and *Calamites* and disappears below a covered interval as it dips to the east. In low areas on top of the coaly zone are concretions and shale with an abundant fauna of gastropods, clams including pectin-like species, ostracodes, and spirorbid worm tubes. A covered interval of about 7.6 m (25 ft.) extends upward to a thick (at least 6 m (20 ft.) is exposed) sandstone exhibiting both trough and planar cross-bedding.

The lower part of this section is interpreted to be an incised paleovalley filled during a probable rise in sea-level that flooded the valley. The coals may represent ponding of fresh water during initial sea-level rise. The laminated shale and sandstones that coarsen upward are most likely estuarine fills deposited as a bay-head delta prograded into the estuary. These deposits are probably tidally influenced. Figure 4 shows several features interpreted by Dr. Steve Greb (personal communication, 2002) as evidence of probable tidal deposition. The alternating black and white arrows show alternating thin and thick layers of siltstone and sandstone versus shale. The shales were likely formed as clay drapes when tidal currents slowed and clays dropped out of suspension. The diamond shapes indicate areas where there are couplets of laminae that are vertically thickening and thinning and which could be interpreted as neap-spring deposited layers. The circles indicate areas where bioturbation has possibly disrupted the tidally deposited laminae.

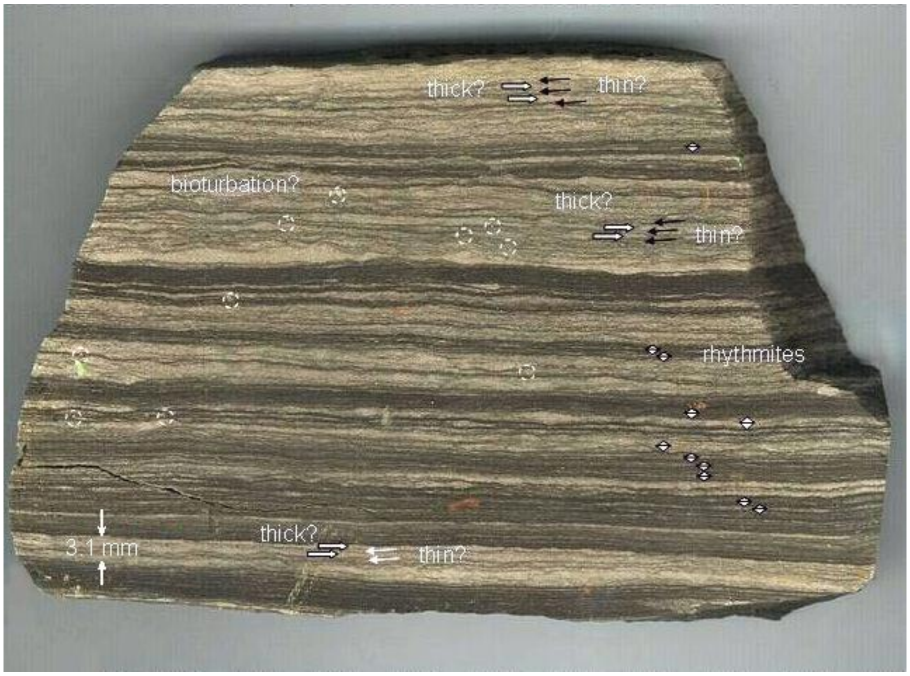

Figure 4. Tidal rhythmite from the field trip stop showing features interpreted as evidence of probable tidal deposition by Dr Steve Greb (personal communication, 2002).

Overall the sandier intervals and the shaly intervals taken together are probably arranged in an annual cycle with the finer laminae forming incomplete records of monthly and neap-spring tides.

When sea-level later fell, paleosols developed on the upper surface of these deposits. The truncation surface is interpreted to be the part of the formation of another large incised paleovalley cut into the previous paleovalley fill, during regression and a low stand of sea-level (Fig. 8F, page 16).

The upper coaly shale and overlying massive sandstone are most likely related to the deposits seen in the eastern part of the outcrop. The fossiliferous zone above the coaly probably represents deposition in brackish water marginal marine conditions.

In the eastern one half of the outcrop (Fig. 5) the deposits seem to be less complex and the extensive exposures allow for better understanding of both vertical and horizontal relationships. In the extreme eastern part the top of a 0.8 m (2.5 ft.) thick cross-bedded sandstone is exposed at lake level. This is overlain by 12 m (40 ft.) of coarsening upward laminated shale and sandstone with abundant carbonized plant debris. These laminated deposits have an apparent dip component to the west.

Figure 5. Photograph of tidal rhythmites overlain by massive bay-head delta sandstones at field trip stop.

To the west, near a ravine that heads near the road at the top of the exposure, they flatten out. Even farther west they exhibit an apparent dip to the east. The upper unit is a thick cross bedded sandstone with irregular intervals of laminated sand and shale in the lower one half.

The eastern part of the outcrop is interpreted to have been deposited during a rise in sea-level that provided accommodation space in another incised valley, forming an estuary. The lower sand may represent aggrading fluvial sediments deposited during initial transgression. The lower sandstone may be underlain by the undulose coaly shale seen above the truncation surface near the center of the outcrop, but this relationship is not readily apparent due to covered parts of the outcrop. The laminated sandstone and shale that coarsen upward into the massive upper sandstone, again is interpreted to be a bay head delta prograding into the estuary. The upper part of the laminated sandstone and shale and the lower part of the upper massive sandstone show probable tidal reworking of the deposits.

Palynological work has not been done on any of the coals at this outcrop. In relation to other outcrops in the area it is inferred to be in the lower Floris and perhaps the upper Kalo formations (personal communication, Mary Howes, 2002).

RECOGNITION OF TIDALLY INFLUENCED ESTUARINE DEPOSITS

Pennsylvanian age rivers (similar to those seen at stop 2) have been recognized to incise valleys during regression and low sea-level stand, and later form estuaries during the next transgression (sea level rise) (Archer et al., 1994). Clifton (1982) describes an estuary as a marginal-marine semi-enclosed body of water that is measurably diluted by fluvial discharge [i.e. a drowned river valley]. Sediments found in estuaries can be influenced by a complex combination of tides and currents, waves, river discharge, temperature, precipitation, and many other factors (Clifton, 1982).

According to Archer et al. (1994) estuaries are commonly sites of tidal amplification and tide-mediated deposition. Course sediments are primarily deposited in the narrow upper parts of estuaries where fluvial processes begin to merge with estuarine processes. In the middle of the estuary bottom currents are weak and muds are deposited. Most of the suspended mud is deposited during slack water at the high and low tides. Muddy tidal flats can be well developed in the middle estuary consisting of sand layers deposited during maximum tidal velocities and clay drapes formed during slack water. The modern vertical sequence of facies usually begins with a fluvial sand deposited on an incised surface, followed by sandy and muddy estuarine facies capped by a bay head delta sand.

Kvale et al. (1999) stated that records of daily tidal deposition are an order of magnitude larger than that attainable from large-scale tidal bundle deposits, and are preserved in the form of tidal rythmites. Kvale et al. (1998) described how synodic (new moon to new moon) tides form. Daily high tides are higher when the Earth, Moon, and Sun are aligned (full or new moon) and lower when the Sun and Moon are at right angles to the Earth (1st or 3rd quarter phases). Tides during full or new moon are referred to as spring tides, and tides at quarter phases are referred to as neap tides. The synodic month has a modern period of 29.53 days and contains two neap-spring cycles. Kvale et al. (1999) described how to recognize these features:

Tidal rythmites include structures consisting of: 1) stacked sets of clay–draped ripples that as cosets can be classified as lenticular, wavy, and flaser bedding; and 2) flat laminated siltstone and silty claystone with thin intercalated claystone layers. These layers drape essentially horizontal reactivation surfaces forming the small scale equivalent of large-scale tidal bundles. The tidal influence on the origin of these rhythmites is indicated by the progressive thickening and thinning of individually accreted packages or bundles in response to changing current velocities associated with lunar cycles.

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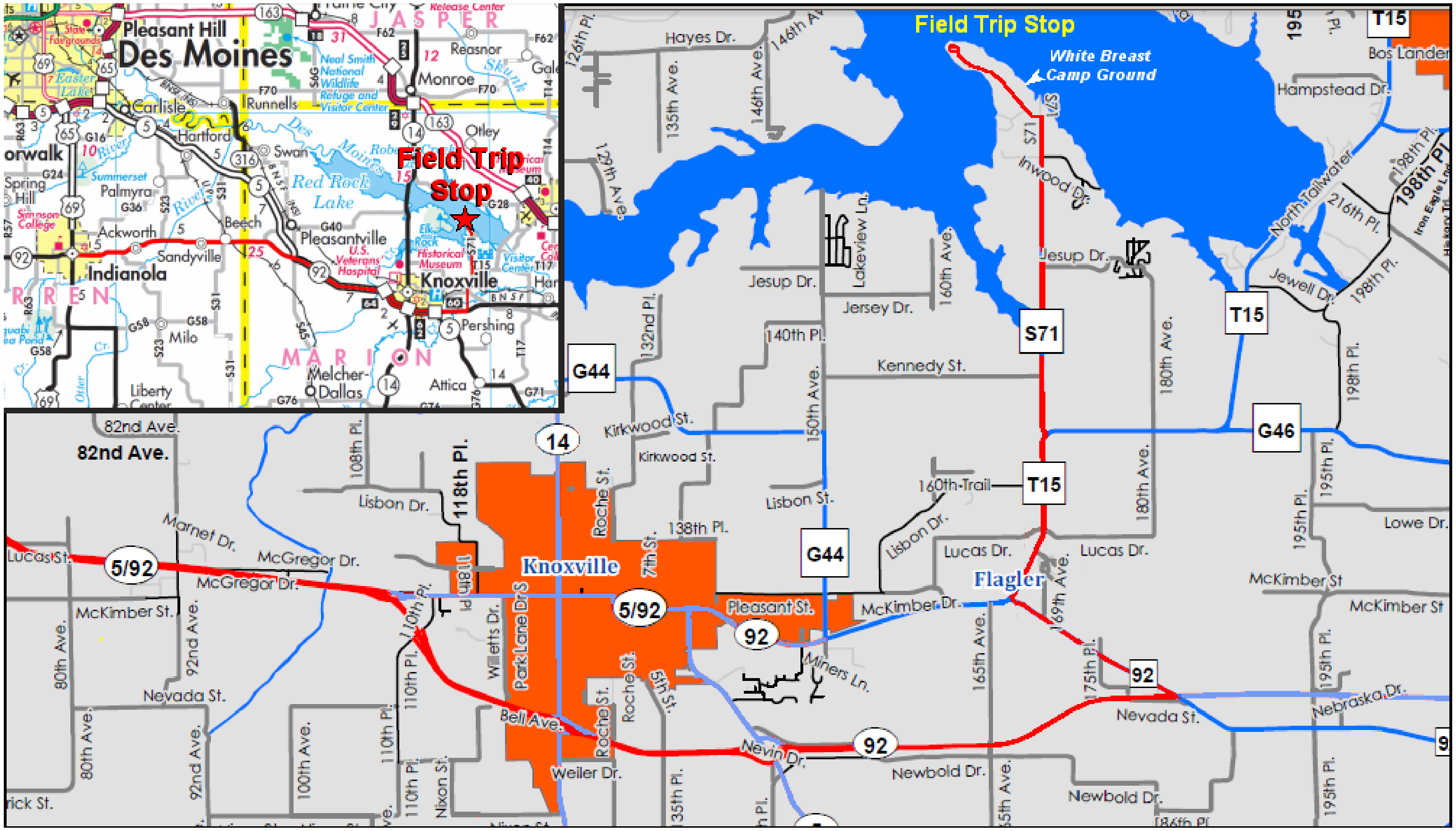

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